Environmental Assessment of the Alaskan Continental Shelf

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Environmental Assessment of the Alaskan Continental Shelf

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VOLUME 1

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RECEPTORS (BIOTA)

MAMMALS

*Final Report

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FINAL REPORT

ANALYSIS OF MARINE MAMMAL REMOTE SENSING DATA

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1 April 1977

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ACKNOWLEDGMENTS

The analysis reported here has been made possible through the skillful and enthusiastic work of George Taylor, Nancy Murray, and Jean Evans in our laboratories. In addition we have received valuable advice from William Campbell of the U. S. Geological Survey, René Ramseier of Environment Canada, Per Gloerson of NASA, and Paul Sebesta of NASA. We also wish to thank all of those, too numerous to mention, who joined us as observers on the NASA-BESMEX flights. It was a special pleasure to be able to have students from the University of Alaska join us to observe our operations.

I. Summary

This contract has supported analysis of marine mammal remote sensing data acquired during the NASA-funding Bering Sea Marine Mammal Experiment (BESMEX). Our work is an attempt to apply remote sensing technologies to problems expressed by marine mammal populations, both intrinsically and as these populations could serve as environmental indicators. We have identified three "target species": (1) walrus, Odobenus rosmarus, (2) belukha, Delphinapterus leucas, and (3) bowhead, Balaena mysticetus. We have analyzed remote sensing imagery and visual observations made during NASA-BESMEX flights to yield data on behavioral, environmental, and habitat characteristics which appear to influence the distributions and visibilities of these animals.

Specifically, our analysis of photographic and visual data has yielded information on:

(1) Walrus presence and sea ice characteristics;

(2) Walrus and ice dynamics;

(3) Walrus hauling-out behavior;

(4) Seasonal distributions of walrus, bowhead and belukha;

(5) Comparisons of visual observation and remote sensing; and

(6) Natural history.

There remains considerable uncertainty in marine mammal survey methods, including remote sensing. Knowledge of marine mammal distributions at different times of the year is obviously required for intelligent interaction between marine mammal management and petroleum development. For this purpose alone, remote sensing may prove cost-effective, even more so than "conventional" methods. For means of environmental monitoring and prediction over so large a region as Alaska's outer continental shelf, such methods could prove to be an essential tool, especially when used in conjunction with projects designed to yield "ground truth."

II. Introduction

A. General Nature and Scope of Study

This contract has supported analysis of marine mammal remote sensing data acquired during the NASA-funded Bering Sea Marine Mammal Experiment (BESMEX). It is generally recognized that present methods of assessing marine mammal populations on the basis of visual survey flights are inadequate. Not only are the actual estimates of numbers of visible animals questionable, but also there is little opportunity for correlating environmental, behavioral and habitat parameters with the proportion of the population visible at the time of the flight. Remote sensing is capable of providing some of these essential data.

The remote sensing aspects of BESMEX employ a variety of sensors all of which allow serendipitous reexamination of hard copies of data. During flights, we also employ pilots and observers and log visual data by computer. Thus, we have the opportunity to determine the comparative accuracy of visual and remote sensing assessment techniques. As a part of this work, we may develop models which might allow estimates of the "true" population numbers, based on habitat and environmental parameters measured at the time of assessment and on certain ground truth information.

OCSEAP funds accounted for approximately 5 percent of the total BESMEX effort; NASA, the Marine Mammal Commission and the Office of Naval Research make up the remainder. Hence, use of OCSEAP funds was restricted almost exclusively to analysis of visual photographic imagery obtained during 22 NASA flights. In this connection, we emphasize that our OCSEAP contract terminates several months prior to termination of other contracts. All remote sensing data analyses cannot, therefore, be included here. For example, data from infrared imagery, which we hold, or of microwave and synthetic aperture radar imagery, held by collaborators, will be important in meeting our objectives. We have some hints of what future analyses will bring but will have to await future publication for full presentation of findings.

B. Specific Objectives

We have identified three "target species": (1) walrus, *Odobenus rosmarus*, (2) belukha, *Delphinapterus leucas*, and (3) bowhead, *Balaena mysticetus*. We have analyzed remote sensing imagery and visual observations made during NASA-BESMEX flights to yield data on behavioral, environmental, and habitat characteristics which appear to influence the distributions and visibilities of these animals.

Our specific objectives fall into two categories: those given in our work statement and additional objectives formulated during analysis. In the work statement we emphasized:

(1) walrus presence in an area and associated ice characteristics;

(2) the degree to which walrus movements are influenced by ice dynamics; and,

(3) the behavioral, ecological, and meteorological conditions influencing walrus hauling-out behavior.

Additional objectives formulated during the course of our analysis include:

(4) seasonal distribution of walrus, bowhead and belukha as related to sea ice;

(5) a comparison of visual observations and remote sensing to determine walrus group sizes and to yield variance in assessment techniques by these two methods; and

(6) natural history data of walruses, bowheads, and belukhas such as relative and absolute orientations, swimming speeds, and inter-individual spacing within groups.

C. Relevance to Problems of Petroleum Development

Our work is an attempt to apply remote sensing technologies to problems expressed by marine mammal populations, both intrinsically and as these populations could serve as environmental indicators. We wish, for example, to ascertain what role remote sensing could play in the continued monitoring of marine mammal populations both before and after petroleum development and related alteration of their environments. This project has contributed to the limited store of knowledge on the seasonal distribution of certain marine mammal species and has demonstrated some of the potential of remote sensing for behavioral and habitat analysis. Knowledge of marine mammal distributions at different times of the year is obviously required for intelligent interaction between marine mammal management and petroleum development.

Equally, it is important to note that an "instantaneous," synoptic view with hard data output will be required for both analytical and predictive purposes as petroleum exploration and exploitation occur. Such synoptic data are only possible through remote sensing techniques, wherein large-scale imagery may be obtained in a very short time period. An important provision is that "ground truth" studies will continue to be required for some time for purposes of validation of imagery. We, therefore, emphasize the contribution remote sensing can make, rather than replacing other means of study by this emergent technology.

III. Current State of Knowledge

The application of remote sensing technology to marine mammal populations is a rather recent development and hence the number of published reports is meager. Heyland (1974) in his aerial photographic study of belukha obtained information on lengths, color, social relationships, group locations, calf production and age and sex classes. He notes that "the original purposes for which the pictures were taken may be surpassed by serendipitous findings which only become evident after prolonged study." Lavigne and Øritsland (1974) used aerial photography within a limited band width (ultraviolet) to detect white-coat harp seal pups on the ice. This method allows a census of the population as well as estimates of annual production. These are two samples of the possibilities of remote sensing of marine mammals in sea ice dominated environments, in addition to our work.

Another important example is the OCSEAP-supported work of Burns, Fay, and Shapiro (Research Unit 248/249, reported in these volumes). However, their work differs as remote sensing is not applied to the animals themselves, those data being obtained largely visually. We discuss some of the potential of remote sensing in the Discussion, below.

IV. Study Area

The study area is described in Ray and Wartzok (1974, 1976a and b). Flight patterns are shown in Ray and Wartzok (1976a and b).

V. Sources, Methods and Rationale of Data Collection

All remote-sensing imagery was acquired from flights of NASA NP-3A and CV-990 aircraft during the BESMEX program. The rationale and methods of data collection are given in Ray and Wartzok (1974 and 1976a) and will not be repeated here.

VI. Results

Preliminary results from our own work, using both visual and infrared remote-sensing techniques have been presented in earlier reports and will not be repeated here (Ray and Wartzok, 1975, 1976a, 1976b).

Since this contract terminates well before other contracts and collaborative efforts, most of the results presented below are in the form of a progress report. Other results are based on analysis of all the data we have available. We now summarize our results relative to each of our specific objectives, given under II.B. above.

1. Walrus Presence and Sea Ice Characteristics

Percentage of ice cover, surface roughness, and thickness appear to be the most important factors indicating walrus "sea ice habitat." The first is the one most easily measured through the visual photography analysis supported by this contract. Ice coverage, by ice type, and surface roughness are best obtainable through radar imagery and ice thickness from infrared imagery. Table I lists the percentages of walrus photographed in different tenths of ice coverage during different seasons of the year. When ice is scattered, as in September 1974 and August 1975, walrus choose this ice as they may have little else available at the ice edge zone. In April, when freezing conditions still prevail, heavy ice cover, not the ice edge, is preferred. Such results have been known for some time. However, no visual technique can reveal or quantify ice structure and we await results of other remote sensing to carry our analysis further.

The X and L band radars on the NASA flights were operated by scientists from the Jet Propulsion Laboratories of the California Institute of Technology. We have provided collaborators there with a detailed list of coordinates where walrus concentrations were found. We are awaiting information from radar imagery for quantified differences between those locations and other selected locations where walrus did not occur.

We have studied all photographic output from the infrared scanner for all the flights. Unfortunately, the photographic analysis is not precise enough to allow us to determine ice thickness from heat flux measurements. In order to do this, we must refer back to the magnetic tape records. We are exploring the possibility of having this work done by Texas Instrument Corp., manufacturers of the IR scanner.

2. Walrus and Ice Dynamics

In order to quantify the extent to which walrus movements are dictated by ice movements, we needed repetitive sampling of an identified walrus herd over several days' time. This was part of the rationale for our request to NASA for blocks of ten flights at three different times of the year. We flew only a fraction of the number of flights requested, so our results on this objective must remain qualitative. The one time when repetitive sampling was possible, 6, 7 and 8 April 1975, there was a precise correlation of walrus movements with ice movements. That is, the animals did not change their positions relative to the ice at all. The change in geographical location of the herd from one day to the next was due to the movement of the ice with which they were associated. Flights on 23 and 24 August 1975 also gave indications that the movements of the animals were correlated with movements of the ice although confidence in the strength of that correlation is not as great as for the previous April because of the more dispersed nature of the walrus groups in August.

3. Walrus Hauling-Out Behavior

Ray and Wartzok (1976a) present a model of walrus hauling-out behavior based on walrus surface temperatures, diurnal hauling-out patterns, and weather conditions. Again the full complement of flights requested would have been necessary to validate this model. The 6, 7 and 8 April 1975 flights did provide important data showing that walrus hauling-out behavior can result in over 1000% change in the number of animals in a population which are hauled out. The most important factors in this case probably were increasing habitat temperatures following several days of stormy weather.

Diurnal patterns of hauling out were preliminarily investigated on two flights in April 1976 over the same walrus concentration at 12.00-15.00 hours and at 18.45-21.30 hours. Exact numerical comparisons are not possible since the latter flight occurred too late in the day for visual photography. Infrared imagery detected the walrus; resolution by this method is not sufficient for accurate counts, but it can detect walrus groups and group size. As stated above, we have not yet completed infrared analysis. We do believe we detected a significant rise in numbers of walruses hauled out during the latter flight.

Much of the remote-sensing information relative to hauling-out behavior needs to be correlated with and interpreted in the light of ground-truth studies. Under support from the Marine Mammal Commission, a former student has acquired data, but they have not yet been passed on to us. We will continue these studies this July during an Office of Naval Research and U. S. Coast Guard supported cruise of the icebreaker Glacier.

4. Seasonal Distributions of Walrus, Bowhead and Belukha

Data from all flights of NASA aircraft have been plotted on OCSEAP maps and sent to the Fairbanks office for use during the Beaufort/Chukchi Sea Synthesis Meeting, 7-11 February 1977. Those maps represent a significant portion of our work under this contract and should be considered as part of this report. Figure 1, for bowhead whales, is an example of the type of information we presented on these maps. In both September 1974 and August 1975 the whales were near the 10 fathom line. The major change in the location of the population between the two years dramatically shows the effect of ice on the distribution of these animals. The apparently anomalous ice conditions during the summer of 1975 are well known to all involved in OCSEAP studies. We may expect such conditions to occur from time to time in the future. In any case, the ecological relationships of the whales for both years was similar, although the distributions were not.

5. Comparisons of Visual Observation and Remote Sensing

An attempt to compare the accuracy and precision of visual population estimates by novice and experienced observers using photographs to simulate a walrus censusing flight was reported in Wartzok and Ray (1975) and as an Appendix to Ray and Wartzok (1976a). We will not repeat these data here.

Another comparison of visual and remote sensing assessment techniques is shown in Figure 2. Each NASA flight carried at least two experienced observers who reported their estimates of walrus group sizes. Part A of Figure 2 is a histogram of the occurrence of different sizes of walrus groups as reported by the observers. This histogram shows a bimodal distribution of group sizes with a secondary peak occurring at groups of about 30 animals. This second peak is strictly an artifact of observer bias as shown by a comparison with part B of Figure 2, the distribution of group sizes as obtained from the photographs. These results are qualitatively in accord with those of the simulated censusing flights in that both show that population estimates obtained visually are over-estimates of the true population numbers, more so for medium-sized groups than for others.

6. Natural History

Whenever possible, photographs of walrus, bowhead and belukha have been studied carefully to obtain the maximum amount of natural history information. Most of these sorts of data are serendipitously acquired as one cannot predict the nature of such information from a rapidly-moving aircraft. The work on walrus is still in progress since walrus constitute the largest portion of our imagery and they are the hardest to differentiate from their feces-covered uglek. We here report only on the analysis concerning bowhead and belukha.

Figure 3 is a histogram of the body lengths of 36 bowheads photographed in such a position that they were measurable. The distribution is bimodal. The animals in the 3.5 to 5 meter class were found lying close beside a much larger animal; presumably the pair is mother and calf. Thirty-three bowheads had body lengths ranging from 8.5 to 14.3 meters. This segment of the population comprises the adults and possibly sub-adults. The mean adult/sub-adult body length is 11.8 meters. These length measurements were made only on whales which appeared to be lying parallel to the water surface. However, without a higher degree of photographic overlap to provide stereographic analysis, we cannot be sure that the animals were indeed parallel and hence these measurements must be considered minimum lengths.

Rather than measuring body lengths, fluke width may be used for these calculations. We have calculated total length based on fluke widths of the adult/sub-adult class being 32% of body length (W. M. Marquette, personal communication). This gave a calculated length for adult/sub-adults of 14.8 meters. The discrepancy between the two averages is perhaps explained by the fact that not all fluke widths were measurable and, hence, the averages are from different individuals. No animals of the yearling class (6.7 - 7.9 meters (Fiscus and Marquette, 1974)) were observed in the groups in our September photographs.

Inter-animal distances were measured from randomly selected frames for each of the five groups. Statistical results are shown in Table II. Five "groups" were subject to analysis, each being bound by the random artifact of being defined as a number of whales represented on a single 1:4000 photograph, covering .84 km^2 of sea. The groups consisted of the following number of pairs and average distances between pairs: I (10 and 4.8 m); II (28 and 233.2 m); III (105 and 258.5 m); IV (10 and 112.0 m); and V (78 and 165.8 m). It is apparent that highly significant spacings occur among bowheads in groups. However, our present data are insufficient to determine what social or environmental parameters are associated with these significant differences in spacing between animals in the different groups.

Figure 4 is a compass diagram of the frequency distribution of the directional headings of 118 bowheads photographed on 20 September 1974. On the basis of a Chi square test, this distribution is non-random ($p \leq 0.01$), although there is no dominant trend toward a particular direction as would be expected if the animals were actively migrating. When individual groups were analyzed, the numbers proved not large enough to perform a statistical test, but there was an indication that the individuals in groups in open water tended to have the same orientation.

Six animals were identified in successive frames so that speed of their movement could be determined. Two animals moving toward different groups of whales had speeds of 10.8 and 11.2 km/hr. One animal in open water was swimming at a speed of 8.6 m/sec. Finally three animals swimming within different groups had speeds of 5.0, 5.8, and 6.5 km/hr.

Turning to the belukha, Figure 5 shows size distribution histograms for this species from different animal concentrations encountered during one flight along the northern coast of Alaska on 8 September 1974. The only animals included in these histograms are ones which were lying in a plane parallel to the water surface. The animals farther east between longitude 144 and 151°W had no observable young and the lengths of all the animals except one were greater than the mean length for "females" (see below). The groups located farther west, around longitude 152.5°W, included young and had a peak in the size distribution curve corresponding to the lengths of "females." It is not surprising to find the larger animals farther to the east since for many whale species, the migration of males lags behind females and young in the fall.

Our measurements of total standard lengths proved repeatable within ± 15 cm. We classified an animal as a "female" if it was in association with a small animal of less than 230 cm. We have photographs of 13 animals which met this criterion. The mean length for these animals was 357 cm. with a standard deviation of 21 cm. This is only slightly larger than the value of 350 cm. for the modal maximal length of females from the Mackenzie Delta as reported by Sergeant and Brodie (1969). For 9 of the "female" belukhas we were able to measure the fluke width. The mean value was 24.5% of the body length with a standard deviation of 1.5%. This is very similar to the value of 23.5% found for female white whales in the St. Lawrence River (Kleinenberg, Yablokov, Bel'kovich and Tarasevich, 1964). We thus feel confidence in our photographic results.

We have no criterion for identifying which animals in a group are "males." However, we have observed that solitary individuals tend to be longer than the mean for individuals in groups. We have been able to obtain accurate length measurements on 10 of these solitary individuals giving a mean of 410 cm. and a standard deviation of 55 cm. The assumption that these solitary individuals are "males" is supported by Sergeant and Brodie's modal maximum length for males from the Mackenzie Delta of 410 cm. Fluke widths were measured on 6 of the solitary individuals and the mean value was 25.4% of the body length. Kleinenberg, _et al._, reported a mean value of 26.6% of body length for flukes of male belukhas from the St. Lawrence River.

Figure 6 shows the distribution of belukhas group sizes photographed on 8 September 1974. The weighting towards single animals or groups of 2 or 3 animals in polynyas near the ice edge at this time of the year is obvious. However, very few of our photographs are of open water areas where large belukha groups occur.

Figure 7 shows three compass diagrams showing orientations of individuals in different concentrations of belukhas at different times of the year. In all cases where there were enough animals to conduct a valid Chi square test, these distributions were tested for randomness and in each case the orientations were non-random ($p \leq 0.005$). The non-randomness of the September 1974 distributions is probably due to as yet unknown aspects of group behavior within the polynyas. On the other hand, the October group was photographed in open water and the tightness of the orientation distribution in this case is probably attributable to migration.

Eight belukhas were identified on successive frames so that speed of movement could be determined. Table III lists the recorded speeds and the social characteristics of the individual, _i.e._, whether it was solitary, in a group or with a calf. As would be expected, in general the speeds of individuals that are with calves are slower than that of solitary individuals. The fastest speed was recorded for a group of large animals, all oriented in approximately the same direction.

VII. Discussion

This is our last report under this contract. It has had to be in summary form for reasons stated above.

As we have also stated, there remains considerable uncertainty in all marine mammal survey methods, including remote sensing, for the simple reason that no method developed to date can predict the proportionate visibility of animals being surveyed. Natural history data, especially related to loafing time at the water's surface or to hauling out, are required. Some of these inherent difficulties of aerial surveys are obviated by remote sensing. Unfortunately, we were not able to fly as often as we would have liked, so that our data are more qualitative than statistically quantitative. Nevertheless, certain features emerge, among which are:

(1) Table II, Ray and Wartzok (1976a), shows that CV-990 can cover same area in 1/5 to 1/10 the time as "conventional" survey aircraft. This is a measure of the cost-effectiveness of the survey methods used.

(2) Demonstrated diurnal hauling-out patterns of walrus imply the need to survey at certain limited times of the day. Such patterns no doubt exist for other species. Survey methods, therefore, must be designed to sample large areas in a short period of time, and this is another measure of cost effectiveness.

(3) Photographs hold a wealth of natural history data as preliminarily explored in our results. Photographic capability should be included in all survey flights, but from altitudes in excess of 1000 m, where little or no disturbance of animals occurs. Such hard data are, once again a measure of cost effectiveness.

(4) Even experienced observers may have a significant and measurable bias in population estimates. Hence, one needs photographs for accurate counts. IR imagery will also no doubt prove of great benefit in detection of hauled-out walrus, especially on dark summer ice where they are easily overlooked. IR can also give relative density, but not absolute numbers. If remote sensing is not available, the best measure aerial observers should take is to undergo pre-flight training and test procedures in order to quantify their biases.

(5) Ice dynamics, ice structure, and microenvironmental conditions have a great deal to do with both distribution and visibility of marine mammals. Such details are but grossly and only qualitatively observable without remote sensing.

(6) By no means should remote sensing replace other methods of study. Ground and sea studies and remote sensing should complement one another to yield data obtainable by no single method by itself.

VIII. and IX. Conclusions and Needs for Further Study

The objective of remote sensing is to sense as large an area over as short a time period as possible. Further, an objective is to realize an all weather, day-night system. These eventualities are not yet within our grasp, although some predictions may be made of the possibilities. For example, certain radars present great potential, providing that ground truth studies are designed for all these technologies specifically to yield ecological relationships of target species. The satellite is the eventual tool of remote sensing. Work from aircraft is an intermediate step which depends on recording data that the eye might also see in an effort to establish certain information from the relatively low altitude of aircraft flight.

It appears reasonable to suggest that remote sensing flights are more cost effective than seemingly less expensive, "traditional," visually-oriented surveys for reasons stated in the Discussion. We note that OCSEAP partially or wholly supported several, overlapping survey efforts. To our knowledge, further remote sensing work is not planned and we believe this is regrettable. There is some urgency to pursue new technologies to meet research and monitoring problems of such scale as development of Alaska's Continental Shelf implies.

X. Summary of Fourth Quarter Operations

The contract was continued through the fourth quarter on a no-cost extension basis. Therefore, Fourth quarter operations were limited to data analysis and report preparation.

All funds awarded under the contract have been expended.

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TABLE I

PERCENTAGE OF WALRUSES PHOTOGRAPHED
ACCORDING TO ICE COVERAGE

Date	Total Walruses Photographed (5" film)	Open Water	0.1-0.3 cover	0.4-0.7 cover	0.8-1.0 cover
Sept. 1974	1004	-	100%	-	-
April 1975	1330	-	0.1%	1.3%	98.6%
Aug. 1975	549	2.0%	87.4%	0.2%	10.4%
April 1976	465	-	1.5%	1.1%	97.4%

TABLE II

t-TEST OF INTERANIMAL DISTANCES

Groups Compared	t	df	p ≤	Significance
I-II	5.42	36	0.01	H.S.
I-III	6.83	113	0.01	H.S.
I-IV	3.74	18	0.01	H.S.
I-V	3.96	86	0.01	H.S.
II-III	0.95	131	0.50	N.S.
II-IV	2.66	36	0.05	S.
II-V	2.32	104	0.05	S.
III-IV	3.84	113	0.01	H.S.
III-V	5.36	181	0.01	H.S.
IV-V	1.28	86	0.50	N.S.

Probability values from Snedecor and Cochran (1967).

t = t value df = degree of freedom H.S. = highly significant

TABLE III

SWIMMING SPEEDS OF INDIVIDUAL BELUKHAS

Sociality	Speed
Female with calf	2.05 km/hr
In group with calves	2.51
In group with random orientation	2.68
Solitary	3.06
Group of two animals	4.03
Female with calf	4.10
Solitary	6.05
In group of large animals all with about the same orientation	7.02

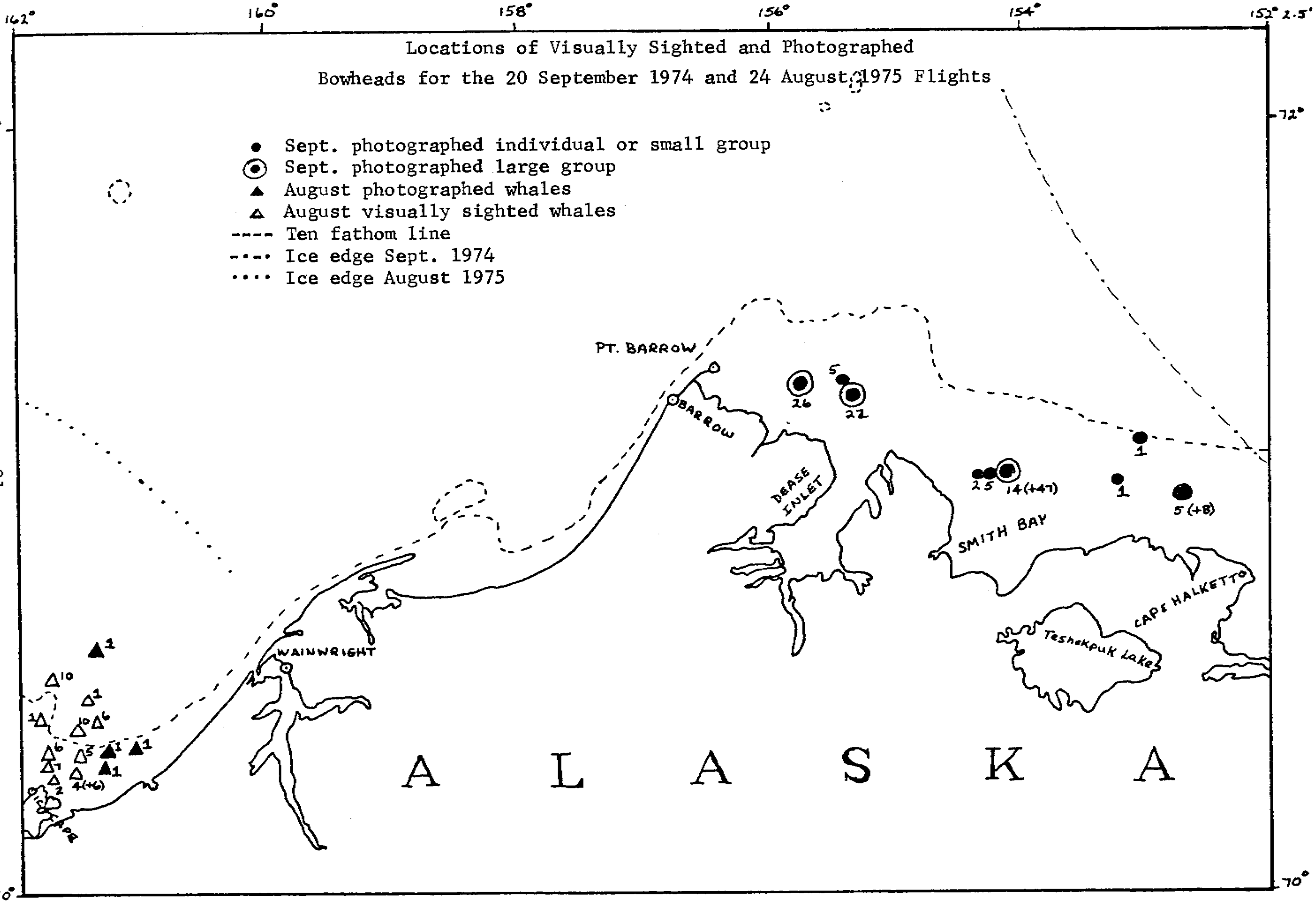
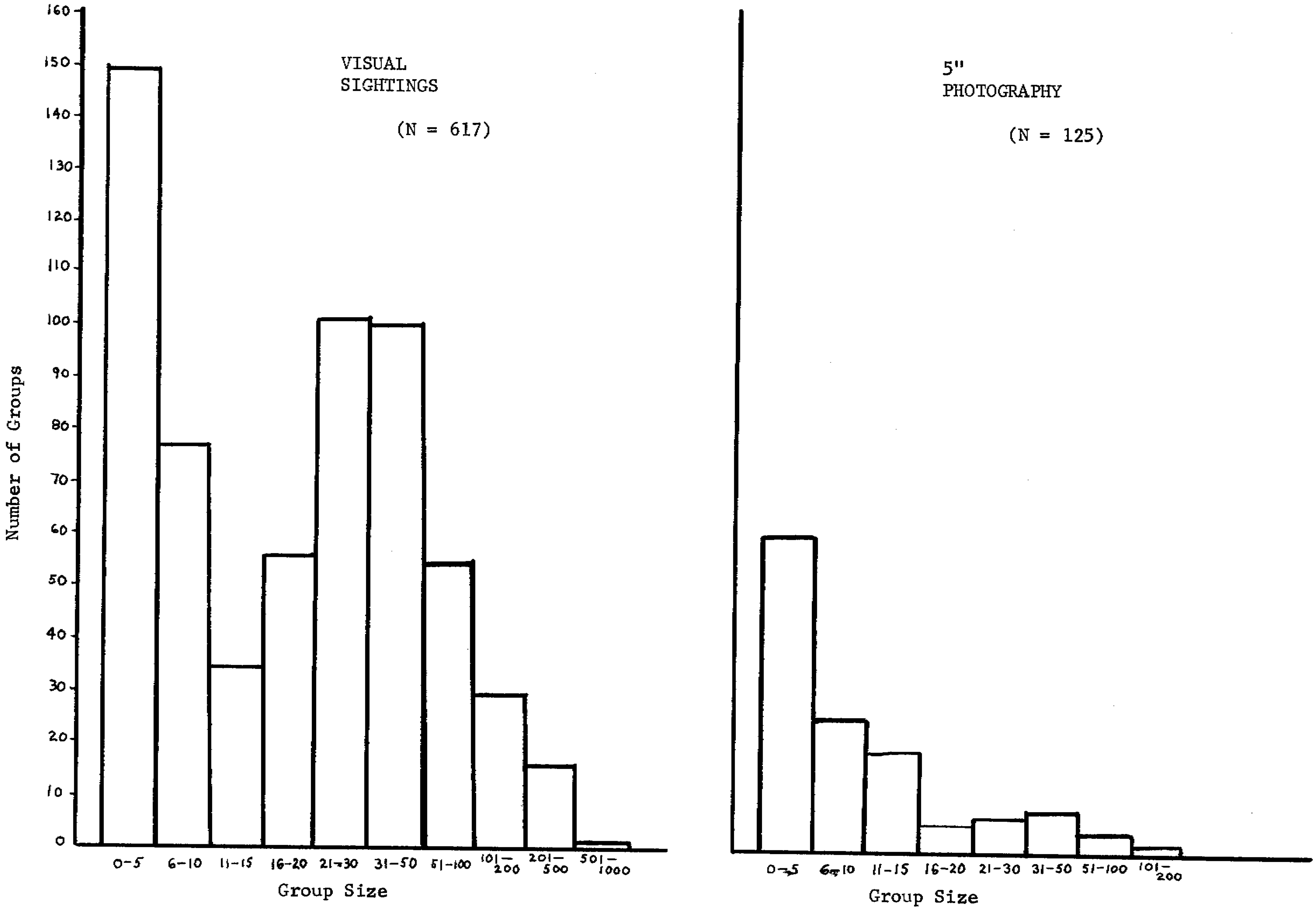

Locations of Visually Sighted and Photographed
Bowheads for the 20 September 1974 and 24 August 1975 Flights
Sept. photographed individual or small group
Sept. photographed large group
August photographed whales
August visually sighted whales
Ten fathom line
Ice edge Sept. 1974
Ice edge August 1975
162°
160°
158°
156°
154°
152° 2.5'
72°
70°
PT. BARROW
BARROW
DEASE INLET
SMITH BAY
CAPE HALKETTO
Teshekpuk Lake
WAINWRIGHT
A L A S K A

Figure 1



WALRUS GROUPS ON THE ICE

Figure 2

BOWHEAD BODY LENGTH HISTOGRAM

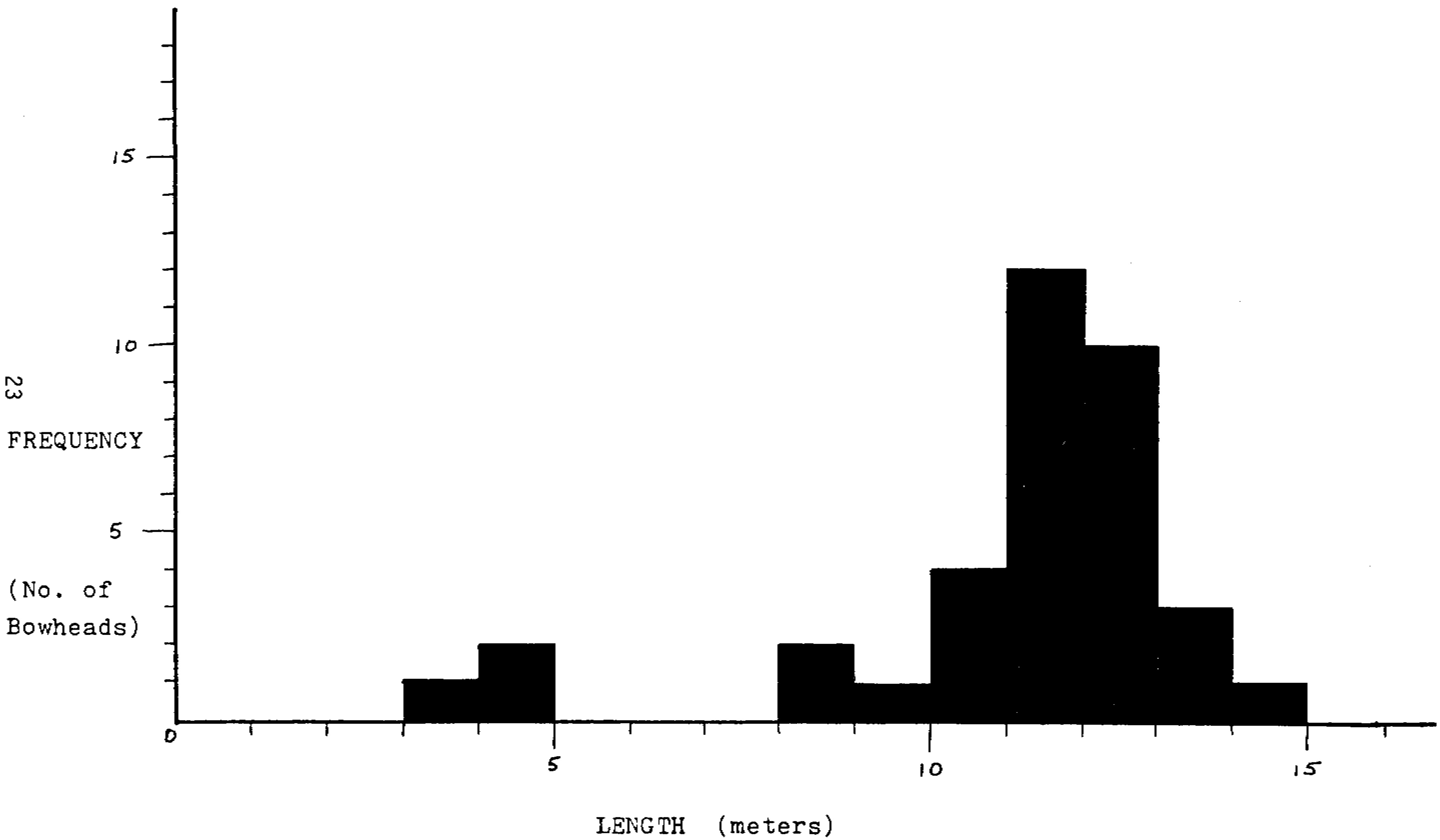
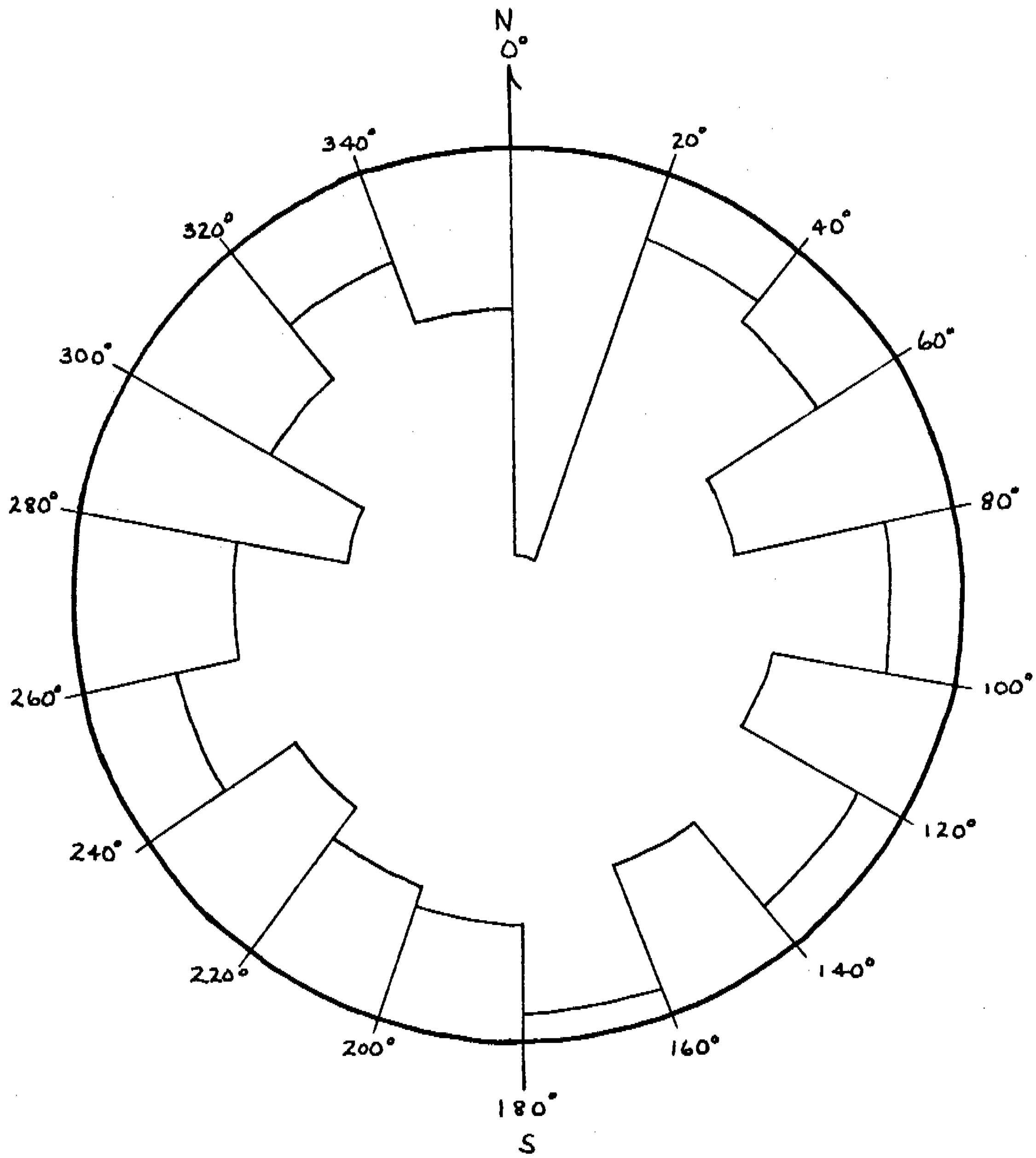


Figure 3

COMPASS DIAGRAM OF THE FREQUENCY
DISTRIBUTION OF THE DIRECTIONAL
HEADINGS OF BOWHEADS



1/8" equals one whale

Figure 4

BELUKHAS BODY LENGTH HISTOGRAMS

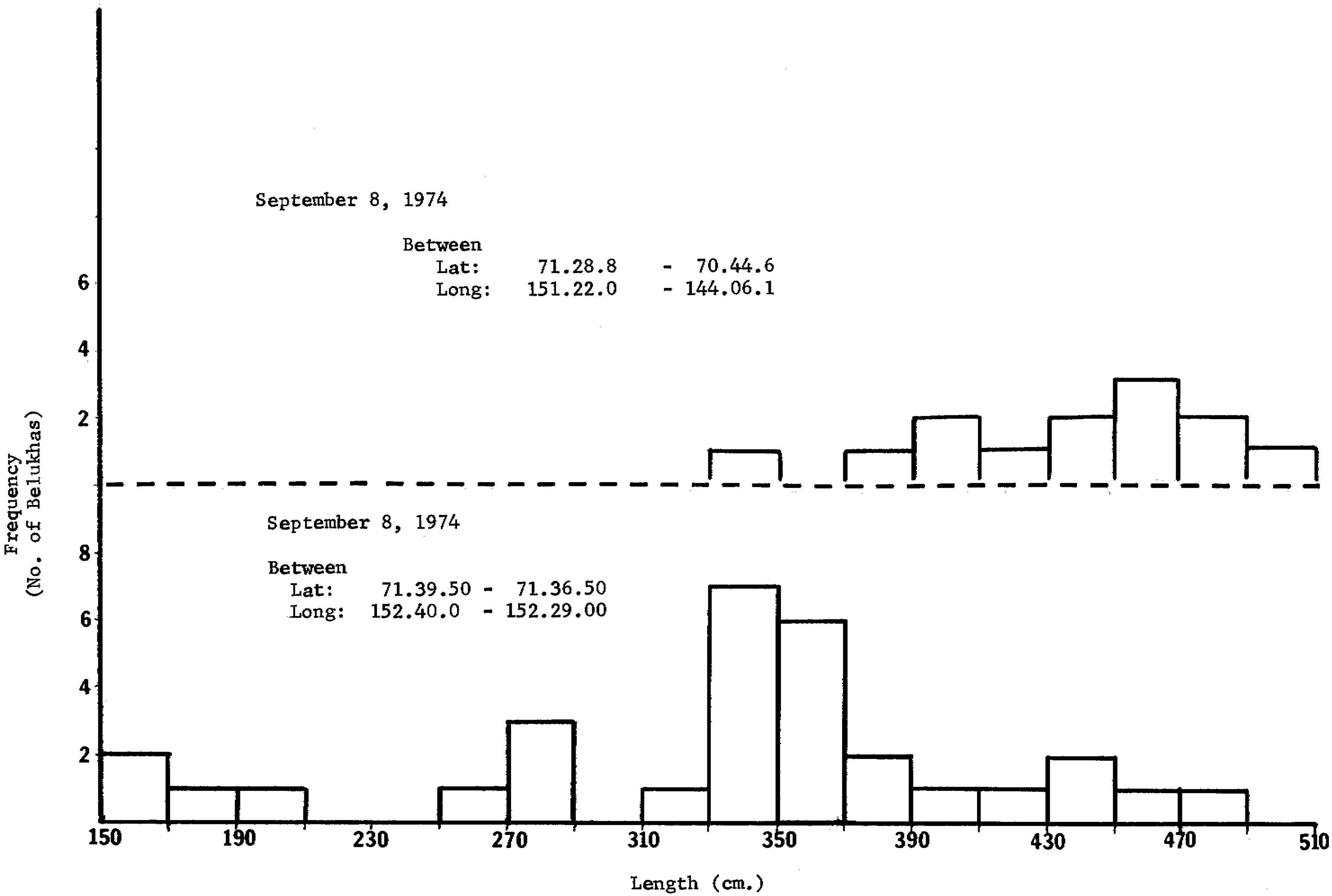


Figure 5

BELUKHA GROUP SIZE HISTOGRAM

(8 September 1974 Flight Data)

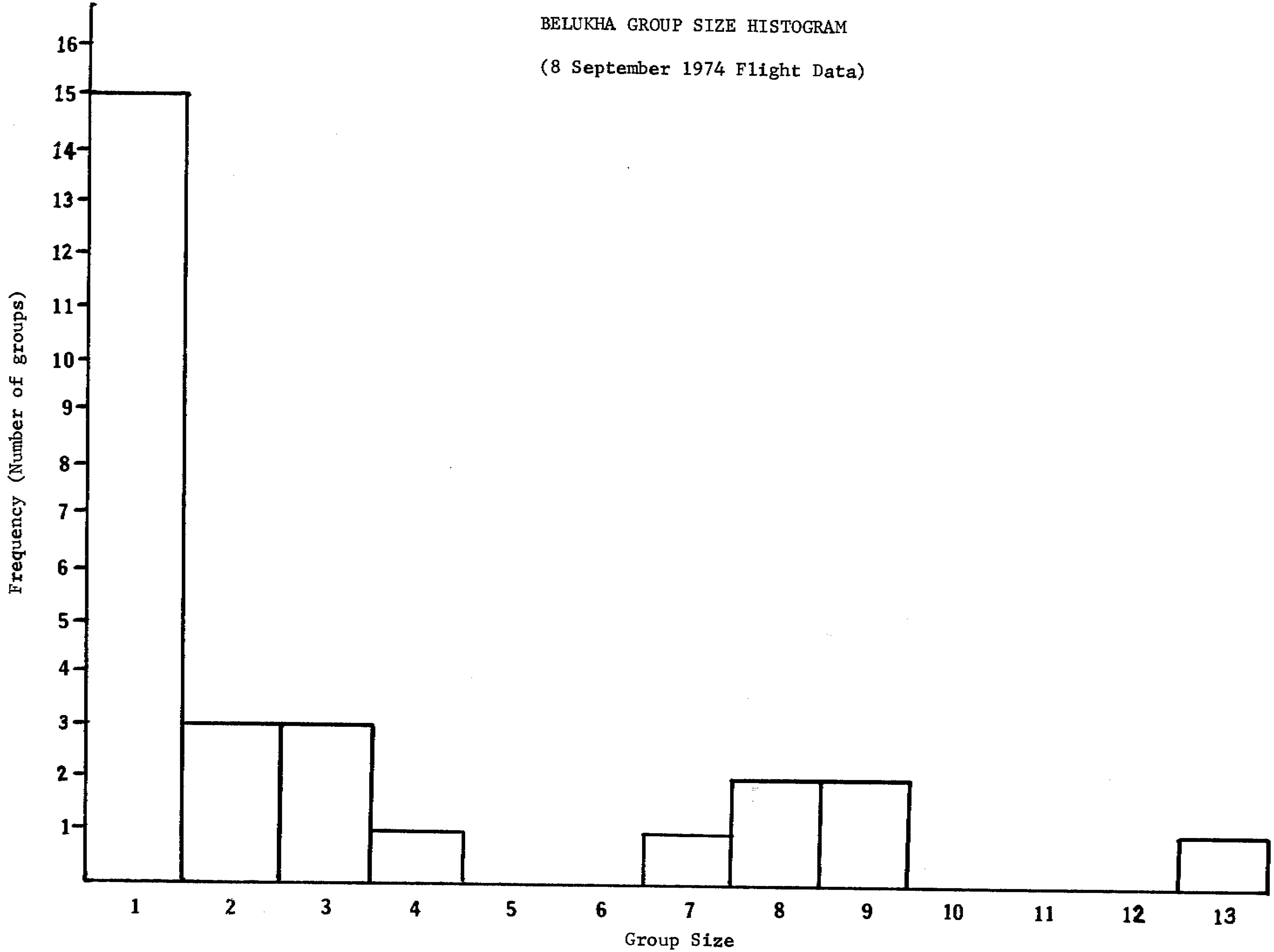
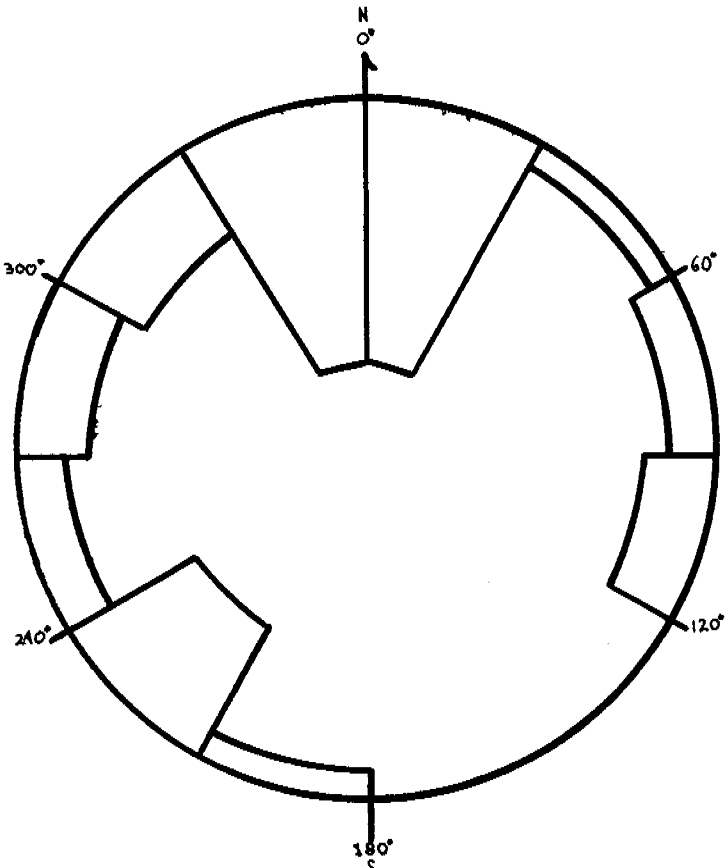
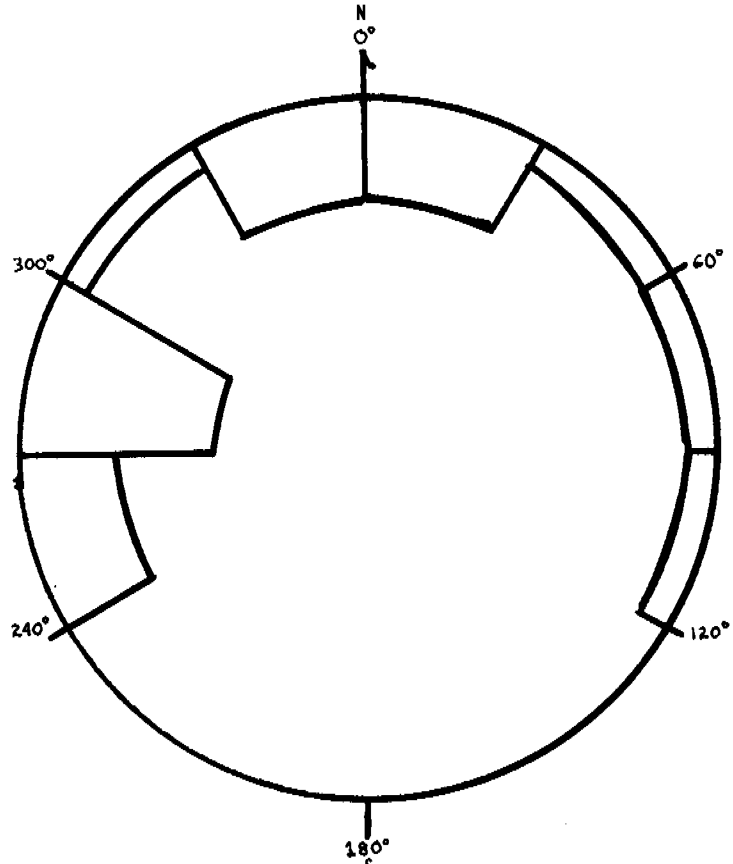


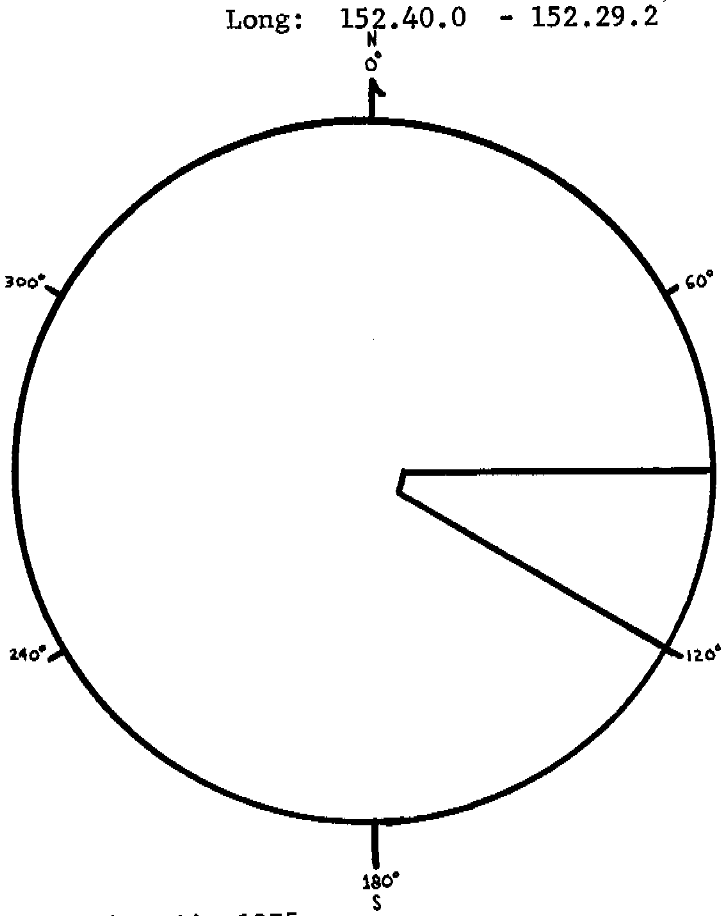
Figure 6



September 8, 1974
Between: Lat: 71.36.50 - 71.39.50
Long: 152.40.0 - 152.29.2



September 8, 1974
Between: Lat: 71.28.8 - 70.44.6
Long: 151.22.0 - 144.06.1



October 14, 1975
Between: Lat: 70.06.09
Long: 169.02.0

COMPASS DIAGRAM OF THE FREQUENCY DISTRIBUTION OF THE DIRECTIONAL HEADINGS OF BELUKHAS

Note: Each (1/8") equals one whale

Figure 7

Contract No. R7120804
Research Unit 67
1 April - 30 June 1977
4 pages

BASELINE CHARACTERIZATION OF MARINE MAMMALS IN THE BERING SEA

Principal Investigators

Howard Braham
David Rugh

Research Assistants

Teresa Bray
Robert Everitt
Mary Nerini
Nancy Severinghaus
Ronald Sonntag
David Withrow

United States Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest and Alaska Fisheries Center
Marine Mammal Division
7600 Sand Point Way NE
Seattle, Washington 98115

24 June 1977

Research Unit 67

Quarterly Report, 1 April - 30 June 1977

I. Task Objectives.

The primary objective for RU67 is a baseline characterization of marine mammals in the Bering and southern Chukchi Seas. Particular emphases during this quarter have been on aerial surveys of ice seals and cetaceans associated with the retreating ice front and on land-based studies of sea lion rookeries.

II. Field Activities.

A. Field trip schedule.

31 March to 10 April, approx. 48 flight hours out of Nome and King Salmon using a chartered Grumman Goose (N780).

11-15 May, approx. 23 flight hours out of Nome and Bethel using a chartered Grumman Goose (N780).

8-15 June, approx. 7 flight hours (other than freight trips) along the Alaska Peninsula in a NOAA UH-1H helicopter.

10 June to 13 July, 2 men stationed on Ugamak Island to conduct studies of sea lion rookeries.

27-30 June fly aerial surveys of the northern shore of the Alaska Peninsula and Eastern Aleutian Islands.

22 June to 15 July include marine mammal observers on NOAA ship <u>Surveyor</u>'s cruise.

B. Scientific Party.

Research Personnel	Survey Dates
Clifford Fiscus*	8-15 June
Howard Braham*	5-10 April, 8 June-15 July
David Rugh*	5-10 April, 8-15 June, 27-30 June
Robert Everitt	31 Mr-5 Ap, 8-15 June, 21 June-15 July
Bruce Krogman	31 Mr-10 Ap, 11-15 May, 27-30 June
Mary Nerini	31 Mr-10 Ap, 11-15 May, 21June-15 July
David Withrow	31 Mr-5 Ap, 11-15 May, 8 June-15 July
Ronald Sonntag	11-15 May
Teresa Bray	21 June-15 July
Roger Mercer	27-30 June

*Principal Investigators

C. Methods.

See FY 76 annual report for aerial survey techniques. See next quarterly report for details on methods used in the land-based survey at Ugamak.

D. Sample Localities.
(All aerial surveys unless noted otherwise)

31 Mr.	Norton Sound
1 Ap.	Bering Straits and S. Chukchi (between Nome and Pt. Hope)
2 Ap.	N. Bering (around St. Lawrence Island and to Nome)
3 Ap.	Norton Sound and N. Bering Sea north of St. Lawrence Island
4 Ap.	Nome to Cold Bay
5 Ap.	Cold Bay to Nome
7 Ap.	N. Bristol Bay
9 Ap.	Bristol Bay
10 Ap.	King Salmon to Port Heiden to Anchorage
11 May	Norton Sound
12 May	Nome to Pt. Hope to Kotzebue Sd. to N. Norton Sd.
14 May	Nome to Bethel incl. Norton Sound
15 May	Kuskakwim Bay to Round Island (Bethel to Anchorage)
8 June	Alaska Pen. north coast (King Salmon to Cape Sarichef)
9-10 June	Cape Sarichef (land-based survey)
10 June to 15 July	Ugamak Island (land-based study)
21 June to 15 July	Kodiak to Unimak Strait to Bering Sea and S. Chukchi Sea and return to Kodiak (ship cruise)
27-30 June	Alaska Pen. north coast and Eastern Aleutian Islands.

E. Data collected or analyzed. See Results.

III. Results.

Date	Flight Hours	Gray Whale	Walrus	Sea Lion	Harbor or Largha Seal	Bearded Seal	Ringed Seal	Ribbon Seal	Beluga
31 Mr.	6:30		13			121	2		
1 Ap.	5:58		7		2	81			355
2 Ap.	5:24		30			26			14
3 Ap.	6:27		2002			95	1		
4 Ap.	4:25								
5 Ap.	4:34		2602	5	14	22	4		
7 Ap.	7:18	3-17	845		41	60	17	2	
9 Ap.	3:27	2	237		49			1	5
10 Ap.	4:10				400				1
11 May	3:49		20			36	67	1	
12 May	6:56		68			207	189	1	149
14 May	7:26	118	933			12	57		7
15 May	4:36	33	9286	100	313				
8 June	5:33	105		52	607				
9-10 June	7:10*	26		86	5				
15 June	1:24	2		3	1				

Also, 2 bowhead whales were seen on Ap. 1, 3 on Ap. 2; 5 polar bears Ap. 1, 2 Ap. 2, 2 Ap. 3, 3 May 12; 11 sea otters Ap. 5, 11 June 8, 10 June 15; 3 harbor porpoise May 15, 8 June 8, 2 June 10; 1 Minke whale June 10.

* land-based count.

IV. Preliminary interpretation of results.

None to date.

V. Problems encountered/recommended changes.

Weather continues to complicate scheduling so that more liberal time allowances and respective logistic preparations are necessary.

VI. Estimate of funds expended.

Salaries/overtime	$17,417
Travel/per diem	13,346
Equipment/misc.	2,216
Charter aircraft	24,150
	$57,129

VII. Revised data submission schedule.

Data collected during this quarter up to June 15 will be submitted by 1 September, 1977.

VIII. Revised milestone chart.

Activity	July	August	September
Ugamak Survey (land-based)	________x		
St. Lawrence Survey	________x		
Eastern Aleutian aerial survey	________x		
Logging and computerization (NODC) of FY77 aerial data	__________	__________	__________x

Contract No. R7120806
Research Unit 68
1 April-30 June 1977
5 pages

SEASONAL DISTRIBUTION AND RELATIVE ABUNDANCE OF OFF-SHORE MARINE MAMMALS IN THE WESTERN GULF OF ALASKA: KODIAK ISLAND TO UMNAK ISLAND

Principal Investigators

Howard Braham
Roger Mercer

Research Assistants

Patrick McGuire
Carl Peterson
Ronald Sonntag

United States Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest and Alaska Fisheries Center
Marine Mammal Division
7600 Sand Point Way NE
Seattle, Washington 98115

24 June 1977

Research Unit 68

Quarterly Report, 1 April - 30 June 1977

I. Task Objectives.

Objectives of RU 68 are to collect data and summarize the literature on the seasonal distribution and relative abundance of marine mammals in the western Gulf of Alaska from Kodiak Island to Unimak Island and the eastern Aleutian Islands.

II. Field or laboratory activities.

A. Ship schedules.

Discoverer.

Leg IV	4-23 April	Kodiak-Lower Cook Inlet
Leg V	26 April-16 May	Bristol Bay
Leg VI	19 May-12 June	Bering Sea
Kodiak-PMC	14-17 June	GOA

Surveyor.

Leg II	15 March-7 April	Bering Sea
Leg III	11 April-3 May	Bering Sea
Kodiak-PMC	3-9 May	GOA
Leg I	6-18 June	PMC-WGOA, Kodiak
Leg II	21 June-14 July	Bering Sea

Miller Freeman.

Leg I	18 Jan.-11 Feb.	PMC-WGOA
Leg II	14 Feb.-10 March	WGOA
Leg III	12-26 March	Bering Sea
Leg IV	28 March-8 April	
Leg V	13-29 April	Bering Sea
Leg VI	3-20 May	Bering Sea
Leg VII	24 May-11 June	Bering Sea, NEGOA
	11-17 June	En route Yakutat-PMC

B. Scientific party.

Marine Mammal Division observer aboard the Miller Freeman 12-26 March and the Discoverer 26 April-17 June was Patrick McGuire. Howard Braham, Teresa Bray and Mary Nerini represented the MMD on the Surveyor 21 June-14 July. Assigned ship's officers were: Ensign Susan Ludwig (Discoverer), Ensign Lewis Consiglieri (Surveyor) and Ltjg. Patrick Rutten (Miller Freeman).

C. Methods.

Watch effort and marine mammal sighting data are recorded by RU 68 personnel when they are aboard. Otherwise, data are collected by assigned ship's officers, who transmit their logged data on Marine Operations and Station Abstracts to RU 68 Principal Investigators via the OCSEAP Juneau Project Office. Field data from both sources are prepared for computer processing as outlined below:

FIELD LOGBOOKS

↓

EVALUATED, INTERPRETED & CODED--
INITIALED BY PERSON CODING DATA

↓

CODING SHEETS CHECKED 100% WITH
FIELD LOGS & INITIALED BY PERSON
CHECKING DATA

↓

CODING SHEETS SENT TO KEYPUNCHING
TWO WEEK TURN AROUND

↓

CARDS RETURNED & LISTED AT NWAFC
FOR CHECKING

↓

LISTING CHECKED WITH 10% OF THE
FIELD LOG ENTRIES FOR KEYPUNCHING
VERIFICATION. LISTING INITIALED
BY PERSON MAKING VERIFICATION
CHECK.

↓

DATA IS EDITED PER FINAL VERIFICATION. PERSON EDITING DATA WILL
INITIAL LISTING.

↓ ↓

DATA IS STORED ON TAPE AT UW COMPUTER CENTER

ORIGINAL CARD DECK IS STORED AT NWAFC

Tracklines flown and sighting data recorded during this quarter are being plotted on chartlets which cover the proposed lease areas of the western Gulf of Alaska. The ratio of sightings of each species to the total number of sightings reported for each month has been computed for cross-tabular representation of relative seasonal abundance.

D. Sample localities.

Data are being collected by OCSEAP vessels in the NWGOA, eastern Aleutian Islands and Bering Sea. Bering Sea data are being archived until funds can be located to analyze them.

E. Data collected or analyzed.

1. a. Approximately 2,000 marine mammal sighting records and 500 watch effort records were computerized during the past quarter.

   b. Approximately 112 hours were spent on watch by Patrick McGuire (MMD) between Kodiak Island and the Pribilof Islands (800 nmi), 12-26 March (Leg III). Over 125 marine mammal sightings were recorded. These data have been coded and will be sent to OCSEAP (Juneau) with the next data transmission.

2. Reported tracklines are being plotted for approximately 50 cruises now in our computer files. These plots will permit examination of part of the data with regard to watch effort (from Kodiak Island to Unimak Pass). Sighting data will be correlated with effort data for relative density plots.

3. Miles of trackline. Not yet determined.

III. Results. The data have not come off the ship(s).

IV. Preliminary interpretation of results. N/A

V. Problems encountered/recommended changes.

A. The NEGOA and Kodiak Island synthesis meetings (January and February 1977) stressed the existence of much information pertinent to assessment of the environment of the Gulf of Alaska and Bering Sea that had not been analyzed. Approximately 60% of our data (12,000 sighting reports) have been coded and verified, and are now on tape and disk in computer files. Many of these data are from areas of the Gulf of Alaska and Bering Sea that are not within the assigned bounds of RU 68. They are from a variety of sources: commercial fishermen, NOAA ships, other government ships and private vessels. These data cannot be utilized until funds are provided for analysis.

B. OCSEAP vessels are not scheduled to work in the Aleutian Islands lease area south of Umnak and Unalaska Islands. Since very few data on marine mammals are available for the Aleutian Islands lease area, no environmental assessment can be made!

VI. Estimate of funds expended.

Salaries/overtime	$6,474.00
Travel/per diem	1,252.09
Equipment	15.70
Computer	350.00
	$8,091.79

VII. Revised data submission schedule.

Data from the following cruises are being translated to File Type 027 format for NODC. They should be received in Juneau by 30 June 1977.

Discoverer	25 Feb.-24 May 1976
Surveyor	18-28 October 1976
Rainier	21 March-31 Oct. 1974
Miller Freeman	16 March-30 May 1976
Davidson	28 March-31 Oct. 1974
Davidson	18 Feb.-3 Nov. 1976
Oregon	10-24 Oct. 1973
Tordenskjold	3 June-17 August 1973
USFS Ferries	2 June-7 Sept. 1976
Oregon	6 April-14 July 1974
Tordenskjold	19 June-4 August 1976
E. L. Bartlett	4 July-30 August 1972
Matanuska	20 June-25 August 1972
Taku	20 June-8 August 1972
Discovery	6 April-28 October 1976
Alaska Enforcement	1 March-12 October 1972
USFS Ferries	15 June-3 Sept. 1971
Foreign Vessel Program	27 August 1973-18 June 1976
Halibut Commission	7-23 June 1972
Oceanographer	28 Jan.-5 March 1975
Discoverer	9 May-6 Dec. 1975
Discoverer	7-30 April 1976
Discoverer	16-19 July 1976
Surveyor	6-25 June 1976
Surveyor	9-13 March 1976
Surveyor	13-26 April 1976
Rainier	22 April-27 August 1975
Miller Freeman	3-22 June 1976
Davidson	6 May-22 October 1975
Tordenskjold	31 May -11 August 1975
Oregon	3 April-13 July 1975
Cromwell	28 April-11 June 1975
Moana Wave	4-17 August 1976
Polar Star	29 April-22 June 1976
Fairweather	5 May-21 August 1975
Oregon	3 April-18 Nov. 1976
Wickersham	23 June-1 July 1972
Matanuska	15 June-24 August 1974

Matanuska	21 June-29 August 1973
Taku	13 June-26 August 1973
Taku	28 June 1974
Malaspina	10-31 July 1973
Columbia	28 July-11 August 1974
Montague	12-19 Sept. 1974
Tordenskjold	27 May-16 August 1974
Discovery	22 May-7 August 1975
Maranatha (Troller)	28 May-21 August 1976
Ole B (Troller)	28 April-7 August 1976
Alaska Enforcement	8 Jan.-6 Oct. 1974
Miscellaneous	1 June 1972-29 Dec. 1976
Surveyor	12 May-13 Dec. 1976
Miller Freeman	16 Feb.-25 March 1977

Incidental marine mammal sightings made by Marine Mammal Division pelagic seal hunters from 1958-1974.

Area	Limits
00-British Columbia	49°01'N to 54°29'N
44-S.E. Alaska	54°30'N to 58°10'N
66-Gulf of Alaska	58°10'N to 153°52'W (North of Cape Spencer to Cape Sitkinak)
77-Western Alaska	153°52'W to 166°00'W

VIII. Revised milestone chart.

Activity	June	July	August	Sept.	Oct.
*Discoverer cruise Bering Sea	—X				
*Surveyor cruise Bering Sea	————	X			
Translation of 1972-76 OCS data to EDS format	—X				
Quarterly report				X——X	
Processing OCS data	————	————	————	——X	

*These vessels are traversing our study area, from Kodiak Island to Unimak Pass. One to four observers will be aboard.

Contract No. R7120807
Research Unit 69
1 April - 30 June 1977
2 pages

DISTRIBUTION AND ABUNDANCE OF BOWHEAD AND BELUGA WHALES IN THE BERING, CHUKCHI AND BEAUFORT SEAS

Principal Investigators

Howard Braham
Bruce Krogman

Research Assistants

Geoff Carroll
Robert Everitt
Edwin Iten
Carl Peterson
David Rugh
Scott Sappington
Steve Savage
John Smithhisler

United States Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest and Alaska Fisheries Center
Marine Mammal Division
7600 Sand Point Way NE
Seattle, Washington 98115

24 June 1977

Research Unit 69

Quarterly Report, 1 April - 30 June 1977

I. Task Objectives.

Objectives of RU 69 are to study the biology of bowhead (Balaena mysticetus) and beluga (Delphinapterus leucas) whales, and to address specifically distribution and relative abundance in the northern Bering Sea, Chukchi Sea and Beaufort Sea.

II. Field or Laboratory Activities.

A. 1. Field camps were deployed to count whales:

a. Pt. Barrow - ice camp (19 April - 3 June) Most bowhead whales were counted 1-16 May as they passed by Pt. Barrow. Thereafter, movements were small and sporadic, partly attributable to changing ice conditions. No trends were apparent regarding movements of beluga whales, except that the animals were extremely clumped. Total number of animals counted by OCS crew: bowheads (327); beluga (611).

b. Cape Lisburne - land camp on cliff (5-17 May) Analysis of data is in progress. Preliminary findings indicate that whale counting from Cape Lisburne may be possible, provided that precautions are taken against high winds. Total number of animals seen: bowheads (51); beluga (155).

c. Pt. Hope - ice camp (18 April - 28 May) Unsafe ice conditions and severe weather prevented intensive watch effort until 27 April. Thereafter (until 4 May) conditions improved and a major pulse of whales passed. Poor viewing occurred again between 5 and 16 May. From 17-28 May viewing was excellent. Total number of whales counted: bowheads (200); beluga (1699).

2. Aerial survey

One aerial survey was made on 30 May to search for whales moving offshore northeast of Pt. Barrow. Thirty-five beluga were counted, but no bowhead were seen. Logistical problems attributable to NARL precluded aerial survey during the peak migration season, i.e., early to mid-May.

B. Laboratory activities.

Field data are being logged and checked; some analysis has begun.

C. Methods.

See FY 76 Annual Report.

III. Results. Analysis is not complete.

IV. Preliminary interpretation of results. None.

V. Problems encountered/recommended changes.

A. Logistic support by NARL for aerial survey.

NARL failed to provide aircraft as contracted. Measures are being taken to ensure that this problem is avoided during upcoming field studies.

B. Cape Lisburne ice camp.

The camp was made inoperative by high winds. This can be avoided by replacing the tent with a wooden structure.

VI. Estimate of funds expended.

Salaries/overtime	$26,846.
Travel/per diem	4,896.
Equipment/misc.	790.
Logistics	13,600.
Computer	100.
	$46,232.

VII. Revised data submission schedule.

All data collected during this quarter will be submitted by 1 September 1977.

VIII. Revised milestone chart.

Activity.	July	August	September
Logging and computerization (NODC) of FY76 ice camp data		X———X	
Logging and computerization (NODC) of FY77 ice camp data			X———X
Analysis of data	———	———	———X

QUARTERLY REPORT

Contract 03-5-022-56
Task Order No. 8
Quarter Ending: 30 June 1977

R.U.#194 - MORBIDITY AND MORTALITY OF MARINE MAMMALS (BERING SEA)

Principal Investigator

Dr. Francis H. Fay
Associate Professor of Marine Science
and Arctic Biology
Institutes of Marine Science and Arctic Biology
University of Alaska
Fairbanks, Alaska 99701

Assisted by: Associate Investigator

Dr. Robert A. Dieterich
Professor of Veterinary Science and Wildlife Disease
Institute of Arctic Biology
University of Alaska
Fairbanks, Alaska 99701

and

Larry M. Shults
Biological Technician
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

June 30, 1977

QUARTERLY REPORT

I. Task Objectives This Quarter

A. To necropsy specimens taken during marine mammal field work of R.U. 230, 232 *via* NOAA vessels working in Bering Sea.

B. To begin annual survey and necropsy of beached carcasses of marine mammals, Bering Sea.

II. Field and Laboratory Activities

A. Field trip schedule

15 March - 8 April *Surveyor* Leg II (Dieterich & Shults) E. Bering Sea

11 April - 3 May *Surveyor* Leg III (Fay & Shults) E. Bering Sea

19 May - 11 June *Discoverer* Leg VI (Fay & Shults) E. Bering Sea

5-20 June Bristol Bay carcass survey (Dieterich)

27 June - 5 July St. Lawrence Island carcass survey (Fay)

B. Laboratory activities

None

C. Methods

Necropsy procedures on specimens collected during the three cruises in eastern Bering Sea were as described in the project manual on "Postmortem procedures" (see Annual Rept. 31 March 1976). Survey procedures also were as described previously (Ibid.).

III. Results

A. Cruise collections

Forty-five specimens of pinnipeds collected during the eastern Bering ice edge cruises were necropsied, as follows:

1 Steller sea lion, *Eumetopias jubatus*

1 Walrus, *Odobenus rosmarus*

8 Bearded seals, *Erignathus barbatus*

14 Ribbon seals, *Phoca fasciata*

18 Spotted seals, *Phoca largha*

3 Ringed seals, *Phoca hispida*

The gross pathological findings in these, as preliminarily interpreted (pending histopathological and further microbiological studies), are shown in Table 1.

Preliminary results of parasitological examinations are shown in Table 2.

A serum sample for antibody titration was obtained from each specimen. Various pathogenic bacterial and mycological agents, isolated from the lesions are in the process of being identified.

B. Carcass surveys

The Bristol Bay survey is under way at this writing, and preliminary results indicate a much lower number of carcasses than was found in either of the previous two years.

The St. Lawrence Island survey will begin in the last week of this quarter.

IV. Preliminary Interpretation of Results

No further interpretation is feasible at this time.

V. Problems Encountered/Recommended Changes

None

Table 1. Preliminary interpretation of gross pathological findings in pinnipeds collected in eastern Bering Sea, March-May 1977.

Findings	Sea Lion	Walrus	Bearded Seal	Ribbon Seal	Spotted Seal	Ringed Seal
No. examined	1	1	8	14	18	3
Wounds	1	0	0	2	3	1
Dermatomycosis	1	0	0	0	0	1
Pox-like lesions	0	0	0	2	0	1
Bone disease or fracture	0	0	0	2	0	0
Eyes inflamed	0	0	0	1	0	1
Lung: nodular consolidations	1	0	0	2	3	0
Lymphadenitis	0	0	0	1	2	0
Bile ducts fibrosed	0	0	2	0	0	0
Microabcesses in liver	1	0	8	14	18	2
Gall stones	0	0	1	0	0	0
Internal hemorrhage (ruptured spleen, liver)	0	0	1	0	1	0
Gastric, duodenal ulcers	1	0	0	0	2	0
Nodular lesions in pancreas	0	0	0	1	0	0

Table 2. Preliminary results of parasitological examinations.

Findings	Sea Lion	Walrus	Bearded Seal	Ribbon Seal	Spotted Seal	Ringed Seal
No. examined	1	1	7	8	9	1
Nasal mites	1	0	0	0	1	0
Heartworms	0	0	0	0	1	0
Trematodes in liver	0	1	4	1	0	0
Nematodes in stomach	1	0	7	8	7	1
Cestodes in gut	1	1	7	0	5	1
Trematodes in gut	0	0	0	0	1	0
Acanthocephalans in gut	1	1	7	7	7	1

QUARTERLY REPORT

Contract #03-5-022-69

Research Unit #229

Reporting Period 1 April thru
30 June 1977

Number of Pages - 2

Biology of the Harbor Seal, *Phoca vitulina richardi*, In the Gulf of Alaska

Principal Investigators:

Kenneth Pitcher, Marine Mammals Biologist

Donald Calkins, Marine Mammals Biologist

Alaska Department of Fish and Game

This project is investigating several phases of the biology and ecology of the harbor seal in the Gulf of Alaska which relate to oil and natural gas development in the area. Basic objectives include: (1) examination of food habits and trophic relationships, (2) investigation of population productivity with emphasis on determining age of sexual maturity and age specific reproductive rates and (3) examination of growth and body condition. Peripheral objectives include collection of data concerning seasonal distribution, use of critical habitat, effects of disturbance, population composition and collection of specimen materials for disease and enviornmental pollutant analyses.

Methods utilized for collection of these data have been previously detailed in the annual reports.

Field activities during the past quarter included two collecting cruises aboard the ADF&G research vessel Resolution. Both cruises were in the Kodiak lease area and a total of 87 seals were collected. A short operation utilizing the NOAA UH-IH helicopter was conducted in the Trinity Islands area to test techniques which may eventually be utilized to assess and monitor harbor seal population status.

Laboratory activities were limited to sorting stomach contents and female reproductive tract analysis. Three very successful collecting trips this spring have produced a considerable backlog of specimen materials.

Personnel participating in field and laboratory activities this quarter include: E. Klinkhart, A. Egbert, D. McAllister, K. Schneider, B. Ballenger, R. Aulabaugh, F. Palmer, C. Lucier, D. Calkins and K. Pitcher. All were ADF&G employees.

No additional data analyses have been completed since preparation of the Annual Report.

Quarterly Report

Contract #02-5-022-53
Research Unit #230
Reporting Period: April-June 1977
Number of Pages: 7

The natural history and ecology of the bearded seal (*Erignathus barbatus*) and the ringed seal (*Phoca hispida*)

Principal Investigators:

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

Assisted by: Kathryn Frost, Lloyd Lowry and Glenn Seaman

30 June 1977

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

A. Schedule

Date	Location	Activity	Personnel
April-June	Fairbanks	Analyses of seal specimens and data	Eley, Burns
March-April	OSS SURVEYOR (southern Bering Sea)	Collection of seal specimens and seal and ice surveys	Lowry, Frost Burns
March-April	Nome, Kotzebue, Cape Lisburne and Barrow	Collection of seal specimen and seal and ice surveys with aid of helicopter	Eley, Burns
May	OSS DISCOVERER (Bering Sea)	Collection of seal specimens	Lowry
May	Point Hope	Collection of seal specimens from native harvest	Seaman
June	Nome	Collection of seal specimens	Frost
June	Wales	Collection of seal specimens from native harvest	Seaman
June	Point Lay to Barter Island	Aerial survey of ice and seals	Eley, Burns

During this quarter a major field effort was undertaken in the Norton Sound, eastern Chukchi Sea and Beaufort Sea areas. We were successful in acquiring a large sample of ringed seals in Norton Sound during a period in which our previous sample size was inadequate (March). The entire field program was directly tied in with the acquisition of required material used in other projects, most notably RU#'s 232 and 248.

Laboratory activities consisted mainly of processing female reproductive tracts and determining ages of seals acquired through March 1977. Various parameters of reproduction were determined.

Data management was continued on an ongoing basis, as was the acquisition of information from other related studies, mainly those conducted by Soviet investigators.

B. Scientific Party

Name	Affiliation	Role
John J. Burns	ADF&G	Principal Investigator
Thomas J. Eley	ADF&G	Principal Investigator
Kathryn Frost	ADF&G	Marine Mammals Biologist
Lloyd Lowry	ADF&G	Marine Mammals Biologist
Glenn Seaman	ADF&G	Marine Mammals Technician

C. Analytical Methods

From all specimens we endeavor to obtain weights, standard measurements, lower jaws, foreflipper claws, stomachs, reproductive tracts and intestines. We also obtain blubber, tissue, organ and blood samples as the situation permits.

The ages of seals are determined by examination of claw annuli (for animals generally six years or younger) and dentine or cementum annuli (for animals over six years of age). Growth rates are based on weight and standard measurements correlated with specimen age, sex and date and locality of collection. Species productivity and parasite burden are determined, respectively, through laboratory examinations of reproducive tracts and various organs and correlation of these data with age, sex, and date and locality of collection of each specimen.

Regional differences in seal density and distribution are assessed through aerial surveys following the methods of Burns and Harbo (1972).

Analytical methods are discussed in detail in our Annual Report for 1977.

III-IV. Results and Preliminary Interpretaion

A. Specimens

During March-June 1977 our major efforts were devoted to collection of specimens in the Bering, Chukchi and Beaufort Seas and to the laboratory analyses of these specimens. Little time was given to data analyses.

A total of 13 male, 11 female and 1 sex unknown bearded seals were obtained (Table 1), yielding a 1:1 sex ratio. Sixty-nine ringed seals were obtained and consisted of 42 males and 27 females. Although this is approximately a 2:1 sex ratio, it is probably not indicative of the true sex ratio of the population. During March to May, when most of our samples were obtained, females are involved in lair construction and birth- and pup-related activities and thereby are not readily available for harvest. When specimens collected throughout the year are examined, ringed seals in Alaska and Canadian waters yield a 1:1 sex ratio.

Table 1. Seal specimens obtained during March-June 1977.

Location	Male	Female	Unknown	Total
Nome				
Ringed seal	12	17	-	29
Bearded seal	7	1	1	9
Point Hope				
Ringed seal	23	8	-	31
Barrow				
Ringed seal	5	1	-	6
Bearded seal	3	3	-	6
OSS SURVEYOR				
Ringed seal	-	1	-	1
Bearded seal	3	7	-	10
OSS DISCOVERER				
Ringed seal	2	-	-	2
Total				
Ringed seal	42	27	-	69
Bearded seal	13	11	1	25

B. Ringed Seals

1. Reproductive biology

The reproductive tracts of 19 female ringed seals collected between January and June 1977 were examined during this quarter and the results of these examinations are presented in Table 2. Five of the 19 females (26%) were 7 years of age or younger and all 5 females were nulliparous and not pregnant. Fourteen of the 19 females (74%) were 8 years or older. Of these 14 females, 3 (21%) were nulliparous, 4 (29%) were primaparous, and 7 (50%) were multiparous. Seven of the 14 females older than 8 years (50%) were pregnant when collected and 2 additional females had been pregnant but had aborted the fetuses sometime during mid-pregnancy.

Table 2. Reproductive status of 19 female ringed seals collected from January to June 1977.

Number	Claw age (years)	Month of collection	Pregnant (yes or no)	Reproductive status	Comments
SUVP-1-77	1	April	No	Nulliparous	-
NP-30-77	4	March	No	Nulliparous	-
NP-5-77	5	March	No	Nulliparous	-
NP-10-77	7	March	No	Nulliparous	-
NP-19-77	7	March	No	Nulliparous	-
NP-14-77	8+	March	Yes	Primaparous	-
NP-29-77	8+	March	No	Nulliparous	-
NP-31-77	8+	March	No	Multiparous	-
NP-2-77	9+	March	Yes	Primaparous	-
NP-21-77	9+	March	No	Nulliparous	-
NP-23-77	9+	March	No	Multiparous	had aborted fetus both ovaries cystic
NP-9-77	10+	March	No	Multiparous	-
NP-13-77	10+	March	Yes	Multiparous	-
NP-28-77	11	March	Yes	Multiparous	-
NP-3-77	12	March	Yes	Primaparous	-
NP-18-77	12+	March	No	Nulliparous	-
BP-9-77	12+	April	No	Multiparous	had aborted fetus
NP-1-77	13+	March	Yes	Primaparous	-
NP-15-77	13+	March	Yes	Multiparous	-

In a sample of 33 adult female ringed seals obtained prior to 1973, 30 were or had just been pregnant, yielding a pregnancy rate of 91 percent. The reproductive tracts of 56 adult females collected during 1975 through 1977 have been examined thus far and 33 (59%) were or had just been pregnant. Johnson et al. (1966) found 240 of 280 (86%) adult females (collected near Cape Thompson, Alaska during 1960 and 1961) pregnant. The decline in the pregnancy rates of our samples between 1964-1973 and 1975-1977 corresponds to the decline in the pregnancy rates reported by Stirling et al. (1975). However, the magnitude of the decline in pregnancy rates in Canadian ringed seals is significantly greater; in 1972 a pregnancy rate of 59 percent was found and in 1974 and 1975 a Ø percent and 11 percent pregnancy rate was found, respectively. The reason for the decline of pregnancy rates of female ringed seals in Alaskan waters is unknown and it is presently under investigation.

B. Bearded Seals

During the March cruise of the SURVEYOR, K. Frost and L. Lowry found bearded seals to be comparatively numerous in the ice front. An aerial survey conducted on 28 March, using the ship based helicopter, indicated a density of 0.65 bearded seals per nautical mile^2 in strip transects covering 103.3 nautical miles^2.

It appeared, however, that by the last third of April, active northward migration of bearded seals was well underway and densities of these seals in the southern margin of pack ice were low. The results of aerial surveys conducted by helicopter from the SURVEYOR during late April are indicated below:

Date	General location	No. miles surveyed (NM^2)	Density of bearded seals
21-IV-77	57°40'N 164°55'W	40.6	0.22
23-IV-77	58°30'N 169°50'W	114.5	0.01
23-IV-77	58°30'N 169°50'W	85.3	0.07
24-IV-77	58°45'N 169°30'W	15.0	0.07
24-IV-77	58°45'N 169°30'W	30.6	0
25-IV-77	58°45'N 169°00'W	43.9	0.07
27-IV-77	59°40'N 174°10'W	31.2	0
27-IV-77	59°45'N 174°30'W	24.7	0

Ovarian analysis of 76 female bearded seals collected during 1975 and 1976 was completed during this quarter. General results indicate no long-term changes in productivity since about 1959.

Of the 76 females examined, preliminary results indicate that 54 (71%) were sexually mature and 22 (29%) were sexually immature. The incidence of pregnancy in sexually mature animals, as indicated by the presence of an active corpus luteum, was 96 percent. However, many of these females were taken during the period between mating and fetal implantation (early May to mid-July).

The presence of an active corpus luteum during this period, although indicative of ovulation and probably conception, overestimates the incidence of successful implantation.

Our examination of uteri from female bearded seals taken after 15 July is not yet complete. Partial results, based on specimens collected at Wainwright, during July and August showed that 10 of 12 sexually mature females (83%) were supporting implanted fetuses. Johnson et al. (1966) found that in adult females collected at Point Hope during January through April in 1960 and 1961, 83 percent supported fetuses. Burns (1967) reported a pregnancy rate of 83.5 percent based on a sample of 133 sexually mature females collected between 1962 and 1966.

It appears that the incidence of pregnancy in bearded seals of the Bering and Chukchi Seas has remained high and stable over a long period of time. This is in marked contrast to an apparent sharp decline in pregnancy rates of ringed seals from the same areas.

D. Ringed Seal Surveys

During June 1977 an area of 987 square statute miles was surveyed between Point Lay and Barter Island to assess changes in ringed seal densities from our previous surveys (1970, 1975 and 1976). The results of this 1977 survey are presented in Table 3. A total of 1708 ringed seals were observed, for a mean density of 1.73 seals per square mile. However, when examined according to geographic area the densities ranged from 0.50 seals per square mile (Lonely to Oliktok) to 3.33 seals per square mile (Point Lay to Wainwright).

Table 3. Geographical variation in ringed seal densities, June 1977.

General Location	Area surveyed (statute miles^2)	# ringed seals observed	density (seals/mile^2)
Point Lay - Wainwright	204	679	3.33
Wainwright - Barrow	202	517	2.56
Barrow - Lonely	285	272	0.95
Lonely - Oliktok	87	44	0.50
Oliktok - Flaxman Island	96	66	0.69
Flaxman Island - Barter Island	113	130	1.15

The combined data from the 1970, 1975, 1976 and 1977 surveys are presented in Table 4. A detailed "population" analysis will be presented in our September 1977 Quarterly Report. However, several trends are apparent at this time. The densities of seals have decreased from 1970 to the present. The reason for this decline is unknown and it is being investigated at this time. In addition, we do not know whether there has been a concomittant increase in ringed seals in other areas or whether this is a major decrease in ringed seal numbers in Alaskan waters.

Table 4. Ringed seal densities (seals per square statute mile) for June surveys conducted during 1970, 1975, 1976 and 1977.

Location	1977	1976	1975	1970
Point Lay - Wainwright	3.3	1.9	2.9	5.4
Wainwright - Barrow	2.6	3.8	6.2	3.7
Barrow - Lonely	1.0	1.4	2.8	2.3
Lonely - Oliktok	0.5	1.1	1.4	1.0
Oliktok - Flaxman Island	0.7	1.4	1.0	1.4
Flaxman Island - Barter Island	1.2	0.4	1.8	2.4

V. Problems Encountered/Recommended Changes

None, with the exception of the anticipated difficulty of obtaining seal specimens from the Beaufort Sea during winter and early spring. Our only change will be to direct more effort toward work in this area.

VI. Estimates of Funds Expended

As of May 30 we have expended the following approximate amounts during FY 77.

Salaries and benefits	-	$83,045
Travel and per diem	-	5,300
Contractual services	-	5,266
Commodities	-	4,587
Equipment	-	518
Total expenditures	-	$98,716

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An Aerial Census of Spotted Seal, *Phoca vitulina largha*, and Walruses, *Odobenus rosmarus*, in the Ice Front of Bering Sea

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August 1, 1977

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I. Summary

Twenty-five individual survey flights for marine mammals were made in the ice front of Bering Sea during the March-April period of 1976 and 1977. These included 8 extensive flights in a Lockheed P-2V aircraft and 17 flights in a Bell 206 helicopter launched from the NOAA vessel OSS SURVEYOR. Results obtained from these flights showed that both spotted seals, Phoca vitulina largha and walruses, Odobenus rosmarus occur throughout the front. Large concentrations of both species were present in central and western Bristol Bay, a region which must be considered as critical habitat. The number of walruses in the ice front during April 1976 was estimated at 10,000. No estimate of the number of spotted seals could be made.

Observed densities of spotted seals in large sectors of the front, as surveyed with the P-2V, ranged from 0.02 to $2.75/NM^2$. Density of seals as determined by localized flights in the helicopter ranged from 0 to $6.75/NM^2$ in 1976 and 0.5 to $6.72/NM^2$ in 1977. Spatial distribution of seals throughout the front in both years was similar. Subadults composed the highest proportion of seals in areas of high seal density. In the vast region of the front west of Bristol Bay most of the seals observed were adults with pups.

The helicopter was slightly better for surveying than was the P-2V. More seals were observed from the helicopter although counts obtained from each were close.

Weather conditions and time of day when surveys were conducted did not significantly affect the results of surveys which were conducted in April of both years.

It was estimated that less than 14 percent of the seals in areas of high seal density were on the ice when surveys were conducted. Twenty-five to 50 percent were hauled out in those areas occupied mainly by adults and pups. The density of pups throughout the ice front was directly related to the density of older seals. However, the proportion of pups in high density areas was low.

Annual differences in the location of the ice front did not result in significantly different patterns of spotted seal distribution within the front during 1976 and 1977. Ice conditions during 1976 resulted in a broader distribution of spotted seals north of the front. This did not appear to occur in April 1977.

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II. Introduction

In the eastern Bering Sea during late winter and spring the southern terminus of sea ice normally reaches a position extending from Bristol Bay to the vicinity of the Pribilof Islands. Two proposed OCS lease areas, Bristol Bay and St. George Basin, occur in this region. During formulation of the Outer Continental Shelf Environmental Assessment Program it was determined that baseline information about the distribution and abundance of ice associated marine mammals occurring in the proposed lease areas should be obtained.

This report is primarily about such an assessment of spotted seals, *Phoca vitulina largha*, based mainly on aerial surveys in the ice front of eastern Bering Sea during the late-winter, early-spring of 1976. A secondary objective was to obtain similar information about winter distribution of walrus, *Odobenus rosmarus*, in the ice front.

Several delays in preparation of this annual report have provided opportunity to incorporate data obtained during the March-April 1977 cruises of the OSS SURVEYOR.

Spotted or largha seals are one of the five ice associated species of pinnipeds which occur in the seasonally ice covered regions of Bering Sea. The others are: ribbon seals, *Phoca fasciata*; ringed seals, *Phoca hispida*; bearded seals, *Erignathus barbatus*; and walrus.

During summer months, when the Bering and Chukchi Seas are ice free, spotted seals are widely distributed mainly along the coasts of Siberia, Alaska and the northern Bering Sea islands. They occupy estuaries, bays and the mouths of rivers, and frequently haul out on land. Along the Alaskan coast, summer distribution extends from the Aleutian Islands and Alaska Peninsula, to Demarcation Point. Greatest numbers occur between Kuskokwim Bay and Wainwright.

In the western Bering Sea these seals occupy a range extending from the Kuril Islands in the south to at least Cape Schmidt in the Chukchi Sea. On the Siberian coast the greatest numbers occur between Karaginski Bay and East Cape (Golt'sev, pers. comm.).

During summer and early fall spotted seals mainly occupy a near shore habitat and haul out on land. From November through June they are associated with ice and appear to prefer particular sea ice conditions. These include relatively thin ice through which the seals can poke holes with their heads, or relatively small floes comprising what can be termed unconsolidated pack ice.

As sea ice forms in late autumn, spotted seals occupying the more northerly parts of their range move south, into Bering Sea. They are most numerous in the "front" zone of the advancing (and forming) ice cover. This process continues throughout the early winter - more spotted seals moving away from the coast and associating with the front of a southward advancing ice cover.

Usually, by late winter the ice cover obtains its maximum extent. Annual differences in climatic conditions and extent of ice in Bering Sea are significant. In some years ice covers all of Bristol Bay, extending down to the western tip of the Alaska Peninsula. In other years it barely reaches St. Matthew and Nunivak Islands. However, on the average, the southern limit of ice in central Bering Sea coincides with the edge of the continental shelf (200m isobath). In eastern Bering Sea it "normally" occurs down to 57° or 58° N latitude.

The preference of spotted seals for ice consisting of relatively small, unconsolidated floes appears to be maintained throughout the late winter and spring and the greatest relative density of these seals occurs in the front zone, extending from Alaska to Siberia. However, density of seals in different regions of the front varies greatly. They also occur in favorable localized areas north of the front.

The diet of spotted seals can be indicated, in general terms, as including a variety of schooling and demersal fishes and, of secondary importance, shrimps. During the late winter-spring period of 1976, studies conducted aboard the OSS SURVEYOR (RU#230) showed that capelin, Mallotus villosus, were of primary importance (Lowry, Frost, Burns 1977). Observations during previous years have indicated that walleye pollock, Theragra chalcogramma, herring, Clupea harengus pallasi, smelt, Osmarus mordax dentex, eulachon, Thaleichthys pacificus, sandlance, Ammodytes hexapterus, saffron cod, Eleginus gracilis, Arctic cod, Boreogadus saida, greenling (Hexagrammidae), sculpins (Cottidae), and flatfishes (Pleuronectidae) among others are also of importance.

Late winter-spring distribution of spotted seals, mainly in the ice front, is no doubt the result of an abundance of appropriate prey species at and just north of the continental shelf break, combined with the presence of favorable sea ice conditions.

The annual sequence of biological events in the life of spotted seals (and all other pinnipeds as well) directly affects opportunities for observation and enumeration of seals hauled out on ice or land. Events of direct significance to aerial surveys are the periods of reduced feeding activity, birth, lactation and molt.

Spotted seals are mainly in the water during the cold months of January and February. They start to haul out on the ice, en masse, during March, depending on air temperature and wind conditions. The period of annual molt begins about mid-March and extends through June (some molting occurs as late as September). Subadult animals molt mainly during the first half of this three and one-half month period and adults during the last half. During the molt seals spend a great amount of time basking on the ice. The number of seals hauled out at any given time is related to weather conditions. Unfortunately, the significance of important correlates influencing hauling out are not adequately known.

Spotted seals breed annually. Birth occurs between the last days of March and the end of April. Most pups are born by mid-April; the peak period being between the 7th to 15th (Tikhomirov 1964, 1966; Burns 1970; Burns et al. 1972). There appears to be minor annual variation in peak pupping dates, associated with prevailing weather conditions. However, additional study is required to confirm this point. Pups are born on the ice. At birth they are covered by a dense coat of lanugo which is off-white or greyish-white in color. The function of lanugo is that of thermal insulation (Davydov and Makarova 1965). Lanugo begins to shed when pups are about two weeks of age. It is entirely lost by four or five weeks of age. The shedding of lanugo occurs simultaneously with an increase in thickness of the blubber layer. Pups do not normally enter the water for long periods of time until they have acquired a thick blubber layer and shed most of their lanugo.

Our experience, based upon capturing pups for marking, indicates that about 50 percent of the pups will enter the water, if harassed, after about 24 April. Under normal conditions they spend almost all of their time on the ice until they are abruptly weaned at three to four weeks of age (early to mid-May).

Adult spotted seals are monogamous. Mothers are relatively attentive toward their pups and males maintain a close association with the females (Burns et al. 1972). On days when temperatures are relatively warm and winds are not strong, triads of a pup, mother and an adult male are commonly seen. Several such pairs with pups may occur in a small area but rarely closer than .25 kilometer apart (Burns et al. 1972). This suggests some degree of territoriality and is a subject deserving of further investigation.

During cold, windy weather pups seek shelter if available, in the rough parts of their "home" floe, resting in crevices or becoming completely covered by a blanket of snow. During such periods the adults may leave the floe to feed or to swim in close proximity to it.

All of the above information relates directly to programs which are dependent upon the detection of seals hauled out of the water during the late winter-spring period.

April is normally optimum for such work because it is the time of maximum concentration of spotted seals; they occur mainly in areas of specific and recognizable ice conditions; it is the time of peak molt in subadult spotted seals; the adults are usually highly visible; and pups are still restricted to the ice floes.

Unfortunately, the proportion of seals, especially subadults, which haul out at any specific time, remains unknown. Also, variation in weather conditions directly influences the proportion of all spotted seals older than young pups which are out of the water.

Walrus are distributed over a broad area in Bering Sea during winter. However, they are mainly north of the ice front and there are regions where they are known to concentrate in large numbers. These areas include northwestern Bristol Bay, outer Kuskokwim Bay and the northcentral Bering Sea south of St. Lawrence Island (Kenyon 1960, 1972; Burns 1965; Fay, in prep.).

Walrus are highly migratory and most move north, leaving Bering Sea when it is ice free. However, several thousand animals, mostly males, remain in Bristol Bay during summer.

A large variety of benthic animals, mainly infauna, are utilized as food by walrus although only a few species comprise the bulk of their diet. Major food items include mollusks of the genera *Mya*, *Spisula*, *Serripes*, *Clinocardium* and *Hiatella*, with lesser amounts of gastropods including *Neptunia*, *Buccinum* and *Polinices*, crabs, shrimps, and tunicates (Fay, Feder and Stoker 1977).

Problems associated with aerial censusing of walrus are generally similar to those mentioned with respect to spotted seals. However, sightability within one half mile of the aircraft was definitely not a problem. Additionally, it appeared that during the period of our surveys most of the walrus were on the ice. Therefore, the numbers of walrus observed approximated more closely the total number in areas surveyed.

During the time of our surveys, two other intensive survey programs were also being conducted. These were by H. W. Braham (RU#67) in eastern Bering Sea mainly north of the ice front and by G. A. Fedoseev (Magadan Branch, TINRO, USSR) in central and western Bering Sea.

It is the mutual intention of investigators that undertook each of these three independent survey efforts to combine their data and prepare a comprehensive report. Formal arrangements to accomplish this objective have been completed and will result in the most intensive and comprehensive assessment of marine mammals ever achieved in the ice covered regions of Bering Sea.

III. Current state of knowledge

No intensive surveys specifically designed to assess the population status and distribution of spotted seals over the broad ice front of central and eastern Bering Sea have been undertaken prior to our effort in April 1976. However, numerous shipboard expeditions (including commercial sealing by the Soviets, since about 1962), general aerial surveys of marine mammals and marine mammal studies from coastal villages, have provided information required for the design of such a survey.

A general picture of the late winter-spring distribution of spotted seals and ribbon seals in Bering Sea can be constructed from the works of Kenyon 1960, 1972; Krylov et al. 1964; Shustov 1965a, b, 1967, 1969, 1972; Kosygin 1966; Kosygin et al. 1975; Tikhomirov 1961, 1964, 1966; Tikhomirov and Kosygin 1966; Fedoseev 1966, 1976; Burns 1969, 1970; Burns et al. 1972; Bychkov 1971; Fay 1974; Golt'sev et al. 1975; and Braham et al., 1977.

Pertinent references dealing with the methodology of aerial surveys as utilized in this study include Kenyon 1960, 1972; Pastukhov 1965; McLaren 1966; Shustov 1969; Fedoseev 1970; Burns and Harbo 1972; Smith 1973; Gilbert et al. 1976; Mate 1976; Schneider 1976; Stirling et al. 1977. A general review of marine mammal census methods is presented by Chapman et al. 1977.

As previously stated, information about the natural history and distribution of spotted seals provided the basis for determining that they are concentrated mainly in the ice front during late winter and spring and that biological activities during April (birth, lactation and molt) result in significant numbers of seals hauling out on the ice.

Previous shipboard studies, particularly aboard the R/V ALPHA HELIX in 1968 and 1972 and on the U. S. Coast Guard Cutter, GLACIER in 1971, indicated that in March and April spotted seals occurred throughout all areas of the ice front traversed by these vessels. Most importantly, although position of the front varied significantly in these years, the seals were associated with it.

The cruise of the GLACIER in 1971 provided a unique opportunity to traverse an extensive region of eastern Bering Sea from Norton Sound to Unimak Pass. During the traverse from Norton Sound to the south, no spotted seals were observed until we reached the ice front on 11 April. Our first sighting of this species was at approximately 58°20'N, 171°57'W. Between 11 and 20 April the ship remained in the front, moving generally eastward. Spotted seals, especially triads of an adult male, an adult female and her pup were common throughout the area between 171°57'W and 166°W and were observed to the edge of the pack ice as we departed it on 20 April. Use of helicopters aboard GLACIER, for survey and capture of seals, provided frequent opportunity to observe seals, to ascertain their response to aircraft and to refine procedures for a large scale survey effort.

During the ALPHA HELIX and GLACIER expeditions very few subadult spotted seals (ages 1-4 or 5) were observed or collected. The wintering area(s) for this cohort of the population were not found.

In March and April 1976 the research vessel OSS SURVEYOR also operated along the extreme southern edge of the ice front in central and eastern Bering Sea. During March, concentrations of spotted seals were located and preliminary surveys, using the ship's helicopter, were undertaken. A large concentration of mainly subadult seals was found in the Bristol Bay area. Information obtained during March was incorporated into the design of our April surveys. Aerial surveys utilizing the SURVEYOR's helicopter were also undertaken during April, and provide data for a comparison with results obtained from the fixed-wing aircraft.

The methodology of aerial surveys for ice associated marine mammals is more or less standard and will be discussed in a subsequent section of this report.

Accurate estimation of the total number of spotted seals, based on aerial survey techniques, is not yet feasible. The proportion of seals which are hauled out on the ice and visible to observers remains unknown. Adequate study of the significance and effects of parameters relating to haul out behavior of spotted seals has not been accomplished.

Haul out behavior of walruses is better known (Fay and Ray 1968, Ray and Fay 1968). Thermal tolerances of walruses are greater than those of spotted seals. Based on field observations, a larger proportion of walruses in a localized area (as compared to spotted seals) haul out when weather conditions are favorable. This is probably related to the highly gregarious nature of walruses.

IV. Study Area

Our studies were conducted in a specific ice habitat (the front) rather than in a fixed geographical area. Previous studies have shown that spotted seals occur in greatest numbers in this ice habitat during late winter and spring (Tikhomirov 1964; Kosygin 1966; Shustov 1967a, b; Burns 1969, 1970; Burns et al. 1972; Fay 1974). The ice front is that zone of seasonal ice extending north from a jagged and indefinite "edge" for between 15 and about 80 miles depending on winds and currents.

The southern limit of seasonal sea ice in eastcentral Bering Sea (from 168°W to 178°W) usually approximates the edge of the continental shelf as indicated by the 200 m contour. In the area east of 168°W longitude, the late winter-spring ice edge is always considerably north of the shelf break. There is considerable annual variation in extent of ice cover in Bering Sea. Accordingly, there are major annual differences in location of the ice edge and front zone. The winter and spring of 1976 was a period of prolonged north winds, lower than normal temperatures (especially in April) and extensive ice coverage. During March and April, the southern limit of ice may be as far south as 55°10'N or as far north as 61° or 62° (as it was in 1967).

The front is characterized by small floes usually less than 20 meters wide, separated by water or slush ice and subject to rapid dispersal or compaction by winds and ocean currents (Burns 1970). In his description of the front, Fay (1974) states:

> "At its southern edge, the pack is intermittently affected throughout the winter also by southerly winds associated with the continuous progression of North Pacific storms. These winds seem to have two major effects: temporary compaction of ice north of the edge, due to opposition to the southwesterly drift, and destruction of the edge itself, due to the heavy swells produced in the open sea. Strictly speaking, there is no actual "edge" for a 15- to 65-km wide zone at the southern periphery of the pack is alternately dispersed and compressed. American biologists working in this zone in recent years (e.g. Burns et al. 1972) have referred to it as the "front,"....

Figures 1 and 2 are Multispectral Scanner (MSS) images of the Landsat 2 satellite system, taken on 13 and 19 April 1976. They show ice conditions in the survey area north of Cold Bay and in central Bering Sea near the Pribilof Islands.

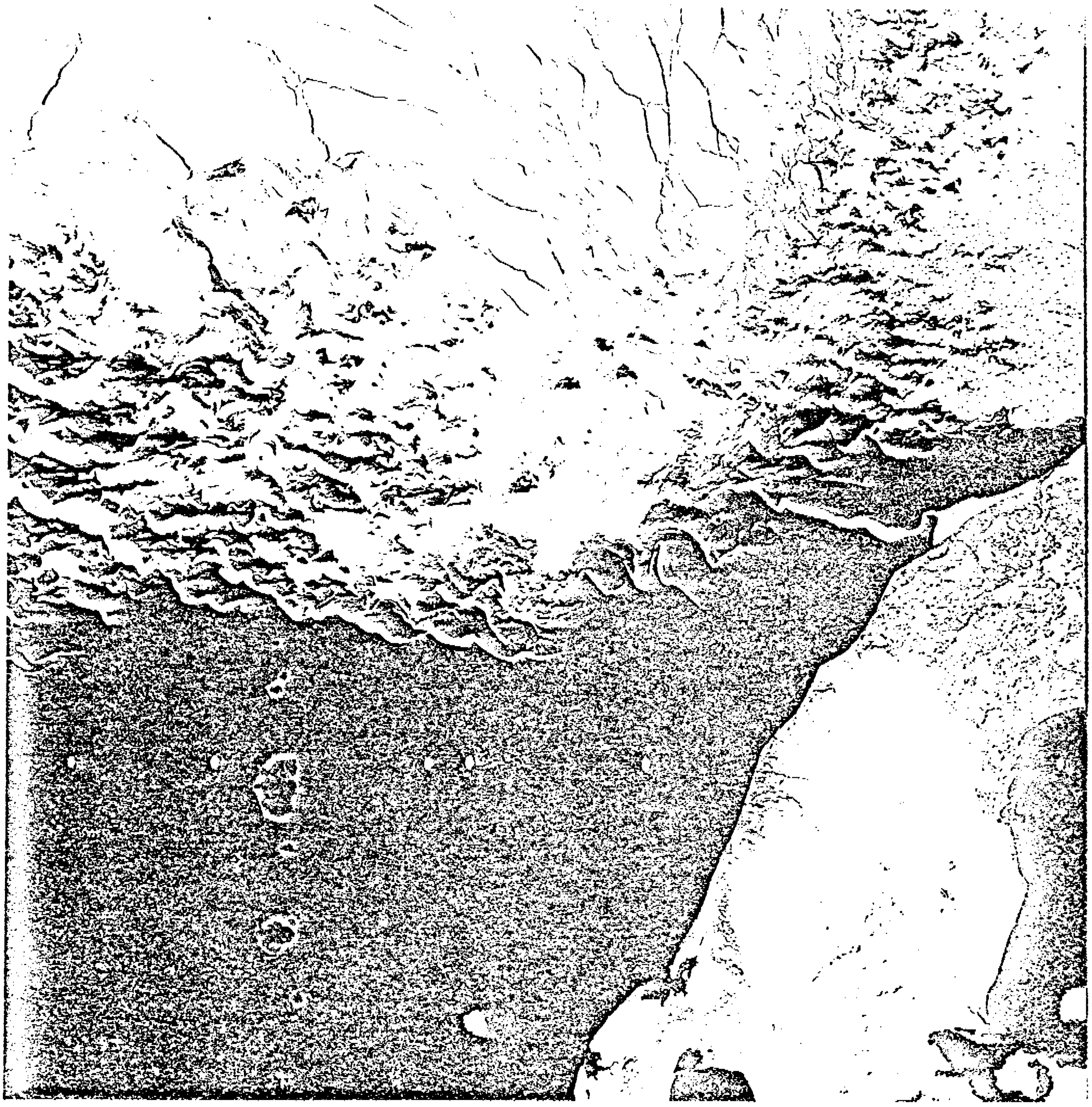

Fig. 1 LANDSAT image 2447-21110; ice edge and front zone in the area north of Cold Bay and Amak Island, 13 April 1976.

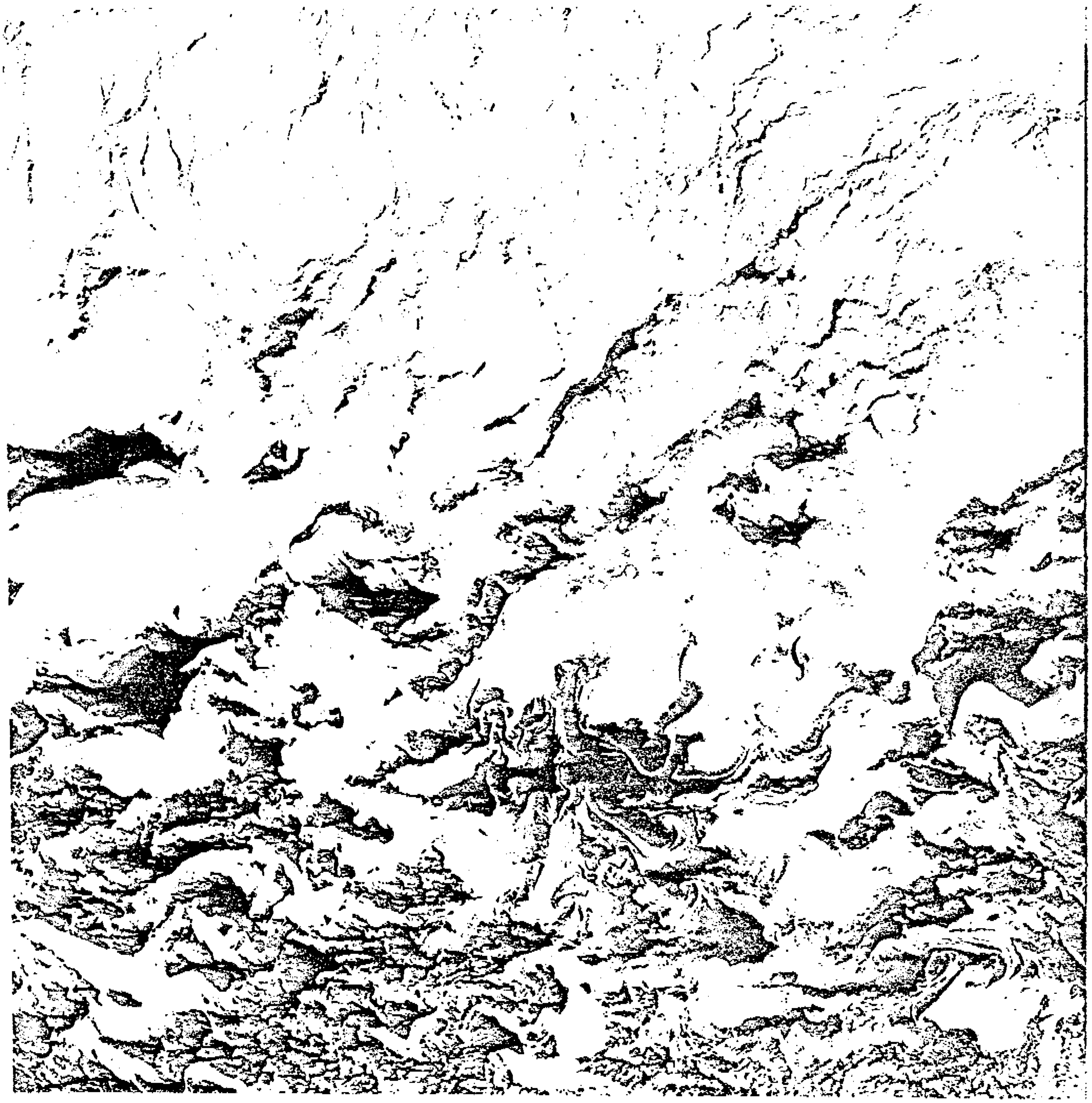

Fig. 2 LANDSAT image 2453-21445; ice edge and front zone in area between $169^{o}30'W$ and $172^{o}30'W$, 19 April 1976.

Spotted seals are mainly pisciverous. Eleven spotted seals were collected from the OSS SURVEYOR, during March and April 1976, within the areas we surveyed (annual report, RU 232, April 1977). Four of the 11 seals had empty stomachs and the remaining 8 had fed entirely on capelin (Mallotus villosus). It is generally assumed that a large standing stock of suitable food fishes occurs at or near the shelf break and that the usual combination of suitable ice conditions and availability of food favors concentration of spotted seals in the ice front. However, the distribution of forage fishes may be correlated more with location of the ice edge than with bathymetry. This question deserves further investigation.

Location of the study areas within which marine mammal surveys were conducted during March and April 1976 are indicated in Figs. 3 and 4. It extended from the eastern limits of Bristol Bay to 178°58'E longitude and from the southern limit of seasonal sea ice to as much as 70 nautical miles north of the ice edge. The most intensive surveys were in eastern Bering Sea within an area bounded by 160°W and 169°W longitudes and 56°N and 57°N latitudes. West of 169°W, the ice edge gradually tended farther north. Accordingly, survey tracks were also farther north.

Survey areas during March and April 1977 are shown in Fig. 5.

A comparison of the general southern limit of drifting ice during March-April 1976 and March 1977 is shown in Fig. 6.

Areas included in the proposed Bristol Bay and St. George Basin leases are shown in Fig. 7.

V. Methods

A. Survey procedures

Aircraft used for surveys were a Bell 206 helicopter (based on board the OSS SURVEYOR) and a Lockheed P-2V. Strip transects were flown.

During March-April 1976 and April 1977 the OSS SURVEYOR operated in the ice front, providing opportunity to obtain information about distribution of species, general age composition and density in different areas, and activity patterns. Sampling schemes for use during the period of intensive survey (8 to 23 April) were developed and tested during 1976, using the helicopter.

Helicopter flights were made along predetermined tracks. A Global Navigation System (GNS) was used for precise navigation during surveys. Width of the strip transect within which all animals were counted was either one-half or one-fourth nautical mile on either side of the helicopter. Transect width depended upon sightability of animals as affected by light conditions, size and surface topography of ice floes and brightness of the background upon which animals were resting.

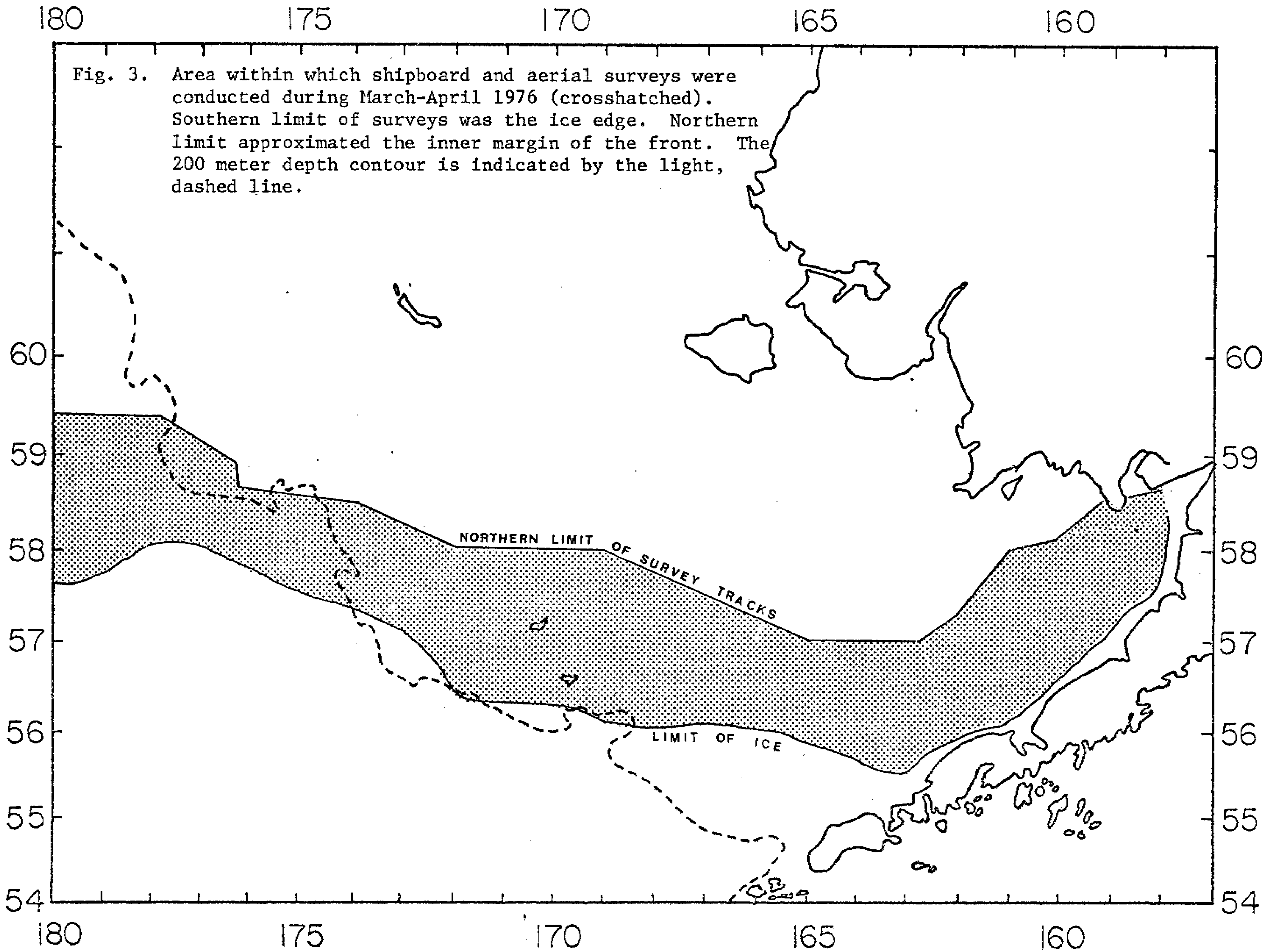

Fig. 3. Area within which shipboard and aerial surveys were conducted during March-April 1976 (crosshatched). Southern limit of surveys was the ice edge. Northern limit approximated the inner margin of the front. The 200 meter depth contour is indicated by the light, dashed line.

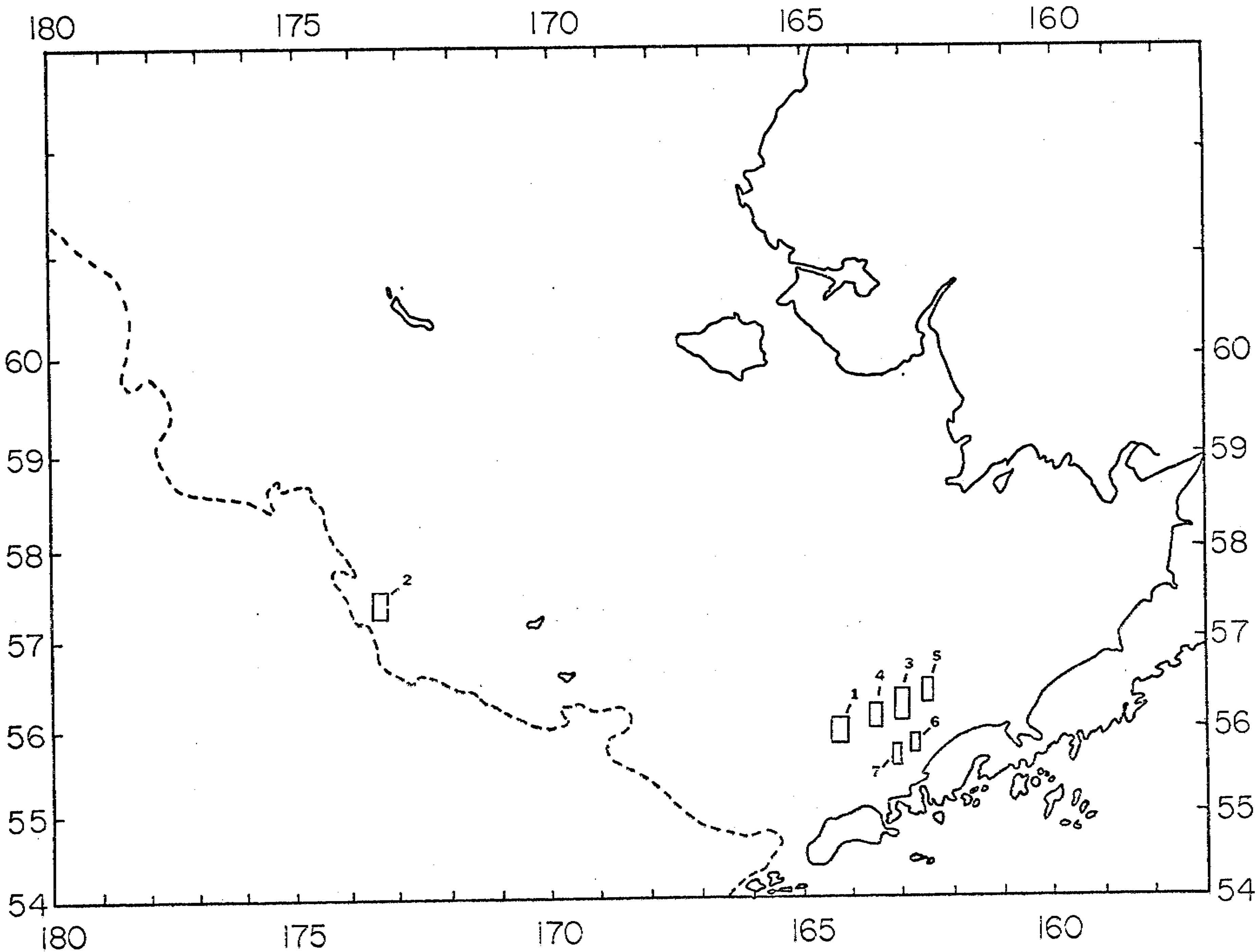

Fig. 4. Areas within which helicopter surveys of spotted seals were conducted during March-April 1976.

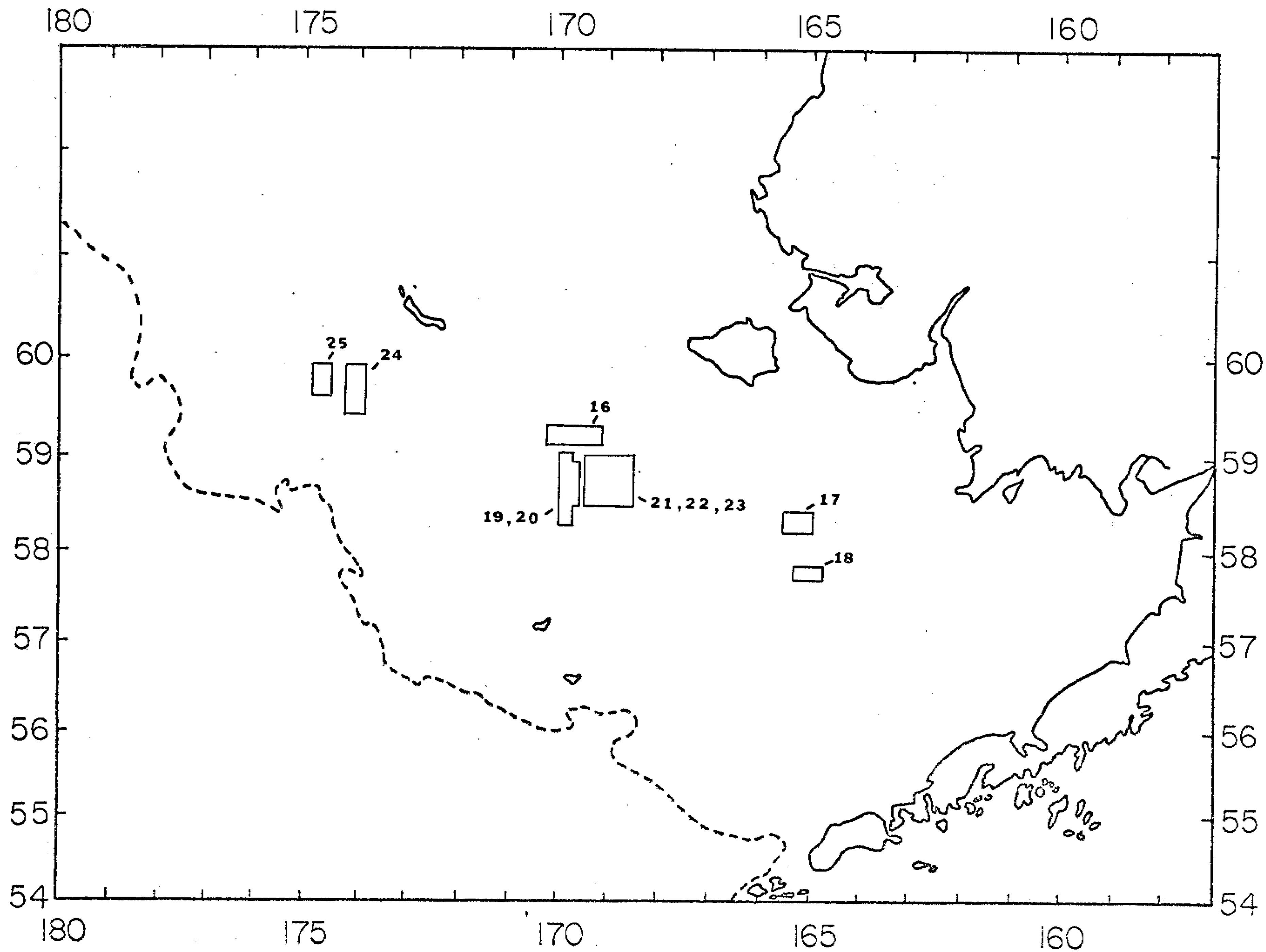

Fig. 5. Areas within which helicopter surveys of spotted seals were conducted during March-April 1977.

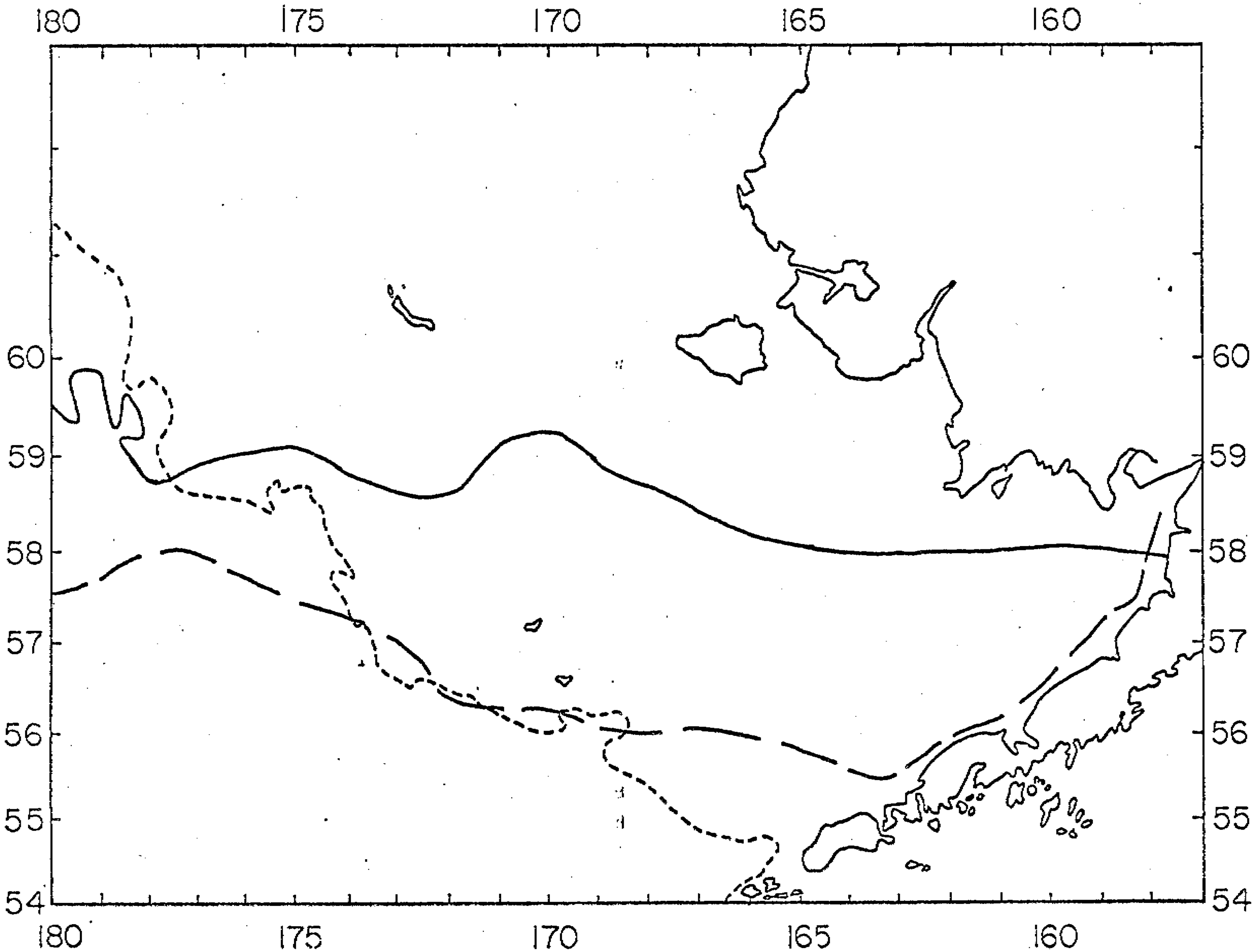

Fig. 6 Location of ice edge during March - April 1976 (----) and on 23 March 1977 (——).

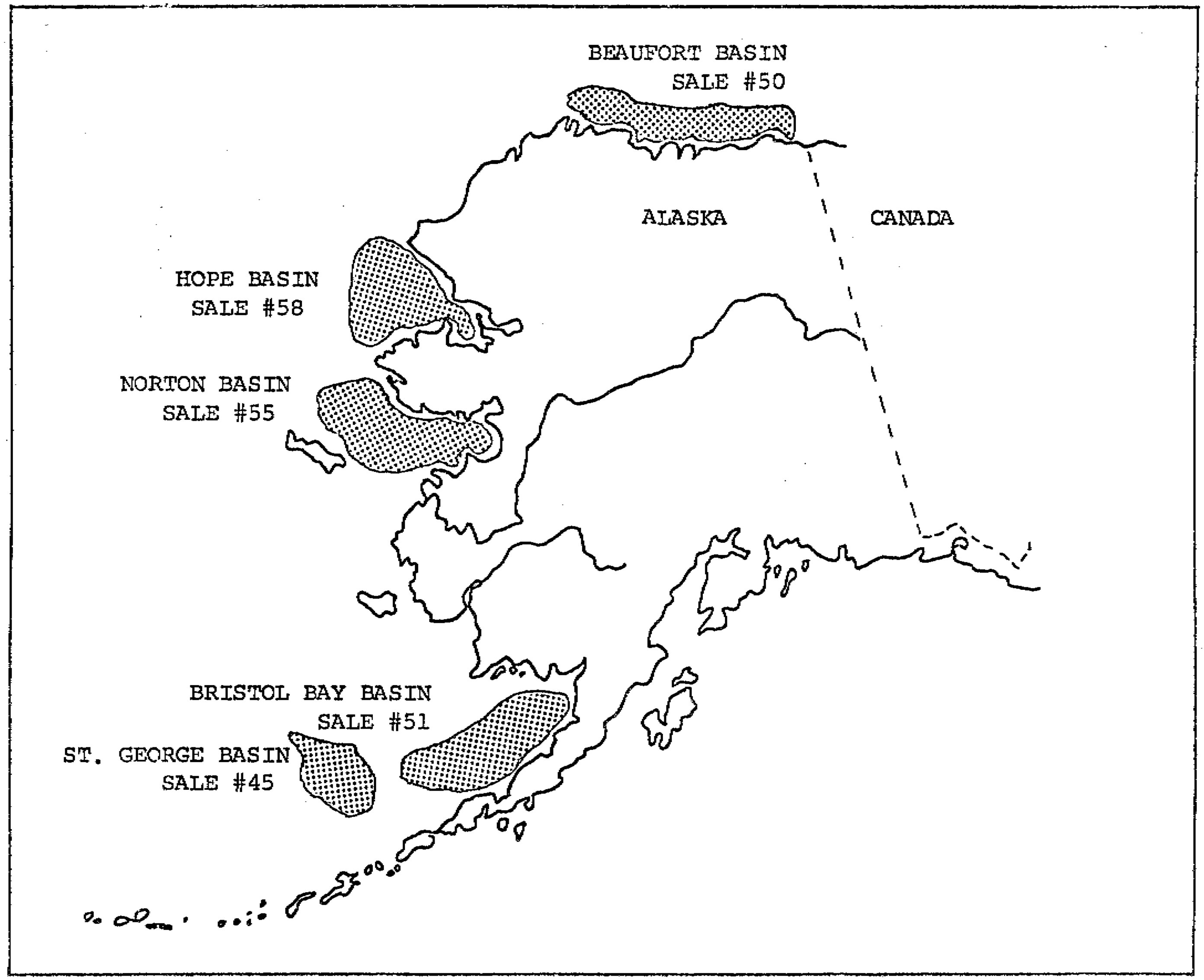

Fig. 7. General locations of proposed OCS leases in the Bering, Chukchi and Beaufort Seas. The Bristol Bay and St. George Basin leases are within areas surveyed for spotted seals and walruses.

Flight altitude was 300 feet at an air speed of 80 miles per hour. Low cloud cover occasionally required that the helicopter fly lower.

Transect width was checked at the beginning of each flight, using the ship as a reference point. This procedure was particularly useful because of daily differences in visibility. For purposes of recording observations, the transect was divided in half; the center line of the helicopter being the mid point. Each sighting was recorded, according to its occurrence, as being on the left or right side.

Information recorded included species and number of animals sighted, group size, animal activities, ice conditions, weather conditions and navigational information. All recorded information was annotated to include local time. Animals seen beyond limits of the transects were also recorded but those data were not included in statistical analyses. To the extent possible, a continuous record of events, by one minute time intervals, was maintained.

Personnel on board the helicopter during marine mammal surveys included an observer for the left side (occupying the left front seat), a pilot-observer in the right front seat and an observer-recorder in the right rear seat. A fourth person was occasionally included for purposes of familiarization, to obtain photographs or to record bird observations. Four flights made during April 1977 were for purposes of surveying and collecting seals. Only the pilot and one observer participated on these in order to make allowance for the weight of seals brought back to the ship. Helicopter survey flights were of relatively short duration and were usually within a 30 mile radius of the ship.

The Lockheed P-2V was utilized as a long range survey aircraft. Duration of some survey flights exceeded 9 hours and covered more than 1,200 miles of track line.

The observation and flight decks were separated and duties of the observers and flight crew did not interfere with each other.

As in the helicopter, the P-2V was equipped with a GNS which was the basic instrument for navigation during surveys. A separate repeater unit of the GNS was mounted in the forward observation bubble, providing instantaneous information to observers and the recorder. Two angle indicators were mounted in the observation bubble and were used to determine boundaries of the strip transects. Width of the strip was one-half mile on either side of the aircraft. This mile wide strip was subdivided into four segments: 0 to 1/4 mile and 1/4 to 1/2 mile on both sides of the plane. All sightings were recorded accordingly. Animals sighted beyond 1/2 mile of the plane were also recorded but these data were not statistically analyzed.

The same basic information was recorded during survey flights of the P-2V as during survey flights of the Bell 206 helicopter.

Flight altitude of the P-2V was 300 ft. Lower altitudes were occasionally necessitated by weather. Flight speed averaged 140 mph.

The P-2V flights of 8, 9 and 11 April were random although restricted mainly to the ice front. Our intent was to determine the general distribution, density and species composition of marine mammals in relation to latitude and longitude within the ice front. The birth period of spotted seals was well underway by 11 April, although it did not appear that most births had occurred. P-2V flights were discontinued until 17 April. Flights of 17 and 19 April were along pre-selected, random flight lines and were designed to achieve a replicate stratified random sample within the recognized area of highest seal density. This area extended generally from 161°30'W to 165°00'W and was between 56°10'N and 57°00'N.

Flights of 20 and 21 April were mainly in an east-west direction. They were not totally random in that the southern part of the front was covered on the 20th, and the northern part of the front (extending into the heavier pack) was covered on the 21st. The flight of 23 April was a traverse of western and northern Bristol Bay, enroute to Anchorage.

B. Procedures used to identify marine mammals on the ice

The greatly increased tempo of research and development activities in the Bering Sea is providing more people with the opportunity to observe marine mammals and to report their observations. We have frequently been asked to provide a resumé of how the various pinniped species can be distinguished from one another when they are hauled out on the ice. It is difficult for an untrained observer to properly identify some of the seals from the air. Our procedures are based on many hundreds of hours of observation from small boats and ships, as well as participation in numerous aerial surveys.

During aerial surveys of marine mammals the aircraft commonly flies at a low altitude (500 feet or less) and at a relatively slow speed (less than 150 knots). There is usually a period of several seconds during which an animal on the ice will be in view. Large, dark colored animals, such as sea lions and walruses, can be observed at far greater distances and are therefore visible for a longer period of time than are the smaller, light colored seals.

It is usually possible to correctly identify an animal on the basis of one or more characteristics including color, relative size, shape, and behavior or escape response. Additional considerations are the ice type, location, orientation of the animal on an ice floe and the season and area of the survey. Although the casual observer can concentrate on an individual animal or group of animals, persons conducting surveys cannot. The surveyor must train himself to constantly scan a transect area, periodically returning to an unidentified animal until an identification has been made or the animal is no longer in sight.

Sea lions appear brown, reddish brown or tan depending on sex and age of the animal and light conditions. They are large and are usually seen on the ice in small groups of three to eight. However, single animals are regularly observed. Larger groups are infrequent on the ice. The body of a sea lion appears long and tapered toward the head. This appearance is accentuated when they are alarmed and extend their long necks. Most sea lions respond to a low flying airplane within one-half mile by escaping into the water. They frequently "gallop" across the ice, at which time the long fore- and hindflippers are obvious. They dive into the water head first. During spring months when sea lions haul out on ice, they do so mainly on small floes at the extreme southern edge of the front or within a few miles of it. They are likely to be encountered at any location along the ice edge.

Walruses also appear dark brown to reddish brown, depending on light conditions. Walruses are large, and rest on the ice as solitary animals or in tightly packed herds. In the ice front during April they are usually seen in groups of between 2 and 15 animals. Large herds of 500 or more walruses are seen on the ice, usually in the northern Bering Sea.

Walruses do not have the sinuous outline of sea lions. They are very stout and seemingly truncated at both ends. The head terminates in a very broad and flat snout. Tusks are obvious at close range but are surprisingly difficult to see at a distance.

Their response to an aircraft is quite variable, apparently depending on weather conditions. On bright, calm days, they will usually remain on the ice unless the aircraft is immediately over them. Often, they will neither rouse nor change position. On cold overcast days walruses within one-quarter mile of a large aircraft will rouse and enter the water at any angle, rolling, sliding, backing or going in head first. They do not "gallop" across the ice floes as do sea lions.

During winter and spring, walruses haul out on a variety of different ice types from the small floes of the front to the large, heavy floes of the southern Chukchi Sea. They rest mainly around the edges of floes, close to cracks, leads or polynyii and may be found anywhere in regions where sea ice is present. Centers of abundance during early spring (depending on ice conditions) are Bristol Bay, outer Kuskokwim Bay and northcentral Bering Sea. They are not usually abundant near the ice edge.

Bearded seals are the largest true seals (Phocids) of the Bering Sea but are smaller than walruses or sea lions. From the air they appear almost uniformly grey (sometimes tan). The anterior part of the head frequently appears dark when seen at close range. The body is long and thick and the head appears unusually small. They appear to rest soundly, raising their heads infrequently.

These seals usually react mildly to an airplane, even at close range. They almost always raise their heads, frequently look up at the plane and usually remain on the ice unless the plane passes directly over them. They do not form herds nor, with the exception of females with pups, do they rest next to each other, with bodies touching. They are encountered mostly as singles, although several may rest on a single floe. They lie on their bellies and, almost without exception, their heads are within a few feet of open water. When several bearded seals are lying on a single ice floe they are at the edge and appear as if facing away from each other. If animals are resting on both sides of a narrow lead they also face the water and orient themselves perpendicular to the axis of the lead. They rarely rest farther than a few feet from water and, when alarmed, move toward it in a wriggling gait using both fore-flippers in unison. They slide head first into the water frequently raising their hind end high in the air as they dive. The hindflippers do not rotate forward and are not used for locomotion over the ice. Fore- and hindflippers are not obvious except at close range. Pups in association with adult females (mainly in April) appear dark.

Bearded seals occur throughout the pack ice where there are openings. However, they are not numerous in areas of extensive, large heavy floes or on shorefast ice.

Ringed seals are the smallest of the ice associated seals. From the air, during April, they appear short and fat. At a distance they look dark grey. At close range they are silver-grey on flanks and belly and dark grey on the dorsal surface. The dark rings, from which this seal derives its common name, are not obvious from the air, although they do account, in part, for the darker appearance of the back. These seals usually lie on their bellies and raise their heads frequently even when not disturbed. The head appears large compared to the body. Except for some very young animals (weaned pups in partially destroyed lairs along pressure ridges during late April and May) ringed seals seem always to haul out where the ice is flat. In areas where drifting ice is subject to considerable motion, they tend to use the rather large, heavy floes, usually coming out of the water through exit holes well away from the floe edge and in a flat area. They are common in the shorefast ice and the heavy drifting ice of the northern Bering and Chukchi seas. In spring they can be seen concentrated around an exit hole or lined up on either side of a narrow crack. When on the ice they orient themselves so that their heads are close to either an exit hole or a narrow lead. If alarmed they move a very short distance by wriggling, using both foreflippers in unison and slide, head first into the water. Exit holes can usually accomodate only one seal at a time. When several ringed seals are resting by a single hole and become alarmed, they sometimes block each other from access to the water. During cold weather their exit holes may refreeze, or the cracks close due to motion of the ice, thus barring re-entry into the water. This has been observed mainly in the thick, stable ice of the Beaufort Sea.

In our experience we have not observed ringed seals at any distance from a hole or crack. They normally do not "run" around on the ice when alarmed, nor are tracks observed except immediately adjacent to the opening through which they exit and enter the water.

From an aircraft, ringed seals can be mis-identified as spotted seals or recently weaned ribbon seals if judgments are based solely on relative size, shape and color.

Spotted seals, at a distance, also appear dark grey against a background of snow covered ice. In bright or sunny conditions and within distances of 1/2 mile of an airplane some variation in color can usually be noted. Most individuals have a straw colored or yellowish cast, at least on the flanks, and are darker on the back. However, individuals vary in color, some being entirely straw-yellow, and others dark on the back and flanks. If the yellow coloration is not noticeable, the two-toned grey appearance of back and sides resembles that of the ringed seal.

As adults, spotted seals are larger than ringed seals, but the younger age animals overlap in size. Shape of the two seals is different; ringed seals appear football shaped and spotted seals less rotund and longer. However, this is extremely difficult to perceive from an aircraft unless there is ample opportunity to observe both species within a close period of time. Spotted seals appear to have a long, dog-like snout.

Based on behavioral characteristics, spotted seals are easily identifiable. During spring they haul out as singles, as breeding pairs with an off-white colored pup or in large but loose aggregations of all age classes. These aggregations may occupy several adjacent ice floes. They do not commonly use holes as do ringed seals, but leave and re-enter the water at the floe edges. Spotted seals are very active on the ice. They rest almost anywhere on floes and, during cool windy weather, seek the shelter of ice ridges or depressions, often several meters from the floe edge. They rest on their bellies or flanks.

When snow and light conditions are good, the tracks of spotted seals are quite obvious, crisscrossing the ice.

Spotted seals generally react strongly to the sound of aircraft even at considerable distances. Their activity makes them quite noticeable as they race across the floes, often changing direction and finally diving off the floe edge head first. They move in the same wriggling motion as do the bearded and ringed seals. The foreflippers are moved mostly in unison. During April, the white-coated pups remain on the ice and can be seen as they move about. If a pup is on a floe with ridges or snow drifts, it will often be in or among them.

During spring, spotted seals are most abundant in the ice front, utilizing the smaller floes near the southern terminus of the pack. In April 1976, they were abundant in the first 30 miles of ice, but mainly from about 2 to 15 miles inside the ice margin. However, they may also be encountered some distance north of the front in areas where currents or winds keep the ice thin and broken.

As sea ice recedes and disintegrates in late spring and spotted seals move north, become more common along the coast and appear in bays and estuaries, hauling out on land.

Ribbon seals can be the easiest or the most difficult species of seal to identify from the air. Males and females, although marked similarly, are different in color. Males older than one year are black or dark brown with white ribbons around the neck, posterior abdomen and encircling each foreflipper. In favorable light conditions their markings are highly visible within one-fourth mile of an airplane. Color pattern of the females is similar to the males. However, instead of white on black, they show white on a background of grey. They frequently appear uniformly grey. Females are often very difficult to identify based on color. At a distance the males appear uniformly dark and the females grey.

Unweaned pups are white (noticeably whiter than spotted seal pups) and have a dark muzzle. By the time they are weaned (late April to early May) and have shed their white hair, they develop a two-toned color pattern, dark on the dorsal surface with silver-grey flanks and belly. They have no noticeable ribbons.

Adult female ribbon seals are commonly misidentified as young bearded seals or spotted seals and the weaned pups as ringed or spotted seals.

Adult ribbon seals are larger than ringed seals and about the same size as spotted seals. They are usually more slender than spotted seals and the comparison of shape with ringed seals is therefore striking to an experienced observer. There is little difference in relative shape of young animals of these three species and, unfortunately, there is considerable overlap in size of subadults.

With the exception of the strikingly marked adult males (and some females), identification of ribbon seals is based on some rather unique behavioral characteristics. These seals usually haul out on relatively thick, clean, rough, snow covered ice floes in the ice front. In April, they are most numerous between 20 and 50 miles north of the southern terminus of seasonal ice. They do not make exit holes like ringed seals but leave and enter the water at the floe edges, similar to spotted seals. They are active on the ice, move well away from water and can be found on any part of a floe, even amidst rough, pressure ridged areas at a considerable distance from water. They commonly rest on their sides. These seals are usually encountered as single animals or in April as mother-pup pairs. White-coated pups are often unattended on the ice. They rest for long periods of time without raising their heads and usually react mildly, if at all, to an aircraft. Their position on the ice, reaction to aircraft and their manner of moving across the ice are the best criteria for identifying ribbon seals which are not distinguishable based on color.

As an airplane approaches, these seals often move around rapidly. Their movements are markedly different from those of the other seals as they do not wriggle but slide along by alternately extending each foreflipper and vigorously moving the posterior torso from side to side. When moving, the head is extended forward and is kept low to the ice. This movement can perhaps best be described as slithering. They commonly appear quite confused, move in circles or abruptly change direction, and often do not go into the water. If they do go into the water they slide, head first.

Ribbon seals are associated with the ice front during spring and become pelagic as the ice disappears from Bering Sea. They are seldom encountered near the coast and sightings in the Chukchi Sea are infrequent.

In summary, the most common misidentification of pinnipeds is likely to be adult female ribbon seals as young bearded or spotted seals, young ribbon seals as spotted or ringed seals and single spotted seals, especially young ones, as ringed seals. Misidentification can be minimized by noting behavior, position on the ice and in relation to holes, cracks or other openings, manner of movement and association with other seals. Color patterns are not always noticeable in "average" or marginal survey conditions.

C. Statistical Procedures

1. Spotted seals

Surveys conducted with the Lockheed P-2V provided broad coverage of the ice front. The total survey area was subdivided into 17 sectors in order to test, if possible, for geographical differences in distribution and density. Observations from all strip transects (or parts thereof) within each sector were analyzed. Density was calculated based on a weighted or ratio estimator. The variances generated were those appropriate for a ratio estimator. Variances were calculated when survey design included a number of randomly selected transects flown on the same day within a sector (i.e. sectors 1 and 2) or when the combination of number of transects flown on the same day and sightings of seals warranted generation of a variance.

Several factors resulted in our reluctance to subject all of the spotted seal data acquired from the P-2V surveys to rigorous statistical analysis. These factors included: the clumped distribution of large aggregations of seals; lack of an indication of measurement error (sightability of seals); the occurrence of surveys on different days in different parts of a sector; and potential problems associated with serial correlation of transects. No attempt was made to estimate size of the spotted seal population in the various subareas.

The data base provided by the P-2V surveys was very useful in providing information about relative density of spotted seals throughout the ice front and the ratio of pups to animals older than pups in the different areas. Comparisons were mainly of derived densities. More rigorous tests of differences are based on results of helicopter flights conducted in 1976 and 1977.

Results of all surveys made with the helicopter were statistically analyzed. Estimated density of seals observed in strip transects and the variance of density were derived as indicated above. Comparisons between pairs of flights in different regions were made utilizing the two-tailed, nonparametric Mann-Whitney test. Comparisons of more than two flights were based on the Kruskal-Wallis analysis of variance by ranks (Zar 1974).

Analysis of the helicopter survey data for spotted seals provides an excellent basis for interpreting results of the more extensive P-2V flights.

Some estimates of the proportion of seals in the water versus on the ice were obtained during seal collecting excursions in small boats immediately prior to conducting a survey with the helicopter.

2. Walruses

As with our analysis of data for spotted seals obtained from the P-2V aircraft, the walrus data were treated by sector. Nine sectors were established covering the total survey area in the ice front extending from Bristol Bay to 180°W longitude. Densities and variances of densities for transects in each sector were derived. Total number of walruses in each sector was estimated by extrapolating the derived density of walruses observed in all transects within a sector, to size of the total sector north of the ice edge.

Estimates of total numbers were made because, unlike spotted seals, walruses were highly visible, groups were well defined and usually small, counts were more accurate and a much higher proportion of animals were apparently resting on the ice during the hours when surveys were conducted.

VI. Results

A total of 25 separate survey flights were made during March-April 1976 and 1977. Seven helicopter flights were made in 1976. These are discussed as surveys 1 through 7. Eight flights were made during April 1976 in a Lockheed P-2V. All of the P-2V flights are treated in relation to transects within sectors. Ten helicopter flights were made during March-April 1977 and are discussed as surveys 16 through 25. The navigation information for all flights is attached as Appendix I.

Participants on the 25 surveys are indicated in Table 1. Flight routes of surveys from the P-2V are illustrated in Figs. 8 through 15. Surveys with the P-2V resulted in 6,593 nautical miles of transects which were treated in our analysis of spotted seals. The total number of transect miles utilized in our analysis of walrus distribution and abundance was 6,858.

Spotted seal surveys from the P-2V

The 17 sectors considered in our analysis of spotted seal distribution are shown in Figs. 16 and 17. Exact locations of these sectors are included in Appendix II. Results of the surveys are summarized in Tables 2 and 3.

A very low density of seals occurred in the eastern part of Bristol Bay (sector 12) and in the southcentral part of the bay (sector 11). Moderate densities occurred in the western part of the bay, between 161°35'W and 162°45'W (sectors 1 and 13). The highest densities found during our P-2V surveys were immediately to the west of 161°35'W and extended to 165°00'W. This area included sectors 2, 3 and 14. The region of the front between 165°00'W and 169°00' (sectors 4 and 15) was generally one of low density, while that west of 169°00'W and extending to 180°00'W was an extensive area of moderate seal density.

Estimates of density for sectors 5, 16 and 17 probably reflect a degree of error associated with sampling. As an example, sector 16 is essentially a combination of sectors 6 and 7, but shifted slightly to the south. Seal densities in sectors 6 and 7 are considered to be moderate whereas in the larger area of sector 16, with its southern extension into the very fringe of the ice front, density of seals appeared to be low.

The general pattern of relative abundance of spotted seals is evident from results of the P-2V surveys.

There was a marked difference in the proportion of pups in various sectors. The proportion of pups was very low in eastern Bristol Bay (sectors 11 and 12). In the sectors of moderate and high seal density in western Bristol Bay (sectors 1, 2, 3, 13 and 14) the proportion of pups was also low, ranging from 1.7 percent to 12.0 percent of the number of spotted seals seen in these sectors. This indicates that most of the seals in these areas of concentration were either subadults or non-breeding adults.

West of 165°00'W (sectors 4-10, 15 and 17) where seal densities were also moderate, the proportion of pups was much higher, ranging from 18.8 percent to 37 percent (sector 16 is considered an anomaly for the reasons indicated above). Apparently the vast majority of seals occurring in the ice front west of 165°00'W are breeding age adults.

Table 1. Personnel who participated in aerial surveys during March-April 1976 and 1977*

A. Bell 206 Helicopter launched from OSS SURVEYOR, 1976

Date	Flight No.	Survey Personnel
27 March	1	J. Burns (ADF&G)
20 April	2	K. Frost (ADF&G), J. Hall (USFWS)
23 April	3	K. Frost, J. Hall
24 April (1st flight)	4	K. Frost, J. Hall, P. McGuire (NMFS)
24 April (2nd flight)	5	K. Frost, J. Hall, L. Shults (UofA)
25 April (1st flight)	6	K. Frost, J. Hall, L. Lowry (ADF&G)
25 April (2nd flight)	7	K. Frost, J. Hall, L. Lowry

B. P2V Aircraft, 1976

Date	Flight No.	Survey Personnel
8 April	8	J. Burns, D. James (ADF&G), S. Harbo (UofA)
9 April	9	J. Burns, D. James, S. Harbo
11 April	10	J. Burns, D. James, S. Harbo
17 April	11	J. Burns, D. James, B. Everitt (NMFS)
19 April	12	J. Burns, D. James, B. Everitt
20 April	13	J. Burns, D. James, B. Everitt
21 April	14	J. Burns, D. James, B. Everitt, G. Harry(NMFS)
23 April	15	J. Burns, D. James, B. Everitt, G. Harry

C. Bell 206 Helicopter launched from OSS SURVEYOR, 1977

Date	Flight No.	Survey Personnel
28 March	16	K. Frost, L. Shults
30 March	17	K. Frost, R. Dieterich (UofA)
21 April	18	J. Burns, K. Frost
23 April (1st flight)	19	L. Lowry
23 April (2nd flight)	20	L. Lowry
24 April (1st flight)	21	J. Burns, E. Muktoyuk (ADF&G)
24 April (2nd flight)	22	K. Frost
25 April	23	J. Burns
27 April (1st flight)	24	J. Burns, E. Muktoyuk
27 April (2nd flight)	25	J. Burns, K. Frost

*In 1976, flight crew for the ship based helicopter included D. Winter (pilot), W. Harrigan (pilot), G. Mitchell (mechanic), all with the National Oceanic and Atmospheric Administration. Flight crew aboard the P-2V included L. Caulkett (chief pilot), T. Belleau (pilot) and W. Bean (engineer), all with the USDI, Office of Aircraft Services. Helicopter flight crew in 1977 included W. Harrigan (pilot), T. Leyden (pilot) and G. Mitchell (mechanic), all with NOAA.

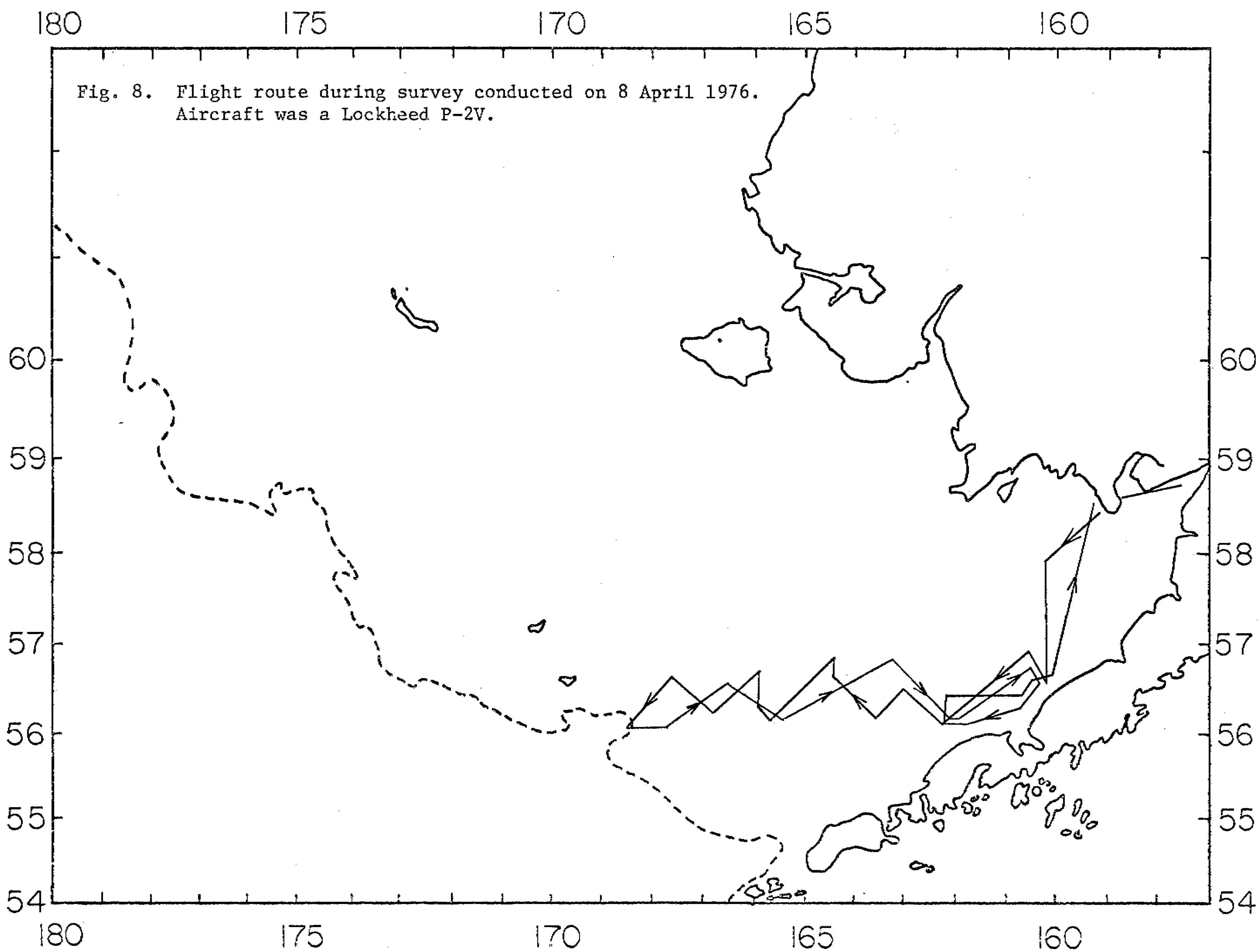

Fig. 8. Flight route during survey conducted on 8 April 1976. Aircraft was a Lockheed P-2V.

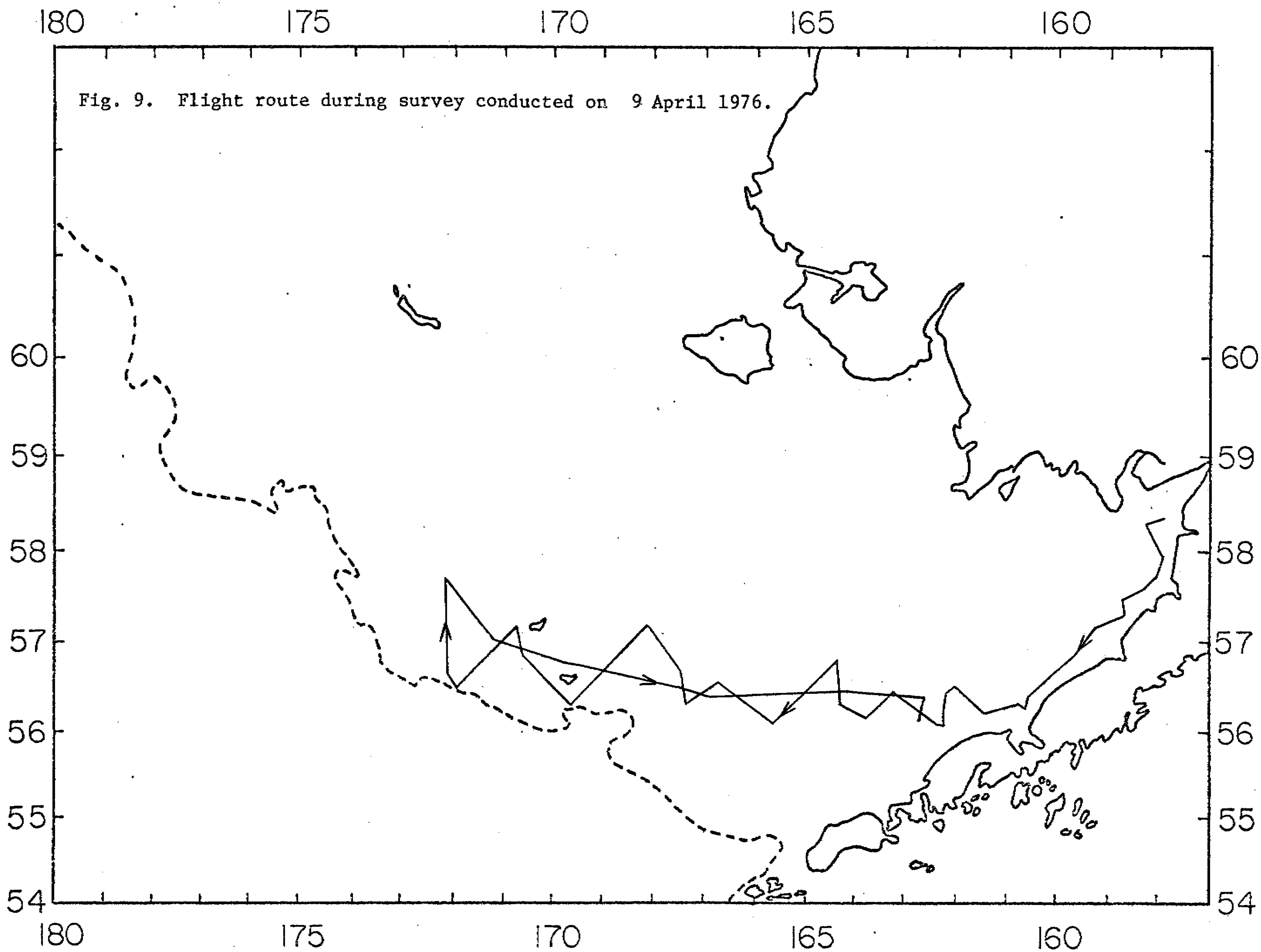

Fig. 9. Flight route during survey conducted on 9 April 1976.

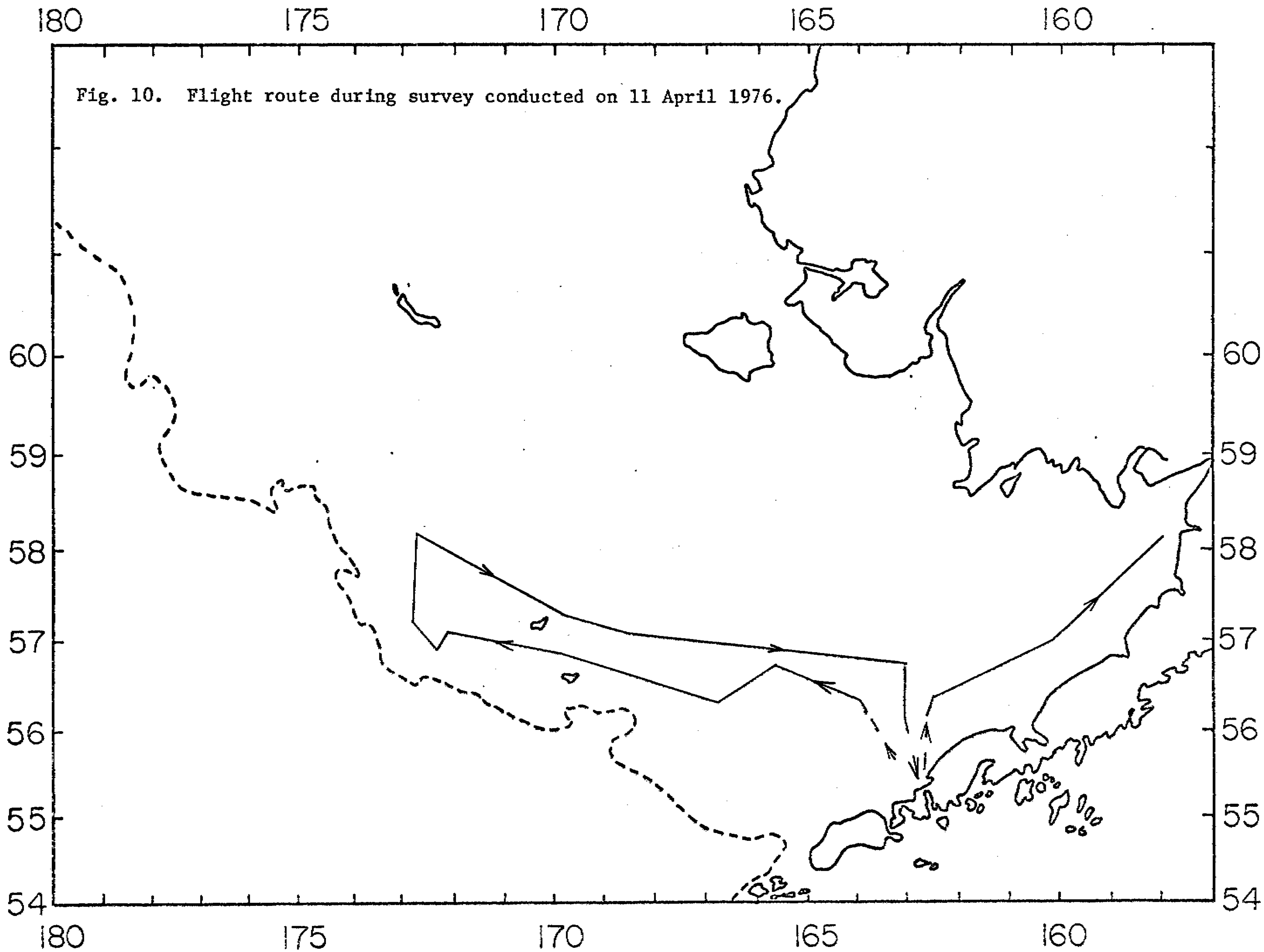

Fig. 10. Flight route during survey conducted on 11 April 1976.

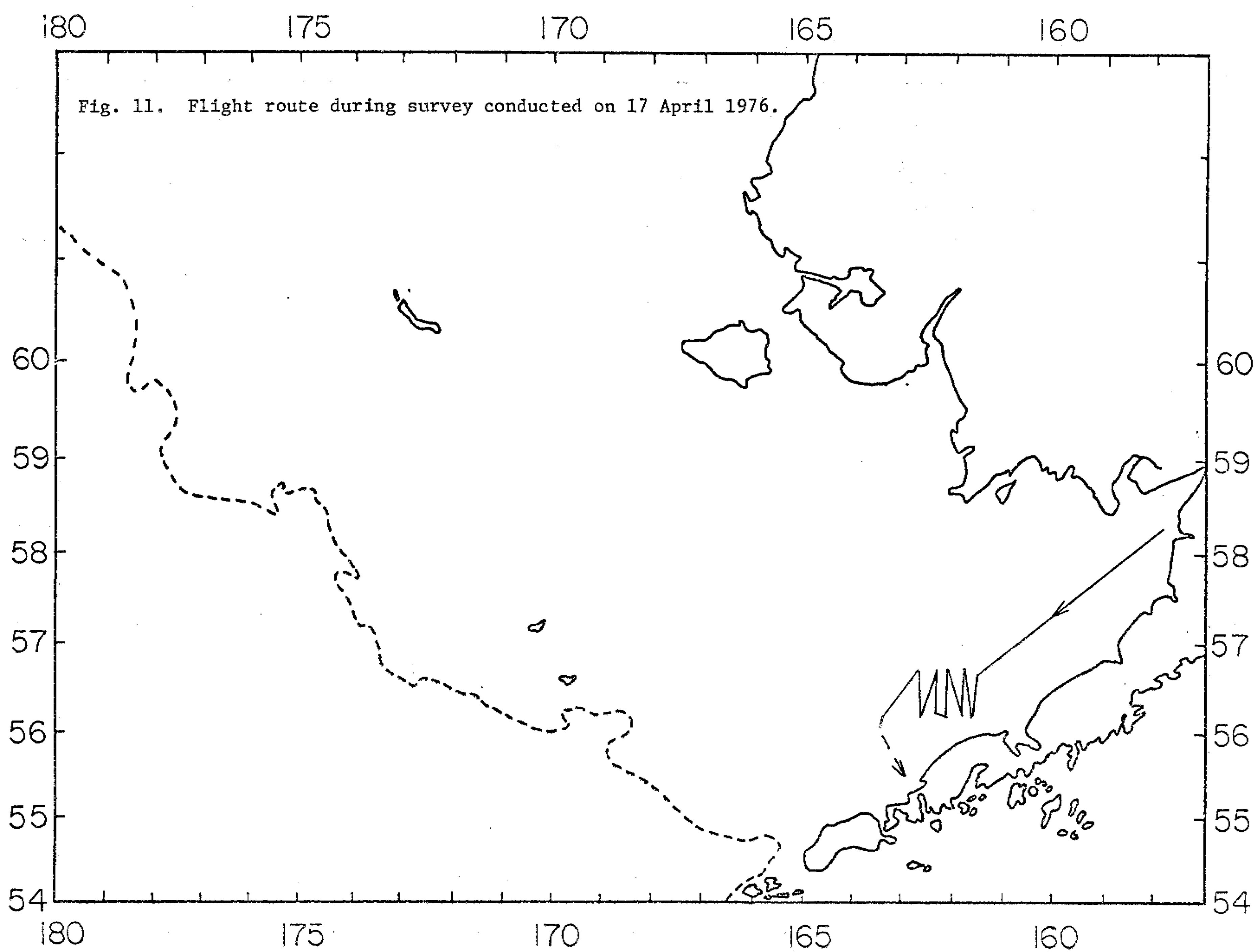

Fig. 11. Flight route during survey conducted on 17 April 1976.

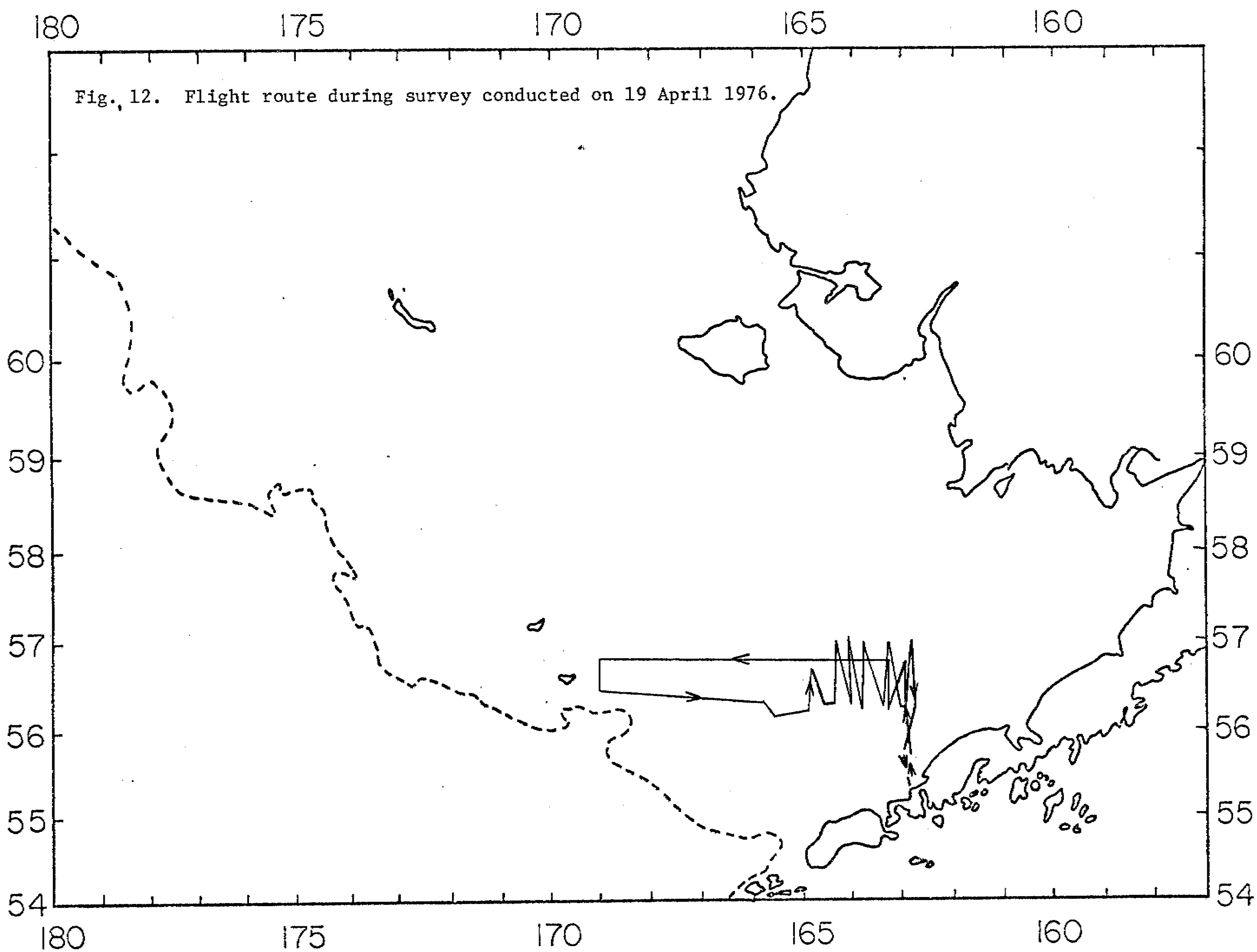

Fig. 12. Flight route during survey conducted on 19 April 1976.

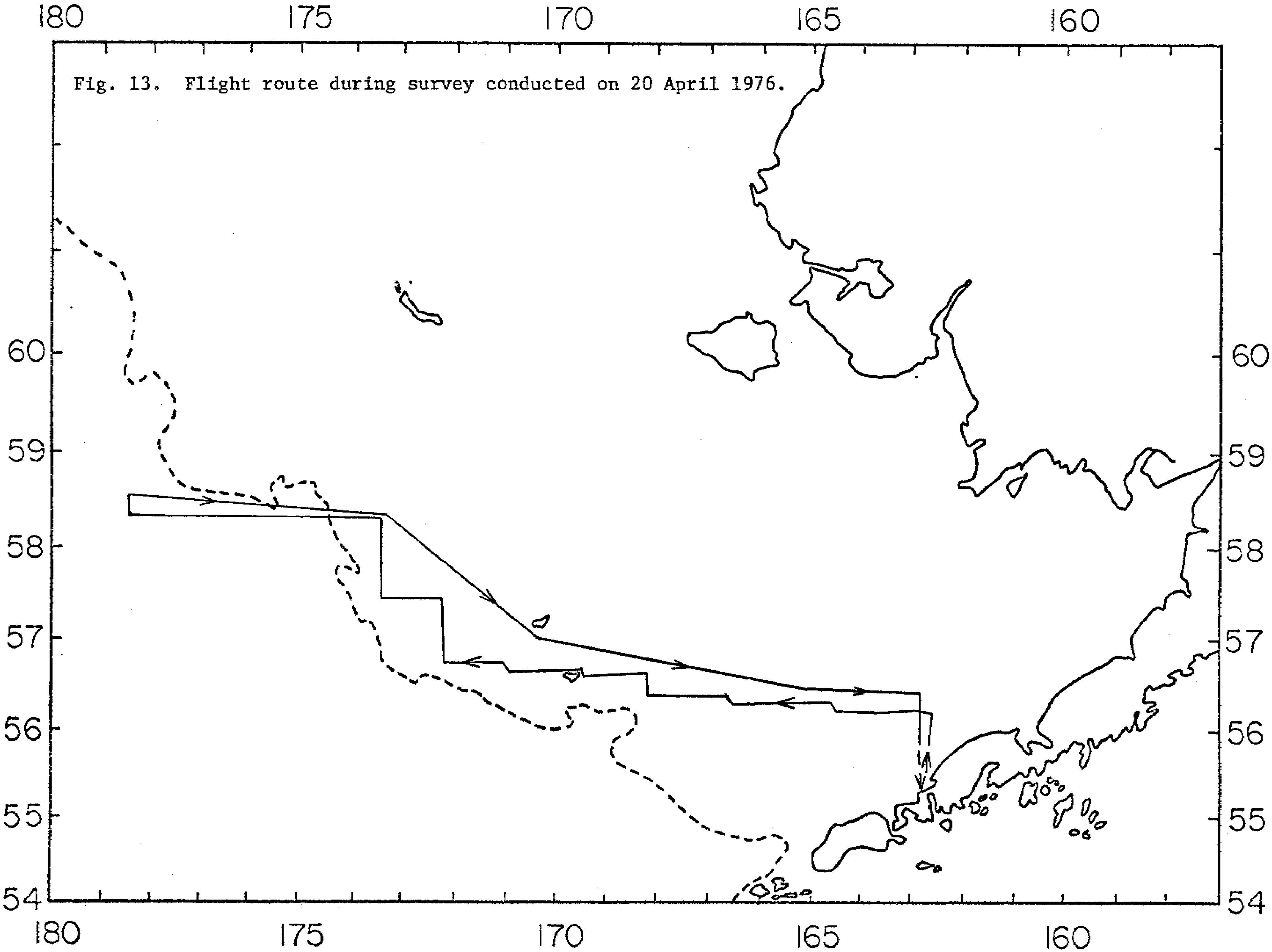

Fig. 13. Flight route during survey conducted on 20 April 1976.

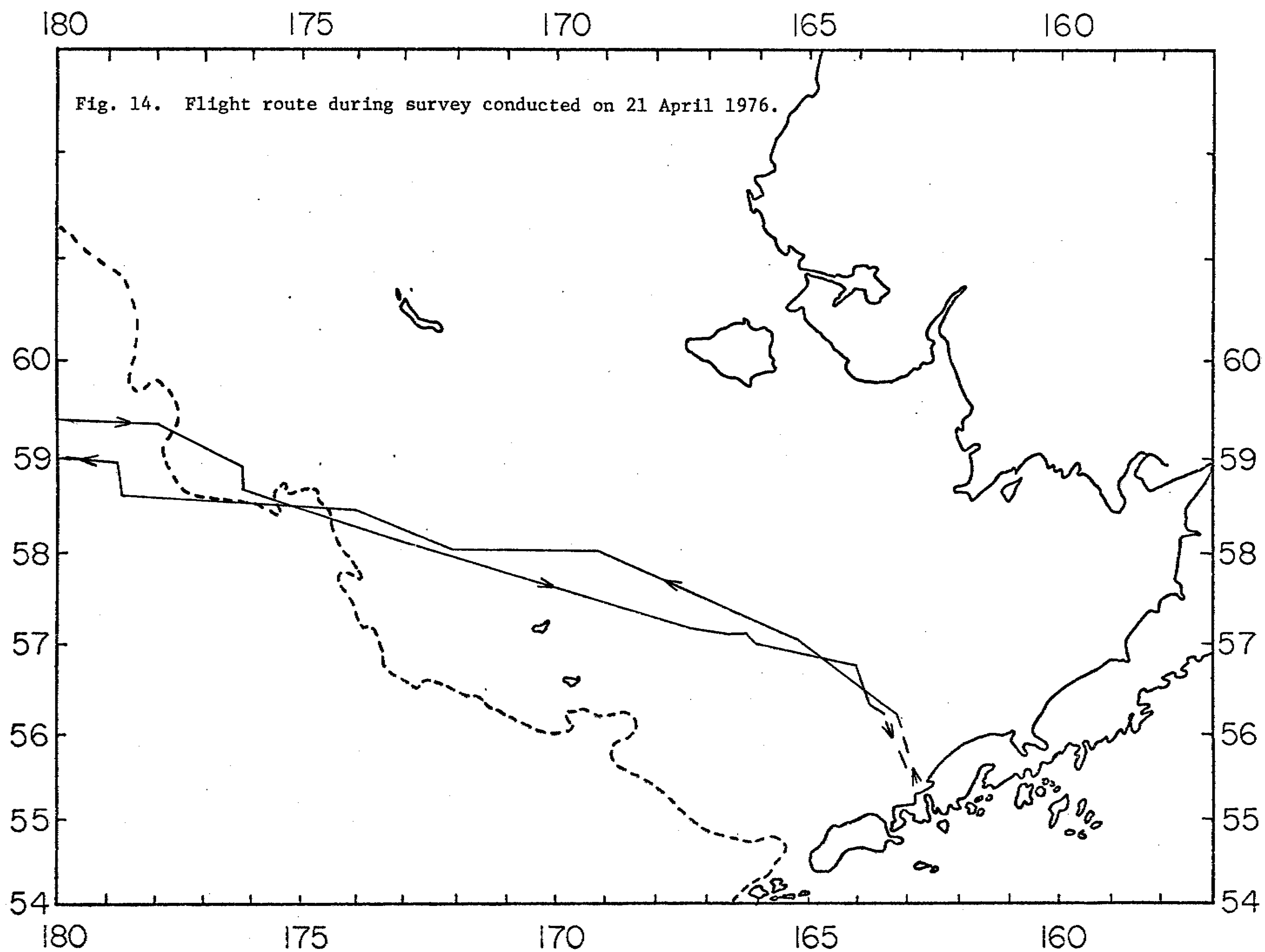

Fig. 14. Flight route during survey conducted on 21 April 1976.

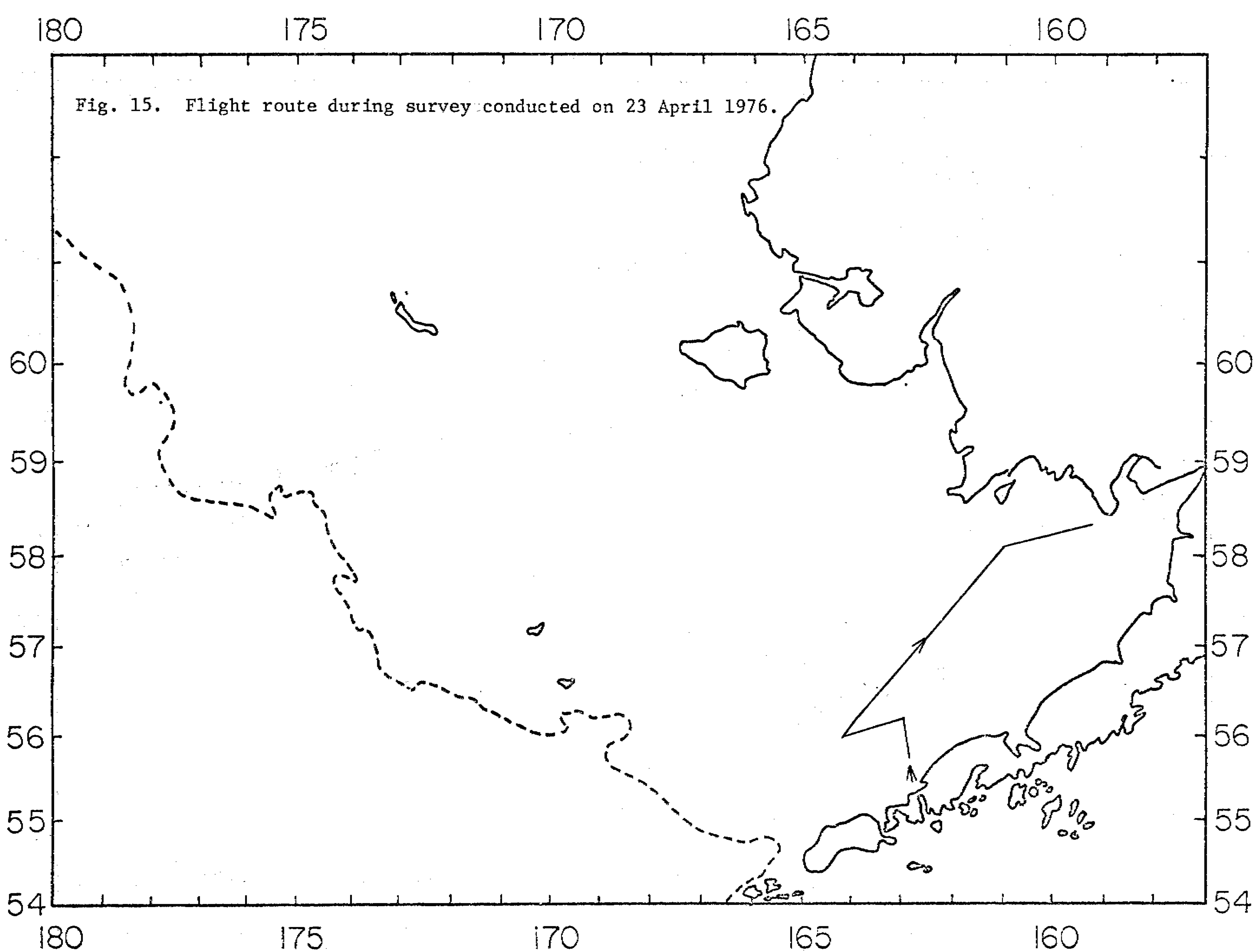

Fig. 15. Flight route during survey conducted on 23 April 1976.

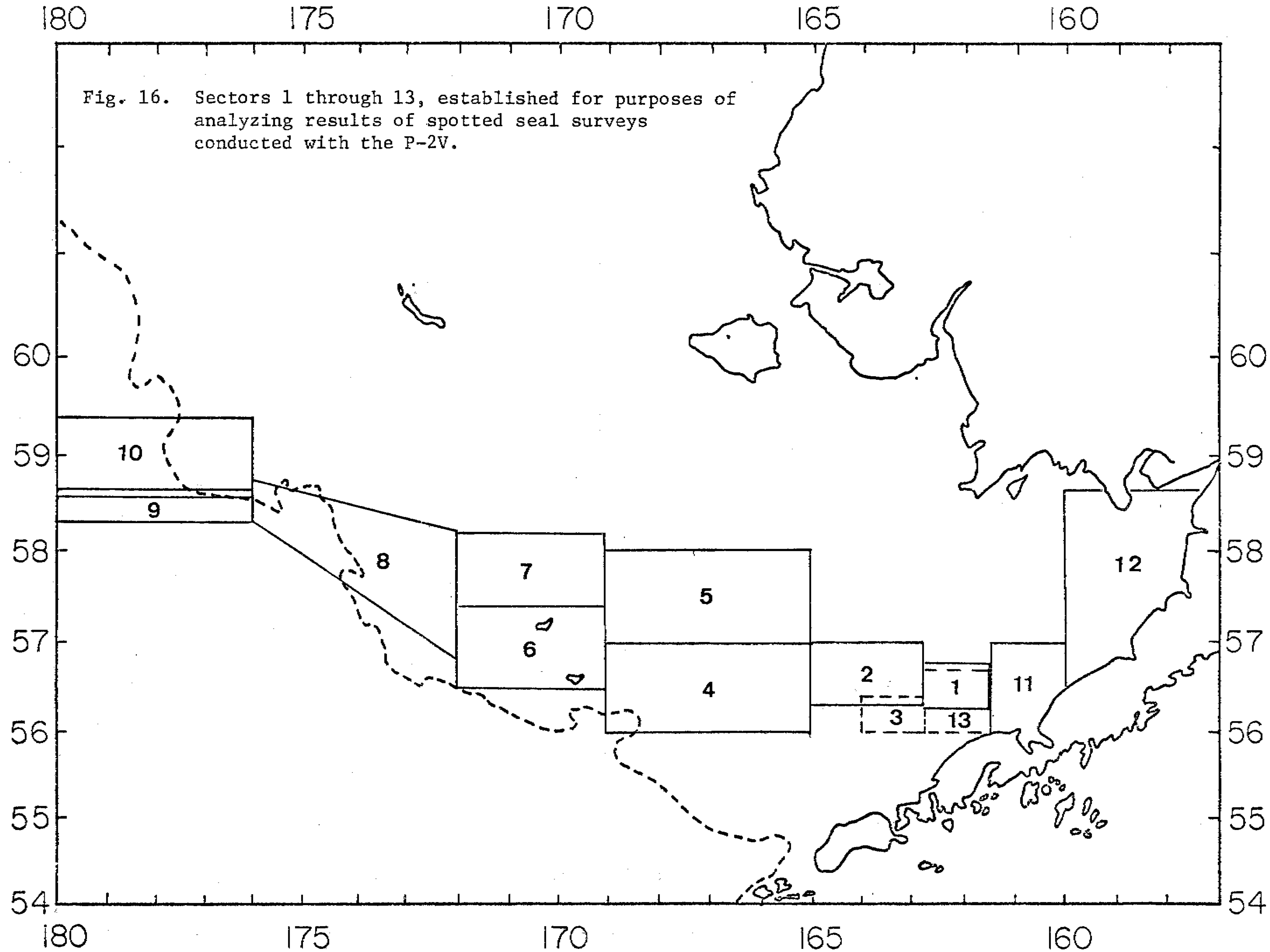

Fig. 16. Sectors 1 through 13, established for purposes of analyzing results of spotted seal surveys conducted with the P-2V.

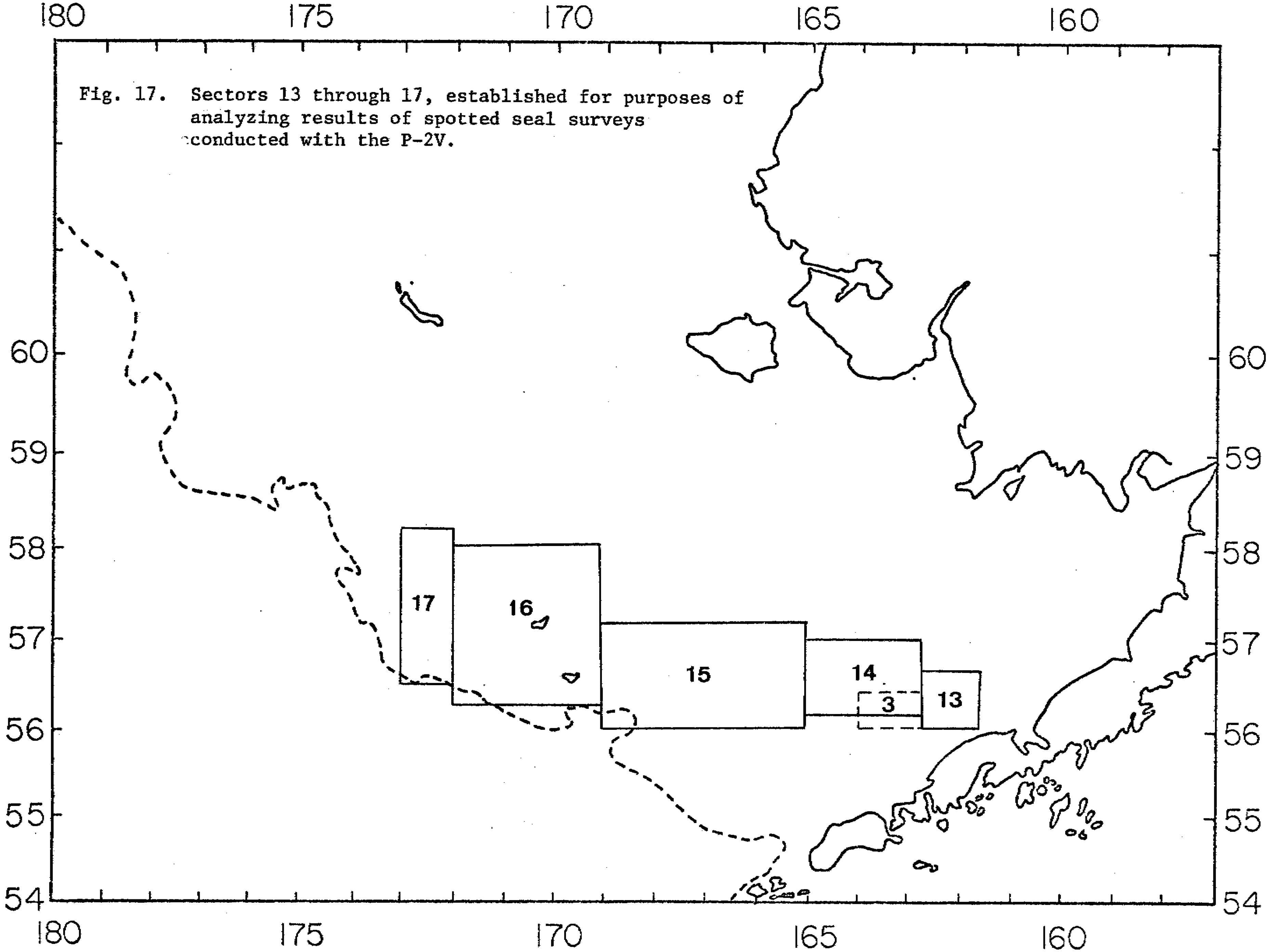

Fig. 17. Sectors 13 through 17, established for purposes of analyzing results of spotted seal surveys conducted with the P-2V.

Table 2. Results of surveys for spotted seals conducted from a Lockheed P-2V aircraft in the ice front of Bering Sea, April 8-23, 1976. Data include sector number, area surveyed, number of seals observed, proportion of pups, density of seals and, where appropriate, variance of density of seals older than pups.

Sector	Area surveyed (NM^2)	Number of seals sighted older than pups	Number of pups sighted	Proportion of pups (%)	Density of seals older than pups/(NM^2)	Density of all seals /(NM^2)	Variance (seals older than pups)
1	111.3	14	1	6.6	0.13	0.13	0.5600
2	109.8	134	16	10.7	1.22	1.37	2.4803
3	142.9	366	27	6.9	2.56	2.75	*
4	249.4	16	7	30.4	0.06	0.09	-
5	106.9	16	9	36.0	0.15	0.23	-
6	91.8	13	3	18.8	0.14	0.17	-
7	85.9	19	7	26.9	0.22	0.30	-
8	273.1	90	25	21.7	0.33	0.42	*
9	78.7	17	10	37.0	0.22	0.34	-
10	161.4	38	12	24.0	0.24	0.31	*
11	178.7	4	0	0	0.02	0.02	-
12	183.1	10	1	9.0	0.05	0.06	-
13	122.9	22	3	12.0	0.18	0.20	-
14	244.8	229	4	1.7	0.94	0.95	*
15	415.2	18	6	25.0	0.04	0.06	-
16	210.9	10	1	9.1	0.05	0.05	-
17	82.9	4	2	33.0	0.05	0.07	-

*Variances for selected data sets within these sectors are included in Table 3.

Table 3. Results of analysis of selected data sets from spotted seal survey of 8-23 April 1976. Aircraft utilized was a Lockheed P-2V.

Sector number	Date	Number of transects	Area surveyed (NM^2)	Number of seals older than pups	Density	Variance
3	April 19	10	38.32	104	2.71	0.9814
8	April 20	8	156.6	47	0.30	0.0026
	April 21	5	116.5	43	0.37	0.0186
10	April 21	8	161.4	38	0.24	0.0026
14	April 8	7	92.0	30	0.34	0.024
	April 9	7	91.17	101	1.11	0.088
	April 11	4	61.64	98	1.59	2.5843

Walrus surveys from the P-2V

The nine sectors examined in our analysis of walrus distribution are shown in Fig. 18. Exact locations of these sectors are included in Appendix III. Results of the walrus surveys are summarized in Table 4.

Walrus densities were very low in the ice front of eastern Bristol Bay (sector 1), between 162°45'W and 165°00'W (sector 5) and in the region west of 172°00'W. Highest densities were in central and western Bristol Bay (sectors 2, 3 and 4), immediately east of the region of high spotted seal densities. The central portion of the survey area (sectors 6, 7 and 8) were areas of comparatively moderate density.

The estimated number of walruses in the areas surveyed was 10,055.

Spotted seal surveys from the helicopter

Areas within which helicopter surveys of spotted seals were made during 1976 and 1977 are shown in Figs. 19 and 20 (the same as Figs. 4 and 5; duplicated here for the reader's convenience). The results of these survey flights are summarized in Tables 5 and 6.

Results of surveys conducted during March of both years (surveys 1, 16 and 17) were not compared with results of surveys made in April. However, they are included as information of general interest.

Five of the six helicopter flights in April 1976 (flights 3 through 7) were within the region of moderate to high seal density as indicated by the P-2V flights. Some southward movement of sea ice occurred after April 23 when surveys with the P-2V were completed, but we consider helicopter flights 3 through 7 to have been in sectors 1, 2, 3 and 13 as shown in Fig. 16.

Application of the Mann-Whitney test in paired comparisons of flights 3 through 7 do not support rejection of the hypothesis that observed seal densities were significantly different for these flights at either the 90 or 95 percent probability level.

Application of the Kruskal-Wallis test also indicated that densities as observed on these five flights were not statistically different H_c = 7.629; chi-square 0.05, 4 df = 9.488; chi-square 0.10, 4 df = 7.779).

No seals were observed on survey number 2, which occurred in sector 8 (an area of moderate seal density as indicated by P-2V flights).

Helicopter surveys of April 1977 were conducted in the ice front which was considerably farther north than it was in 1976 (see Fig. 6). The pattern of seal distribution in the front as it existed in 1977 closely approximated that in the front as it existed in 1976: A high density of seals in the vicinity of 165°W

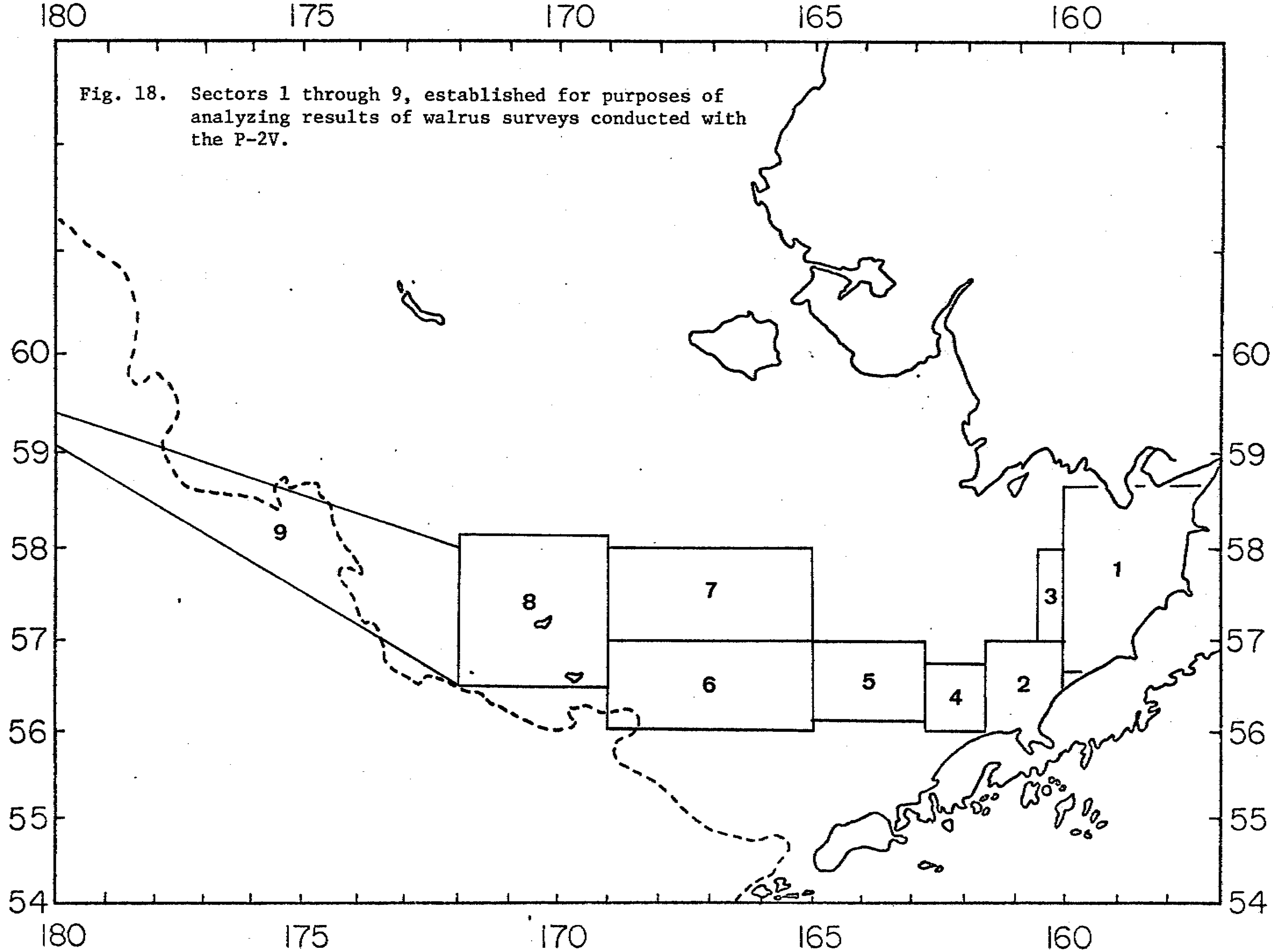

Fig. 18. Sectors 1 through 9, established for purposes of analyzing results of walrus surveys conducted with the P-2V.

Table 4. Results of walrus surveys in the ice front, April 8-23, 1976. Aircraft used was a Lockheed P-2V. Data included are sector number (refer to Fig. 18), number of strip transects within each sector, area surveyed, walruses observed in strip transects, density of walruses in transects, variance of density, total area of sector[1] and estimated number of walruses in each sector.

Sector	Number of transects	Area surveyed (NM^2)	Number walruses counted	Density of walrus in transects ($/NM^2$)	variance	Area of sector (NM^2)[1]	Estimated number of walrus in sector
1	14	433.0	9	0.021	0.4427	6382	134
2	16	356.8	215	0.603	0.3814	2708	1633
3	3	81.4	156	1.917	0.1923	966	1852
4	28	494.4	630	1.286	0.3770	1764	2269
5	51	1399.8	94	0.067	0.0010	3869	259
6	39	1364.3	219	0.161	0.0213	7932	1190
7	11	268.3	46	0.171	0.0342	7728	1321
8	19	777.2	100	0.129	0.0038	9675	1248
9	27	1167.0	13	0.011	0.0040	13504	149

[1] Exclusive of the area within each sector which was beyond the southern margin of sea ice during the survey period.

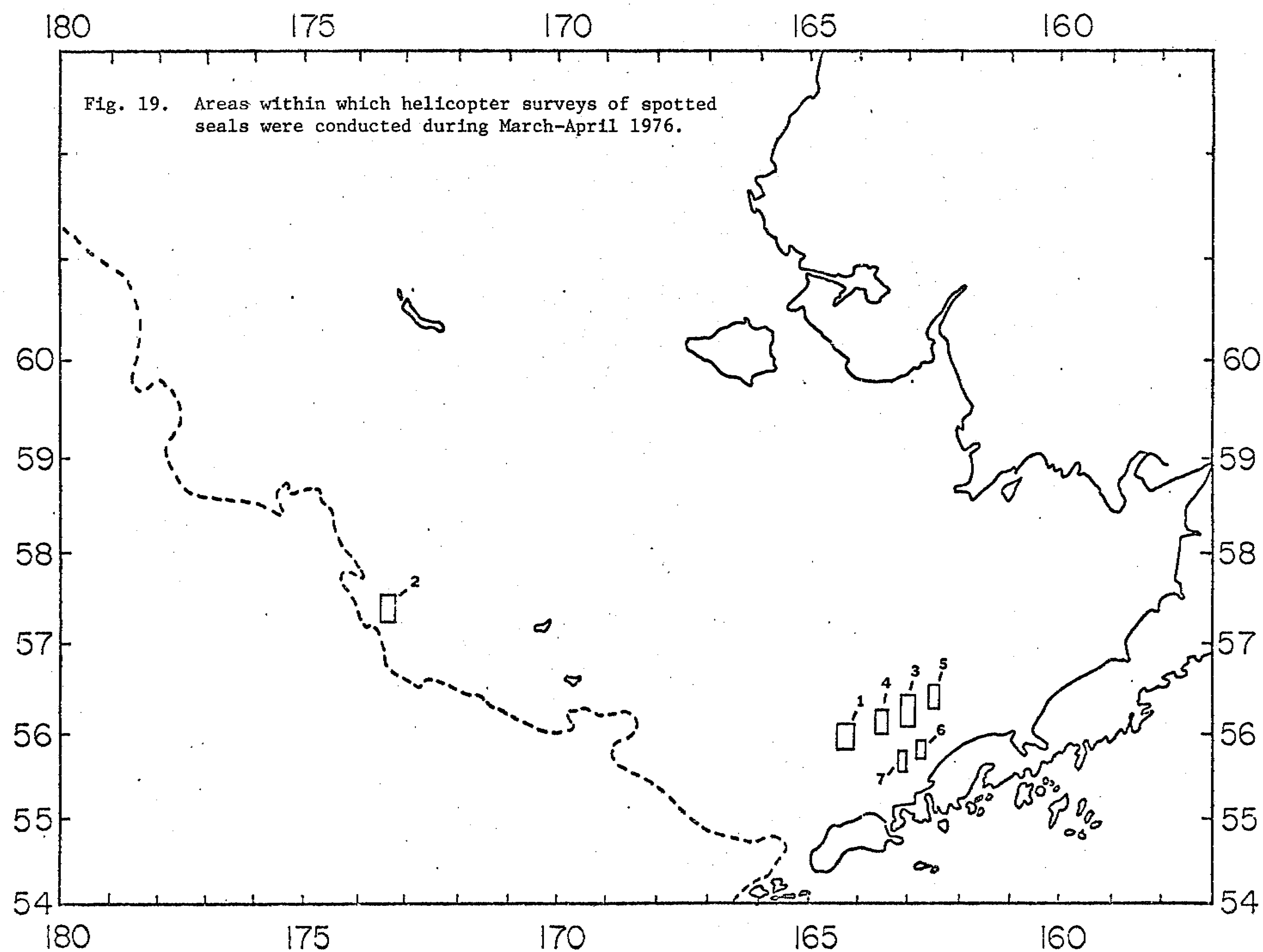

Fig. 19. Areas within which helicopter surveys of spotted seals were conducted during March-April 1976.

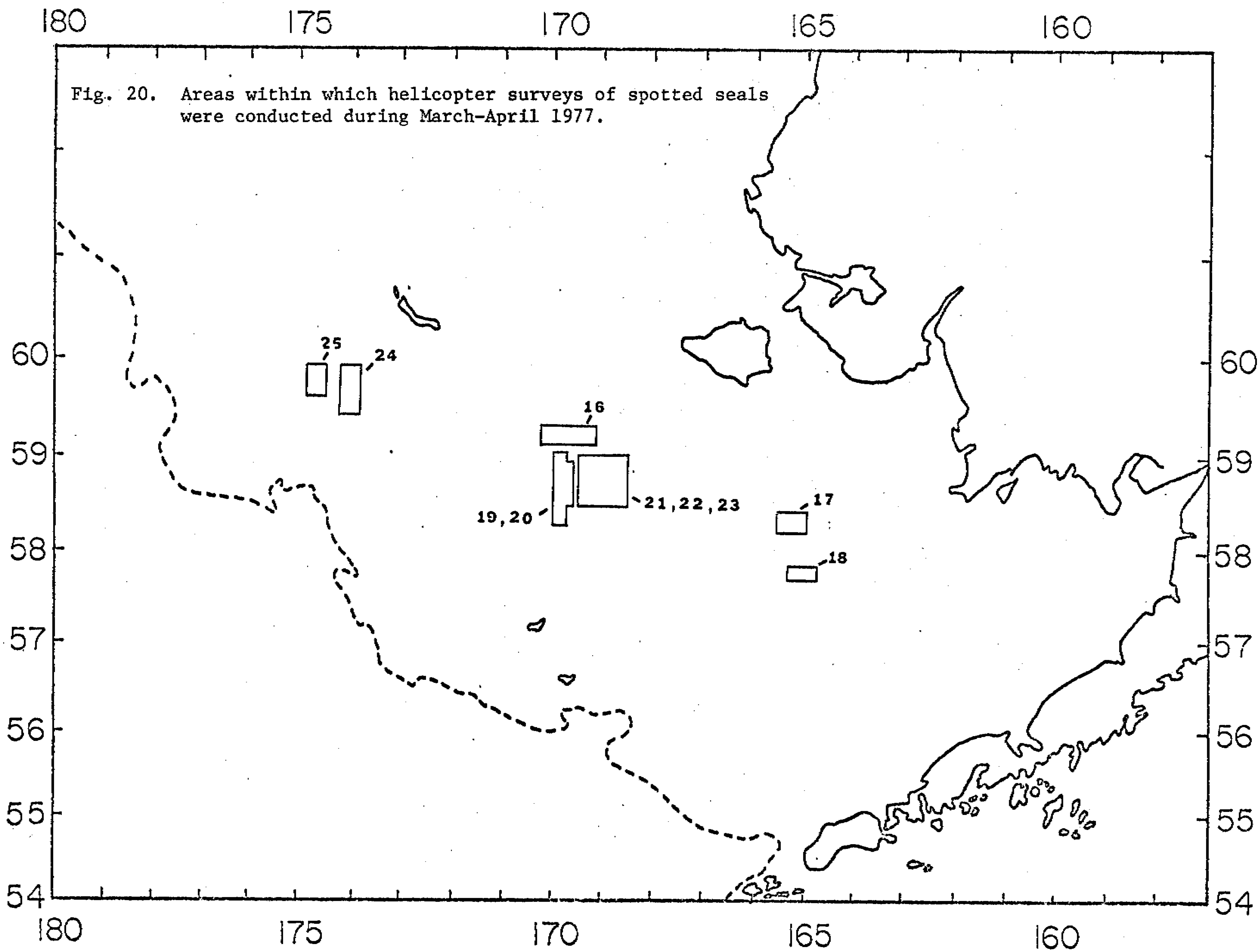

Fig. 20. Areas within which helicopter surveys of spotted seals were conducted during March-April 1977.

Table 5. Results of helicopter surveys of spotted seals conducted during March-April 1976 (surveys 1-7). Data include flight number, date, type of flight, area surveyed, density of seals and variance.

Survey number	Date	Type of flight	Area surveyed (NM^2)	Density of seals/NM^2*	Variance
1	March 27	survey	82.7	6.75	14.2786
2	April 20	survey	40.0	0	0
3	April 23	survey	27.5	3.16	0.1392
4	April 24	survey	26.0	5.77	0.4272
5	April 24	survey	13.0	2.60	0.0688
6	April 25	survey	24.5	3.06	2.1952
7	April 25	survey	24.5	6.61	5.0944

*Includes all age classes of spotted seals observed on surveys.

Table 6. Results of helicopter surveys of spotted seals conducted during March-April 1977 (surveys 16-25). Data include flight number, date, type of flight, density of seals (pups, seals older than pups and all seals combined), variance, corrected density[1] and proportion of pups.

Survey number	Date	Type of flight	Area surveyed (NM^2)	Observed density of seals/NM^2			Variance of totals	Corrected density (pups /NM^2	Corrected density (seals/NM^2)	Proportion of pups(%)
				pups	older than pups	total				
16	March 28	survey	103.3	0	1.13	1.13	0.1646	0[2]	1.13	0[2]
17	March 30	survey	81.2	0	0.05	0.05	0.0010	0[2]	0.05	0[2]
18	April 21	survey	40.5	0.47	6.25	6.72	1.9056	0.47	6.72	7.0
19	April 23	survey	85.0	0.04	0.08	0.12	0.0053	0.04	0.12	30.0
20	April 23	survey	85.3	0	0.06	0.06	0.0008	0	0.06	0
21	April 24	survey	15.0	0.13	0.27	0.40	0.0256	0.13	0.40	33.3
22	April 24	tag/collect	30.6	0.16	0.72	0.88	0.0160	0.08	0.44	18.5
23	April 25	tag/collect	43.9	0.14	0.23	0.36	0.0064	0.09	0.23	37.5
24	April 27	tag/collect	31.2	0.38	0.48	0.87	0.0112	0.19	0.43	44.4
25	April 27	tag/collect	24.7	0.57	0.65	1.21	0.0496	0.29	0.61	46.6

1 Corrected density is adjusted in accordance with ice conditions in general area when flights were restricted to searches of ice fields only.

2 Surveys occurred prior to birth period.

longitude, low to moderate density north of the Pribilof Islands and moderate density west of the Pribilofs.

Considering that all surveys occurred in the ice front during both years, and disregarding the latitudinal differences in position of the "edge," the proportion of pups observed in areas of the same longitude were strikingly similar. In 1976, the proportions of pups in sectors of high seal density (sectors 1, 2, 13 and 14) were 1.7 percent to 12.0 percent. In 1977 (flight 18) it was 7.0 percent. In the vicinity of the Pribilof Islands in 1976, pups accounted for 18.8 percen [illegible] seals in sector 6 and 29 percent in sector 7. This compares with 18.5 percent to 37.5 percent as observed on flights 19, 21, 22 and 23. A similar correlation exists for the region west of 172°W during both years.

The Mann-Whitney test was used for paired comparisons of surveys 19 through 25 (results of survey 18 were obviously significantly different from those of 19 through 25).

These paired tests showed that densities obtained on flights 19 and 20 were not significantly different (U = 55.5, table value 0.10 = 76); 21 and 22 were not significantly different (U = 113, table value 0.10 = 115); 22 and 23 were similar (U = 156, table value 0.10 = 172); 21 and 23 were similar (U = 109.5, table value 0.10 = 130) and 24 and 25 were similar (U = 22, table value 0.10 = 29).

Surveys 18 through 25 consisted of four significantly different groupings as follows: 1, survey 18; 2, surveys 19 and 20; 3, surveys 21-23 and 4, surveys 24 and 25.

An interesting comparison of the survey resulting in the highest density of seals in 1976 (survey 7) with survey 18 made in 1977 indicated no significant difference in densities (U = 41, table value 0.10 = 54).

The tests discussed above also suggest that there was little variation attributed to time of day during which our surveys were conducted, or that significant day to day variation occurred during the period of our April surveys by helicopter (April 20-25, 1976 and April 21-27, 1977).

Tests of the comparative efficiency of the P-2V versus the Bell 206 helicopter were made by comparing results obtained from each in 1976. As expected, observers in the helicopter saw slightly more seals than those in the faster flying aircraft. Comparable segments of transects from the two aircraft, flown on April 20, resulted in an observed density of 0.03 seals/NM^2 with the helicopter and 0 with the P-2V. On 23 April the comparison was 2.17/NM^2 vs 1.53. A transect flown on 21 April in the P-2V resulted in a density of 4.59 seals/NM^2.

In 1977, several attempts were made to determine the proportion of seals which were in the water versus on the ice. On April

20, when small boats were used to collect seals, 14 were seen in the water and one pup was seen on the ice. On April 21, during a small boat trip, which preceded survey 18, 21 seals were seen of which 3 were on the ice. The survey resulted in an observed density of 6.72 seals/NM^2. The actual density of seals in the region of this survey (most were subadults) may well have exceeded 40/NM^2.

In areas farther to the west, occupied primarily by adult spotted seals with pups, the ratio appeared to be more on the order of 1 to 3 seals in the water to each one on the ice. The high proportion of pups seen on the surveys of 25 and 27 April 1977 reflects the fact that the older pups are not as closely attended on the ice by the adults.

VIII. Discussion

The effects of precipitation on hauling out behavior of seals was a priori, considered to be significant. We did not conduct surveys when it was snowing. Other components of local weather conditions during our April surveys in 1976 and 1977 did appear to have some influence on the results. Some trends, especially during the last week of April, are suggested.

Appendix IV is a summary of weather conditions as officially recorded at weather stations near the survey area (King Salmon, Cold Bay and St. Paul Island) or from the OSS SURVEYOR. Records of air temperature and wind velocity were used to crudely estimate a corrected temperature (reported dry bulb thermometer temperature minus the wind velocity). The corrected temperatures are considered in this discussion.

As indicated in the previous section, helicopter surveys 3 through 7, conducted during the 3 day period of April 23-25, can be considered as producing similar results. Wind velocities during these five surveys varied from 7 to 10 knots and corrected temperatures from 10° to 25°.

In a general sense, these variations in winds and temperatures apparently did not significantly influence the survey results (i.e. the number of seals hauled out on the ice).

A little more insight can be gained by examination of the 1977 data and interpretation of the possible significance of differences in the observed proportion of pups.

Helicopter surveys of 27 April 1977 (surveys 24 and 25) indicated that pups comprised 44.4 to 46.6 percent of all seals seen. We attribute this to two things; 1) adult seals do not normally attend their pups on the ice as closely during the later stages of the nursing period and 2) the adults are therefore likely to exhibit a lower threshold tolerance for marginal weather conditions. During surveys 24 and 25 winds were recorded at 22 and 30 knots respectively and corrected temperatures were 7° and 1° respectively.

Although weather conditions in April apparently did influence estimates of the proportion of pups observed on a survey, the derived densities of all seals were less obvious and probably more significantly affected by errors associated with sampling.

Geographical differences in density of pups (as opposed to proportion of pups) are directly related to the density of all seals. Thus, areas of high seal density exhibit a high density of pups although the proportion of pups may be low. Table 6 illustrates this relationship. As examples, survey number 18 resulted in a high observed density of 6.72 seals/NM^2, 0.47 pups/NM^2, but only 7.0 percent of the seals were pups. Survey number 21 resulted in a moderate observed density of 0.4 seals/NM^2, 0.13 pups/NM^2 but 33.3 percent of all seals seen were pups.

In our opinion one of the most significant factors influencing the distribution of spotted seals during April 1976, was the rapid and persistent southward movement of ice during the March-April period. This produced a very wide front zone and also resulted in favorable conditions for spotted seals well north of where they would be expected to occur. Results of our surveys in April 1976 together with those of H. Braham (Braham et al., 1977) showed that in eastern Bering Sea spotted seals occurred in an area extending from 56°N to 59°30'N (210 nm north to south).

Our P-2V surveys in April 1976 indicated similar or slightly higher densities of seals in sectors which could be compared on a north-south basis. Seal densities in sectors 9 and 10 were 0.34 and 0.31/NM^2 respectively; sectors 6 and 7 were 0.17 and 0.30 and sectors 4 and 5 were 0.09 and 0.23 respectively.

This is in marked contrast to previously reported information (Shustov 1965; Kosygin 1966) and our own observations based on ship board expeditions in 1968, 1971 and 1972 (Burns, unpublished) when spotted seals were mainly confined to the narrow ice front during March-April.

In April 1977, distribution of spotted seals was again restricted to the ice front. Our helicopter surveys and collecting flights indicated that few spotted seals occurred beyond 30 miles north of the ice edge.

It seems plausible to conclude that greatest concentrations of spotted seals occur in the ice front during those years when it becomes more or less stabilized during the February-April period at latitudes where it "usually" occurs (between 57°N and 58°N).

VIII. Conclusions

Spotted seals are distributed continuously throughout the ice front although there are significant regional differences in density and general age composition. The highest density of these seals in 1976 and 1977 occurred in western Bristol Bay between 162°W and 165°30'W longitudes.

A high proportion of the seals in Bristol Bay are subadult animals whereas farther to the west the proportions of adults and pups are higher.

Observed density of seals on the ice reflects regional differences in relative abundance but is a poor and very variable indication of actual numbers. Our data indicate that in areas where subadult seals are numerous only 14 percent or less of the seals may be hauled out on the ice where they can be seen by observers in an aircraft. In regions where adults and pups predominate, 25 to 50 percent of the seals may be on the ice.

Aircraft surveys in general can be utilized to determine distribution, relative abundance and population composition of spotted seals although it is not yet possible to estimate the actual number of seals by these techniques. Observers see more seals from helicopters than from fixed-wing aircraft. The differences in results, although consistent, are not very great.

Weather conditions during the survey periods in April of 1976 and 1977 were of lesser significance than was error associated with sampling procedures and factors affecting sightability of seals.

Location and characteristics of the ice front appear to have a significant influence on the distribution of spotted seals. In most years spotted seals are concentrated in a relatively restricted front zone. During April 1976 they were broadly distributed over a wide area of southeastern Bering Sea.

Aerial surveys of walruses provide a more accurate approximation of the total number of animals in a survey area. During April 1976, the highest density of walruses in the ice front occurred in central Bristol Bay. The estimated number of walruses in the total area we surveyed was 10,000.

Critical Areas

Fig. 21 illustrates the observed distribution of sightings of spotted seals (groups) in the ice front as determined by aerial surveys with the P-2V during April 1976. Fig. 22 shows observed densities of spotted seals and walruses plotted in relation to degrees of longitude.

Based solely on consideration of relative density, it is apparent that central and western Bristol Bay are areas critical to the support of spotted seals and walruses.

However, density of animals per unit of area is only one consideration. Areas within which seals give birth and nurture their pups is another. From the standpoint of pupping areas the entire ice front, with the exception of the extreme eastern portion of Bristol Bay, is very important. Based on the results of our surveys, areas critical for the successful production of pups are: (1) central and western Bristol Bay (162°W to 165°W) and (2) the entire ice front west of 169°W longitude.

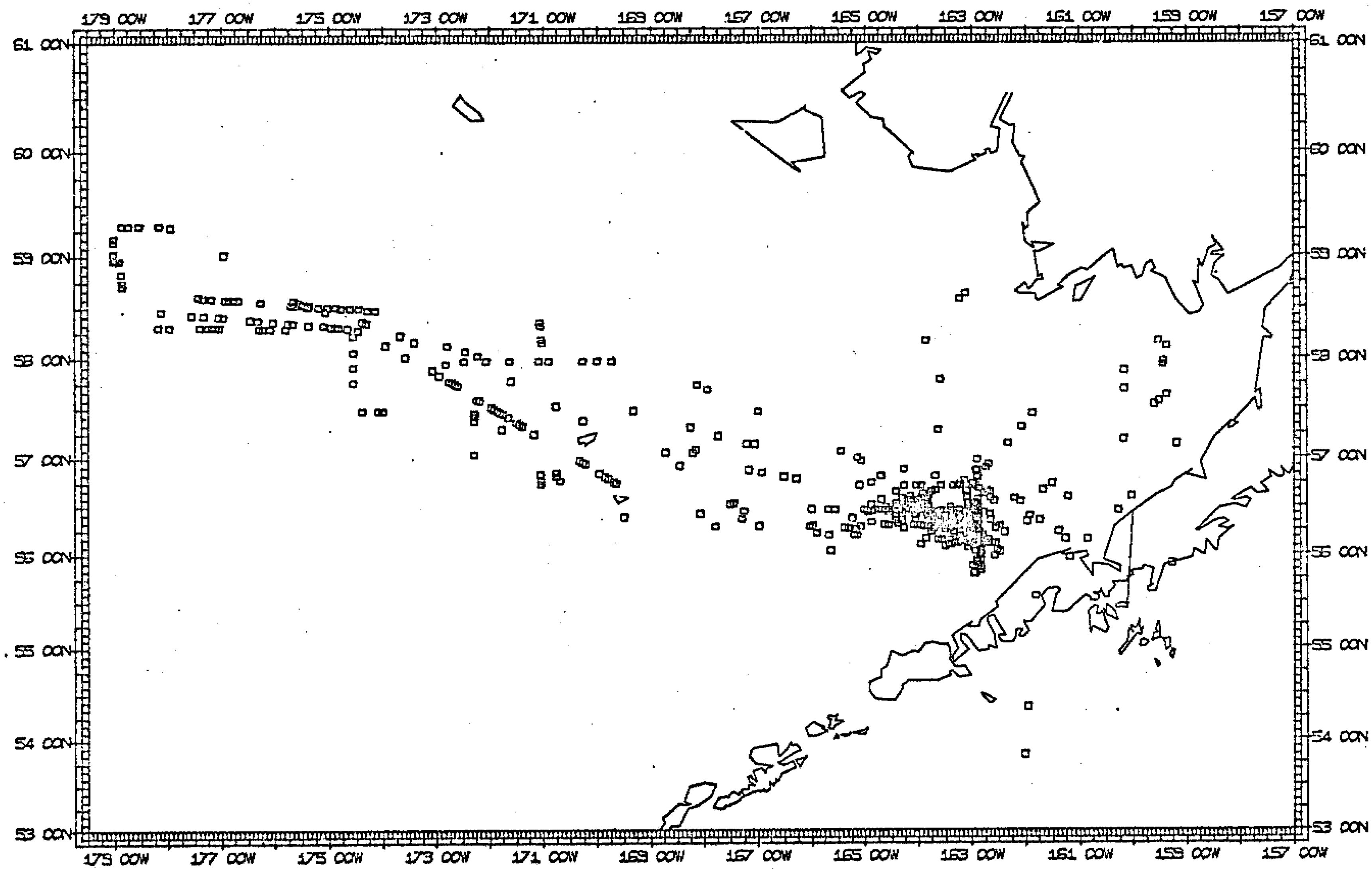

Fig. 21. Sightings of spotted seals recorded during surveys from the P-2V, April 8-23, 1976. (Figure prepared by B. Krogman, NMFS, Seattle. Anomalus indicated sightings outside of the area surveyed have not been corrected.)

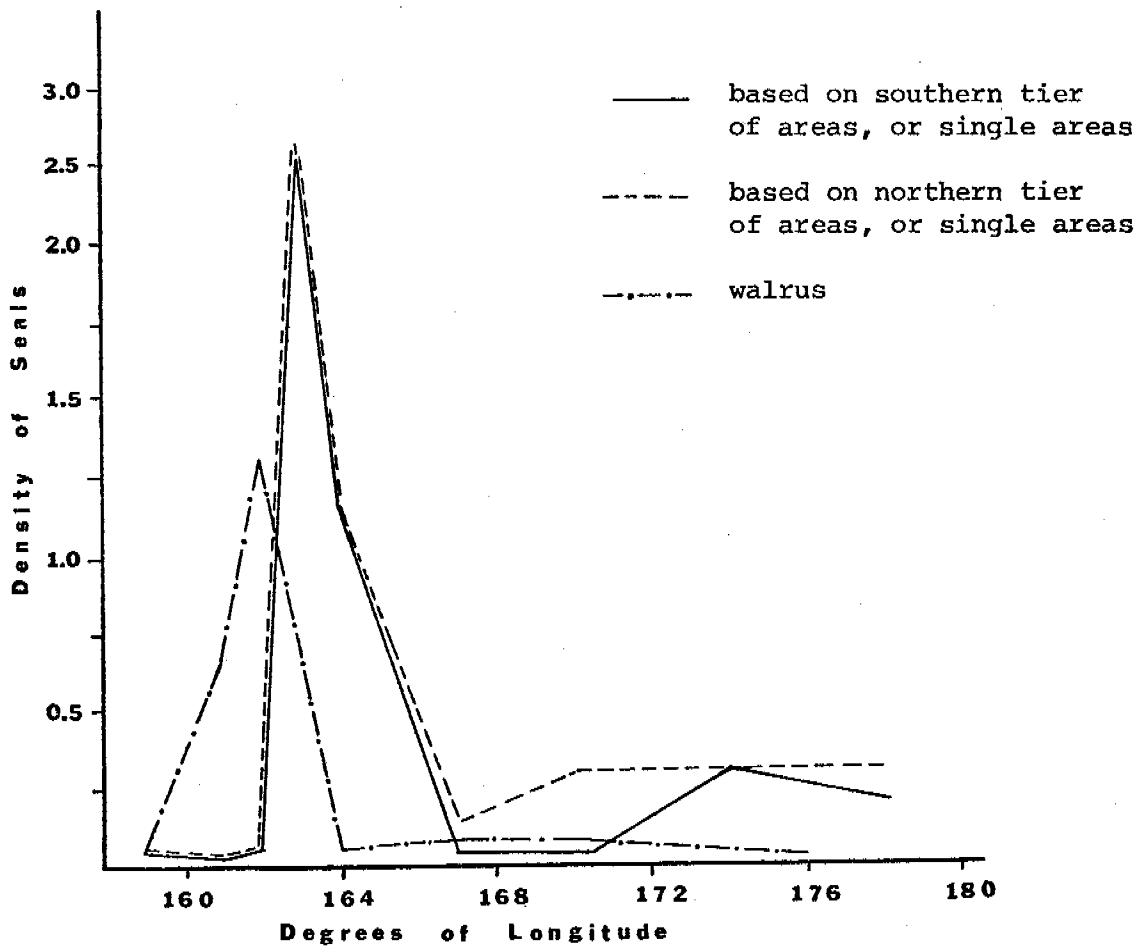

Fig. 22. Observed densities of spotted seals (——— and -----) and walrus (—.—.) in the ice front plotted in relation to longitude. (From P-2V surveys, April 8-23, 1976).

IX. Needs for Further Study

The most obvious needs for further investigation which are pointed out by the results of this study are:

1) to determine what physical and biological factors contribute to the support of the concentrations of spotted seals and walruses in central and western Bristol Bay;

2) to determine how OCS development in the areas of high seal and walrus densities will impact the marine mammals or the habitats which support them;

3) to more clearly understand the diurnal activity patterns of spotted seals as a basis for converting the indices of abundance, derived through surveys of various kinds, into estimates of actual population size;

4) to understand how and to what extent the annual variations in sea ice conditions influence the seasonal movements and distribution of marine mammals occurring in the ice front.

X. Acknowledgments

We are greatly indebted to each person who participated in our surveys. These people are indicated in Table 1. Our special thanks are expressed to Ms. Kathryn Frost for her involvement in this effort, particularly with the tedious tasks of data compilation and "data management." Other persons who contributed significantly to this effort and have not been identified are H. Braham, B. Krogman, and D. Day. We wish to thank collectively the officers and crew who served aboard the OSS SURVEYOR during March-April of 1976 and 1977.

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Appendix I. Aerial surveys for spotted seals (and walrus), undertaken in 1976 and 1977. Information includes aircraft types, dates and transect check points (time, number and position of each).

Time	Checkpoint No.	Position	
I. Helicopter Survey, Bell 206, 27 March 1976			
1411	1	55°49'N	164°26'W
1427	2	56°00'N	164°07'W
1444	3	56°10'N	164°07'W
1448	4	56°10'N	164°15'W
1457	5	56°00'N	164°14'W
1500	6	56°00'N	164°21'W
1510	7	56°10'N	164°22'W
1514	8	56°10'N	164°30'W
1522	9	56°00'N	164°28'W
1528	10	56°00'N	164°35'W
1538	11	55°49'N	164°26'W
II. Helicopter Survey, Bell 206, 20 April 1976			
1635	1	57°19'N	173°19'W
1641	2	57°24'N	173°19'W
1646	3	57°24'N	173°28'W
1652	4	57°29'N	173°28'W
1657	5	57°29'N	173°19'W
1703	6	57°34'N	173°19'W
1708	7	57°34'N	173°28'W
1714	8	57°39'N	173°28'W
1720	9	57°39'N	173°19'W
III. Helicopter Sruvey, Bell 206, 23 April 1976			
1620	1	56°05'N	163°01'W
1625	2	56°10'N	163°00'W
1630	3	56°10'N	163°09'W
1636	4	56°15'N	163°09'W
1645	5	56°15'N	162°52'W
1652	6	56°20'N	162°52'W
1701	7	56°20'N	163°09'W
1706	8	56°25'N	163°09'W
1716	9	56°25'N	162°52'W
IV. Helicopter Survey, Bell 206, 24 April 1976			
1335	1	56°00'N	163°22'W
1348	2	56°12'N	163°22'W
1350	3	56°12'N	163°24'W
1360	4	56°00'N	163°24'W
1401	5	56°00'N	163°26'W

1415	6	56°12'N	163°26'W
1416	7	56°12'N	163°28'W
1426	8	56°00'N	163°28'W
1427	9	56°00'N	163°29'W

V. Helicopter Survey, Bell 206, 24 April 1976

1642	1	56°24'N	162°27'W
1654	2	56°36'N	162°27'W
1655	3	56°36'N	162°29'W
1708	4	56°24'N	162°29'W
1710	5	56°24'N	162°31'W

VI. Helicopter Survey, Bell 206, 25 April 1976

1330	1	55°53'N	162°57'W
1333	2	55°48'N	162°57'W
1334	3	55°48'N	162°55'W
1344	4	55°58'N	162°55'W
1346	5	55°58'N	162°53'W
1354	6	55°48'N	162°53'W
1356	7	55°48'N	162°51'W
1414	8	55°58'N	162°51'W
1416	9	55°58'N	162°49'W
1425	10	55°48'N	162°49'W

VII. Helicopter Survey, Bell 206, 25 April 1976

1642	1	55°50'N	163°00'W
1649	2	55°55'N	163°00'W
1650	3	55°55'N	163°02'W
1658	4	55°45'N	163°02'W
1660	5	55°45'N	163°04'W
1711	6	55°55'N	163°04'W
1712	7	55°55'N	163°06'W
1720	8	55°45'N	163°06'W
1721	9	55°45'N	163°08'W
1752	10	55°55'N	163°08'W

VIII. P2V Survey, 8 April 1976

0905	1	58°43'N	157°27'W
0921	2	58°32'N	158°46'W
0924	3	58°26'N	158°58'W
0943	4	57°55'N	160°07'W
1018	5	56°34'N	160°08'W
1031	6	56°57'N	160°47'W
1058	7	56°12'N	162°15'W
1113	8	56°34'N	162°59'W
1126	9	56°13'N	163°37'W
1143	10	56°38'N	164°22'W

1150	11	56°52'N	164°22'W
1218	12	56°07'N	165°43'W
1225	13	56°14'N	165°56'W
1239	14	56°44'N	165°55'W
1258	15	56°15'N	166°48'W
1315	16	56°40'N	167°30'W
1334	17	56°06'N	168°17'W
1342	18	56°06'N	167°44'W
1404	19	56°40'N	166°30'W
1421	20	56°07'N	165°31'W
1458	21	56°52'N	163°07'W
1519	22	56°17'N	162°06'W
1521	23	56°17'N	161°55'W
1543	24	56°51'N	160°43'W
1552	25	56°35'N	160°16'W
1603	26	56°18'N	160°40'W
1606	27	56°13'N	160°48'W
1610	28	56°19'N	161°00'W
1615	29	56°17'N	161°14'W
1621	30	56°13'N	161°40'W
1631	31	56°13'N	162°10'W
1637	32	56°28'N	162°09'W
1700	33	56°29'N	160°26'W
1703	34	56°36'N	160°20'W
1707	35	56°39'N	160°02'W
1758	36	58°31'N	159°08'W

IX. P2V Survey, 9 April 1976

1031	1	58°18'N	157°56'W
1035	2	58°14'N	158°14'W
1042	3	57°58'N	158°57'W
1047	4	57°46'N	158°00'W
1050	5	57°39'N	158°11'W
1058	6	57°26'N	158°42'W
1102	7	57°15'N	158°41'W
1109	8	57°09'N	159°13'W
1121	9	56°48'N	159°44'W
1137	10	56°18'N	160°31'W
1140	11	56°10'N	160°35'W
1141	12	56°12'N	160°37'W
1152	13	56°11'N	161°26'W
1204	14	56°34'N	162°06'W
1207	15	56°31'N	162°14'W
1217	16	56°09'N	162°20'W
1220	17	56°03'N	162°20'W
1222	18	56°04'N	162°25'W
1236	19	56°30'N	163°11'W
1251	20	56°08'N	163°55'W

1300	21	56°23'N	164°23'W
1310	22	56°46'N	164°22'W
1337	23	56°03'N	165°38'W
1358	24	56°36'N	166°47'W
1408	25	56°21'N	167°21'W
1419	26	56°45'N	167°25'W
1433	27	57°09'N	168°03'W
1503	28	56°21'N	169°36'W
1523	29	56°49'N	170°42'W
1534	30	57°11'N	170°46'W
1558	31	56°31'N	171°59'W
1603	32	56°39'N	172°12'W
1630	33	57°43'N	172°14'W
1654	34	57°00'N	171°18'W
1714	35	56°50'N	169°58'W
1753	36	56°34'N	167°27'W
1800	37	56°30'N	166°57'W
1840	38	56°30'N	164°19'W
1904	39	56°28'N	162°40'W
1912	40	56°09'N	162°46'W

X. P2V Survey, 11 April 1976

0924	1	56°19'N	163°49'W
0925	2	56°20'N	163°52'W
1007	3	56°20'N	166°42'W
1101	4	56°47'N	170°00'W
1136	5	57°00'N	172°13'W
1140	6	56°53'N	172°26'W
1150	7	57°11'N	172°52'W
1218	8	58°09'N	172°46'W
1259	9	57°19'N	169°57'W
1317	10	57°03'N	168°31'W
1357	11	56°45'N	165°35'W
1431	12	56°46'N	163°00'W
1447	13	56°12'N	163°00'W
1627	14	56°12'N	162°32'W
1630	15	56°19'N	162°31'W
1708	16	57°00'N	160°00'W
1747	17	58°12'N	157°54'W

XI. P2V Survey, 17 April 1976

1307	1	58°15'N	157°48'W
1339	2	57°16'N	160°18'W
1356	3	56°42'N	161°37'W
1407	4	56°14'N	161°41'W
1421	5	56°45'N	161°52'W
1435	6	56°15'N	161°51'W

1452	7	56°45'N	162°02'W
1505	8	56°14'N	162°03'W
1507	9	56°15'N	162°10'W
1522	10	56°45'N	162°09'W
1537	11	56°14'N	162°37'W
1554	12	56°45'N	162°37'W
1608	13	56°16'N	163°23'W
1611	14	56°08'N	163°22'W

XII. P2V Survey, 19 April 1976

1002	1	55°52'N	162°50'W
1012	2	56°18'N	162°56'W
1026	3	56°52'N	162°55'W
1043	4	56°18'N	163°10'W
1059	5	56°53'N	163°10'W
1129	6	56°53'N	165°06'W
1204	7	56°53'N	167°29'W
1225	8	56°54'N	169°00'W
1237	9	56°30'N	168°59'W
1250	10	56°27'N	168°02'W
1310	11	56°24'N	166°38'W
1320	12	56°19'N	165°52'W
1323	13	56°18'N	165°38'W
1335	14	56°18'N	164°49'W
1349	15	56°50'N	164°50'W
1403	16	56°25'N	164°24'W
1405	17	56°24'N	164°16'W
1422	18	57°00'N	164°16'W
1438	19	56°25'N	164°00'W
1456	20	57°01'N	163°59'W
1512	21	56°25'N	163°47'W
1531	22	57°00'N	163°45'W
1550	23	56°19'N	163°12'W
1607	24	57°00'N	163°10'W
1626	25	56°19'N	162°56'W
1629	26	56°22'N	162°54'W
1647	27	57°01'N	162°52'W
1710	28	56°09'N	162°50'W
1716	29	55°55'N	162°52'W

XIII. P2V Survey, 20 April 1976

1127	1	55°53'N	162°35'W
1136	2	56°09'N	162°30'W
1142	3	56°11'N	162°56'W
1152	4	56°11'N	163°40'W
1201	5	56°10'N	164°17'W
1203	6	56°14'N	164°19'W
1231	7	56°15'N	166°24'W
1235	8	56°20'N	166°34'W
1245	9	56°23'N	167°13'W

1255	10	56°23'N	168°02'W
1301	11	56°35'N	168°04'W
1319	12	56°35'N	169°27'W
1330	13	56°37'N	169°50'W
1339	14	56°36'N	170°55'W
1346	15	56°50'N	171°01'W
1402	16	56°50'N	172°14'W
1419	17	57°29'N	172°14'W
1448	18	57°31'N	174°30'W
1509	19	58°20'N	174°31'W
1605	20	58°20'N	178°39'W
1611	21	58°31'N	178°40'W
1712	22	58°20'N	174°29'W
1740	23	57°48'N	172°43'W
1824	24	57°03'N	170°23'W
1942	25	56°20'N	165°00'W
2014	26	56°20'N	162°49'W
2025	27	55°52'N	162°47'W

XIV. P2V Survey, 21 April 1976

1102	1	56°06'N	163°01'W
1105	2	56°10'N	163°03'W
1138	3	57°02'N	165°05'W
1153	4	57°17'N	166°03'W
1237	5	58°01'N	169°03'W
1310	6	58°01'N	172°02'W
1336	7	58°30'N	174°00'W
1434	8	58°41'N	178°48'W
1441	9	58°59'N	178°51'W
1506	10	59°00'N	178°58'E
1515	11	59°20'N	178°58'E
1550	12	59°20'N	177°59'W
1609	13	58°55'N	176°24'W
1614	14	58°42'N	176°22'W
1635	15	58°24'N	174°26'W
1655	16	58°06'N	172°58'W
1806	17	57°11'N	167°09'W
1815	18	57°07'N	166°30'W
1819	19	57°05'N	166°09'W
1821	20	57°00'N	166°00'W
1845	21	56°49'N	164°00'W
1859	22	56°22'N	163°38'W
1903	23	58°18'N	163°24'W

XV. P2V Survey, 23 April 1976

1115	1	55°50'N	162°55'W
1123	2	56°12'N	163°01'W
1141	3	56°00'N	164°09'W
1148	4	56°07'N	163°58'W
1246	5	58°01'N	161°00'W
1315	6	58°27'N	158°18'W

XVI. Helicopter Survey, Bell 206, 28 March 1977

1352	1	59°08'N	169°35'W
1410	2	59°08'N	170°10'W
1413	3	59°10'N	170°10'W
1437	4	59°10'N	169°00'W
1438	5	59°12'N	169°00'W
1515	6	59°12'N	169°51'W
1517	7	59°14'N	169°50'W
1524	8	59°14'N	169°30'W
1530	9	59°08'N	169°33'W

XVII. Helicopter Survey, Bell 206, 30 March 1977

1341	1	58°20'N	164°50'W
1357	2	58°20'N	165°26'W
1359	3	58°22'N	165°26'W
1418	4	58°22'N	164°50'W
1420	5	58°24'N	164°50'W
1436	6	58°24'N	165°26'W
1438	7	58°26'N	165°26'W
1457	8	58°26'N	164°50'W

XVIII. Helicopter Survey, Bell 206, 21 April 1977

1832	1	57°45'N	164°55'W
1841	2	57°45'N	165°11'W
1844	3	57°49'W	165°11'W
1859	4	57°49'N	164°34'W
1905	5	57°45'N	164°55'W
1916	6	57°45'N	164°34'W
1926	7	57°47'N	165°11'W
1942	8	57°47'N	164°34'W
1950	9	57°45.4'N	164°45.3'W

XIX. Helicopter Survey, Bell 206, 23 April 1977

1008	1	58°13.3'N	169°59.4'W
1018	2	58°24.3'N	169°55.1'W
1027	3	58°36.7'N	169°54.3'W
1040	4	58°49.5'N	169°50.3'W
1048	5	59°00.7'N	169°46.6'W
1140	6	59°00.0'N	169°53.4'W
1200	7	58°48.6'N	169°55.9'W
1222	8	58°40.0'N	169°59.1'W
1235	9	58°34.1'N	169°57.4'W
1258	10	58°27.3'N	169°42.2'W

XX. Helicopter Survey, Bell 206, 23 April 1977

1356	1	58°28.0'N	169°41.3'W
1407	2	58°41.6'N	169°51.1'W
1412	3	58°48.7'N	169°48.6'W
1418	4	58°52.9'N	169°50.1'W

1425	5	58°58.0'N	169°55.0'W
1440	6	58°57.5'N	169°56.6'W
1457	7	58°53.8'N	169°49.3'W
1506	8	58°49.2'N	169°48.6'W
1520	9	58°40.1'N	169°43.9'W
1523	10	58°37.5'N	169°42.8'W
1536	11	58°30.0'N	169°39.9'W
1610	12	58°29.1'N	169°41.9'W
1620	13	58°41.2'N	169°46.4'W
1623	14	58°43.8'N	169°47.7'W
1631	15	58°52.3'N	169°39.5'W

XXI. Helicopter Survey, Bell 206, 24 April 1977

1258	1	58°30.9'N	169°25.7'W
1303	2	58°31.6'N	169°18.8'W
1310	3	58°37.2'N	169°13.2'W
1312	4	58°38.6'N	169°11.3'W
1317	5	58°42.1'N	169°09.3'W
1321	6	58°43.6'N	169°05.6'W
1328	7	58°48.4'N	168°57.8'W
1335	8	58°51.8'N	169°02.0'W
1345	9	58°57.2'N	169°02.0'W
1351	10	58°56.3'N	169°09.5'W
1415	11	58°54.6'N	169°13.7'W
1508	12	58°33.9'N	169°25.5'W

XXII. Helicopter Survey, Bell 206, 24 April 1977

1550	1	58°29.3'N	169°25.7'W
1554	2	58°29.6'N	169°27.3'W
1556	3	58°31.2'N	169°31.2'W
1601	4	58°35.0'N	169°37.2'W
1606	5	58°40.2'N	169°40.5'W
1637	6	58°34.0'N	169°32.3'W
1640	7	58°30.6N	169°26.5'W
1720	8	58°34.9'N	169°28.8'W
1732	9	58°40.2'N	169°37.3'W
1737	10	58°44.1'N	169°38.7'W
1742	11	58°46.7'N	169°34.8'W
1749	12	58°50.3'N	169°32.7'W
1756	13	58°51.5'N	169°23.8'W
1802	14	58°49.2'N	169°24.6'W
1806	15	58°46.7'N	169°28.4'W
1810	16	58°44.6'N	169°27.6'W
1820	17	58°45.0'N	169°28.1'W
1825	18	58°40.3'N	169°28.9'W

XXIII. Helicopter Survey, Bell 206, 25 April 1977

1556	1	58°29.7'N	169°14.3'W
1558	2	58°32.2'N	169°16.3'W
1604	3	58°40.6'N	169°12.7'W

1609	4	58°48.2'N	169°12.7'W
1611	5	58°52.3'N	169°11.8'W
1613	6	58°53.0'N	169°07.9'W
1625	7	58°54.5'N	169°06.6'W
1634	8	59°00.9'N	168°48.7'W
1636	9	58°59.4'N	168°42.7'W
1638	10	58°58.0'N	168°40.1'W
1650	11	58°55.9'N	168°40.7'W
1702	12	58°55.3'N	168°42.3'W
1705	13	58°52.8'N	168°43.8'W
1708	14	58°51.5'N	168°39.3'W
1710	15	58°49.8'N	168°39.7'W
1720	16	58°49.4'N	168°39.3'W
1802	17	58°36.0'N	168°57.2'W
1825	18	58°25.4'N	169°23.1'W

XIV. Helicopter Survey, Bell 206, 27 April 1977

0808	1	59°54.4'N	173°54.1'W
0815	2	59°42.5'N	174°05.2'W
0818	3	59°39.5'N	174°05.6'W
0835	4	59°38.5'N	174°06.0'W
0842	5	59°36.9'N	174°04.5'W
0853	6	59°36.9'N	174°06.6'W
0900	7	59°35.8'N	174°03.9'W
0914	8	59°32.0'N	174°01.7'W
0929	9	59°31.8'N	174°00.2'W
0936	10	59°31.5'N	174°00.0'W
0943	11	59°28.8'N	174°01.9'W
0946	12	59°28.3'N	173°58.3'W
0958	13	59°26.2'N	173°56.4'W
1009	14	59°27.9'N	173°51.5'W
1031	15	59°32.0'N	173°57.3'W
1034	16	59°32.7'N	173°58.6'W
1045	17	59°35.0'N	174°00.4'W
1054	18	59°36.0'N	174°00.8'W
1101	19	59°44.4'N	173°59.3'W

XXV. Helicopter Survey, Bell 206, 27 April 1977

1835	1	59°46.7'N	174°23.7'W
1839	2	59°44.3'N	174°26.9'W
1846	3	59°44.0'N	174°26.3'W
1857	4	59°43.5'N	174°31.2'W
1858	5	59°44.0'N	174°32.8'W
1905	6	59°45.3'N	174°32.8'W
1908	7	59°46.3'N	174°32.4'W
1926	8	59°47.4'N	174°37.0'W
1951	9	59°50.3'N	174°37.5'W
1955	10	59°52.6'N	174°39.1'W
2001	11	59°52.2'N	174°40.1'W
2007	12	59°52.3'N	174°40.7'W

2022	13	59°52.8'N	174°37.4'W
2034	14	59°52.3'N	174°44.8'W
2041	15	59°46.8'N	174°47.0'W
2049	16	59°42.1'N	174°45.5'W
2100	17	59°44.9'N	174°33.7'W
2102	18	59°43.0'N	174°30.6'W
2115	19	59°47.4'N	174°25.3'W

Appendix II. Boundary points and area (nautical miles)^2 of sectors within which surveys for spotted seals were flown in the P-2V aircraft, April 8-23, 1976.

Sector Number	Boundary points: Longitude	Boundary points: Latitude	Area of sector (NM^2)	Dates of survey flights within sector	Total area surveyed (NM^2)	Total length of transects (NM)
1	161°35'00"W - 162°45'00"W	56°14'00"N - 56°45'00"N	1209	17 April 1976	111.3	252.9
2	162°45'00"W - 165°00'00"W	56°17'36"N - 57°00'00"N	3152	19 April 1976(am)*	51.0	115.9
				19 April 1976(pm)	109.8	249.6
3	162°45'00"W - 164°00'00"W	56°00'00"N - 56°25'00"N	1053	17 April 1976	9.37	21.3
				19 April 1976	38.32	87.1
				20 April 1976	44.97	102.2
				21 April 1976	18.30	41.6
				23 April 1976	31.94	72.6
4	165°00'00"W - 169°00'00"W	56°00'00"N - 57°00'00"N	8018	19 April 1976	127.1	288.8
				20 April 1976	107.8	245.0
				21 April 1976	14.5	33.0
5	165°00'00"W - 169°00'00"W	57°00'00"N - 58°00'00"N	7823	21 April 1976	106.88	242.9
6	169°00'00"W - 172°00'00"W	56°30'00"N - 57°30'00"N	5925	20 April 1976	91.78	208.6
7	169°00'00"W - 172°00'00"W	57°30'00"N - 58°10'00"N	3855	21 April 1976	85.9	195.3
8	172°00'00"W - 176°00'00"W	56°50'00"N - 58°10'00"N (at eastern end) 58°20'00"N - 58°40'00"N (at western end)	6310	20 April 1976	156.6	355.8
				21 April 1976	116.5	264.8
9	176°00'00"W - 178°55'00"E	58°20'00"N - 58°31'00"N	1757	20 April 1976	78.72	178.9
10	176°00'00"W - 178°55'00"E	58°35'00"N - 59°20'00"N	7088	21 April 1976	161.4	366.8

Appendix II. Continued.

11	160°00'00"W - 161°35'00"W	56°00'00"N - 57°00'00"N	3165	8 April 1976	122.9	279.2
				9 April 1976	30.5	69.3
				11 April 1976	25.3	57.6
12	157°40'00"W - 160°00'00"W	56°30'00"N - 58°40'00"N	9767	8 April 1976	79.4	180.4
				9 April 1976	60.2	137.6
				11 April 1976	43.6	99.0
13	161°35'00"W - 162°45'00"W	56°00'00"N - 56°40'00"N	1565	8 April 1976	63.1	143.3
				9 April 1976	41.3	93.9
				11 April 1976	18.5	42.1
14	162°45'00"W - 165°00'00"W	56°08'00"N - 57°00'00"N	3907	8 April 1976	92.0	209.0
				9 April 1976	91.1	207.2
				11 April 1976	61.6	140.1
15	165°00'00"W - 169°00'00"W	56°00'00"N - 57°10'00"N	9310	8 April 1976	146.8	333.7
				9 April 1976	149.8	339.9
				11 April 1976	118.8	270.0
16	169°00'00"W - 172°00'00"W	56°20'00"N - 58°00'00"N	9800	9 April 1976	119.0	270.5
				11 April 1976	91.8	208.7
17	172°00'00"W - 173°00'00"W	56°30'00"N - 58°10'00"N	3238	9 April 1976	38.2	86.9
				11 April 1976	44.7	101.6

*Data from this flight were not used.

Appendix III. Boundary points and area (NM^2) of sectors within which surveys for walruses were flown in the P-2V aircraft, April 8-23, 1976.

Sector Number	Boundary points: Longitude	Boundary points: Latitude	Area of sector (NM^2)	Dates of survey flights within sector	Total area surveyed (NM^2)	Total length of transects (NM)
1	157°40'W - 160°00'W	56°30'N - 58°40'N	6382	8 April	158.8	180.4
				9 April	120.3	136.7
				11 April	87.1	99.0
				17 April	67.7	76.9
2	160°00'W - 161°35'W	56°00'N - 57°00'N	2708	8 April	221.0	251.1
				9 April	61.0	69.3
				11 April	50.7	57.6
				17 April	24.2	27.5
3	160°00'W - 160°30'W	57°00'N - 58°00'N	966	8 April	48.3	54.9
				17 April	33.1	37.6
4	161°35'W - 162°45'W	56°00'N - 56°45'N	1764	8 April	126.2	143.3
				9 April	82.6	93.9
				11 April	37.0	42.1
				17 April	226.5	257.4
				20 April	22.1	25.1
5	162°45'W - 165°00'W	56°08'N - 57°00'N	3869	8 April	183.9	209.0
				9 April	182.3	207.2
				11 April	123.3	140.1
				17 April	611.5	654.9
				21 April	33	29
6	165°00'W - 169°00'W	56°00'N - 57°00'N	7932	8 April	293.7	333.7
				9 April	276.8	314.6
				11 April	207.0	235.2
				19 April	254.2	288.8
				20 April	303.6	345.0
				21 April	29.0	33.0

Appendix III. Continued.

7	165°00'W - 169°00'W	57°00'N - 58°00'N	7728	9 April	21.8	24.8
				11 April	30.7	34.9
				21 April	215.8	245.2
8	169°00'W - 172°00'W	56°30'N - 58!10'N	9675	9 April	238.0	270.5
				11 April	183.6	208.7
				20 April	183.6	208.6
				21 April	172.0	195.4
9	172°00'W - 180°00'W	56°30'N - 58°00'N	13504	9 April	98.5	102.1
		(at eastern end)		11 April	106.0	120.5
		59°00'N - 59°20'N		20 April	467.3	531.0
		(at western end)		21 April	503.8	572.5

Appendix IV. Weather conditions during survey periods recorded at indicated stations. Positions recorded in the column indicating reporting locations are for the OSS SURVEYOR, which was in the survey area.

					Wind			
Date	Location	Time	Sky	Visibiliby (nautical miles)	Direction (degrees)	Velocity (knots)	Temp (°F)	Corrected temperature*
27-III-76	55°51'N 164°24'W	1600	partly cloudy	7	330	8	18	10
8-IV-76	King Salmon	1100	cloudy	.75	260	06	32	26
	Cold Bay	1300	cloudy	.50	270	20	30	10
	St. Paul	1300	cloudy	7	330	19	16	-3
9-IV-76	King Salmon	1400	cloudy	30	270	7	35	28
	Cold Bay	1300	cloudy	1.25	130	14	31	17
	St. Paul	1300	partly cloudy	7	120	3	22	19
11-IV-76	King Salmon	1400	cloudy	13	250	13	35	22
	Cold Bay	1300	partly cloudy	25	240	10	36	26
	St. Paul	1300	partly cloudy	7	300	17	18	1+
17-IV-76	King Salmon	1100	partly cloudy	40	140	6	44	38
	Cold Bay	1300	partly cloudy	7	150	15	37	23
19-IV-76	Cold Bay	1300	cloudy	7	300	8	32	24
	St. Paul	1300	clear	7	040	7	23	16
	57°11'N 172°53'W	1300	partly cloudy	7	050	10	23	13

Appendix IV. Continued.

Date	Location	Time	Sky	Visibility (nautical miles)	Wind Direction (degrees)	Wind Velocity (knots)	Temp (°F)	Corrected temperature*
20-IV-76	Cold Bay	1300	cloudy	10	140	13	37	24
	St. Paul	1300	cloudy	7	040	10	22	12
	57°19'N 173°19'W	1300	cloudy	6	065	9	24	15
21-IV-76	Cold Bay	1300	partly cloudy	unlimited	180	12	41	29
	St. Paul	1300	cloudy	7	010	13	21	8
	57°04'N 173°08'W	1300	cloudy	3.5	050	11	20	9
23-IV-76	Cold Bay	1300	partly cloudy	7	350	7	20	13
	56°04'N 163°01'W	1300	partly cloudy	6	340	9	19	10
	King Salmon	1400	cloudy	20	260	15	30	15
24-IV-76	56°00'N 163°22'W	1300	partly cloudy	10	300	8	21	13
	56°24'N 162°27'W	1500	partly cloudy	10	310	7	26	19
25-IV-76	55°53'N 162°57'W	1300	partly cloudy	5	010	8	33	25
	55°50'N 163°00'W	1600	partly cloudy	5	355	10	30	21
28-III-77	55°08'N 169°35'W	1400	cloudy	5	255	10	35	25

Appendix IV. Continued.

Date	Location	Time	Sky	Visibility (nautical miles)	Wind Direction (degrees)	Wind Velocity (knots)	Temp (°F)	Corrected temperature*
30-III-77	58°22'N 165°26'W	1400	cloudy	0.8	035	9	29	20
21-IV-77	57°45'N 164°55'W	1800	cloudy	5	153	27.5	33	5.5
23-IV-77	58°13'N 169°59'W	1100	cloudy	6	213	6	32	26
	58°42'N 169°19'W	1400	partly cloudy	5	210	5	32	27
24-IV-77	58°30'N 169°19'W	1300	partly cloudy	15	259	10.5	30	19.5
	58°35'N 169°37'W	1600	clear	15	235	8.0	30	22
25-IV-77	58°40'N 169°13'W	1600	partly cloudy	8	135	11	30	19
27-IV-77	59°36'N 174°04'W	0900	cloudy	8	085	22	29	7
	59°45'N 174°33'W	1900	cloudy	8	080	30	29	1

*Corrected temperature, as used here, is the dry bulb thermometer temperature minus the recorded wind velocity.

Quarterly Report

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Trophic Relationships Among Ice Inhabiting Phocid Seals

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30 June 1977

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

Field activities during March to June 1977 were extensive. NOAA ships were utilized for ice front collections. Seal stomach samples and fish and invertebrate reference material were collected in Bristol Bay and the southcentral Bering Sea from the SURVEYOR in March and April, and in the Bering Sea ice remnants from the DISCOVERER in May and June. A helicopter was utilized to make a March collection in Norton Sound and an April collection from Barrow. Village collections of seal specimen material were made at Pt. Hope, Nome and Shishmaref. See Fig. 1 for sample localities.

Laboratory activities consisted of intermittent processing of stomach samples and of working up trawl specimens for reference material. Considerable lab work was done while on board ships. All stomachs collected on the SURVEYOR and DISCOVERER were processed in the field, as were all trawls.

Data management occurred on an ongoing basis. Specimen records and stomach contents data sheets were completed in the field when possible and submitted for keypunching immediately upon return to Fairbanks. Final corrections were made on previously submitted data and this data was resubmitted. Data was requested from other projects through EDS and incorporated into our existing knowledge of distribution and abundance of key prey species.

Table 1 provides a complete listing of field and laboratory activities during spring quarter 1977. Dates and personnel are included.

Methods

Field collection procedures at coastal hunting villages and methods for laboratory analysis of specimen material are described in our 1977 annual report for RU #232. The SURVEYOR and DISCOVERER cruises were utilized to collect seals for food habits, parasitology and natural history information (RU#s 230, 232, and 194) and to do aerial surveys in conjunction with RU#s 230 and 248. Most of the collection of seals on the SURVEYOR was done with the aid of a Bell 206 helicopter. Some spotted seals were taken in the water from the Boston whaler in more open areas. All hunting on the DISCOVERER was done from small boats. Animals were collected, returned to the ship and processed. Stomach contents were analyzed immediately. In addition, contents of the small intestines were examined for otoliths. In cases where the stomach was empty this sometimes provided information on recent diet.

Bottom sampling for fishes and invertebrates was conducted on both the SURVEYOR and DISCOVERER with a 16 foot otter trawl. Trawls were of 20 minute duration, at a ship speed of 3-4 knots. Contents of each trawl were identified, enumerated, weighed and representative specimens of organisms retained. Fish were measured, weighed and the otoliths removed and measured to determine otolith size to fish size relationships. Some fish were preserved as reference specimens and some were frozen to provide skeletal parts for comparative identification purposes.

Hunting out of Barrow was done exclusively from a Bell 206 helicopter with a fixed wing cover plane. Large areas of ice could be surveyed and hunted in this manner. Specimen material was frozen and sent to the Fairbanks lab for workup.

Whenever feasible when collections were made by ADF&G personnel, usable meat from seals was given to residents of coastal communities.

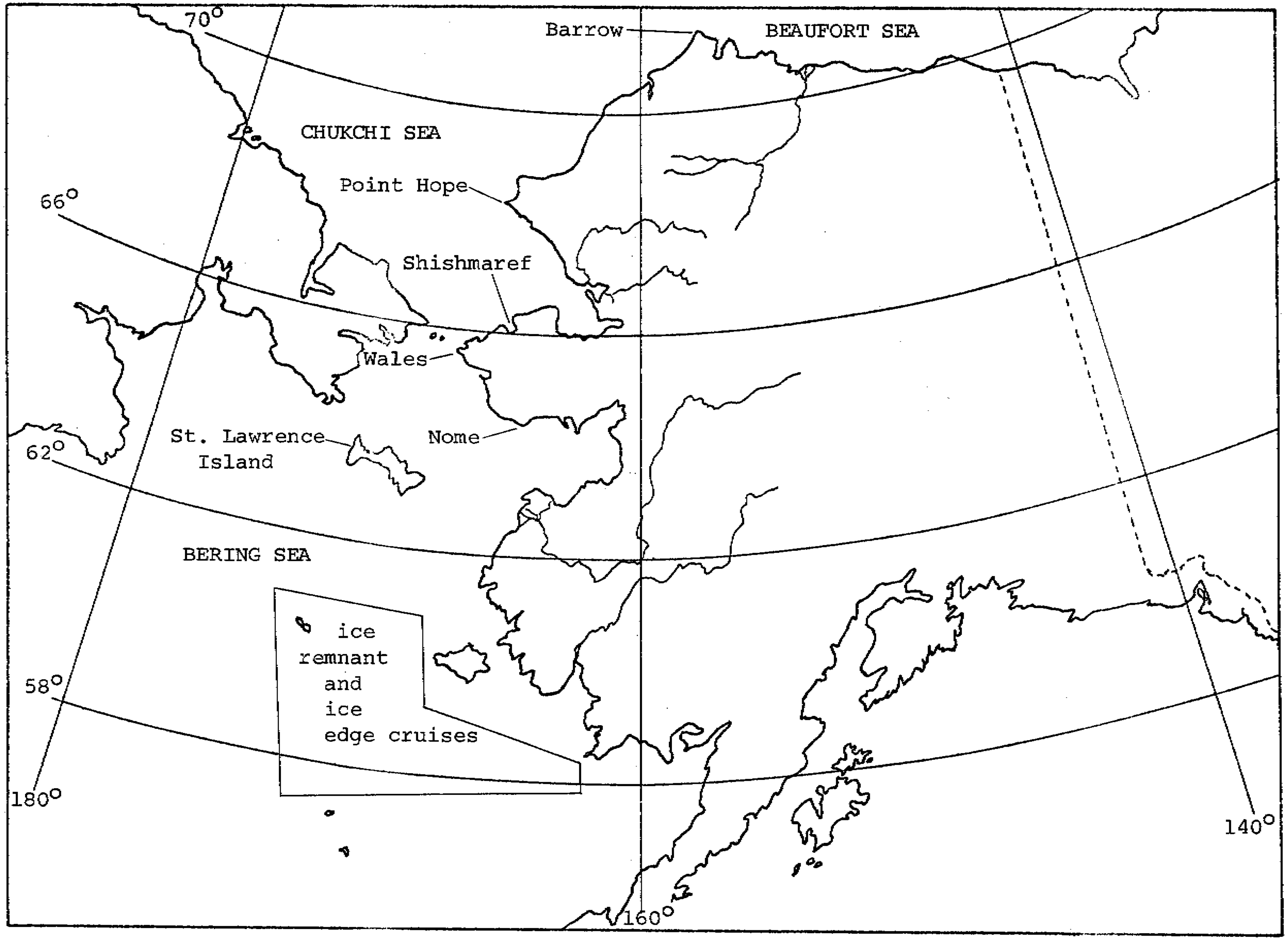


Figure 1. Locations from which seals were collected during this quarter.

Table 1. Field and laboratory activities from 10 March to 15 June 1977.

Activity	Date	Personnel
Bering Sea/Bristol Bay ice front cruise on SURVEYOR, collection of specimens and otter trawls	15 March - 3 May	L. Lowry, K. Frost, J. Burns, E. Muktoyuk
Specimen collection in Norton Sound with Bell 206 helicopter	8 March - 20 March	J. Burns, T. Eley
Specimen collection in Barrow/ Beaufort Sea with Bell 206 helicopter	4 April - 14 April	T. Eley
Specimen collection at Pt. Hope in conjunction with bowhead whale studies	15 April - 2 June	G. Seaman
North Bering Sea ice remnant cruise on DISCOVERER, collection of specimens and otter trawls	18 May - 13 June	L. Lowry
Specimen collection Nome/ Norton Sound	28 May - 10 June	K. Frost, E. Muktoyuk
Specimen collection at Barrow/ Beaufort Sea	10 June - 20 June	T. Eley, J. Burns
Specimen collection at Wales and Shishmaref	10 June - on going	G. Seaman
Laboratory processing of specimen material - seal stomachs, invertebrates and fish material, reference collections	Continuous	K. Frost, L. Lowry
Compilation and analysis of data	Intermittent	L. Lowry, K. Frost
Data management - transcription, keypunching, taping, format changes, etc.	Continuous	K. Frost
Preparation of quarterly report		K. Frost, L. Lowry, J. Burns

Data Collected or Analyzed

Table 2 summarizes the results of our collection efforts from 1 March to 15 June 1977. A total of 115 stomachs was collected. Forty-one were from the Bering Sea, 37 from Norton Sound, 29 from the Chukchi Sea and 8 from the Barrow area.

Table 2. Seal stomachs collected during the period 1 March to 15 June 1976. Not all stomachs contained food.

Location	*Phoca* (*Pusa*) *hispida*	*Erignathus barbatus*	*Phoca vitulina largha*	*Phoca* (*Histriophoca*) *fasciata*
Central Bering Sea/ Bristol Bay (SURVEYOR)	1	7	9	8
Central Bering Sea (DISCOVERER)	2	0	8	6
Norton Sound/Nome (Bell 206)	22	5	0	0
Nome - June	6	4	0	0
Pt. Hope	29	0	0	0
Barrow/Beaufort Sea (Bell 206)	4	4	0	0
Total	64	20	17	14

Forty-five otter trawls were conducted on the SURVEYOR cruises in March and April. Seven of these trawls were from an area south of St. Matthew Island at 59°N 173°W. Nine trawls were done north of the Pribilof Islands at 58°30'N, 169°30'W and six trawls were done southwest of Cape Newenham at 57°45'N, 165°W. Twelve trawls were conducted in Bristol Bay and 11 were done in transit from Unimak Pass to ice stations.

Thirty-six trawls were conducted from the DISCOVERER. Twenty of the trawls were made in the ice front between 60° and 61° north latitude. The remainder were done in transit to and from the ice edge.

Otoliths were collected from any unusual fish. Series of otoliths were taken from different size classes of pollock and eelpouts for use in determining age and size of fish in relationship to otolith characteristics. Length frequencies, individual fish weights and lengths, and stomach contents were determined for gadids, eelpouts, sculpins and capelin. Weights, carapace lengths, sex and reproductive state were noted for several species of crabs and shrimps.

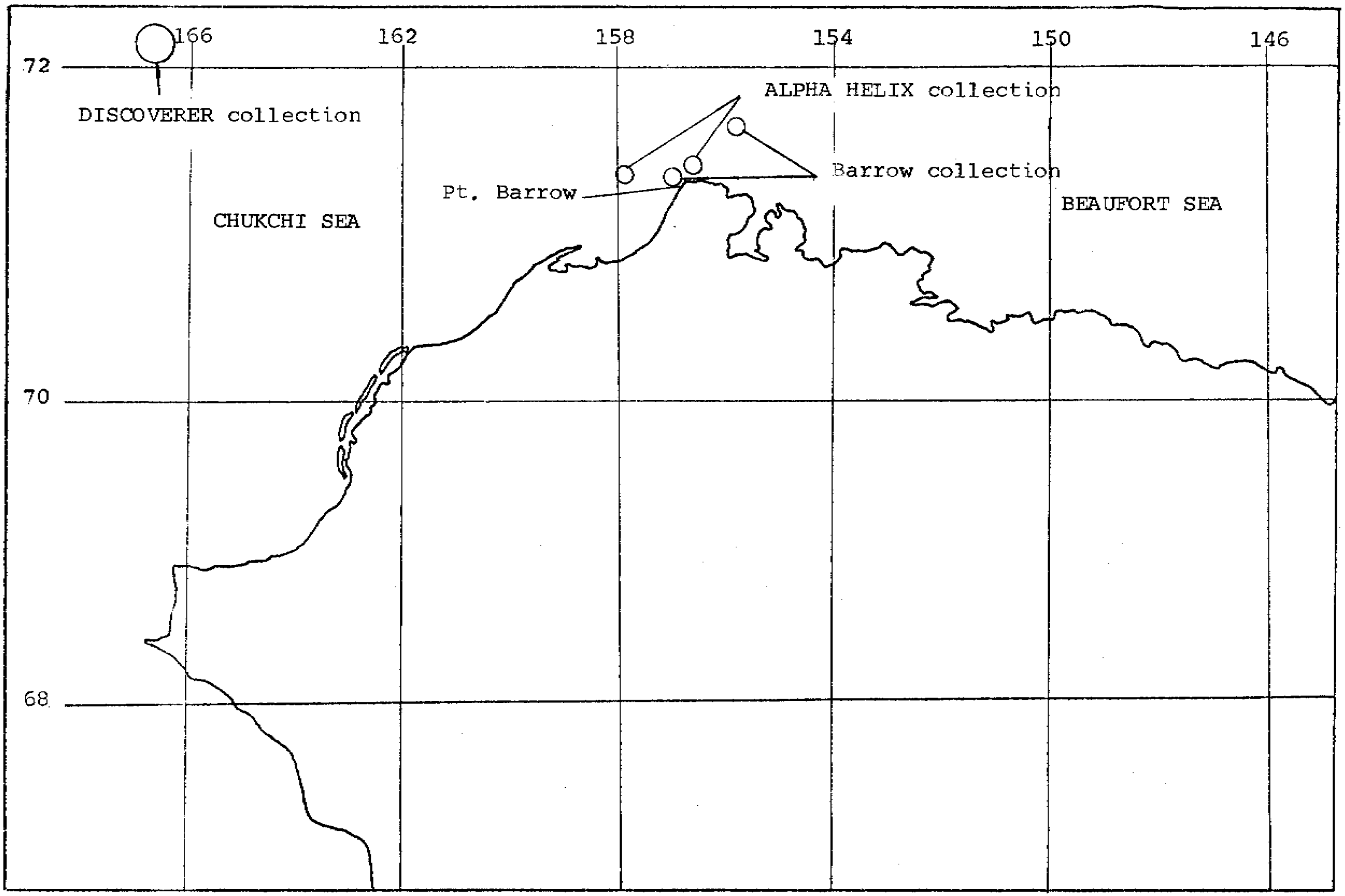


Figure 2. Map of the Chukchi and Beaufort Seas showing specimen collection locations.

Table 3. Food items identified from stomachs of 10 bearded seals taken in the Beaufort and northern Chukchi Seas. Data are expressed in part A as percent of total volume of contents made up by each species or group. Part B indicates the species composition of fishes expressed as percent of the total number of fishes identified.

Food Item	N. Chukchi DISCOVERER August 1976 n = 1 % vol/#	W. Beaufort ALPHA HELIX September 1973 n = 7 % vol/#	W. Beaufort Barrow April 1977 n = 2 % vol/#
A. Gastropods Total	*	*	1.3
Buccinum sp.	*	*	1.3
Others	*	*	
Octopus sp.		*	19.3
Amphipods Total	1.5		7.2
Brachyuran Crabs Total	47.0	31.2	29.3
Chionoecetes opilio	20.6	3.7	18.6
Hyas coarctatus	5.8	16.7	10.7
F. Majidae	20.6	10.8	
Hermit Crabs Total	11.0	*	37.2
Shrimp Total	5.4	50.3	3.9
Eualus gaimardii	2.4		
Sclerocrangon boreas	*	50.2	
Sabinea septemcarinata			3.9
Argis dentata	2.3		
Others	*	*	
Other Invertebrates	4.7	11.2	1.2
Invertebrates total	70.3	94.2	99.4
Fishes Total	29.4	2.2	*
B. Fishes			
Lycodes sp.	90.9	3.4	94.4
Boreogadus saida		96.4	
F. Cottidae	9.1		5.6
Lumpenus fabricii		*	
Total number of fishes identified	22	477	18
Mean volume of contents	655.5	94.6	139.7

* Indicates food items which constituted less than one percent of the total volume.

Table 4. Food items identified from stomachs of six ringed seals collected in the Beaufort and northern Chukchi Seas. Data are expressed in the same manner as in Table 3.

Food Item	N. Chukchi DISCOVERER August 1976 n = 2 % vol/#	W. Beaufort Barrow February 1977 n = 1 % vol/#	W. Beaufort Barrow April 1977 n = 3 % vol/#
A. Amphipods Total	1.8	42.8	54.3
Gammarus wilkitzkii		18.6	44.8
Others	1.8	24.2	9.5
Mysids Total	*		44.9
Mysis littoralis			44.6
Other	*		*
Shrimp Total	84.2	7.1	
Eualus gaimardii	79.1		
Eualus macilenta	4.1		
Others	1.0	7.1	
Invertebrates Total	86.0	50.0	99.2
Fishes Total	13.2	50.0	*
B. *Boreogadus saida*	100.0	98.2	
F. Cottidae		1.8	
Total number of fishes identified	7	55	1
Mean volume of contents	75.9	14.0	172.5

III. Results

Most of this quarter was devoted to collection efforts in the field. However, with renewed emphasis in the Beaufort and Chukchi Seas in mind, all samples from that area were processed and analyzed. In addition a previous collection made from the R/V ALPHA HELIX in 1973 near Point Barrow was analyzed. Results of these collections will be reported below. Results of the southwestern Bering Sea collections will be reported at a later date.

Beaufort/Chukchi Seas - Bearded Seals

The stomach contents of nine bearded seals from the Barrow area and one from the northern Chukchi Sea were analyzed. Results of these analyses appear in Table 3. Collection locations are shown in Fig. 2.

All nine Beaufort Sea/northeastern Chukchi Sea specimens were collected within 50 miles of Point Barrow. Seven were taken in September 1973 on a pre OCS ALPHA HELIX cruise and two in mid-April of this year. In both samples invertebrates made up more than 94 percent of the diet. Brachyuran crabs (*Chionoecetes opilio* and *Hyas coarctatus*) accounted for about 30 percent of the diet at both times of the year. In the September ALPHA HELIX sample the crangonid shrimp *Sclerocrangon boreas* was the other most abundant food item, comprising 50 percent of the volume of stomach contents. In April hermit crabs and *Octopus* sp. were major food items. Only very small amounts of recently ingested fish were present in the stomachs examined. However, in several of the stomachs large numbers of fish otoliths were present indicating that fish had been eaten in recent meals. Otoliths of polar cod (*Boreogadus saida*) were the most common in the September sample whereas those of eelpouts (*Lycodes* sp.) were most common in April.

The single bearded seal collected in the northern Chukchi Sea in August had eaten almost 50 percent spider crabs and tanner crabs, and lesser amounts of hermit crabs. In addition 30 percent of the stomach contents was fish, primarily eelpouts.

Ringed Seals

Four ringed seals were collected in the northeastern Chukchi Sea and western Beaufort Sea off Barrow; one was taken in February and the other three in April. In August two ringed seals were collected in the northern Chukchi Sea at the ice edge. Table 4 presents the results of stomach contents analyses. Fig. 2 shows collection locations.

The seal taken in February at Barrow had eaten 50 percent invertebrates, almost all amphipods, and 50 percent fish, almost exclusively polar cod. Of the three seals taken in April one had eaten mostly amphipods, one mostly mysids and the third very small amounts of both. Although no fish material was present in the stomachs, polar cod and eelpout otoliths were found in the intestines indicating previous meals of fish.

The Chukchi Sea ringed seal stomachs contained shrimp and polar cod. One seal had eaten all polar cod and the other almost all shrimp (Eualus gaimardii). There were numerous polar cod otoliths in the intestine of the latter animal.

IV. Discussion of Results

Beaufort Sea

Specimens analyzed from the Beaufort Sea this quarter increased our sample size from that area considerably (see Final report of Beaufort Sea activities RU #232). Previously only three bearded seal stomachs had been examined. An additional nine were examined this quarter. The total of ringed seals was raised from 21 to 25, and the first midwinter (February) sample was obtained.

Sample sizes are so small in all collections that it is as yet impossible to separate temporal differences in diet from day to day variation in spectrum of prey items consumed. The three bearded seal stomachs previously examined had eaten no crabs but instead isopods, crangonid shrimps, amphipods and both polar and saffron cods.

In our Beaufort Sea report we suggested that other potential food items of bearded seals might be brachyuran crabs, gastropods, octopus, crangonid shrimps and demersal fishes. Table 3 confirms this speculation. Brachyuran crabs were important in all months and all samples. Octopus were common in the April sample, and eelpouts, an apparently numerous Beaufort Sea demersal fish, were also eaten in April. As in the previous stomachs examined crangonid shrimps and polar cod were also eaten in quantity.

Ringed seals previously reported on (Beaufort Sea Final Report) were taken in late spring and summer months. Euphausiids were by far the most common food item. Mysids, amphipods and polar cod were eaten but not in as great a quantity as euphausiids. The four winter and early spring seals reported in Table 4 had also eaten mysids, amphipods and polar cod, but no euphausiids. Euphausiids may be found near shore in highest concentrations during spawning in May through August and it is probable that these seals were collected before such concentrations were available.

V. Problems Encountered/Recommended Changes

None.

VI. Estimates of Funds Expended

As of May 30 we have expended approximately the following amounts during FY77.

Salaries and benefits	-	$46,100
Travel and per diem	-	6,029
Contractual services	-	5,697
Commodities	-	2,574
Equipment	-	270
Total expenditures	-	$60,682

QUARTERLY REPORT

Contract #03-5-022-69
Research Unit #243
Reporting Period Apr. 1 thru June 30, 1977
Number of Pages - 6

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

June 30, 1977

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. Ship schedule

1. M.V. Resolution ADF&G research vessel

   a. Apr. 25 through May 5, 1977

2. M.V. Resolution ADF&G research vessel

   a. May 19 through May 28

B. Scientific Parties

1. April 25 through 5 May 1977

   a. Donald G. Calkins, Alaska Dept. of Fish & Game
      Principal Investigator

   b. Kenneth Pitcher, Alaska Dept. of Fish & Game
      Co-Principal Investigator

   c. Roger Aulabaugh, Alaska Dept. of Fish & Game
      Collecting and survey crew

   d. Dennis McAllister, Alaska Dept. of Fish & Game
      Collecting and survey crew

   e. Allan Egbert, Alaska Dept. of Fish & Game
      Collecting and survey crew

2. May 19 through May 28

   a. Donald Calkins, Alaska Dept. of Fish & Game
      Principal Investigator

   b. Kenneth Pitcher, Alaska Dept. of Fish & Game
      Co-Principal Investigator

   c. Roger Aulabaugh, Alaska Dept. of Fish & Game
      Collecting crew

   d. Karl Schneider, Alaska Dept. of Fish & Game
      Collecting crew

   e. Ben Ballenger, Alaska Dept. of Fish & Game
      Collecting crew

   f. Edward Klinkhart, Alaska Dept. of Fish & Game
      Collecting crew

D. Methods

1. Sex and age composition counts - each hauling area which was accessible by helicopter was visited. A ground party was landed on the area and counts were made of the animals in the area, separating them by sex and age class where possible.

2. Search for branded animals - while the animals were being counted, they were inspected for brands.

3. Collection of samples - sea lions are collected from the rookery or hauling areas by the use of helicopters or from the water by skiffs working off a larger vessel.

Quarterly Report

Contract #03-5-022-55
Research Unit Number: 248
Report Period: 8 March-1 July 1977
Number of Pages: 4

The relationships 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: Lloyd F. Lowry, Kathryn J. Frost, Thomas J. Eley

30 June 1977

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 relates to major biological events in the lives of marine mammals (e.g., birth, nurture of young, mating, molt and migrations).

II. Field or Laboratory Activities:

A and B. The following is a listing of activities during this report period:

Table 1. Field and laboratory activities from 10 March to 15 June 1977.

Activity	Date	Personnel
Bering Sea/Bristol Bay ice front cruise on SURVEYOR	1) 15 March-6 April 2) 10 April-3 May	1) Lowry, Frost 2) Fay, Burns, Lowry, Frost
Ice and mammal observations in Norton Sound with Bell 206 helicopter	8 March-20 March	Burns, Eley
Ice and mammal observations, northern Chukchi and Beaufort Seas	4 April-14 April	Eley
Bering Sea ice front cruise on DISCOVERER	18 May-13 June	Fay, Lowry
Ice observations, Norton Sound St. Lawrence Island	28 May-10 June	Burns, Frost
Ice and mammal observations, shore fast ice of northern Chukchi and Beaufort Seas	13 June-18 June	Burns, Eley
Ice observations - Barrow area	Intermittent	Shapiro
Compilation and analysis of data	Intermittent	Fay, Burns, Shapiro
Data management	Intermittent	Frost

C. For a discussion of methods refer to Annual Report, March 31, 1977

D. Sample localities

See Figure 1.

E. Data collected or analyzed

The main kinds of data collected in the field were 1) records of spatial and temporal differences in ice characteristics; 2) photographs of ice characteristics for comparison with satellite imagery; 3) information about species composition, density and distribution of marine mammals in relation to ice types, and 4) the routine acquisition and archiving of NOAA and Landsat satellite imagery.

Approximately 1,100 miles of trackline were flown with helicopters and aircraft and an as yet undetermined number of trackline miles were covered by small boat or ship.

Our major effort during this quarter was toward field work and the data acquired has not yet been analyzed.

III. Results

Most of the data acquired during this quarter have not yet been analyzed. Some preliminary results from the cruise of the SURVEYOR (10 April-3 May) are as follows:

During the duration of Leg III the ice edge was disintegrating rapidly and retreating northward. Almost all of the very thin ice which was rapidly forming, and at times advancing southward during Leg II, was gone. Ice Station I was dominated by ice of thin and medium thickness, with floe sizes between 10 and 15 meters. Deformation was mainly less than 15 percent. Ice Station II was dominated almost entirely by ice of medium thickness in floes with an average size of about 15 meters and a deformation of 15 to 20 percent. Ice Station III was characterized by thick ice in greatly deformed floes, mainly between 15 and 30 meters across. Extent of deformation was, overall, between 15 and 30 percent.

Those areas within which ship, small boat, and helicopter operations were conducted were mainly near the southern terminus of the front, with an ice cover, on a broad scale, of two to four oktas. Ice was usually in bands oriented diagonally to the direction of the wind. The ice was more widely scattered during periods of little or no wind.

Major differences in the density, relative age composition, and species composition of seals at the ice stations were noted, verifying information obtained during previous surveys by ships and aircraft operating in the ice front. Aerial surveys utilizing the Bell 206 helicopter produced the following results:

Table 1. Geographical differences in density of seals at three stations in the ice front of Bering Sea, April 1977.

Station Number	Density seals of all species and age classes	Density spotted seals (all age classes)	Density spotted seals (pups)	Density bearded seals (all age classes)	Density bearded seals (pups)	Density ribbon seals (all age classes)	Density ribbon seals (pups)	Spotted Seals - percent pups	Nautical Miles (square) surveyed
1	6.92	6.7	0.48	0.22	0.02	0.0	0.0	0.07	40.6
2	0.39	0.29	0.07	0.05	0.0	0.4	0.01	24.0	184.8
3	1.57	1.4	0.45	0.0	0.0	0.2	0.1	32.0	55.9

IV. Problems encountered:

None

V. Estimate of funds expended during this quarter - $12,000

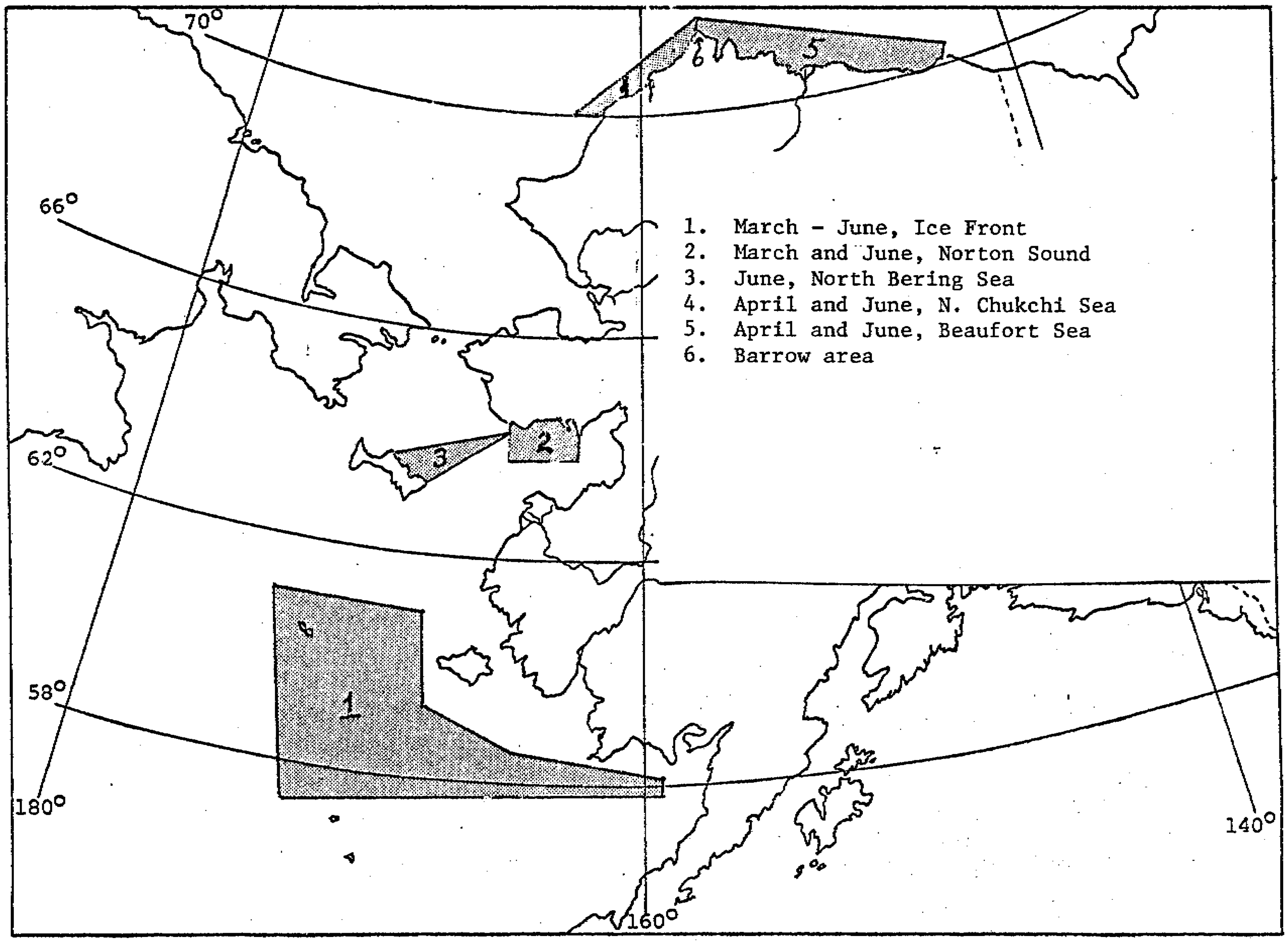


Fig. 1. Sample localities in which field work was conducted, March-June 1977.

RU-481 QUARTERLY REPORT
1 April - 30 June 1977

A SURVEY OF CETACEANS OF PRINCE WILLIAM SOUND AND ADJACENT VICINITY

John D. Hall - U.S. Fish and Wildlife Service
James H. Johnson - National Marine Fisheries Service
1 July 1977

I. ABSTRACT

During this past quarter two aerial surveys and three surface surveys were conducted. The aerial surveys covered 940 nautical miles and the surface surveys covered a total of 1140 nautical miles.

Significant concentrations of fin whales, gray whales, humpback whales, minke whales and dall porpoises were located. Areas of intense concentration continued to be Hinchenbrook Entrance, Knight Passage, Montague Strait, near Green and Naked Islands, and in Wells Passage.

II. TASK OBJECTIVES

1. Determine seasonal distribution and abundance of principal cetacean species utilizing Prince William Sound and adjacent nearshore areas in the Northern Gulf of Alaska.

2. To determine major foraging areas and critical habitats for principal species.

3. To determine food habits of selected species.

III. FIELD ACTIVITIES

A. Survey Schedule

1. Ship Survey
   - a) 27 April - 12 May - Shelby D. (charter)
   - b) 29 May - 4 June - Shelby D. (charter)
   - c) 19 June - 25 June - Shelby D. (charter)

2. Aircraft Survey
   - a) 14 April - N-780 (OAS)
   - b) 6 June - N-780 (OAS)

B. Scientific Party

John D. Hall - U.S. Fish and Wildlife Service
James H. Johnson - National Marine Fisheries Service
Craig S. Harrison - U.S. Fish and Wildlife Service
Fritz Hoezl - National Oceanic Atmospheric Administration/ERL

C. Methods

1. Static tagging of Dall porpoise, humpback whales, fin whales and

minke whales.

2. Photographic identification - humpback whales and killer whales.

3. Capture/release of Dall porpose.

D. Ship/Aircraft Tracklines
(attached)

E. Data Collected

1. Observations numbered in the low thousands this quarter. Exact counts are not yet available.

2. Miles of trackline - 2080 total.

IV. RESULTS

Generally excellent weather allowed us to cover the study extensively. The April aerial survey located gray whales very close to shore (c400 meters) from Gore Pt. to Cape St. Elias, with numbers sighted in Montague Strait and Hinchenbrook Entrance. We located significant numbers of fin whales in May and early June, but none in late June. Humpbacks were increasing in numbers throughout the quarter and totaled 28 by late June, including two mother/calf pairs.

Minke whales were numerous by late June, with one sighting near Naked Island of at least 12 individuals. Dall porpose increased rapidly in numbers during the quarter. 351 Dalls were sighted during 5 days of ship survey in late June. Killer whales became very numerous, and by late June a pod of at least 66 was encountered. This pod contained at least 10 to 12 very small calves accompanied by their mothers.

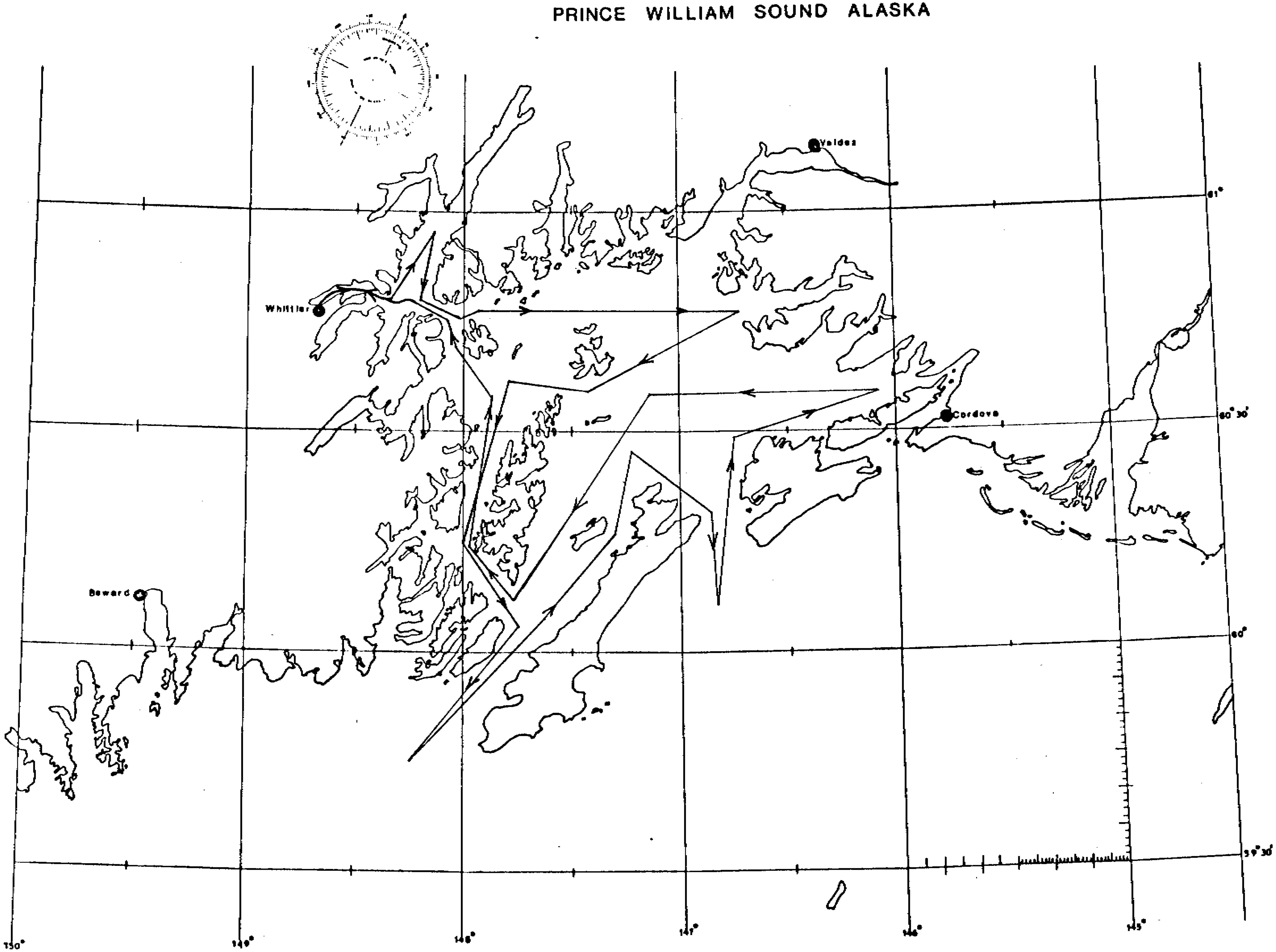
VI. AUXILIARY MATERIAL

B. Papers in Preparation
Hall and Johnson plan on presenting at least four papers based on the work to date at the Marine Mammal Conference in San Diego, California in December, 1977.

VII. PROBLEMS ENCOUNTERED

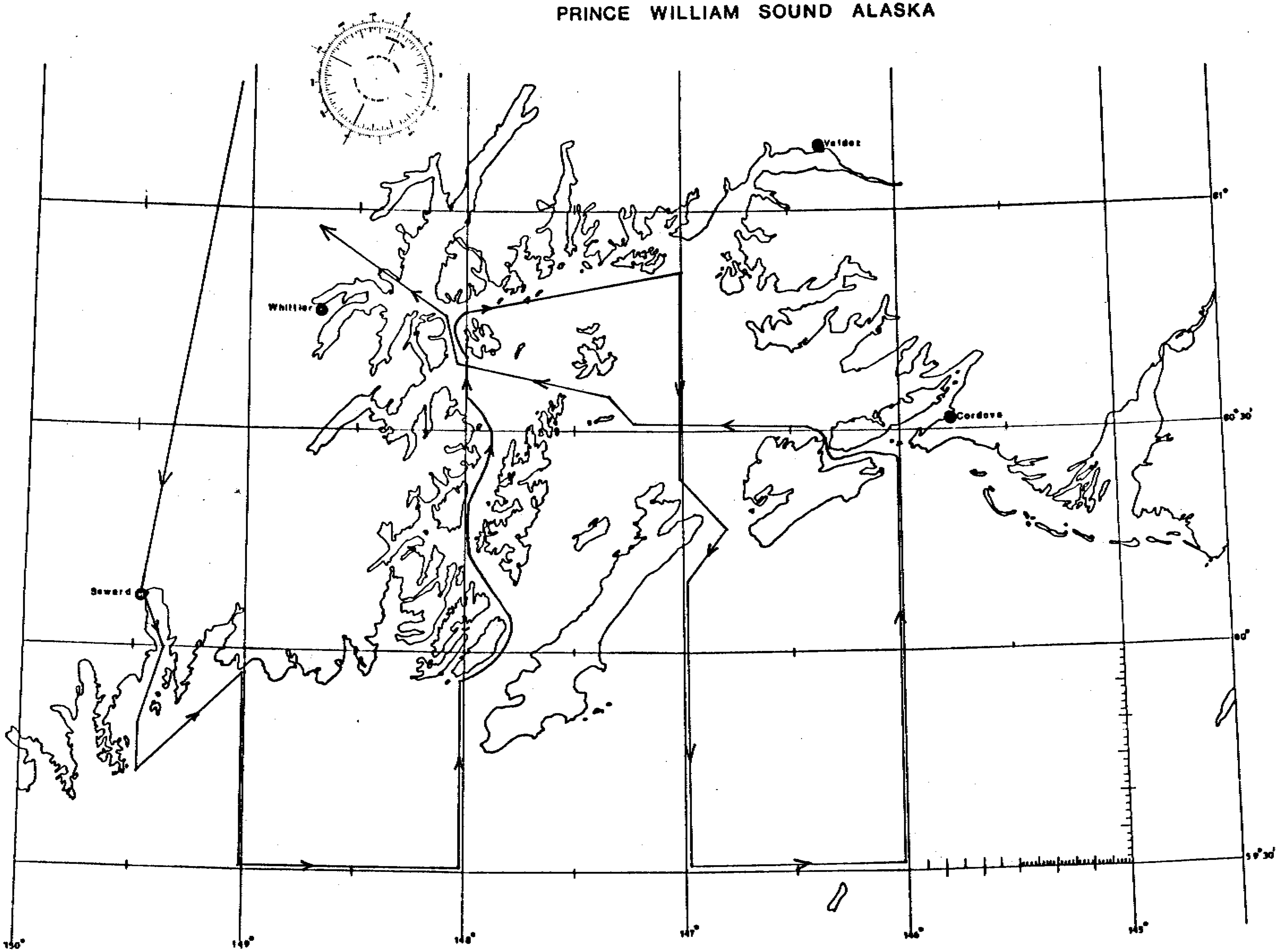
An aerial survey conducted just two days after a surface survey was completed reported far fewer sightings than made by the vessel. It is possible, perhaps likely, that the speed of the aircraft (120 kts) is so fast that it causes observers to miss significant numbers of cetaceans. This possibility will be explored further in July, August and September by using a lower speed survey aircraft.

PRINCE WILLIAM SOUND ALASKA



RU-481 Ship Survey Transects (380 NM)

PRINCE WILLIAM SOUND ALASKA



RU-481 Aerial Survey Transects (470 NM)

RECEPTORS (BIOTA)

MARINE BIRDS

RECEPTORS (BIOTA)

BIRDS

RECEPTORS (BIOTA)

BIRDS

QUARTERLY REPORT

Contract #03-5-022-69
Research Unit #3
Reporting Period April 1-June 14, 1977

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

Paul D. Arneson
Alaska Department of Fish and Game

June 14, 1977

I. Task Objectives

1. Summarize and evaluate existing literature and unpublished data on the distribution, abundance, behavior, and food dependencies of birds associated with littoral and estuarine habitat in the Gulf of Alaska, Bristol Bay, and Aleutian Shelf.

2. Determine seasonal density distribution, critical habitats, migratory routes, and breeding locales for principal bird species in littoral and estuarine habitat in the Gulf of Alaska, Bristol Bay and Aleutian Shelf, Identify critical species particularly in regard to possible effects of oil and gas development.

II. Field Activities

A. Field trip schedule: On May 6 and 7, 1977 a NOAA Jet Ranger Helicopter was used for shoreline and pelagic transects in bird surveys of Kvichak and Bristol Bays.

Shoreline bird surveys were conducted with a Peninsula Airways Cessna 180 on May 10-12, 1977 from Naknek to Bechevin Bay on the North Alaska Peninsula. North Bristol Bay from Kvichak River to Tvativak Bay was flown on May 13, 1977. These surveys were sponsored by NOAA because of an engine failure on the helicopter.

B. Scientific Party

For bird surveys during this quarter, observers were Paul Arneson and Dave McDonald, Alaska Department of Fish and Game, Anchorage.

C. Methods

For the first time in this project a helicopter was used for shoreline counts and pelagic transects. As in the past, observers enumerated birds on both sides of the aircraft. During shoreline counts the shorebird observer covered the area to high tide and the seaside observer looked out to 200 meters from the aircraft. We flew at an altitude of approximately 30 meters and at about 100 km/hr.

While crossing over bays, pelagic transects were conducted looking 200 meters out both sides of the aircraft.

Similar shoreline survey techniques were used while completing the remainder of the survey in a fixed-wing aircraft.

All observations were recorded on cassette-type tape recorders. Information recorded was: bird identification to lowest taxon possible (order, family, genus, species); bird numbers, habitat type in which the bird was found and other information including activities, sex, color phase, etc., as outlined in the data processing format. Weather observations were recorded at the start of each flight and a coded survey conditions number was noted as often as conditions changed. Time was recorded each time a new station was started and ended.

D. Sample Localities

See attached maps (Figures 1 and 2).

E. Data Collected

Using the helicopter, 110 kilometers of coastline in 11 stations on North Alaska Peninsula and 75 km in 9 stations on North Bristol Bay were surveyed. Also 175 km of pelagic transects were conducted.

Approximately 1125 km of shoreline from Naknek River to Bechevin Bay were surveyed in a Cessna 180. There are about 140 stations subdividing that portion of coastline.

III. Results

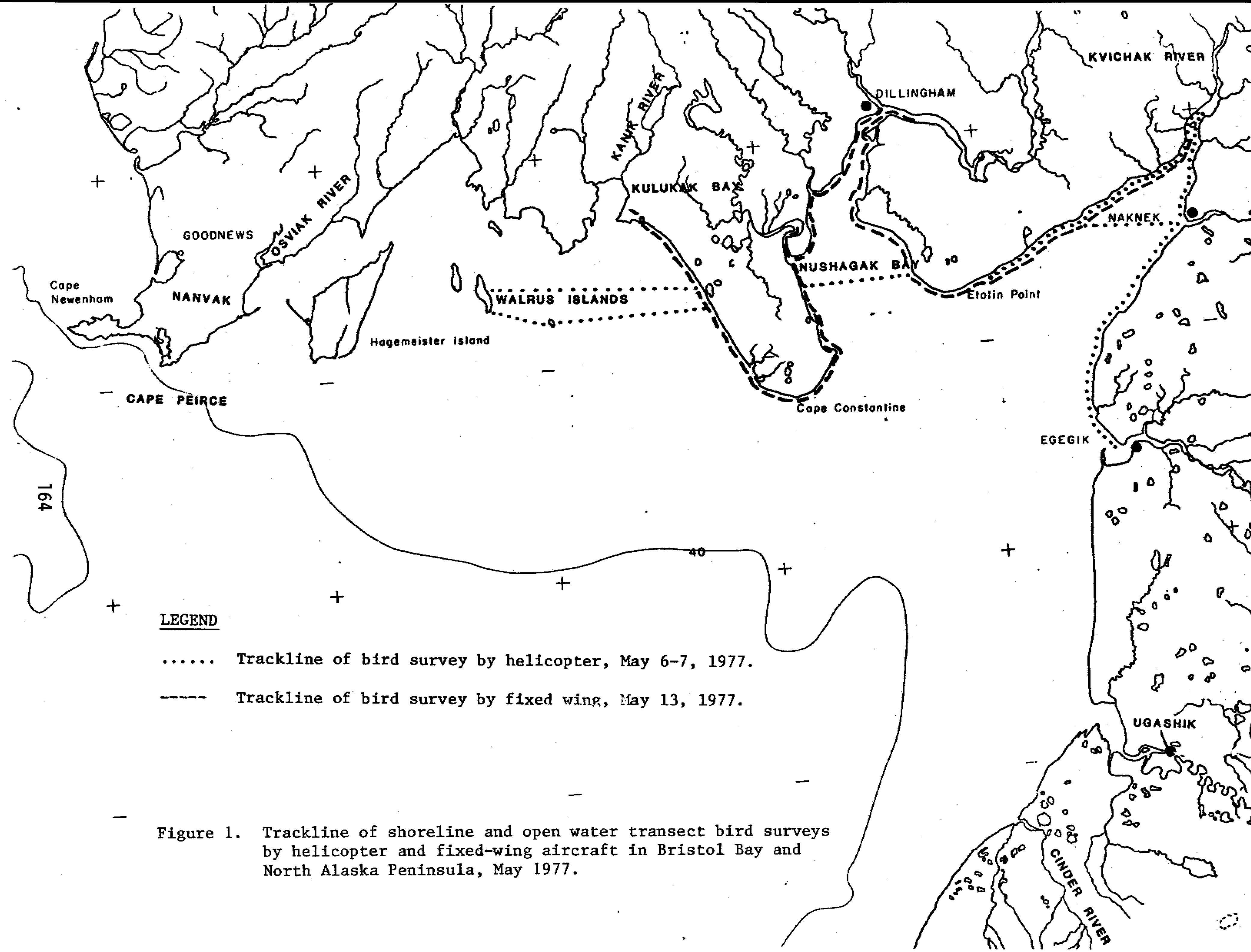
Data from these surveys have not yet been transcribed and therefore no summarization is available at this time.

Data from a March survey has been transcribed during this quarter and is being readied for keypunching and verification.

IV. Interpretation of Results

Until the data is transcribed, only general impressions can be given for the spring Bristol Bay survey. Large numbers of shorebirds were observed from the helicopter on the mudflats of Kvichak Bay on May 6, 1977. A large percentage of the shorebirds were black-bellied plovers. Portions of the same area were surveyed again on May 10 in a fixed-wing and very few shorebirds were observed. At this time I'm not sure whether this was a result of birds migrating out of the area but that appeared to be the case. Unexpectedly large numbers of waterfowl particularly Canada geese and pintails were on the mudflats at the mouth of the Kvichak River.

As we proceeded down the north side of the Alaska Peninsula, large numbers of larids were observed throughout the entire area. Arctic tern migration began on about May 6 and appeared to peak by May 11 or 12. Waterfowl were concentrated in the large estuaries except for occasional large rafts of seaducks in the open ocean near capes or estuaries. A surprisingly large number of gadwalls were observed on the northern half of the Peninsula. Approximately 40-50,000 black brant were observed in Izembek Lagoon while scattered flocks were observed migrating northeasterly up the coast. Many emperor geese were still in the area and had not yet migrated to nesting areas.



LEGEND

...... Trackline of bird survey by helicopter, May 6-7, 1977.

----- Trackline of bird survey by fixed wing, May 13, 1977.

Figure 1. Trackline of shoreline and open water transect bird surveys by helicopter and fixed-wing aircraft in Bristol Bay and North Alaska Peninsula, May 1977.

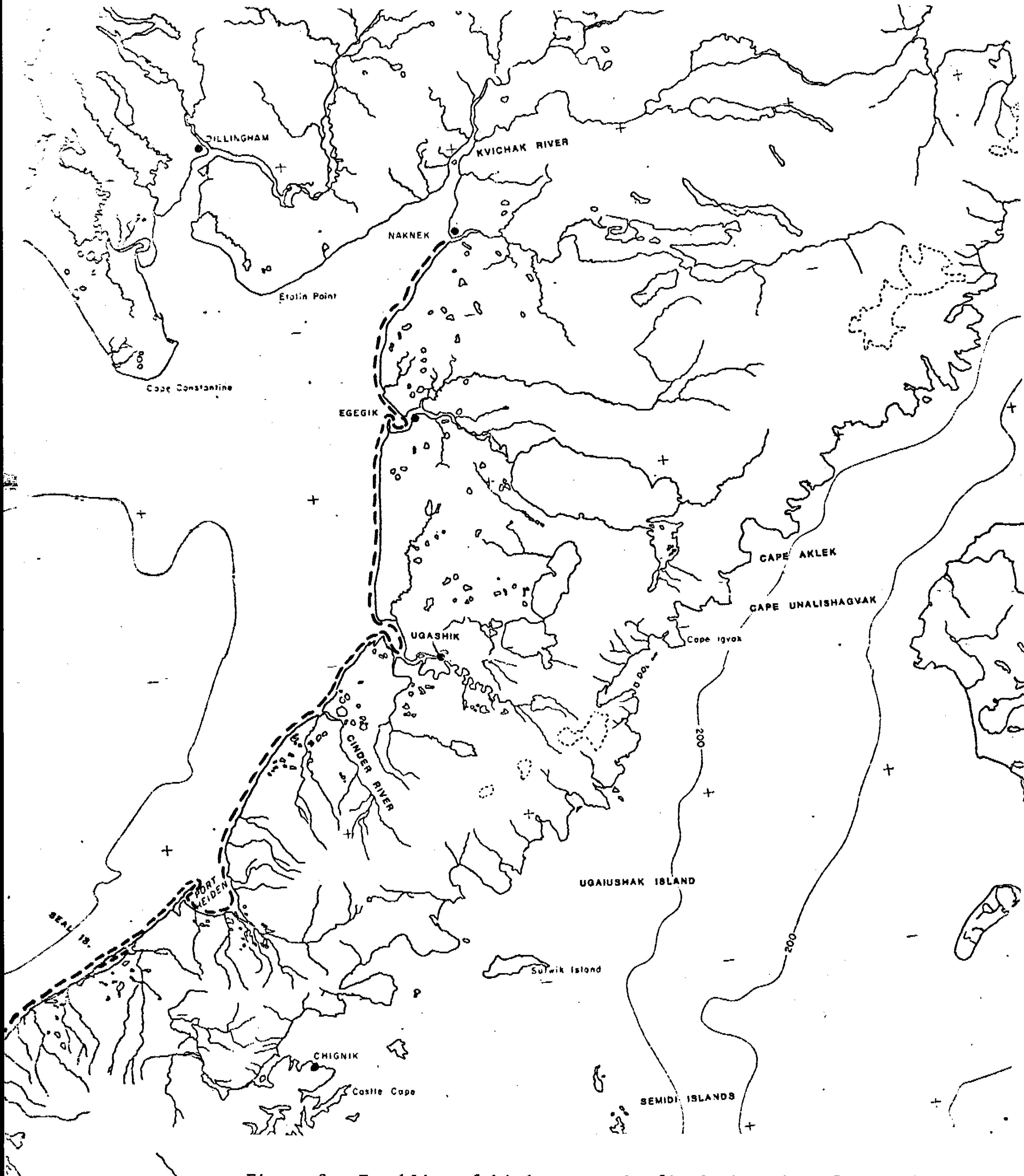


Figure 2. Trackline of bird surveys by fixed-wing aircraft, North Alaska Peninsula, May 11-12, 1977.

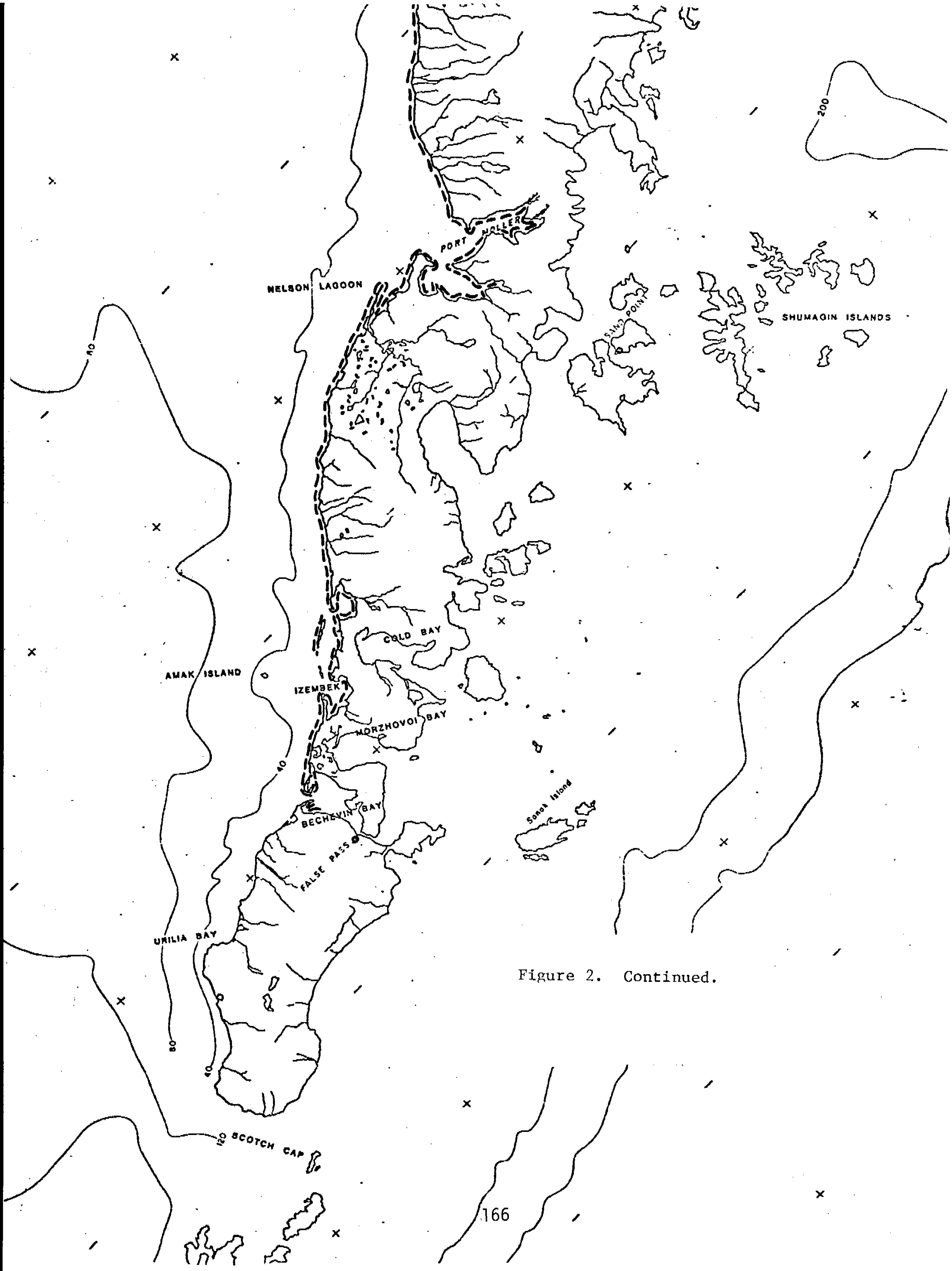


Figure 2. Continued.

Between May 10 and May 12, 200-300 bar-tailed godwits migrated into Cinder River Lagoon but relatively few shorebirds were observed on much of the survey. Also, few alcids were observed along this portion of the coast.

In the North Bristol Bay portion on May 7, 1977 during pelagic transects across Nushagak Bay, 10-12 rafts each with several thousand king eiders were observed. Several large rafts of murres and kittiwakes were on the water between the mainland and the Walrus Islands.

During shoreline surveys in the fixed-wing from Kvichak River to Tvativak Bay on May 13, large numbers of scaup were observed on nearshore waters. The same was true during a survey in the area a year previous. They were particularly abundant in the Flounder Flats vicinity. Also, large numbers of black scoters were found in areas similar to the scaup. Surprisingly, two male redheads were observed along this coastline and large numbers of red-breasted mergansers were also observed.

Cranes, swans, ducks and five species of geese were found at Protection Point but few other waterfowl were observed except at river mouths. Typical staging habitat was not available because much snow was still present and most lakes and ponds were still frozen.

Large numbers of red-throated loons were found in shallow water all along the coast and the expected large number of gulls was found throughout the area.

As outlined in the annual report for RU#3, the estuaries on North Alaska Peninsula are extremely important to migrating birds as well as Nushagak Bay on North Bristol Bay. The mouth of Kvichak River - particularly intertidal mudflats - were determined to be more important to migrating birds than previously thought.

V. Problems

Except for malfunctioning helicopter engines, no noteworthy problems were encountered.

VI. Estimate of Funds Expended

Salaries	$11,789
Per Diem/Travel	750
Contractural Services (Air charter, etc.)	326
Commodities	1,978
Equipment	-0-
Total	$14,843

9th Quarterly Report

Contract # 03-5-022-72
Research Unit 83
Reporting Period 1 April - 30 June 1977

Reproductive Ecology of Pribilof Island Seabirds

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

1 July 1977

I. Task Objectives

The task objectives for the 9th quarter were:

a) To arrange logistics and mail equipment and supplies to St. Paul and St. George Islands.

b) To commence the third field season of studies on the reproductive ecology, food habits and foraging areas used by seabirds on St. Paul and St. George Islands.

II. Field or Laboratory Activities

A. Laboratory schedule

1) 1 April - 15 May - a) work on the cost of the 1976 food sample identifications. Consultation with experts on various groups of organisms.

b) plan logistics for 1977 field season and ship equipment and supplies to the Pribilofs.

c) work on data management with Mike Crane.

B. Ship and field trip schedule

18 May 1977 - Barbara Mayer, William Rodstrom to St. Paul, Ron Squibb and Sam Sharr to St. George. Commence colony studies.
7 June 1977 - George Hunt to St. Paul Island.
25 June 1977 - George Hunt to St. George Island for day.

C. Scientific Party

George L. Hunt, Jr. Associate Professor, University of California, Irvine, Principal Investigator.

Barbara Mayer, Assistant Specialist, University of California, Irvine, Project Leader, St. Paul, and coordinator St. Paul and St. George.

William Rodstrom, Laboratory Assistant, University of California, Irvine, Field Observer, St. Paul.

Ron Squibb, Laboratory Assistant, University of California, Irvine, Field Observer, in charge, St. George Island.

Sam Sharr, Laboratory Assistant, University of California, Irvine, Field Observer, St. George.

D. Methods

1) Reproductive studies have been commenced by censusing the cliffs every 3-4 days to establish when birds return. Photographs of cliff areas have been made and 8x10 inch black and white prints made. Nest sites on these prints have been numbered, and the progress of numbered sites followed. Phenology will be studied at disturbed and undisturbed sites, reproductive success at undisturbed sites.

2) Information on food habits is being gathered by collecting adult birds as they fly over the shore line. Stomachs are injected with 70% alcohol as soon as the birds are shot and dissected out when time is available.

E. Sample Localities

Reproductive data and food habits information are being gathered on St. Paul and St. George Islands, Pribilof Islands at 19 sites and 12 sites respectively (see tables 1 and 2). The numbers of nest sites are appropriate, especially for Northern Fulmars, Cormorants, and Thick-billed Murres, and will change as the season progresses.

Sites checked by ladder will be used for studies of chick growth rates and will have nests from which food samples will be collected. Reproductive success will be measured both at ladder checked sites and visually checked sites.

F. Data Collected

1) Phenology and reproductive success: Studies of timing of nest initiation, competition for nest sites, laying dates, numbers of eggs laid and hatching and fledging success have commenced at sites as listed in Tables 1 and 2. The number of nest sites under observation on St. Paul is current as of 17 June; the estimate of numbers of nests under study on St. George was current as of 5 June. Since then additional sites have been added.

2) Foods: As of 16 June, on St. Paul Island we had collected 15 Black-legged Kittiwakes, 1 Red-legged Kittiwake, 16 Common Murres, 9 Thick-billed Murres and 1 Parakeet Auklet. We have not had a recent report from St. George on their success in collecting, but they sent in 73 samples on 15 June, as follows: 8 Red-faced Cormorant pellets plus one regurgitated fish, 25 Black-legged Kittiwake stomachs, 31 Red-legged Kittiwake stomachs including 18 collected by a local Aleut hunter before we arrived on the island and saved for us, 1 Common Murre, and 7 Thick-billed Murres. In total we have collected samples to date:

Red-faced Cormorant	- 9
Black-legged Kittiwake	- 40
Red-legged Kittiwake	- 32
Common Murre	- 17
Thick-billed Murre	- 16
Parakeet Auklet	- 1
Total	- 115

Although we have yet to begin work-ups of these samples, in all probability less than half will contain recognizable food items.

Numbers of nest sites being studied on St. Paul Island

Location	Fulmar	Red-faced Cormorant	Black-legged Kittiwake	Red-legged Kittiwake	Common Murre	Thick-billed Murre	Type of Site
Tsammana No.		10	29				ladder (growth)
Tsammana So.		12	27	5			visual
Rush Gap		10	16	10	20	30	visual
Rush Gap So.	13	2		11			visual
Gun Emplacement			10	28			visual
Southwest 29	10						visual
Southwest a					20	10	visual
Southwest b						10	visual
Ridge West						5	visual
Ridge Tourist Pt	3	30	16	7			visual
Ridge Spine			20	5			visual
Zapadni A						15	visual
Zapadni B					15		visual
Zapadni C					20	5	visual
Zapadni D						10	visual
Zapadni E						20	visual
Zapadni F						15	visual
Zapadni bottom					10		ladder (growth)
Ridge bottom						10	ladder (growth)
Total	34	64	118	66	85	130	

Numbers of nest sites being studied on St. George Island

Location	Northern Fulmar	Red-faced Cormorant	Black-legged Kittiwake	Red-legged Kittiwake	Common Murre	Thick-billed Murre	Type of Site
Starya Cliffs		3	12	27	8	15	ladder
Rosy Finch Cove	12	3					visual
Tolstoi		2	17	33			ladder
Kitsealogh		3					visual
Marie Cove	15						visual
Red Bluffs middle	4		14			20	visual
Red Bluffs East			4	4		12	visual
First Bluff			2	20			visual
High Bluffs East							
Upper				19			visual
Cove	2			25			visual
Murre ledge						100(ad)	visual
High Bluffs West				12	50(ad)		visual
Total	33	11	49	140	58	147	

III and IV. Results and Interpretation

It is too early in the data gathering process to present results or interpret our findings in detail. However, one interesting hypotheses concerning colony size and vulnerability to ecological disturbance is beginning to emerge.

Red-faced Cormorants appear to be nesting earlier on St. Paul than St. George. It is too early to know about differences in timing of nesting between St. Paul and St. George birds for other species, but it is possible that breeding is consistantly earlier on St. Paul than St. George. For Black-legged and Red-legged Kittiwakes and Thick-billed Murres breeding was earlier on St. Paul than St. George in 1975. Also, growth rates were generally lower on St. George than St. Paul in 1975. It is possible that competition for food among the vast numbers of Murres and Kittiwakes on that island influences reproductive ecology more than on St. Paul where the lack of available nest sites limits population size. If this hypothesis is correct, then any disturbance of the food chains used by St. George birds should have a greater impact on their reproductive success than would be expected on St. Paul. Additional years of comparative data are needed in order to know if the differences we have found between the islands are biologically significant. If they are, then we may find that large colonies, that support sufficiently large numbers of birds that local food availability is depressed, are very vulnerable, in fact more vulnerable to disturbances in food supplies, such as might be caused by an oil spill, than small colonies that are not pushing the limits of their food resources. In the OCSEAP research effort it will be valuable to look for this kind of colony size - food relationship in other areas.

V. Problems Encountered

1) Thanks to the new Honda bikes on St. Paul and St. George, we are encountering few problems in our field effort. With a better supply of tools and spare parts we even have managed to keep two of the three Harley-Davidson motorcycles running.

2) The U. S. Fish and Wildlife Service Enforcement branch failed to reply to our request for permits to carry out aircraft disturbance experiments, so we have been forced to cancel these. The need for careful documentation of the effect of aircraft on cliff-nesting birds at different stages of their reproductive cycles remains. Hopefully the Fish and Wildlife Service will conduct the needed, controlled studies.

3) Data management has proven a modest problem, perhaps because we were changing systems of data taking and adjusting to direct entry from field sheets rather than coding in our shop before data entry took place. Mike Crane has been most helpful to us in streamlining our efforts and without his good offices I am convinced that data management for my research unit, and, I suspect, a number of others would not have progressed as far as it has.

VI. Estimate of Funds Expended

	Estimated Accumulated expense to 30 June 1977	Total funds allocated
		$117,005.00
Salaries	$ 63,187.70	
Employee Benefits	3,987.00	
Supplies and expenses	10,156.62	
Equipment	8,739.24	
Travel & Per Diem	20,800.00	
Other	1,655.02	
	$108,525.58	
	Funds remaining	$8,479.42

It is my belief that the funds remaining will be sufficient to cover the anticipated costs that will be incurred in the fulfillment of our contract obligations.

QUARTERLY REPORT

Contract No. 03-5-022-68

Research Unit No. 108

Reporting Period: 1 April -
30 March 1977

Number of Pages: 17

COMMUNITY STRUCTURE, DISTRIBUTION, AND INTERRELATIONSHIPS OF MARINE BIRDS IN THE GULF OF ALASKA

John A. Wiens

Research Assistants: Wayne Hoffman
Dennis Heinemann

Department of Zoology
Oregon State University
Corvallis, Oregon 97331

25 June 1977

I. Task Objectives

A. Patterns of seasonal abundance and distribution are being studied because of their direct relevance to oil development and transport activities, and also to use in our analysis of marine bird energetic impact.

B. The dynamics of feeding flocks of seabirds are being investigated to determine the degrees and directions of dependency and/or interference between seabird species. This involves a description of the roles of different species in flock formation and development and an analysis of their contribution to the efficiency and performance of the system as a whole.

C. The energetics analysis is designed to estimate the impacts of marine birds on oceanic ecosystems in the Gulf of Alaska, and to predict the effects on those systems of major changes in bird populations, such as may occur from oil development and transport accidents.

II. Field and Laboratory Activities

A-D. We did not conduct any field work during this quarter, so we have no ship schedule, scientific parties, field methods or sample localities or tracklines to report.

E. Data Analysed.

1. Bird Densities. This quarter we directed our activities toward the computer simulation of seabird transect censusing. The goals of the simulation exercise are evaluation of the various methods of calculating seabird densities from transect data, and identifying and adjusting for sources of bias in the methods. Table 1 lists the censusing methods we are evaluating. The simulation is running, and we are just

Table 1. Transect Censusing Methods to be Simulated

Method	Reference
King's	Leopold, A.S. 1933. Game Management. Chas. Scribner's Sons, New York.
Hayne's	Hayne, D.W. 1949. J. Wildl. Mgt. 13:145-147.
Gates I.	Gates, C.E., W.H. Marshall and D.P. Olson. Biometrics 24:135-145.
Gates II.	Gates, C.E. 1969. Biometrics 25:317-328.
Gates III.	Ibid.
Webb's	Webb, W.L. 1942. J. Wildl. Mgt. 6:67-69.
Leopold's	Leopold, A.S., T. Riney, R. McCain, and L. Tevis Jr. 1951. Calif. Fish and Game, Game Bull. 4, 139 pp.
Frye's	Overton, W.S. 1971 chapter in Wildlife Management Techniques. Wildlife Society, Washington, D.C. 633 pp.
Kelker's	Kelker, G.H. 1945. Measurement and interpretation of forces that determine populations of managed deer. Ph.D. Thesis, Univ. Michigan, 422 pp.
Anderson and Pospahala's	Anderson, D.R. and R.S. Pospahala. 1970 J. Wildl. Mgt. 34:141-146.

commencing the evaluation of the methods. In the simulation, birds are generated stochastically along two adjacent sides of a square matrix 2000 meters on a side. The birds travel in randomly derived straight paths across the matrix at set velocities. Transect censusing is simulated by creating a detection area occupying part of the matrix, and counting birds detected within it. One corner of the detection area corresponds to the ship, and the probability of any bird in the area being detected is a function of its distance from the ship. Figure 1 is a generalized flowchart of the simulation program.

2. Feeding Flocks.

Our feeding flock observations were all coded, keypunched and submitted to NODC-EDS during this quarter. Table 2 lists the files and the number of flocks contained. Table 3 summarizes the feeding flock data over all files. We collected data on 223 flocks. The initial formation was observed and described for 112 of these flocks.

3. Energetics Analysis.

The energetics simulation model is set up and running now, and we are waiting for the results of the transect simulation, to provide the best possible estimates of density to input to the energetics simulation.

III. Results and Interpretation

A. Seabird Densities. We have no new results to add to the results in our most recent annual report. The simulation will undoubtedly allow us to make refinements on our density estimates, and may allow us to resolve discrepancies between our estimates and those of the U.S. Fish and Wildlife Service.

Figure 1.

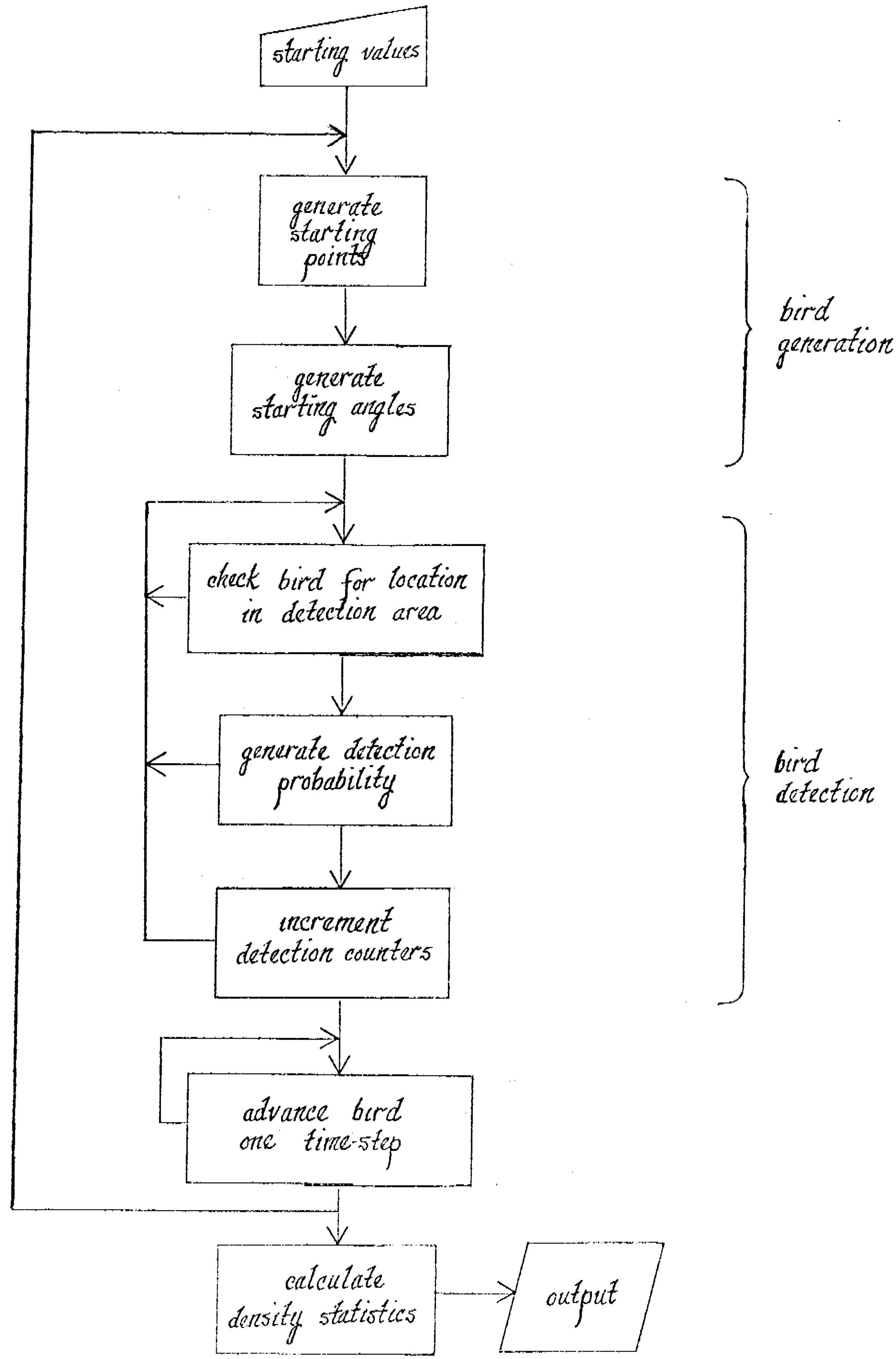

starting values
generate starting points
generate starting angles
bird generation
check bird for location in detection area
generate detection probability
increment detection counters
bird detection
advance bird one time-step
calculate density statistics
output

Table 2. Feeding Flock Data

File Identifiers	Dates	Locations	Flocks	Initiations
58FEED	Aug. 1975	Kodiak, Unalaska	56	15
59KOFF	Sept. 1975	Kodiak	14	9
65SURU	May 1976	Kodiak	4	0
67ACON	July-Aug. 1976	Kodiak, N.W. Gulf, Unalaska	25	5
68CHFF	July-Aug. 1976	Chowiet I.	55	32
68SUKO	Aug. 1976	Kodiak	13	5
68KODF	Aug. 1976	Kodiak	34	28
69UNFF	Sept. 1976	Unalga I.	22	18
			223	112

Table 3. Feeding Flock Participation

Species	No. of Flocks	No. of Initiations by
Blacklegged Kittiwakes	207	85
Horned Puffin	119	7
Tufted Puffin	84	0
Glaucous-winged Gull	79	2
Cormorants	75	2
Short-tailed Shearwater	32	9
Sooty Shearwater	15	1
Common Murre	11	0
Fulmar	11	0
Northern Sea Lion	8	4
Mew Gull	6	0
Pomarine Jaeger	5	0
Fork-tailed Petrel	4	0
Thick-billed Murre	4	0
Parasite Jaeger	4	0
Arctic Tern	2	0
Harbor Seal	2	2
Northern Phalarope	1	0
Pigeon Guillemot	1	0
Marbled Murrelet	1	0
Skua	1	0
White-winged Scotor	1	0
Harlequin Duck	1	0
Rhinoceros Auklet	1	0
Cussin's Auklet	1	0
Aleatian Tern	1	0
		112

B. Feeding Flocks. Our continuing analysis of the feeding flock observations has not produced major revisions to the conclusions in our most recent annual report, but we can make several minor modifications and extensions of the conclusions. To provide the appropriate context, we will first abstract the conclusions of our annual report, and then discuss the modifications.

1. Results Reported Previously.

Feeding flocks can be grouped into three categories - Type I flocks, Type II flocks, and rip flocks. Type I flocks are small short-lived aggregations that form over discrete, cohesive fish schools and last until the schools disperse or descend too deep for the birds to follow. Type II flocks are much larger and longer-lived. They form over large concentrations of baitfish. Normally the fish are dispersed to the extent that at least one to three meters may separate adjacent fish, and the fish do not appear to respond as a unit to the activity of the birds. Rip flocks form where water-mass discontinuities concentrate zooplankton and small fish. Their formation and duration are normally dependent on the tidal regime. Most of the feeding flock activity in the OCS areas were found to occur close to shore; and rip flocks were most common in island archaepelage areas.

The bird species involved can be grouped into four functional categories - Catalysts, Divers, Kleptoparasites, and Suppressors (Table 4). These categories are not mutually exclusive.

The catalysts are conspicuous as they forage in the flocks, so that other species use them as indicators of the fish schools' presence. The divers forage by searching for and pursuing prey underwater. They may play a stabilizing role in flock feeding by keeping the school close to

TABLE 4. FUNCTIONAL GROUPS

Catalysts	Divers	Kleptoparasites	Suppressors
Black-legged Kittiwake	Horned Puffin	Pomarine Jaeger	Short-tailed Shearwater
Glaucous-winged Gull	Pelagic Cormorant	Parasitic Jaeger	Sooty Shearwater
Herring Gull	Red-faced Cormorant	Black-legged Kittiwake	
Mew Gull	Tufted Puffin	Glaucous-winged Gull	
Sooty Shearwater	Common Murre	Long-tailed Jaeger	
Short-tailed Shearwater	Rhinoceros Auklet		
	Thick-billed Murre		
	Double-crested Cormorant		

the surface and concentrated. Kleptoparasites are birds that steal fish or other food from other birds. Jaegers are highly specialized kleptoparasites upon gulls and terns, but their activity has surprisingly little effect on flock coherence and stability. Gulls and kittiwakes, however, facultatively rob the other flock members. Their activity may serve to stabilize Type I flocks by forcing the alcids (divers) to the periphery of the flock and thus into the configuration where they are most effective at manipulating the fish school. Suppressors (shearwaters), by their activities and tremendous numbers, exclude other birds from flocks and decrease flock longevity.

2. Modifications and extensions.

a. Roles of Black-legged Kittiwakes and Glaucous-winged Gulls in flock initiation. In areas where kittiwakes are not common, Glaucous-winged Gulls are active as catalysts. However, where kittiwakes are common, the Glaucous-wings are much less active in fish school location, and tend to wait around until the kittiwakes have located schools.

b. We can be more specific about behavioral accomodation in the responses of diving birds to a flock initiation. In the 1977 annual report we described Horned Puffin and Pelagic Cormorant responses in a situation of rather extreme "choosiness". The divers waited until the behavior of the kittiwakes indicated that a school had been located, and not just a single fish. Under circumstances where schools were more predictable, in the sense that almost all kittiwakes circling and plunging was indicative of a fish school, the Puffins and Cormorants responded much more quickly. Thus the diving birds have the ability to adjust, perhaps on a day-to-day basis, the appropriate responses to the kittiwake behaviors.

c. Kittiwake vocalizations. It has been suggested (Graham 1975 and others) that gulls that locate large concentrations of food call loudly in order to attract other birds. If this were true, it would strongly support the hypothesis that marine bird communities are extensively co-evolved assemblages with a large degree of species interdependence. We found that groups of kittiwakes were quite noisy early in flock development and at other times when feeding was intense and concentrated. However, close observation showed that the first birds that located fish did not call, but that the next birds to arrive called extensively, as part of robbery attempts or when they approached each other closely while circling. This last observation suggests that a "personal distance" effect may be involved. Other birds may use this calling as a cue, but it clearly is not done for that purpose. The other birds do respond, apparently as quickly, when the gulls do not call. We still conclude that the community is a co-evolved, interacting unit, but this co-evolution probably doesn't extend to food-finding calls.

d. Importance of interference by the Suppressors. We reported that the suppressors (the shearwaters) can make flock participation unprofitable for the alcids, by scattering or decimating the fish schools. We have since examined the data more extensively, and can describe some limits to the adverse effects that flock suppression may have on the community.

Shearwaters are effective as suppressors only when they are present in large number, and large shearwater concentrations apparently only gather in areas where food is abundant. Thus the shearwaters are likely to suppress flocks only at times when food is fairly easy to obtain anyway. The activities of the shearwaters must increase the incidence of scattered fish by dispersing some of the schools they attack. Puffins and Murres frequently concentrate in areas where shearwaters are feeding but they don't actually join the flocks. The "background" levels of dispersed fish and/or deep schools may be sufficient to support them.

IV. Conclusions With Respect the Petroleum Production and Transport.

This section will include conclusions already presented in previous reports. Thus we are presenting the total of our conclusions to date, rather that just recent modifications.

A. Seabird Densities.

The two areas where petroleum development activites have begun in Alaskan waters, Lower Cook Inlet and NEGOA, clearly have lower overall species diversities and densities of marine birds than the other areas. Suitable breeding situations are less common in these areas, and food resource levels appear to be lower. The marine birds that do occur in these areas are almost all widespread species that occur in larger numbers elsewhere.

The as yet unbroken areas -- Kodiak, NWGOA, and the Bering Sea -- have notably higher species numbers, bird densities, and breeding colony densities. They contain the principal North American habitat of several uncommon or rare seabirds, most notably the Aleutian Tern, the Red-legged Kittiwake, and the Whiskered Auklet. Further, large aggregations of alcids occur here, and these species are especially susceptible to oil spills (Vermeer and Anweiler 1975). A spill in the Kodiak area in February and March 1970, for example, claimed an estimated 10,000 birds, and roughly 2/3 of the small sample identified were alcids, notably murres (Marine Pollution Bulletin 1970).

We thus conclude that the course of OCS petroleum development that would cause the least damage to seabird populations would be to concentrate development in the two areas already opened, the NEGOA and Cook Inlet, and to avoid opening Kodiak, the NWGOA, and the Bering Sea for development. Kodiak and the NWGOA study areas probably do not differ greatly in the physical aspects of hazards to bird populations.

With respect to marine bird populations, the Bering Sea is easily the most important and most vulnerable to the effects of petroleum development. There are a number of reasons for this. The bird populations are larger, especially if the Aleutian Passes (where Bering Sea oil must be shipped) are included. The water is colder, so floating oil will remain dangerous in the water for longer periods. Moreover, birds are most susceptible to oil fouling in cold situations (e.g., during winter months, Joensen 1972), when increased cooling may increase thermoregulatory metabolism costs and reduce foraging effectiveness, leading to death by accelerated starvation if not by exposure. Winter pack ice in the Bering Sea will inevitably cause problems for petroleum production, and will also interfere with any cleanup efforts on spills at the ice edge or in the pack. The eastern Aleutian passes will be hazardous areas for the passage of tankers, especially those of very large size, and the frequently inclement weather of the area will compound that problem. The likelihood of major spills or oil "disasters" thus seems greater in the Bering Sea than in other areas of the Gulf of Alaska. But while such major spills undoubtedly have profound and often spectacular and obvious effects upon the biological systems of the areas, minor pollution events associated with petroleum development, production, and transport activities may also have important consequences. Reviewing the effects of petroleum on seabirds in Danish waters, Joensen (1972) observed that, apart from a few cases, most oil-caused mortality of seabirds was due to pollution that in other respects went unnoticed, and was simply a result of increased traffic and activity.

B. Feeding Flocks. Feeding flocks are assemblages of birds that gather to exploit localized concentrations and patchy distribution of their prey organisms. This brings a great many individuals into a small and localized area, increasing the possiblity that environmental disruptions that are quite localized may nonetheless influence a large number of individuals and species that range over a much broader area. Further, since the food supplies that stimulate the formation of feeding flocks are locally concentrated, environmental alterations that reduce the birds' access to such food concentrations may lead to a breakdown of the feeding flock relationships or force foraging into other areas; both of these effects may have important consequences for marine bird populations.

Our functional analysis of flock organization and analysis of initiation cues indicate that a biologically significant degree of coevolution has occurred, and that significant interdependencies occur. Behavior and morphology have evolved to increase the efficiency of fish school exploitation. The behavioral adaptations include highly developed responsiveness to behavioral cues indicating fish schools and interspecies manipulative behaviors resulting in a more efficient species organization within flocks, but apparently do not include food-finding calls. The morphological characters evolved include plumage characters that act as flock-location cues.

Reduction in the numbers of kittiwakes (for example by development of facilities near nesting cliffs) would have an impact on the populations of jaegers and large alcids, and probably on the populations of cormorants. Reduction in the numbers of puffins or marres might adversely affect the kittiwake and gull populations, but this relation is not certain. A major reduction in shearwater numbers would probably not adversely affect the other species of birds. The impact of a kittiwake population reduction on alcid populations will be greater in areas without extensive tidal rips, but will probably be major in all areas.

Figures 2 and 3 illustrate information flow and energy flow respectively in the exploitation of fish schools by catalysts. The catalysts (kittiwakes and gulls) clearly have a critical function in information flow. Without them, the number of birds responding to a fish school would be drastically reduced.

The important features of the energy flow diagram are the rate controlling feedbacks (dotted lines). The suppressors clearly have negative, or controlling, effects on all flows from the fish school to the bird community. The feedbacks from the divers to the flow rates to the catalysts and to themselves may be positive. When considered locally (i.e., within the flock) the catalysts exert a negative feedback upon their own foraging and upon that of the divers, but when their function in attracting birds to the flock is considered, the overall effects are positive. Once again, it is clear that the system could not function without catalysts, and would function poorly without divers (Tropical seabird communities without divers feed extensively in flocks, but Tunas and other large fish perform their function - e.g., King 1974).

INFORMATION FLOW DIAGRAM — FLOCK FORMATION

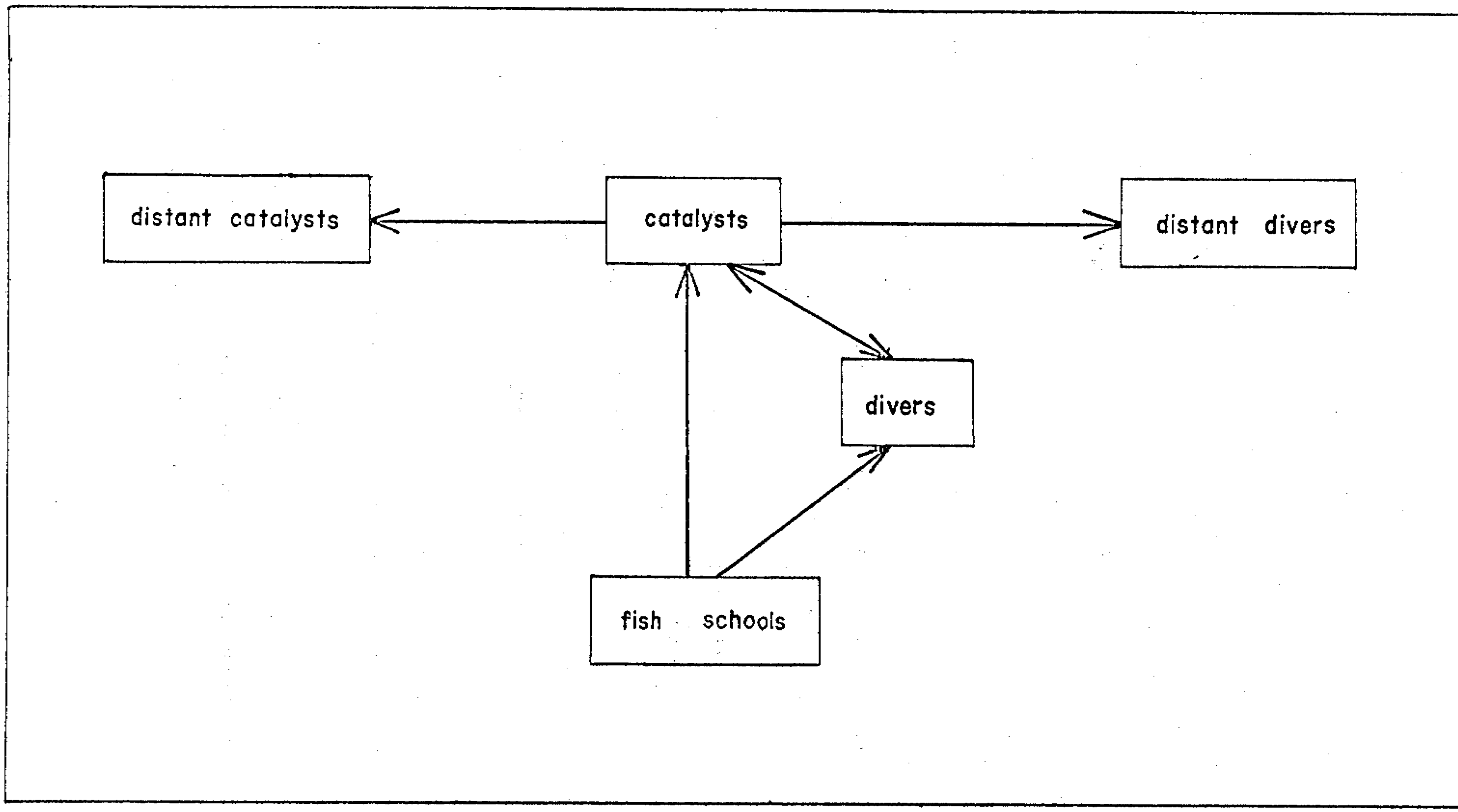


Figure 2: Diagram of major paths of information flow ("communication") among the elements involved in the dynamics of feeding flock formation.

ENERGY FLOW DIAGRAM —— FLOCK FEEDING

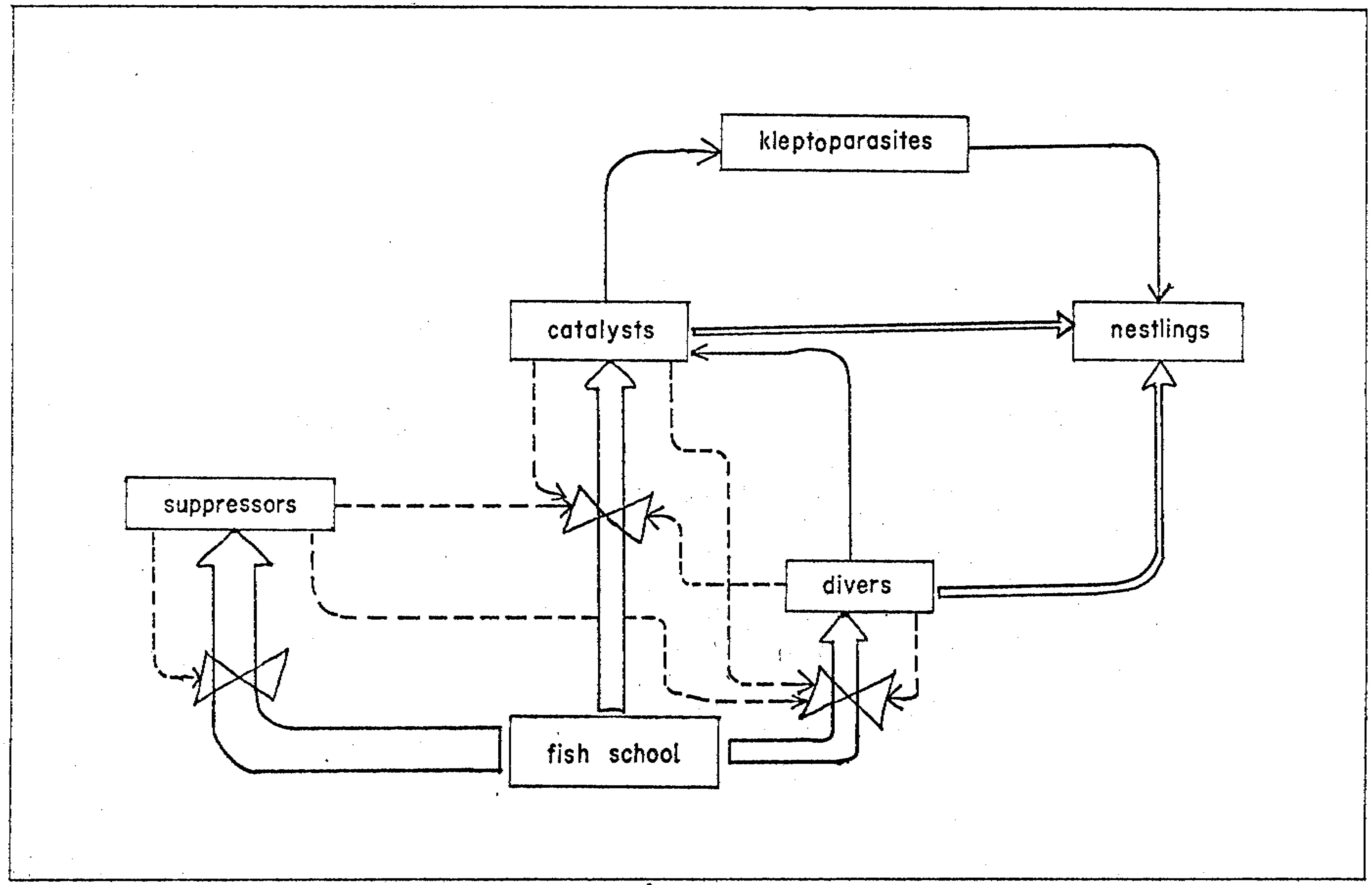


Figure 3: Diagram of the major energy flow pathways among the components of marine bird feeding flocks. Dashed lines indicate control pathways.

Budget Summarization:

Expenditures through 21 June 1977

Salaries and Wages	21516	
Payroll Assessments	3125	
Services and Supplies	5380	
Travel	11291	
Permanent Equipment	6272	
Computer Services	2997	
Total Direct Costs		50581
Indirect Costs		12673
		63254

QUARTERLY REPORT

Contract No.: 03-5-022-84
Research Unit: #172
Reporting Period: 1 April - 30 June 1977
Number of Pages: 1

Shorebird Dependence on Arctic Littoral Habitats

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

Principal Investigator: R. W. Risebrough

Date of Report: 1 July 1977

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.

2. Foraging habitat preferences of shorebirds within the littoral zone, by species.

3, Diets of shorebirds in the arctic littoral zone, by species, as these change through the season.

II. Field and Laboratory Activities

A. Field Schedule:

Cape Krusenstern	26 May - 30 June
Wales	2 June - 30 June

B. Scientific Party

Peter G. Connors, research coordinator
Carolyn Connors, research assistant
Katherine Hirsch, research assistant
Douglas Woodby, research assistant

C. Methods

Establish series of census transects and breeding bird census plots at each site, to sample densities of bird use of different tundra and littoral habitats. Begin regular schedule of census, repeated at 5 day intervals. Observe shorebird foraging in littoral habitats.

III. Results

No data have been analyzed yet, since the field season will continue until mid-September. Preliminary results show very low use of sand and gravel beaches during this mainly ice-bound season, but high densities of several shorebird species on mudflat areas on small lagoons, stream sloughs, and storm-littoral ponds.

IV. Problems Encountered

None

V. Funds Expended

Not possible to determine while in the field.

Quarterly Report

Contract # 03-7-022-35140
Research Unit: 196
Report Period: 1 April - 30 June 1977
Number of Pages: [illegible]2

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

George J. Divoky
Principal Investigator

Assisted by:

Katherine V. Hirsch
Harriet R. Huber
Karen L. Oakley
Douglas A. Woodby

Point Reyes Bird Observatory
4990 State Route 1, Stinson Beach
California 94970

July 1, 1977

I. Task Objectives

Determine the relationship of pelagic seabirds to the ice environment on a seasonal basis in the Bering, Chukchi and Beaufort seas.

II. Field Activities

A. Ship and field trip schedule

Dates	Ship & Location	Personnel
15 March - 6 April	SURVEYOR Bering Sea	Woodby and Hirsch
14 April - 3 May	SURVEYOR Bering Sea	Woodby and Hirsch
20 May - 10 June	DISCOVERER Bering Sea	Divoky, Oakley and Huber

B. Data collected

First SURVEYOR cruise	
15 - minute transect	= 271
Specimens collected	= 32
Second SURVEYOR cruise	
15 - minute transects	= 290
Specimens collected	= 32
DISCOVERER cruise	
15 - minute transects	= 350
specimens collected	= 109

III. Results

None

IV. Preliminary Interpretation of Results

None

V. Problems encountered

Payment for bills sent to the NOAA office at Boulder has been slow. At this time payment for April has not been received resulting in a number of financial problems.

VI. Estimate of funds expended.

As of 30 June the following amounts have been expended:

Salaries	16,474.00
Travel	3,641.00
Commodities and supplies	1,118.00
Equipment	623.00
Total expenditures	$ 21,856.00
Overhead	4,371.00
	$ 26,227.00

QUARTERLY REPORT

Contract #: 03-6-022-35208
Research Unit #: 237
Reporting Period: 1 April - 30 June 1977
Number of Pages: 6

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

by

William H. Drury
Principal Investigator
College of the Atlantic

July 1, 1977

I. Task Objectives

1. To determine the numbers and distribution of species of seabirds, shorebirds and waterfowl.

2. To describe the schedule and phenology of events during migration and the breeding season.

3. To examine the trophic relations by estimating reproductive success, by finding the distribution of feeding birds at sea, and by collecting the food brought to the cliffs.

4. To study the behavior of Ravens and Glaucous Gulls as predators on nesting seabirds.

5. To survey coastal waters, lakes, estuaries, lowland tundra and uplands for use by waterfowl and shorebirds.

II. Field Activities

1. Schedule

May 15, 1977, first party to Nome to work on waterfowl surveys and the arrival of seabirds at Bluff Cliffs.

June 7, 1977, second party to Nome; permanent party to Bluff Cliffs.

June 5 to June 30, surveys of coastal waters, lagoons and uplands for use by waterfowl and shorebirds.

June 18 to 24, party on Sledge Island.

June 22 to 24, offshore aerial surveys of Chirikov Basin and Norton Sound.

2. Scientific Party

William H. Drury, College of the Atlantic, Principal Investigator.
Ben Steele, Utah State Univ. in charge of field party in May.
J. B. French, Univ. of Wisconsin, in charge of field party.
John Biderman, member of field party.
John Drury, member of field party.
Craig Kesselheim, member of field party.
David Rand, member of field party.

3. Methods

Field methods have already been described in detail in proposals and annual reports.

a. Censuses of cliffs from small boat or aircraft.

b. Surveys for waterfowl and shorebirds from low-flying aircraft or transects along all roads. These transects involve three-minute stops at half-mile intervals for 25 miles.

c. Regular visits to study sites to record numbers and activities of birds at mapped or numbered nests or ledges.

d. Recording special events.

4. Sample Localities - see maps in previous reports

a. Surface studies at seabird cliffs at Sledge Island, Bluff Cliffs, Topkok and Square Rock.

b. Air surveys for waterfowl along the south shore of the Seward Peninsula from Cape Spencer to the Koyuk River, especially Safety Lagoon and Golovnin Lagoon.

c. Surface surveys of the roads from Nome to Teller, from Nome to the Kugarok River and from Nome to the ferry at Safety Lagoon for waterfowl, shorebirds and songbirds.

d. Air surveys for seabirds and waterfowl of the waters of Norton Sound from Rocky Point to Sledge Island.

5. "Data Collected" - operations carried out are listed:

a. Seabird cliffs - 4 surface censuses, 6 air censuses
3 24-hour continuous watches
300 visits to study sites

b. Air surveys for waterfowl - 40 5-minute samples

c. Air surveys for seabirds - 20 5-minute samples

d. Road surveys - 250 3-minute samples

6. Milestone Chart and Schedule of Data submission

Quarterly reports will be submitted about October 1, 1977 and January 1, 1978.

Annual report will be submitted on or before April 1, 1977.

Coding sheets for our data from 1975 and 1976 have been submitted to AEIDC, Anchorage on June 5. Most of the print-out has been reviewed. The checking should be completed and print-out returned to AEIDC for correction of the cards by August 1, 1977.

III. Results

Our data are contained in field notebooks, and on data sheets filled out at study sites and following air and surface surveys.

Events move very fast in the lives of seabirds, waterfowl and shorebirds during the periods of migration, establishment of territory and laying of eggs. We would have to neglect field work to prepare the maps, graphs and tables called for in this section, and have not done so.

IV. Preliminary Interpretation of Results

Some unexpected events affected the migration and early reproductive schedule and our observations.

First, the spring was late and the sea ice persisted into late June. Because there were few patches of open water the usual spring phenomenon of aggregation of waterfowl and seabirds into leads was exaggerated.

Second, the dryness of the winter and spring in the Prairie Provinces caused an influx of prairie waterfowl. Most of these birds stayed in flocks and failed to breed. Their presence emphasizes the importance of the gathering grounds.

Third, the Wien Alaska strike brought a flood of freight and passenger business to other airlines. Because of the difficulty of chartering twin-engined aircraft, we missed the main period of break-up of the sea ice in our surveys off-shore.

1. Waterfowl

   a. Temporary bodies of open water were heavily used by waterfowl during the spring thaw in late May and early June. Several meltwater ponds formed next to roads and these had disappeared by late June. Openings in lake ice which occur each year at the mouth of drainages were again important, such as the mouth of the Flambeau River, the mouth of Pine Creek, the outlet of Safety Lagoon towards the Bonanza River.

   b. We saw an unusually large number of Pintail together with Canvasbacks, Shovellers and some individual Baldpate, Mallards and Lesser Scaup. J. Bartonek and J. King of the U.S. Fish and Wildlife Service suggested that the unusually dry conditions in the prairies resulted in these birds' drifting northwest beyond the limits of their usual range. R. Jones of the U.S. Fish and Wildlife Service remarked that the Pintail on the Yukon Delta were not nesting, so we made a number of counts of the proportion of male Pintail to females. We found that most of the ducks gathered in flocks on the south shore lagoons were still in pairs. Most of the Pintail seen on isolated, especially inland ponds were single drakes or ducks with ducklings. Our guess is that the local birds bred normally, but that those that moved into the area beyond their usual nesting range failed to nest.

c. During the single flight while the sea ice was breaking up, we looked for a staging area for King Eiders after they leave the Alaska Peninsula and before they pass through the Bering Strait. We found no sign of one. We asked several people who hunt on the sea ice off Nome and Saint Lawrence Island whether they knew of a concentration of Eiders. All agreed that Eiders do not stop for any length of time but "keep going".

   H. Springer of the Alaska Dept. of Highways reported seeing many small (50-150) flocks of Eiders on the ice. When disturbed, these flocks continue to fly out of sight. Springer made a survey flight on June 13, 1977 and reported flocks of thousands of Eiders in the Bering Strait, in the last open water before the solid ice pack.

   These reports suggest that there is no staging area for King Eiders in our area, but that Eiders press northward as far as there is open water.

d. Large numbers of Emperor Geese were seen on migration. The migration of Black Brant across Norton Sound occurred in normal numbers. Some of the geese turn and fly West when they meet the coast of the Seward Peninsula; others turn and fly East. Two flocks of Black Brant, totalling over 150 birds, were present in Safety Lagoon in late June. Canada Geese were unusually conspicuous and wide-spread in pairs inland on the peninsula.

2. Shorebirds

   a. Other activities kept us from observing the shorebird migration which seems to reach a peak during the first two weeks of June. We surveyed those areas of the Peninsula accessible by road for the distribution of nesting shorebirds and as a result can present a preliminary description of their nesting habitats. The data from three-minute stops at 1/2 mile intervals will be presented in a later report. Whimbrel, Bar-tailed Godwit and Western Sandpiper choose wet tundra on depositional slopes. Characteristically the cottongrass tussocks are largely overgrown with mosses. This terrain and vegetation occurs near the sea and on lower valley slopes and especially on the upper reaches of the rivers draining the middle of the peninsula. Golden Plovers choose dry upland tundra in which tussocks are replaced by Avens and mat willows and are especially widely distributed over the peninsula. Their song flights often extend over the previous and following habitat types. Baird's Sandpipers, Rock Sandpipers, Ruddy Turnstones, Black-bellied Plovers and Wandering Tattlers choose the driest ridge tops, the gravel outwash of depositional fans on which the vegetation is limited to scattered lichens, Ruddy Turnstones and Wandering Tattlers also choose gravel bars by rivers and are joined there by Spotted Sandpipers and Semi-palmated Plovers. Wandering Tattlers, Semi-palmated Plovers and vagrant Lesser Yellowlegs choose abandoned mine talings occasionally. Semi-palmated Sandpipers choose sandy outwash or coastal beaches stabilized by saltmarsh sedges, dune grass or Crowberry. Northern Phalaropes choose small ponds with emergent sedges around the margins.

Something had a marked effect on Western Sandpipers this year. In 1975 and 1976 they were numerous and almost ubiquitous, but in 1977 they were restricted in range and few in numbers. Those present were primarily inland on the lower depositional slopes instead of on the coastal wet tundra. In contrast, Semi-palmated Sandpipers were exceptionally numerous and seemed to have extended their habitats onto what have been, in other years, the margins of Western Sandpipers' habitat.

To summarize our impressions of the movements of waterfowl and shorebirds during these three years, their populations appear to be notably mobile. They, like the populations of predators reported by Pitelka et al. appear to move through inhospitable traditional habitats when conditions dictate and to gather where they find favorable conditions for survival (if not for breeding). Similarly weak attachment to any one breeding site seems to be part of the tactics of raptors such as Peregrines and Gyrfalcons which move irregularly among several preferred eyries. These tactics are presumably associated with the long-familiar phenomenon of chronic breeding failure among arctic birds. (Bertram & Lach 1933)

3. Seabirds

a. During June, after Murres and Kittiwakes have occupied the cliffs and before they have laid eggs, the birds may be conspicuous on the cliffs some days and at some times of day while at other times they are virtually absent.

Day-long continuous watches during June indicated that the times when the Murres at Bluff Cliffs would visit the cliffs were out of phase with the times when the Murres at Square Rock were on the cliffs.

At Bluff, the largest counts are made during the evening. An air transect over Norton Sound from 9 to 11 pm on June 24 found almost no Murres or Kittiwakes at sea. Large numbers of both were on the cliffs at Bluff. These watches will be continued to see whether the pattern changes with the season.

b. Pelagic Cormorants had laid eggs but we saw no hatched young by June 30.

About half of the Glaucous Gull nests we watched at Bluff had hatched by June 30. The first Kittiwake eggs were seen on June 28. Ravens had found Murre eggs and were bringing them to their young as early as June 24, but we had not seen any eggs at our study sites by June 30.

4. Ravens and Glaucous gulls - predators

We have begun a special study of Ravens and Glaucous Gulls, their reproductive biology and their actions as predators on the seabird cliffs. About a fifth of the Glaucous Gull nests and half of the Raven nests were known to have failed. One Raven's nest was still active at Bluff on June 30. The Raven parents were feeding the four nearly fledged young frequently with Murre eggs. There seemed to be little, if any, predation by Glaucous Gulls on the early Murre eggs, but the presence of Glaucous Gull breeding territories excluded large numbers (hundreds) of Murres from preferred nesting sites at the tops of stacks.

The conclusion seems inescapable that heavy predation by Ravens has an important effect on the success of Murres which lay their eggs early. We will be looking for the conditions underwhich these early eggs are made vulnerable.

V. Estimate of Funds Expended

We have been given permission to transfer some funds between R.U. #237 and R.U. #447. The following accounting is approximate and assigns costs between the two Research Units arbitrarily. (See comments under R.U. #447)

CPF 1	$12,950
CPF 2	6,420
CPF 3	4,515
CPF 4	570
	$24,450

Quarterly Report January-March 1977

To: NOAA Environmental Research Laboratories
Boulder, Colorado
Arctic Project Office, Fairbanks, Alaska

From: Principal Investigator, William H. Drury
Organization: College of the Atlantic
Eden Street
Bar Harbor, Maine 04609

Subject: Summary of 4th quarter operations for 1976/1977
Contract: 03-6-022-35208 Research Unit # 237
Period January 1 to March 31, 1977

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

A. Library Activities

2. Scientific party

William H. Drury	Reducing data, writing report
Benjamin B. Steele	Reducing data, writing report
Mary C. Drury	Accounts
Peter L. Drury	Preparing data and entering on forms

5. Data analysed

The entire period was spent writing the annual report and preparing accounts/budgets.

a. Data from field notebooks were reduced. Graphs, maps and illustrations were prepared. Text was written.
b. Accounts for 1976 were summarized and budgets for 1977 were prepared.
c. Data from field notebooks for 1975 and 1976 and field sheets from 1976 were transcribed onto forms to be delivered to a key-punch operator.

6. Data submission schedule

a. The annual report is due from the typist on March 28. It will be photocopied and sent on Air Express.
b. Seventy-five percent of the data from 1975 and from 1976 have been put onto forms and can be delivered to a key-punch operator as soon as funds are available. We have been told that it will require six months for the data to be punched after they are delivered to the operator.

B. Problems

1. We have now had the scheme for putting data into archives explained adequately and have learned how to use the data reporting systems. However we do not have a clear picture of the goals or needs of the projects which will take the data out of the archives and use them. As a result we have some unresolved questions about the purposes, types of data and quality of data which justify this effort.

C. Estimate of funds expended January 1 to March 31, 1977

None

To: NOAA Environmental Research Laboratories
Boulder, Colorado
Arctic Project Office, Fairbanks, Alaska

From: Principal Investigator, William H. Drury
Organization: College of the Atlantic
Eden Street
Bar Harbor, Maine 04609

Subject: Summary of 4th quarter operations for 1976/77
Contract: 03-6-022-35208 Research Unit # 447
Period January 1 to March 31, 1977

Title: Studies of Populations, Community Structure and Ecology of Marine Birds at King Island, Bering Strait Region, Alaska.

A. Library Activities

2. Scientific party

William H. Drury	Reducing data, writing report
Benjamin B. Steele	Reducing data, writing report
Mary C. Drury	Accounts
Peter L. Drury	Preparing data and entering on forms

5. Data analysed

The entire period was spent writing the annual report and preparing accounts/budgets.

a. Data from field notebooks were reduced. Graphs, maps and illustrations were prepared. Text was written.
b. Accounts for 1976 were summarized and budgets for 1977 prepared.
c. Data from field notebooks and sheets were transcribed onto forms to be given to key-punch operator.

6. Data submission schedule

a. The annual report was put in the mail on March 25.
b. Seventy-five percent of the data for 1976 have been entered onto forms. We have been notified that it will require six months for the data to be punched after they are in the hands of the operator.

B. Problems

1. We have not heard from the people of Little Diomede Island whether they will give us permission to go to the island. We plan to send a copy of our annual report as usual to the Bering Straits Native Corporation and will ask them to enquire of the Little Diomeders what their thoughts or decisions are. Unless we hear soon it will be too late to arrange logistics. We do not want to be caught in the position we were in 1976 with regard to King Island. We want to have our agreements in writing before we go.
2. Our contract reads for work to be done at King Island. It will be necessary to have the contract modified to allow us to use the money to work at other islands, because we had planned to use the people in the 'King Island' party for other work when they were not on the island.

4th quarter report Research Unit #447

C. Estimate of funds expended

CPF 1	Salaries	$ 11,200
CPF 2		0
CPF 3		1,030
CPF 4		250

QUARTERLY REPORT

RU 337

SEASONAL DISTRIBUTION AND ABUNDANCE OF MARINE BIRDS

By

Calvin J. Lensink
Patrick J. Gould
Craig S. Harrison

U. S. Fish and Wildlife Service
Office of Biological Services - Coastal Ecosystems
800 A Street - Suite 110
Anchorage, Alaska 99501

July 1, 1977

Contract: 01-5-022-2538
Reproting Period: April 1 - June 30, 1977
Research Unit: RU 337
Number of Pages: 5

SEASONAL DISTRIBUTION AND ABUNDANCE OF MARINE BIRDS
APRIL - JUNE, 1977

Major activities for this reporting period include: data management, site-specific shipboard surveys in offshore and nearshore Kodiak Island waters, aerial reconnaissance surveys of the Saint George Basin, Southern Bering Sea, Alaskan Peninsula South, Shelikof Straits, Lower Cook Inlet and Kodiak Island areas, and the preparation of the FY78 funding proposal.

Data Management

Table 1 is a summary of the status of all RU 337 digital data as of June 30, 1977. We are aiming at a final tape submission for all 1975-1976 data of September 30, 1977.

Shipboard Surveys

The first leg of the 1977 charter vessel surveys (FW7032) was conducted from May 22 through June 3, 1977, in the nearshore and offshore Kodiak Island waters from Marmot Bay south and west to the Southern Albatross Bank area. A number of observations were also made on the transit from Seward to Chiniak Bay (Figure 1). Poor weather during most of the survey prevented extended offshore work, especially in the Chiniak Bay area.

Thirty-five bird species were recorded on 276 transects completed during the first charter vessel leg. Estimated marine bird densities per transect ranged from 0.3 birds/km2 to 5,045 birds/km2 with highest densities occurring over A) nearshore waters south of Narrow Cape (= 102 birds/km2), B) offshore waters north of Narrow Cape (= 143 birds/km2), and C) offshore waters between Seward and Kodiak (= 94 birds/km2). High densities were primarily the result of large shearwater concentrations, the largest being 60,000 Slender-billed Shearwaters just west of Ugak Island. A preliminary review of the data suggests that highest foraging concentrations of marine birds occur over bank areas adjacent to steep shelf slopes.

The second leg of the charter vessel surveys (FW7033) began on June 15, and had not terminated as of the writing of this report.

Aerial Surveys

Aerial surveys for this reporting period were completed on 21-26 April, 19-20 May and 17-18 June, 1977. All three surveys covered Lower Cook Inlet and Kodiak Basin while the April survey additionally surveyed Shelikof Strait, Alaska Peninsula South, Saint George Basin and Bristol Bay.

A proposed intercalibration of aerial and shipboard indices in June was concelled due to the inability of the charter vessel to work in offshore waters in any but the most ideal weather conditions. This work is indefinitely postponed until logistic arrangements with a NOAA vessel can be made.

TABLE 1. Status of RU337 digital data as of June 30, 1977.

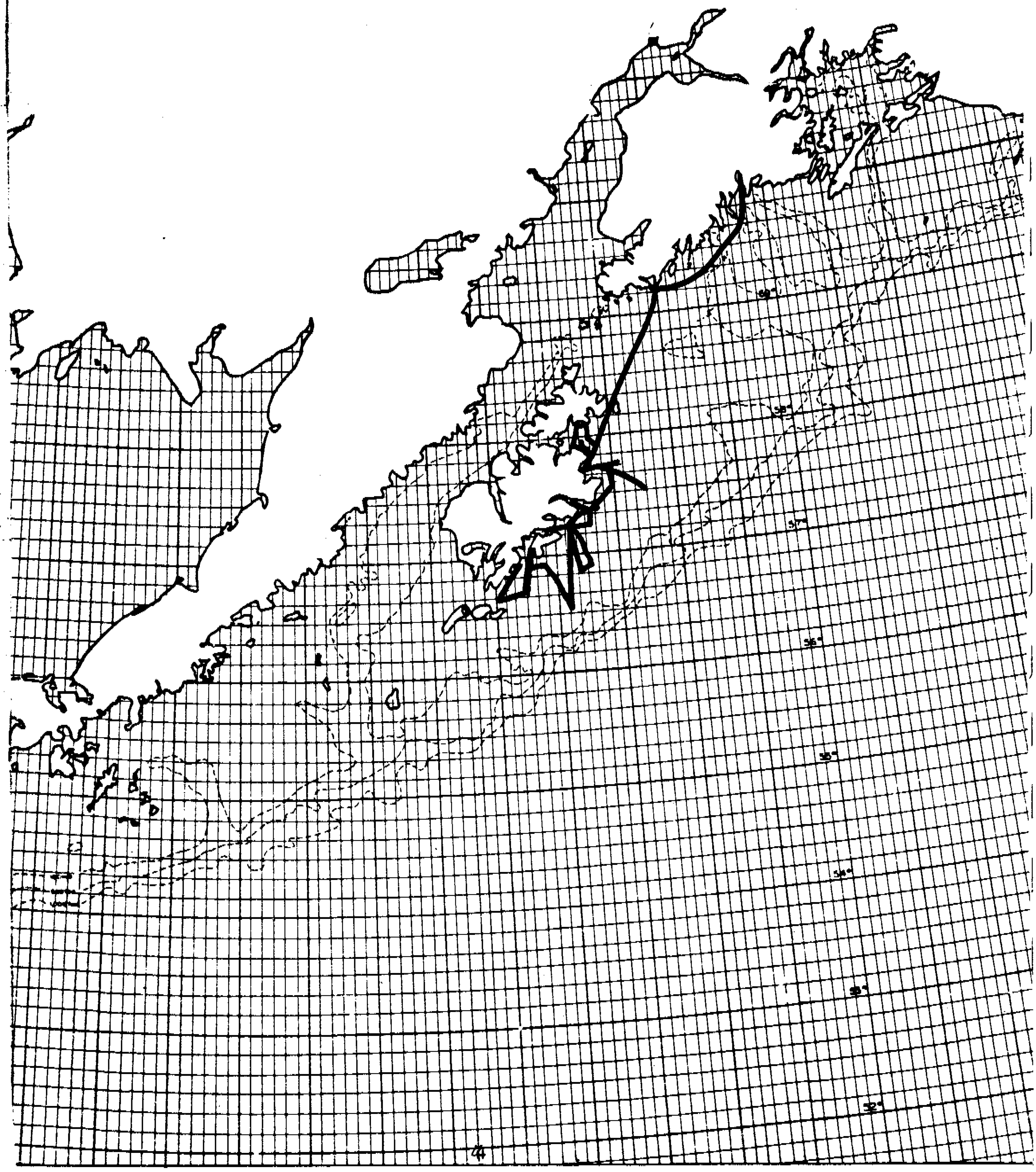
FIELD OPERATION NUMBER	DATA TRANSCRIBED	DATA KEY-PUNCHED	PRELIMINARY DATA EDITING COMPLETED	TAPE SENT TO HAL PETERSON	FINAL TAPE SUBMITTED
FW5003	XXX	XXX	000	000	000
FW5004	XXX	XXX	XXX	NA	XXX
FW5006	XXX	XXX	000	000	000
FW5008	XXX	XXX	XXX	XXX	000
FW5009	XXX	XXX	XXX	NA	XXX
FW5010	XXX	XXX	000	000	000
FW5011	XXX	XXX	XXX	XXX	000
FW5012	XXX	XXX	XXX	XXX	000
FW5013	XXX	XXX	XXX	NA	XXX
FW5014	XXX	XXX	XXX	000	000
FW5015	XXX	XXX	XXX	XXX	000
FW5016	XXX	XXX	XXX	XXX	000
FW5018	XXX	XXX	XXX	NA	XXX
FW5020	XXX	XXX	XXX	XXX	000
FW5021	XXX	XXX	XXX	XXX	000
FW5022	XXX	XXX	000	000	000
FW5023	XXX	XXX	XXX	NA	XXX
FW5024	XXX	XXX	XXX	NA	XXX
FW5025	XXX	XXX	XXX	XXX	000
FW5026	XXX	XXX	XXX	XXX	000
FW5027	XXX	XXX	XXX	XXX	000
FW5028	XXX	XXX	XXX	NA	XXX
FW5029	XXX	XXX	XXX	000	000
FW5030	XXX	XXX	XXX	NA	XXX
FW5031	XXX	XXX	XXX	XXX	000
FW5032	XXX	XXX	XXX	NA	XXX
FW5033	XXX	XXX	XXX	XXX	000
FW5034	XXX	XXX	XXX	XXX	000
FW5035	XXX	XXX	XXX	XXX	000
FW5036	XXX	XXX	XXX	000	000
FW5037	XXX	XXX	XXX	000	000
FW5038	XXX	XXX	000	000	000
FW6001	XXX	XXX	XXX	XXX	000
FW6002	XXX	XXX	XXX	XXX	000
FW6004	XXX	XXX	XXX	000	000
FW6005	XXX	XXX	XXX	000	000
FW6006	XXX	XXX	000	000	000
FW6007	XXX	XXX	XXX	XXX	000
FW6008	XXX	XXX	XXX	XXX	000
FW6009	XXX	XXX	XXX	XXX	000
FW6010	XXX	XXX	000	000	000
FW6011	XXX	XXX	XXX	000	000
FW6012	XXX	XXX	000	000	000
FW6013	XXX	XXX	000	000	000
FW6014	XXX	XXX	000	000	000
FW6015	XXX	XXX	XXX	XXX	000

TABLE 1. Continued.

FIELD OPERATION NUMBER	DATA TRANSCRIBED	DATA KEY-PUNCHED	PRELIMINARY DATA EDITING COMPLETED	TAPE SENT TO HAL PETERSON	FINAL TAPE SUBMITTED
FW6016	XXX	XXX	XXX	000	000
FW6018	XXX	XXX	XXX	XXX	000
FW6019	XXX	XXX	XXX	XXX	000
FW6021	XXX	XXX	XXX	XXX	000
FW6025	XXX	XXX	XXX	000	000
FW6026	XXX	XXX	XXX	XXX	000
FW6027	XXX	XXX	XXX	XXX	000
FW6028	XXX	XXX	XXX	000	000
FW6029	XXX	XXX	XXX	XXX	000
FW6050	XXX	XXX	XXX	XXX	000
FW6051	XXX	XXX	XXX	XXX	000
FW6052	XXX	XXX	XXX	000	000
FW6057	XXX	XXX	XXX	XXX	000
FW6064	XXX	XXX	XXX	XXX	000
FW6066	XXX	XXX	XXX	XXX	000
FW6067	XXX	XXX	XXX	XXX	000
FW6068	XXX	XXX	XXX	XXX	000
FW6070	XXX	XXX	XXX	XXX	000
FW6074	XXX	XXX	XXX	XXX	000
FW6077	XXX	XXX	XXX	000	000
FW6078	XXX	XXX	XXX	000	000
FW6082	XXX	XXX	000	000	000
FW6083	XXX	XXX	XXX	XXX	000
FW6084	XXX	XXX	000	000	000
FW6085	XXX	XXX	XXX	000	000
FW6086	000	000	000	000	000
FW6087	XXX	XXX	000	000	000
FW6088	XXX	XXX	XXX	XXX	000
FW6089	XXX	XXX	XXX	XXX	000
FW6092	XXX	XXX	000	000	000
FW6093	000	000	000	000	000
FW6094	XXX	XXX	XXX	XXX	000
FW6095	XXX	XXX	XXX	XXX	000
FW7026	XXX	XXX	000	000	000
FW7027	XXX	XXX	000	000	000
FW7028	000	000	000	000	000
FW7029	000	000	000	000	000
FW7031	000	000	000	000	000
FW7032	XXX	000	000	000	000
FW7045	000	000	000	000	000

XXX = completed, 000 = not completed, NA = Not Applicable

FIGURE 1. Marine Bird Observation Transits on the May-June Charter Vessel Survey.



Contract: 01-5-022-2538
Period: 1 April - 30 June 1977
RU: 338

QUARTERLY REPORT

SEABIRD COLONY CATALOG

Principal Investigators
C. J. Lensink and K. D. Wohl

U. S. Fish and Wildlife Service
Office of Biological Services - Coastal Systems
800 A Street Suite 110
Anchorage, Alaska 99501

July 1977

I. INTRODUCTION. Research Unit 338 is designed to help satisfy OCSEAP task objective E which is "what are the biological populations and ecological systems most subject to impact from petroleum exploration and development?" More specifically, this RU helps satisfy Task E-3 which is "to determine the seasonal density distribution, critical habitats, migratory routes, and breeding locales of key marine bird species." The Seabird Colony Catalog contains maps showing the location and approximate size of all known seabird colonies in Alaska and provides a summary of existing information on each colony including general characteristics, species present, approximate populations, photographs, maps and relevant reference material.

II. TASK OBJECTIVE

The objective of this Research Unit is to catalog the location of seabird colonies including data such as species composition and population estimates.

III. OFFICE, FIELD AND LABORATORY ACTIVITIES

A. Field Schedule

Study Site	Site Occupancy	FWS Personnel	Task Objectives
Trinity Islands	Late May	K. Wohl C. Harrison	Catalog new seabird colonies
Sundstrom/Aiatalik Islands	Late May	K. Wohl C. Harrison	"
Flat Island	Late May	K. Wohl C. Harrison	"
Middleton Island	Early June	A. Sowls et al.	"
Chirikof Island	Late June	A. Sowls A. DeGange	"
St. Matthew Island/ Hall Island	July, Aug.	A. Sowls A. DeGange	"

Chamisso Island	August	A. Sowls A. DeGange	"

B. Data Management Schedule

Activity	Time Period	FWS Personnel
Passive Data Collection	October to April	A. Sowls
Prepare Colony Maps & Tables	October to June September to April	"
Data Transcription and Tape Submission	October to June September to April	"

C. Methods

See our Annual Report of 1 April 1977.

IV. RESULTS

Primary efforts during this quarter have been directed toward summarization of unpublished colony data and transcription of colony data. To date, we have transcribed all colony information for the northeast and western Gulf of Alaska regions; that data is presently being key punched. Transcription of colony data for the Bering Sea, Chukchi Sea, Beaufort Sea, Alaska Peninsula/Aleutian Islands and SE Alaska is continuing.

Contract: 01-5-022-2538
Period: 1 April - 30 June 1977
RU: 341

QUARTERLY REPORT

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

Principal Investigators
C. J. Lensink and K. D. Wohl

U. S. Fish and Wildlife Service
Office of Biological Services - Coastal Systems
800 A Street, Suite 110
Anchorage, Alaska 99501

July 1977

I. INTRODUCTION. Research Unit 341 is designed to help satisfy OCSEAP task objective E which is "what are the biological populations and ecological systems most subject to impact from petroleum exploration and development?" More specifically, this RU helps satisfy tasks E-3 and E-4 which are to "determine the seasonal density distribution, critical habitats, migratory routes, and breeding locales of key marine bird species "and" to describe dynamics and trophic relationships of key marine bird species at offshore and coastal study sites" (FY 78 OCSEAP TDP). Since our personnel are in the field, this report is necessarily brief and cursorily reviews those activities which occurred from 1 April to 1 July 1977.

II. TASK OBJECTIVES

A. To determine the reproductive success and the chronology and phenology of breeding events for key seabird species at selected colonies.

B. To determine the amount, kinds and trophic levels of prey utilized by key seabird species and, when possible, to determine the relationship of prey selected to prey availability, and to describe feeding cycles, areas, and behavior.

C. To determine the species composition, numerical abundance, timing, and habitat use of selected seabird colonies.

III. OFFICE, FIELD AND LABORATORY ACTIVITIES

A. Field Schedule

Study Site	Site Occupancy	FWS Personnel	Task Objectives
Wooded Islands	Mid April	P. Mickelson et al.	Pop. Dynamics/ Breeding Success Beached Bird Survey & Colony Inventory
Barren Islands	Early May	D. Manuwal D. Boersma et al.	Pop. Dynamics/ Breeding Success Feeding Ecology & Colony Inventory
Chiniak Bay	Late May	D. Nyswander E. Hoberg	Pop. Dynamics/ Breeding Success Beached Bird Survey Colony Inventory and Feeding Ecology
Sitkalidak Straits	Late May	P. Baird A. Moe	Same as above
Ugaiushak Island	Mid April	D. Wehle et al.	Same as above
Chowiet Island	Mid April	S. Hatch et al.	Same as above

Nelson Lagoon	Mid April	R. Gill C. Handel M. Peterson J. Nelson	Same as above
Kodiak Pelagic Feeding Ecology Study (Charter Vessel)	26 May-3 June 18 June-29 June	G. Sanger V. Hironaka J. Guzman D. Forsel P. Gould	Feeding ecology and at sea population assessment & distribution
Unimak Pass	Early April-Mid May	J. Nelson et al.	Migration Survey

B. Laboratory Schedule

	Through 1 April 1977	Through 10 June 1977	Total Through 10 June 1977
Accessioned Food Samples into Collection	798	153	951
Final Analysis and Transcription	19	286	305

C. Methods

See our Annual Report of 1 April 1977 and draft FY 78 proposal renewal.

Our intertidal invertebrate sampling scheme at Nelson Lagoon was initiated in June, 1977 and is an integral part of our feeding and trophic relationship study. Two 50-meter transect lines were established adjacent to the Nelson Lagoon field camp. Five stations have been established along each transect whereby five samples each are periodically obtained. The sample equipment is a clam gun which is used to obtain a sample 14 cm in depth, i.e., equal to a volume of 1 liter. Each sample is sorted through 2 mm and .59 mm sieves. All organisms retained in both seives are preserved in 10% formalin and later transferrred to 50% isopropanol solution.

IV. RESULTS

Field activities under this RU were largely restricted to the Gulf of Alaska and southern Bering Sea. Major field accomplishments during this quarter included preparation for and occupation of our site-specific intensive colony study areas at Wooded Islands, Barren Islands, Chiniak Bay, Sitkalidak Straits, Ugaiushak Island, Chowiet Island and Nelson Lagoon. These study sites were selected because of the presence of and accessibility to key species, diversity of habitat,strategic location in relation to potential vulnerability of the locale to impacts from OCS activities, and/or continuation of previously initiated studies.

Attached as an Appendix are quarterly reports prepared for the University of Alaska's Cooperative Wildlife Research Unit's Quarterly Report, Vol.28(3), on our Wooded Islands and Copper River Delta studies.

We also initiated a 70-day, 5-leg cruise associated with our pelagic feeding study with the acquisition of our charter vessel "Yankee Clipper", a 52-ft. vessel from Cordova, Alaska. Seabird distribution and abundance observations are also being collected in support of RU-337 at no additional cost. The vessel is also used to a limited extent in resupplying and supporting our data collection efforts at our Sitkalidak Straits field camp.

A total of 138 birds have been collected for determination of food habits during the first two legs of the charter vessel operation. Species collected were Sooty and Short-tailed Shearwaters, Black-legged Kittiwakes, Tufted Puffins and Common Murres. Most birds have been collected in the offshore regions of Marmot Bay and Albatross Banks.

A radio network linking our above field camps, charter vessel, and Anchorage FWS office has been established. This network has provided for timely exchange of biological and logistical information and a measure of safety for our personnel.

During this quarter, our 1976 field camp data were key punched and returned for our verification and submission. In addition, preparation and Juneau Project Office review of our FY 78 proposal renewal occurred during this quarter. Our personnel participated in the TDP Review and Research Planning Committee meetings in Boulder, Colorado in June.

Project Title

The food habits of migrating dunlins (*Calidris alpina*) and western sandpipers (*Calidris mauri*) in the Copper River Delta area, Alaska.

Investigator: Stan Senner
Advisors: Dr. David W. Norton (committee chairman) and David R. Klein
Funding: U.S. Fish and Wildlife Service.

Objectives

1. Determine the diet of shorebirds with emphasis on dunlins and western sandpipers while they are feeding, primarily on tidal flats. Food habits will be considered in relation to time of year, location within region, daily tide cycles, and patterns of feeding within the tidal flats habitat.
2. Determine the availability, abundance, and productivity of food items utilized on the tidal flats. The prey species will be considered in relation to time of year, location within region, daily tide cycles. and intrahabitat distribution.
3. Determine the condition of dunlins and western sandpipers in terms of body fat as they arrive in and leave the region.

General

Dr. Frank Pitelka chaired a special Shorebird Symposium at the 3rd Annual Meeting of the Pacific Seabird Group at Pacific Grove, California, 6-9 January. I attended the meeting and presented a paper titled "An evaluation of the Copper River Delta as critical habitat for migrating shorebirds". This paper will be published in the proceedings of the Shorebird Symposium edited by Dr. Pitelka.

Virtually all laboratory work regarding stomach and intertidal invertebrate samples was completed. Data from shorebird censes were punched onto computer cards. Card punching for invertebrate samples, stomach samples, and shorebird specimens was initiated.

Plans for Next Quarter

Computer analyses using the Statistical Package for the Social Sciences (SPSS) will be completed and the thesis written.

Project Title

A comparison of habitats used by four species of alcids nesting on Fish Island, Prince William Sound, Alaska[1].

Investigator: William Lehnhausen
Advisors: Drs. Peter G. Mickelson (committee chairman), David R. Klein and Brina Kessel
Funding: U.S. Fish and Wildlife Service

Objectives

1. Determine the total number of tufted puffins, horned puffins, pigeon guillemots, and parakeet auklets using nesting habitat on Fish Island.
2. Determine distribution patterns of the 4 alcids, including general areas, specific habitats, and nest sites.
3. Compare distribution patterns of the 4 alcids and identify the major factors affecting the nesting of each species.
4. Compare utilization of nesting habitat by the 4 alcids on Fish Island with the same species in other geographic areas.

General

Much of the quarter was spent doing classwork. Course requirements will be completed this semester. During this quarter an annual report for U.S. Fish and Wildlife Service was written. This report included a narrative of observations and data gathered during the 1976 field season.

The specific thesis project has been altered slightly. Instead of working with the nesting habitat of the tufted puffin on all islands, the 4 alcids concomitantly nesting on Fish Island will be studied.

[1]The previous title of this project was "Distribution and abundance of tufted puffins at Wooded Islands, Alaska".

Four species of alcids on Fish Island, parakeet auklet, pigeon guillemot, horned puffin, and tufted puffin may show preferences for specific nest sites, thereby minimizing overlap of nesting sites. Observations in 1976 revealed similar habitats used by some of these species for nest sites (Table 1). Table 1 suggests there is potential for overlap and competition for nesting sites. In addition, phenology (mainly arrival at colony, nest site defense, and egg-laying) may be a factor reducing competition between species. If one species is able to initiate breeding earlier than another species, the first may occupy preferred nest sites. This assumes preferred nest sites are limited. Bedard (1969) found 3 species of plankton feeding alcids on St. Lawrence Island selected different nesting habitats.

The tufted puffin is the most abundant breeder on Fish Island. Using both raft counts and burrow density for various habitats there were approximately 1125 pairs nesting. Iselib (pers. comm.) in 1972 estimated 7000 pairs in the Wooded Island group. During his 16 August 1974 survey he estimated 1100 pairs at Fish Island. Earthen burrows are the most frequently used nest sites of tufted puffins on Buldir Island (Wehle 1976). Sealy (1973: 107) found tufteds nesting to a small degree in the "rubble at the base" of a slope. On Fish Island I considered the tufted puffins to be utilizing 4 different types of habitats; cliff edge, cliff face, rocky slope, and grassy slope. Cliff edge and grassy slope nests were burrows in soil while rocky slope and cliff face nests were in natural cavities.

Nettleship (1972) and Grant and Nettleship (1971) used a number of nest measurements to look at nest site utilization and habitat selection for common puffins. Distance to cliff edge and angle of slope were found by Nettleship (1972) to have a significant affect on nesting success of common puffins. Burrow density was correlated most closely with distance from cliff edge and perimeter of boulders in Grant and Nettleship's study (1971). To investigate habitat utilization by tufted puffins I established 4 transects on Fish Island; one 14 m wide by 55m long on a vegetated rocky slope, one 14m wide by 64m long on an unvegetated rocky slope, one (actually a large plot) 25m wide by 15m long on a grassy slope, and consecutive plots 10m wide by 5m long along the cliff edge (140m done in 1976). Nests within these transects were measured for 15 different characteristics. In the vegetated rocky slope only 14 burrows were found for an average of 2 per $100m^2$ while in the unvegetated rocky slope there was an average of 4 per $100m^2$ (34 burrows). A rocky slope transect (14m wide by 62m long) on Tanker Island for comparison had an average of 7 burrows per $100m^2$ (60 burrows). A rocky slope transect was started but not completed on South Island due to inclement weather. Within the lower 45m, 22 burrows were found, or approximately 3 burrows per $100m^2$. This was probably representative of the entire transect.

Twenty-five completed burrows were found in the grassy slope transect on Fish Island for an average of 7 burrows per $100m^2$. No other grassy slope transects were run which would be comparable to the one on Fish Island.

In 1976 over 140m of cliff edge were searched for burrows resulting in an average of 11 burrows per $100m^2$. This is a small part of the estimated cliff perimeter, most of which contains burrows of puffins. Another cliff edge transect was conducted completely around Tanker Island. Along the 377m of cliff edge there were 510 burrows, or an average of 14 per $100m^2$. These averages may be deceiving because in both transects 83 percent of the burrows were within 2m of the cliff edge.

Preliminary analysis indicates distance from cliff edge is an important factor influencing nest site location for cliff edge burrows. On rocky slopes boulder size may influence availability of nest sites while soil depth could be a determinent on grassy slopes. In all areas the slope of land may influence selection and utilization of a possible nest site. This hypothesis will be tested.

Horned puffins were the least numerous, approximately 5 pairs. Although no eggs or chicks were observed, nesting probably occurred. Isleib (pers. comm.) made brief surveys in 1972 and 1974. He estimated 300 pairs of horned puffins in the island groups during 1972 and 50-100 pairs on Fish Island alone in 1974. Nesting habitat for horned puffins is generally considered to be deep holes between rocks or deep crevices in cliff faces (Sealy 1973). These birds have been known to burrow only on Kodiak Island (Bretherton 1896) and Chamisso Island (Grinnell 1900). "Rock crevices beneath the soil-covered slope" was the main substrate used by horned puffins on Buldir Island (Wehle 1976:15). Horned puffins I observed were mainly near crevices in vertical cliff faces. These birds were seen from early June on, flying by the cliffs and sitting on certain ledges on the cliff face. Horned puffins were probably the last of the 4 alcids to arrive at the colony. Tufted puffins used the same areas and probably the same type of nest sites as horned puffins. For this reason some horned puffins may have been excluded from breeding due to nest sites already being occupied, although the numbers of horned puffins were very low. One bird was observed flying into a hole underneath a small boulder 17.5m from the water at the base of a rocky slope. No egg or nest could be seen from the entrance. Horned puffins were seen on many occasions flying by this area as well as landing on the rocks 10-20m away. A mid-August search of the cliff-face where horned puffins had been seen sitting, revealed only 2 rock-crevice nests of tufted puffins.

During 1976, 30 pigeon guillemot pairs were thought to be breeding on fish Island. Isleib saw no pigeon guillemots around the island in 1974 but in 1972 he estimated 500 pairs around the whole Wooded Island group. The pigeon guillemot is noted for its diversity of nesting sites, occupying the whole range of nest types used by the auk family (Storer 1952). Cover seems to be important around natural holes, cavities and burrows that have been recorded as pigeon guillemot nests (Drent 1965). Nine nests were located on the north side of Fish Island. Of these, 3 were in crevices of the cliff-face the otherswere between boulders of the rocky slopes. One additional guillemot nest was found on Tanker Island in a small crevice in the cliff face.

Only 25 parakeet auklets are thought to have nested on Fish Island in 1976. Isleib in 1972 reported over 100 pairs probably nesting in the Wooded Islands. On his 16 August 1974 survey auklets were not reported but they may have been missed due to the late date. These birds along with the Smith Island colony (Nysewander pers. comm.) represent the eastern most breeding parakeet auklets. Sealy and Bedard (1973:61) briefly describe the types of nest sites used by parakeet auklets on St. Lawrence Island. Talus slopes of "weakly weathered outcrops" as ridges near the edge of mountain "and on the peaty slopes where most of the boulders are covered with soil and vegetation" served as nesting areas. In most of their range parakeet auklets are characterized as cliff-nesters, except in the Pribilof Islands where talus slopes of rounded boulders are used (Bent 1919). Two actual nests and the general area of a third nest were found on Fish Island in 1976. All of the nests were in cracks of large boulder piles and 15m or less from the waterline. These nests were within the same area as nesting pigeon guillemots and tufted puffins (one of the presumed horned puffin nests was also in the same area).

Literature Cited

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Bent, A. C. 1919. Life histories of North American diving birds. U.S. Nat. Mus. Bull. No. 107. 239 pp.

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Table 1. Nesting habitats on Fish Island and species utilizing the areas in 1976.

Grassy Slope	Cliff Edge	Cliff Face	Rocky Slope
tufted puffin	tufted puffin	tufted puffin	tufted puffin
	pigeon guillemot	pigeon guill.	pigeon guillemot
		horned puffin	horned puffin
			parakeet auklet

Project Title

Breeding biology of storm petrels of Wooded Island, Alaska.

Investigator: Susan E. Quinlan
Advisors: Drs. Peter G. Mickelson (committee chairman), Samuel J. Harbo, Jr., and Stephen F. MacLean, Jr.
Funding: U.S. Fish and Wildlife Service

Objectives

1. Estimate population size and productivity of Wooded Island fork tailed and Leach's storm petrels colonies.
2. Determine the effects of colony density on breeding success.
3. Further determine the effects of predation on nesting success of storm petrels, with emphasis on river otter predation.

4. Further determine breeding phenology, molt schedule, breeding behavior and chick growth patterns.

5. As possible, obtain information on food habits, aging and sexing techniques and habitat preference.

General

During the past quarter, the investigator attended classes at the University of Alaska. Work on literature review and data processing continued. She attended the Pacific Seabird Group conference in Monterey, California. An annual report was prepared for the U.S. Fish and Wildlife Service. Estimates of colony size and productivity in 1976 on Fish Island were finalized.

The nocturnal habits of storm petrels, and the density of vegetation on Fish Island made census work difficult. Two methods of population estimate were used. Capture-mark-recapture techniques using nocturnal banding operations yielded estimates of total active birds on Fish. Transects across the island, following the technique of Nettleship (1976) were used to obtain an estimate of the number of breeding pairs.

A total of 43 nights of banding between 23 May and 2 August yielded 810 fork-tails and 86 Leach's storm petrels. Data were grouped for use in the Schnabel method of population estimation based on 50 recaptures. This method yielded an estimate of 4,800 fork-tails and 400 Leach's storm petrels. Net sites varied throughout the summer. While this estimate could be used as a rough index to population size, there are many inherent faults with the technique. Adult and juvenile birds cannot be separated. Since juvenile birds may only visit the island sporadically, this would include the effect of both immigration and emmigration which would result in an over-estimate of the population. Harris (1974) indicated that storm petrels at Trinidad Rocks in California did not fly over the entire island on their nightly visits, but flew over the same area on each visit. Birds with burrows in the vicinity of the net would thus be more likely to be caught than birds nesting in another area. Also, netting with this technique was not conducted on the rocky slope areas of the island due to safety considerations. Hence, the estimate does not pertain to birds utilizing that area. Estimates using this technique appear to be of limited value, although future comparisons, using the same techniques with nets in the same locations, over the same period of time might reflect population changes through time.

According to Nettleship (1976) transects across a petrel colony are useful for population estimation. Thus 6, 3m wide transects across Fish Island were used to determine burrow density. As shown in Fig. 1 sub-colonies of petrels were located on the perimeter of the central plateau on Fish Island. Due to the clumped distribution of petrel subcolonies, the transects were not as valuable as originally hoped. However, estimates of burrow density were obtained in the transects, and in plots set up in subcolonies. Along with estimates of burrow density based on mean distance between burrow, an estimate of burrow density around the perimeter of Fish Island was made. The major difficulty with this technique is obtaining an accurate estimate of the available habitat within 12m of the cliff edge. High altitude infrared photos were used to map Fish Island and by counting the squares within the 12m parameter, a total area estimate of 8,554m^2 was obtained. Unfortunately, due to the conversion factor of 1 cm:2904 there is a great deal of error associated with the estimate of area. Total population estimate for the plateau of Fish, based on this technique yields an estimate 1842 burrows. Conversion factors based on 1976 data for burrow activity and percent burrows with eggs (See Table 1) yield an estimate of 1026 breeding pairs, further divided into 820 fork-tailed and 205 Leach's storm petrel breeding pairs. Since active burrows not containing eggs are utilized by non-breeding birds, the estimate of active burrows without eggs can be used to estimate non-breeding birds visiting the island. Since each burrow may be utilized by 1, 2 or 3 birds this estimate ranges from 400 to 1200 non-breeding fork-tails and 50 to 150 Leach's storm petrels. Again, however, emphasis on the error associated with this estimate must be stressed. The estimate could be improved measuring all available habitat on the island, however this does not appear to be worth the cost in time. For the purposes of future comparisons of the population of petrels on Fish Island, selected plots and carefully mapped subcolony areas should yield useful information. Three such plots were marked and studied last year and during 1977 several more of these plots will be established. Comparisons of density, breeding success, and activity in these plots over a long period of time will provide more precise information about storm petrel population changes than total population estimates based on either of the above techniques.

Similar plots will be established on the rocky areas of Fish Island and on South Island next field season.

Plans for Next Quarter

The investigator will be in the field from 13 April until mid-October 1977. Since the remote location of the study area precludes a contribution to the quarterly report during this time period, a detailed description of the plans for the field season are provided here.

Census and Productivity

The researcher will maximize population estimate effort by establishing permanent plots and delineating and measuring subcolonies on both Fish and South Islands. Plots, 1m x 12m will be placed along the entire cliff edge of Fish Island. In areas of known storm petrel subcolonies, a systematic sample of plots, with 3 replications will be made. A systematic sample of the remaining cliff edge will be made using plots 3m x 12m. If subcolonies are located in new areas, these will be sampled in the same manner as those already known.

In each plot, vegetation, soil depth, and all burrows will be noted. Each burrow will be examined for activity. The plots will not be disturbed between the time of egg-laying and hatching, except for the initial check.

On the rocky areas of Fish, transects 3m by the length of the slope will be used for estimating nesting density. These transects will be run at night and all crevices where storm petrels are heard calling will be marked. A diurnal check of these marked crevices will be made to determine if the burrow is active. Due to the large size of boulders in this rocky slope, most burrows are inaccessible and signs of petrel activity (droppings, diurnal calling, smell, feathers) will be used as evidence of activity. This will provide a rough estimate of the number of breeding birds in that area.

Due to the inaccessible location of South Island, and the uncertainty about the status of storm petrels there, visits will probably be limited to 3 or 4 weeks during the field season. Several nights early in the field season will be necessary to determine the location of nesting petrels. Tenatively, colonies will be roughly delineated and plots 1m by the width of the subcolony will be used in a systematic sample across the area.

Phenology

Phenology will be based on information collected during census work, nightly banding operations, and selected burrows. Smoked index cards will be used for monitoring incubation shifts. If this technique is successful adults may be web-tagged for individual identification. Thirty chicks will be selected for daily weight measurements. All others will be checked at 9 day intervals.

Predation

Both common ravens and river otters prey on storm petrels on Fish Island. Glaucous-winged gulls may prey on storm petrels on South Island. Thus, castings of all avian predators, and droppings of river otters will be collected regularily throughout the summer. These will be examined upon returning to the lab.

River otter predation will be carefully studied on Fish Island. Three exclosures will be set up on peninsulas of high petrel nesting density and cliffs will be used as one or more sides of the otter exclosure. Exclosures will be similar to that described by Sargeant et al. (1974). Guards of chicken wire will extend 0.2 meters beyond the cliff edge.

Otter trails on Fish Island will be monitored using smoothed plots to detect otter movements. Checks will be made at daily intervals, and as possible throughout the day and night.

Literature Cited

Harris, S. W. 1974. Status, chronology, and ecology of nesting storm petrels in northwestern California. Condor 76:249-261.

Nettleship, D. N. 1976. Census techniques for seabirds of arctic and eastern Canada. Can. Wildl. Serv. Occas. Pap. No. 25. 31 pp.

Sargeant, A. B., A. D. Kruse and A. D. Afton. 1974. Use of small fences to protect ground bird nests from mammalian predators. The Prairie Naturalist 6:60-63.

Table 1. Nesting success of storm petrels on Fish Island in 1976. Plots A and B were disturbed by river otters before the study began; plot C was disturbed by otters after study began. All values are expressed as percentages.

	Plots			Mean[3]
	A	B	C	
Inactive burrows	40 (24)[2]	24 (15)	37 (11)	19 (134)
Active burrows	60	86	63	81
Active with eggs	85	54	77	69
Eggs destroyed/otter	67	29	29	25
Eggs deserted	17	14	29	17
Eggs hatching	17	57	43	58
Chicks lost to otter	100	50	33	33
Chicks lost to other[1]	0	0	25	5
Young fledged/egg	0	29	14	31
Production lost/otter	83	57	43	48
Production lost/other	17	14	43	21

[1] Other causes include starvation, chick killed by adult, and unknown.

[2] Parentheses indicate the sample size, n.

[3] Mean for all burrows studied, inside and outside plots.

Quarterly Report

Contract 03-5-022-56
Task Order #27
Research Unit #441
Reporting Period 4/1/77 - 6/30/77

AVIAN COMMUNITY ECOLOGY AT TWO SITES ON ESPENBERG PENINSULA IN KOTZEBUE SOUND, ALASKA

Dr. P. G. Mickelson
Institute of Arctic Biology
University of Alaska
Fairbanks, Alaska 99701

June 30, 1977

I. Task Objectives

To determine the baseline ecology of two geographically close avian breeding sites. To compare the results between sites and insofar as possible and determine the possible effects of oi.l related pertubations on these areas.

II. Field and Laboratory Activities.

A. Field Activities

All personnel associated with this project are currently conducting on site field observations. These persons are not able to be contacted concerning the progress made during the last quarter.

B. Laboratory Activities

None.

III. Results

None presently available.

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 27 R. U. #441

PRINCIPAL INVESTIGATOR: Dr. P. G. Mickelson

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		Estimated Submission Dates[1]			
	From	To	Batch 1	2	3	4
1976 Field Season	6/4/76	9/15/76	6/30/77	6/30/77	5/30/77	9/30/77
1977 Field Season	Current					
			Batch 5	6	7	8
1976 Field Season			5/30/77	5/30/77	4/30/77	4/30/77
1977 Field Season						

Data submission delayed due to current field season.

1 Data management plan has been submitted and approved by F. Cava; we await contractual approval.

QUARTERLY REPORT

Contract #: 03-6-022-35208
Research Unit #: 447
Reporting Period: 1 April - 30 June 1977
Number of Pages: 6

Site Specific Studies of Seabirds at King Island and Little Diomede Island

by

William H. Drury
Principal Investigator
College of the Atlantic

July 1, 1977

I. Task Objectives

1. To determine the numbers and distribution of species of seabirds.

2. To describe the schedule and phenology of events during occupation of cliffs and the breeding period.

3. To examine trophic relations by making estimates of reproductive success, by determining distribution and concentrations of feeding birds at sea, and by establishing the species used as food.

4. To provide data for comparative purposes in the same and other regions.

II. Field Activities

1. Schedule

May 15, 1977, first party to Nome.
May 18, 1977, party of two to Little Diomede Island.
June 10-17, attempts to fly third member of party to the island failed as sea ice was breaking up.
June 26, third member of party arrived on the island.

2. Scientific Party

Ben Steele, Utah State Univ., in charge of field party.
Alan Watson, member of field party.
Edward Steele, member of field party.

3. Methods

Field methods have been described in detail in proposals and annual reports.

a. Daily observations of the kinds, numbers and movements of birds during the weeks when they come to the island and occupy the cliffs or scree slopes.

b. Selection of study sites and monitoring the cliff faces.

c. Censusing sample areas of cliff and scree slopes and extrapolating from these samples to the total population of the island.

d. Tours of the islands interior and perimeter censusing all species.

e. Noticing and recording unanticipated events.

f. Running air transects over the Chirikov Basin, Bering Strait and Chukchi Sea to establish the distribution of feeding birds.

g. Climbing cliff faces looking for food brought by parents.

4. Sample Localities

This is the first year of study on Little Diomede Island.
Study sites will be selected.
Tracks of the air censuses run in June are shown on the chart which accompanies this report.

5. "Data collected" - operations carried out are listed.

Communication with the party on the island has been poor.
I estimate that 50-75 visits have been made to study sites, and 20-30 excursions made to census.
We have made 135 five-minute counts of species and numbers of birds on the feeding grounds from the air.
Miles of trackline - 1100.

6. Milestone chart and schedule of data submission

Quarterly reports will be submitted about October 1, 1977 and January 1, 1978.
An annual report will be submitted about April 1, 1978.
The final processing of coding sheets will begin sometime after the party leaves the island about August 15.

III. Results

Telephone to Little Diomede was not working during the last two weeks of this period so detailed results are not available.
Earlier reports indicated that the island was surrounded by solid ice well into the end of May. Murres and Kittiwakes appeared in the leads but their numbers were difficult to estimate because the leads extended as far as the eye could see away from the island and birds could be seen at extreme distances. Murres and kittiwakes appeared around the island as soon as leads opened, but Auklets had not arrived until after June first.
Several sites suitable for study had been found on the north end of the island.

IV. Preliminary Interpretation of Results

1. The Murres and Kittiwakes nest on the cliff faces at the foot of the islands steep sides. They do not nest on the stone slabs high on the islands sides as they do at King Island. Censuses had not been completed and put together into an estimate for the whole island in time to be included in the quarterly report.

2. Auklets nest in the scree (depositional slopes of frost-rived boulders) on the west side of the island and on the valley sides of a cut towards the East side. The first inspection suggests that suitable nesting sites occupy about one third of the islands surface.

   Estimates of numbers of birds per unit area of scree have been made and a vertical photograph of the island has been requested to help translate these samples into estimates of the numbers of birds nesting.

3. Air transects of the Chirikov Basin, the Bering Strait, and the southernmost part of the Chukchi Sea indicated that Murres, Puffins and Auklets were concentrated West of a line drawn from the east end on St. Lawrence Island to a point 20 miles East of King Island and thence to the York Mountains. The contrast in density is conspicuous, there being virtually no birds to the East and large numbers to the West. The largest concentrations were found near the major breeding cliffs on the north shore of St. Lawrence Island, around King Island and in the Bering Strait, but also in an area 50 miles SSW from King Island and in an area half to 3/4 of the way between King Island and Fairway Rock.

4. Small numbers of Fulmers were seen, but no petrels or shearwaters.

   Large numbers (up to 200 in one day) of Gray Whales were seen in the areas where seabirds congregate. They seemed to attract Kittiwakes and Murres to feed in the plume of bottom sediments which they brought to the surface after a dive. We saw, typically, 4-10 Kittiwakes and 2-4 Murres on the water or flying toward a whale as it surfaced. The great majority of all Kittiwakes seen away from the cliffs were associated with whales. The numbers of Murres, on the other hand, were only a small proportion of the total of Murres seen feeding.

   I wonder whether this specialized method of feeding is the source of the polychaete worms found in the stomachs of some Murres.

V. Problems

1. Although we wrote asking permission in early winter, we did

not know until after the party arrived in Nome in Mid-May that the people of Little Diomede would let us put a party on the island for the summer. Part of the problem was that the names we had been given were not those who make decisions for the community.

We have not felt free to plan our work simply as a scientific project because of concern for the politics of our relations with the people. We have heard talk that their attitude toward outsiders is not always favorable. We had similar problems in trying to patch together last minute arrangements to go to King Island in 1976. This situation puts us at an unfortunate disadvantage for seeing that all parties understand the arrangements and that misunderstandings do not develop. The situation also required us to extemporize in assigning people to work on the island. I would have preferred to have someone in the early party who was more familiar with what we wanted to learn and how we have gathered data in the past. I would also have preferred to have someone on the party who had a lot of experience handling small boats at sea. The party does consist of outstandingly resourceful individuals who are notable for their good will and they have been fully instructed.

Perhaps the only solution to this sort of problem is to have someone go to the island in late winter on a special trip to ask permission and make arrangements.

2. Although I had made arrangements to charter aircraft for our over-water transects and even had a back-up, when the time came for transects, no aircraft were available in Nome. One company had sold its airplane and the other had a flood of business as a result of the Wien Alaska strike and our work was of too low priority for them. It was only through the exceptional efforts of a local friend who went to Anchorage twice on our behalf that a suitable plane and willing pilot was found.

   In this case, solutions to future problems seem to lie with loyalty to and rewarding the friend.

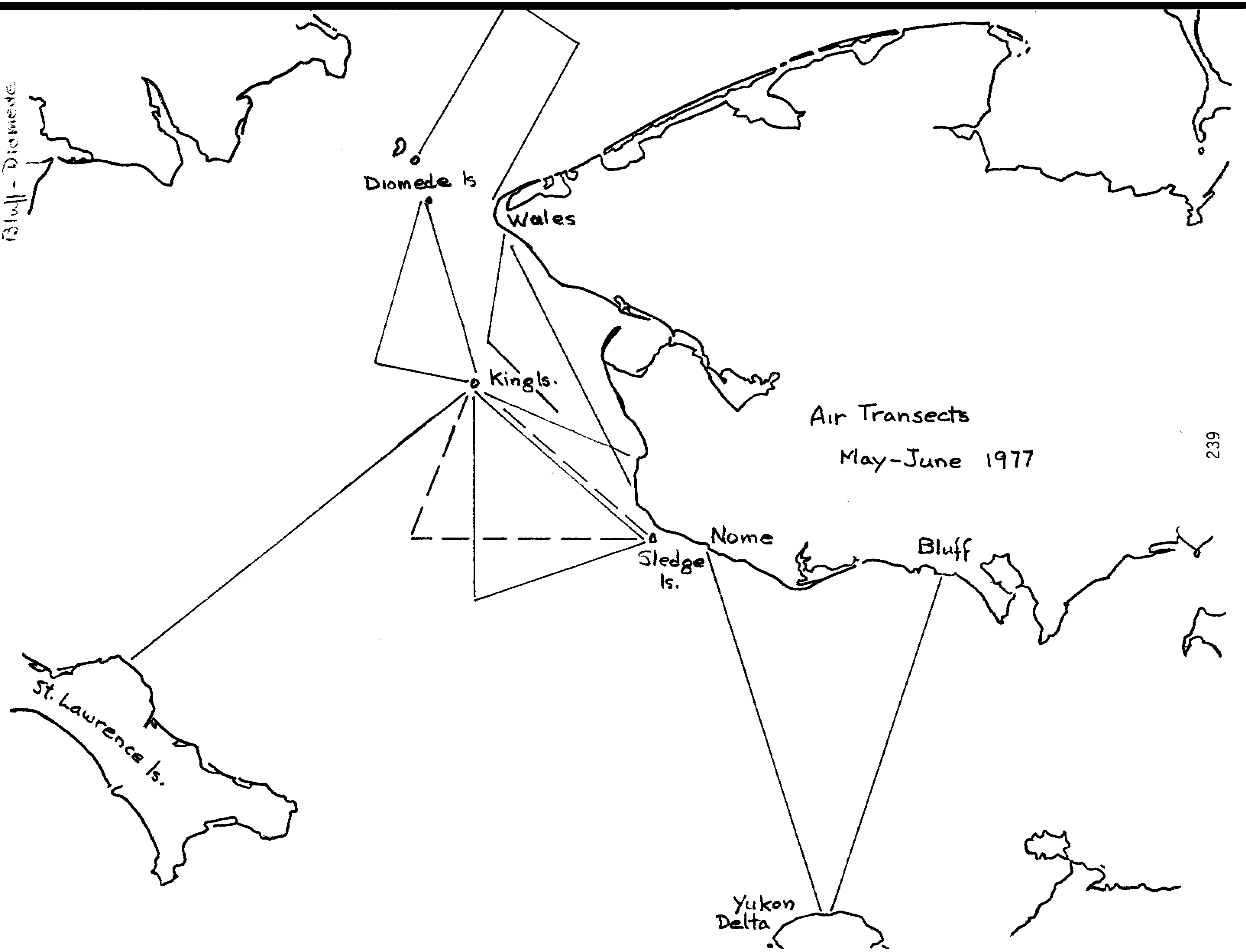
3, The sides of Little Diomede Island are precipituous, like those of King Island. The geology of the two islands seems to be similar. Access to good study sites is difficult. Furthermore the Diomeders make extensive use of seabirds for food and for sport. It is not advisable to use data collected at the island to compare with data from other sites without corrections. If we can find unvisited cliffs and scree slopes (which doubtless do exist) we can use them to measure basic reproductive rates, and hence to gather additional, valuable information on the impact of human predation.

There is apparently no simple solution to this complex of problems. We will have to decide after the field season whether the 'cost benefit ratio' is favorable.

VI Estimate of Funds Expended

We have been given permission to transfer some funds between R.U. #237 and R.U. #447. The following accounting is approximate and assigns costs between the two Research Units appropriately in those cases in which costs can be directly assigned. In those several cases in which costs are shared between the two units, costs are assigned according to the relative effort going into each research unit.

CPF 1	$ 8,650
CPF 2	13,255
CPF 3	1,485
CPF 4	570
	$23,960


Bluff - Diomede
Diomede Is
Wales
King Is.
Air Transects
May-June 1977
Sledge Is.
Nome
Bluff
St. Lawrence Is.
Yukon Delta

Quarterly Report

Contract 03-5-022-56
Task Order #28
Research Unit #458
Reporting Period 4/1/77 - 6/30/77

AVIAN COMMUNITY ECOLOGY OF THE AKULIK - INGLUTALIK RIVER DELTA, NORTON BAY, ALASKA

G. Shields and L. Peyton
Co-Principal Investigators
Institute of Arctic Biology
University of Alaska
Fairbanks, Alaska 99701

June 30, 1977

I. Task Objectives

This study will determine the relative importance of the Norton Bay area as breeding habitat for resident birds. Having made this determination, we hope to provide recommendations to lessen potential deleterious effects on this area by future oil development and concomitant human habitation.

II. Field and Laboratory activities

A. Field Activities

All personnel associated with this project are currently conducting on site field observations. These persons are not able to be contacted concerning the progress made during the last quarter.

B. Laboratory Activities

None.

III. Results

None presently available.

IV. Appendix

Trip report submitted at end of quarter.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 28 R.U. NUMBER: 458

PRINCIPAL INVESTIGATOR: Dr, G. F. Shields and Mr. L. J. Peyton

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		Estimated Submission Dates[1]			
	From	To	Batch 1	2	3	4
1976 Field Season	6/14/76	8/24/76	Submitted	None	9/30/77	Submitted
1977 Field Season	Current					

	Batch 5			
1976 Field Season	9/15/77			
1977 Field Season				

1 Data management plan has been submitted and approved by F. Cava; we await contractual approval.

IV. Appendix

The Principal Investigators, Shields and Peyton, left Fairbanks on May 7, arriving in Nome late that afternoon. The NOAA helicopter crew contacted them that evening and arrangements were made to transport them and their gear to the study site on the Inglutalik River the following day.

The helicopter left Nome on Sunday, May 8, arriving in Koyuk shortly before noon. Part of the camp gear that had been stored in Koyuk over the winter was then loaded on the helicopter and transported to the study site on the Inglutalik River, 10 1/2 miles south east of the village. Two more helicopter trips from the village to the study site were accomplished that afternoon before the helicopter had to return to Nome for additional fuel. The following day the helicopter returned from Nome to the study site, bringing a load of outboard motor and pressure appliance fuel with them. One more helicopter shuttle flight was needed to complete the transfer of camp gear from its winter storage site in Koyuk to the study site.

A temporary camp was set up on May 8, as the site for the permanent camp was covered with 1 1/2 ft. of snow. This snow was removed and the permanent tent erected on May 11.

Limited bird observations were initiated soon after their arrival on the study area. These limited bird observations were continued until May 11 when a twice daily count of the birds on the study area was started. The first count was taken between eight and nine o'clock each morning and the last count between 20:00 and 21:00 each evening.

General observations of noticable bird movement were noted throughout the day on a time, species, and number basis. Interruptions in the taking of this data were due to adverse weather conditions.

The initial migration of Whistling Swan, Canada Geese, Pintail, Sandhill Crane, Glaucous Gulls and Lapland Longspur had already passed through the study area before May 8, as there were pairs and small flocks of these birds scattered throughout the area when they arrived. The residents of the village of Koyuk indicated that the Glaucous Gulls had arrived there about a week before, or about the 1st of May.

The Sandhill Cranes, many of which probably nested in Northeastern Asia, use the delta between the Inglutalik and Akulik rivers as a major staging area for their westerly migration along the south side of the Seward Peninsula. 54 cranes were present on the delta on May 8th, by May 17th, 3,700 cranes were present. There had been a continuing exodis of cranes moving towards the northwest off the delta during this time but on May 18 a general exodis started and on May 19 only 800 cranes were left. The number of cranes continued to drop until there were 108 cranes on May 31, and 55 on June 15. The crane population remained near the 55 level through the rest of June.

Movements of Snow Geese, Black Brant and other birds were documented but none were as dramatic as the movement of Sandhill Crane.

A COMPARATIVE SEA-CLIFF BIRD INVENTORY
OF THE CAPE THOMPSON VICINITY, ALASKA
(R.U. No. 460)

A SEA-CLIFF BIRD SURVEY OF THE CAPE
LISBURNE - PT. HOPE, ALASKA COASTLINE
(R.U. No. 461)

(Contract 03-6-022-35210)

Quarterly Report
30 June, 1977

RENEWABLE RESOURCES CONSULTING SERVICES, Ltd.

Principal Investigators

David G. Roseneau
Alan M. Springer

I. Activities

Upon completion of the annual report (1 April 1977), April and May activities concentrated on data handling and the process of computerization of 1976 data groups. R.R.C.S. Systems Analyst, Gerry McGonigal, undertook formatting tasks while awaiting delivery of the Data Management Handbook. As of 30 June the final revised edition of the handbook has not been received. McGonigal has completed formatting and coding tasks (subject to changes that may be required upon receipt of the revised handbook). McGonigal is presently awaiting further information and final revisions. Upon receipt, he will submit a Data Management Plan for review. McGonigal reports that after discussions with F. Cova (Juneau), the 1976 and 1977 data will be processed together but submitted separately.

Preparations for 1977 field work at both Cape Thompson and Cape Lisburne commenced during May. Copies of the R.U. 460/461 Annual Report were sent to both the Arctic Slope Regional Corporation and the Tigara (Pt. Hope Village) Corporation along with letters informing them of our forthcoming activities within their areas. Permission to operate in the Cape Thompson and Cape Lisburne vicinities was obtained, (replies attached).

Correspondence was also initiated with Major Joesph T. Zadereky, Base Commander, 711 ACW Squadron, Cape Lisburne Air Force Base. Through Major Zadereky's cooperation and helpfullness we obtained permission to stay on site while conducting our work. Cape Lisburne Air Force Base is in a state of transition since a civilian contractor (RCA) commenced takeover of operations 1 June 1977. Consequently further discussions with Major Zadereky and RCA personnel proved fruitful; RCA personnel agreed to continue support of our effort similar to that provided by the Air Force and a small unused building was set up as a field bunk and work area. Logistics details were discussed with the OCS Arctic Project Office, Fairbanks, and during late May and June some new equipment and supplies were purchased; placement of fuel and some equipment of both study sites occurred.

During early June field work commenced at both sites. Emphasis was placed on early observations of birds present and the collection of specimens (Common Murre, Thick-billed Murre and Black-legged Kittiwakes) for analysis of stomach contents and gonadal development. Field crews began preparation for the approaching census counts.

A summary of data collection, colony observations and funds expended will be included in the next quarterly report.

ARCTIC SLOPE REGIONAL CORPORATION

P. O. Box 129
BARROW, ALASKA 99723

PHONE: 852-6930
852-6970

May 5, 1977

David G. Roseneau
Renewable Resources Consulting
Services Ltd.
4 Mile College Road
Fairbanks, Alaska 99701

Dear Mr. Roseneau:

With this letter, the Arctic Slope Regional Corporation hereby grants permission to allow you to continue your sea bird study as described in your letter of request dated April 20, 1977, on Arctic Slope Regional Corporation lands in the Cape Thompson and Cape Lisburne areas.

Thank you for providing this office with copies of your annual report.

Sincerely,

Wm Thomas

Wm Thomas
Land & Resource Department
ARCTIC SLOPE REGIONAL CORPORATION

WT/al

QUARTERLY REPORT

NOAA-OCSEAP Contract: 01-5-022-2538
Research Unit: 488
Report Period: 1 April - 30 June 1977

CHARACTERIZATION OF COASTAL HABITAT

FOR MIGRATORY BIRDS

RU-488

Principal Investigators
Calvin J. Lensink and Robert D. Jones, Jr.

U. S. Fish and Wildlife Service
Office of Biological Services - Coastal Systems
Anchorage, Alaska

July 1977

INTRODUCTION

This study will complete the characterization of coastal habitats conducted elsewhere on the Alaskan coast by the Alaska Department of Fish and Game under OCSEAP Research Unit 3/4. The region between Cape Newenham and the Bering Straits, which is covered by this study, has long been considered of unique importance to birds, most particularly to several species of waterfowl, shorebirds, and seabirds, which are dependent on estuarine or marine habitat.

The coastline within the region is variable ranging from precipitous marine escarpments of Cape Newenham and Nunivak to tide flats and lowlands of the Yukon Delta where tidal estuaries may extend inland for more than 50 kilometers. Coastal lagoons and barrier islands or spits provide important habitat on Kuskokwim Bay, Nunivak Island, and the Seward Peninsula. The variation in habitat signifies the variety of species and use by birds.

Objectives of this study are:

1. To characterize coastal habitat utilized by marine birds by:

    a. Describing extent and characteristics of unvegetated intertidal beaches.

    b. Describing extent and characteristics of intertidal plant communities.

    c. Identifying, where possible, the maximum limit of tidal influence on terrestrial habitat by mapping the occurrence of drift lines.

    d. Identify ownership status (private or public) and responsible land management agency.

    e. Identify and quantify existing land uses.

2. To characterize use of habitat by birds including:

    a. Identification of principal species.

    b. Identification and/or description of habitat use or dependencies by principal species.

c. Identify relative and/or approximate numbers of birds utilizing habitats seasonally.

3. To identify habitats which may be considered of unique or critical importance to any species considering overall populations of the species relative to the number present, and the availability of similar alternative habitat.

METHODS

This study will depend primarily on existing published and unpublished information including maps and aerial or satellite imagery, and on results from ongoing OCSEAP studies.

Field studies will be confined to aerial surveys and on site studies essential as ground truth for photo interpretation, identification of drift lines, and determining use by smaller species of birds in areas not covered by prior or ongoing studies.

SUMMARY OF WORK IN PROGRESS

Primary effort during the quarter has been devoted to studies of bird use of Coastal habitats adjacent to Norton Sound on the North Delta of the Yukon River. Robert Jones initiated work on May 2 to observe the passage and use of habitats by migrants. Jones was joined by Matthew Kirchhoff on June 1 to continue studies of habitat use during the nesting season. Work will continue into late summer when large numbers of waterfowl and shorebirds utilize coastal habitats as foraging and staging areas prior to migration.

Robert Gill and Colleen Handel initiated studies of shorebird use of tideland habitats between Nelson Island and Cape Romanzof on June 27 and will continue these studies until July 8. Logistical support for the study is being provided by the Clarence Rhode National Wildlife Refuge. This support includes aircraft for periodic censuses necessary to evaluated ground based studies.

Additional work planned for the period July through September includes a mid-August aerial survey of coastal habitats from Cape Newenham to the Bering Straits.

Work in progress and that planned for the last quarter will complete all field studies required by this project.

Analysis of results from studies conducted from the third quarter will not be initiated until the first quarter FY78. Observations to date, however, indicate substantially increased use of coastal areas by several species of waterfowl as compared to 1976. This increased use apparently results from the large number of birds which moved into Alaska as extended drought conditions in prairie states and provinces reduced habitat available in those regions.

SCHEDULE

Intensive studies, North and Middle Delta, Yukon River	In progress, Continue to early September
Aerial surveys, Cape Newenham to Bering Straits	August 10 to 20
Data analysis and preparation of final report.	October and November
Submit all numerical data to EDS through Juneau Project Office	November 30
Submit final report	December 31

RECEPTORS (BIOTA)

FISH

RECEPTORS (BIOTA)

FISH

RECEPTORS (BIOTA)

FISH

QUARTERLY REPORT

Contract No. 03-5-022-68, Task Order 5
Research Unit #6
Reporting Period: 1 April - 30 June 1977

The distribution, abundance, diversity and productivity of the western Beaufort Sea benthos.

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

June 24, 1976

John J. Dickinson

I. Task Objectives

A. General nature and scope of the problem

The distribution, abundance and natural variability of benthic macrofauna will be described on the southwestern Beaufort Sea continental shelf. Patterns of faunal distributions will be described and characterized using suitable bio-indices and multivariate techniques. Seasonal changes in the structure of benthic populations will be studied by sampling four times within a single year.

B. We propose to describe the benthic infauna of the western Beaufort Sea continental shelf including studies of both geographic and seasonal variability. Data are to be obtained on the faunal composition and abundance to form baselines to which potential future changes can be compared.

Specific objectives include the continuation of studies and analyses to:

1. Describe the distribution, species composition, numerical density, and biomass of the benthos in the area of interest.
2. Describe the spatial and seasonal variability of faunal distributions and abundances.
3. Describe the benthic communities present and delineate their geographical and environmental extent.
4. Describe the effect of seasons on population size and reproductivity activity of dominant species.
5. Determine the degree of correlation of species distributions and of various bio-indices with features of the benthic environment.

II. Research Activities

A. Field Activities

No field work was conducted this quarter.

B. Laboratory Activities

1) Personnel

No changes in personnel.

2) Methods

The techniques fro sample processing have not been altered this quarter

3) Data Analyzed

Smith-McIntyre grab samples from OCS-5 and OCS-6 have been sorted to phyla. Determinations of animal density and biomass have been completed for these two field trips. The gammarid amphipods from OCS-4 and OCS-6 have been identified to species.

III. Results

A. Laboratory Results

1) Biomass

Wet weights fro OCS-5 and OCS-6 samples are listed in Tables 1 and 2.

2) Faunal Density

Animal densities for OCS-5 and OCS-6 samples are listed in Tables 3-10.

3) Gammarid Amphipods

The gammarid amphipods from OCS-4 and OCS-6 have been identified to species (Tables 11-19).

IV. Preliminary Results

Interpretation of the results will not be profitable until a detailed statistical analysis has been completed.

V. Problems Encountered

No major difficulties developed this quarter.

VI. Data Management Milestone Chart

	Processed	Coded	Keypunched	Final Verification	Expected Submission	FILE ID
WEBSEC 1971					FEB. 1977	WBSC71
WEBSEC 1972					FEB. 1977	WBSC72
OCS 1						
Station						
Taxonomic					MARCH 1977	OCS-1
OCS 2						
Station						
Taxonomic					MARCH 1977	OCS-2
OCS 3						
Station						
Taxonomic					JULY 1977	OCS-3
OCS 4						
Station					APRIL 1977	OCS-4
Taxonomic					01 Oct. 1977	
OCS 5						
Station					MAY 1977	OCS-5
Taxonomic					01 Oct. 1977	
OCS 6						
Station					MAY 1977	OCS-6
Taxonomic					01 Oct. 1977	

No dates for the expected submission of information have been changed.

VII. Budget for Task Order 5

	Budget	Spent	Committed	Balance
Salaries & Wages	94,128	70,577	23,551	--
Materials & Services	18,240	19,271	657	<1,688>
Travel	9,300	8,315	--	985
Equipment	47,617	47,224	--	393
Payroll Assm't	14,637	10,356	4,281	--
Overhead	45,260	33,409	11,851	--
Total	$229,182	$189,152	$16,853	< 310>

Table 1: Biomass data from OCS-5, Pitt Point transect. Wet weight in grams per .1 m^2.

Station	Grab	Anthozoa	Polychaeta	Crustacea	Mollusca	Misc. Phyla	Total
PPB-5	1395		1.59	.26	6.28	.21	8.34
	1396		1.34	.07	4.07	10.08	15.56
	1398		1.36	.21	.97	.13	2.67
	1399		.64	.30	1.46	.04	2.44
PPB-10	1401		.88	.61	1.66	.01	3.16
	1402		.33	.04	.59	4.79	5.75
	1403		.85	2.20	.35	.01	3.41
	1404		.50	3.71	6.48	.01	10.70
	1406		.64	.36	11.35	.05	12.40
PPB-15	1407	.09	.01	.21	.08		.39
	1408		1.74	.26	.13	.01	2.14
	1409		.04	.35	.74		1.13
	1410		3.54	2.00	.12		5.66
	1411		.20	.32	.28		.80
PPB-20	1413		2.05	.27	.73		3.05
	1414		.10	.60	.30		1.00
	1415		.14	.12	.31	.01	.58
	1416		.04	.07	.02		.13
	1417		.01	.13	.04		.18

Table 2: Biomass data from OCS-6 Pitt Point transect. Wet weight in grams per .1 m^2.

Station	Grab	Anthozoa	Sipuncula	Polychaeta	Arthropoda	Mollusca	Ophiuroidea	Misc.	Total
PPB-70	1485		.07	.43	1.43	.47	1.67	.05	4.12
	1486	.06	.07	.45	2.65	1.89	1.64	.03	6.79
	1487	.13	.09	1.10	1.51	.21	2.21	.26	5.51
	1488	.01	.13	.85	1.79	.19	.14	.06	3.17
	1489	.03	.21	1.66	1.56	.25	.09	.06	3.86
PPB-100	1490	.36	.35	2.85	1.95	6.60	3.02	.10	15.23
	1491	.27	.89	3.14	1.97	7.49	1.45	.17	15.38
	1492	.19	.69	1.66	2.25	4.01	3.24	.08	12.12
	1493	.14	.04	3.96	1.59	2.26	3.57	.20	11.76
	1494	.66	.01	8.04	1.91	6.38	1.66	.16	18.82
PPB-55	1495	.13	.03	1.21	.91	4.24	.02	.14	6.68
	1496	.12	.04	1.51	1.17	7.85	.01	.09	10.79
	1497	.20	.01	2.20	1.71	.58	.03	.06	4.79
	1498	.21	.02	.83	.82	.41		.04	2.33
	1499	.04	.01	.69	.50	.14		.02	1.40
PB-25	1502	.11		2.01	.45	.29		.04	2.90
	1501			1.13	.39	.29		.03	1.84
	1500	.05		1.64	1.03	.89		.01	3.62
	1503	.42		2.97	.29	1.58		.01	5.27
	1504		.01	1.96	.04	.26		.02	2.29

Table 3: Animal densities for PPB-5 (OCS-5) collected on 20 August 1976.

			Grab Number				
Phylum:	Class:	Order	1395	1396	1398	1399	Total
Nematoda			236	250	248	455	1189
Nemertinea			7	4	8	4	23
Annelida:	Polychaeta		295	220	469	248	1232
Priapulida			2	3	8	5	18
Arthropoda:	Crustacea:	Amphipoda	11	15	3	5	34
		Harpacticoida	19	10	478	80	587
		Isopoda	2				2
		Ostracoda	72	52	466	84	674
		Tanaidacea		6	14	4	24
		Cumacea				3	3
		Mysidacea	2	2	1		5
Mollusca:	Pelecypoda		816	523	575	381	2295
	Gastropoda		10	12	7	6	35
Hemichordata					2	7	9
Chordata:	Urochordata:	Ascidacea	1	3	7		11
Total			1473	1100	2286	1282	6141

Table 4: Animal densities for PPB-10 (OCS-5) collected on 20 August 1976.

Phylum:	Class:	Order	1401	1402	1403	1404	1406	Total
			Grab Number					
Cnidaria:	Anthozoa				1			1
Nematoda			7				7	14
Nemertinea				1	1		2	4
Annelida:	Polychaeta		172	31	47	28	60	338
Priapulida						1		1
Arthropoda:	Crustacea:	Amphipoda	12	5	4	17	23	61
		Harpicticoida	1				9	10
		Isopoda	2		4	7	2	15
		Ostracoda	60				19	79
		Tanaidacea	9		1	1	6	17
		Cumacea				2	1	3
		Mysidacea				3	2	5
Mollusca:	Pelecypoda		71	23	51	152	54	351
	Gastropoda		5	8	8	2	3	26
Chordata:	Urochordata:	Ascidacea		1			2	3
Total			339	69	117	213	190	928

Table 5: Animal densities for PPB-15 (OCS-5) collected on 20 August 1976.

			Grab Number					
Phylum:	Class:	Order	1407	1408	1409	1410	1411	Total
Cnidaria:	Anthozoa		3					3
Nematoda				2				2
Nemertinea						1		1
Annelida:	Polychaeta		1	31	6	175	70	283
Arthropoda:	Crustacea:	Amphipoda	37	16	27	36	40	156
		Isopoda	5	9	8	8	18	48
		Cumacea		2	2			4
		Mysidacea	6		3	7	7	23
Mollusca:	Pelecypoda		5	13	63	12	32	125
	Gastropoda				2		1	3
Total			57	73	111	239	168	648

Table 6: Animal densities for PPB-20 (OCS-5) collected on 20 August 1976.

			Grab Number					
Phylum:	Class:	Order	1413	1414	1415	1416	1417	Total
Nematoda					1			1
Nemertinea				1				1
Annelida:	Polychaeta		77	30	27	3	4	141
Priapulida					1			1
Arthropoda:	Crustacea:	Decapoda		1				1
		Amphipoda	3	26	10	10	15	64
		Isopoda	2	11				13
		Ostracoda		1				1
		Cumacea		2		2		4
		Mysidacea		2				2
Mollusca:	Pelecypoda		51	55	40	1	3	150
	Gastropoda			3	4		1	8
Hemichordata			1					1
Chordata:	Urochordata:	Ascidacea			1			1
Total			134	132	84	16	23	389

Table 7: Animal densities for PPB-25 (OCS-6) collected on 11 November 1976.

			Grab Number					
Phylum:	Class:	Order	1500	1501	1502	1503	1504	Total
Cnidaria:	Anthozoa		1		1	1		3
Nematoda			16	3	5	5	7	36
Nemertinea			2	3	4	2	2	13
Annelida:	Polychaeta		64	62	62	60	73	321
Anthropoda:	Crustacea:	Amphipoda	13	16	8	12	1	50
		Isopoda	1	1		1		3
		Ostracoda	5	5	3	6	4	23
		Tanaidacea	2		2	1	1	6
		Cumacea	2	1	1	2		6
Mollusca:	Bivalvia		13	1	4	6	4	28
	Gastropoda			2			2	4
Echinodermata:	Holothuroidea		1					1
Hemichordata					2	1	1	4
Total			120	94	92	97	95	498

Table 8: Animal densities for PPB-55 (OCS-6) collected on 4 November 1976.

			Grab Number					
Phylum:	Class:	Order	1495	1496	1497	1498	1499	Total
Cnidaria:	Anthozoa		5	4	7	8	2	26
Nematoda			58	73	48	56	7	222
Nemertinea			3	3	3	6	1	16
Annelida:	Polychaeta		112	123	122	66	36	459
Sipuncula			7	6	2	3	2	20
Echiura					1	1		2
Arthropoda:	Crustacea:	Amphipoda	63	91	40	52	24	270
		Harpacticoida	2	2	3			7
		Isopoda	6					6
		Ostracoda	113	134	79	55	7	388
		Tanaidacea	10	6	1	19	1	37
		Cumacea	19	11	5	13		48
	Pycnogonida				1			1
Mollusca:	Bivalvia		45	32	28	22	6	133
	Gastropoda		12	6	1	3	1	23
	Aplacophora		2	2	1			5
Brachiopoda			1	1	2	2		6
Echinodermata:	Ophiuroidea		3	4	1			8
Hemichordata			1	1	2	1		5
Chordata:	Urochordata:	Ascidacea	4	3	2	1	1	11
Total			466	502	349	288	88	1693

Table 9: Animal densities for PPB-70 (OCS-6) collected on 2 November 1976.

			Grab Number					
Phylum:	Class:	Order	1485	1486	1487	1488	1489	Total
Cnidaria:	Anthozoa			3	3	1	2	9
Nematoda			16	18	22	9	18	83
Nemertinea			3	2	4	3	6	18
Annelida:	Polychaeta		56	55	66	44	92	313
Sipuncula			10	17	9	11	22	69
Echiura				1		2	1	4
Arthropoda:	Crustacea:	Amphipoda	115	150	103	142	161	671
		Cirripedia	1				1	2
		Harpacticoida	1		1			2
		Isopoda	2		2		1	5
		Ostracoda	102	115	98	80	115	510
		Tanaidacea	18	17	8	7	9	59
		Cumacea	22	17	22	18	19	98
		Decopoda	3		3			6
	Pycnogonida		1				1	2
Mollusca:	Bivalvia		18	13	16	15	17	79
	Gastropoda		1	2	2	1	2	8
	Polyplacophora					1		1
Echinodermata:	Ophiuroidea		3	5	3	2	1	14
Chordata:	Urochordata:	Ascidacea		1	4	2	1	8
Total			372	416	366	338	469	1961

Table 10: Animal densities for PPB-100 (OCS-6) collected on 3 November 1976.

			Grab Number					
Phylum:	Class:	Order	1490	1491	1492	1493	1494	Total
Cnidaria:	Anthozoa		5	5	3	5	10	28
Nematoda			60	90	104	114	112	480
Nemertinea			4	6	4	3	2	19
Annelida:	Polychaeta		121	140	140	182	178	761
Sipuncula			9	47	22	12	3	93
Priapulida							1	1
Arthropoda:	Crustacea:	Amphipoda	156	171	205	157	132	821
		Cirripedia				1		1
		Harpacticoida			1	1		2
		Isopoda	2	1	5	3	1	12
		Ostracoda	90	93	85	114	105	487
		Tanaidacea	5	3	4	2	2	18
		Cumacea	37	27	58	42	41	205
	Pycnogonida					2		2
Mollusca:	Bivalvia		25	28	25	19	24	121
	Gastropoda		3	6	4	7	4	24
	Aplacophora		1				1	2
	Polyplacophora			1		1	1	3
Brachiopoda				3	3	1	5	12
Echinodermata:	Ophiuroidea		6	4	8	13	6	37
Hemichordata			1			2		3
Chordata:	Urochordata:	Ascidacea	4	4	4	3	1	16
Total			529	629	675	684	629	3146

Table 11: The Gammarid Amphipods from PPB-25 collected during OCS-4. 8 species were represented in the 28 specimens.

Family	Mean No./m^2	Frequency	Rank
Ampeliseidae			
Byblis arcticus	10	3/5	2
Haploops laevis	10	2/5	2
Haploops tubicola	10	1/5	2
Corophiidae			
Podoceropsis inaequistylis	4	1/5	3
Gammaridae			
Maera danae	2	1/5	4
Lysianasidae			
Hippomedon abyssi	4	1/5	3
Tryphosella sp.	2	1/5	4
Oedicerotidae			
Aceroidea latipes	14	2/5	1

Table 12: The Gammarid Amphipods from PPB-40 collected during OCS-4. 30 species were represented in the 306 specimens.

Family	Mean No./m^2	Frequency	Rank
Ampeliscidae			
Ampelisca birulai	10	1/5	11
Ampelisca eschrichti	14	5/5	9
Ampelisca macrocephala	4	1/5	14
Byblis arcticus	102	5/5	2
Hoploops laevis	8	2/5	12
Hoploops tubicola	6	2/5	13
Argissidae			
Argissa hamatipes	4	2/5	14
Corophiidae			
Corophium clarencense	8	2/5	12
Goesia depressa	6	2/5	13
Photis vinogradova	22	4/5	7
Protomedeia fasciata	168	5/5	1
Unciola leucopsis	24	5/5	6
Eusiridae			
Rhactropis aculata	2	1/5	15
Gammaridae			
Melita dentata	6	3/5	13
Lysianassidae			
Boeckosimus platus	4	1/5	14
Tryphosella sp. AA	2	1/5	15
Lysianasid	2	1/5	15
Oedicerotidae			
Aceroides latipes	32	4/5	5
Arrhinopsis longicornis	4	2/5	14
Bathymedon obtusifrons	16	3/5	8
Monoculodes borealis	4	2/5	14
Monoculodes diamesus	4	1/5	14
Perioculodes longimanus	2	1/5	15
Westwoodilla megalops	12	3/5	10
Paradaliscidae			
Paradaliscella lavroui	2	1/5	15
Phoxocephalidae			
Harpinia kobjakovae	8	2/5	12
Harpinia serrata	92	5/5	3
Paraphoxus oculatus	40	4/5	4
Podoceridae			
Paradulichia typica	2	1/5	15
Stenothoidae			
Metopa sp.	2	1/5	15

Table 13: The Gammarid Amphipods from PPB-55 collected during OCS-4. 24 species were represented in the 246 specimens.

Family	Mean No./m^2	Frequency	Rank
Ampeliscidae			
Ampelisca birulai	4	2/5	11
Ampelisca eschrichti	10	3/5	9
Byblis arcticus	116	5/5	1
Haploops laevis	58	4/5	3
Haploops tubicola	10	2/5	9
Argissidae			
Argissa hamatipes	12	4/5	8
Corophiidae			
Goesia depressa	2	1/5	12
Photis vinogradova	16	3/5	7
Protomedeia fasciata	12	3/5	8
Usciola leucopsis	28	5/5	4
Dexaminidae			
Gurnea nordenskioldi	8	2/5	10
Lysianassidae			
Hippomedon robustus	2	1/5	12
Oedicerotidae			
Aceroides latipes	22	5/5	6
Arrhinopsis longicornis	2	1/5	12
Arrhis phyllonyx	2	1/5	12
Bathymedon obtusifrons	12	3/5	8
Monoculodes diamesus	4	1/5	11
Monoculodes latimanus	2	1/5	12
Westwoodilla megalops	24	5/5	5
Paradaliscidae			
Paradaliscella lavroui	2	1/5	12
Phoxocephalidae			
Harpinia kobjakovae	2	1/5	12
Harpinia serrata	106	5/5	2
Paraphoxus oculatus	22	5/5	6
Stenothoidae			
Metopa sp.	12	4/5	8

Table 14: The Gammarid Amphipods from PPB-70 collected during OCS-4. 32 species were represented in 415 specimens.

Family	Mean No./m^2	Frequency	Rank
Acanthonotozomatidae			
Acanthonotozoma serratum	2	1/5	16
Odius kelleri	2	1/5	16
Ampeliscidae			
Ampelisca birulai	2	1/5	16
Byblis arcticus	92	5/5	3
Haploops laevis	2	1/5	16
Haploops setosa	2	1/5	16
Haploops sirbirica	12	1/5	12
Haploops tubicola	14	3/5	11
Amphilochidae			
Gitana abyssicola	4	2/5	15
Aoridae			
Lembos arcticus	2	1/5	16
Argissidae			
Argissa hamatipes	2	1/5	16
Corophiidae			
Goesia depressa	10	4/5	13
Photis rheinhardi	10	1/5	13
Photis vinogradova	18	3/5	10
Podoceropsis inaequistylis	22	5/5	9
Podoceropsis lindhaldi	130	5/5	2
Protomedeia fasciata	10	3/5	13
Unciola leucopsis	14	4/5	11
Dexaminidae			
Guernea nordenskioldi	74	5/5	5
Eusiridae			
Rhactropis oculata	4	1/5	15
Gammaridae			
Melita dentata	138	5/5	1
Ischyroceridae			
Ischyrocerus commensalis	2	1/5	16
Lysianassidae			
Aristias tumidus	2	1/5	16
Anonyx nugax	12	4/5	12
Oedicerotidae			
Bathymedon obtusifrons	6	1/5	14
Monoculodes diamesus	6	2/5	14
Monoculodes packardi	4	1/5	15
Westwoodilla megalops	28	5/5	8

(continued

Table 14 (continued)

Phoxocephalidae			
Paraphoxus occulatus	46	5/5	7
Pleustidae			
Stenopleustes malgreni	6	2/5	14
Stenothoidae			
Metopa sp.	86	5/5	4
Synopiidae			
Tiron spinifera	66	5/5	6

Table 15: The Gammarid Amphipods from PPB-100 collected during OCS-4. 39 species were represented in the 663 specimens.

Family	Mean No./m^2	Frequency	Rank
Ampeliscidae			
Ampelisca birulai	4	2/5	16
Ampelisca macrocephala	4	2/5	16
Byblis arcticus	12	2/5	13
Haploops laevis	6	2/5	15
Haploops tubicola	2	1/5	17
Argissidae			
Argissa hamatipes	6	2/5	15
Corophiidae			
Corophium clarenscense	2	1/5	17
Ericthonius megalops	6	3/5	15
Goesia depressa	8	2/5	14
Photis rheinhardi	34	3/5	9
Photis vinogradova	136	4/5	4
Podoceropsis inaequistylus	44	5/5	8
Podoceropsis lindhaldi	148	5/5	3
Protomedeia fasciata	20	5/5	11
Unciola leucopsis	168	5/5	2
Dexaminidae			
Guernea nordenskioldi	64	5/5	7
Gammaridae			
Maera danae	18	2/5	12
Melita dentata	8	2/5	14
Ischyroceridae			
Ischyrocerus megalops	2	1/5	17
Lysianassidae			
Anonyx nugax	2	1/5	17
Anonyx sp. BB	2	1/5	17
Boeckonisimus normani	4	1/5	16
Onisimus litoralis	2	1/5	17
Opisa eschrichti	2	1/5	17
Tryphosella sp. A	4	1/5	16
Oedicerotidae			
Bathymedon obtusifrons	2	1/5	17
Monoculodes diamesus	6	2/5	15
Monoculodes packardi	2	1/5	17
Westwoodilla megalops	24	5/5	10
Paradaliscidae			
Halice sp. A	4	2/5	16
Paradaliscella lavroui	4	2/5	16

(continued)

Table 15 (continued)

Phoxocephalidae			
Harpinia serrata	82	5/5	5
Paraphoxus oculatus	18	4/5	12
Pleustidae			
Pleusymtes karianus	4	1/5	16
Stenopleustes malgremi	2	1/5	17
Podoceropsidae			
Dulichia sp. A	6	2/5	15
Stenothoidae			
Metopa sp. A	72	5/5	6
Synopiidae			
Syrrhoe crenulata	2	1/5	17
Tiron spinifera	386	5/5	1

Table 16: The Gammarid Amphipods from PPB-25 collected during OCS-6. 11 species were represented in 50 specimens.

Family	Mean No./m^2	Frequency	Rank
Ampeliscidae			
Ampelisca eschricti	26	4/5	1
Byblis arcticus	4	2/5	6
Haploops laevis	2	1/5	7
Haploops tubicola	6	1/5	5
Etsiridae			
Rozinante fragilis	14	2/5	3
Gammaridae			
Gammarus sp. AA	20	3/5	2
Lysianssidae			
Anonyx nugax	2	1/5	7
Onisimus litoralis	4	2/5	6
Oedicerofidae			
Bathymedon obtusifrons	2	1/5	7
Pleustidae			
Pleusymtes karianus	2	1/5	7
Phoxocephalidae			
Harpinia kobjakovae	12	4/5	4

Table 17: The Gammarid Amphipods from PPB-55 collected during OCS-6. 28 species were represented in 270 specimens.

Family	Mean No./m^2	Frequency	Rank
Ampeliscidae			
Ampelisca birulai	10	3/5	10
Ampelisca eschricti	6	3/5	12
Byblis arcticus	74	5/5	1
Byblis sp. BB	12	3/5	9
Haploops laevis	8	3/5	11
Haploops sirbirica	16	2/5	8
Argissidae			
Argissa hamatipes	2	1/5	14
Corophiidae			
Corophium shoemakeri	2	1/5	14
Goesia depressa	12	2/5	9
Photis vinogradova	68	3/5	2
Podoceropsis lindhaldi	16	3/5	8
Protomedeia fasciata	6	1/5	12
Unciola leucopis	54	5/5	4
Dexaminidae			
Gurnea nordenskioldi	12	4/5	9
Gammaridae			
Gammarus sp. AA	4	1/5	13
Melita dentata	24	4/5	7
Haustoriidae			
Pontoporeia femorata	2	1/5	14
Lysianssidae			
Anonyx nugax	12	3/5	9
Onisimus litoralis	6	2/5	12
Oedicerotidae			
Aceroides latipes	8	3/5	11
Arrhinopsis longicornis	2	1/5	14
Monoculodes tuberculatus	2	1/5	14
Paradaliscidae			
Paradiscella lavroui	4	2/5	13
Phoxocephalidae			
Harpinia kobjakovae	2	1/5	14
Harpinia serrata	48	4/5	5
Paraphoxus occulatus	54	5/5	3
Stenothoidae			
Metopa sp.	2	1/5	14
Synopiidae			
Tiron spinifera	26	2/5	6

Table 18: The Gammarid Amphipods from PPB-70 collected during OCS-6. 41 species were represented in 671 specimens.

Family	Mean No./m^2	Frequency	Rank
Ampelisicidae			
Ampelisca birulai	4	2/5	15
Ampelisca eschricti	12	5/5	12
Ampelisca latipes	2	1/5	16
Byblis arcticus	12	4/5	12
Haploops laevis	4	1/5	15
Haploops tubicola	2	1/5	16
Aoridae			
Lembos arcticus	36	3/5	6
Argissidae			
Argissa hamatipes	4	2/5	15
Calliopiidae			
Leptamphopus sp. A	28	4/5	8
Corophiidae			
Corophium shoemakeri	2	1/5	16
Goesia depressa	22	4/5	9
Photis rheinhardi	12	3/5	12
Photis vinogradova	248	5/5	2
Podoceropsis inaequistylis	4	2/5	15
Podoceropsis lindhaldi	30	4/5	7
Protomedeia fasciata	8	1/5	13
Unciola leucopsis	524	5/5	1
Dexaminidae			
Gurnea nordenskioldi	2	1/5	16
Etsiridae			
Rozinante fragilis	8	3/5	13
Gammaridae			
Gammarus sp. AA	92	5/5	3
Melita dentata	12	3/5	12
Melita sp.	2	1/5	16
Maera danae	2	1/5	16
Lysianassidae			
Anonyx nugax	2	1/5	16
Onisimus litoralis	14	4/5	11
Orchomene sp. AA	4	1/5	15

(continued

Table 18 (continued)

Oedicerotidae			
Aceroides latipes	8	3/5	13
Arrhinopsis longicornis	4	1/5	15
Bathymedon obtusifrons	4	1/5	15
Monoculodes diamesus	2	1/5	16
Monoculodes latimanus	2	1/5	16
Monoculodes tuberculatus	2	1/5	16
Monoculopsis longicornis	2	1/5	16
Westwoodilla megalops	8	3/5	13
Phoxocephalidae			
Harpinia kobjakovae	2	1/5	16
Harpinia serrata	46	5/5	4
Paraphoxus occulatus	18	4/5	10
Pleustidae			
Pleusymtes karianus	4	2/5	15
Podoceropsidae			
Dulichia sp. A	2	1/5	16
Stenothoidae			
Metopa sp.	6	2/5	14
Synopiidae			
Tiron spinifera	38	5/5	5

Table 19: The Gammarid Amphipods from PPB-100 collected during OCS-6. 42 species are represented in 821 specimens.

Family	Mean No./m^2	Frequency	Rank
Ampeliscidae			
Ampelisca birulai	2	1/5	21
Ampelisca eschricti	4	2/5	20
Byblis arcticus	2	1/5	21
Haploops setosa	2	1/5	21
Haploops tubicola	2	1/5	21
Aoridae			
Lembos arcticus	6	2/5	19
Calliopiidae			
Leptamphopus sp. A	4	2/5	20
Corophiidae			
Corophium shoemakeri	6	2/5	19
Goesia depressa	16	3/5	15
Photis rheinhardi	70	4/5	8
Photis vinogradova	104	4/5	6
Podoceropsis inaequistylis	70	5/5	7
Podoceropsis lindhaldi	108	5/5	4
Protomedeia fasciata	60	5/5	9
Unciola leucopis	310	5/5	1
Dexaminidae			
Gurnea nordenskioldi	34	5/5	12
Etsiridae			
Rozinante fragilis	2	1/5	21
Eusiridae			
Rhactropis aculeta	1	1/5	21
Gammaridae			
Gammarus sp. AA	50	5/5	11
Maera danae	6	1/5	19
Melita dentata	4	1/5	20
Haustoriidae			
Pontoporeia femorata	4	2/5	20
Ischyroceriidae			
Ischyrocerus commensalis	4	2/5	20
Ischyrocerus megacheir	118	5/5	3

(continued)

Table 19 (continued)

Lysianassidae			
Anonyx nugax	8	3/5	18
Hippomedon abyssi	28	4/5	13
Onisimus littoralis	122	5/5	2
Oedicerotidae			
Aceroides latipes	2	1/5	21
Bathymedon obtusifrons	52	5/5	11
Monoculodes diamesus	8	2/5	18
Monoculodes latimanus	2	1/5	21
Monoculodes tuberculatus	4	2/5	20
Monoculopsis longicornis	14	4/5	16
Westwoodilla megalops	8	3/5	18
Paradalisicidae			
Paradalisca cuspidata	1	1/5	21
Phoxocephalidae			
Harpinia serrata	54	5/5	10
Paraphoxus oculatus	12	5/5	17
Pleustidae			
Pleustes medius	4	1/5	20
Pleusymtes karianus	2	1/5	21
Podoceropsidae			
Dulichia sp. A	20	4/5	14
Stenothoidae			
Metopa sp.	8	3/5	18
Synopiidae			
Tiron spinifera	106	5/5	5

Quarterly Report

R.U. 19 PART I
April 1 - June 30

FINFISH RESOURCE SURVEYS IN NORTON SOUND AND KOTZEBUE SOUND

Principal Investigator

LOUIS H. BARTON
Alaska Department of Fish and Game
Commercial Fisheries Division
333 Raspberry Road
Anchorage

August 1977

I. Task Objectives

The objectives of these research units are to:

1) Determine the spatial and temporal distribution, species composition and relative abundance of finfishes in the coastal waters of Norton Sound and Kotzebue Sound east of 166 Degrees West Longitude.

2) Determine the timing and routes of juvenile salmon migrations as well as examine age and growth, relative maturity and food habits of important species in Norton Sound and Kotzebue Sound east of 166 Degrees West Longitude.

3) Determine the spatial and temporal distribution and relative abundance of spawning populations of herring and other forage fish within the study area.

4) Monitor egg density, distribution and development and document types of spawning substrates of herring and other forage fish species.

5) Monitor local resident subsistence utilization of the herring fishery resource.

II. Field Activities

Activities during this quarter (April - June) included completion and submission of the 7Y76 Annual Report to OCSEAP in April. In April and May, operational plans were completed, temporaries hired and equipment purchased. By late May-early June, all field camps had been established and sampling in the nearshore waters of Norton Sound initiated immediately following ice breakup. Field camps and projects were established as follows:

1) Yukon River Delta camp - May 18

2) Unalakleet camp - May 27

3) Golovin camp - May 25

4) Port Clarence camp - June 25

A large vessel contract was finalized with the 108 foot crabber Royal Atlantic for conducting pelagic fish surveys in the offshore waters of Norton Sound and Kotzebue Sound. The Royal Atlantic arrived off Nome to begin operations on June 22. By the end of June approximately 35 towing stations and eight gillnet stations in Norton Sound were completed.

Aerial coverage of the coastline for monitoring the timing and distribution of spawning herring populations was initiated in early June as ice and weather conditions permitted. Approximately 3,500 kilometers of coastline coverage was made by June 28.

An 7Y78 work proposal (156.8K) for R.U. 19 was completed at the request of the OCS Juneau project office and submitted by the end of this quarter.

III Results and Preliminary Interpretation

None at this time.

IV Problems and Changes

None encountered during this quarter

V Estimate of Funds Expended

The following balances are through July 31,1977:

	8/1/77 Balance
Salaries	$21,900
Contractual services	33,376 1/
Commodities/Equipment	4,300
	$59,576

1/Includes $30,000 large vessel charter monies

Quarterly Report

Contract #03-5-022-69
Research Unit #19 PART II
Reporting Period May 1, 1977 - June 30, 1977
Number of Pages: 10

Forage Fish Assessment Surveys, Southern Bering Sea

Irving M. Warner
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P.O. Box 686
Kodiak, Alaska 99615

June 30, 1977

I. Task Objectives

The primary objective of this work to continue the assessment and life history studies of forage fish species in the Bering Sea initiated in FY 76. The primary objectives of this work are:

A. Determine spatial and temporal distribution of forage fish species between Cape Sarichef, north to the Yukon-Kuskokwim Delta.[1]

B. Document the relative abundance of forage fish species temporaly and spacially with emphasis on their late spring and summer spawning periods.

C. Investigate basic life history parameters of the principal forage fish species ancillary to all activities connected with the study.

II. Field or Laboratory Activites

A. Field Schedule and Activities:

Regular aerial surveilance of spawning forage fish schools by low level flights throughout the study area were initiated for FY 77 on May 8. This survey encompassed the coastline of that portion of the study area from Smokey Point (Ugashik Bay) to Cape Sarichef at the southwest extremity of the Alaska Peninsula (1166 km). Since that time eighteen additional survey flights have been conducted over various portions of the study area, six between Cape Sarichef and Smokey Point, six between Smokey Point and Cape Newenham, and six between Cape Newenham and the north mouth of the Yukon River (total of 3782 km). A major objective of this survey effort is to conduct surveys prior to, during and following spawning in all portions of the study area, so as to document the spatial and temporal distribution of spawning activity. Spawning ground surveys began on May 17, 1977, at which time residence was set up at the R.C.A. White Alice station at Port Heiden. Test fishing activities were then initiated at the Port Heiden (Meshik Beach) fishing site where similar sampling was conducted by this research unit in FY 76. Field activities at this site shall be continued until approximately July 4, when a brief collection foray will be made to

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[1] It should be noted that while the study area for this work extends from the Yukon River Delta to Cape Sarichef, the original work statement clearly states that ground truth surveys would only be applicable to the portion of this area south of Cape Newenham.

the Bear River area in search of spawning eulachon.

Regularly planned sampling efforts were supplemented by the opportunity to obtain herring and capelin samples from the floating processor, MV ALL ALASKAN which was present in the greater Togiak Bay region from May 15 to June 15, 1977. This opportunity was made possible through cooperation and coordination with Alaska Department of Fish and Game (ADF&G) management personnel. A resident ADF&G biologist collected daily herring samples from the herring (and in one case capelin) catch brought to the floating processor by its fleet of catcher boats. Processing and/or preservation of samples was then done on board the MV ALL ALASKAN on a time available basis. Some 1700 frozen samples were shipped to Kodiak for detailed, AWL analyses.

B. The scientific personnel involved in this study were as follows:

1. Peter B. Jackson, ADF&G-OCS Coordinator and co-principal investigator.

2. Irving M. Warner, ADF&G-OCS Biologist and co-principal investigator.

3. Dan Wieczorek, ADF&G Biologist, Kodiak, Alaska (on loan).

4. Mrs. Pamela Shafford, ADF&G-OCS Biologist, Kodiak, Alaska. (Assistant to the P.I.'s.)

5. Brian Bue, ADF&G-OCS Fisheries Technician, Kodiak, Alaska.

6. Mr. Ron Regnart, ADF&G Regional Supervisor, Anchorage, Alaska.

7. Mr. Mike Nelson, ADF&G Area Management Biologist, Dillingham, Alaska.

8. Mr. Richard Randall, ADF&G Assistant Area Management Biologist, King Salmon, Alaska.

C. Methods

1. Ground Truth Surveys

Test fishing procedures at the Port Heiden fish site employed gill nets and beach seines as primary sampling tools. The gill nets used were 32 meters long, 2 meters deep, and constructed of multi-filament mesh comprising 5 separate panels of 1/2, 3/4, 1, 1-1/4, and 1-1/2 inch bar mesh; smaller (13 meter) mono-filament gill nets consisting of 5 separate panels with bar meshes of identical dimension as the multi-filament nests described above were also used. Gill nets were fished by anchoring them with 20 pound "Navy" anchors in the intertidal area in Port Heiden Bay and picked at the near low tide phase, twice daily when possible. Specimens collected received primary processing at the Port Heiden facility (length and weight determinations), and scales (and/or otoliths) were collected for later age analysis at the Kodiak laboratory. Beach seining was also conducted in Port Heiden Bay with a 50 meter by 2 meter (tapered) beach seine with 4-10 millimeter bar mesh. Beach seining was conducted on an opportunistic basis. Specimens collected were processed in an identical manner as described above for gill net catches. Scales for age analysis as well as body length and age were obtained for all boreal smelt herring and capelin caught. Otoliths were also taken from capelin and eulachon. Female gonads are being collected for fecundity analysis for all species when possible. Biological processing is taking place in Kodiak at this time under the direction of the Assistant to the Principal Investigator. Herring were measured from snout to the hypural plate (standard length), and all other species captured and sampled were measured from snout to fork of tail (fork length). Weights of all species were recorded to nearest gram.

Scales of all herring processed so far have been mounted on glass slides. Since the laboratory analysis is being conducted by one person, a small tape recorder was utilized for recording data. The tapes were transcribed immediately after each day's sample was completed. Ages have been determined with a dissecting scope equipped with glass plate, movable mirror and transmitted light.

2. Aerial Surveys

Aerial surveys conducted during FY 77 have followed methodology described for this study component in the FY 76 Project Completion Report for R.U. 19. Surveys between Cape Sarichef and Cape Newenham were flown in Cessna 180 and 206 aircraft, and those between Cape Newenham and the Yukon River Delta were flown in light twin engine aircraft. All pertinent biological, chronological, climatological and geographical data were recorded onto a Model 210 Dictaphone tape recorder during these surveys and transcribed onto aerial survey forms conforming to the File Type 057 Format for ADF&G processing immediately following each flight.

D. Sample Localities

The primary sampling sites in FY 77 are identical to those utilized by this study in FY 76. These include Metervik Bay, Port Heiden and Port Moller-Herendeen Bays. The Port Heiden test fishing site is presently being sampled and the Port Moller-Herendeen Bay complex has yet to be sampled as forage fish spawning has not yet occured there. These aforementioned stations are the primary spawning ground survey stations for R.U. 19 in FY 77.

The trackline for aerial surveys extends south and west on the intertidal zone from the north mouth of the Yukon River through Bristol Bay and the north coast of the Alaska Peninsula to Cape Sarichef.

III. Data Collected or Analyzed, Results

A. Aerial Surveys

A total of nineteen individual survey flights have been conducted to date in the 3782.8 km study area. The sum total of this effort is surveilance of 9756 km, or coverage of the entire study area approximately 2.5 times. In an effort to show quantitatively whether differences in abundance of forage fish schools exist within the study area, this total area was considered in three subareas which were compared on the basis of schools seen per kilometer flown. This provides a directly comparable unit of density which is not affected by differences in total sample size. The three subareas and their respective density rates were Cape Sarichef to Smokey Point (.0120 schools/km), Smokey Point to Cape Newenham (0.1953 schools/km) and Cape Newenham to the north mouth of the Yukon River Delta (0.0876 schools/km). The school density index in the Smokey Point to Cape Newenham subarea exceeds those north and south of it by 223% and 1628%, respectively. As will be seen later in this report, the absence of forage fish schools between Cape Sarichef and Smokey Point is a radical departure from the results of FY 76 studies and cannot be explained at this time. These results are inconclusive as surveys of the northernmost and southernmost of these subareas are still in progress. In viewing the results of the northernmost subarea it should be noted that the peak of the spawning in this area has not yet been attained as schools normally begin to appear at a later date than in other areas surveyed. A summarization of aerial survey data obtained to date is shown in Table 1.

B. Spawning Ground Surveys

A summarization of results of the extent of spawning ground survey data obtained to date from the Metervik Bay

Table 1. Preliminary summarization of forage fish aerial surveilance in the southern Bering Sea, May-June, 1977.

Subarea	Length of coastline - km	Total km surveyed	Total forage fish school sighted	Schools seen/km flown
Cape Sarichef to Smokey Point	1166.0	4158	50	0.0054
Smokey Point to Cape Newenham	962.3	3395	663	0.1953
Cape Newenham to Yukon Delta	1657.5	2203	193	0.0876
Totals	3782.8	9756	906	0.0929

and Port Heiden areas is shown in Tables 2 and 3. In addition, 526 herring from the Togiak region have received detailed processing in the Kodiak laboratory. Mean lengths and weights of herring were calculated from a subsample of 214 of these fish (table 2). Further, gonads from 42 female herring have been preserved in Gilson's solution in preparation for detailed fecundity analysis.

IV. Preliminary Interpretation of Results

The total catch at the Port Heiden test fishing area is only fifty percent of that at a comparable time last year. Aerial surveys have demonstrated that there are very few fish in the Port Heiden area, and these observations closely reiterate ground truth data obtained so far. Although this fact is readily apparant and documented by OCSEAP field personnel, the reasons for it are so far unknown.

An even more dramatic contrast has occured between the FY 76 and FY 77 forage fish catch results at the Port Moller-Herendeen Bay complex. By mid June, well over fifty schools of herring had been sighted and subsequently sampled in FY 76; in FY 77, however, not a single aggregation of forage fish has been seen. Seven OCSEAP aerial surveys as well as eight others of commercial and ADF&G management origin have been conducted in this area since May 8, 1977, and no schools have been seen. The reason for the absence of fish in this area is unknown.

The radical difference between FY 76 and FY 77 in the abundance of spawning forage fish schools sighted between Cape Sarichef and Smokey Point noted in results of ground surveys are further reflected in aerial survey results. It was shown earlier in this report that the number of schools seen per kilometer flown in this subarea during FY 77 was only 2.8% of that between Smokey Point and Cape Newenham where significant commercial and subsistance utilization recently occured. The severity of this decline is documented by the fact that the mean density index for the Cape Sarichef to Smokey Point subarea between May 22 and June 26, 1976 was .0878, 732% greater than that during the comparable period in FY 77. The fact that the peak FY 76 density index in this subarea of 0.17376 schools per kilometer was quite comparable (11% less) to the mean density index between Smokey Point and Cape Newenham thus far in FY 77 documents that this former area can and has supported significant forage fish spawning stocks (Barton, Warner, Shafford, 1977).

The preliminary analyses of data obtained from spawning ground surveys and the small sample size make overall interpretations difficult at this time. This is due to the fact that the primary processing is not yet half completed and the standing morphemetric data have not yet been fully examined since the field season is still in progress.

Table 2. Preliminary summary of southern Bering Sea forage fish morphometric data obtained and processed by R.U. 19 staff between May 1 and June 22, 1977.

Species	No. Collected	No. Processed	Area Caught	Catch Method	Parameters Sampled to Date			
					Scales Collected	Female Gonads Collected	Otoliths Collected	No. Aged
Boreal Smelt [1]	423	334	Port Heiden	Gill net & seine	175	0	0	0
Eulachon	32	31	Port Heiden	Gill net	0	6	31	0
Capelin	1000	0	Togiak	Power purse seine	0	0	0	0
Capelin	83	83	Port Heiden	Gill net	65	3	75	0
Herring	17	16	Port Heiden	Gill net & beach seine	16	-	0	0
Herring	1783	876	Togiak area	Power purse seine	1783	42	0	602
Herring	1085	1035	Metervik Bay	Power purse	1085	50	0	1035
Misc.	52	51	Port Heiden	Gill net &Beach seine	4	0	0	0
Totals	4475	2426	-	-	3128	101	106	1637

[1] Macro-organism stomach analysis completed.

Table 3. Preliminary analyses of morphometric data obtained on southern Bering Sea forage fish stocks sampled by R.U. 19 staff between May 1 and June 22, 1977.[1]

Species	Mean Lenght mm	Mean Weight grms	Area Represented	N =
Herring	(S.L.)[2] 234	-	Port Heiden	16
Herring	(S.L.) 228 - female 235 - male	164 - female 176 - male	Togiak	107 - female 107 - male
Boreal Smelt	(F.L.)[3] 149	-	Port Heiden	334
Eulachon	(F.L.) 22	-	Port Heiden	31
Capelin	(F.L.) 149	-	Port Heiden	83
Capelin	(F.L.) 137 - female 151 - male	16 - female 25 - male	Togiak	100 - female 100 - male (subsample)

[1] Sample shown here represents subset of total sample obtained.
[2] S.L. - Standard length
[3] F.L. - Fork length

V. Problems Encountered/Recommended Changes

One of the most difficult situations encountered thus far in this study is the air strike now in progress which affects all of South Central Alaska in regards to air freight and passenger travel. This situation has necessitated the additional costs of chartering two engine aircraft to transport over three tons of freight and scientific personnel to and from the study area. This increased the anticipated costs of the study by approximately $2700. Since the tight constraints of original funding demands daily audits and constant interchange of fiscal information between Kodiak base and field stations, the additional unexpected costs due to the air strike have had a severe impact on this project. The principal investigators thereby request the additional $2700 above the $50,000 FY 77 R.U. 19 funding level to absorb this addtional expense.

Aside from the aforementioned problem, all field and laboratory situations have been handled as scheduled, and, although the field personnel are presently perplexed over the complete absence of forage fish in the Port Moller-Herendeen Bay complex, project activities are going as expected. Aerial surveys have gone smoothly, perhaps due to the principal investigators being increasingly accurate in their choice of reliable air taxi service, the lack of which caused constant logistical problems in FY 76. Also, it is apparent that these surveys are increasingly accurate due to increased observer experience.

VI. Estimate of Funds Expended

Approximately $12,000 has been expended for air logistics, travel, freight, air charter, housing and commodities (including equipment). This leaves us approximately $8000 for air charter (aerial surveys) and movement of ground truth crew for continuance of sample collection effort. Of this $8000, approximately $4700 is obligated for aerial surveys in the northern portion of the R.U. 19 contract area and $1900 is obligated for aerial surveys between Cape Sarichef and Smokey Point. This leaves approximately $1400 for other costs of continuing this project. With the present air strike still in progress, we expect to need an additional $2700 to cover air charter costs of closing camp and freighting materials e.g. equipment, etc., back to the Kodiak base.

With little over two months remaining in our time allowance to complete this project, (monies terminating September 1) we would like to reiterate the statement made in the original work statement for this project. This statement stresses that the completion of analyses and final reporting of the agreed upon work is dependant on funding being available for the FY 77-78 Kodiak forage fish project to cover salaries of necessary personnel beyond September 1.

Literature Cited

Barton, Louis H., I.M. Warner, P. Safford, 1977.
Herring spawning surveys southern Bering Sea. Outer Continental Shelf Environmental Assessment Project, Project Completion Report, Research Unit 19, 104 pp.

QUARTERLY REPORT

Contract No.
Research Unit #78
Reporting Period-April 1-June 30, 1977
Number of Pages - 8

BASELINE/RECONNAISSANCE CHARACTERIZATION LITTORAL BIOTA, GULF OF ALASKA AND BERING SEA

by

Steven T. Zimmerman*
Theodore R. Merrell, Jr.*

*Northwest and Alaska Fisheries Center Auke Bay Laboratory

OUTER CONTINENTAL SHELF ENERGY ASSESSMENT PROGRAM
Sponsored by
U.S. Department of the Interior
Bureau of Land Management

July 1, 1977

I. Task Objectives

This task has three principal objectives: to characterize the coastline according to major habitat types (sandy, muddy, rocky, etc.), to determine the densities and distribution of biotic populations within these habitat types; and to initiate intensive studies at selected sites to determine seasonal and ecological interrelationships of the major biota, and their significance in the food web of higher trophic levels.

There are several phases to each objective. Determination of the distribution of habitat types (using visual reconnaissance methods from fixed wing aircraft) has been largely completed. Additional information utilizing aerial photography and multispectral scanning methods has been produced in cooperation with NASA and the Environmental Research Institute of Michigan and is undergoing interpretation.

Surveys and collections of organisms within habitat types has been completed by field parties from the Auke Bay Laboratory (ABL), with vessel and helicopter logistical assistance from the Pacific Marine Center. Analysis of the collections is partially completed. Additional phases include: a study of the accumulation of biotic debris in the "drift zone," which was completed in July 1976; and the estimation of biological variability between sampling areas.

Intensive studies of seasonal and ecological interrelationships were initiated in April/May at two sites: Kodiak Island (Chiniak Bay) and Hinchinbrook Entrance (Port Etches).

II. Field or Laboratory Activities

April

A. Schedule: April 14-21, 1977.

B. Scientific Party: Steve Zimmerman, Joyce Gnagy, Natasha Calvin, John MacKinnon (ABL); Charles O'Clair (Consulting Intertidal Ecologist).

C. Methods: The purpose of this trip was to investigate the Kodiak area and select a site for the intensive phase of the littoral program. Methodology was, therefore, mostly limited to general observation and SCUBA reconnaissance at several locations.

D. Sample localities: Approximately eight locations (Fig. 1) along the shores of Chiniak Bay were examined. Two other possibilities (Woody Island and Long Island) may be investigated at a later date.

E. Data collected: No data were taken other than qualitative general field notes concerning the abundance of biota at the different sites.

May

A. Schedule: May 1-8, 1977. Charter vessel: Yankee Clipper.

B. Scientific party: Steve Zimmerman, Joyce Gnagy, Natasha Calvin, John MacKinnon (ABL); Charles and Rita O'Clair (Consulting Intertidal Ecologists).

C. Methods:

1. Rocky intertidal: The reef at Nuchek was selected as the location for intensive baseline studies in the Hinchinbrook Entrance area. Several areas were permanently marked and organisms were counted and measured in order to observe the growth of *Alaria* plants and the reestablishment of *Balanus cariosus* and *Mytilus edulis* populations on cleared quadrats. Several *Pisaster ochraceus* were measured, weighed and tagged.

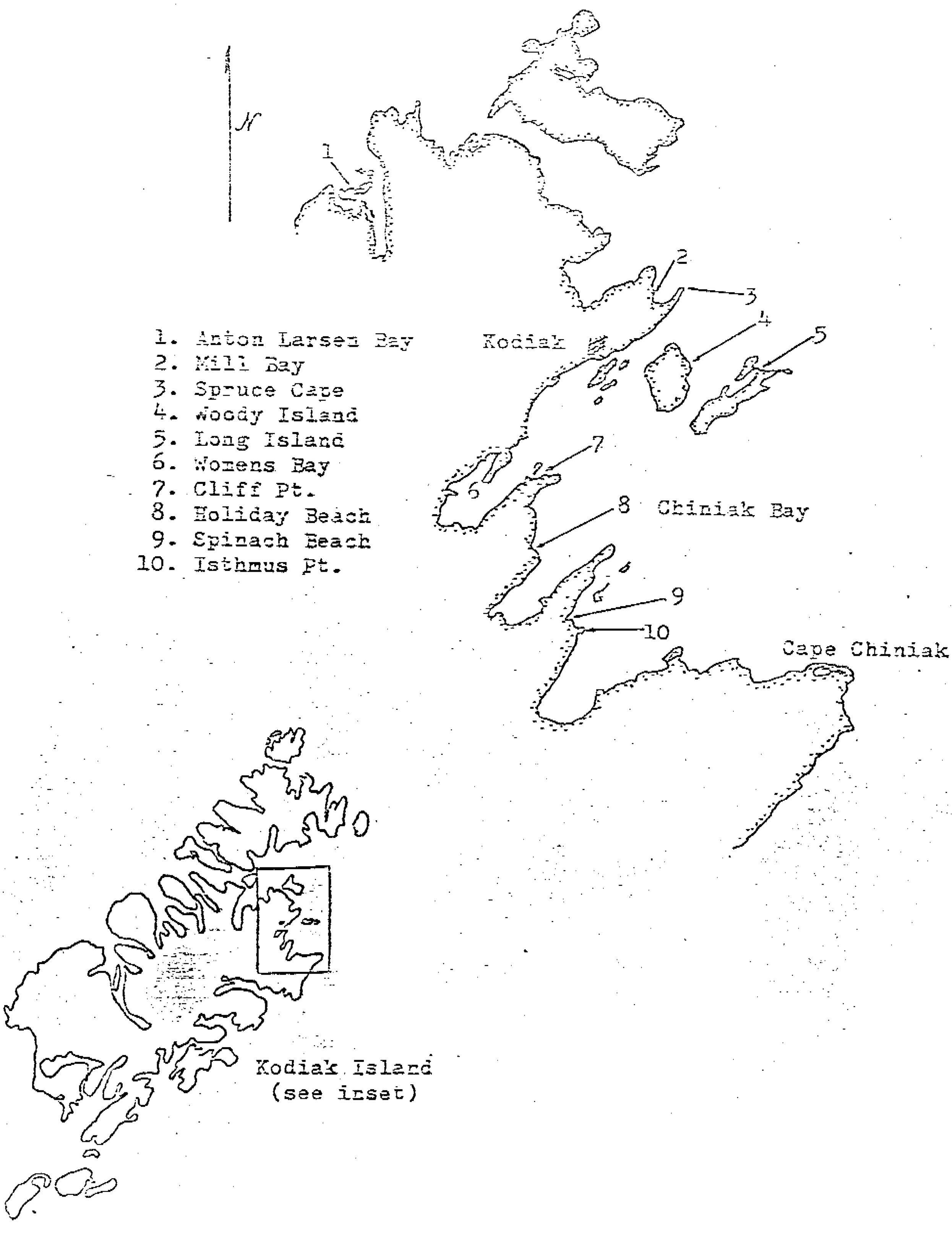

Figure 1. City of Kodiak and Chiniak Bay

2. Muddy intertidal: Two permanent transect lines were established and photographed. The populations along each transect line were enumerated. Several of the dominant organisms, e.g. Cucumeria, Archidoris, and Echiurus, were quantitatively collected from random plots, weighed and measured.

3. Subtidal: Both rocky and muddy intertidal sites were observed with SCUBA at high tide. Behavior of dominant species was noted. A total of 75 m^2 quantitative quadrat collections were made of the dominant kelps in Constantine Harbor, and biomass of the kelp species was determined.

D. Sample localities: Rocky intertidal studies were carried out on Nuchek Reef at the mouth of Port Etches on Hinchinbrook Island (Fig.2). Muddy intertidal studies were on the south shore of Constantine Harbor inside Port Etches.

E. Data collected: Most of the data were concerned with the size and density of dominant species. These will later be used to construct seasonal patterns of distribution and growth.

III. & IV. Results and discussion.

All of the plates for the Intertidal Survey Atlas were completed in June. The Juneau GSA Printing Office anticipates 1 month will be needed for printing, so the atlas should be ready for distribution by early August.

During May a new contract with the University of Alaska Sorting Center was negotiated to sort the remaining samples from littoral surveys made in 1975 and 1976. During the negotiating period very little data was received from the Sorting Center. Therefore, no new tapes have been submitted to NODC. With the new contract however, and receipt of additional samples from the Sorting Center it will be possible to complete data workups and tapes for several cruises.

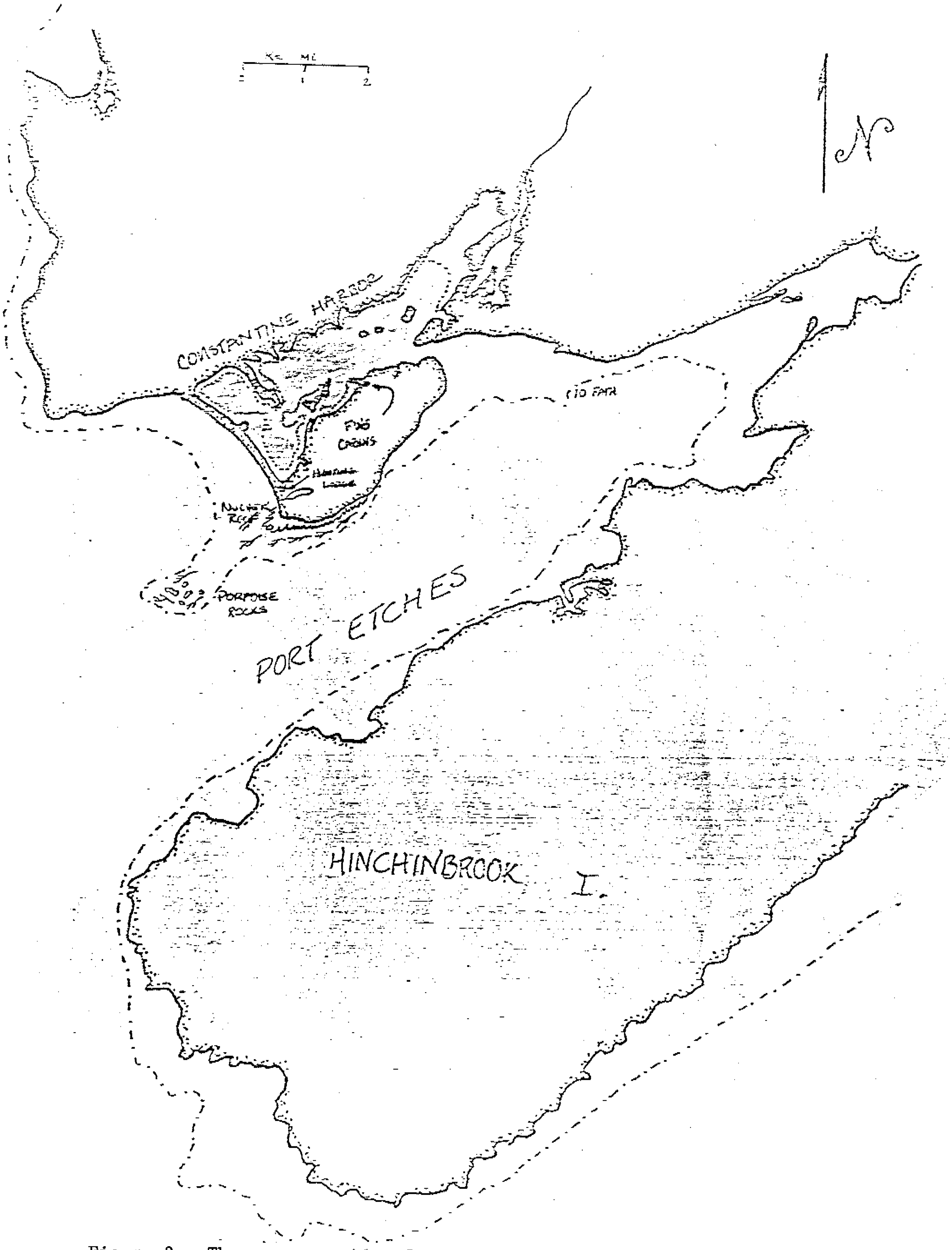

Figure 2. The eastern side of Hinchinbrook Entrance showing Port Etches and Constantine Harbor.

A second draft of the Kodiak Report was completed in June. This report, which includes an intensive analysis of our data from the Kodiak area, will be completed by mid-summer.

Several discussions were held with OCSEAP concerning the next phase of the multispectral scanning (ERIM) research program. Auke Bay scientists have completed analysis of existing data and comparisons with the preliminary computer output. Additional computer work utilizing new training areas by the scanner will be necessary to verify the accuracy of this data service.

A manuscript describing the data collected on biomass and distribution of laminarian kelps on the Kodiak Continental Shelf has been submitted to Marine Biology for publication.

The field trip to Kodiak centered around the Chiniak Bay area, both because of convenient and inexpensive road access and because of OCSEAP priorities in this area. The consensus of the field party was that Isthmus Point was the most suitable of all of the sites examined. However, discussion with former Kodiak residents indicates that the south side of Chiniak Bay may have been impacted by a JP-5 spill in March 1970 and may continue to receive chronic inputs from the Coast Guard Base and local fishing fleet. Furthermore, discussions with OCSEAP Juneau Project Office have indicated that Chiniak Bay may now have a reduced priority for intensive study and integrated multidisciplinary research. Consequently, we shall put off any further intensive sampling on Kodiak Island until new directions are received from OCSEAP.

The field trip to Hinchinbrook Entrance (Port Etches) indicated that this area would be an outstanding site for integrated intensive studies. This decision was based on a number of criteria including: 1) year-round accessability; 2) the presence of a diversity of habitats and abundant biological populations; 3) high potential for oil impact; and 4) it is relatively unaffected by human activities.

Constantine Harbor, within Port Etches, is enclosed by land except for a narrow entrance, where many of the ecological functions of the harbor can conveniently be studied. It has large standing stocks of subtidal kelps and the infauna is diverse and abundant (*Cucumeria* for instance averaged 1800/m^2). Large populations of birds and sea otters utilize the area. Nuchek Reef, across the spit from Constantine Harbor, supports large populations of algae and invertebrates, many of them oil-sensitive species such as *Pisaster ochraceus*, which apparently play a major role in structuring the community. For these reasons, Constantine Harbor is an ideal location for intensive ecosystem studies.

V. Problems encountered/recommended changes.

Before we can continue the intensive phase of our littoral research, two problems must be resolved. First, the availability of future funding for the research must be confirmed. At present it appears that there will not be adequate funding in FY 78 unless our request for additional funds is approved. Second, additional guidance from OCSEAP is needed to select a site on Kodiak which meets OCSEAP criteria for multidisciplinary intensive studies.

VI. Estimate of Funds Expended Through Third Quarter (Oct. 1, 1976-June 30, 1977)

Salaries	$213.1k
Travel	12.6
Contracts	29.1
Equipment & Supplies	2.6
Other Costs	16.6
Support	69.5
Total	$343.5k

Quarterly Report June 1977

RU 174 - Baseline Studies of the Demersal Resources of the Eastern and Western Gulf of Alaska Shelf and Slope: A Historical Review

I. Task Objective

To review and analyze existing literature on the distribution, abundance, and productivity of demersal fish and shellfish from Unimak Pass (165^{o} W. long.) to Cape Spencer (137^{o} W. long.) including trawl survey data and domestic and foreign catch records.

II. Field or Laboratory Activities

A. Ship or field schedule

None involved.

B. Scientific Investigators (both are personnel of the Northwest and Alaska Fisheries Center, Seattle, Washington)

Lael L. Ronholt (Principal Investigator)

Herbert H. Shippen (Fishery Biologist)

C. Methods

Historical survey data on ADP cards have been transferred to computer disc for compiling and analysis. Existing computer programs have been utilized to provide: (1) species composition and biomass estimates by area, depth, and time; (2) charts showing the distribution and relative abundance (catch in weight per unit area) of the major fish and shellfish species; and (3) average length and length composition of major species.

Biomass estimates have been obtained by the "area swept" technique described by Alverson and Pereyra (1969).

Domestic and foreign fishery catch statistics have been examined and analyzed for historical changes in magnitude of catches by species and fishing grounds.

D. Sample localities/ship or aircraft tracklines

Not applicable.

E. Data collected or analyzed

1. Number and types of samples or observations

No samples have been collected and none are to be collected.

2. Number and types of analyses

Not applicable.

3. Miles of trackline

Not applicable.

III. Results

The scope of the survey area includes the northern Gulf of Alaska from Unimak Pass (165^{o} W. long.) to Cape Spencer (136^{o} W. long.). All data sources have been gathered, the data keypunched and verified, and the information loaded onto discs for analysis. Species composition, distribution, abundance, and biomass data analyses are 97% completed, while species distribution plots and size composition are 90% and 70% respectively. Domestic and foreign catch statistics and areas of high fisheries yield analysis are completed and that section of the report is presently being written. Records of commercial catches by domestic and foreign fishermen have been compiled and analyzed; specific areas of outstanding importance to commercial fisheries have been identified.

IV. Preliminary interpretation of results

Not applicable.

V. Problems Encountered/Recommended Changes

No insurmountable problems have been encountered and preparation of the final report, due in September 1977, is progressing according to expectations.

References

Alverson, D. L. and W. T. Pereyra

1969. Demersal fish explorations in the northeastern Pacific Ocean--an evaluation of exploratory fishing methods and analytical approaches to stock size and yield forecasts.

J. Fish. R. Board of Canada 12 (8): 1895-2001.

QUARTERLY REPORT

Contract No. R7120802
Research Unit #175
Period April 1, 1977 to
June 30, 1977

BASELINE STUDIES OF FISH AND SHELLFISH RESOURCES OF NORTON SOUND AND THE SOUTHEASTERN CHUKCHI SEA

Principal Investigator:

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Associate Investigators:

Terrance M. Sample
Martin Morin, Jr.

Northwest and Alaska Fisheries Center
National Marine Fisheries Service
2725 Montlake Boulevard East
Seattle, Washington 98112

Research Unit 175-A-14

Quarterly Report, April-June, 1977

I. Task Objectives

The objectives of RU 175-A-14 are to determine the distribution and abundance of fish and shellfish resources in the southern Chukchi Sea and Norton Sound, estimate the productivity, length, weight and age distribution of selected demersal fish and shellfish to develop growth models and to provide a data base against which later changes in these parameters may be compared.

II. Field and Laboratory Activities

A. Ship or field trip schedule

1. No field season

B. Methods

1. Ship cruises

N/A

2. Laboratory activities

Laboratory time was primarily utilized in the analysis of the 1976 survey data. Biomass estimates were computed for the principle fish and invertebrate taxa encountered. Age compositions, based on otoliths taken and length-frequency samples have been determined for key fish species. Additionally, major recurrent species groups were identified through fish and invertebrate species associations analysis. Nearly all preliminary tables and figures to be included in the final report have been completed. Catch contours, showing distributions, were delineated for the major species and species groups. Historical catch statistics have been compiled for the description of the commercial fisheries of the survey region.

III. Results

The analysis of the 1976 FRS Miller Freeman data collected in the Chukchi Sea and Norton Sound region is nearing completion. A preliminary draft organizing the analytical results and other findings is currently being developed for the final report. Sections describing the geography, marine fauna, and commercial fisheries of the survey area have been completed. Also, a historical review of Chukchi Sea and Norton Sound fishery explorations is nearly finished. Age compositions indicating year-class strengths have been completed for the following species: Pacific herring (Clupea harengus pallasi), Bering flounder (Hippoglossoides robustus), Arctic cod (Boreogadus saida), toothed smelt (Osmerus mordax dentex), yellowfin sole (Limanda aspera), saffron cod (Eleginus gracilis), Alaska plaice (Pleuronectes quadrituberculatus), and starry flounder (Platichthys stellatus). Length-weight relationships have also been determined and plotted for the preceding species. Charts showing survey catch rate isopleths are now in final preparation for the final report.

IV. Preliminary Interpretation of Results

Biomass estimates of the major taxonomic groups of benthic fauna in Norton Sound and the southeastern Chukchi Sea have been determined and are presented in Table 1. Invertebrates were found to be the most dominant taxa comprising nearly 86% of the total apparent biomass. Starfish accounted for approximately 50% of the total invertebrate biomass for the entire survey region, being most abundant in the relatively shallow waters of Subarea 4 (see Figure 1 for an identification of the subareas defined for the survey region).

Of the commercially important crab species, the Tanner crab (Chionoecetes opilio) is the most abundant in Subareas 1 and 2 (waters north of Bering Strait). Their biomass is greatly reduced in the more southerly waters of Subareas 3 and 4 where king crab (Paralithodes sp.) becomes the dominant form.

Fish comprise only 14% of the total benthic fauna biomass of the survey region with the families Gadidae, Pleuronectidae, and Cottidae being most abundant. The gadids, saffron cod and Arctic cod, account for 67% of the total fish biomass; their greatest concentrations are found in Subareas 3 and 4. The pleuronectids represent 31% of the total fish biomass with the heaviest concentrations in Subareas 1 and 4.

V. Problems Encountered/Recommended Changes

Dr. Walter T. Pereyra, Co-principle Investigator, departed NMFS in April for employment with private industry. His services will not be available for the remainder of the research unit duration, however, subsequent adjustments have been made and no major problems are anticipated.

Table 1. Apparent biomass by major taxonomic groups by subarea estimated from the BLM/OCS survey in Norton Sound and the southeastern Chukchi Sea, September-October, 1976.

Taxa	Biomass for 1/ total survey area (mt)	Proportion of total biomass 1/	Biomass by subarea				Proportion of taxa biomass by subarea			
			1	2	3	4	1	2	3	4
Gadidae	22,692	.067	1,447	1,027	7,674	12,544	.063	.045	.338	.553
Pleuronectidae	10,509	.031	2,783	399	1,999	5,328	.264	.038	.190	.507
Cottidae	6,699	.020	695	101	4,547	1,356	.104	.015	.679	.202
Clupeidae	2,878	.009	637	1,607	453	181	.221	.558	.157	.063
Osmeridae	2,463	.007	320	740	1,035	368	.130	.300	.420	.149
Zoarcidae	888	.003	250	65	387	186	.282	.073	.436	.209
Cyclopteridae	574	.002	333	7	224	10	.580	.012	.390	.017
Stichaeidae	222	.001	45	24	23	130	.203	.108	.104	.586
Agonidae	248	.001	83	8	79	78	.335	.032	.319	.315
Other fish	271	.001	8	2	211	50	.029	.007	.779	.186
Total fish	47,444	.140	6,601	3,980	16,632	20,231	.139	.084	.351	.426
Gastropod molluscs	19,341	.057	8,649	1,253	6,368	3,071	.447	.064	.329	.159
Pelecypod molluscs	632	.002	191	40	99	302	.302	.063	.157	.478
Shrimp	2,904	.009	1,171	175	936	622	.403	.060	.322	.214
Chionoecetes sp.	8,741	.026	3,879	3,597	1,210	55	.444	.412	.138	.006
Paralithodes sp.	5,192	.015	76	13	1,515	3,588	.014	.003	.292	.691
Telemessus sp.	2,769	.008	1,199	217	330	1,023	.433	.078	.119	.480
Total commercially important invertebrates	39,579	.117	15,165	5,295	10,458	8,661	.398	.134	.264	.219
Starfish	161,251	.478	38,842	17,252	34,264	70,893	.24	.107	.212	.440
Other echinoderms	27,010	.080	4,221	42	22,626	121	.156	.002	.838	.006
Other invertebrates 3/	62,395	.185	31,337	4,804	19,243	7,011	.502	.077	.308	.146
Total invertebrates	290,235	.859	89,565	27,393	86,591	86,686	.309	.094	.298	.299
TOTAL CATCH 4/	337,679		96,166	31,373	103,223	106,917	.285	.093	.306	.317

1/ Apparent estimated biomass susceptible to the trawl.
2/ Total biomass for all fish and invertebrate taxa.
3/ Primarily includes coelenterates, pagurid crabs and ascidians.
4/ Total catch of all fish and invertebrate taxa.

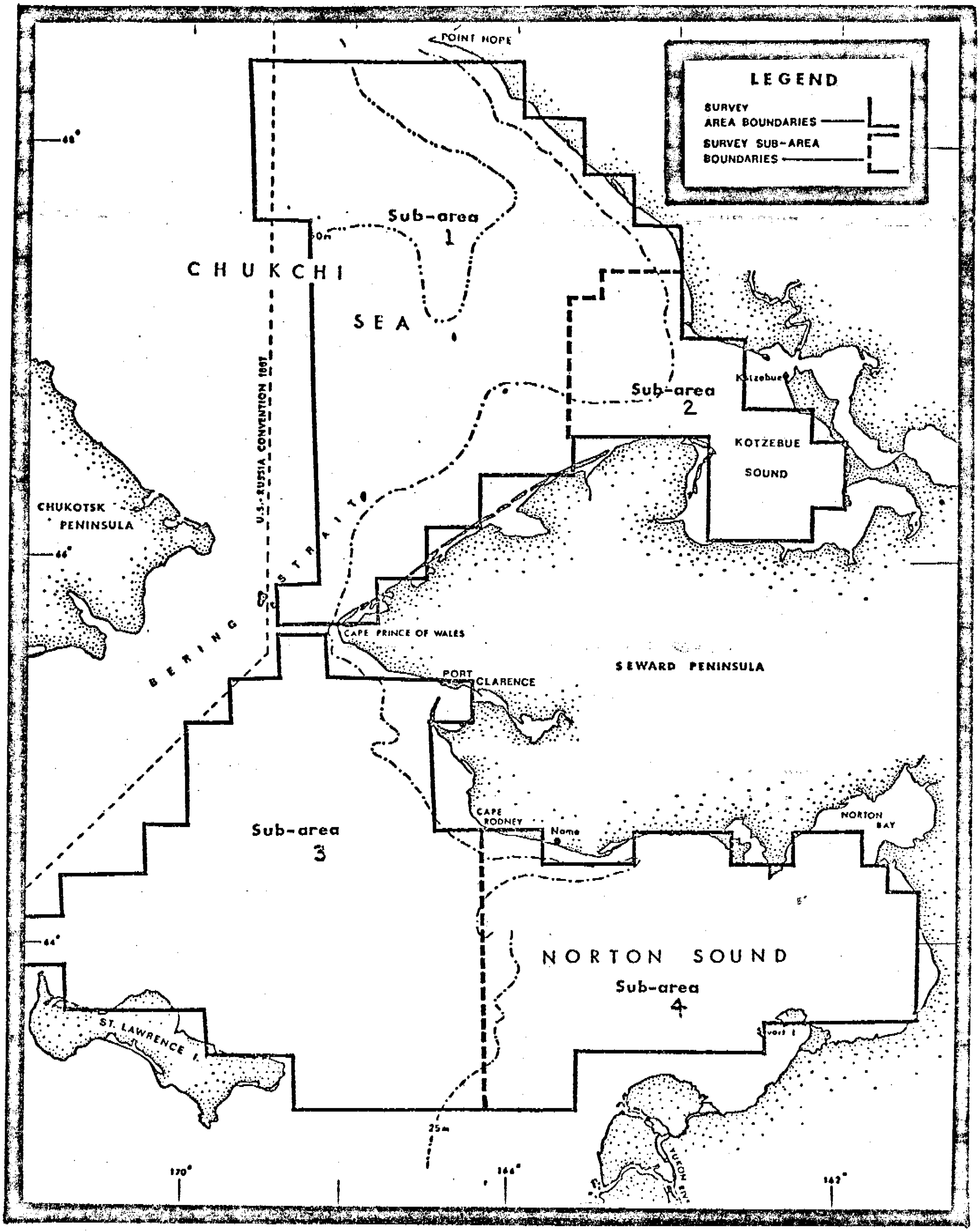

Figure 1.--Sub-area boundaries, 1976 baseline survey.

Quarterly Report

Contract #03-5-022-69
Research Unit #233
Reporting Period - April
through July 1977

Beaufort Sea Estuarine Fishery Study

Principal Investigator:

Terrence N. Bendock
Fisheries Biologist
Sport Fish Division
Alaska Department of Fish and Game
1300 College Road
Fairbanks, Alaska 99701

1 July 1977

I. Task Objectives

The objectives of the Beaufort Sea Estuarine Fishery Study are as follows:

A. To determine the seasonal distribution, relative abundance, size and species composition, growth rates, feeding habits and reproductive capabilities of Beaufort Sea nearshore fishes in the area from the Colville to the Canning rivers and between shore and the barrier islands, including river deltas.

B. To determine migration patterns and timing of these fishes.

C. To identify critical habitats including spawning, overwintering, feeding, rearing and migration areas.

D. To determine the interrelationship of Arctic fishes to lower food-web organisms.

E. To determine the present rate of exploitation of the anadromous fishes of the area and to monitor changes in this usage as development of the area's petroleum resource progresses.

II. Field or Laboratory Activities

There was no field work conducted under this contract during the reporting period. Preparations for the 1977 summer field season were made.

III. Results

The results of our 1976 field season were reported in our April 1977 annual report. Raw data from 1976 field work has been submitted to the Geophysical Institute for programming and storage on magnetic tape.

IV. Preliminary Interpretation of Results

None at this time.

V. Problems Encountered/Recommended Changes

To date we have encountered no problems while conducting the field studies of this project.

QUARTERLY REPORT

Contract 03-5-022-56
Task Order No. 15
Research Unit No. 281
Reporting Period: 4/1 - 6/30/77

THE DISTRIBUTION, ABUNDANCE, DIVERSITY AND PRODUCTIVITY OF BENTHIC ORGANISMS IN THE BERING SEA AND THE GULF OF ALASKA

Principal Investigator

H. M. Feder
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Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

Assisted by: Associate Investigators

G. Mueller, M. Hoberg, S. Jewett and G. Matheke
Research Assistants
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

June 1977

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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

Gulf of Alaska and Bering Sea

1. No cruises were scheduled for this quarter.

2. The analysis of all samples collected in the past two years is still in progress at the Marine Sorting Center of the University of Alaska. All data is being keypunched as it becomes available. Refinement of computer programs used in analyses continues. The methods used in Cluster Analysis are outlined in the Annual Report for 1976 and are discussed in some detail in the Annual Report for 1977.

3. Grab material from all stations occupied on the cruises of the past two and one-half years have been submitted to the Marine Sorting Center for processing.

B. Trawl and Pipe Dredge Program

1. No cruises scheduled for this quarter.

2. All unprocessed trawl and pipe dredge material from Cook Inlet and the Bering Sea were examined, species determined and data submitted for keypunching.

3. Dominant clam species from Cook Inlet and the Bering Sea have been intensively examined as part of age-growth study initiated the last quarter under Judy McDonald at the Seward Marine Laboratory.

III. RESULTS

A. Grab Program

Northeast Gulf

1. All samples from the following cruises have been processed, and data analyses completed:

   (a) Cruise 815 - R/V *Silas Bent* - September 1975

   (b) Cruise 816 - R/V *Discoverer* - November-December 1975

2. Samples from the following cruise are processed, and are awaiting confirmation of identifications of vouchered specimens prior to keypunching:

   (a) Cruise DS001 - *Discoverer* - March 1975

3. A computer program has been written to examine data by Principal Coordinate Analysis. A preliminary analysis of data from selected cruises is currently in progress, and interpretation of the results of several computer runs using this program should be available soon.

4. A computer program has been written to examine community structure of station groups by way of Dominance-Diversity curves for (a) each station, (b) all stations, and (c) all station groups formed by cluster analysis.

Bering Sea

1. One-hundred seventy-five samples have been processed by the Marine Sorting Center during the past quarter. It is anticipated that an additional 90 samples, now at the Sorting Center, will be processed by the end of July. This will complete all the stations needed to initiate a final cluster analysis of all of the major stations on the entire Bering Sea grid.

B. Trawl and Pipe Dredge Program

Northeast Gulf

1. Some specific trawl data and some generalizations have been included in Institute of Marine Science Report R76-8 entitled *Distribution and Abundance of Some Epibenthic Invertebrates of the Northeast Gulf of Alaska with Notes on Feeding Biology* (61 pp.).

2. Trawl data from the northeast Gulf of Alaska will be included in the printed report of the Alaska Science Conference of the summer of 1976. The trawl section will be mainly based on Institute of Marine Science Report R76-8.

Cook Inlet

1. Sixty-two pipe and two clam dredge station samples, collected 18 October - 25 October 1976, were processed and analyzed. All invertebrates were sorted, field identifications confirmed, unidentified field specimens determined, and all species weighed (wet formalin weight). All clams were removed (35 species) for age-growth determinations of dominant species. Polychaetous annelids (10 families) were removed for later determinations at the Marine Sorting Center.

2. Clam species from Cook Inlet have been aged, measured, data recorded on computer forms and subjected to analysis.

   (a) Six-hundred and three *Nuculana fossa* have been examined. All data has been analyzed by computer programs developed at the Institute of Marine Science for clam age-growth studies. A size-age curve for this species has been generated.

   (b) Five-hundred fifty-six *Spisula polynyma* have been examined. All data has been recorded on computer forms and is in process of analysis.

   (c) A comparison was made of the mean shell length at each annulus of Cook Inlet and Hartney Bay (Prince William Sound) *S. polynyma*. Shell growth seems to be better in Hartney Bay clams.

Bering Sea

1. Forty-three pipe and one clam dredge station samples, collected 20 May - 4 June 1976, were processed and analyzed. All invertebrates were sorted, field identifications confirmed, unidentified field specimens determined, and all species weighed (wet formalin weight). All clams were removed (14 species) for age-growth analysis of dominant species. Polychaetous annelids (4 families) were removed for later determination at the Marine Sorting Center.

2. Thirty-six available specimens of the clam *Spisula polynyma* were aged, measured and recorded.

3. Ninety-nine of the clam *Macoma calcarea* were aged, measured and recorded.

IV. PRELIMINARY INTERPRETATION OF RESULTS

General interpretations of grab and trawl data are included in the 1976 and 1977 Annual Reports and in Institute of Marine Science Technical Report R76-8. Additional comments on this and pipe-dredge data will be included in the Final Report.

V. PROBLEMS ENCOUNTERED

No direct problems. However, the initial decisions by OCSEAP that, (1) our survey in the Gulf and the Bering Sea be primarily one of assessment of distribution and abundance of invertebrata, (2) our survey should not examine crab stomachs, and (3) the fish stomach survey by Dr. Ron Smith should have minimal and limited funding (also that we should not examine any fish stomachs in our project), are now proving to be seriously in error. If it had not been directly suggested that we not look at stomachs as we progressed in our assessment program (and frequently time was available as was our desire to collect this type of data), we would now have a good and sound basis for benthic food webs. Now the program is moving into the shelf area less than 40 m, and we have a serious lack of understanding of food interactions of benthic organisms on the rest of the shelf. We have essentially no food data from the northeast Gulf of Alaska with only slightly better data from Cook Inlet. Bering Sea food data is spotty, and now this program is terminated. I would strongly suggest that data on food habits of fishes in these regions be collected in the near future.

Quarterly Report

Contract #03-5-022-56
Research Unit #284
Task Order # 21
Reporting Period 4/1/ - 6/30/77
Number of Pages

FOOD AND FEEDING RELATIONSHIPS IN THE BENTHIC AND DEMERSAL FISHES OF THE GULF OF ALASKA AND BERING SEA

Dr. Ronald L. Smith
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

June 30, 1977

I. Task Objectives

Objectives for this quarter included a continuation of very limited archival procedures on recently acquired Bering Sea samples, completion of preliminary sorts on our five target species for the year and devising a computer program for analysis of data to be submitted in the immediate future.

II. Field and Laboratory Activities

A. Ship or field work:

None.

B. Scientific Party Involved in Project:

R. L. Smith, IMS	Principal Investigator
A. C. Paulson, IMS	Research Technician

C. Methods:

Same as previous methods outlined in June 30, 1976, "Procedures and Quality Control".

D. Sample Localities:

No new localities were sampled during this quarter.

E. Results:

stomach contents of all species for this project have been sorted. Computer analysis has been completed on the rex sole, flathead sole, pollock, arrowtooth flounder, and greenland halibut. Detailed reports on these species are partially completed.

We are awaiting identifications of unknown prey species by the Marine Sorting Center which should be available in mid-July for the dover sole, rock sole, shortfin eel pout and capelin. Hopefully keypunching and computer runs will be completed by the first week in August, when detailed reports on each of these last four species will be prepared.

F. Problems Encountered:

Dr. Smith had to rush his newborn child to Seattle for surgery and must remain outside from the last part of June through July. Technician funding was exhausted several months ago, but work will be completed on schedule.

Contract 03-5-022-81
Research Unit 356
April 1 to June 30, 1977

QUARTERLY REPORT

RECONNAISSANCE CHARACTERIZATION OF LITTORAL BIOTA, BEAUFORT AND CHUKCHI SEAS

and

ENVIRONMENTAL ASSESSMENT OF SELECTED HABITATS IN THE BEAUFORT AND CHUKCHI SEA LITTORAL SYSTEM

Principal Investigator, A. C. Broad

Western Washington State College

July 15, 1977

I. TASK OBJECTIVES: During the quarter work continued on analysis of biological samples collected during the 1976 field season. Final plans and other arrangements for the 1977 field season were completed, and a few investigators were in the field by June 30.

II. FIELD AND LABORATORY ACTIVITIES:

A. Ship and field trip schedule: Mason, Kiera, and Broad were in the Kotzebue area.

B. Scientific Party (all of Western Washington State College)

1. Principal Investigator:

A. C. Broad, on salary June 1 to 30.

2. Laboratory Supervisor:

Helmut Koch, April 1 to June 30.

3. Computer programmer:

Gregg Petrie, hourly wages.

4. Laboratory Assistants (all hourly wages):

Mark Childers

David Cormany

James Hanes

Scott Hansen

Gary Heckman

Patricia Jackson

Wendy Pounds

Carl Wheelers

Marijean Winchell

5. Associate Investigator:

David T. Mason (no salary during quarter)

6. Research Aide:

   Eileen Kiera, June 15 to 30.

C. Methods: see item 4 of page 6 of September 30, 1976, Quarterly Report.

D. Sample locations: Mason and Kiera established a sampling station at Arctic Circle Landing Strip south of Kotzebue.

E. Data collected or analyzed:

   1. No data collected

   2. About 275 biological samples and 43 sediment samples analyzed

   3. No miles of trackline

F. Milestone chart and data submission schedules:

   1. Update of schedules

      a. none

III. RESULTS: None presented at this time.

IV. PRELIMINARY INTERPRETATION OF RESULTS: None presented at this time.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES: See renewal request for fiscal 1978.

VI. ESTIMATE OF FUNDS EXPENDED: None presented at this time. (P.I. is in field.)

OUTER CONTINENTAL SHELF
ENVIRONMENTAL ASSESSMENT PROGRAM:
Marine Ecosystems Studies at AIDJEX in the Southeast Beaufort Sea

Adjunct to Final Report

Research Unit #359

Clarence G. Pautzke
Gerald F. Hornof
Kevin D. Wyman

Department of Oceanography
University of Washington
Seattle, Washington 98195

Introduction

The deep oceanic waters of the Beaufort Sea are separated from the Alaskan and Canadian northern coasts by a shelf of 60-100 mile width. Proceeding seaward from the coastline, not only does the marine ecosystem change from a nearshore neritic environment to a deep oceanic but the sea surface alters as well. Inshore, the presence of shorefast and drifting sea-ice is highly seasonal. Offshore, the pack-ice becomes more concentrated and perennial. The Beaufort Sea thus provides two extremes: a shallow water, seasonal ice environment; and a deep oceanic, perennial ice environment.

The Outer Continental Shelf Environmental Assessment Program included several studies describing the shallow water, seasonal ice environment. Various components of the marine ecosystem were observed such as fisheries (Roguski, RU 233), benthos (Carey, RU 6: Broad, RU 356), microbial activity (Morita, RU 190), and marine plankton (English and Horner, RU 359). These efforts were concentrated in the 1975-1976 field seasons and some are continuing at present.

An additional part of the marine plankton studies (English and Horner, RU 359) was conducted during the summer 1975 at the Arctic Ice Dynamics Joint Experiment (AIDJEX) main camp, Big Bear. Because the research effort took place within the perennial ice zone over deep oceanic waters, it provided a suitable contrast to the nearshore activities.

Research Objective

The objective of the biology program at AIDJEX was to develop an understanding of the seasonal changes in abundance and distribution of the plankton components of the marine pelagic ecosystem. Equipment and time limitations somewhat reduced the scope of the program to an emphasis on the primary producer level though regular zooplankton sampling was done also. The results are relevant to development of the outer shelf areas, and, additionally, are useful in filling information gaps for an area intermediate between the shelf and the drift tracks of Fletcher's Ice Island, T-3.

The research program was designed to progress through a sequence of stages (Fig. 1) toward the ultimate goal of understanding the marine ecosystem well enough to formulate a predictive model. This report covers those phases completed to date. Most of the analysis has been concerned with phytoplankton standing stocks and primary productivity. Presently we are in the descriptive phase and attempting a preliminary system definition.

Background

In the past 80 years, in excess of 40 expeditions and field programs have been staged in the Arctic Ocean and its periphery. Approximately 25 of these have yielded biological information (Table 1). Much of this information has been descriptive wherein species of phytoplankton or zooplankton were classified and only marginal efforts were made to relate these components to their environment or to one another (Shoemaker 1920, Farran 1936, Brodskii and Nikitin 1955, Barnard 1959, Hand and Kan 1961, Hülsemann 1963, Shirley 1966). The earliest investigators to attempt to associate higher levels of phytoplankton abundance with environmental factors pinpointed light and temperature as most important (Gran 1904, 1912). Later papers emphasized the processes of mixing, and supply of

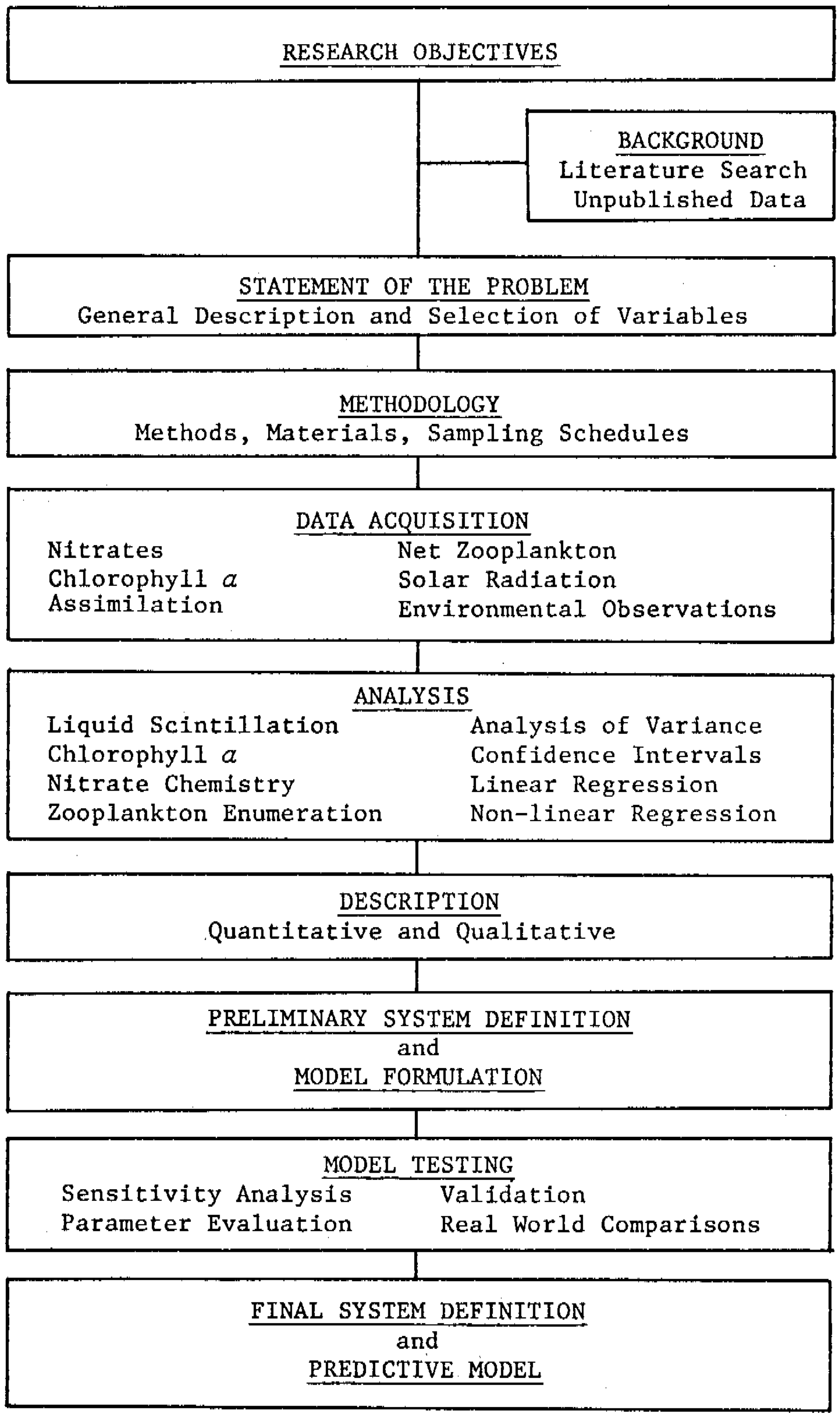


Fig. 1. Stages of the marine ecosystems studies at AIDJEX in the Southeast Beaufort Sea.

Table 1. Expeditions, years of field collections, authors and years of publications of marine biological studies in the Arctic Ocean.

Expedition or Vessel	Dates	Papers Published
Fram	1893-1896	Sars 1900 Nansen 1902 Gran 1904 Gran 1912
Canadian Arctic	1913-1918	Shoemaker 1920 Willey 1920 Bigelow 1920
Maud	1922-1924	Sverdrup 1929
Sedov	1925-1929	Bernstein 1932
Øst	1929	Braarud 1935
Nautilus	1931	Farran 1936 Hardy 1936 Garstang and Georgeson 1936
NP-1	1937-1938	Shirshov 1938, 1944
Sedov	1937-1939	Bogorov 1938, 1939, 1946 a,b Shirshov 1944 Usachev 1946
N-169	1941	Shirshov 1944
NP-2	1950-1951	Brodskii and Nikitin 1955
Burton Island	1950-1951	Johnson 1956 Hand and Kan 1961
M.V. Cancolina II	1951	Grainger 1965
NP-2,3,4,5	1954-1957	Brodskii 1956
T-3	1954-1955	Barnard 1959 Green 1959 Knox 1959 Mohr 1959 Hülsemann 1963
Bravo	1957-1958	Apollonio 1959 Grainger 1965

Table 1. (continued)

Expedition or Vessel	Dates	Papers Published
Alpha	1957-1958	English 1961, 1963 Johnson 1963 a,b
Seadragon	1960	Grice 1962
Arlis I	1960-1961	Tibbs 1964 Shirley 1966
Polar Continental Shelf Project	1960-1961	Grainger 1965
M.V. Salvelinus	1960-1962	Grainger 1965
Arlis II	1964	Shirley 1966 Kawamura 1967 Minoda 1967
T-3	1964 1966-1974	Harding 1965 Hopkins 1969 Hughes 1968 Scott 1969

nutrients to the phytoplankton (e.g., Sverdrup 1929, Braarud 1935), and the temperature and salinity as important to zooplankton distribution (Bigelow 1920, Bernstein 1932, Johnson 1956, Grainger 1961, Tibbs 1964).

More quantitative estimates of phytoplankton abundance, primary production, and zooplankton standing stocks and life cycles resulted from the Soviet North Pole stations (Brodskii 1956) and the U.S. drift stations Alpha (English 1961, 1963; Johnson 1963 a, b), Bravo (Apollonio 1959, Grainger 1965), Arlis II (Kawamura 1967), and T-3 (Harding 1966, Hughes 1968, Hopkins 1969, English unpublished data). From these investigations emerged a general recognition of components and processes of possible importance in determining change in the marine ecosystem below the pack ice.

This understanding is based mainly on data collected in the central Arctic Ocean or below 80°N but to the west of 160°W meridian. With the exception of two papers accounting the protozoa (Tibbs 1964) and medusae (Shirley 1966) taken from Arlis I, there is little published biological information for the deep oceanic perennial ice zone of the southeast Beaufort Sea where the AIDJEX platforms were located. Consequently, any preliminary description drawn from the literature and unpublished data must be applied to this area with caution in recognition that it is correct only to the extent that the conditions are rather uniform throughout the deep oceanic perennial ice zone.

Statement of the Problem

Our problem was first to generate *a priori* a description of the ecosystem based on information composited from published and unpublished accounts, and secondly, to formulate an appropriate inquiry and select variables to be measured based on the *a priori* description.

General Description

Phytoplankton abundance remains low throughout the period of low submarine illumination from late September to mid-June. Solar radiation incident on the pack-ice surface increases from sunrise in late February, until the summer solstice on 21 June, variations in cloudiness disregarded. Maximum submarine illumination lags several weeks, being an indirect function of snow thickness and elevated surface air temperatures. As the snow cover ablates bare ice and ponds of lowered albedo and absorbance dominate the surface. Together with any increase in lead area, these features more than compensate for the decreasing incident solar radiation and a maximum in submarine illumination occurs in early to mid-July.

Responding to this increased submarine illumination, the phytoplankton biomass increases, the rate somewhat dependent on the depth of the mixed layer (25-50 m). The extent and duration of biomass may depend on: (1) availability of light influenced by the degree of melt, the frequency of summer freeze-ups and snow storms, the declining solar angle, the eventual day-night solar cycle, and the timing of the first sustained autumn snow buildup; (2) availability of nutrients influenced by the initial spring nutrient concentrations, and maintenance of these through turbulent mixing, convective overturn, and possible remineralization processes; and (3) losses from the phytoplankton population through sinking below the pycnocline, or grazing by herbivorous zooplankton. The major decrease in phytoplankton biomass occurs in the latter half of August and low concentrations prevail from September throughout the ensuing dark period.

Though much is known about the species composition of the herbivorous zooplankton and their general depth distribution, there are no studies showing the extent to which the Arctic herbivores interact with the phytoplankton populations. There is evidence of a general movement toward the surface from depths exceeding 100-200 m by *Calanus hyperboreus* early in the spring, and by *C. glacialis* later on. The degree to which they crop the phytoplankton is not yet known.

Selection of Variables

The main biological component of interest was the phytoplankton biomass measured as chlorophyll *a*, carbon assimilation potential, or species cell counts. The assimilation response to varying light intensities was also measured. The second biological component was the zooplankton biomass especially the herbivorous copepods. These were measured as species counts or biomass in terms of wet or dry weights.

A suite of environmental variables was also measured periodically. Nitrate concentrations were selected to represent the nutrient regime. Solar radiation was measured at the ice surface and the melt conditions were logged on a daily basis. Additional environmental variables such as air temperature, wind speeds, island movement, and seawater temperature and salinity were recorded by other research teams on AIDJEX.

Methodology

Water samples for phytoplankton chlorophyll *a*, cell counts, C^{14} assimilation experiments and nitrates were taken with a Scott-Richards modified Van Dorn bottle. All of the above analyses except cell counts were done according to Strickland and Parsons (1968). The routine depth profiles of assimilation represent the potential photosynthetic activity of a volume of seawater subjected to controlled high light intensities in an incubator box, not *in situ* production. No attempt has been made in these experiments to enumerate the phytoplankton species responsible for the photosynthesis or their relative contributions.

Net zooplankton was sampled with overlapping depth-to-surface vertical hauls using a non-closing conical 1-m diameter ring net with 73 μm mesh. Samples were preserved in 4% buffered formalin or frozen for later analysis in Seattle. A LI-COR-185 quantum meter was used to record daily incoming solar radiation. Melt conditions were logged daily and aerial photographs were taken infrequently.

The depth pattern and frequency of sampling of such attributes as chlorophyll *a*, assimilation, nitrates, and zooplankton were designed to provide an intensive time series with emphasis on the upper 60 m of water (Table 2). The waters below the pycnocline were sampled less frequently. The deepest depth for zooplankton samples was 150 m and for phytoplankton, 100 m.

Supplemental experiments were run concomitant to the semi-continuous monitoring described above. These included graduated light experiments in which the assimilation of a volume of water was measured in an incubation chamber under several different light intensities up to and including the high or 100% light intensity, and *in situ* assimilation incubations where samples from 10 m were suspended below leads, melt ponds, bare ice, and snow-covered ice.

The replication experiments entailed 4 Van Dorn bottle casts to the same depth. These were done in rapid succession and the total elapsed time between the first and fourth cast was less than 5 minutes. One

Table 2. Field Biology Sampling Program at AIDJEX Main Camp, Summer 1975

Variable	Sampling Regime	Schedule	Depths
Nitrate	Depth Profile	Irregular; every 3-6 days Occasionally Occasionally	10-70 m, every 10 m; Every 2 m, 46-64 m; 80 and 100 m
	Synoptic	One time only; Every 6-10 miles out to Blue Fox and Caribou	10 and 20 m
Chlorophyll *a*	Depth Profile	Every 3 days	3 m, 5-60 m, every 5 m
	Intensive Profile	Frequent but irregular	Every 2 m, 46-64 m, and 80 m, 100 m
	Replications	Every 7-10 days	4 samples for each of 4 depths: 5, 10, 20, 30 m
	Synoptic	One time only; Every 6-10 miles out to Blue Fox and Caribou	10 and 20 m
Primary Production	Depth Profile	Every 3 days	3 m, 5-50 m every 5 m, 60 m
	Replications	Every 7-10 days	8 samples for each of 4 depths: 5, 10, 20, 30 m
	Graduated Light	Every 3 days	10 intensities for each of 4 depths: 5, 10, 20, 30 m
	In situ	Irregular	10 m sample under pond, ice, and lead
Zooplankton	Net Preserved and Frozen	Every 3 days	Every 10 m to 50 m; Every 25 m, 50-100 m; 150-0 m
Solar Radiation	Continuous	Every 30 seconds	1 m above ice surface

4-liter chlorophyll *a* sample and two 125-ml light bottle assimilation samples were taken from each Van Dorn. Thus for each replication experiment, there are 4 chlorophyll *a* values, and 8 assimilation values. There were a total of ten such experiments done every 7-10 days at each of 4 depths (5, 10, 20 and 30 m) during the summer.

Finally, chlorophyll *a* and nitrate were measured at 10 and 20 m at various distances (usually 7-10 mile intervals) from the main camp enroute by helicopter to the satellite camps, Caribou and Blue Fox.

Data Acquisition

The field program was conducted from 2 June to 1 October 1975 at the AIDJEX main camp, Big Bear. During these four months, Big Bear drifted approximately 870 km in a southeasterly direction, generally within the geographic area bounded by lines drawn through 76.5°N-148°W, 74°N-139°W, and 76.5°N-149.5°W (Fig. 2). Sampling ended abruptly on 1 October when the ice floe broke apart and camp members were evacuated.

Table 3 briefly summarizes the accomplishments of the summer program as well as the current extent of analysis.

Analysis

The determination of nitrate concentration was done at Big Bear. All other analyses were done in Seattle at the Department of Oceanography, University of Washington.

The statistical analysis has been completed on the chlorophyll *a* and assimilation measurements. Both data sets were $\log_{10}(x + .01)$ transformed to assure independence of the mean and variance. Beyond a

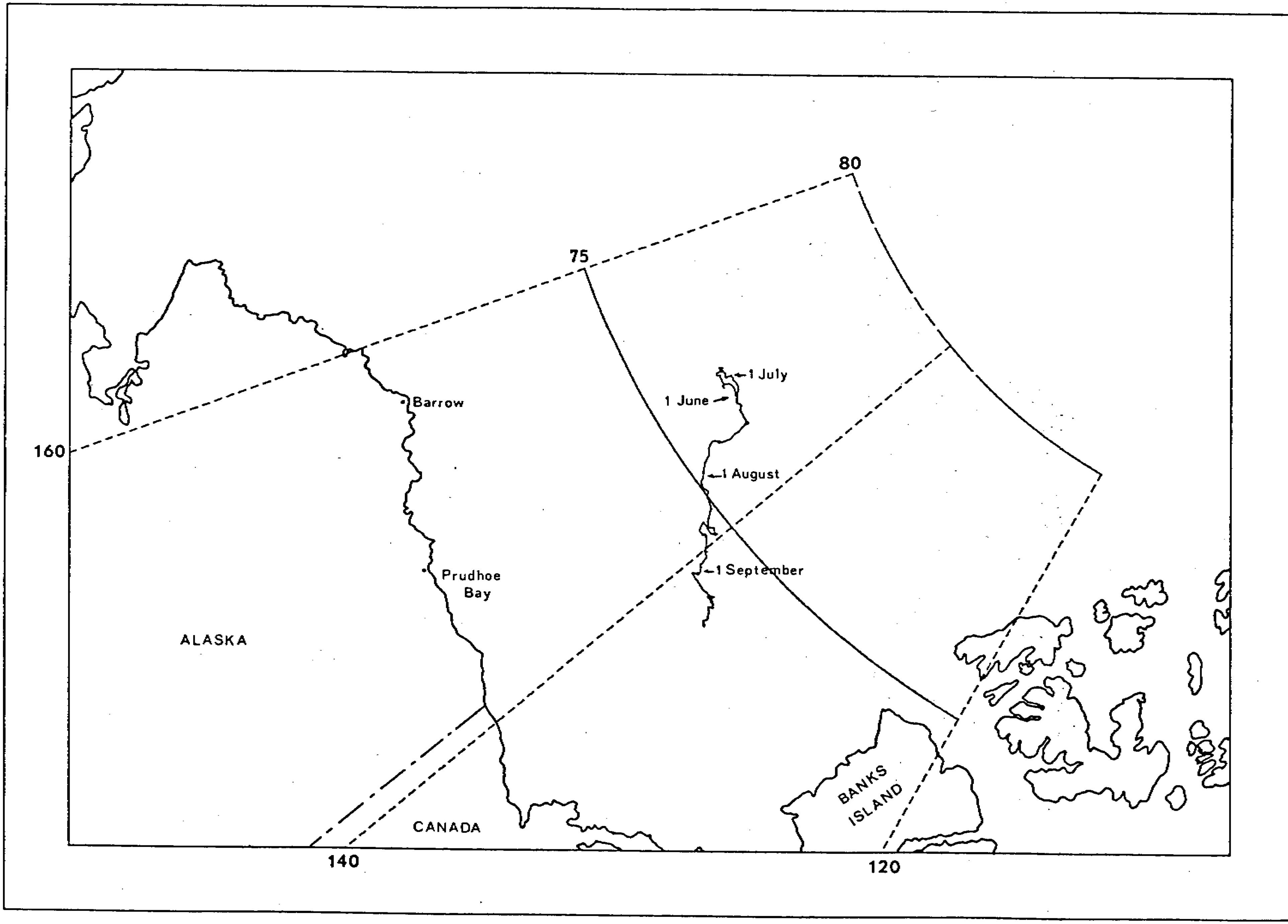


Fig. 2. Drift track of AIDJEX main camp, Big Bear, 1 June to 30 September 1975.

Table 3. Summary of samples taken and analyzed

Type	Number Taken	Number Analyzed
Net zooplankton	994	20
Phytoplankton (Preserved)	209	0
Chlorophyll *a*	1096	1096
Radiocarbon Uptake	2941	2941
Nitrate	272	272

simple description of the spatiotemporal pattern of chlorophyll *a*, an attempt was made to analyze the variance associated with our samples. The 4-month sampling period was subdivided into equal 5-day intervals beginning 1 June. Those chlorophyll *a* samples from a single depth in the same interval were pooled. These included samples from depth profiles and graduated light experiments. Having grouped the data this way, a one-way analysis of variance was run to determine the within mean square error (MSE) for each depth. The MSE and its associated degrees of freedom (df) were used in the equation,

$$CI = \bar{X} \times/\div \text{antilog} (t_{.05,df} \sqrt{MSE}/\sqrt{n})$$

where CI is the 95% confidence interval about the time cell geometric mean $\bar{X}$ (mg chl a/m^3), and n is the number of samples in that cell.

A similar approach was used to determine the 95% confidence intervals about the time cell geometric means of assimilation at 100% light. In addition, the results of the graduated light experiments were fitted with the theoretical assimilation versus light model suggested by Steele (1962). After normalizing on chlorophyll *a*, the values of initial slope and I_k, the light intensity at which assimilation is just saturated, are readily comparable to measurements made in other years in the Arctic Ocean and other areas.

A one-way analysis of variance was performed on the chlorophyll *a* and assimilation results from the replication experiments. The data first were transformed using $\log_{10}$ (x + 0.01). The resultant mean square error is an estimator of the variability attributable to inhomogeneities of the point depth sample's ambient seawater environment. Also subsumed in this estimator are lower level, assumed random, experimental errors.

No statistical analysis has been performed on the zooplankton counts. Solar radiation measurements and phytoplankton cell samples have not been analyzed at this time.

Description

Nitrates

The concentrations of nitrate remained undetectable in the upper 40 m throughout the summer (Table 4). The same held true at the top of the pycnocline between 48 and 52 m until early September when trace amounts of nitrate (< 1.0 μg at/l) spread slowly upward reaching 42 m by the last sampling on 27 September. Concentrations generally increased with depth across the pycnocline at 50-60 m. At 100 m, they were > 10.0 μg at/l.

No nitrate replicates were made. At the 1 μg at/l level, experimental error results in the correct value being within ± 0.05 μg at/l of the measured value (Strickland and Parsons 1968). The variability within 5-day periods has not been assessed.

Chlorophyll a

The concentrations of chlorophyll *a* in the upper 40-45 m mixed layer were about 0.10 mg/m^3 on initial sampling in early June (Figs. 3, 4). They decreased through June and remained low (< 0.03 mg/m^3) throughout the summer except for a minor resurgence in late September. During July and August a major increase in chlorophyll *a* occurred in the pycnocline at 58-64 m. At mid-summer the concentrations in this stratum were above 0.25 mg/m^3 and declined thereafter. Chlorophyll *a* below 70 m remained less than 0.10 mg/m^3 throughout the summer.

Table 4. Nitrate Concentrations (μg A/1) Measured at AIDJEX Main Camp Big Bear during Summer 1975

	Date (1975)																				
	June					July						August						September			
Depth (m)	11	17	20	23	29	5	7	11	17	23	29	4	10	16	22	28	30	6	12	22	27
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42																	0.0	0.0	0.0	0.1	0.1
44																	0.0	0.0	0.0	0.0	0.2
46		0.0							0.0				0.0				0.0	0.0	0.4	0.4	0.7
48									0.0				0.0				0.2	0.0	0.4	0.4	1.1
50		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.0	0.8	1.0	1.9
52								0.0	0.0				0.3				1.2	0.2	1.3	1.4	3.0
54								0.1	0.2				0.5				1.9	0.3	1.8	2.1	3.3
56						0.0	0.1	0.2	0.4	0.0	0.0	0.0	0.8				2.6	0.9	1.9	2.4	3.6
58									0.4				1.2				2.4	1.3	2.1	2.1	4.3
60		1.3	0.2	0.6	1.3	0.0	0.3	0.4	1.1	0.2	0.1	2.4	0.9	0.5	1.2	1.7	3.0	1.9	2.1	3.4	5.6
62									0.9				1.9				3.4	3.7	3.4	5.0	5.4
64						0.3	0.6	2.4	1.4				2.4				3.7	5.8	2.8	4.4	6.4
70		6.3			3.5	2.8	2.6	4.7	4.5	2.4	4.0	6.6	3.6			3.0	5.8	6.5			
80					7.4		5.8	8.4	6.6				7.0				10.1	10.2	10.2	9.6	10.8
100					11.0				10.5				12.2				13.5	14.8	14.3		13.3

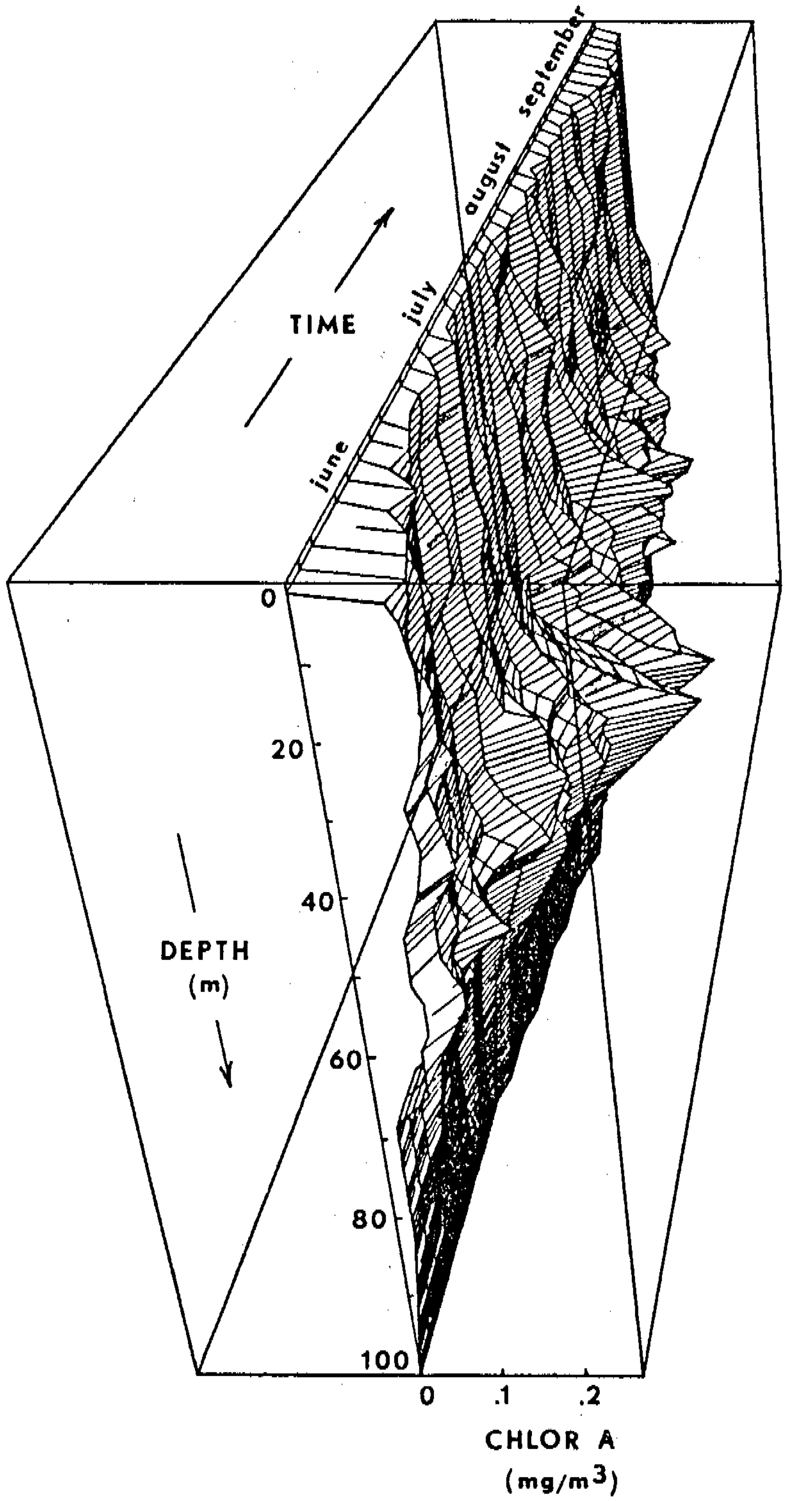


Fig. 3. Three dimensional plot of chlorophyll *a* (mg/m^3), 0-100 m, 1 June to 30 September 1975.

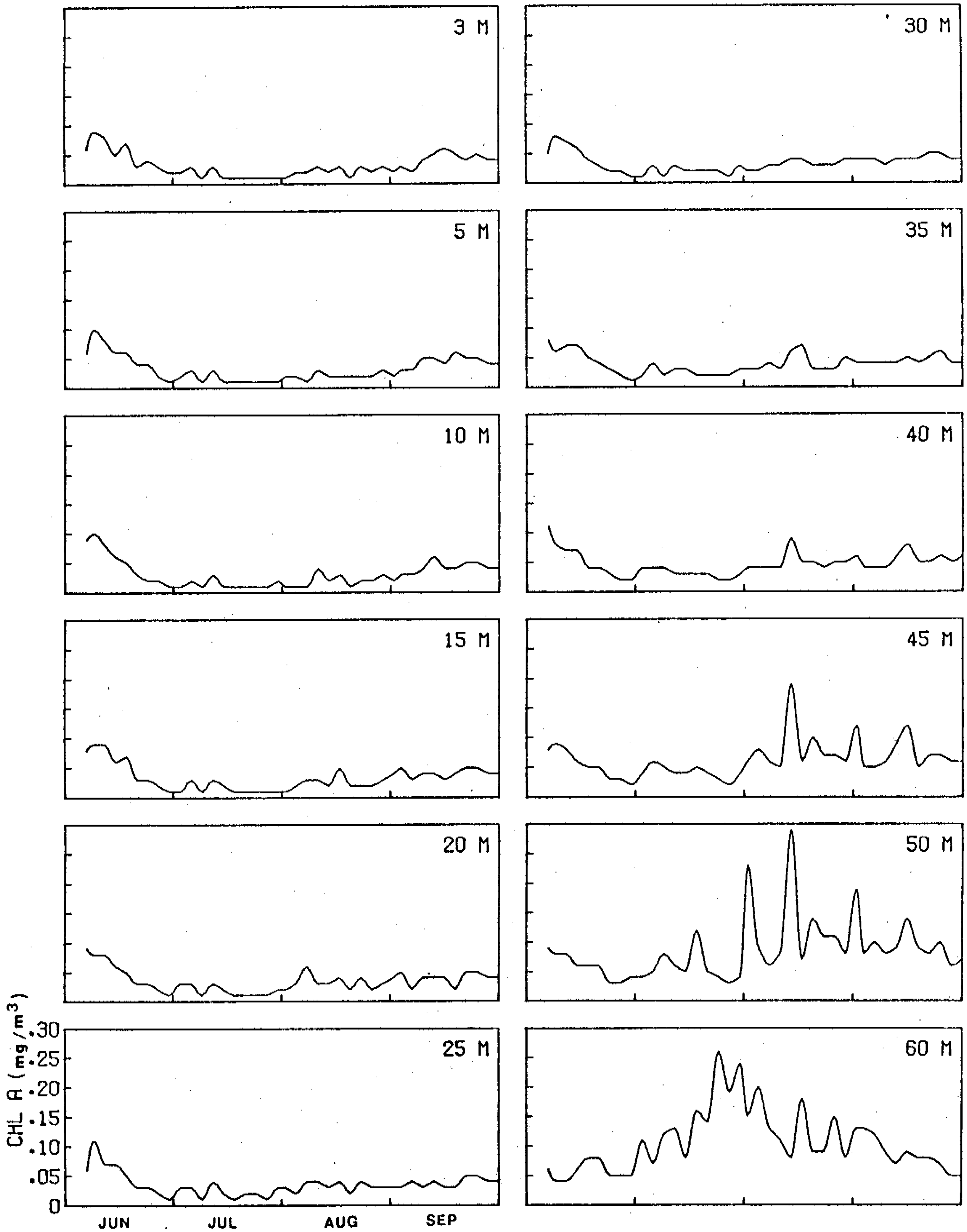


Fig. 4. Chlorophyll *a* (mg m^{-3}) measured at depths indicated during the summer of 1975.

The total chlorophyll *a* integrated over the upper 100 m showed two peaks (Fig. 5). The first of about 6.0 mg/m^2 occurred in early June concomitant with the increased chlorophyll *a* concentrations in the upper 40 m. Following a decline to less than 2.0 mg/m^2 in late June, a second peak of about 6.8 mg/m^2 occurred in early August concomitant with the bloom at the pycnocline.

The results of the one-way analysis of variance conducted on chlorophyll *a* data aggregated into 5-day time cells give a transformed mean square error of 0.0187 for 5 m, 0.0189 for 10 m, 0.0151 for 20 m, and 0.0141 for 30 m (Table 5). Taking an average of 0.0167, the resultant 95% confidence interval is the geometric mean of the time cell, $\bar{X} \times/\div 1.40$ mg chl a/m^3 if the number of samples in the cell is n=3, and $\bar{X} \times/\div 1.34$ mg chl a/m^3 if n=4. The value of n was either 3 or 4 for our data series. These confidence intervals have been calculated for each 5-day time cell for 5, 10, 20, 30 and 60 m, and overlaid on the time trace of chlorophyll *a* concentration (Fig. 6).

The results of the chlorophyll *a* replication experiments (Table 5) show that the error attributable to both variability in the sampling environment over short periods, and to lower level experimental error, is an order of magnitude less than the variability within 5-day periods estimated above.

Chlorophyll *a* data from the depth series were forwarded in the Annual Report of Beaufort Sea Plankton Studies, RU-359, 1 April 1976.
The remaining data will be forwarded in our next annual report due 1 April 1977.

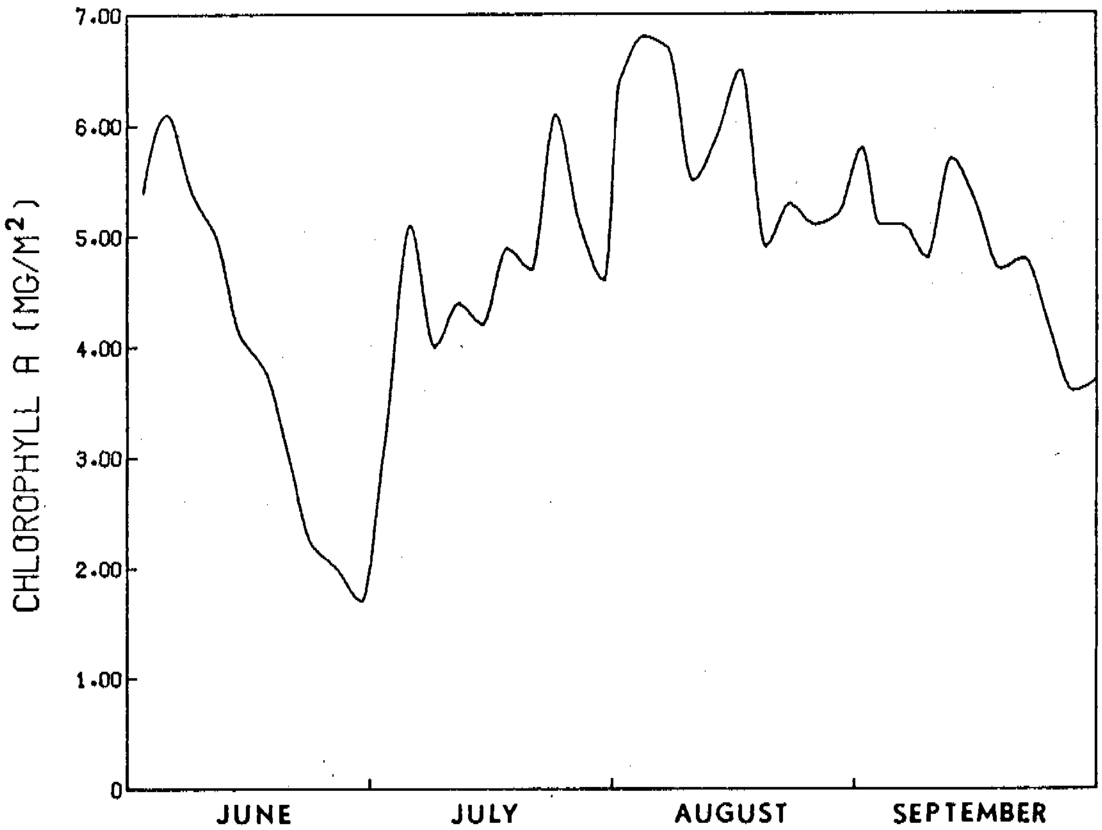


Fig. 5. Chlorophyll *a* (mg/m^2) integrated over the upper 100 m.

Table 5. Analysis of variance of the $\log_{10}(x + .01)$ transformed ^{14}C uptake assimilations. The upper table is for measurements aggregated from depth profiles and graduated light series into 5-day time cells. The lower table is for measurements from the replication experiments.

Aggregation

Depth	Source	DF	SS	MS	F
5 m	Between	22	3.090	.140	5.0
	Within	44	1.242	.028	
	Total	66	4.332		
10 m	Between	22	3.408	.155	7.3
	Within	50	1.067	.021	
	Total	72	4.475		
20 m	Between	22	2.678	.122	5.3
	Within	45	1.027	.023	
	Total	67	3.705		
30 m	Between	22	2.273	.103	7.1
	Within	44	.644	.015	
	Total	66	2.917		

Replication

Depth	Source	DF	SS	MS	F
5 m	Between	9	6.565	.729	57.6
	Within	70	.886	.013	
	Total	79	7.451		
10 m	Between	9	7.009	.779	72.3
	Within	70	.754	.011	
	Total	79	7.764		
20 m	Between	9	5.212	.579	27.9
	Within	70	1.451	.021	
	Total	79	6.663		
30 m	Between	9	.896	.100	6.9
	Within	70	1.004	.014	
	Total	79	1.900		

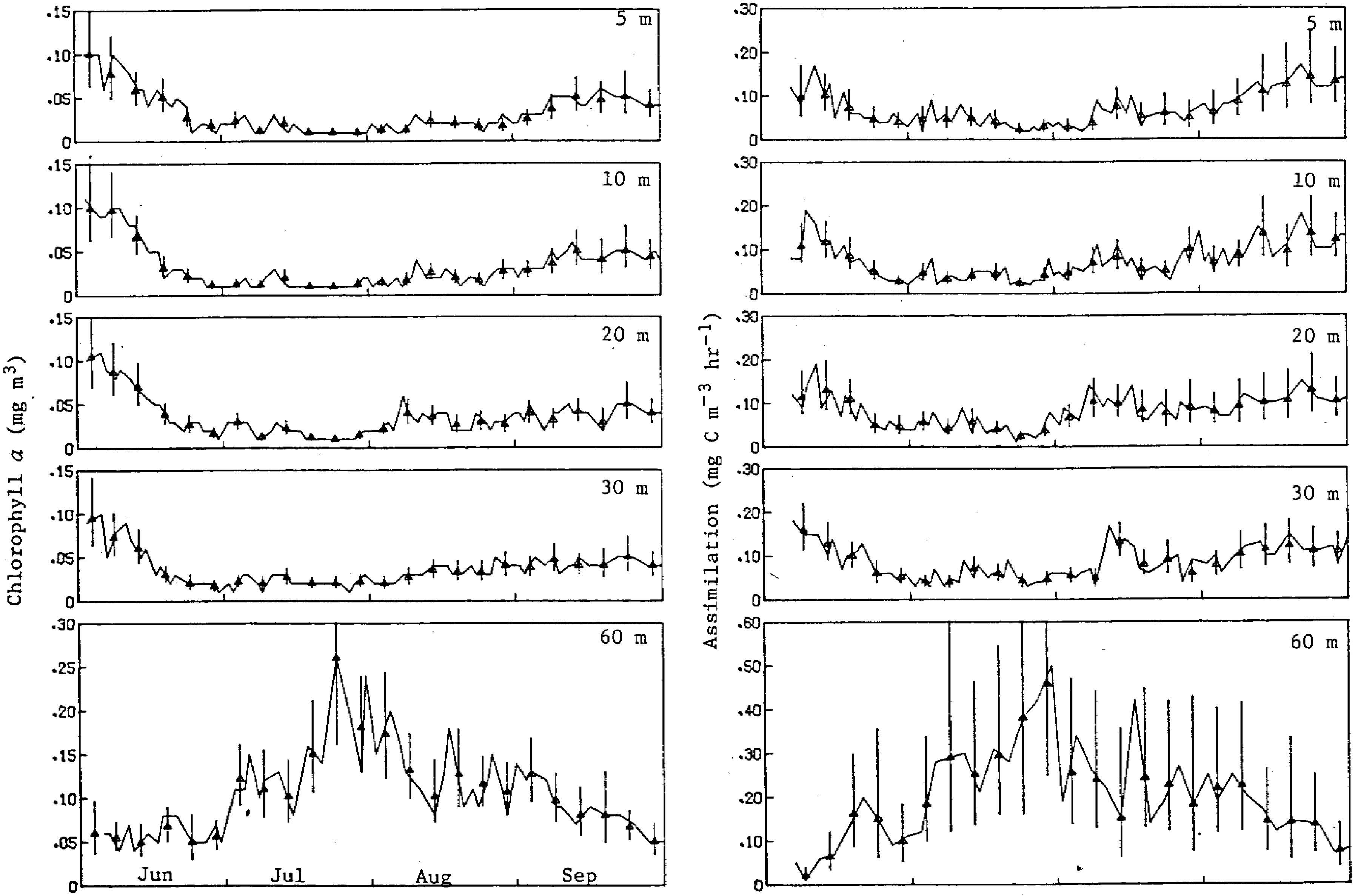


Fig. 6. Chlorophyll a (mg m^{-3}) and assimilation potential (mg C m^{-3} hr^{-1}) measured at the depths indicated and overlaid with 5-day geometric means and confidence intervals as determined by a one-way analysis of variance.

Assimilation

The photosynthetic assimilation potential followed closely the pattern of chlorophyll *a* abundance (Fig. 7). In the upper 40-45 m, peak assimilations (0.1-0.2 mg C $m^{-3} \cdot hr^{-1}$) were found in early June. During July and August, the values remained less than 0.1 mg C $m^{-3} \cdot hr^{-1}$. A second increase was noted in late September. Similar to chlorophyll *a* the major increase in assimilation potential occurred at the pycnocline in late July and early August (Fig. 8). Values of 0.48-0.50 mg C $m^{-3} \cdot hr^{-1}$ were recorded in this period. Assimilation decreased at these depths through the rest of the summer.

The results of the one-way analysis of variance conducted on assimilation data aggregated into 5-day time cells give an average transformed mean square error of 0.0217 for the depths 5, 10, 20, and 30 m (Table 6). The resultant 95% confidence interval is the geometric mean of the time cell, $\bar{X}$ x/÷ 1.47 for n=3, and $\bar{X}$ x/÷ 1.39 for n=4. These confidence intervals have been calculated for each 5-day time cell for 5, 10, 20, 30, and 60 m, and overlaid on the time trace assimilation potential (Fig. 6).

The results of the replication experiments (Table 6) show that the error attributable to both variability in the sampling environment over short periods, and to lower level experimental error, is on the same order as that for 5-day periods. The former error averages about 70% of the latter. Thus there is considerably more variability associated with the radiocarbon technique than with the chlorophyll *a* technique.

The data from the assimilation depth series and replication experiments were forwarded in the Quarterly Report on Beaufort Sea Plankton Studies, RU-359, 1 June 1976.

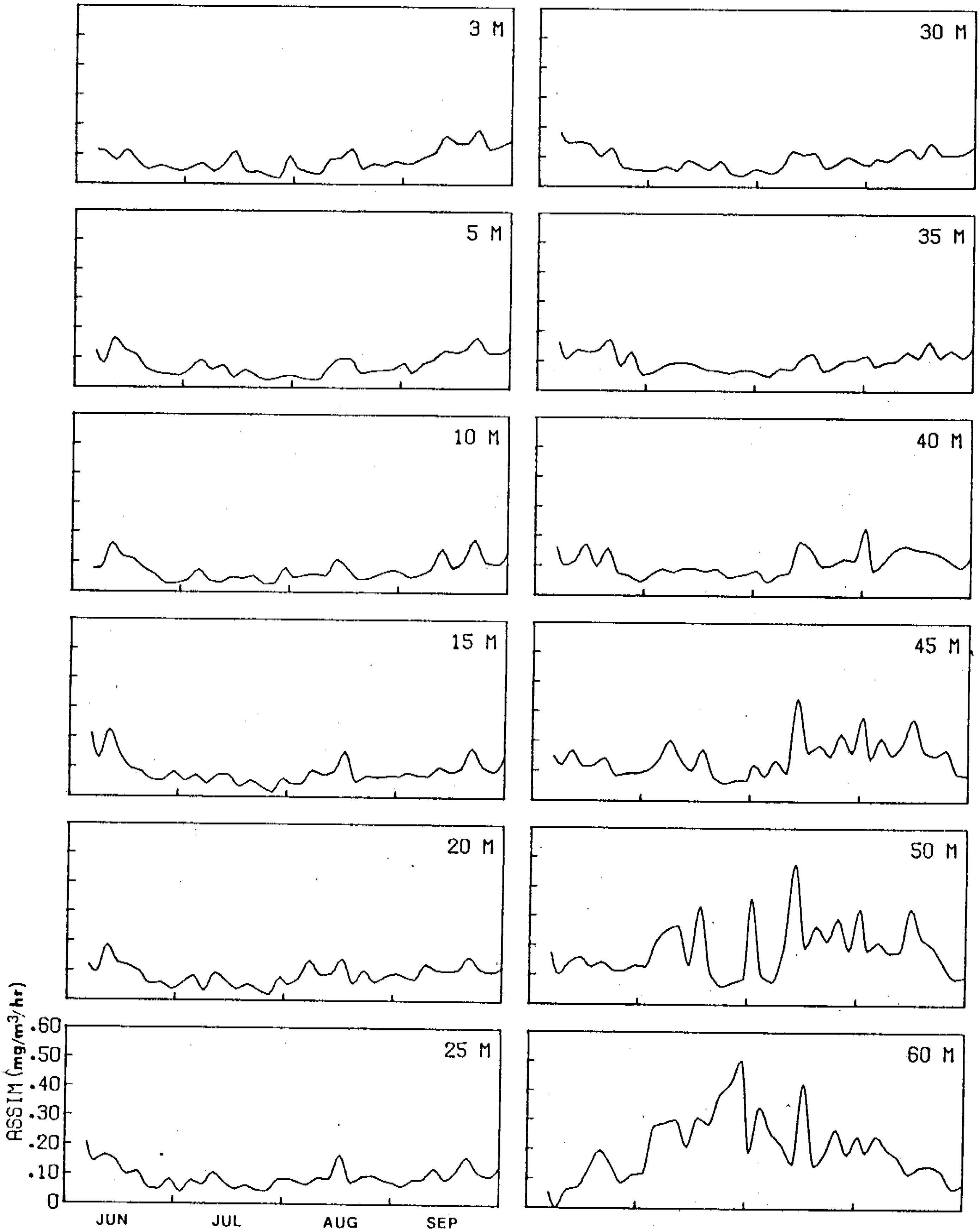


Fig. 7. Net ^{14}C assimilation (mg C m^{-3} hr^{-1}) measured on water samples taken from depths indicated and incubated under constant light during summer of 1975.

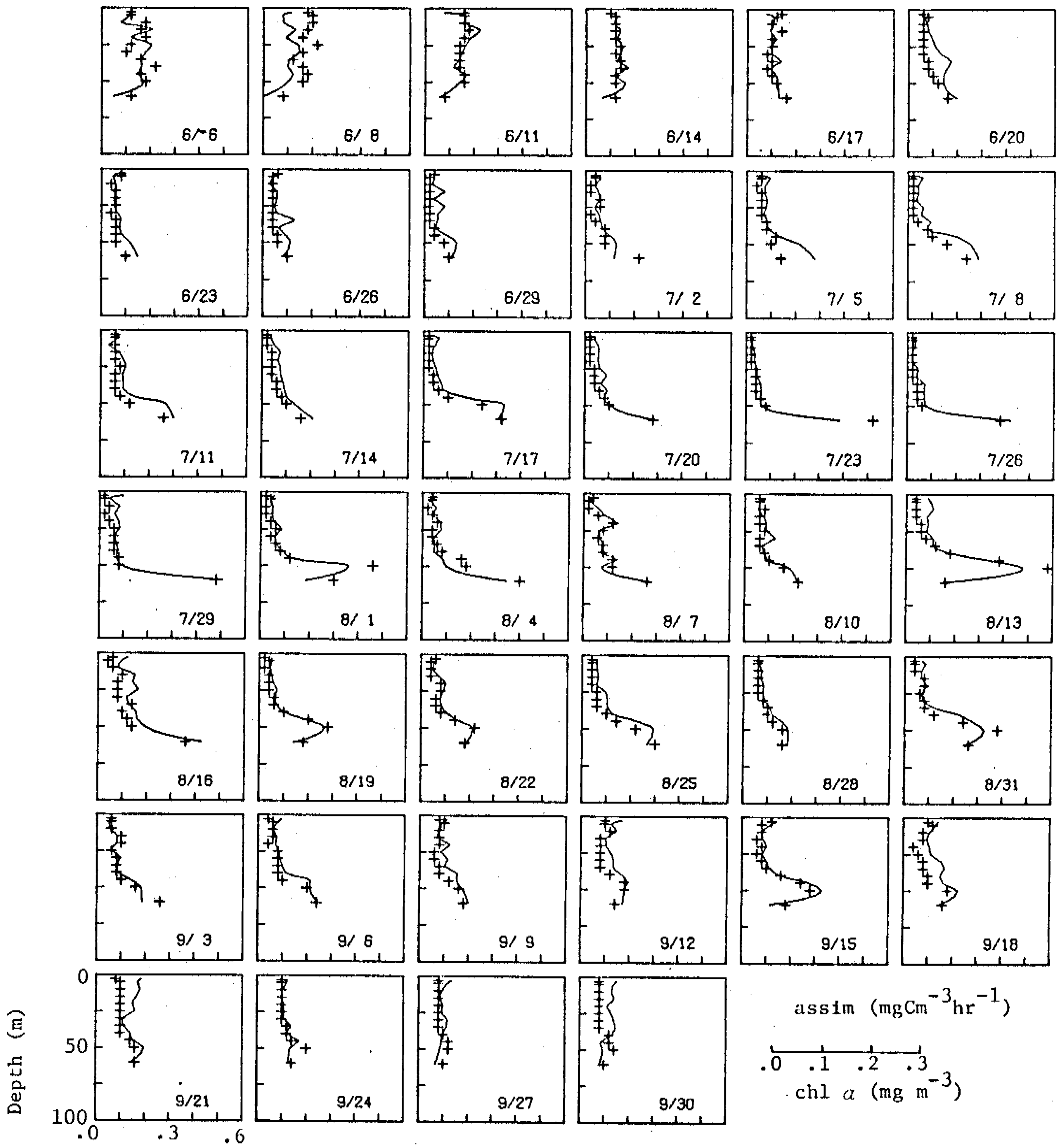


Fig. 8. Chlorophyll *a* (mg m^{-3}) depth profile (3-60 m) overlaid on net ^{14}C assimilation (mgC$m^{-3}$$hr^{-1}$) depth series for month and day indicated (+) chl *a*. (-) assim.

Table 6. Analysis of variance of the $\log_{10}(x + .01)$ transformed chlorophyll a concentration measurements. The upper table is for measurements aggregated from depth profiles and graduated light series into 5-day time cells. The lower table is for measurements from the replication experiments.

Aggregation

Depth	Source	DF	SS	MS	F
5 m	Between	23	5.574	0.242	12.9
	Within	51	0.954	0.019	
	Total	74	6.528		
10 m	Between	23	6.153	0.268	14.1
	Within	53	1.004	0.019	
	Total	76	7.157		
20 m	Between	23	4.539	0.197	13.1
	Within	53	0.800	0.015	
	Total	76	5.339		
30 m	Between	23	2.591	0.113	8.0
	Within	51	0.720	0.014	
	Total	74	3.312		

Replication

Depth	Source	DF	SS	MS	F
5 m	Between	9	1.280	0.142	106.1
	Within	30	0.040	0.001	
	Total	39	1.320		
10 m	Between	9	1.712	0.190	88.3
	Within	30	0.065	0.002	
	Total	39	1.776		
20 m	Between	9	1.116	0.124	120.1
	Within	30	0.031	0.001	
	Total	39	1.147		
30 m	Between	9	0.531	0.059	35.2
	Within	30	0.050	0.002	
	Total	39	0.581		

Synoptic Sampling

At the time of the synoptic sampling by helicopter, the two satellite camps, Blue Fox and Caribou, were in very different directions from main camp. Thus the results of this sampling give representative chlorophyll *a* and nitrate values over a wide area. The nitrate results show that at least the upper 10-20 m of the mixed layer was devoid of nitrate for distances up to 35-42 miles from camp (Table 7). Chlorophyll *a* concentrations were uniformly low in both directions.

In situ Assimilation Experiments

An attempt has been made to ascertain the significance of the character of the pack ice surface to the photosynthetic assimilation below. The results of these experiments where samples from 10 m were resuspended at 10 m below a melt pond, lead or bare ice surface, are summarized in Table 8. The character of the three features varied as a result of freezing temperatures, snow storms, or thawing periods. Each assimilation typically is an average of 2-3 replicates incubated under the same conditions.

These results are given without further analysis at this time merely to show how similar the photosynthetic assimilation was under such diverse surface conditions. The melt pond site was about 40-50 m from the lead and about 4 m in diameter. The bare ice site was about 40-50 m from the lead and 70-100 m from the melt pond. At the ice site, the ice was 2.3 m thick and at the pond site, the ice was 1.6 m thick and the pond 25 cm deep. These sites may be close enough together and the pond small enough that in effect there is an averaged submarine light. Any further conclusions must await an analysis of the variance associated with the

Table 7. Results of synoptic sampling for nitrate and chlorophyll *a*.

Camp		Caribou					Big Bear				Blue Fox
Mileage	Depth	+35	+27	+18	+10	+4	0	+12	+22	+32	+42
Nitrate (μg at/l)	10 m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	20 m	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chl *a* (mg/m^3)	10 m	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
	20 m	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02

Table 8. Character of the surface of melt ponds, lead, and bare ice during *in situ* incubations, and the associated assimilation (mg C $m^{-3} \cdot hr^{-1}$).

	Pond		Lead		Ice	
Date	Character	Assim.	Character	Assim.	Character	Assim.
0722	Skim ice	0.010	Open	0.009	Snow veneer, bright white	0.006
0723	Open	0.007	Open	0.011	Snow veneer, bright white	0.013
0725	Open	0.007	Open	0.011	Melting greyish ice	0.008
0726	Skim ice	0.008	Ice bergs but open	0.009	Snow veneer, bright white	0.008
0728	Ice and snow	0.008	Open	0.007	Snow drifts	0.005
0729	Snow, ice and slush	0.043	Ice bergs but open	0.021	Fresh snow, 6-7 cm	0.034
0801	2 cm ice, 1/3 snow covered	0.042	Open	0.024	Fresh snow, 5-6 cm	
0803	Split by lead		Ice raft	0.014	Frost and snow, 4-5 cm	0.012
0807	New pond, skim ice	0.022	50% mush	0.030	Snow, 2-5 cm	0.021
0809	Snow drifted		Open	0.039	Wind-blown snow, greyish	0.036
0811	Clear, some ice chunks	0.051	Open	0.047	Snow veneer	0.040
0812	Open	0.044	Open	0.052	Bright white, frosty	0.049
0813	Open	0.025	Open	0.030	Snow frosted	0.026
0814	Skim ice, some slush-snow	0.076	Open	0.061	Snow frosted	0.052
0815	Skim ice, grey slush	0.033	Open	0.040	Snowy, melting	0.032
0816	Open	0.066	Open	0.050	Melting	0.053
0818	Skim ice	0.030	Skim ice	0.026	Frosted	0.020
0821	4 cm ice	0.030	2 cm ice	0.025	Melting, grey	0.025
0824	Blue ice	0.019	Open	0.024	Frosty white	0.021
0902	Drifted snow		Open	0.053	Drifted snow	
0908	Drifted snow		Ice and snow	0.059	Drifted snow	
0914	Drifted snow		Mush, drifted snow	0.053	Drifted snow	

experiment. The data for these *in situ* experiments will be forwarded in our next annual report due 1 April 1977.

Assimilation Numbers

The assimilation number or index is the observed assimilation under saturating light conditions divided by the phytoplankton biomass, here represented as a chlorophyll *a* concentration. Throughout the depths sampled and over the time period sampled, the patterns of chlorophyll *a* and radiocarbon assimilation were very similar (Figs. 4, 7, 8). Though the assimilation number ranged from 4.4 to 8.3 mg C mg chl a^{-1} hr^{-1}, they generally were 1.5-2.5 mg C mg chl a^{-1} hr^{-1}.

In order to examine the variability of the assimilation index, the values will be $\log_{10}(x + 0.01)$ transformed and pooled into 5-day time cells. Then an analysis of variance will be performed similar to that for chlorophyll *a* and assimilation. From this analysis, we will look for significant changes in the assimilation number that may have accompanied the higher chlorophyll *a* concentrations in early and late summer. The results will be reported in our final report due in April 1977.

Graduated Light Experiments

The data set generated by one graduated light experiment was comprised of ten assimilation measurements paired with their associated light intensities of incubation determined as a percent (2, 4, 6, 8, 14, 16, 19, 49, 74, or 100%) of the total ambient light available (approx. 117 microeinsteins m^{-2} sec^{-1}) in the chamber. The data were forwarded in the Quarterly Report on Beaufort Sea Plankton Studies, RU 359, 30 June 1976.

The data sets from the individual graduated light experiments have been fitted with a curvilinear assimilation versus light relationship proposed by Steele (1962):

$$P = P_{max} \cdot I_{rel}/I_k \cdot e^{1-I_{rel}/I_k}$$

where P is the assimilation (mg C $m^{-3} \cdot hr^{-1}$), P_{max} is maximum assimilation (mg C $m^{-3} \cdot hr^{-1}$), I_{rel} is light expressed as a fraction of the maximum intensity in the incubation chamber, and I_k is the light intensity at which P_{max} occurred, expressed as a fraction of the total light. The procedure required substitution of paired measured assimilation and light values into the equation and the iterative adjustment of P_{max} and I_k to minimize the sum of squared differences of calculated and observed P. The division of all measured assimilations in an experiment by the calculated P_{max} allowed the comparison of relative production versus relative light relationships, independent of the magnitude of the assimilation or incubation chamber light intensities. The results of the experiments and the fitted curves are shown in Figure 9.

In general, the calculated P_{max} was the same or near to the value of assimilation recorded at the highest light in the incubation chamber. Of the 122 experiments, P_{max} occurred at 80-100% full light 81 times, at 60-80% full light 29 times, and at less than 60% full light 12 times. In those experiments when the maximum photosynthesis occurred at less than full light, a small degree of photoinhibition was noted (e.g., Fig. 9, 5 m on 12-13 June).

Further analysis of the graduated light data will include a calculation of initial slopes. One-way analyses of variance will be performed on both initial slopes and I_k, the saturating light intensity. These will

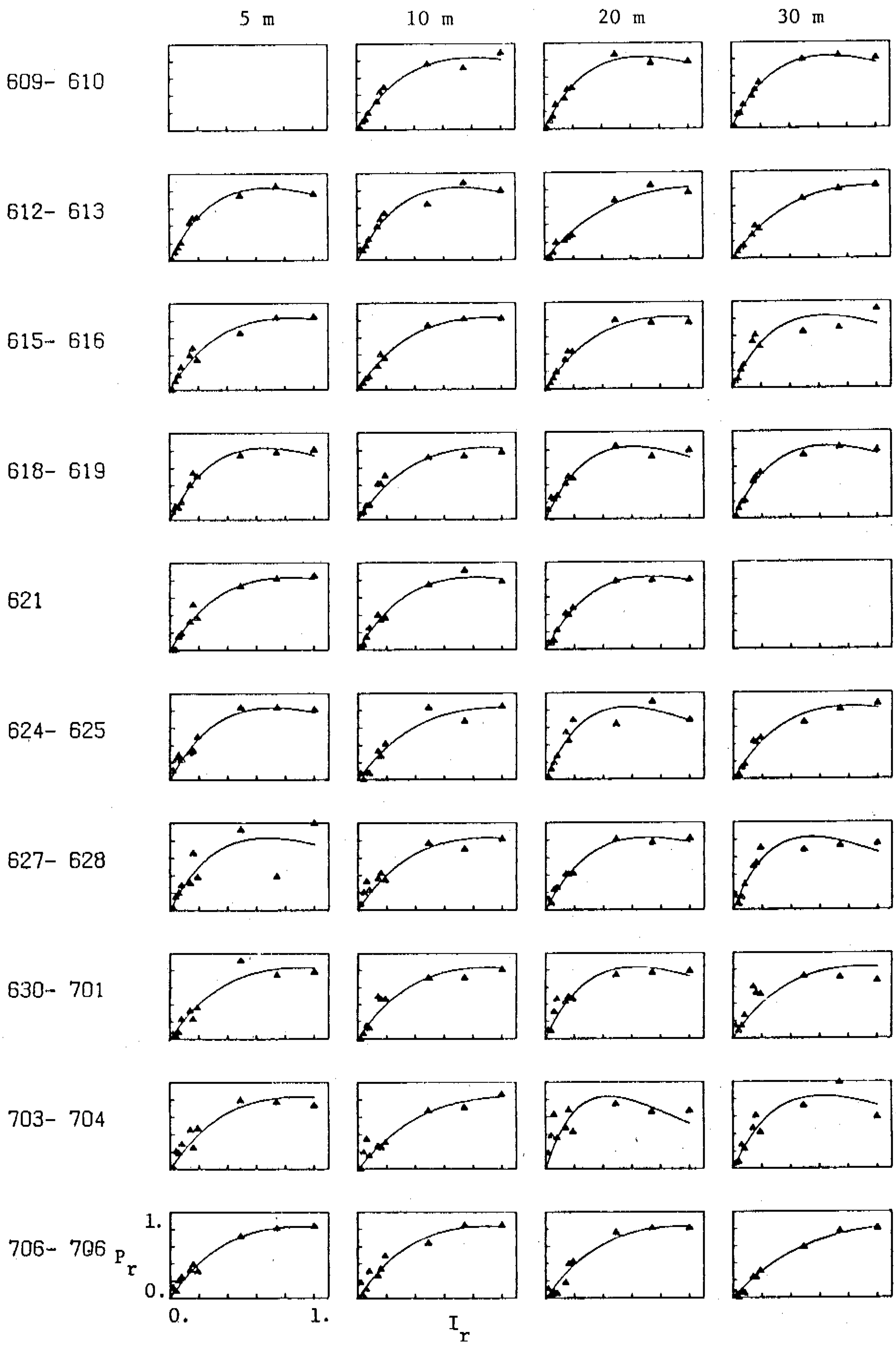


Figure 9. Relative assimilation (P_r) versus relative light (I_r) for observations from graduated light experiments from 5, 10, 20, and 30 m. The curves are the best fit Steele (1962) model for a particular data set. Month and day are indicated to the left. The last five graphs are from 60 m.

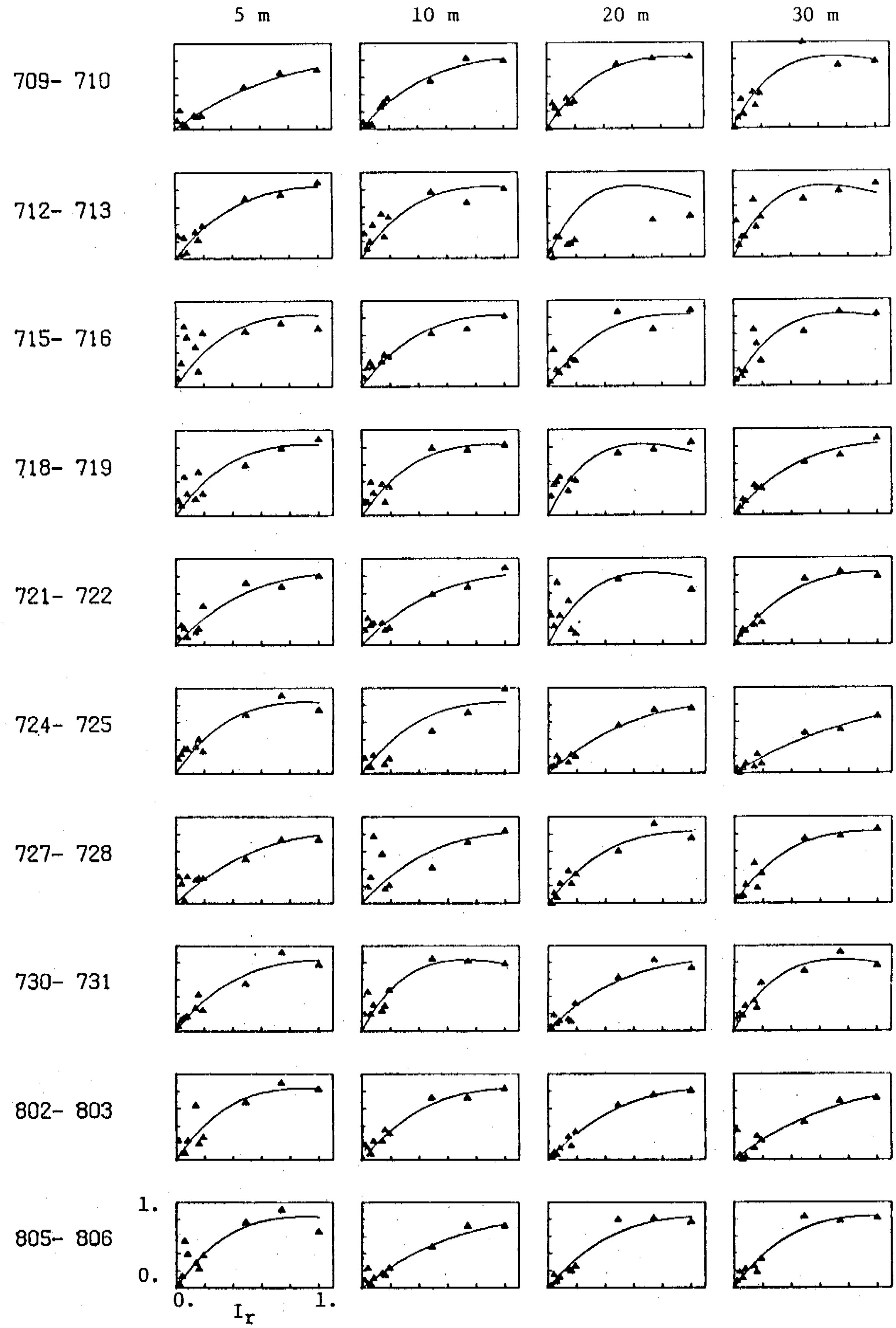
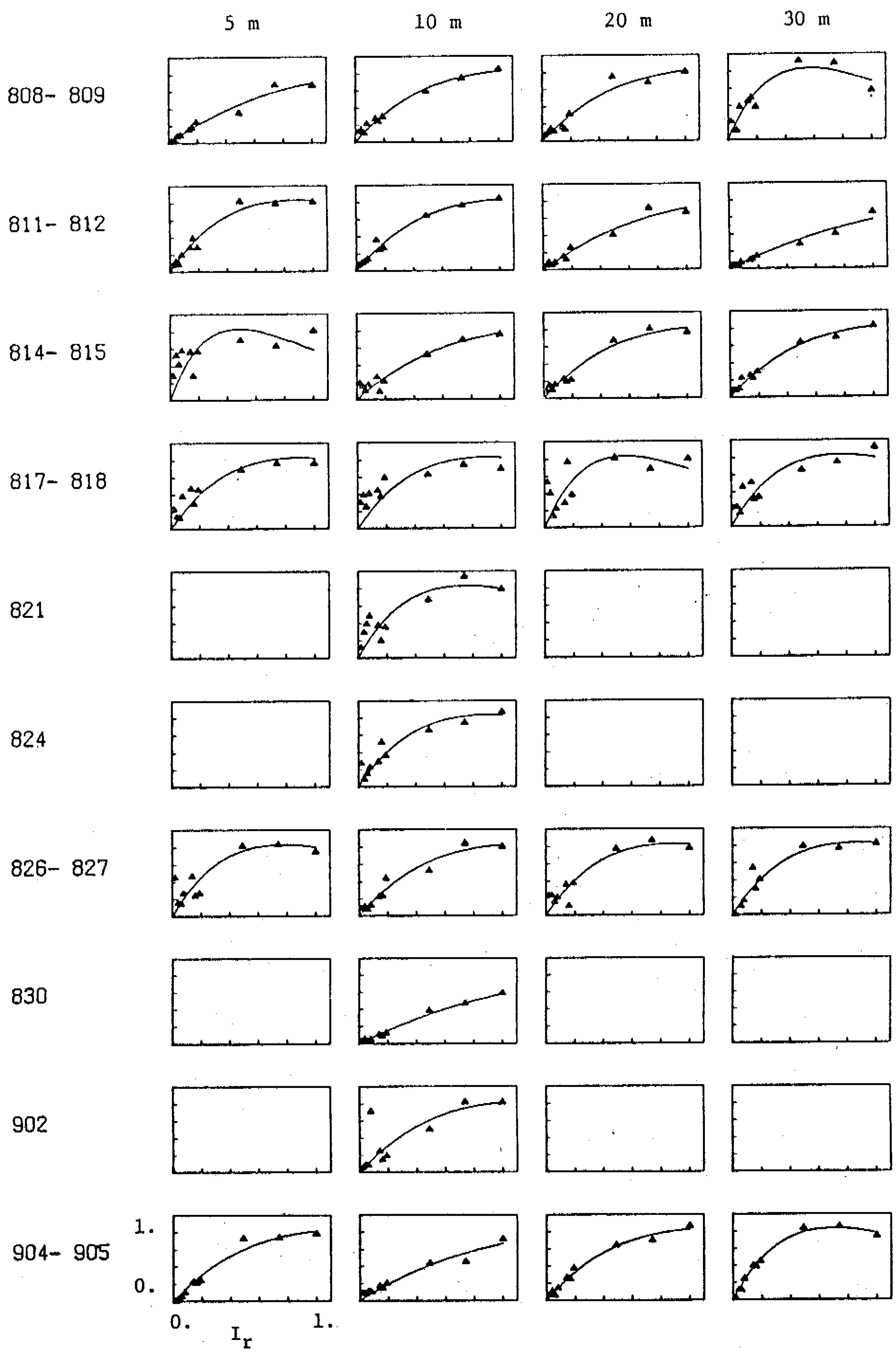
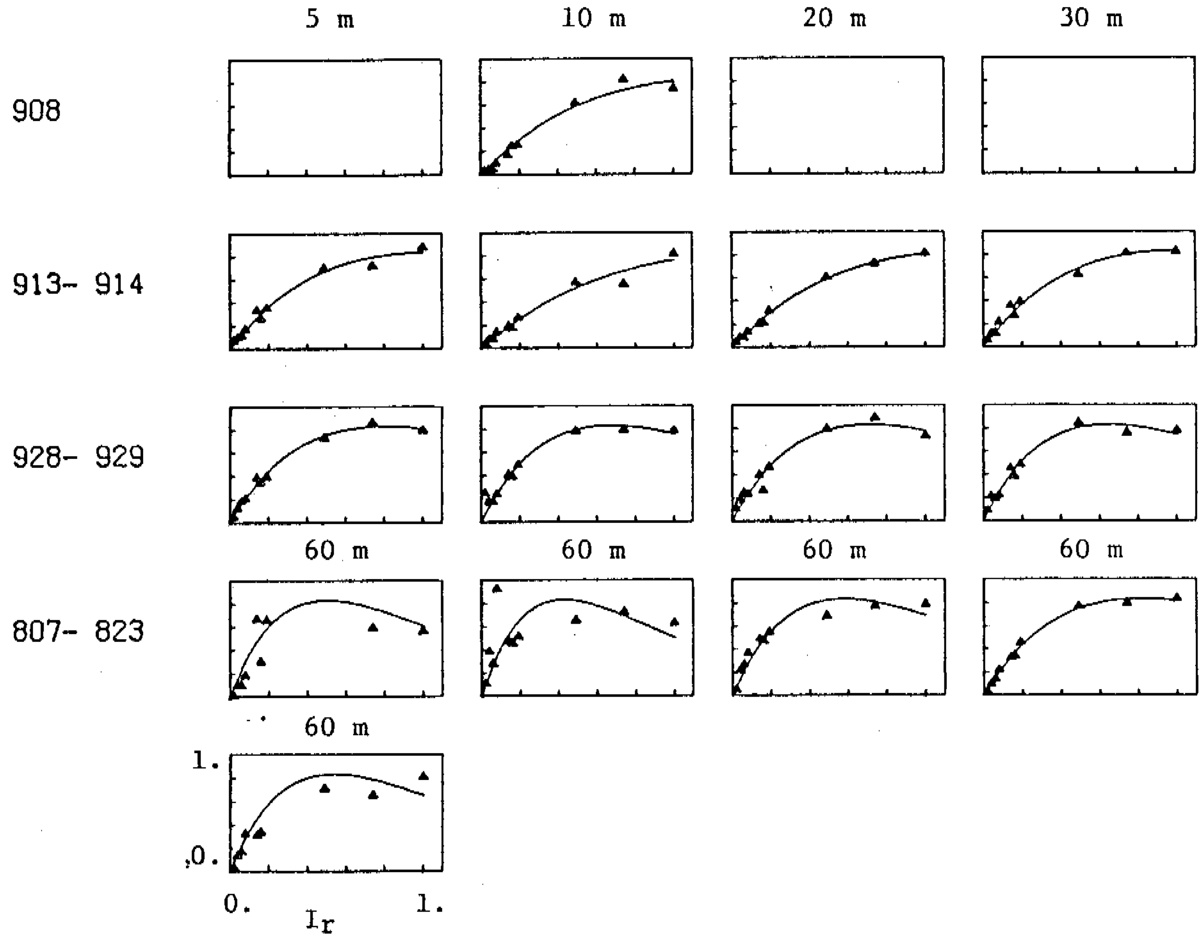

5 m
10 m
20 m
30 m
709- 710
712- 713
715- 716
718- 719
721- 722
724- 725
727- 728
730- 731
802- 803
805- 806
1.
0.
0.
1.
I_r

Fig. 9 (cont.)



5 m
10 m
20 m
30 m
808- 809
811- 812
814- 815
817- 818
821
824
826- 827
830
902
904- 905
1.
0.
0.
1.
I_r

Fig. 9 (cont.)



5 m
10 m
20 m
30 m
908
913- 914
928- 929
60 m
60 m
60 m
60 m
807- 823
60 m
1.
0.
0.
1.
I_r

Fig. 9 (cont.)

be pooled into time cells and the significance of trends during the summer will be investigated.

Environmental Observations

Measurements were made of air temperature, wind speed, and island movement on a daily basis by the meteorological team on AIDJEX. Air temperatures increased and remained near the freezing point about June 22 (Fig. 11). They remained there until late July when a temporary cold period brought snow accumulation and iced-over ponds. This lasted until late August when a brief rainy period caused a slight melting of the surface. The autumn snow began to accumulate in September as temperatures plummetted. Though there was a brief rise in temperatures to near freezing in the first half of September, snow continued to accumulate.

The seasonal pattern of submarine light may be deduced from changes in the ice cover recorded from June to September. Eight periods can be delineated roughly:

June 1-22: pre-melt, crusty, snowy, bright white surface

June 22-July 1: heavy melting, melt ponds increasing, intermittent rains

July 2-9: maximum meltwater (40-60%), intermittent snows

July 10-15: pond drainage, increased leads, intermittent snow

July 16-25: little change, grey ice, ponds skimmed, some snow

July 26-Aug 19: heavy snow accumulation, ponds drifted over, bare ice snow covered

Aug 20-29: brief rain, warm melt period, grey ice, slight regeneration of ponds

Aug 30-Sep 30: final snow build-up, ponds and bare ice all snow covered

Submarine light increased with the rains and warming temperatures in late June. Optimal light conditions prevailed until late July when snow

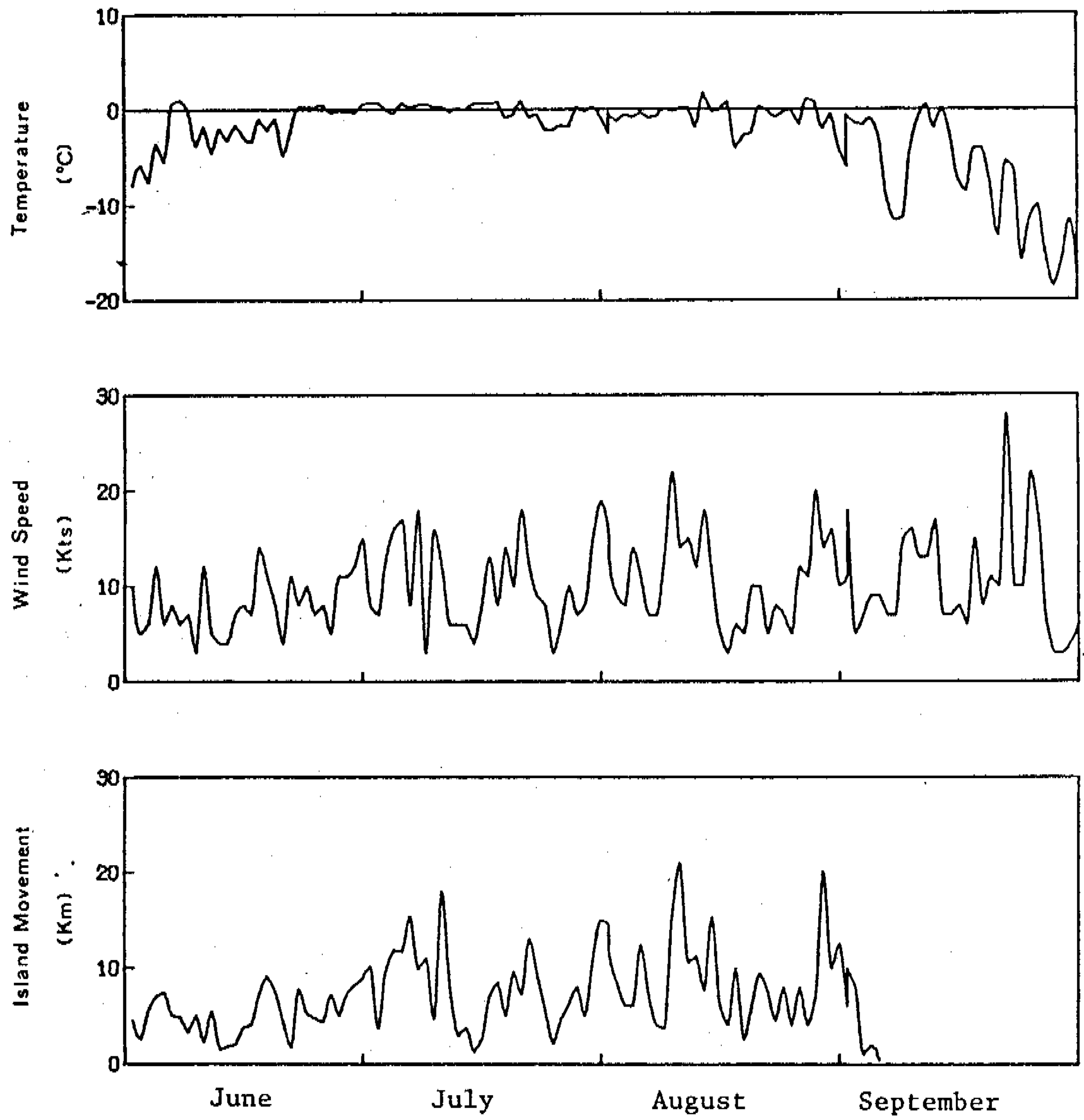


Fig. 10. Air temperature (°C), windspeed (kts), and daily island movement (km) recorded on AIDJEX main camp, summer 1975.

drifted over many melt ponds. The slight warming in late August temporarily increased submarine light, but that effect was minimized by low sun elevations.

Wind speed rarely was greater than 20 knots (Fig. 11). There were roughly seven periods of sustained high winds over 12-13 knots. The initial and longest period was in late June and early-July. The highest winds were recorded in late September. The response of the ice movement (Fig. 11) to the increased winds was on the order of hours.

Seawater temperatures and salinities were recorded daily by Lamont Geological Observatory throughout the summer. The mixed layer has a sharp increase in salinity at its base, though there may be small incremental steps in salinity within the mixed layer itself. From June through mid-July, the bottom of the mixed layer was generally at 50-60 m. At present, we do not have the temperature and salinity data for the remainder of the summer. The depth of the subsurface chlorophyll *a* maximum during July and August was at 55-60 m. Nitrate concentrations increased substantially at these depths. Thus we may infer from these two variables that the sharp increase in density remained at about 50-60 m all summer long through there were varying degrees of density stratification above this depth stratum.

Net Zooplankton

A complete account of the zooplankton counted to date will be forwarded in the next annual report due 1 April 1977. Those copepod species identified from the samples are listed in Table 9.

Table 9. Copepods observed from AIDJEX drift station June, 1975 to October, 1975.

Aetidiopsis multiserrata
Calanus glacialis
Calanus hyperboreus
Chiridius obtusifrons
Derjuginia tolli
Euchaeta glacialis
Gaidius brevispinus
Gaidius tenuispinus
Heterorhabdus compactus
Heterorhabdus norvegicus
Lubbockia glacialis
Metridia longa
Microcalanus pygmaeus
Microcalanus sp.
Oithona similis
Oncaea borealis
Oncaea notopus
Scaphocalanus magnus
Scolecithricella minor
Spinocalanus longicornis
Spinocalanus sp.
Temorites brevis
unidentified copepoda

Preliminary Interpretation

The summer increase in phytoplankton occurred at the pycnocline. Concentrations of nitrate that were mixed into the upper 40-50 m through turbulence and convective processes during the winter, were completely used during the initial spring activity of the phytoplankton. Our first measurements of nitrate were not made until 11 June. Substantially high concentrations of chlorophyll *a* were present in the mixed layer in early June and had decreased by late June. Visual microscopic examination of *Thalassiosira* and *Chaetoceros* spps. cells from the upper 50 m during mid-summer showed the cells to be very washed out and pale in color. Toward the end of summer, as nitrate spread into the upper 40 m, there was a minor resurgence of chlorophyll *a*, and the cells appeared deep golden and healthy.

The growth of phytoplankton at the pycnocline effectively limited the supply of nutrients to the mixed layer from below the sharp density gradient. The development was stimulated by changes in the surface of the pack ice allowing greater transmission of incident radiation to the waters below. The most rapid increase in phytoplankton was concomitant with the late June ablation of snow, development of melt ponds, and frequent rainy periods. Considering the low levels of light that are transmitted through the pack ice, it is interesting that any development even occurred at these 50-60 m depths.

The best period for growth was during July. On 26 July, lowered temperatures put skim ice on ponds and snow rapidly accumulated. The ponds themselves being in depressions were rapidly filled with drifted snow. This period of lowered submarine light levels lasted until about 20 August. Then for about a week, warmer temperatures and some rain caused the ice surface to melt and turn greyish. There was a slight rebirth of ponds but for the most part, they remained snow filled.

This warmer period in the second half of August was evidenced only weakly in the abundance of chlorophyll *a* at the pycnocline. There was a discernible, but barely significant, resurgence. Sun elevations are low and days short this time of year. Through September, phytoplankton abundance at depth declined. Nutrients, unutilized at the pycnocline and possibly helped by periods of higher winds, spread into the mixed layer, contributing to the brief fall increase in phytoplankton above 30 m.

The pattern of early summer and late fall development of phytoplankton in the mixed layer coupled with a mid-summer development in the pycnocline resulted in generally high amounts of total chlorophyll *a* throughout the summer. Only in late June did any substantial decrease occur.

The sampling done by helicopter enroute to the satellite camps gave evidence that our results may apply over a broad geographic area. At mid-summer, the chlorophyll *a* values over this 75-mile transect were consistently low. This together with the absence of nitrate from the mixed layer, show that nutrients may be limiting on large scales.

Chlorophyll *a* values from the helicopter transects were uniformly low. Nitrate concentrations always were undetectable. These features were sampled over an area approximately 75 miles wide. The results provide evidence that the processes observed at the main camp may have occurred on a broad geographic scale. The results further suggest that the variability in observations due to short term island movement may be small. Unfortunately our sampling time on these transects was very limited and the pycnocline could not be sampled.

The zooplankton counts show that the juveniles of several of the copepods advanced through 3-4 stages during the summer. This period of higher food abundance was probably very important to the survival of the cohort. Unfortunately, our sampling program was constrained in time and space and changes due to emigration and immigration in and out of the sample space cannot be assessed. Nor can any conclusions be drawn about the survival in the fall or the overwintering process.

Recommendations

A longer time series is required for this region to allow the assessment of trophic dependencies and seasonal changes of the vertical distributions of zooplankton. A sequence of zooplankton samples throughout the year, to depths of 300 m could be enumerated to species and stages within species to elucidate the critical periods of development.

Herbivore development may depend on the depth and timing of increased phytoplankton activity. Therefore it is important to know if significant yearly differences occur in the cycle of phytoplankton abundance due to summer melt patterns, nutrient fluxes, mixing, or other environmental factors. The continued monitoring of the changes in the character of the pack ice surface as well as the nutrient regime and mixing processes in the mixed layer would help pinpoint the significant driving forces of the marine ecosystem. This monitoring should include a synoptic sampling program in order to assess small and large scale patchiness.

Sampling of the various environmental attributes as well as the phytoplankton and zooplankton populations at close intervals in time and depth allow the variability in these dimensions to be assessed. This assessment would allow a more efficient field program to be formulated as well as provide constraints within which model-generated outputs must be validated. Only with the estimation of variability inherent in the environment and several complete time series of samples will we be in a position to attempt an evaluation of short and long term changes that may be attributable to man's resource developments of the outer shelf.

QUARTERLY REPORT

Contract No.	:R7120824
Research Unit No.	:RU-380
Reporting Period	:1 April-30 June, 1977
Number of Pages	:6

ICHTHYOPLANKTON OF THE EASTERN BERING SEA

Co-Principal Investigators

Kenneth D. Waldron and Felix Favorite
National Marine Fisheries Service
Northwest and Alaska Fisheries Center

I. <u>Task Objective</u>:

Collect and analyze ichthyoplankton samples from a portion of the eastern Bering Sea during the spring of 1976 (completed) and 1977 (in progress).

II. <u>Field or Laboratory Activities</u>:

A. Ship Schedule:

1. April 13-30, 1977 RP-4-MF-77B, Leg V

   May 1-17, 1977 RP-4-MF-77B, Leg VI

   Both legs were aboard the NOAA vessel MILLER FREEMAN

B. Scientific Party:

K. D. Waldron	NMFS, NWAFC, Chief Scientist
J. R. Dunn	NMFS, NWAFC, Field Party (Leg V)
D. M. Fisk	NMFS, NWAFC, Field Party
K. L. Larson	NMFS, NWAFC, Field Party
D. M. Stehr	NMFS, NWAFC, Field Party (Leg VI)

C. Methods:

1. Plankton samples were collected with 60 cm bongo nets and neuston nets following general methods prescribed by MARMAP I Field Office, and in addition a small number of samples was collected with a plankton sled and with a Tucker trawl.

   Temperature and salinity were measured with CTD and XBT probes.

D. Sample Localities: See attached chart.

E. Data Collected:

1. Numbers of samples: Plankton samples were collected at 63 locations in the Bering Sea, and at 14 locations in the Pacific Ocean just south of the Alaska Peninsula and Aleutian Islands while the

vessel was in transit to and from the survey area. A total of 417 individual plankton samples was collected (41 of the stations were occupied more than one time during the two legs of the cruise). In conjunction with the plankton stations 62 CTD casts and 84 XBT casts were made by vessel personnel.

2. Analyses: No formal analyses were made at sea. Samples from the 505-bongo and the neuston net were subjected to a cursory examination for the presence of pollock larvae or fish eggs. After the samples were received at the laboratory in Seattle, approximately 10% of the combined 505-bongo and neuston samples were pre-sorted as a quality control measure prior to shipping the samples to the sorting contractor, the Ecological Services Division of Texas Instruments, Inc. of Dallas, Texas.

   As set forth in the work statement, there will be no analyses of the 333-bongo samples, and instructions are requested regarding disposition of these samples.

III. Results

Samples collected with the 505-bongo and the neuston net were shipped to Seattle by air cargo, arriving on May 23rd, were pre-sorted as noted above, and by June 14th all had been shipped to the sorting contractor. Under the terms of the contract the ichthyoplankton portion will be returned to Seattle in 30 days, at which time we will begin identification procedures.

The cursory examination of samples noted above showed fewer eggs and a more restricted distribution of eggs during 1977 as compared with the similar survey made during April-May 1976. This was especially noticeable in the neuston samples. Fish eggs, possibly those of walleye pollock (Theragra chalcogramma), were abundant only in the vicinity of stations 19, 22, 23, and 24. Relatively few eggs were seen that could be tentatively identified as those of flathead sole (Hippoglossoides sp.).

Larvae, tentatively identified as walleye pollock, were present in a slightly different location than was observed in 1976, and were most abundant in the vicinity of stations 50-52 and 2-4 along the southwestern edge of our survey area. Plankton collected at stations west of these noted above, e.g., stations 64-66, over deeper water, contained pollock larvae, but in noticeably smaller numbers. Furthermore, it appeared on the basis of the cursory examination, that the pollock larvae were larger than those collected at the same time of year in 1976.

Neuston samples, especially those collected at night, contained larger numbers of small juvenile or late larvae of fish identified as belonging to the family Hexagrammidae, as well as some larvae of the families Cottidae and Osmeridae. A greater number of fish appear to have been caught by the neuston net during 1977 as compared with 1976.

As a experimental procedure, and at no cost to the project in either time or money, pollock eggs were collected at stations 22 and 23, held in plastic containers, and transported from Adak to Seattle at the end of Leg V. These eggs were then incubated at the NWAFC Field Station at Mukilteo where they hatched and were maintained alive for a period of about three weeks. It is believed that this is the first time pelagic eggs from the Bering Sea have been successfully transported alive to Seattle.

IV. Preliminary Interpretation of Results:

None

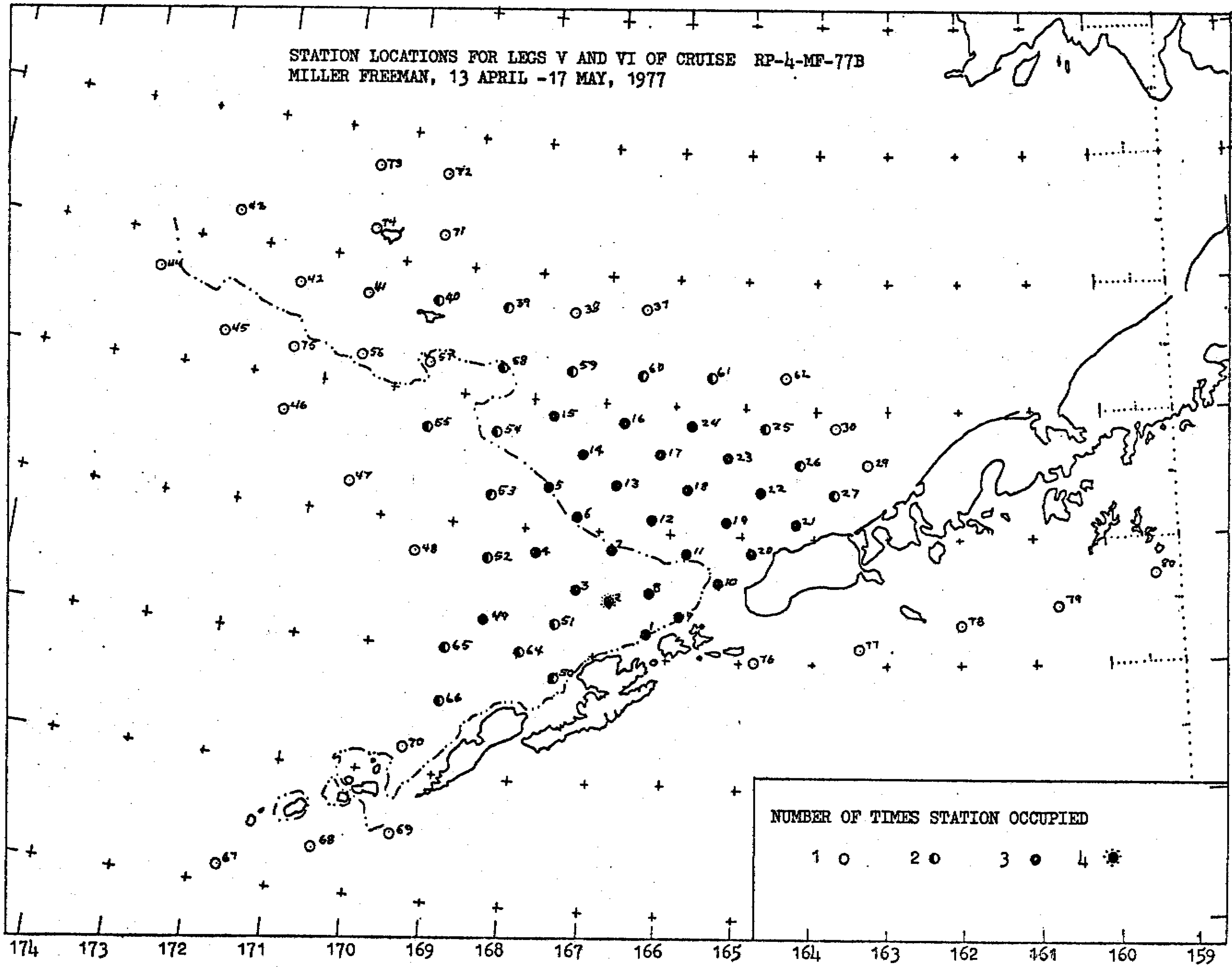
V. Problems Encountered and Recommended Changes:

Collection of samples at sea was accomplished with a minimum of difficulty, and personnel of the MILLER FREEMAN are to be commended for the way in which the work was carried out. Rough seas resulted in loss of only about 3 days of sampling time during Legs V and VI.

It had been planned to occupy stations 1-30 a fourth time during the last few days of Leg VI, and during this period to collect additional eggs for shipment to Seattle for rearing at the Mukilteo laboratory. However, on May 15th a fire which disabled one of the generators necessitated termination of the cruise and loss of the final three days of sampling. On May 16th the Deputy Director of PMC advised the vessel to proceed to Kodiak for generator evaluation and repair. Because the vessel was scheduled for use by other investigators, it was not possible to resume sampling for RU-380.

VI. Estimate of Funds Expended:

$46,300


STATION LOCATIONS FOR LEGS V AND VI OF CRUISE RP-4-MF-77B
MILLER FREEMAN, 13 APRIL -17 MAY, 1977
NUMBER OF TIMES STATION OCCUPIED
1 2 3 4
174 173 172 171 170 169 168 167 166 165 164 163 162 161 160 159
59 58 57 56 55 54 53 52

PROJECT RU-380 Ichthyoplankton of the Eastern Bering Sea, NWAFC

DATE 20 June 1977

PRINCIPAL INVESTIGATORS F. Favorite and K. Waldron, NWAFC

	MAJOR MILESTONES/ ACTIVITIES
1	MILLER FREEMAN Cruise 76A, Collect Plankton Samples
2	Samples returned to Seattle aboard FREEMAN
3	Award sorting contract
4	Sort plankton for ichthyoplankton and major taxa
5	Identification of ichthyoplankton
6	Analysis of data
7	Annual Report
8	Quarterly Reports
9	Transcription to OCSEAP format & submit mag tapes
10	MILLER FREEMAN Cruise 77B, Collect plankton samples
11	Samples returned to Seattle via commercial carrier
12	Sort samples for ichthyoplankton by contract
13	Identification of ichthyoplankton
14	Analysis of data
15	Final Report (a) Start
16	(b) Submit for internal review
17	(c) Final draft preparation
18	(d) Submit to NOAA

QUARTERS: FY76 (Ap, Jl), FY77 (O, Jny, Ap, Jl), O, Jny

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August 3, 1977

Dr. Herb Bruce, Director
National Oceanic & Atmospheric Administration
OCSEAP Office
P.O. Box 1808
Juneau, Alaska 99802

Gentlemen:

Research Unit 417

Quarterly Report
Ecological Studies of Intertidal and Shallow Subtidal Habitats in Lower Cook Inlet

This administrative summary reports the status of this study after the spring field season. During this period we accomplished most of what we had planned. On rocky habitat, we sampled at Gull Island, Jakolof Bay and Seldovia Point, and on soft substrates, at Homer Spit, Deep Creek and Chinitna Bay.

During this period we commenced growth studies for three of the major plant species, namely Laminaria groenlandica, Agarum cribrosum and Alaria fistulosa. Results for the latter two species were not satisfying because of technical problems, but methods are being developed to permit study.

Algal assemblages appeared to be developing rapidly. Intertidal species of Alaria were already mature and growing rapidly. At Jakolof Bay and Seldovia Point, the kelp beds areas supported large numbers of juveniles for both Alaria fistulosa and Nereocystis luetkeana, and gave the impression that the kelp beds will be large and of mixed composition during the summer.

The field schedule is intact and planned activities are essentially on schedule. If you have any questions, please contact me at the Homer office, (235-8316).

Very truly yours,

DAMES & MOORE

Dennis C. Lees

Dennis C. Lees
Project Manager

DCL:klr

Enclosure

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. The 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-First Survey Period (January-March 1977)

1. 4 February - Deep Creek sand beach-via personal car.
2. 5,6 February - Chinitna Bay mudflat-via chartered plane--aborted trip because of plane breakdown.
3. 9-13 February - Jakolof Bay and Seldovia Point dive studies--via chartered vessel, M.V. Centurion.
4. 15, 16 February - Gull Island and Seldovia Point rocky beach--via chartered vessel, M.V.Centurion.
5. 17 February* - Homer Spit and beach -- via personal car.
6. 18 February* - 1.5 mi west of Seafair Beach -- via personal car.
7. 5-7 March - Chinitna Bay mudflat--via chartered airplane --aborted because of weather.
8. 7-8 March - Homer Spit sand beach -- via personal car.
9. 12, 13 March - Jakolof Bay dive studies -- via chartered vessel, M.V. Centurion.

Ship or Field Trip Schedule - Second Survey Period (April-June 1977)

1. 6 April - Chinitna Bay mudflat - via chartered plane.
2. 7 April - Deep Creek sand beach - via personal car.

---

* Cancelled scheduled work at Gull Island and Seldovia Point because of weather.

3. 22 April - Jakolof Bay dive study - via Dames & Moore vessel, Sea Star.
4. 2, 3 May - Gull Island rocky beach - via Dames & Moore vessel, Sea Star.
5. 5, 6 May - Seldovia Point rocky beach - via Dames & Moore vessel, Sea Star.
6. 10, 11, 13 May - Seldovia Point dive studies - via Dames & Moore vessel, Sea Star.
7. 12 May - Jakolof Bay dive studies - via Dames & Moore vessel, Sea Star.

B. Scientific Party

1. Deborah Boettcher, Dames & Moore, Assistant Biologist
2. William Driskell, Dames & Moore, Assistant Biologist
3. Dr. Jonathan Houghton, Dames & Moore Project Marine Biologist
4. Dennis Lees, Dames & Moore, Project Manager
5. Richard Rosenthal, Alaska Coastal Research, Consulting Biologist

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 MLLW.

(4) Samples are individually bagged and labeled.

(5) After sample collection is completed (about one hour), 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% 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., MLLW, -1 ft., -30 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, individual plants of Laminaria groenlandica, Agarum cribrosum and Alaria fistulosa were tagged, measured and marked 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 or 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) A representative series of laminarians are also dried to establish length-wet weight-dry weight relationship.

(4) Sizes are measured for various invertebrate species to establish size distributions.

(5) Fish and selected invertebrate species are observed or dissected in order to determine food habits and develop food webs.

D. Sample Localities

1. Soft Substrates

(a) Deep Creek - 1½ mi. south of beach access at beach park (Figure 1); transect based on very large triangular boulder at base of cliff;

(b) Homer Spit - 2½ mi. south of Kachemak Drive, off beach access ramp on west side of spit (Figure 1);

(c) Glacier Spit - at Byer's home site, on the north side of Chinitna Bay (Figure 1); transect based on a solitary intertidal boulder clump near MLLW.

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 Substrate

(a) Deep Creek (4-7-77)

(1) Beach profile

(2) Forty core samples - sorted and identifed

(b) Chinitna Bay - Glacier Spit (4-6-77)

(1) Beach profile

(2) Forty core samples - sorted and identifed

(3) 1/16 m^2 quadrats for density and dominant invertebrate - 100

2. Rock Substrate

(a) Gull Island

(1) 1/4 m^2 quadrats for plant cover, density and biomass - 41

(2) 1/4 m^2 quadrats for cover and density of plants and invertebrates - 15

(3) Beach profile

(4) Feeding observations - 1

(5) Size distribution for two species

(b) Seldovia Point Intertidal Survey

(1) 1/4 m^2 quadrats for plant cover, density and biomass - 37

(2) 1/4 m^2 quadrats for cover and density of plants and invertebrates - 1

(3) Feeding observations - 3

(4) Size distribution for four species

(5) Reproductive status data for one species

(c) Seldovia Point Subtidal Survey

(1) Large quadrats for plants and large invertebrates:

1 x 25 m - 6

(2) 1/4 m^2 quadrats for plant cover, density and biomass - 30

(3) 1/4 m^2 quadrats for cover and density of dominant plants and animals - 13

(4) 1/4 m^2 detailed quadrats for cover and density of plants and animals - 39

(5) Feeding observations - 9

(6) Size distribution for four species

(d) Jakolof Bay Subtidal Studies

(1) Large quadrats for plants and large invertebrates:

0.5 x 28 m - 1

0.5 x 30 m - 1

1 x 25 m - 2

(2) 1/4 m^2 quadrats for plant density, cover and biomass - 7

(3) Tagged plants measured:

Agarum cribrosum - 4

Alaria fistulosa - 10

Laminaria groenlandica - 18

(4) Feeding observations - 22

(5) Size distribution for one species

F. Milestone Chart and Data Submission Schedule

The scheduling projected in the milestone chart (Figure 2) is being met, with two exceptions. Submission of data reports and digital data are lagging because of field schedules, keypunch backlog and delays in taxonomic assistance. Scheduling will ease somewhat after August.

III. Results

A brief data report will be submitted after laboratory analysis is completed.

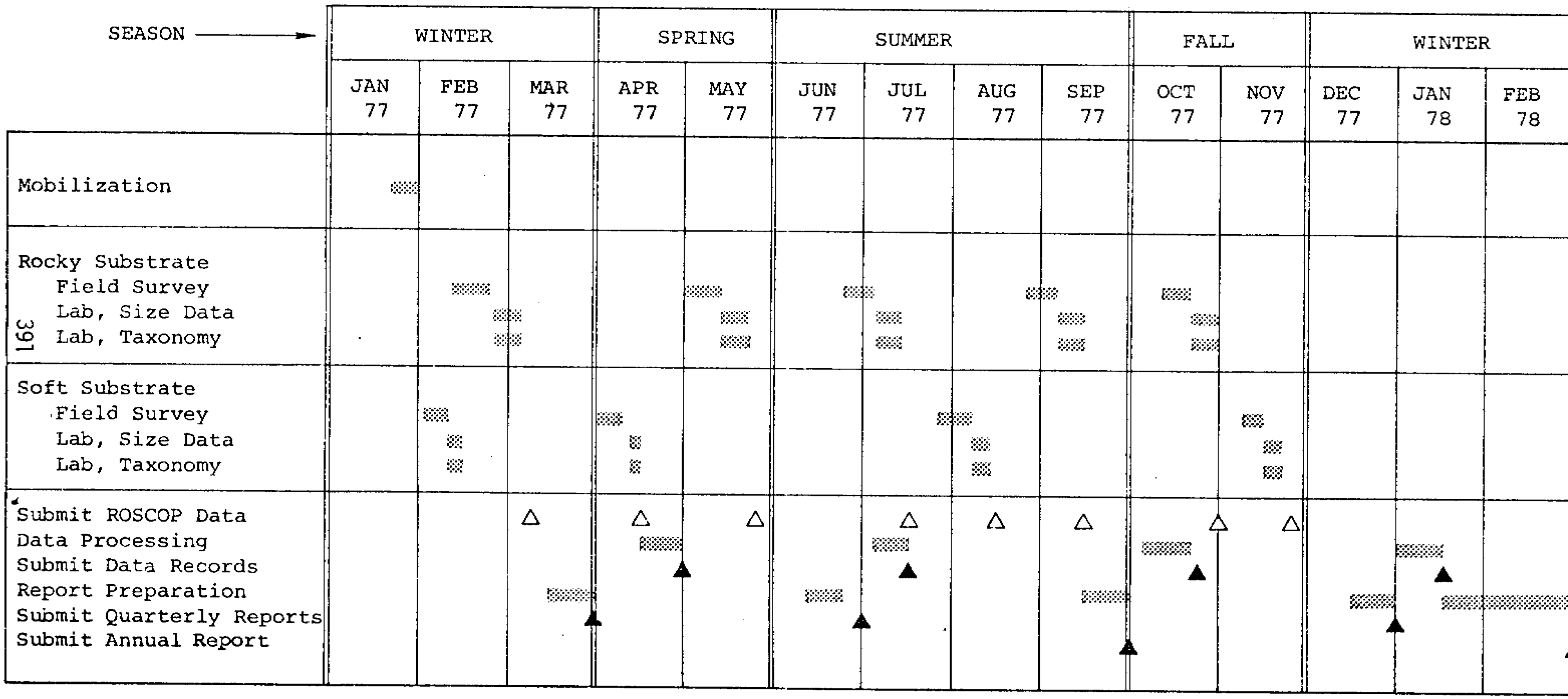
IV. Preliminary Interpretation of Results

Plant assemblages generally survived the winter in good condition. Spring surveys indicated heavy recruitment by *Alaria*, *Nereocystis*, *Agarum* and *Laminaria* at the rocky subtidal study sites, and by *Alaria* and assorted red algae at the rocky intertidal sites. However, the midtidal bench at Gull Island exhibited very little recruitment.

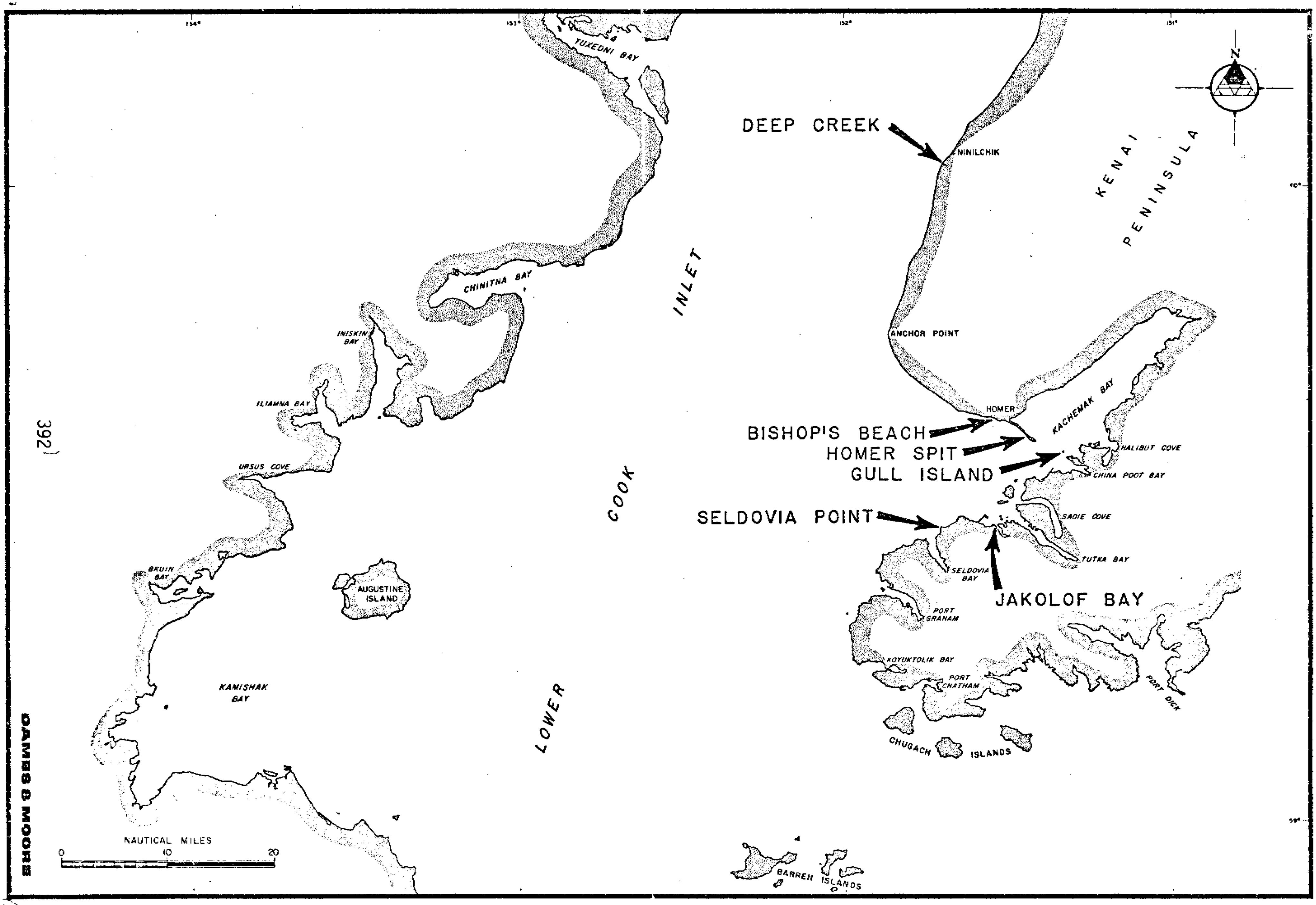
The urchin population at the Jakolof Bay study site is expanding and is starting to create problems in the plant assemblage in one of the areas. Growth data for *Laminaria groenlandica* and *Agarum cribrosum* were obtained, but other techniques must be developed for *Agarum*, *Alaria* and *Nereocystis*.

V. Estimate of Funds Expended

$55,000



ACTIVITIES SCHEDULE FOR LOWER COOK INLET STUDIES (R.U. NO. 417) - MILESTONE CHART


DEEP CREEK
NINILCHIK
KENAI PENINSULA
TUXEDNI BAY
CHINITNA BAY
INLET
COOK
LOWER
INISKIN BAY
ILIAMNA BAY
URSUS COVE
BRUIN BAY
AUGUSTINE ISLAND
KAMISHAK BAY
ANCHOR POINT
HOMER
KACHEMAK BAY
BISHOP'S BEACH
HOMER SPIT
GULL ISLAND
HALIBUT COVE
CHINA POOT BAY
SELDOVIA POINT
SADIE COVE
TUTKA BAY
SELDOVIA BAY
JAKOLOF BAY
PORT GRAHAM
KOYUKTOLIK BAY
PORT CHATHAM
PORT DICK
CHUGACH ISLANDS
BARREN ISLANDS
NAUTICAL MILES
0
10
20
N
DAMES & MOORE

QUARTERLY REPORT

Contract # 03-5-022-67-TA8 #4
Research Unit #424
Reporting Period: 1 Apr - 30 Jun 1977
Number of Pages:

Lower Cook Inlet Meroplankton

T. Saunders English
Department of Oceanography
University of Washington
Seattle, Washington 98195

1 July 1977

Departmental Concurrence: [signature]
Francis A. Richards
Associate Chairman for Research

REF: A77-9

I. Task Objective

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.

E. Data Analyzed

1. The number and kinds of net hauls analyzed from the *Discoverer* cruise, Leg V, 05-09 May 1976 are reported in Tables 1 and 2. Twelve replicate samples were collected by standard MARMAP procedures using a 60 centimeter Bongo net with 333 and 505 μm mesh sizes, and one sample was collected with a 1-m NIO (National Institute of Oceanography) net at 11 stations including 2 stations in the Gulf of Alaska. Samples were sorted and identified for fish eggs, fish larvae, crab and shrimp larvae and adult shrimp. These data are complete and correct and correspond to data cards (024 DIS 002 V 76/05/05 - 76/05/09 GOA/ICHTHYOPLANKTON) submitted concurrently with this report.

2. The number and kinds of net hauls analyzed from the *Discoverer* cruise, Leg VII, 22-30 May 1976 are reported in Tables 3 and 4. Eighteen replicate samples were collected by standard MARMAP procedures using a 60 centimeter Bongo net with 333 and 505 μm mesh sizes, and one sample was collected with a 1-m NIO net at twelve stations including 3 stations in the Gulf of Alaska and one in Prince William Sound. Samples were sorted and identified for fish eggs, fish larvae, crab and shrimp larvae and adult shrimp. These data are complete and correct and correspond to data cards (024 DIS 003 VII 76/05/22 - 76/05/30 GOA/ICHTHYOPLANKTON) also submitted concurrently with this report.

3. Additional samples from stations 2, 3, and 4 were analyzed for fish eggs and larvae from the *Surveyor* cruise, Leg II, 24-31 August 1976.

4. Additional samples from stations 2, 3, 4, 5, 6, 7, and 8 were analyzed for fish eggs and larvae from the *Miller Freeman* cruise, Leg III, 17-29 October 1976.

F. Milestone Chart and Data Submission Schedules

The milestone/data submission schedule remains unchanged from that reported in the annual report dated 1 April 1977.

<u>Activity/Milestone/Data Management</u>

	Jul			Oct			Jan
1. Submit May 76 cruise data	Δ						
2. Quarterly Report 3	Δ						
3. Submit July 76 cruise data			Δ				
4. Submit August 76 cruise data				Δ			
5. Submit October 76 cruise data				Δ			
6. Submit February 77 cruise data				Δ			
7. Final Report				Δ			

III. Results

The results of this quarter are presented as tables. The summaries of samples analyzed from the *Discoverer* cruise, Leg V, 05-09 May 1976 cover the taxonomic categories of fish eggs, fish larvae, crab and shrimp larvae, and adult shrimps (Tables 7-12). The summaries of samples analyzed from the *Discoverer* cruise, Leg VII, 22-30 May 1976 cover the taxonomic categories of fish eggs, fish larvae, crab and shrimp larvae, and adult shrimps (Tables 13-17).

Additional samples of fish eggs and larvae are presented from the *Surveyor* cruise, Leg II, 24-31 August 1976 and the *Miller Freeman* cruise, Leg III, 17-29 October 1976 (Tables 18-23).

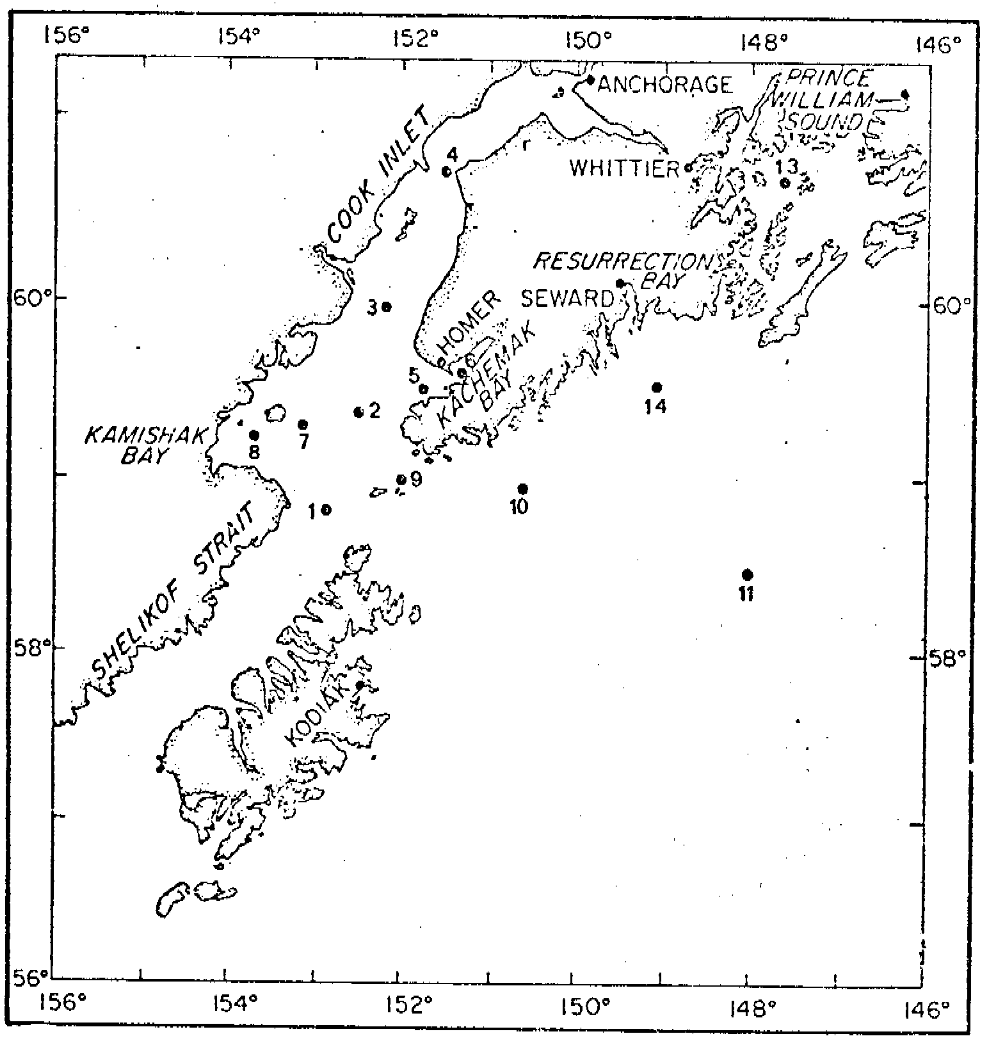


Fig. 1. Station locations

Table 1. UW Haul Summary Sheet, *Discoverer*, Leg V, 05-09 May 1976

Bongo Tows

Date (1976) (GMT)	Time (GMT)	Station	Haul	Latitude (N)	Longitude (W)	Depth (m)	Volume Filtered* (m^3)
6 May	1325	1	1	58° 52.5'	152° 49.2'	170	645
6 May	1552	2	1	59° 21.0'	152° 39.7'	53	242
6 May	2117	3	1	59° 58.5'	152° 11.4'	65	280
7 May	0259	4	1	60° 39.2'	151° 37.1'	65	260
7 May	1030	5	2	59° 34.4'	151° 47.2'	20	244
7 May	1312	6	1	59° 37.0'	151° 18.3'	75	182
7 May	1709	6	2	59° 37.1'	151° 19.0'	70	268
8 May	0020	5a	1	59° 34.6'	151° 47.5'	25†	116
8 May	0402	7	1	59° 30.0'	153° 10.4'	35	--
8 May	0734	8	1	59° 14.2'	153° 40.3'	32†	121
8 May	1315	9	1	59° 02.0'	151° 59.1'	130	546
9 May	0145	11	1	58° 21.8'	148° 01.7'	195†	795

†estimated by wire angle
BKG not used
*averaged

Table 2. UW Haul Summary Sheet, *Discoverer*, Leg V, 05-09 May 1976

1-m NIO Tows

Date (1976) (GMT)	Time (GMT)	Station	Haul	Latitude (N)	Longitude (W)	Depth (m)	Volume Filtered* (m^3)	Mesh Size (μm)
7 May	1757	6	3	59° 37.2'	151° 17.6'	40	710	571

*averaged

Table 3. UW Haul Summary Sheet, *Discoverer*, Leg VII, 22-30 May 1976

Bongo Tows

Date (1976) (GMT)	Time (GMT)	Station	Haul	Latitude (N)	Longitude (W)	Depth (m)	Volume Filtered* (m^3)
24 May	0732	1	1	58° 53.7'	152° 47.5'	105	652
25 May	1150	2	1	59° 23.6'	152° 38.1	40	216
25 May	1607	3	1	59° 59.5'	152° 11.5'	58	170
25 May	2217	4	1	60° 41.5'	151° 37.5'	40	252
26 May	0541	5a	2	59° 34.6'	151° 47.0'	45	149
26 May	0835	6	1	59° 36.7'	151° 17.8'	90	221
26 May	1928	6	3	59° 36.6'	151° 18.6'	67	212
27 May	0056	6	4	59° 36.5'	151° 19.5'	51	174
27 May	0708	6	7	59° 36.5'	151° 19.6'	50	193
27 May	1300	7	1	59° 29.1'	153° 09.8'	36	156
27 May	1701	8	1	59° 13.4'	153° 38.5'	32	87
30 May	1813	10	1	58° 52.0'	150° 41.4'	90	348
30 May	0253	11	1	58° 24.1'	148° 06.2'	103	797
30 May	0813	11	2	58° 21.3'	148° 02.4'	265	764

*averaged

Table 3. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Latitude (N)	Longitude (W)	Depth (m)	Volume Filtered* (m^3)
28 May	1831	13	1	60° 42.1'	147° 40.5'	165	1055
28 May	2248	13	2	60° 42.5'	147° 40.9'	230	2244
29 May	1029	13	3	60° 42.6'	147° 40.9'	190	1114
28 May	0536	14	1	59° 24.0'	149° 05.5'	165	708

*averaged

Table 4. UW Haul Summary Sheet, *Discoverer*, Leg VII, 22-30 May 1976

1-m NIO Tows

Date (1976) (GMT)	Time (GMT)	Station	Haul	Latitude (N)	Longitude (W)	Depth (m)	Volume Filtered* (m^3)	Mesh Size (μm)
27 May	0120	6	5	59° 36.7'	151° 19.5'	49	581	571

*averaged

Table 5. UW Haul Summary Sheet, *Surveyor*, Leg II, 24-31 August 1976

Bongo Tows

Date (1976) (GMT)	Time (GMT)	Station	Haul	Latitude (N)	Longitude (W)	Depth (m)	Volume Filtered* (m^3)
25 Aug	0840	1	1	58° 53.2'	152° 46.2'	162	476
25 Aug	1206	2	1	59° 22.1'	152° 40.0'	70	--
25 Aug	1952	3	1	59° 59.5'	152° 11.0'	48	217
26 Aug	0400	4	1	60° 42.1'	151° 36.5'	90	322
26 Aug	1040	5	1	59° 34.9'	151° 50.6'	30	277
26 Aug	2203	6	1	59° 36.5'	151° 17.7'	40	488
27 Aug	1000	6	2	59° 36.5'	151° 17.7'	50	370
28 Aug	0650	7	1	59° 30.1'	153° 07.7'	48	1190
28 Aug	0330	8	1	59° 14.3'	153° 40.5'	34	33
28 Aug	1832	9	1	59° 02.2'	151° 58.6'	100	1387
28 Aug	1919	9	2	59° 02.2'	151° 58.6'	115	1989
29 Aug	0459	10	1	58° 51.5'	150° 40.2'	135	1907
29 Aug	1922	11	1	58° 24.4'	148° 06.2'	270	3645
31 Aug	0600	13	1	60° 41.2'	147° 40.7'	165	848
30 Aug	0559	14	1	59° 24.9'	149° 05.0'	170	468

*averaged

Table 6. UW Haul Summary Sheet, *Miller Freeman*, Leg III, 17-29 October 1976

Bongo Tows

(1976) (GMT)	Time (GMT)	Station	Haul	Latitude (N)	Longitude (W)	Depth (m)	Volume Filtered* (m^3)
19 Oct	0400	1	1	58° 54.3'	152° 51.1'	172	243.6
19 Oct	2057	2	1	59° 24.3'	152° 41.5'	- - - - - - -	ABORT - - -
28 Oct	0845	2	2	59° 22.8'	152° 40.8'	66	129.8
23 Oct	1935	3	1	60° 00.8'	152° 13.6'	57	115.2
24 Oct	1004	4	1	60° 38.4'	151° 39.0'	50	161.7
23 Oct	1006	5	1	59° 35.1'	151° 49.2'	32	110.2
22 Oct	1758	6	1	59° 36.7'	151° 16.8'	75	162.4
21 Oct	0907	7	1	59° 29.9'	153° 10.0'	31	44.9
22 Oct	0403	8	1	59° 15.9'	153° 41.8'	27	152.6
28 Oct	1244	9	1	59° 02.6'	151° 59.4'	199	706.0

*averaged

Table 7. Number of fish eggs and larvae at each station
Lower Cook Inlet, *Discoverer*, Leg V, 05-09 May 1976

Bongo Tows

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae
6 May	1325	1	1	333	42	34
6 May	1325	1	1	505	32	40
6 May	1552	2	1	333	0	26
6 May	1552	2	1	505	3	13
6 May	2117	3	1	333	41	12
6 May	2117	3	1	505	37	18
7 May	0259	4	1	333	0	3
7 May	0259	4	1	505	0	2
7 May	1030	5	2	333	40	119
7 May	1030	5	2	505	136	852
7 May	1312	6	1	333	992	290
7 May	1312	6	1	505	1616	326
7 May	1709	6	2	333	1296	352
7 May	1709	6	2	505	364	236
8 May	0020	5a	1	333	48	182
8 May	0020	5a	1	505	50	162
8 May	0402	7	1	333	54	4
8 May	0402	7	1	505	60	8
8 May	0734	8	1	333	360	17
8 May	0734	8	1	505	353	20
8 May	1315	9	1	333	25	22
8 May	1315	9	1	505	24	18
9 May	0145	11	1	333	11	44
9 May	0145	11	1	505	11	24

1-m NIO Tows

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae
7 May	1757	6	3	571	1096	352

Table 8. Summary of taxonomic categories of fish eggs, larvae, young and adults found in Bongo and 1-m NIO net samples collected on Lower Cook Inlet, *Discoverer* cruise, Leg V, 05-09 May 1976.

A total of 25 samples were collected. The fish are distributed into 15 families, 16 genera and 11 species. The eggs are distributed into 4 size categories.

Family Agonidae

24 larvae genus? species?

Family Ammodytidae

1373 larvae sandlance[1] *Ammodytes hexapterus* Pallas

Family Bathylagidae

4 larvae smoothtongue *Bathylagus stilbius* (Gilbert)

Family Bathymasteridae

18 larvae genus? species?

Family Cottidae

3 larvae cabezon *Scorpaenichthys marmoratus* (Ayres)
120 larvae genus? species?

Family Cyclopteridae

12 larvae genus? species?

Family Gadidae

20 larvae Alaska pollock *Theragra chalcogramma* (Pallas)
77 larvae genus? species?

Family Liparidae

1 larva snailfish *Liparis* sp.

Family Myctophidae

23 larvae northern lampfish *Stenobrachius leucopsarus* (Eigenmann and Eigenmann)
6 larvae genus? species?

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[1] The common name is presented for the first time for each species; thereafter only the scientific name is recorded.

Table 8. (continued)

Family Osmeridae

11 larvae capelin *Mallotus villosus* (Müller)
4 larvae longfin smelt *Spirinchus thaleichthys* (Ayres)
11 larvae genus? species?

Family Pholidae

4 larvae penpoint gunnel *Apodichthys flavidus* Girard
4 larvae gunnel *Pholis* sp.
96 larvae genus? species?

Family Pleuronectidae

11 larvae butter sole *Isopsetta isolepis* (Lockington)
4 larvae rock sole *Lepidopsetta bilineata* (Ayres)?

Family Scorpaenidae

16 larvae rockfish *Sebastes* sp.
3 larvae genus? species?

Family Stichaeidae

10 larvae cockscomb *Anoplarchus* sp.
1137 larvae prickleback *Lumpenus* spp.
2 larvae rock prickleback *Xiphister mucosus* (Girard)

Family Tetragonuridae

1 larva genus? species?

181 larvae unidentified

6691 eggs categorized (see Table 9. List of possible fish for egg size categories):

12 eggs < 1 mm (0.74-0.88 mm)
6510 eggs ∿ 1 mm (0.90-1.28 mm)
78 eggs ∿ 2 mm (1.30-2.54 mm)
89 eggs ∿ 3 mm (2.56-3.90 mm)
2 eggs unidentified, damaged

Table 9. List of Possible Fish for Egg Size Categories

< 1 mm category (0.74-0.88 mm)

Limanda aspera
Limanda proboscidea

∿ 1 mm category (0.90-1.28 mm)

Gadus macrocephalus
Isopsetta isolepis
Parophrys vetulus
Platichthys stellatus
Psettichthys melanostictus

∿ 2 mm category (1.30-2.54 mm)

Bathylagus stilbius
Eopsetta jordani
Glyptocephalus zachirus
Lyopsetta exilis
Microstomus pacificus
Pleuronectes quadrituberculatus
Pleuronichthys coenosus
Pleuronichthys decurrens
Theragra chalcogramma

∿ 3 mm category (2.56-3.90 mm)

Hippoglossoides elassodon
Hippoglossoides robustus
Hippoglossus stenolepis

Table 10. Identification of Fish Eggs and Larvae by Station
Lower Cook Inlet Bongo Tows, *Discoverer*, Leg V, 05-09 May 1976

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
6 May	1325	1	1	333	42[a]	34[a]	2 eggs ∿ 2 mm (1.60 mm)[b]
							38 eggs ∿ 3 mm (2.90-3.20 mm)
							2 eggs damaged unidentified
							4 larvae 32, 42 mm *Mallotus villosus*
							2 larvae 9.7 mm *Sebastes* sp.
							8 larvae 4.4 mm *Stenobrachius leucopsarus*
							8 larvae 3.6-5.2 mm *Theragra chalcogramma*
							6 larvae 5.5 mm Myctophidae
							2 larvae 10 mm unidentified (elongate)
							4 larvae unidentified due to extensive damage

[a] All specimens are classified into four main categories: eggs include all stages of eggs prior to hatching; larvae include newly hatched and all stages prior to metamorphosis; young include fish after metamorphosis to acquisition of adult fin rays and adult body configuration; adults include fish that are sexually mature. Approximately ½ of sample was sorted for fish eggs and larvae; 21 eggs and 17 larvae were identified.

[b] Eggs are measured to the nearest hundredths of a millimeter in diameter. Fish or larvae, if less than 10 mm in length, are measured to the nearest tenth of a millimeter under a microscope using a calibrated micrometer eye piece. If 10 mm or greater in length, the fish or larvae are measured by a metric ruler to the nearest millimeter. When there are more than three eggs, fish or larvae, the largest and the smallest are measured. Larvae are measured by standard length.

Table 10. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
6 May	1325	1	1	505	32	40	3 eggs ∿ 1 mm (1.28 mm)
							29 eggs ∿ 3 mm (2.97–3.52 mm) (23 whole eggs, 2 yolksac embryos without membrane)
							4 larvae 7.2–54 mm *Mallotus villosus*
							9 larvae 4.0–5.2 mm *Stenobrachius leucopsarus*
							4 larvae 3.6–5.2 mm *Theragra chalcogramma*
							8 larvae 6.0–7.0 mm Bathymasteridae
							8 larvae 3.1–11 mm Gadidae
							1 larva 8.0 mm Scorpaenidae
							6 larvae 5.0 mm damaged, unidentified
6 May	1552	2	1	333	0	26	4 larvae 7.7–18 mm *Sebastes* sp.
							2 larvae 6.0 mm *Stenobrachius leucopsarus*
							2 larvae 3.8 mm *Theragra chalcogramma*
							2 larvae 5.6, 18 mm Bathymasteridae
							1 larva 5.6 mm Cottidae
							5 larvae 3.8–5.0 mm Gadidae
							9 larvae 7.7–8.1 mm Osmeridae
							1 larva 6.0 mm Scorpaenidae

Table 10. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
6 May	1552	2	1	505	3	13	1 egg < 1 mm (0.93 mm) 2 eggs ∿ 2 mm (1.68 mm) 5 larvae 7.0-9.0 mm *Ammodytes hexapterus* 2 larvae 4.8 mm *Sebastes* sp. 2 larvae 3.8, 4.0 mm *Theragra chalcogramma* 3 larvae 4.0 mm Gadidae 1 larva 5.6 mm Scorpaenidae
6 May	2117	3	1	333	41	12	36 eggs ∿ 1 mm (0.97-1.10 mm) 5 eggs ∿ 2 mm (1.33-1.50 mm) 9 larvae 4.8-6.0 mm *Ammodytes hexapterus* 2 larvae 3.6, 4.0 mm Cottidae 1 larva 4.8 mm damaged, unidentified
6 May	2117	3	1	505	37	18	33 eggs ∿ 1 mm (0.93-1.10 mm) 4 eggs ∿ 2 mm (1.30-1.40 mm) 16 larvae 4.4-7.7 mm *Ammodytes hexapterus* 2 larva 4.0 mm Cottidae
7 May	0259	4	1	333	0	3	1 larva 4.4 mm Cottidae 1 larva ∿ 5 mm damaged Gadidae 1 larva > 6 mm extensively damaged, elongate, unidentified

Table 10. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
7 May	0259	4	1	505	0	2	2 larvae 5.2 mm *Ammodytes hexapterus*
7 May	1030	5	2	333	40	119	36 eggs ∿ 1 mm (0.96-1.20 mm)
							4 eggs ∿ 2 mm (1.76-1.91 mm)
							63 larvae 5.0-10 mm *Ammodytes hexapterus*
							1 larva 9.0 mm *Liparis* sp.
							24 larvae 12-23 mm *Lumpenus* spp.
							1 larva 40 mm *Mallotus villosus*
							1 larva 10 mm *Scorpaenichthys marmoratus*
							3 larvae 9.0 mm Agonidae
							2 larvae 9.0, 10 mm Cottidae
							1 larva 10 mm Cottidae
							20 larvae 10-15 mm Pholidae
							1 larva 10 mm Tetragonuridae
							2 larvae 5.0 mm unidentified
7 May	1030	5	2	505	136[c]	852[c]	124 eggs ∿ 1 mm (0.96-1.20 mm)
							12 eggs ∿ 2 mm (1.52-1.92 mm)
							486 larvae 6.0-10 mm *Ammodytes hexapterus*
							134 larvae 12-24 mm *Lumpenus* spp.
							2 larvae 43 mm *Mallotus villosus*

[c] Approximately ½ of sample was sorted for fish eggs and larvae; 68 eggs and 436 larvae were identified.

Table 10. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
7 May	1030	5	2	505	136	852	2 larvae 10 mm *Scorpaenichthys marmoratus*
							4 larvae 9.3 mm *Sebastes* sp.
							4 larvae ∿ 29 mm *Spirinchus thaleichthys*
							4 larvae 4.8 mm *Theragra chalcogramma*
							16 larvae 8.1–10 mm Agonidae
							8 larvae Bathymasteridae
							10 larvae 9.0-12 mm Cottidae
							18 larvae 3.7–5.1 mm Cottidae
							18 larvae 4.0-8.5 mm Cottidae
							38 larvae 4.8-6.2 mm Cottidae
							8 larvae 8.0-12 mm Cottidae
							12 larvae 3.2-4.0 mm Gadidae
							76 larvae 9.0-11 mm Pholidae
							4 larvae 9.0, 10 mm unidentified
							8 larvae unidentified
8 May	0020	5a	1	333	48	182	45 eggs ∿ 1 mm (0.96-1.03 mm)
							3 eggs ∿ 2 mm (1.28-1.36)
							159 larvae 7.0-10 mm *Ammodytes hexapterus*
							12 larvae 12-24 mm *Lumpenus* spp.

Table 10. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
8 May	0020	5a	1	333	48	182	3 larvae 3.7, 3.8, 4.8 mm *Isopsetta isolepis*
							1 larva 8.2 mm Agonidae
							5 larvae 4.7-9.6 mm Cottidae
							1 larva 7.9 mm Cottidae
							1 larva unidentified due to extensive damage (elongate)
8 May	0020	5a	1	505	50	162	48 eggs ∿ 1 mm (0.91-1.10 mm)
							2 eggs ∿ 2 mm (1.30, 1.69 mm)
							143 larvae 5.7-8.5 mm *Ammodytes hexapterus*
							6 larvae 4.0-5.9 mm *Isopsetta isolepis*
							6 larvae 12-21 mm *Lumpenus* spp.
							6 larvae 5.0-8.4 mm Cottidae
							1 larva 7.4 mm Cottidae
7 May	1312	6	1	333	992[d]	290[d]	992 eggs ∿ 1 mm (0.96-1.10 mm)
							84 larvae 4.0-6.3 mm *Ammodytes hexapterus*
							184 larvae 9.0-14 mm *Lumpenus* spp.

[d] Approximately ½ of sample was sorted for fish eggs and larvae; 496 eggs and 145 larvae were identified.

Table 10. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
7 May	1312	6	1	333	992	290	2 larvae 4.4 mm *Sebastes* sp.
							2 larvae 20 mm *Xiphister mucosus*
							18 larvae unidentified due to extensive damage (elongate)
7 May	1312	6	1	505	1616[e]	326[e]	1616 eggs ∿ 1 mm (0.98-1.10 mm)
							96 larvae 4.3-7.7 mm *Ammodytes hexapterus*
							184 larvae 9.0-18 mm *Lumpenus* spp.
							4 larvae 8.1-9.5 mm *Pholis* sp.
							2 larvae 30 mm Osmeridae
							40 larvae unidentified due to extensive damage (elongate)
7 May	1709	6	2	333	1296[f]	352[f]	1280 eggs ∿ 1 mm (0.96-1.08 mm)
							16 eggs ∿ 2 mm (1.40-1.83 mm)
							92 larvae 5.1-8.3 mm *Ammodytes hexapterus*
							220 larvae 9.7-17 mm *Lumpenus* spp.
							4 larvae 4.2 mm Cottidae

[e] Approximately ½ of sample sorted for fish eggs and larvae; 808 eggs and 163 larvae were identified

[f] Approximately 1/8 of sample sorted for fish eggs and 1/4 of sample sorted for larvae; 162 eggs and 88 larvae were identified.

Table 10. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
7 May	1709	6	2	333	1296	352	12 larvae 3.3–3.7 mm Cyclopteridae 24 larvae unidentified due to extensive damage (elongate)
7 May	1709	6	2	505	364[g]	236[g]	362 eggs ∿ 1 mm (0.96–1.10 mm) 2 eggs ∿ 2 mm (1.95 mm) 44 larvae 4.4–7.3 mm *Ammodytes hexapterus* 4 larvae 8.2–9.5 mm *Apodichthys flavidus* 154 larvae 9.6–21 mm *Lumpenus* spp. 34 larvae unidentified due to extensive damage (elongate)
8 May	0402	7	1	333	54[h]	4[h]	54 eggs ∿ 1 mm (1.00–1.20 mm) 2 larvae 8.4 mm *Ammodytes hexapterus* 2 larvae 10 mm *Lumpenus* sp.
8 May	0402	7	1	505	60[i]	8[i]	56 eggs ∿ 1 mm (1.06–1.24 mm) 4 eggs ∿ 2 mm (1.36 mm) 8 larvae unidentified due to extensive damage (1 elongate and 1 non-elongate)

[g] Approximately ½ of sample was sorted for fish eggs and larvae; 182 eggs and 118 larvae were identified.

[h] Approximately ½ of sample was sorted for fish eggs and larvae; 27 eggs and 2 larvae were identified.

[i] Approximately ¼ of sample was sorted for fish eggs and larvae; 15 eggs and 2 larvae were identified.

Table 10. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
8 May	0734	8	1	333	360[j]	17	358 eggs ∿ 1 mm (0.92-1.30 mm)
							2 eggs ∿ 2 mm (1.36 mm)
							17 larvae 6.9-9.0 mm *Ammodytes hexapterus*
8 May	0734	8	1	505	353	20	346 eggs ∿ 1 mm (0.94-1.24 mm)
							7 eggs ∿ 2 mm (1.34-1.64 mm)
							18 larvae 3.4-4.5 mm *Ammodytes hexapterus*
							1 larva 9.7 mm *Lumpenus* sp.
							1 larva 3.7 mm *Lepidopsetta bilineata* (?)
8 May	1315	9	1	333	25	22	13 eggs ∿ 1 mm (0.94-1.16 mm)
							1 egg ∿ 2mm (1.40 mm)
							11 eggs ∿ 3 mm (2.80-3.84 mm)
							4 larvae 5.8-6.0 mm *Anoplarchus* sp.
							1 larva 5.3 mm *Isopsetta isolepis* (?)
							2 larvae 3.3, 3.9 mm *Lepidopsetta bilineata*
							2 larvae 5.1, 6.3 mm Cottidae
							1 larva 4.4 mm Gadidae
							1 larva 5.3 mm unidentified (intense body pigment)

[j] Approximately 1/2 of sample was sorted for fish eggs; 180 eggs were identified.

Table 10. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (µm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
8 May	1315	9	1	333	25	22	1 larva 5.2 mm unidentified (elongate)
							10 larvae unidentified due to extensive damage (all elongate)
8 May	1315	9	1	505	24	18	12 eggs ∿ 1 mm (0.94-1.20 mm)
							1 egg ∿ 2 mm (1.60 mm)
							11 eggs ∿ 3 mm (2.97-3.56)
							3 larvae 4.6, 5.5, 9.5 mm *Ammodytes hexapterus*
							6 larvae 5.0-6.2 mm *Anoplarchus* sp.
							1 larva 3.5 mm *Isopsetta isolepis*
							1 larva 11 mm *Lumpenus* sp.
							2 larvae 4.0 mm, one damaged, Gadidae
							5 larvae unidentified due to extensive damage (all elongate)
9 May	0145	11	1	333	11	44	11 eggs < 1 mm (0.67-0.83 mm)
							3 larvae 7.9, 11, 21 mm *Bathylagus stilbius*
							1 larva 29 mm *Lumpenus* sp.
							4 larvae 3.4-4.1 mm *Stenobrachius leucopsarus*
							32 larvae 3.4-4.4 mm Gadidae

Table 10. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
9 May	0145	11	1	333	11	44	1 larva 8.8 mm unidentified (elongate) 2 larvae 3.7, 6.0 mm unidentified (non-elongate) 1 larva 12 mm unidentified (w/large ellipsoidal eyes extending to the articulation of the jaws)
9 May	0145	11	1	505	11	24	11 eggs ∿ 2 mm (1.36-2.56 mm) 1 larva 7.4 mm *Bathylagus stilbius* 1 larva 3.3 mm *Lepidopsetta bilineata* (?) 2 larvae 5.5, 6.1 mm *Sebastes* sp. 13 larvae 3.5-4.6 mm Gadidae 7 larvae unidentified due to extensive damage (all elongate)

Table 11. Identification of Fish Eggs and Larvae by Station
Lower Cook Inlet 1-m NIO Tows, *Discoverer*, Leg V, 05-09 May 1976

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
7 May	1757	6	3	571	1096[k]	352[l]	1096 eggs ∿ 1 mm (0.96-1.10 mm)
							134 larvae 5.6-9.4 mm *Ammodytes hexapterus*
							214 larvae 12-22 mm *Lumpenus* spp.
							4 larvae 7.1-8.3 mm Agonidae

[k] Approximately 1/8 of sample was sorted for fish eggs; 137 eggs were identified.

[l] Approximately 1/2 of sample was sorted for fish larvae; 176 larvae were identified.

Table 12. Identification of Crab and Shrimp Larvae by Station

Lower Cook Inlet Bongo and 1-m NIO Net Tows, *Discoverer*, Leg V, 05-09 May 1976

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
6 May	1325	1	1	333	zoea	140	unidentified anomurans
					I	3	*Cancer productus*
					I	1	*Chionoecetes bairdi*
					zoea	122	unidentified brachyurans
					I	9	*Pandalus borealis*
					II	8	*P. borealis*
					I	39	*P. montagui tridens*
					I	4	*P. stenolepis*
					zoea	247	unidentified hippolytids
6 May	1325	1	1	505	zoea	122	unidentified anomurans
					I	4	*Cancer productus*
					megalopa	2	*Chionoecetes* sp.
					zoea	88	unidentified brachyurans
					I	18	*Pandalus borealis*
					II	10	*P. borealis*
					I	85	*P. montagui tridens*
					I	3	*P. stenolepis*
					zoea	295	unidentified hippolytids
6 May	1552	2	1[a]	333	zoea	64	unidentified anomurans
					megalopa	4	*Chionoecetes* sp.
					zoea	180	unidentified brachyurans
					zoea	82	unidentified hippolytids

[a] Approximately 1/4 of the sample was sorted for crab larvae; totals are given for entire sample.

Table 12. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
6 May	1552	2	1	505	zoea	50	unidentified anomurans
					I	1	*Cancer productus*
					megalopa	5	*Chionoecetes* sp.
					zoea	126	unidentified brachyurans
					I	1	*Pandalus borealis*
					II	1	*P. borealis*
					I	1	*P. montagui tridens*
					I	2	*P. stenolepis*
6 May	2117	3	1	333	I	1	*Paralithodes camtschatica*
					megalopa	3	*Chionoecetes* sp.
					zoea	16	unidentified brachyurans
					I	2	*Pandalus goniurus*
					zoea	51	unidentified hippolytids
					adult	12	*Crangon franciscorum angustimana* (1 gravid female)
6 May	2117	3	1	505	I	1	*Paralithodes camtschatica*
					I	1	*Chionoecetes bairdi*
					zoea	14	unidentified brachyurans
					zoea	50	unidentified hippolytids
					adult	1	*Crangon alaskensis*
					adult	13	*C. franciscorum angustimana* (4 gravid females)
7 May	0259	4	1	333	zoea	1	unidentified anomuran
					I	1	*Chionoecetes bairdi*
					I	1	*Pandalus goniurus*
					zoea	4	unidentified hippolytids

Table 12. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
7 May	0259	4	1	505	zoea	2	unidentified hippolytids
7 May	1030	5	2[b]	333	I	880	*Paralithodes camtschatica*
					II	384	*P. camtschatica*
					zoea	944	unidentified anomurans
					zoea	208	unidentified brachyurans
					I	440	*Pandalus borealis*
					II	104	*P. borealis*
					I	1416	*P. goniurus*
					II	152	*P. goniurus*
					I	8	*P. hypsinotus*
					zoea	696	unidentified hippolytids
7 May	1030	5	2[c]	505	I	1792	*Paralithodes camtschatica*
					II	544	*P. camtschatica*
					zoea	1696	unidentified anomurans
					megalopa	32	*Chionoecetes* sp.
					zoea	608	unidentified brachyurans
					I	752	*Pandalus borealis*
					II	192	*P. borealis*
					I	2984	*P. goniurus*
					II	640	*P. goniurus*
					zoea	1168	unidentified hippolytids

[b] Approximately 1/16 of the sample was sorted for crab larvae and approximately 1/8 of the sample was sorted for shrimp larvae; totals given are for entire sample.

[c] Approximately 1/32 of the sample was sorted for crab larvae and approximately 1/8 of the sample was sorted for shrimp larvae; totals given are for entire sample.

Table 12. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (µm)	Stage	Total	Identification of Larvae
8 May	0020	5a	1[d]	333	I	192	*Paralithodes camtschatica*
					II	140	*P. camtschatica*
					zoea	628	unidentified anomurans
					I	444	*Chionoecetes bairdi*
					zoea	316	unidentified brachyurans
					I	80	*Pandalus borealis*
					II	44	*P. borealis*
					I	480	*P. goniurus*
					II	76	*P. goniurus*
					I	4	*P. hypsinotus*
					I	4	*P. montagui tridens*
8 May	0020	5a	1[d]	505	I	336	*Paralithodes camtschatica*
					II	160	*P. camtschatica*
					zoea	312	unidentified anomurans
					I	284	*Chionoecetes bairdi*
					zoea	56	unidentified brachyurans
					I	120	*Pandalus borealis*
					II	28	*P. borealis*
					I	592	*P. goniurus*
					II	84	*P. goniurus*
7 May	1312	6	1[e]	333	I	46	*Paralithodes camtschatica*
					II	24	*P. camtschatica*
					zoea	50	unidentified anomurans

[d] Approximately 1/4 of the sample was sorted for crab larvae and shrimp larvae; totals given are for entire sample.

[e] Approximately 1/2 of the sample was sorted for crab and shrimp larvae; totals given are for entire sample.

Table 12. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
7 May	1312	6	1[e]	333	zoea	252	unidentified brachyurans
					II	2	*Pandalopsis dispar*
					I	142	*Pandalus borealis*
					II	8	*P. borealis*
					I	412	*P. goniurus*
7 May	1312	6	1[f]	505	I	76	*Paralithodes camtschatica*
					II	44	*P. camtschatica*
					zoea	64	unidentified anomurans
					zoea	264	unidentified brachyurans
					I	140	*Pandalus borealis*
					II	2	*P. borealis*
					I	562	*P. goniurus*
					I	2	*P. hypsinotus*
7 May	1709	6	2[g]	333	I	92	*Paralithodes camtschatica*
					zoea	110	unidentified anomurans
					I	4	*Chionoecetes bairdi*
					zoea	430	unidentified brachyurans
					I	156	*Pandalus borealis*
					I	256	*P. goniurus*
					II	4	*P. goniurus*
					I	2	*P. hypsinotus*
					zoea	178	unidentified hippolytids

[f] Approximately 1/4 of the sample was sorted for crab larvae and approximately 1/2 of the sample was sorted for shrimp larvae; totals given are for the entire sample.

[g] Approximately 1/2 of the sample was sorted for crab and shrimp larvae; totals given are for the entire sample.

Table 12. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
7 May	1709	6	2[g]	505	I	42	*Paralithodes camtschatica*
					II	2	*P. camtschatica*
					zoea	24	unidentified anomurans
					megalopa	2	*Chionoecetes* sp.
					zoea	190	unidentified brachyurans
					I	70	*Pandalus borealis*
					I	148	*P. goniurus*
					I	2	*P. hypsinotus*
					I	2	damaged *Pandalus* sp.
					zoea	78	unidentified hippolytids
7 May	1759	6	3[h]	571	I	100	*Paralithodes camtschatica*
					II	8	*P. camtschatica*
					zoea	24	unidentified anomurans
					I	4	*Chionoecetes bairdi*
					zoea	400	unidentified brachyurans
					II	4	*Pandalopsis dispar*
					I	108	*Pandalus borealis*
					I	352	*P. goniurus*
						168	unidentified hippolytid larvae
8 May	0402	7	1[i]	333	I	226	*Paralithodes camtschatica*
					I	52	damaged *Paralithodes* sp.
					zoea	14	unidentified anomurans
					megalopa	2	*Chionoecetes* sp.

[h] Approximately 1/4 of the sample was sorted for crab and shrimp larvae; totals given are for entire sample.

[i] Approximately 1/4 of the sample was sorted for crab larvae and approximately 1/2 of the sample was sorted for shrimp larvae; totals given are for the entire sample.

Table 12. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
8 May	0402	7	1	333	zoea	10	unidentified brachyurans
					I	8	*Pandalus borealis*
					I	60	*P. goniurus*
					zoea	120	unidentified hippolytids
					adult	2	*Crangon dalli*
8 May	0402	7	1[j]	505	I	272	*Paralithodes camtschatica*
					II	4	*P. camtschatica*
					I	28	damaged *Paralithodes* sp.
					zoea	26	unidentified anomurans
					zoea	34	unidentified brachyurans
					I	12	*Pandalus borealis*
					I	42	*P. goniurus*
					zoea	116	unidentified hippolytids
					adult	2	*Crangon alaskensis*
					adult	2	*Crangon dalli*
8 May	0734	8	1	333	I	136	*Paralithodes camtschatica*
					II	2	*P. camtschatica*
					I	3	damaged *Paralithodes* sp.
					zoea	14	unidentified anomurans
					zoea	2	unidentified brachyurans
					I	316	*Pandalus goniurus*
					II	6	*P. goniurus*
					zoea	94	unidentified hippolytids
					adult	3	*Crangon alaskensis*
					adult	1	*Pandalus borealis*
					adult	2	*P. goniurus*

[j] Approximately 1/2 of the sample was sorted for crab and shrimp larvae; totals given are for the entire sample.

Table 12. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
8 May	0734	8	1	505	I	135	*Paralithodes camtschatica*
					II	3	*P. camtschatica*
					I	3	damaged *Paralithodes* sp.
					zoea	22	unidentified anomurans
					megalopa	1	*Chionoecetes* sp.
					zoea	5	unidentified brachyurans
					I	340	*Pandalus goniurus*
					II	5	*P. goniurus*
					zoea	94	unidentified hippolytids
					adult	1	*Crangon alaskensis*
					adult	1	*Pandalus borealis*
					adult	2	*P. goniurus*
8 May	1315	9	1	333	I	14	*Paralithodes camtschatica*
					zoea	34	unidentified anomurans
					zoea	75	unidentified brachyurans
					I	30	*Pandalus borealis*
					II	22	*P. borealis*
					I	15	*P. goniurus*
					I	197	*P. montagui tridens*
					I	22	*P. stenolepis*
					zoea	227	unidentified hippolytids
					adult	1	*Pandalus goniurus*
8 May	1315	9	1	505	I	19	*Paralithodes camtschatica*
					zoea	38	unidentified anomurans
					megalopa	4	*Chionoecetes* sp.
					zoea	35	unidentified brachyurans
					I	28	*Pandalus borealis*

Table 12. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (m)	Stage	Total	Identification of Larvae
8 May	1315	9	1	505	II	9	*P. borealis*
					I	17	*P. goniurus*
					I	233	*P. montagui tridens*
					I	10	*P. stenolepis*
					II	2	*P. stenolepis*
					II	2	damaged *Pandalus* sp.
					zoea	132	unidentified hippolytids
9 May	0145	11	1	333	megalopa	7	*Chionoecetes* sp.
					II	2	*Pandalopsis dispar*
					zoea	6	unidentified hippolytids
9 May	0145	11	1	505	I	4	*Chionoecetes bairdi*
					megalopa	7	*Chionoecetes* sp.
					zoea	7	unidentified brachyurans
					I	2	*Pandalopsis dispar*
					IV	1	*P. dispar*
					I	2	*Pandalus borealis*
					I	3	*P. montagui tridens*
					zoea	10	unidentified hippolytids

Table 13. Number of fish eggs and larvae at each station

Lower Cook Inlet Bongo Tows, *Discoverer*, Leg VII, 22-30 May 1976

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae
24 May	0732	1	1	333	68	122
24 May	0732	1	1	505	46	97
25 May	1150	2	1	333	11	59
25 May	1150	2	1	505	6	58
25 May	1607	3	1	333	85	7
25 May	1607	3	1	505	86	8
25 May	2217	4	1	333	3	4
25 May	2217	4	1	505	1	2
26 May	0541	5a	2	333	28	70
26 May	0541	5a	2	505	85	167
26 May	0835	6	1	333	648	27
26 May	0835	6	1	505	684	29
26 May	1928	6	3	333	380	36
26 May	1928	6	3	505	242	29
27 May	0056	6	4	333	169	84
27 May	0056	6	4	505	181	79
27 May	0708	6	7	333	17	70
27 May	0708	6	7	505	37	76
27 May	1300	7	1	333	692	67
27 May	1300	7	1	505	656	52
27 May	1701	8	1	333	189	27
27 May	1701	8	1	505	256	22
30 May	1813	10	1	333	22	121
30 May	1813	10	1	505	18	57
30 May	0253	11	1	333	1	55
30 May	0253	11	1	505	0	40
30 May	0813	11	2	333	2	31
30 May	0813	11	2	505	1	51
28 May	1831	13	1	333	13	940
28 May	1831	13	1	505	8	876
28 May	2248	13	2	333	99	2992
28 May	2248	13	2	505	100	2384

Table 13. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae
29 May	1029	13	3	333	1	200
29 May	1029	13	3	505	0	700
28 May	0536	14	1	333	74	11
28 May	0536	14	1	505	74	13

1-m NIO Tows

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae
27 May	0120	6	5	571	248	162

Table 14. Summary of taxonomic categories of fish eggs, larvae, young, and adults found in Bongo net samples and 1-m NIO net sample collected in Lower Cook Inlet and Prince William Sound, *Discoverer* cruise, Leg VII, 22-30 May 1976.

A total of 38 samples were collected. With the exception of stations 6 (haul 5), 11, 13 and 14, results were previously reported. All samples were sorted for fish larvae and identified or sized for fish eggs and summarized below. The fish are distributed into families, genera, and species. The eggs are distributed into 4 size categories.

Family Agonidae

17 larvae genus? species?

Family Ammodytidae

376 larvae Pacific sandlance[1] *Ammodytes hexapterus* Pallas
1 adult *Ammodytes hexapterus*

Family Bathylagidae

4434 larvae smoothtongue *Bathylagus stilbius* (Gilbert)
32 young *Bathylagus stilbius*

Family Bathymasteridae

4 larvae genus? species?

Family Clupeidae

138 larvae Pacific herring *Clupea harengus pallasi* Valenciennes

Family Cottidae

1 larva northern sculpin *Icelinus borealis* Gilbert (?)
3 larvae sculpin *Myoxocephalus* sp. (2 uncertain)
187 larvae genus? species?
2 young genus? species?

Family Cyclopteridae

58 larvae genus? species?
68 young genus? species?

Family Gadidae

390 larvae cod *Gadus* sp.
3 larvae Alaska pollock *Theragra chalcogramma* (Pallas)
317 larvae genus? species?

[1] The common name is presented for the first time for each species; thereafter only the scientific name is recorded.

Table 14. (continued)

Family Hexagrammidae

2 young greenling *Hexagrammos* sp.
19 young genus? species?

Family Myctophidae

1 young bigeye lanternfish *Protomyctophum thompsoni* (Chapman)
104 larvae smallfin lanternfish *Stenobrachius leucopsarus* (Eigenmann and Eigenmann)
3 young *Stenobrachius leucopsarus*

Family Osmeridae

6 larvae capelin *Mallotus villosus* (Müller)
2 larvae genus? species?

Family Pholidae

3 larvae penpoint gunnel *Apodichthys flavidus* Girard
21 larvae genus? species?

Family Pleuronectidae

64 larvae sole *Hippoglossoides* sp.
33 larvae butter sole *Isopsetta isolepis* (Lockington)
12 larvae rock sole *Lepidopsetta bilineata* (Ayres) (8 uncertain)
3 larvae slender sole *Lyopsetta exilis* (Jordan and Gilbert)

Family Ptilichthyidae

1 larva quillfish *Ptilichthys goodei* Bean

Family Scorpaenidae

2328 larvae rockfish *Sebastes* spp.

Family Stichaeidae

30 larvae cockscomb *Anoplarchus* sp.
157 larvae prickleback *Lumpenus* spp.
1 young *Lumpenus* sp.

1040 larvae unidentified, many badly damaged.

5243 eggs categorized (see Table 9. List of possible fish for egg size categories):

146 eggs $<$ 1 mm (0.74-0.88 mm)
4539 eggs $\sim$ 1 mm (0.90-1.28 mm)
302 eggs $\sim$ 2 mm (1.30-2.54 mm)
256 eggs $\sim$ 3 mm (2.56-3.90 mm)

Table 15. Identification of Fish Eggs and Larvae by Station

Lower Cook Inlet Bongo Tows, *Discoverer*, Leg VII, 22-30 May 1976

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
24 May	0732	1	1	333	76[a]	138[a]	1 egg ∿ 2 mm (2.16 mm)[b]
							75 eggs ∿ 3 mm (2.74-3.60 mm)
							7 larvae 4.7-6.5 mm *Ammodytes hexapterus*
							2 larvae 8.1, 8.7 mm *Anoplarchus* sp.
							40 larvae 4.3-6.9 *Hippoglossoides* sp.
							1 larva 3.3 mm *Icelinus borealis* (?)
							6 larvae 6.8-8.7 mm *Lepidopsetta bilineata* (?)
							3 larvae 3.6, 4.2, 5.2 mm *Lyopsetta exilis*
							2 larvae 8.9, 9.9 mm *Myoxocephalus* sp.
							1 larva 36 mm *Ptilichthys goodei*
							2 larva 3.8, 5.4 mm *Stenobrachius leucopsarus*

[a] All specimens are classified into four main categories: eggs include all stages of eggs prior to hatching; larvae include newly hatched and all stages prior to metamorphosis; young include fish after metamorphosis to acquisition of adult fin rays and adult body configuration; adults include fish that are sexually mature.

[b] Eggs are measured to the nearest hundredths of a millimeter in diameter. Fish or larvae, if less than 10 mm in length, are measured to the nearest tenth of a millimeter under a microscope using a calibrated micrometer eye piece. If 10 mm or greater in length, the fish or larvae are measured by a metric ruler to the nearest millimeter. When there are more than three eggs, fish or larvae, the largest and the smallest are measured. Larvae are measured by standard length.

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
24 May	0732	1	1	333	76	138	1 larva 7.7 mm Cottidae
							2 larvae 4.4, 4.2 mm Gadidae
							65 larvae 3.6-6.7 mm unidentified (elongate)
							1 larva 5.8 mm unidentified (non-elongate)
							5 larvae unidentified due to extensive damage (1 elongate and 1 non-elongate)
24 May	0732	1	1	505	47	107	1 egg ∿ 2 mm (2.08 mm)
							46 eggs ∿ 3 mm (2.74-3.60 mm)
							4 larvae 8.8-14 mm *Ammodytes hexapterus*
							2 larvae 8.0, 8.5 mm *Anoplarchus* sp.
							3 larvae 5.3, 7.4, 9.0 mm *Gadus* sp.
							19 larvae 4.0-5.6 mm *Hippoglossoides* sp.
							2 larvae 3.2, 8.0 mm *Lepidopsetta bilineata* (?)
							1 larva 4.1 mm *Myoxocephalus* sp. (?)
							2 larva 4.3 mm *Stenobrachius leucopsarus*
							1 larva 6.4 mm Cottidae ("Cottid 2" from Blackburn 1973)
							3 larvae 3.8, 3.9, 5.0 mm Cottidae

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
24 May	0732	1	1	505	47	107	1 larva 4.8 mm Cyclopteridae
							1 larva 5.5 mm Gadidae
							62 larvae 5.5-6.4 unidentified (elongate)
							1 larva 8.9 mm unidentified (non-elongate)
							5 larvae unidentified due to extensive damage
25 May	1150	2	1	333	11	59	7 eggs $\sim$ 1 mm (0.94-1.02 mm)
							3 eggs $\sim$ 2 mm (1.34, 1.34, 1.40 mm)
							1 egg $\sim$ 3 mm (3.12 mm)
							16 larvae 7.4-13 mm *Ammodytes hexapterus*
							5 larvae 5.5-11 mm *Anoplarchus* sp.
							3 larvae 14, 17, 18 mm *Apodichthys flavidus*
							8 larvae 4.9-6.5 mm *Isopsetta isolepis*
							1 larva 6.5 mm *Theragra chalcogramma*
							1 larva 6.7 mm Bathymasteridae
							17 larvae 4.1-9.1 mm Cyclopteridae
							8 larvae unidentified due to extensive damage (elongate)

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
25 May	1150	2	1	505	6	58	6 eggs ∿ 1 mm (0.93-1.00 mm)
							17 larvae 6.8-13 mm *Ammodytes hexapterus*
							3 larvae 5.5, 9.3, 9.5 mm *Anoplarchus* sp.
							1 larva 4.4 mm *Hippoglossoides* sp.
							2 larvae 5.2, 5.5 mm *Isopsetta isolepis*
							2 larvae 5.6, 18 mm *Lumpenus* spp.
							1 larva 5.9 mm *Sebastes* sp.
							1 larva 9.4 mm *Theragra chalcogramma*
							3 larvae 6.6, 6.7, 7.2 mm Bathymasteridae
							2 larvae 6.9, 7.1 mm Cottidae
							2 larvae 5.8, 6.4 mm Cottidae
							1 larva 8.3 mm Cottidae
							14 larvae 4.8-7.8 mm Cyclopteridae
							1 larva 4.7 mm unidentified (very intensely pigmented larva)
							8 larvae unidentified due to extensive damage
25 May	1607	3	1	333	85	7	80 eggs ∿ 1 mm (0.96-1.24 mm)
							5 eggs ∿ 2 mm (1.30-1.50 mm)

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
25 May	1607	3	1	333	85	7	1 larva 13 mm *Ammodytes hexapterus*
							5 larvae 3.4-4.0 mm Cottidae
							1 larva unidentified due to extensive damage
25 May	1607	3	1	505	86	8	85 eggs ∿ 1 mm (0.90-1.20 mm)
							1 egg ∿ 2 mm (1.54 mm)
							1 larva 6.2 mm *Ammodytes hexapterus*
							1 larva 5.9 mm *Theragra chalcogramma*
							5 larvae 3.4-4.0 mm Cottidae
							1 larva 5.5 mm unidentified (non-elongate)
25 May	2217	4	1	333	3	4	2 eggs ∿ 1 mm (1.10-1.16 mm)
							1 egg ∿ 2 mm (1.70 mm)
							4 larvae 3.8-4.1 mm *Ammodytes hexapterus*
25 May	2217	4	1	505	1	2	1 egg ∿ 1 mm (1.10 mm)
							2 larvae 5.1, 6.3 mm *Ammodytes hexapterus*
26 May	0541	5a	2	333	28	70	26 eggs ∿ 1 mm (0.93-1.02 mm)
							1 egg ∿ 2 mm (1.36 mm)
							1 egg ∿ 3 mm (3.28 mm)

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (µm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
26 May	0541	5a	2	333	28	70	38 larvae 5.2-11 mm *Ammodytes hexapterus*
							5 larvae 4.7-5.9 mm *Anoplarchus* sp.
							2 larvae 4.4, 4.5 mm *Hippoglossoides* sp.
							5 larvae 2.8-5.5 mm *Isopsetta isolepis*
							2 larvae 15, 24 mm *Lumpenus* sp.
							1 larva 3.4 mm Cottidae
							3 larvae 3.7, 4.3, 5.4 mm Cyclopteridae
							6 larvae 10-17 mm Pholidae
							2 larvae 1.9, 2.3 mm unidentified (yolk sac absorption has already occurred)
							6 larvae unidentified due to extensive damage (5 elongate, 1 other)
26 May	0541	5a	2	505	85	167	1 egg < 1 mm (0.79 mm)
							80 eggs ∿ 1 mm (0.91-1.06 mm)
							3 eggs ∿ 2 mm (1.34-1.38 mm)
							1 egg ∿ 3 mm (2.56 mm)
							69 larvae 5.5-17 mm *Ammodytes hexapterus*
							8 larvae 4.7-7.0 mm *Anoplarchus* sp.
							2 larvae 5.3, 6.1 mm *Hippoglossoides* sp.

Table 15 (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
26 May	0541	5a	2	505	85	167	18 larvae 2.1-6.7 mm *Isopsetta isolepis*
							4 larvae 19-24 mm *Lumpenus* sp.
							1 larva 6.8 mm *Agonidae*
							1 larva 7.1 mm Cottidae
							3 larvae 3.0, 4.3, 4.7 mm Cyclopteridae
							8 larvae 9.6-18 mm Pholidae
							2 larvae 2.3, 3.4 mm unidentified
							51 larvae unidentified due to extensive damage (45 elongate, 6 others)
26 May	0835	6	1	333	648[c]	27	4 eggs < 1 mm (0.86 mm)
							644 eggs ∿ 1 mm (0.94-1.10 mm)
							1 adult 73 mm *Ammodytes hexapterus*
							2 larvae 29, 30 mm *Lumpenus* sp.
							1 larva 13 mm Agonidae
							23 larvae unidentified due to extensive damage (22 elongate, 1 non-elongate)

[c] Approximately one-fourth of the sample sorted for fish eggs; 162 eggs were identified.

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
26 May	0835	6	1	505	684[d]	29	4 eggs < 1 mm (0.86 mm)
							680 eggs ∿ 1 mm (0.90-1.06 mm)
							1 larva 7.3 mm *Anoplarchus* sp.
							8 larvae 15-29 mm *Lumpenus* spp.
							1 larva 18 mm Pholidae
							1 larva 19 mm unidentified (non-elongate)
							18 larvae unidentified due to extensive damage (elongate)
26 May	1928	6	3	333	380[e]	36	378 eggs ∿ 1 mm (0.90-1.06 mm)
							2 eggs ∿ 2 mm (1.34 mm)
							13 larvae 5.1-9.0 mm *Ammodytes hexapterus*
							13 larvae 20-28 mm *Lumpenus* sp.
							1 larva 35 mm *Mallotus villosus*
							1 larva 8.0 mm Cottidae
							2 larvae 4.2, 6.3 mm Cyclopteridae
							6 larvae unidentified due to extensive damage (elongate)

[d] Approximately one-fourth of the sample sorted for fish eggs; 171 eggs were identified.

[e] Approximately one-half of the sample sorted for fish eggs; 190 eggs were identified.

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
26 May	1928	6	3	505	242[f]	29	2 eggs < 1 mm (0.84 mm)
							238 eggs ∿ 1 mm (0.94-1.06 mm)
							2 eggs ∿ 2 mm (1.36 mm)
							13 larvae 5.9-13 mm *Ammodytes hexapterus*
							7 larvae 13-23 mm *Lumpenus* spp.
							2 larvae 5.5, 6.3 mm *Mallotus villosus*
							3 larvae 3.8, 4.8, 5.8 mm Cyclopteridae
							1 larva 6.7 mm Osmeridae
							2 larvae 2.9, 3.2 mm unidentified (non-elongate)
							1 larva unidentified due to extensive damage (elongate)
27 May	0056	6	4	333	169	84	168 eggs ∿ 1 mm (0.94-1.16 mm)
							1 egg ∿ 2 mm (1.40 mm)
							42 larvae 6.5-12 mm *Ammodytes hexapterus*
							1 larva 6.7 mm *Anoplarchus* sp.
							11 larvae 17-30 mm *Lumpenus* spp.
							3 larvae 5.3, 5.9, 6.4 mm *Mallotus villosus*

[f] Approximately one-half of the sample sorted for fish eggs; 121 eggs were identified.

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
27 May	0056	6	4	333	169	84	2 larvae 4.7, 5.5 mm Cottidae ("Cottid 6" from Blackburn 1973)
							3 larvae 3.4, 4.4, 5.2 mm Cyclopteridae
							7 larvae 2.5-3.3 mm unidentified (non-elongate)
							15 larvae unidentified due to extensive damage (elongate)
27 May	0056	6	4	505	181	79	180 eggs ∿ 1 mm (0.94-1.10 mm)
							1 egg ∿ 2 mm (1.40 mm)
							49 larvae 6.2-14 mm *Ammodytes hexapterus*
							11 larvae 16-23 mm *Lumpenus* spp.
							1 larva 6.1 mm Cottidae
							1 larva 3.9 mm Cyclopteridae
							1 larva 3.8 mm Gadidae
							6 larvae 2.0-3.3 mm unidentified (non-elongate)
							10 larvae unidentified due to extensive damage (elongate)
27 May	0708	6	7	333	17	70	16 eggs ∿ 1 mm (0.94-1.10 mm)
							1 egg ∿ 2 mm (1.40 mm)

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
27 May	0708	6	7	333	17	70	18 larvae 2.9-4.9 mm *Ammodytes hexapterus*
							37 larvae 15-29 mm *Lumpenus* spp.
							1 young 58 mm *Lumpenus* sp.
							2 larvae 6.5, 6.7 mm Cottidae ("Cottid 6" from Blackburn 1973)
							1 young 21 mm Cottidae
							1 larva 7.5 mm Cyclopteridae
							1 larva 19 mm Pholidae
							1 larva 5.6 mm unidentified (non-elongate)
							8 larvae unidentified due to extensive damage (elongate)
27 May	0708	6	7	505	37	76	36 eggs ∿ 1 mm (0.94-1.16 mm)
							1 egg ∿ 2 mm (1.40 mm)
							36 larvae 4.4-13 mm *Ammodytes hexapterus*
							2 larvae 3.2 mm *Lepidopsetta bilineata*
							28 larvae 16-29 mm *Lumpenus* spp.
							4 larvae 5.1-5.8 mm Cottidae ("Cottid 6" from Blackburn 1973)
							1 larva 2.8 mm unidentified (non-elongate)
							5 larvae unidentified due to extensive damage (elongate)

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
27 May	1300	7	1	333	692[g]	67	20 eggs < 1 mm (0.84-0.86 mm)
							668 eggs ∿ 1 mm (0.90-1.10 mm)
							4 eggs ∿ 2 mm (1.30 mm)
							16 larvae 5.9-10 mm *Ammodytes hexapterus*
							1 larva 8.0 mm *Anoplarchus* sp.
							2 young 33, 36 mm *Hexagrammos* sp.
							17 larvae 10-17 mm *Lumpenus* spp.
							8 larvae 6.4-8.4 mm Agonidae
							1 larva 4.7 mm Cyclopteridae
							22 larvae unidentified due to extensive damage (elongate)
27 May	1300	7	1	505	656[h]	52	36 eggs < 1 mm (0.82-0.86 mm)
							620 eggs ∿ 1 mm (0.90-1.10 mm)
							7 larvae 6.3-7.9 mm *Ammodytes hexapterus*
							7 larvae 10-20 mm *Lumpenus* spp.
							5 larvae 7.2-8.1 mm Agonidae
							2 larvae 4.0, 5.5 mm Cyclopteridae
							31 larvae unidentified due to extensive damage (elongate)

[g] Approximately one-fourth of the sample sorted for fish eggs; 173 eggs were identified.

[h] Approximately one-fourth of the sample sorted for fish eggs; 164 eggs were identified.

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (µm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
27 May	1701	8	1	333	190	33	38 eggs < 1 mm (0.80-0.88 mm)
							151 eggs ∿ 1 mm (0.90-1.14 mm)
							1 egg ∿ 2 mm (1.40 mm)
							2 larvae 9.6, 10 mm *Ammodytes hexapterus*
							1 larva 8.3 mm *Lepidopsetta bilineata*
							1 larva 9.6 mm *Lumpenus* sp.
							4 larvae 5.6-5.9 mm Cottidae ("Cottid 6" from Blackburn 1973)
							1 larva 4.9 mm Cyclopteridae
							7 larvae 2.5-3.2 mm unidentified (non-elongate)
							17 larvae unidentified due to extensive damage (7 elongate, 6 non-elongate)
27 May	1701	8	1	505	258[1]	26	36 eggs < 1 mm (0.80-0.86 mm)
							222 eggs ∿ 1 mm (0.90-1.14 mm)
							3 larvae 11, 11, 13 mm *Ammodytes hexapterus*
							1 larva 6.7 mm *Anoplarchus* sp.
							6 larvae 5.0-5.4 mm Cottidae ("Cottid 6" from Blackburn 1973)

[1] Approximately one-half of the sample sorted for fish eggs; 128 eggs were identified.

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
27 May	1701	8	1	505	258	26	1 larva 9.3 mm Cottidae
							1 larva 3.2 mm unidentified (non-elongate)
							14 larvae unidentified due to extensive damage (9 elongate, 1 non-elongate)
30 May	1813	10	1	333	22	121	1 egg < 1 mm (0.84 mm)
							2 eggs ∿ 1 mm (0.90-0.94 mm)
							9 eggs ∿ 2 mm (1.26-2.26 mm)
							10 eggs ∿ 3 mm (3.06-3.80 mm)
							1 larva 14 mm *Bathylagus* sp.
							1 larva 4.3 mm *Sebastes* sp.
							8 larvae 3.7-5.5 mm *Stenobrachius leucopsarus*
							101 larvae 4.2-6.1 mm unidentified (elongate)
							10 larvae unidentified due to extensive damage (elongate)
30 May	1813	10	1	505	18	57	2 eggs < 1 mm (0.74-0.84 mm)
							1 egg ∿ 1 mm (0.96 mm)
							12 eggs ∿ 2 mm (1.50-2.54 mm)
							3 eggs ∿ 3 mm (2.70-3.90 mm)

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
30 May	1813	10	1	505	18	57	1 larva 3.7 mm *Sebastes* sp.
							3 larvae 3.7, 4.2, 5.2 mm *Stenobrachius leucopsarus*
							44 larvae 4.4-6.5 mm unidentified (elongate)
							9 larvae unidentified due to extensive damage (7 elongate, 2 non-elongate)
30 May	0253	11	1	333	1	55	1 egg $\sim$ 2 mm (1.37 mm)
							26 larvae 3.2-17 mm *Bathylagus stilbius*
							10 larvae 3.4-6.1 mm *Sebastes* spp.
							11 larvae 3.2-5.6 mm *Stenobrachius leucopsarus*
							2 larvae 5.3, 6.4 mm Cottidae
							2 larvae 10, 10 mm Gadidae (both larvae are quite damaged)
							4 larvae unidentified due to extensive damage (3 elongate, 1 non-elongate)
30 May	0253	11	1	505	0	40	3 larvae 6.4, 8.2, 9.8 mm *Bathylagus stilbius*
							6 larvae 3.4-5.5 mm *Sebastes* spp.
							24 larvae 3.6-6.9 mm *Stenobrachius leucopsarus*

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
30 May	0253	11	1	505	0	40	1 young 19 mm Cottidae
							2 larvae 10, 11 mm Gadidae (both larvae are quite damaged)
							4 larvae unidentified due to extensive damage (2 elongate, 2 non-elongate)
30 May	0813	11	2	333	2	31	1 egg < 1 mm (0.89 mm)
							1 egg ∿ 1 mm (1.04 mm)
							1 larva 8.2 mm *Bathylagus stilbius*
							4 larvae 3.0-4.9 mm *Sebastes* spp.
							22 larvae 3.5-5.5 mm *Stenobrachius leucopsarus*
							3 young 21, 25, 39 mm *Stenobrachius leucopsarus*
							1 larva unidentified due to extensive damage (non-elongate)
30 May	0813	11	2	505	1	51	1 egg < 1 mm (0.85 mm)
							2 larvae 19, 28 mm *Bathylagus stilbius*
							1 young 21 mm *Protomyctophym thompsoni*
							3 larvae 4.0, 5.3, 7.2 mm *Sebastes* sp.
							24 larvae 3.9-4.8 mm *Stenobrachius leucopsarus*
							19 young 14-30 mm Hexagrammidae
							2 larvae unidentified due to extensive damage (1 elongate, 1 non-elongate)

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
28 May	1831	13	1	333	13	940[c]	3 eggs ∿ 1 mm (1.02, 1.21, 1.24 mm)
							10 eggs ∿ 2 mm (1.29-1.72 mm)
							704 larvae 7.0-17 mm *Bathylagus stilbius*
							88 larvae 8.8-13 mm *Clupea harengus pallasi*
							8 larvae, 13 mm *Gadus* sp.
							92 larvae 4.6-4.8 mm *Sebastes* sp.
							4 larvae 4.8 mm *Stenobrachius leucopsarus*
							16 larvae 4.4-5.5 mm Cottidae
							4 larvae 8.4 mm Gadidae
							24 larvae unidentified due to extensive damage (elongate)
28 May	1831	13	1	505	8	876[d]	8 eggs ∿ 2 mm (1.26-2.17 mm)
							632 larvae 8.0-16 mm *Bathylagus stilbius*
							32 larvae 11-14 mm *Clupea harengus pallasi*
							20 larvae 8.5-11 mm *Gadus* sp.
							76 larvae 4.2-4.7 mm *Sebastes* sp.
							4 larvae 4.5 mm *Stenobrachius leucopsarus*
							8 larvae 6.0-7.6 mm Cottidae

[c] Approximately 1/4 of the sample was sorted for fish larvae; 235 larvae were identified.

[d] Approximately 1/4 of the sample was sorted for fish larvae; 219 larvae were identified.

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
28 May	1831	13	1	505	8	876[d]	20 larvae 5.8-10 mm Gadidae
							84 larvae unidentified due to extensive damage (elongate)
28 May	2248	13	2	333	99	2992[e]	99 eggs ∿ 2 mm (1.25-1.92 mm)
							1424 larvae 6.3-17 mm *Bathylagus stilbius*
							16 young 37 mm *Bathylagus stilbius*
							16 larvae 13 mm *Clupea harengus pallasi*
							192 larvae 9.0-13 mm *Gadus* sp.
							1104 larvae 3.9-5.1 *Sebastes* sp.
							32 larvae 5.9-7.3 mm Cottidae
							16 young 26 mm Cyclopteridae
							80 larvae 6.0-9.1 mm Gadidae
							112 larvae unidentified due to extensive damage (elongate)
28 May	2248	13	2	505	100	2384[f]	100 eggs ∿ 2 mm (1.29-2.17 mm)
							1056 larvae 7.4-15 mm *Bathylagus stilbius*
							16 young 30 mm *Bathylagus stilbius*

[e] Approximately 1/16 of the sample was sorted for fish larvae; 187 larvae were identified.

[f] Approximately 1/16 of the sample was sorted for fish larvae; 149 larvae were identified.

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
28 May	2248	13	2	505	100	2384[f]	80 larvae 10-13 mm *Gadus* sp.
							880 larvae 4.3-5.0 mm *Sebastes* sp.
							64 larvae 6.3-6.9 mm Cottidae
							32 young 15, 71 mm Cyclopteridae
							16 young 25 mm Cyclopteridae
							160 larvae 7.3-12 mm Gadidae
							80 larvae unidentified due to extensive damage (elongate)
29 May	1029	13	3	333	1	800[g]	1 egg ∿ 2 mm (1.71 mm)
							8 larvae 9.5-10 mm *Ammodytes hexapterus*
							580 larvae 7.7-18 mm *Bathylagus stilbius*
							8 larvae 13, 14 mm *Clupea harengus pallasi*
							44 larvae 9.0-14 mm *Gadus* sp.
							116 larvae 4.4-5.3 mm *Sebastes* sp.
							4 larva 6.3 mm Cottidae
							32 larvae 5.5-13 mm Gadidae
							8 larvae unidentified due to extensive damage (non-elongate)

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
29 May	1029	13	3	505	0	700[g]	4 larvae 20 mm *Ammodytes hexapterus*
							440 larvae 8.1-15 mm *Bathylagus stilbius*
							76 larvae 9.4-16 mm *Gadus* sp.
							120 larvae 4.7-5.5 mm *Sebastes* sp.
							16 larvae 5.6-6.8 mm Cottidae
							4 young 96 mm Cyclopteridae
							32 larvae 5.1-9.7 mm Gadidae
							4 larvae 6.1 mm unidentified (elongate)
							4 larvae unidentified due to extensive damage (non-elongate)
28 May	0536	14	1	333	74	11	14 eggs ∿ 2 mm (2.00-2.40 mm)
							60 eggs ∿ 3 mm (2.80-3.77 mm)
							4 larvae 13 mm *Lumpenus* sp.
							2 larvae 5.7, 6.7 mm Gadidae
							5 larvae 5.2-6.6 mm unidentified (elongate)

[g] Approximately 1/4 of the sample was sorted for fish larvae; 175 larvae were identified.

Table 15. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
28 May	0536	14	1	505	74	13	15 eggs ∿ 2 mm (2.00-2.48 mm)
							59 eggs ∿ 3 mm (2.97-3.52 mm)
							1 larva 4.6 mm *Sebastes* sp.
							3 larvae 4.0-5.5 mm Gadidae
							9 larvae 5.2-6.1 mm unidentified (elongate)

Table 16. Identification of Fish Eggs and Larvae by Station

1-m NIO Tow, *Discoverer*, Leg VII, 22-30 May 1976

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
27 May	0120	6	5	571	248[a]	162	244 eggs ∿ 1 mm (0.93-1.05 mm) 4 eggs ∿ 2 mm (1.29-1.37 mm) 12 larvae 5.0-14 mm *Ammodytes hexapterus* 1 larva 7.7 mm *Anoplarchus* sp. 1 larva 3.9 mm *Lepidopsetta bilineata* (?) 3 larvae 10, 17, 18 mm *Lumpenus* sp. 2 larvae 10, 13 mm Agonidae 5 larvae 6.9-9.0 mm Cottidae ["Cottid 6" from Blackburn 1973] 6 larvae 4.7-6.3 mm Cyclopteridae 1 larva 8.0 mm Osmeridae 5 larvae 13-19 mm Phlidae 126 larvae unidentified due to extensive damage (123 elongate, 3 non-elongate)

[a] Approximately 1/2 sample sorted for fish eggs; 124 eggs were measured.

Table 17. Identification of Crab and Shrimp Larvae by Station

Lower Cook Inlet Bongo and 1-m NIO Net Tows, *Discoverer*, Leg VII, 22-30 May 1976

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
25 May	0732	1	1[a]	333	I	6	*Paralithodes camtschatica*
					II	2	*P. camtschatica*
					III	8	*P. camtschatica*
					zoea	274	unidentified anomurans
					I	4	*Cancer productus*
					I	12	*Chionoecetes bairdi*
					megalopa	4	*Chionoecetes* sp.
					zoea	906	unidentified brachyurans
					II	6	*Pandalus borealis*
					III	28	*P. borealis*
					IV	4	*P. borealis*
					I	2	*P. montagui tridens*
					II	49	*P. montagui tridens*
					III	4	*P. montagui tridens*
					I	5	*P. stenolepis*
					II	1	*P. stenolepis*
					zoea	590	unidentified hippolytids
					adult	1	*Eualus* sp.
25 May	0732	1	1	505	I	3	*Paralithodes camtschatica*
					II	5	*P. camtschatica*
					III	1	*P. camtschatica*
					zoea	265	unidentified anomurans
					I	6	*Cancer productus*

[a] Approximately 1/2 of the sample was sorted for crab larvae; totals are given for the entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (µm)	Stage	Total	Identification of Larvae
25 May	0732	1	1	505	I	17	*Chionoecetes bairdi*
					megalopa	9	*Chionoecetes* sp.
					zoea	917	unidentified brachyurans
					II	1	*Pandalopsis dispar*
					II	7	*Pandalus borealis*
					III	41	*P. borealis*
					II	1	*P. goniuris*
					I	9	*P. montagui tridens*
					II	45	*P. montagui tridens*
					III	2	*P. montagui tridens*
					I	3	*P. stenolepis*
					II	3	*P. stenolepis*
					zoea	567	unidentified hippolytids
					adult	1	*Eualus* sp.
25 May	1150	2	1[b]	333	II	16	*Paralithodes camtschatica*
					zoea	2432	unidentified anomurans
					I	288	*Chionoecetes bairdi*
					zoea	2272	unidentified brachyurans
					I	1	*Pandalus borealis*
					III	1	*P. borealis*
					III	1	*P. goniurus*
					zoea	239	unidentified hippolytids

[b] Approximately 1/8 of the sample was sorted for crab larvae; totals are given for entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
25 May	1150	2	1[c]	505	I	8	*Paralithodes camtschatica*
					II	16	*P. camtschatica*
					zoea	1352	unidentified anomurans
					I	144	*Chionoecetes bairdi*
					zoea	1816	unidentified brachyurans
					III	1	*Pandalopsis dispar*
					II	1	*Pandalus montagui tridens*
					II	1	*P. stenolepis*
					III	1	*P. stenolepis*
					zoea	291	unidentified hippolytids
25 May	1607	3	1	333	zoea	8	unidentified anomurans
					I	4	*Chionoecetes bairdi*
					zoea	304	unidentified brachyurans
					I	1	*Pandalus goniurus*
					zoea	67	unidentified hippolytids
25 May	1607	3	1	505	zoea	7	unidentified anomurans
					I	2	*Chionoecetes bairdi*
					zoea	300	unidentified brachyurans
					I	3	*Pandalus goniurus*
					zoea	93	unidentified hippolytids
					adult	1	*Crangon franciscorum angustimana*
25 May	2217	4	1	333	megalopa	1	*Chionoecetes* sp.
					zoea	48	unidentified brachyurans
					zoea	16	unidentified hippolytids

[c] Approximately 1/8 of the sample was sorted for crab larvae; totals are given for the entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
25 May	2217	4	1	505	zoea	1	unidentified anomuran
					zoea	46	unidentified brachyurans
					zoea	9	unidentified hippolytids
26 May	0541	5a	2[d]	333	II	64	*Paralithodes camtschatica*
					zoea	376	unidentified anomurans
					V	8	*Cancer oregonensis*
					I	312	*Chionoecetes bairdi*
					zoea	1112	unidentified brachyurans
					I	240	*Pandalus borealis*
					III	24	*P. borealis*
					I	8	*P. goniurus*
					II	512	*P. goniurus*
					III	320	*P. goniurus*
					zoea	1984	unidentified hippolytids
26 May	0541	5a	2[d]	505	II	40	*Paralithodes camtschatica*
					zoea	176	unidentified anomurans
					I	312	*Chionoecetes bairdi*
					zoea	1232	unidentified brachyurans
					II	24	*Pandalus borealis*
					III	8	*P. borealis*
					IV	24	*P. borealis*
					I	24	*P. goniurus*
					II	296	*P. goniurus*
					III	152	*P. goniurus*
					I	8	*P. hypsinotus*
					zoea	1816	unidentified hippolytids

[d] Approximately 1/8 of the sample was sorted for crab and shrimp larvae; totals are given for the entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
26 May	0835	6	1[e]	333	I	88	*Chionoecetes bairdi*
					I	320	damaged *Chionoecetes* sp.
					zoea	1024	unidentified brachyurans (many damaged)
					IV	16	*Pandalus goniurus*
					adult	235	*P. borealis*
					adult	26	*P. goniurus*
26 May	0835	6	1[e]	505	zoea	16	unidentified anomurans
					I	120	*Chionoecetes bairdi*
					I	416	damaged *Chionoecetes* sp.
					zoea	1864	unidentified brachyurans (many damaged)
					II	8	*Pandalus borealis*
					I	24	*P. goniurus*
					II	24	*P. goniurus*
					adult	211	*P. borealis*
					adult	44	*P. goniurus*
					adult	1	*Crangon communis*
26 May	1928	6	3[e]	333	III	8	*Paralithodes camtschatica*
					zoea	8	unidentified anomuran
					I	128	*Chionoecetes bairdi*
					I	96	damaged *Chionoecetes* sp.
					zoea	552	unidentified brachyurans (many damaged)
					III	24	*Pandalus borealis*

[e] Approximately 1/8 of the sample was sorted for crab and shrimp larvae; totals are given for the entire sample. Adult shrimp were sorted from the entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
26 May	1928	6	3	333	I	24	*P. goniurus*
					zoea	24	unidentified hippolytids
					adult	20	*P. borealis*
					adult	4	*P. goniurus*
26 May	1928	6	3[f]	505	III	8	*Paralithodes camtschatica*
					IV	4	*P. camtschatica*
					I	83	*Chionoecetes bairdi*
					I	52	damaged *Chionoecetes* sp.
					zoea	308	unidentified brachyurans (many damaged)
					I	4	*Pandalus borealis*
					II	4	*P. borealis*
					I	16	*P. goniurus*
					II	16	*P. goniurus*
					III	4	*P. goniurus*
					zoea	68	unidentified hippolytids
					adult	20	*P. borealis*
27 May	0056	6	4[g]	333	II	32	*Paralithodes camtschatica*
					III	32	*P. camtschatica*
					zoea	48	unidentified anomurans
					I	264	*Chionoecetes bairdi*
					I	104	damaged *Chionoecetes* sp.
					zoea	584	unidentified brachyurans (some damaged)

[f] Approximately 1/4 of the sample was sorted for crab and shrimp larvae; totals are given for the entire sample. Adult shrimp were sorted from the entire sample.

[g] Approximately 1/8 of the sample was sorted for crab and shrimp larvae; totals are given for the entire sample. Adult shrimp were sorted from the entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
27 May	0056	6	4	333	I	32	*Pandalus borealis*
					II	8	*P. borealis*
					III	8	*P. borealis*
					I	16	*P. goniurus*
					II	8	*P. goniurus*
					III	16	*P. goniurus*
					I	72	*P. hypsinotus*
					II	24	*P. hypsinotus*
					zoea	272	unidentified hippolytids
					adult	6	*P. borealis*
					adult	1	*P. goniurus*
27 May	0056	6	4[h]	505	II	32	*Paralithodes camtschatica*
					III	56	*P. camtschatica*
					zoea	48	unidentified anomurans
					I	248	*Chionoecetes bairdi*
					I	80	damaged *Chionoecetes* sp.
					zoea	496	unidentified brachyurans (some damaged)
					III	8	*Pandalus borealis*
					IV	8	*P. borealis*
					I	8	*P. goniuris*
					III	8	*P. goniuris*
					I	112	*P. hypsinotus*
					II	48	*P. hypsinotus*
					III	16	*P. hypsinotus*
					zoea	208	unidentified hippolytids
					adult	8	*P. borealis*
					adult	1	*P. goniuris*

[h] Approximately 1/8 of the sample was sorted for crab and shrimp larvae; totals are given for the entire sample. Adult shrimp were sorted from the entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
27 May	0120	6	5[i]	571	II	24	*Paralithodes camtschatica*
					III	28	*P. camtschatica*
					IV	8	*P. camtschatica*
					zoea	104	unidentified anomurans
					I	24	*Chionoecetes bairdi*
					zoea	544	unidentified brachyurans
					I	28	*Pandalus borealis*
					II	16	*P. borealis*
					III	20	*P. borealis*
					I	16	*P. goniurus*
					II	36	*P. goniurus*
					III	8	*P. goniurus*
					II	12	damaged *Pandalus* sp.
					zoea	728	unidentified hippolytids
27 May	0708	6	7[j]	333	II	8	*Paralithodes camtschatica*
					III	8	*P. camtschatica*
					zoea	56	unidentified anomurans
					I	288	*Chionoecetes bairdi*
					zoea	552	unidentified brachyurans
					III	8	*Pandalus borealis*
					I	8	*P. goniurus*
					III	16	*P. goniurus*
					I	120	*P. hypsinotus*
					II	64	*P. hypsinotus*

[i] Approximately 1/4 of the sample was sorted for crab and shrimp larvae; totals are given for the entire sample.

[j] Approximately 1/8 of the sample was sorted for crab and shrimp larvae; totals are given for the entire sample. Adults were sorted from the entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
27 May	0708	6	7	333	zoea	16	damaged *Pandalus* sp.
					adult	56	*P. borealis*
					adult	3	*P. goniurus*
					adult	1	*Crangon franciscorum angustimana*
27 May	0708	6	7[j]	505	II	8	*Paralithodes camtschatica*
					zoea	56	unidentified anomurans
					I	304	*Chionoecetes bairdi*
					zoea	616	unidentified brachyurans
					III	8	*Pandalus goniurus*
					III	8	*P. hypsinotus*
					adult	36	*P. borealis*
					adult	4	*P. goniurus*
					adult	1	*Crangon franciscorum angustimana*
27 May	1300	7	1[k]	333	I	8	*Paralithodes camtschatica*
					II	196	*P. camtschatica*
					III	20	*P. camtschatica*
					zoea	88	unidentified anomurans
					I	8	*Chionoecetes bairdi*
					zoea	128	unidentified brachyurans
					I	280	*Pandalus goniurus*
					II	1440	*P. goniurus*
					III	128	*P. goniurus*
					zoea	20	damaged *Pandalus goniurus* ?
					zoea	544	unidentified hippolytids

[k] Approximately 1/4 of the sample was sorted for crab and shrimp larvae; totals are given for the entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (µm)	Stage	Total	Identification of Larvae
27 May	1300	7	1[l]	505	I	32	*Paralithodes camtschatica*
					II	204	*P. camtschatica*
					III	24	*P. camtschatica*
					zoea	92	unidentified anomurans
					I	8	*Chionoecetes bairdi*
					zoea	96	unidentified brachyurans
					I	328	*Pandalus goniurus*
					II	1752	*P. goniurus*
					III	152	*P. goniurus*
					zoea	8	damaged *Pandalus* sp.
					zoea	544	unidentified hippolytids
27 May	1701	8	1[m]	333	II	24	*Paralithodes camtschatica*
					III	36	*P. camtschatica*
					zoea	212	unidentified anomurans
					I	8	*Chionoecetes bairdi*
					zoea	976	unidentified brachyurans
					II	5	*Pandalus goniurus*
					III	1	*P. goniurus*
					zoea	122	unidentified hippolytids
27 May	1701	8	1[m]	505	II	20	*Paralithodes camtschatica*
					III	20	*P. camtschatica*
					zoea	284	unidentified anomurans
					I	4	*Chionoecetes bairdi*

[l] Approximately 1/4 of the sample was sorted for crab larvae and approximately 1/8 of the sample was sorted for shrimp larvae; totals are given for the entire sample.

[m] Approximately 1/4 of the sample was sorted for crab larvae; totals are given for the entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
27 May	1701	8	1	505	megalopa	4	*Chionoecetes* sp.
					zoea	892	unidentified brachyurans
					I	1	*Pandalus borealis*
					II	2	*P. borealis*
					I	1	*P. goniurus*
					II	10	*P. goniurus*
					III	2	*P. goniurus*
					zoea	3	damaged *Pandalus* sp.
					zoea	152	unidentified hippolytids
30 May	1813	10	1	333	zoea	7	unidentified anomurans
					I	18	*Chionoecetes bairdi*
					megalopa	2	*Chionoecetes* sp.
					zoea	41	unidentified brachyurans
					III	1	*Pandalopsis dispar*
					III	2	*Pandalus borealis*
					IV ?	1	damaged *P. borealis* ?
					II	1	*P. goniurus*
					I	7	*P. montagui tridens*
					II	6	*P. montagui tridens*
					III	2	*P. montagui tridens*
					zoea	2	unidentified hippolytids
30 May	1813	10	1	505	zoea	7	unidentified anomurans
					I	13	*Chionoecetes bairdi*
					megalopa	2	*Chionoecetes* sp.
					zoea	46	unidentified brachyurans
					I	1	*Pandalopsis dispar*
					II	2	*Pandalus borealis*

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (µm)	Stage	Total	Identification of Larvae
30 May	1813	10	1	505	III	2	*P. borealis*
					IV	3	*P. borealis*
					I	10	*P. montagui tridens*
					II	8	*P. montagui tridens*
					III	1	*P. montagui tridens*
					IV	1	damaged *Pandalus* sp.
					zoea	14	unidentified hippolytids
30 May	0253	11	1	333	zoea	1	unidentified anomuran
					I	6	*Chionoecetes bairdi*
					megalopa	6	*Chionoecetes* sp.
					zoea	33	unidentified brachyurans
					I	1	*Pandalus montagui tridens*
					II	1	damaged *Pandalus* sp.
					zoea	11	unidentified hippolytids
					adult	1	*Pasiphaea* sp.
30 May	0253	11	1	505	I	1	*Chionoecetes bairdi*
					megalopa	2	*Chionoecetes* sp.
					zoea	4	unidentified brachyurans
					IV ?	1	*Pandalopsis dispar*
					zoea	6	unidentified hippolytids
30 May	0813	11	2	333	megalopa	3	*Chionoecetes* sp.
					zoea	7	unidentified brachyurans
					zoea	4	unidentified hippolytids

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
30 May	0813	11	2	505	megalopa	5	*Chionoecetes* sp.
					zoea	24	unidentified brachyurans
					IV	1	*Pandalopsis dispar*
					III	1	*Pandalus montagui tridens*
					zoea	4	unidentified hippolytids
28 May	1831	13	1[n]	333	zoea	4	unidentified anomurans
					I	140	*Chionoecetes bairdi*
					megalopa	4	*Chionoecetes* sp.
					zoea	96	unidentified brachyurans
					I	4	*Pandalopsis dispar*
					II	2	*P. dispar*
					III	2	*P. dispar*
					II	2	*Pandalus borealis*
					III	48	*P. borealis*
					IV	60	*P. borealis*
					V	6	*P. borealis*
					I	2	*P. montagui tridens*
					II	6	*P. montagui tridens*
					III	6	*P. montagui tridens*
					zoea	72	unidentified hippolytids
28 May	1831	13	1[o]	505	zoea	8	unidentified anomurans
					I	122	*Chionoecetes bairdi*
					megalopa	2	*Chionoecetes* sp.

[n] Approximately 1/2 of the sample was sorted for crab and shrimp larvae; totals are given for the entire sample.

[o] Approximately 1/2 of the sample was sorted for crab and shrimp larvae; totals are given for the entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
28 May	1831	13	1[o]	505	zoea	102	unidentified brachyruans
					I	2	*Pandalopsis dispar*
					II	2	*P. dispar*
					II	4	*Pandalus borealis*
					III	46	*P. borealis*
					IV	40	*P. borealis*
					V	10	*P. borealis*
					I	6	*P. montagui tridens*
					II	14	*P. montagui tridens*
					III	2	*P. montagui tridens*
					I	2	*P. stenolepis*
					zoea	62	unidentified hippolytids
28 May	2248	13	2	333	zoea	2	unidentified anomurans
					I	88	*Chionoecetes bairdi*
					II	1	*Chionoecetes* sp.
					megalopa	1	*Chionoecetes* sp.
					zoea	23	unidentified brachyurans
					I	8	*Pandalopsis dispar*
					II	3	*P. dispar*
					III	2	*P. dispar*
					III	60	*Pandalus borealis*
					IV	66	*P. borealis*
					V	3	*P. borealis*
					II	8	*P. montagui tridens*
					III	1	*P. montagui tridens*
					zoea	64	unidentified hippolytids
					adult	34	*Pasiphaea* sp.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
28 May	2248	13	2[p]	505	zoea	2	unidentified anomurans
					I	59	*Chionoecetes bairdi*
					megalopa	2	*Chionoecetes* sp.
					zoea	10	unidentified brachyurans
					II	2	*Pandalopsis dispar*
					III	96	*Pandalus borealis*
					IV	55	*P. borealis*
					V	7	*P. borealis*
					I	2	*P. montagui tridens*
					II	9	*P. montagui tridens*
					zoea	94	unidentified hippolytids
					adult	2	*Pandalus borealis*
					adult	39	*Pasiphaea* sp.
29 May	1029	13	3[p]	333	zoea	3	unidentified anomurans
					I	104	*Chionoecetes bairdi*
					II	1	*Chionoecetes* sp.
					megalopa	2	*Chionoecetes* sp.
					zoea	9	unidentified brachyurans
					II	2	*Pandalopsis dispar*
					III	2	*P. dispar*
					II	4	*Pandalus borealis*
					III	46	*P. borealis*
					IV	78	*P. borealis*
					V	16	*P. borealis*
					II	9	*P. montagui tridens*
					III	2	*P. montagui tridens*
					IV	2	*P. montagui tridens*
					zoea	66	unidentified hippolytids
					adult	25	*Pasiphaea* sp.

[p] Approximately 7/16 of the sample was sorted for shrimp larvae and adult shrimp; totals are given for the entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
29 May	1029	13	3[q]	505	zoea	8	unidentified anomurans
					I	168	*Chionoecetes bairdi*
					zoea	6	unidentified brachyurans
					III	2	*Pandalopsis dispar*
					II	2	*Pandalus borealis*
					III	53	*P. borealis*
					IV	96	*P. borealis*
					V	18	*P. borealis*
					II	2	*P. montagui tridens*
					III	4	*P. montagui tridens*
					zoea	82	unidentified hippolytids
					adult	16	*Pasiphaea* sp.
28 May	0536	14	1	333	III	1	*Paralithodes camtschatica*
					zoea	10	unidentified anomurans
					I	44	*Chionoecetes bairdi*
					megalopa	39	*Chionoecetes* sp.
					zoea	33	unidentified brachyurans
					I	1	*Pandalopsis dispar*
					II	1	*P. dispar*
					II	1	*Pandalus borealis*
					I	16	*P. montagui tridens*
					II	3	*P. montagui tridens*
					III	1	*P. montagui tridens*
					zoea	12	unidentified hippolytids

[q] Approximately 5/8 of the sample was sorted for crab larvae and approximately 7/16 of the sample was sorted for shrimp larvae; totals are given for the entire sample.

Table 17. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Stage	Total	Identification of Larvae
28 May	0536	14	1	505	zoea	14	unidentified anomurans
					I	35	*Chionoecetes bairdi*
					megalopa	32	*Chionoecetes* sp.
					zoea	27	unidentified brachyurans
					I	1	*Pandalopsis dispar*
					I	1	*Pandalus borealis*
					II	1	*P. borealis*
					III	5	*P. borealis*
					IV	1	*P. borealis*
					I	28	*P. montagui tridens*
					II	6	*P. montagui tridens*
					III	3	*P. montagui tridens*
					I	1	*P. stenolepis*
					III	1	*P. stenolepis*
					zoea	23	unidentified hippolytids

Table 18. Number of fish eggs and larvae at each station

Lower Cook Inlet Bongo Tows, *Surveyor*, Leg II, 24-31 August 1976

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae
25 Aug	0840	1	1	333	0	125
25 Aug	0840	1	1	505	0	772
25 Aug	1206	2	1	333	0	102
25 Aug	1206	2	1	505	0	127
25 Aug	1952	3	1	333	0	4
25 Aug	1952	3	1	505	0	24
26 Aug	0400	4	1	333	0	458
26 Aug	0400	4	1	505	0	50
26 Aug	1040	5	1	333	34	476
26 Aug	1040	5	1	505	25	536
26 Aug	2203	6	1	333	21	856
26 Aug	2203	6	1	505	17	332
27 Aug	1000	6	2	333		
27 Aug	1000	6	2	505	48	1568
28 Aug	0650	7	1	333	0	
28 Aug	0650	7	1	505		
28 Aug	0330	8	1	333		
28 Aug	0330	8	1	505	0	
28 Aug	1832	9	1	333	2	21
28 Aug	1832	9	1	505	1	17
28 Aug	1919	9	2	333	0	218
28 Aug	1919	9	2	505	1	207
29 Aug	0459	10	1	333	0	39
29 Aug	0459	10	1	505	1	55
29 Aug	1922	11	1	333		
29 Aug	1922	11	1	505		

Table 19. Summary of taxonomic categories of fish eggs, larvae, young and adults found in Bongo net samples collected on Lower Cook Inlet and Prince Williams Sound *Surveyor* cruise, Leg II, 24-31 August 1976.

A total of 30 samples were collected. Samples from stations 2, 3 and 4 are identified for fish larvae and summarized below. The fish are distributed into 6 families, 8 genera, and 6 species. No eggs were found in any of the samples from these three stations.

Family Clupeidae

2 larvae Pacific herring *Clupea harengus pallasi* Valenciennes

Family Gasterosteidae

500 young threespine stickleback *Gasterosteus aculeatus* Linnaeus
1 young ninespine stickleback *Pungitius pungitius* (Linnaeus)

Family Hexagrammidae

1 larva greenling *Hexagrammos* sp.

Family Osmeridae

115 larvae genus? species?
80 larvae capelin *Mallotus villosus* (Müller)
1 young *Mallotus villosus*

Family Pleuronectidae

3 larvae sole *Hippoglossoides* sp. (1 uncertain)
1 larva sand sole *Psettichthys melanostictus* Girard

Family Ptilichthyidae

1 young quillfish *Ptilichthys goodei* Bean

60 larvae unidentified due to extensive damage

Table 20. Identification of Fish Eggs and Larvae by Station

Lower Cook Inlet Bongo Tows, *Surveyor*, Leg II, 24-31 August 1976

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
25 Aug	1206	2	1	333	0	102[a]	24 larvae 6.5-22 mm[b] *Mallotus villosus*
							34 larvae 7.0-31 mm Osmeridae
							44 larvae unidentified due to extensive damage (43 elongate, 1 non-elongate)
25 Aug	1206	2	1	505	0	127	1 larva 14 mm *Hippoglossoides* sp.
							1 larva 20 mm *Hippoglossoides* sp. (?)
							38 larvae 6.3-20 mm *Mallotus villosus*
							1 young 63 mm *Mallotus villosus*
							1 larva 18 mm *Psettichthys melanostictus*
							1 young 123 mm *Ptilichthys goodei*
							70 larvae 7.3-20 mm Osmeridae
							14 larvae unidentified due to extensive damage (elongate)

[a] All specimens are classified into four main categories: eggs include all stages of eggs prior to hatching; larvae include newly hatched and all stages prior to metamorphosis; young include fish after metamorphosis to acquisition of adult fin rays and adult body configuration; adults include fish that are sexually mature.

[b] Eggs are measured to the nearest hundredths of a millimeter in diameter. Fish or larvae, if less than 10 mm in length, are measured to the nearest tenth of a millimeter under a microscope using a calibrated micrometer eye piece. If 10 mm or greater in length, the fish or larvae are measured by a metric ruler to the nearest millimeter. When there are more than three eggs, fish or larvae, the largest and the smallest are measured. Larvae are measured by standard length.

Table 20. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
25 Aug	1952	3	1	333	0	4	2 larvae 5.2, 9.3 mm *Mallotus villosus*
							2 larvae 3.0, 20 mm Osmeridae
25 Aug	1952	3	1	505	0	24	13 larvae 3.7-21 mm *Mallotus villosus*
							9 larvae 7.7-21 mm Osmeridae
							2 larvae unidentified due to extensive damage (elongate)
26 Aug	0400	4	1	333	0	458	1 larva 30 mm *Clupea harengus pallasi*
							452 young 15-27 mm *Gasterosteus aculeatus*
							1 larva 29 mm *Hippoglossoides* sp.
							3 larvae 24, 25, 31 mm *Mallotus villosus*
							1 young 30 mm *Pungitius pungitius*
26 Aug	0400	4	1	505	0	50	1 larva 27 mm *Clupea harengus pallasi*
							48 young 18-24 mm *Gasterosteus aculeatus*
							1 larva 7.5 mm *Hexagrammos* sp.

Table 21. Number of Fish Eggs and Larvae at each Station

Lower Cook Inlet Bongo Tows, *Miller Freeman*, Leg III
17-29 October 1976

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae
19 Oct.	0400	1	1	333	0	13
19 Oct.	0400	1	1	505	0	15
28 Oct.	0845	2	2	333	No sample:	cod end of net broke
28 Oct.	0845	2	2	505	0	6
23 Oct.	1935	3	1	333	0	0
23 Oct.	1935	3	1	505	0	1
24 Oct.	1004	4	1	333	0	1
24 Oct.	1004	4	1	505	0	0
23 Oct.	1006	5	1	333	0	3
23 Oct.	1006	5	1	505	0	5
22 Oct.	1758	6	1	333	0	0
22 Oct.	1758	6	1	505	0	1
21 Oct.	0907	7	1	333	0	1
21 Oct.	0907	7	1	505	0	0
21 Oct.	0403	8	1	333	0	9
21 Oct.	0403	8	1	505	0	2
28 Oct.	1244	9	1	333	0	0
28 Oct.	1244	9	1	505	0	12

Table 22. Summary of taxonomic categories of fish eggs, larvae, young and adults found in Bongo net samples collected on Lower Cook Inlet *Miller Freeman* cruise, Leg III, 17-29 October 1976.

A total of 18 samples were collected. Samples from stations 2, 3, 4, 5, 6, 7 and 8 are identified for fish larvae and summarized below. The fish are distributed into 3 families, 3 genera, and 2 species. No eggs were found in any of the samples.

Family Clupeidae

1 young Pacific herring *Clupea harengus pallasi* Valenciennes

Family Hexagrammidae

14 larvae greenling *Hexagrammos* sp.

Family Osmeridae

1 larva genus? species?
12 larvae capelin *Mallotus villosus* (Müller)

1 larva unidentified due to extensive damage

Table 23. Identification of Fish Eggs and Larvae by Station

Lower Cook Inlet Bongo Tows, *Miller Freeman,* Leg III, 17-29 October 1976

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
28 Oct.	0845	2	2	505	0	6[a]	3 larvae 5.1, 5.7, 6.3 mm[b] *Hexagrammos* sp. 2 larvae 16, 27 mm *Mallotus villosus* 1 larva unidentified due to extensive damage (elongate)
23 Oct	1935	3	1	505	0	1	1 larva 12 mm *Hexagrammos* sp.
24 Oct	1004	4	1	333	0	1	1 young 59 mm *Clupea harengus pallasi*
23 Oct	1006	5	1	333	0	3	3 larvae 7.3, 8.5, 11 mm *Hexagrammos* sp.
23 Oct	1006	5	1	505	0	5	5 larvae 8.6-11 mm *Hexagrammos* sp.
22 Oct	1758	6	1	505	0	1	1 larva 16 mm *Mallotus villosus*
21 Oct	0907	7	1	333	0	1	1 larva 27 mm Osmeridae

[a] All specimens are classified into four main categories: eggs include all stages of eggs prior to hatching; larvae include newly hatched and all stages prior to metamorphosis; young include fish after metamorphosis to acquisition of adult fin rays and adult body configuration; adults include fish that are sexually mature.

[b] Eggs are measured to the nearest hundredths of a millimeter in diameter. Fish or larvae, if less than 10 mm in length, are measured to the nearest tenth of a millimeter under a microscope using a calibrated micrometer eye piece. If 10 mm or greater in length, the fish or larvae are measured by a metric ruler to the nearest millimeter. When there are more than three eggs, fish or larvae, the largest and the smallest are measured. Larvae are measured by standard length.

Table 23. (continued)

Date (1976) (GMT)	Time (GMT)	Station	Haul	Mesh Size (μm)	Eggs	Fish or Larvae	Identification of Fish Eggs and Larvae
22 Oct	0403	8	1	333	0	9	2 larvae 11, 12 mm *Hexagrammos* sp.
							7 larvae 28-36 mm *Mallotus villosus*
22 Oct	0403	8	1	505	0	2	2 larvae 31, 34 mm *Mallotus villosus*

IV. Preliminary Interpretation of Results

The further results available on fish eggs support the earlier preliminary interpretation of concentrations of abundance in Kachemak and Kamishak Bays, with fewer organisms northward, southward, and in the center of Lower Cook Inlet.

The results so far available on crab and shrimp show a progression in life history stages from April through May. Kamishak Bay appears to have fewer shellfish larvae than outer Kachemak Bay. Larvae are relatively less abundant inside the Homer Spit. Again, there are fewer organisms northward in Cook Inlet and outside Lower Cook Inlet.

We now have a wider variety of species and life history stages available to us from the shellfish analyses. We are using these data to plan our formats for the presentation of results of quantitative density distributions as numbers/square meter by location and season.

V. Problems Encountered

The only problem encountered was a misunderstanding about our data submission schedule. We thought the program office wanted our best updated estimates of when data blocks, by cruise, would be submitted. Our last estimate has now become a deadline and we are under threat of contract modification if we are late. This misunderstanding has not been resolved to our satisfaction.

VI. Estimate of Funds Expended

We estimate 81% of our funds will be expended by the end of June 1977.

QUARTERLY REPORT

Contract 03-5-022-56
Research Unit #426
Task Order #13
Reporting Period 4/1 - 6/30/77

ZOOPLANKTON AND MICRONEKTON STUDIES IN THE BERING - CHUKCHI SEAS

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July 20, 1977

QUARTERLY REPORT
R.U. #426

1. Task Objectives

In the Norton Sound/Chukchi Sea inshore waters the following tasks will be addressed:

1. Determine the species of zooplankton and micronekton (including ichthyoplankton) of importance for sustaining vertebrate species of high forage, subsistance, economic, or esthetic significance.

2. Define the trophodynamics of these zooplankton and micronekton species.

3. Describe the general distributional features of the characteristic inshore species of zooplankton and micronekton based on reconnaissance - level surveys conducted during the ecological spring or early summer of the region.

II. Field or Laboratory Activities

Activities this past quarter have been directed toward preparing for and conducting collections aboard the NOAA vessel Surveyor, June 28 - July 7, operating in the Norton Sound/Chukchi Sea nearshore zones. Since this effort overlapped the reporting period and a cruise report is not available as yet, this activity will be reported on in the final report.

III. Results

Samples collected in the nearshore zone by small boat and from the NOAA vessel Discoverer during the summer of 1976 have been processed and some preliminary interpretations made. These results, together with material gathered this summer, will be presented as part of the final report of this work.

IV. Interpretation of Results

The nearshore plankton and micronekton assembleges in summer show an affinity with communities further off-shore over the broad shelf (61-88 percent species in common) although the numerically abundant organisms very close to the beach (one mile or less) seem to be restricted to this habitat (see Cooney annual report; March 31, 1977).

V. Problems Encountered/Recommended Changes

None.

FRI-UW-7719
May 1977

FISHERIES RESEARCH INSTITUTE
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ASSESSMENT OF PELAGIC AND NEARSHORE FISH IN THREE BAYS ON THE EAST AND SOUTH COASTS OF KODIAK ISLAND, ALASKA

By

Colin K. Harris
Project Leader

Allan C. Hartt
Principal Investigator

FINAL REPORT

A contribution to biological information needed by OCSEAP/BLM in making decisions with respect to offshore oil leases. Work performed under proposal number RU485, Tasks A-7, A-8, A-9, and A-11.
Contract No. 03-5-022-67, T.O. No. 12

Approved

Submitted May 25, 1977 Robert L. Burgner
Director

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ABSTRACT

As part of the large baseline study of the Alaskan outer continental shelf sponsored by the Bureau of Land Management, this project was a qualitative assessment of the nearshore and pelagic fishes in Ugak, Kaiugnak, and Alitak bays on the east and south coasts of Kodiak Island. Our principal objectives were to determine the species composition of the pelagic and nearshore estuarine fish fauna, the distribution and relative abundance of common species, and age class composition and food habits of principal species. Sampling took place during four cruises from late May to mid-September, 1976, and employed a midwater herring trawl, a surface tow net, a beach seine, a try net, and trammel nets.

Our main finding was the use of the estuarine bays as nursery areas by numerous fish species. Larval fish were caught abundantly despite the mesh sizes of our gear, but mainly juvenile fish were found in the nearshore and pelagic habitats within the bays. Seventy species were found in the study area, but our checklist should not be considered exhaustive. More species were encountered in the subtidal zone than in the intertidal and pelagic habitats. Large numbers of juvenile capelin and young-of-the-year Pacific sandfish were found in the pelagic zone, yet very few adults of these species occurred in the catches. Capelin were especially abundant throughout the study area while the sandfish population decreased toward the southern end of the island. Diel vertical migrations were evinced for both species. The other major pelagic forms were young-of-the-year and postlarval sand lance, caught only in the early summer, and juvenile salmon. Pink salmon and, in much less abundance, chum salmon moved from the nearshore to pelagic habitats during early summer, and had largely left the bays by the last cruise. Numerous other species represented mainly by juvenile stages were also found in the pelagic zone. Few large fish were caught, perhaps a result of gear selectivity. The nearshore zone especially hosted a diverse community of predominantly juvenile fishes. Greenling, salmonids, pleuronectids, cottids, and sand lance made up most of the catches, but many other species were represented in the nearshore zone as well. Sand lance and, in the first part of the summer, juvenile pink and chum salmon were the most abundant nearshore residents, but nonschooling species such as greenling, flatfishes, cottids, and blennioids were caught more frequently albeit in much less abundance. Areas of concentration were found for a number of nearshore species.

The food habits of principal species were determined to identify the important food resources in the estuaries. There was a wide variation in the diets, but generally the nearshore fishes ate large quantities of benthic and epibenthic organisms such as harpacticoids, cumaceans, gammarideans, polychaetes, barnacles, and bivalve and univalve molluscs. Piscivorous fish fed mainly on sand lance, but also on juveniles of many other species. Calanoid copepods were the major prey of most pelagic fishes examined, but crustacean and fish larvae, pelagic eggs, amphipods and euphausiids were also important.

While a baseline assessment does not permit firm conclusions regarding the impacts of industry on an environment, some relevant interpretations should be possible. The habitats surveyed in this study are critical in light of potential oil pollution as they are used as spawning and rearing areas by numerous commercial and noncommercial species. The nearshore and epipelagic fishes might be especially susceptible to the inimical effects of oil contamination. Toxic, water soluble fractions of oil would presumably first contaminate the surface waters, important to juvenile salmonids and greenling. Inshore drift of contaminants would pose a threat to spawning capelin, herring, and greenling and to their inshore larval progeny, as well as to homing salmon, juvenile salmon in the late spring and early summer, and to many other populations of juvenile fishes such as flatfishes, sculpins, and sand lance.

ASSESSMENT OF PELAGIC AND NEARSHORE FISH IN THREE BAYS ON THE EAST AND SOUTH COASTS OF KODIAK ISLAND, ALASKA

INTRODUCTION

This project is one of the many research efforts designed to provide environmental baseline information needed to assess the potential impact of offshore oil exploration and production on the Alaskan outer continental shelf. Before the potential oil resources under the shelf can be explored or exploited, an environmental impact statement must be prepared, as mandated by the National Environmental Policy Act of 1969. The Bureau of Land Management (Department of Interior) was given jurisdiction of the outer continental shelf by the Outer Continental Shelf Lands Act of 1953, and is responsible for producing the impact statement. The BLM enlisted the technical, logistic, and administrative assistance of the National Oceanic and Atmospheric Administration (NOAA), which set up the Outer Continental Shelf Environmental Assessment Program (OCSEAP) office to contract, manage, and coordinate the research projects needed to provide the information for the preliminary and final environmental impact statements.

One of the proposed areas to be leased for offshore oil exploration lies on the outer shelf just east of Kodiak Island. The Kodiak lease area has a diverse and abundant flora and fauna, and supports some of the most important domestic and foreign fisheries in the north Pacific. Many commercial and non-commercial species depend on the estuarine nearshore and pelagic habitats along the Kodiak coast for spawning, juvenile rearing, or feeding, and therefore these habitats and their biota have received much attention in the OCSEAP research effort. This project was designed to provide qualitative baseline information on the finfish inhabiting the nearshore and pelagic habitats of three representative bays on the east and south coasts of Kodiak Island. The information will be used by OCSEAP/BLM in making decisions with respect to petroleum resource exploration of the Kodiak lease area.

Our specific goals, pursuant to OCS Task Nos. A-7, A-8, A-9, and A-11, were to determine (1) the species composition of the pelagic and nearshore ichthyofauna of the three bays, (2) relative abundance by species, (3) age composition of the populations of major species by means of length frequency analysis, (4) food habits of abundant or otherwise major species, and (5) seasonal and diel migrations and changes in distribution.

This project is complemented by a similar study of the demersal fishes in the same area by the Alaska Department of Fish and Game (OCSEAP Research Unit No. 486). The most complete picture of the island's estuarine fish fauna will necessitate review of both studies.

CURRENT STATUS OF KNOWLEDGE

A fair amount of exploratory research has been done on the demersal fauna inhabiting the bays and banks around Kodiak Island, but there is very little published literature on the nearshore and pelagic estuarine fishes of the island.

Rutter's (1898) paper is certainly one of the first accounts of intertidal fishes on Kodiak Island, although most of the effort in that study was on the outer, exposed coast on the west side. His paper is a list and description of several intertidal fishes, primarily cottid species, which he encountered near Karluk and in Uyak and Alitak bays. Very little ichthyological survey work took place in the Gulf of Alaska after the frequent expeditions around the turn of the century. The next comprehensive study of Kodiak intertidal fishes to our knowledge was by Hubbard and Reeder (1965a,b), who examined 71 samples from several bays on the east side of the island. They documented several range extensions and concluded from their results that the intertidal fish fauna of Kodiak Island is more similar to that of northern Washington and British Columbia than to that of the Aleutian chain and the Bering Sea.

To our knowledge, there is no published literature on the subtidal, littoral fishes of Kodiak Island.

The midwater habitat of the island's estuarine bays has not been studied, but the epipelagic zone at least has been sampled repeatedly. Each summer since 1963 FRI personnel have sampled by a surface tow net several large bays on Kodiak and Afognak islands (including the bays surveyed in the present study) to monitor the abundance and distribution of juvenile pink salmon (Tyler, 1972, and unpublished ms.). The intent has been to use juvenile abundance to forecast the size of the adult run one year later. Other fishes were noted in these studies, especially the abundant ones such as juvenile greenling, Pacific sandfish, and capelin. Juvenile greenling were often found in close association with young pink and chum salmon. Gosho studied the food habits of pink and chum salmon and juvenile greenling caught in the 1971 townet sampling of Kiliuda and Alitak bays (Gosho, 1977, and unpublished data).

Considerable information on the timing of salmon runs to the Kodiak-Afognak area has come from aerial stream surveys conducted since 1952 by Fisheries Research Institute personnel (*see* Bevan, 1950 for earlier information, and annual stream survey reports in FRI Circulars starting with Bevan, 1953). The Karluk sockeye salmon population has been extensively studied through tagging projects and stream surveys. A study by Rich and Morton (1929) showed that most of the sockeye salmon tagged near Uganik Bay were bound for the Karluk River, and that the mean rate of travel in the last leg of the spawning migration was 10 to 15 miles per day. Major tagging experiments in 1948 and 1949 on the sockeye salmon on the west side of Kodiak Island, designed largely to provide estimates of run size, provided information on migratory routes and timing in the immediate Kodiak area (Bevan, 1959). A tagging study of Olga Bay sockeye salmon by Barnaby and DeLacy (Bower, 1940) indicated a one- to two-week lag between when the fish are encountered at the mouth of Moser Bay (northwest corner of Alitak Bay) and their arrival at the stream weirs around Olga Bay.

DESCRIPTION OF THE STUDY AREA

Kodiak Island is a southwestern extension of the Kenai Peninsula and has a mostly mountainous terrain and a "highly dissected, fiord indented, rugged coast" (AEIDC and ISEGR, 1974). There are stretches of sandy shoreline on the southwest coast but most of the shoreline is perhaps best described as a drowned glacial erosion coast (Shepard, 1973) featuring numerous estuarine bays extending deep into the interior. Climatologically, the Kodiak area is mild for its latitude and moist (mean monthly temperatures at Shearwater Bay range from 30.2 F in December to 54.0 F in August, mean annual precipitation is 97.9 in at Shearwater Bay and 54.4 in at Kodiak; data from Environmental Data Service, NOAA). Marine ice forms only locally in bays during periods of exceptionally cold weather (Nybakken, 1969).

The dominant circulatory feature in the area is the Alaska Stream which flows in a south-southwesterly direction at about 25-75 cm/sec at the shelf break 60-80 km off the east coast of the island (AEIDC and ISEGR, 1974). The inshore circulation is poorly known, but is determined mostly by the complex interaction of tidal fluctuations (2.6 m mean diurnal range at Kodiak; National Ocean Survey, 1976) and geomorphology, and any westward drift or suspected eddy from the Alaska Stream.

The Kodiak Island region is very productive biologically, and its many and diverse fisheries make it one of the most important seafood producing areas in the nation. The east and south coasts contribute greatly to the overall production and should be considered especially important in light of the proposed oil lease areas just north, east, and southeast of the island.

We selected Ugak, Kaiugnak (including Kiavak Bay) and Alitak bays to be our study area as they are quite different from each other in size and morphology but together well represent most of the estuarine habitats on the east and south coasts of the island (Fig. 1). Ugak Bay is about 35 km long and gradually narrows to form a very protected and diverticulate head. Most of the shoreline is precipitous or at least steep, with solid rock faces, boulders, rubble, or cobble comprising the intertidal substrate. Beaches that terminate gentler slopes and beaches near river mouths have muddy (only at the head of the bay), sandy, or black gravel substrate. The neritic zone is narrow in most places since the subtidal bottom is submarine mountainside. In a few bights and harbors alluvial deposits have formed fairly wide banks and shelves. The inner region of Ugak Bay attains a depth of about 97 m, and is separated from the outer bay by a narrow sill 33 m deep extending across the bay from Saltery Cove. The outer region of the bay has a maximum depth of 104 m. Kaiugnak Bay is basically similar to Ugak Bay except that it is only 15 km long and hence more exposed to the ocean, and includes two large lagoons. The bottom of Kaiugnak Bay is quite irregular, but has no sill to make the bay a true fjord. The maximum depth is 123 m at the mouth, and the mean depth near the middle of the bay is about 80 m. Alitak Bay is much larger than the other bays, opens on the south side of the island, and has a considerably more complex shoreline and bottom topography. The exposed eastern shore consists of rubble, rocky bluffs and a few sand and gravel bights. The west side of Alitak is shallow and has many islands, reefs, and small, protected bays. Alitak Bay is only about 46 m deep at the southeast corner of the mouth, and reaches a maximum depth of about 181 m in the long, deep trough forming Deadman Bay. The bottom contour is irregular and features two large reefs near the middle of the bay.

FIELD METHODS

Gear, Sampling Methods and Locations

We sampled the pelagic and nearshore zones of the bays with five types of fishing gear, each considered appropriate for a particular genre of habitat. The pelagic zone was sampled by a midwater herring trawl in the mesopelagic and lower epipelagic zones, and by a tow net in surface waters. A beach seine was used to sample the intertidal zone, and a try net (small otter trawl) and trammel nets were used in the subtidal littoral region. The try net sampled the smooth-bottomed banks and shelves, and the trammel nets were set off rocky bluffs, amidst boulders, and in kelp beds to sample habitats unworkable by active gear. Detailed descriptions of these gear follow.

1) The tow net was 14.9 m long, 6.1 m wide and 3.1 m deep at the mouth, and made from green nylon. The stretch mesh sizes were 7.6 cm at the mouth, 3.8 cm and 1.9 cm in the body, and 0.64 cm in the last 5.6 m of the net. The codend had a zipper for opening and closing, and the foot rope and head rope had leads and floats, respectively, to ensure proper opening of the net. The net was attached to two vertical steel poles, and a 6.8 kg weight and a large float were attached to each pole near the foot rope and head rope connections, respectively. Towing bridles were 9.2 m long. This net is designed to be towed between and behind two boats to avoid propeller wash.

2) The Marinovitch herring trawl was 27.5 m long, 6 m wide and 5 m deep at the mouth, and made from black nylon. The stretch mesh sizes were 7.6 cm in the wings, 6.4 cm in the throat, 5.1 cm and 3.8 cm in the body, and 1.3 cm in the codend. The 1.53 x 2.14 m steel V-doors were attached to the trawl via 55 m steel cable bridles. A standard warp formula of 2.25 times desired depth + 7.3 m was used.

3) The beach seine was 47.3 m long by 3.05 m deep at the ends, and by 4.4 m deep at the middle. Stretch mesh sizes graduated from 3.2 cm in the outer 14.9 m panels, to 1.0 cm, and finally to 0.3 cm in the innermost partial bag, 3.9 m wide. Sufficient floats and 56.2 gm leads were present to keep the net on the bottom and the float line from sagging below the surface. Netting was white knotted nylon in the outside mesh and green knotless nylon in the inner three panels.

4) The try net was 6.1 m long, 3.3 m wide and 0.76 m deep at the mouth, and made from green knotted and knotless nylon. Stretch mesh sizes were 3.8 cm in the throat and body, 2.9 cm in the 1.8 m long codend, and 0.64 cm in the codend liner. Four 12.7 cm diameter floats and a tickler chain were affixed to the head and foot ropes, respectively, in turn attached directly to the 0.61 x 0.33 m steel and wooden otter doors. A 7 m bridle connected the doors to

a swivel at the end of the towing cable, and a 6.8 kg lead ball was attached near the swivel to help keep the net on the bottom. A standard warp formula of 4 times desired depth + 7.3 m was used.

5) Each trammel net was 45.7 x 1.8 m with 51 cm stretch mesh in the two outer panels and 5 cm mesh in the loosely hanging inner panel. Material was green knotted nylon. The lead line was 1.27 cm diameter leadcore rope, and four floats were evenly spaced along the polypropylene float line. The two nets were shackled together in an L-shape, with one end tied to shore, a 7.3 kg anchor at the right angle, and a small Danforth anchor at the outer end.

Field sampling took place during four cruises. The first cruise (May 21 - June 3, 1976) was on the R/V Commando, a 20.4 m fisheries research vessel maintained by the College of Fisheries, University of Washington. The Commando is equipped with radar, loran, and a Simrad EH2 echosounder which was used during trawling. The beach seine and midwater trawl were the only types of gear available in the first cruise. The second cruise (June 16 - June 30) was on the 12.8 m commercial purse seiner M/V Dutch Girl, also equipped with radar and a Simrad echosounder. All gear types were used during the second cruise except the midwater trawl, which could not be set from the seiner. All five gear were employed in the last two cruises (July 15 - August 7 and August 25 - September 16), again on the R/V Commando.

Midwater trawl hauls were usually ten minutes in duration, and were about 1.3 km long. In the first cruise the midwater trawl was fished also on the surface since the tow net was not available. Trawling transects and stations were selected to represent all major morphological features of the bays (arms, bights, troughs, etc.). Additional sets were made in cruise 1 when the echosounder indicated large or numerous traces. Trawling depths were in 9 or 18 m increments, and were decided largely in advance. A slight modification toward proportional sampling seemed warranted on the basis of early catches and echosounding information, which indicated more fish in the deeper strata (within about 30 m from the bottom). All cruise 1 stations except one were repeated and a few more were added in subsequent cruises. The original trawl depths of cruise 1 were generally repeated in cruises 3 and 4, although in both later cruises a few stations were sampled randomly with respect to depth. Midwater trawling was done in all daylight hours, and four nighttime sets were made in Ugak Bay during the third cruise.

We townetted in cruises 2-4 by towing the net on the surface between the large boat and an outboard skiff or a diesel-powered purse seine skiff. At the end of a ten minute tow, covering about 0.74 km, the entire net was hoisted on board the large boat for emptying. To allow valid comparison of our results with past FRI tow net data from these bays, we duplicated past methods closely. This included using many of the transects and stations of past projects, and sampling at night in Ugak and Kaiugnak bays and in day in Alitak Bay. In the fourth cruise (early September) a few experimental nighttime tows were made around Cape Hepburn in Alitak Bay as well.

The try net was towed from the Dutch Girl in cruise 2 and from the diesel-powered seine skiff with help from a Model 8274 12-v Warn winch in the last two cruises. Try net sites were selected in cruise 2 on the basis of smooth and workable substrate, habitat type, and location in the bays. Trawl depths of 4, 9, and 13 m were maintained by an echosounder or sounding line. Tows were ten minutes long and covered about 0.46 km depending on the force and direction of wind and current. Try net sampling was diurnal.

The trammel nets and beach seine were set from a 4.6 m Delta Marine fiberglass skiff. The trammel nets were set off rocky bluffs and/or in kelp beds, usually near beach seine and try net sites. The two trammel nets were always set together, one attached to and perpendicular to shore, and the other attached to the first but parallel to shore. Sets were 10, 5, and 2.5 hrs long in cruise 2, and almost always 2.5 hrs long in subsequent cruises since the shorter sets produced adequate samples. Trammel net sets were mostly diurnal. The beach seine was set by anchoring one end to shore and laying the net out from the skiff to form a semicircle. As the arc was closed, the seine was manually pulled to shore. Seine sites were selected to represent as many intertidal habitats as feasible, and while many stations were sampled repeatedly during the summer, a few spot sets were made in each cruise to represent especially interesting habitats and to prevent the systematic neglect of major intertidal community variations. Seine sites included weedy, soft-bottomed habitats near the heads of bays, and protected and exposed sandy, gravel, and cobble beaches.

Figures 2-5 show sampling transects and stations for all gear types, although not all stations shown were sampled in each cruise. Table 1 presents the number of sets and standard hauls (defined in Methods of Analysis) for each gear type in each bay and cruise.

Processing Catches

Catches were sorted to the finest taxon feasible, usually to species. Specimens tentatively identified were saved for later laboratory examination.

In most cases we recorded the predominant life history stage of each species present in a haul. "Larvae" was recorded for fish thought not to have fully metamorphosed from the postlarval stage. "Juvenile" signified young of the year for gadids, gasterosteids, hexagrammids, trichodontids, *Oncorhynchus gorbuscha*, and *O. keta*, smolts and immatures for *O. nerka* and *O. kisutch*, and especially small individuals for *Salvelinus malma*. Pleuronectids under about 150 mm were arbitrarily called "juvenile" since we could not always distinguish young of the year and since 150 mm was the size above which sexes were usually distinguishable. This length may not be attained until the third year or so, depending on species. For most other species "juvenile" was recorded for fish in the smallest one or two apparent length classes. "Adult" was recorded for other specimens, and obviously our use of the term does not necessarily connote sexual maturity.

Usually the catches were entirely sorted and counted. Our pelagic sampling and beach seining, however, frequently yielded large catches of small fish, and in those cases a volumetric estimation of numbers was made.

Species represented in small numbers were first separated and counted directly. Then a single random subsample was chosen to displace exactly 200, 500, or 1000 ml of water, depending on the size of the fish. Fish in the subsample were counted by species and usually retained for length measurements. The volume of the remaining catch was found by water displacement, and thereby catch in numbers of each species could be estimated proportionately. This technique was also employed when fish were inextricably mixed with large quantities of shrimp or jellyfish.

With few exceptions total length measurements (in mm) were recorded for all fish or a subsample of fish from every haul. When subsampling we attempted to obtain measurements from the full range of sizes present in the catch, although we did not practice truly proportional subsampling.

Stomachs were taken from selected fish which had been injected with 10% formalin immediately after capture or from uninjected fish caught within one hour to prevent excessive post-capture digestion. Stomachs were labelled, tied to prevent loss of contents, and after fixation they were transferred to 40% isopropyl alcohol. Small fish saved for food habits analysis were preserved whole, after slitting the abdominal cavity, and dissected later.

Physical Measurements

Temperature and salinity were the principal physical variables measured. Surface temperatures (± 0.1 C) were read from a protected laboratory thermometer, an unprotected reversing thermometer, and from a Beckman R55-3 induction thermometer/salinometer. Midwater temperatures were taken by a bathythermograph in cruise 1, and by the Beckman salinometer in cruises 3 and 4. Nearshore salinity samples were returned to Seattle after cruises 1-3 and were there analyzed with a UW-PNL electrode salinometer (± 0.1 ppt). The Beckman salinometer gave all measurements of pelagic salinities in cruises 3 and 4.

LABORATORY METHODS

Laboratory work consisted of specimen identification and stomach content analysis. Specimens which were unidentified or tentatively identified in the field were examined later in the laboratory. We used several published and unpublished keys and taxonomic descriptions, and tried to identify each specimen to the species level. Our identifications of juvenile and adult forms are very reliable, but larval identification received no special effort and should be viewed accordingly.

Stomach samples were transferred from formalin to 40 percent isopropyl for storage before examination. The contents of each stomach were examined separately to give as much detailed information as possible. The fullness of the stomach and the percent digestion of contents were first judged according to interval scales. Total wet weight of contents (±.01 g) was taken, and then each prey category, consisting of a taxon/life history stage combination, was counted directly or estimated by subsampling, and weighed (±.001 g). The extent of taxonomic indentification varied, and was dependent on the degree of digestion, the general taxon, and the life history stage. Most prey were identified to class, order, or suborder.

METHODS OF ANALYSIS

We analyzed catch data in terms of catch per unit of effort (CPUE), and data from each gear type were analyzed separately to avoid making fallacious assumptions about relative efficiencies of the gear. To show distributional trends various regions within the bays were defined to correspond to major ecological or hydrographic features such as head of the bay, protected inlets, and exposed rocky shore (Fig. 2-5). Calculating mean CPUE values for various regions loses some precision compared to a station-by-station analysis, but it suffices to show the major distributional features and permits figures which are readily interpretable and unoccluded by often enormous sampling variability. Ugak Bay was divided into three regions (inner, middle, and outer) graduating from the protected, narrow head of the bay to the open and more exposed outer section. Kaiugnak Bay was divided into two similarly conceived regions (inner and outer). The nearshore zone of Alitak Bay was divided into four regions for analysis: 1) Deadman, 2) eastside, representing the rocky exposed beaches of the east side of the bay, 3) westside, consisting of the protected Moser and Kempff bays, and 4) Tannerhead, a shallow-profile, exposed sandy beach. The pelagic zone of Alitak Bay was broken into five relevant regions: 1) Deadman, 2) Hepburn, of particular interest because of its typically large concentrations of juvenile pink salmon, 3) westside, consisting of the several protected inlets, 4) middle, and 5) outer.

For each combination of cruise, region, and gear type the total catch of a species was divided by the appropriate number of standard hauls to arrive at the CPUE values. For the midwater trawl, tow net, and try net a standard haul was defined as one ten minute tow. A single set comprised one beach seine standard haul, and one 2.5-hr set of both trammel nets comprised one standard trammel net haul. For the few longer trammel sets, the number of standard hauls was simply the number of multiples of 2.5, ignoring any relation between set length and catchability.

RESULTS AND DISCUSSION

Distribution and Abundance

Appendix Table 1 provides a checklist of the 70 species caught in this study and their relative abundances and where and when they were caught. Appendix Tables 2-52 summarize all catch data in terms of catch per unit of effort (CPUE; mean number of fish/haul) of each species in the various regions of the bays, and these tables are arranged by bay, gear type (= habitat), and cruise. The salient results of this CPUE breakdown are presented visually via maps (Figures 6-23) showing geographical and temporal trends in relative CPUE of major species. The lengths of the bars on the maps reflect relative CPUE, and for each map the highest CPUE pictured is given for standardization.

Each bay is discussed separately, and a fourth section summarizes important results and compares and contrasts findings from the three study bays.

Ugak Bay

Surface: The surface waters of Ugak Bay contained, in order of decreasing relative abundance, large numbers of capelin (*Mallotus villosus*), Pacific sandfish (*Trichodon trichodon*), Pacific sand lance (*Ammodytes hexapterus*; almost only in cruise 1), and age-0 pink salmon (*Oncorhynchus gorbuscha*). Capelin were represented by all life history stages, although mature (i.e., sexually dimorphic) adults were rare and present only in the first two cruises. Capelin were most abundant in the inner two-thirds of the bay, especially in the middle region and that part of the inner region east of about 152°53" (Fig. 6A). The apparent decline of overall mean CPUE of capelin from 591.5 fish/haul in cruise 3 to 55.9 fish/haul in cruise 4 (cf. Appendix Tables 3 and 4) cannot be explained by distributional changes, as the midwater sampling in cruise 4 showed that large numbers of juvenile capelin were still in the bay at that time. It possibly reflects a seasonal change of depth distribution, however.

Age-0 sandfish were caught on the surface in very small numbers in cruises 1 and 2, but in great abundance later (Fig. 7A). This suggests that there might be an influx of larval and/or juvenile sandfish into the bay in early July, but we cannot dismiss the possibility that increasing susceptibility to capture concomitant with growth was primarily responsible for the suddenly large catches in later summer. Juvenile sandfish were most abundant in the outer region of Ugak Bay.

The lack of townetting in cruise 1 hampers our study of epipelagic residence by juvenile pink and chum (*O. keta*) salmon. However, the several surface hauls made with the herring trawl indicated that some juvenile pinks were in the pelagic zone as early as late May (Appendix Table 5). Townetting in cruise 2 (late June) produced greatest numbers of pinks in the middle part of the bay (Fig. 8A), although the overall mean catch then was only about 1.5 fish/haul. In late July juvenile pinks were still mainly in the middle region of the bay, but the overall mean catch was near 13 fish/haul. In the fourth cruise (late August) the mean CPUE dropped to 5.7 fish/haul, which may be explained by outmigration or by greater gear avoidance concomitant with larger size, or both. Fig. 8A shows that in cruise 4 catches of young pink salmon increased toward the mouth of the bay, offering strong evidence that the fish were in the process of migrating out from the bay. Surface catches of young chum salmon were neither large nor consistent enough to permit similar inferences about distributional changes with time; the overall catch of age-0 chum salmon was about 40% that of pinks, and most of that catch was from a single haul.

Other salmonid species found in the surface waters were, in order of decreasing CPUE, coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), and, incidentally, Dolly Varden (*Salvelinus malma*). The coho and sockeye salmon were caught in cruises 2-4, and had obviously smolted and entered marine waters the immediately past spring.

The surface trawling in cruise 1 indicated a considerable abundance of larval and juvenile sand lance (*A. hexapterus*) in the inner and middle regions of the bay (Appendix Table 5). Interestingly, this species was only incidental in surface catches in later cruises.

Other species caught regularly on the surface were postlarval and/or juvenile yellow Irish Lord (*Hemilepidotus jordani*), age-0 greenlings (*Hexagrammos* spp.), and age-0 threespine stickleback (*Gasterosteus aculeatus*). The juvenile greenling could not be identified to species in the field, but subsequent laboratory examination proved these to be white-spotted greenling (*H. stelleri*) and masked greenling (*H. octogrammus*). Other incidental but notable surface catches were mainly juveniles of snake prickleback (*Lumpenus sagitta*), black rockfish (*Sebastes melanops*), Pacific herring (*Clupea harengus pallasi*), walleye pollock (*Theragra chalcogramma*), silverspotted sculpin (*Blepsias cirrhosus*), soft sculpin (*Gilbertidia sigalutes*), tubenose poacher (*Pallasina barbata*), and Bering wolffish (*Anarhichas orientalis*).

Midwater zone: Capelin and, in the last two cruises, sandfish were by far the most abundant species throughout the water column of Ugak Bay (Appendix Tables 6-8). As in the surface stratum, capelin were consistently most abundant in the inner and middle regions (Fig. 10A). Analyzing the diurnal catches by depth showed capelin to be present in all depth strata (incremented 9-20 m, 21-60 m, 61-100 m), with density generally increasing toward the bottom (Table 2A).

The midwater trawl first encountered juvenile sandfish in the third cruise (late July), although their earlier presence in the bay was verified by surface trawling. Sandfish occurred throughout the bay, but an exceptionally large catch was made in five hauls in the outer region in late August (Fig. 11A). Like the capelin, sandfish were distributed all through the water column but with highest densities in the deepest (61-100 m) stratum (Table 2A).

Larval, juvenile, and small adult sand lance occurred in the mesopelagic zone as well as on the surface in cruise 1, but subsequent midwater sampling yielded only incidental numbers (Fig. 12A). Sand lance were found principally in the inner two-thirds of the bay.

Other midwater species were also represented almost only by juvenile forms. Midwater salmonid catches were negligible, and considering that 19.5 standard midwater trawl hauls were made in the 9-20 m stratum over the summer, the data verify that juvenile salmon are surface dwellers. Larvae and juveniles of the yellow Irish Lord comprised the most abundant midwater cottid form, followed in order of decreasing abundance by *Triglops* sp. (probably *T. pingeli*), *B. cirrhosus*, *B. bilobus*, and *G. sigalutes*. Other incidental catches were larval and/or juvenile bathymasterids, walleye pollock, and snake pricklebacks.

The four nighttime midwater trawl hauls in the third cruise yielded capelin and sandfish but also juvenile and adult flathead sole (*Hippoglossoides elassodon*), rock sole (*Lepidopsetta bilineata*), snake prickleback, and adult ribbed sculpin (*T. pingeli*). In one night tow near Eagle Harbor the echosounder indicated a large aggregation over twenty meters deep and at least as long as the tow (1.3 km); the catch was almost entirely juvenile capelin. Daytime echosounding traces were invariably small and patchy, and usually turned out to be aggregations of invertebrates, principally Euphausiacea and Hyperiidea.

Nearshore zone: In terms of CPUE alone, the sand lance was by far the most abundant species in the intertidal zone. Sand lance were distributed throughout the bay, with highest densities apparently in the middle region (Fig. 13A). In each cruise almost the entire catch came from a very few hauls, substantiating that sand lance occur in dense schools or aggregations. They occurred most often over black sand and small gravel substrate, and in all tide stages.

Juvenile pink and chum salmon were also dominant intertidal species in the early part of the season (Appendix Tables 9-12). In late May they were mostly near the mouths of streams, although since we could not seine along the precipitous shoreline between bights and major streams, we cannot say how dispersed along the shore the young salmon may have been. The largest juvenile pink salmon catches in late May were from the head of the bay (including Hidden Basin), Saltery Cove, Eagle Harbor, and from Pasagshak Bay. As found for sand lance, young salmon were distributed along the shore in dense schools. Pink and chum salmon were usually found schooled together (at least they were frequently caught in the same hauls), and pinks generally outnumbered chums severalfold at least. Juvenile salmon catches generally declined through the summer, although one beach seine site in the northwest corner of Eagle Harbor was found to have a consistently large concentration of salmon fingerlings (Fig. 2 and 14A). In cruises 2 and 3 a large catch of both species was made at that site, and the third cruise catch of 10,000 was probably greatly underestimated. (The entire catch was released). Adult pink and to less extent chum salmon were encountered only in late July near the mouths of major streams.

Other salmonid species occurring in the intertidal zone included sub-adult and adult Dolly Varden, a few sockeye and coho smolts, and small numbers of coho fry (Appendix Tables 9-12). We suspect that the coho fry were somehow displaced from their usually lotic habitat. Dolly Varden were caught mostly in aggregations near the mouths of streams, especially along the south shore of the inner region and in Pasagshak Bay (Fig. 16A).

While the intertidal catches of juvenile salmon declined greatly by late July (except for the Eagle Harbor concentration just mentioned), juvenile greenling (*H. octogrammus* and *H. stelleri* mostly, and apparently fewer *H. lagocephalus*) were moving inshore where they metamorphosed from pelagic to littoral residents. This was first noticed in mid-June, but especially in late July greenling were caught in all stages of transition from the pelagic morph (countershaded, forked caudal fins) to the littoral morph (square caudal fins and typical adult markings and coloration). Greenling catches, consisting mainly of juveniles, increased throughout the summer (mean CPUE values were 0.3, 0.4, 3.9, and 4.6 fish/haul in cruises 1-4, respectively), and all three species were found mostly over small rock substrate covered with *Fucus* and/or *Ulva*.

Juvenile great sculpin (*Myoxocephalus polyacanthocephalus*) comprised the dominant intertidal cottid species, and they were most abundant in the inner region of the bay (Fig. 17A). In the first cruise many of these were around 20 mm total length and were surely young of the year. Silverspotted sculpin (*B. cirrhosus*), staghorn sculpin (*Leptocottus armatus*), padded sculpin (*Artedius fenestralis*), *Gymnocanthus* spp. (*G. galeatus* and *G. pistilliger* were several times identified, but specimens were recorded only to genus), and yellow Irish Lord were common in beach seine catches. Of ichthyological interest, two specimens of *Porocottus quadrifilis* were caught in the same haul, one fish being ochre and the other bright green.

Other intertidal catches included surf smelt (*Hypomesus pretiosus*), found only in Pasagshak Bay, largely young-of-the-year and juvenile pleuronectids (mostly rock sole, *L. bilineata*, but also starry flounder, *Platichthys stellatus* and sand sole, *Psettichthys melanostictus*), crescent gunnel (*Pholis laeta*), tubenose poacher (*P. barbata*), capelin (almost all of the adults were caught in late May), snake prickleback, herring larvae in late August, and threespine stickleback.

Subtidal catches were dominated by yellowfin sole (*Limanda aspera*), rock sole (*L. bilineata*), and snake prickleback (*L. sagitta*) in the try net, and by adult greenlings (*Hexagrammos* spp.), rock sole, adult sturgeon poachers (*Agonus acipenserinus*), and adult herring in the trammel nets. The principal try net catches of snake prickleback were in Saltery Cove and especially in Pasagshak Bay (Fig. 18A). Yellowfin sole were trawled mainly in the inner two-thirds of the bay, while rock sole catches generally increased toward the mouth of the bay (cf. Figs. 19A and 20A). Table 3 shows a consistent tendency for highest rock sole catches in the shallower water and highest yellowfin sole catches in the deeper littoral zone.

Despite the constant problem of kelp clogging the opening of the try net, nearshore trawling produced the greatest species richness of all gear types employed (Appendix Tables 13-15). Other notable try net catches were butter sole (*Isopetta isolepis*, almost only from Pasagshak Bay), juvenile and small adult greenlings, juvenile halibut (*Hippoglossus stenolepis*), and several species never seen in beach seine catches, including ribbed sculpin (*T. pingeli*), plain sculpin (*Myoxocephalus jaok*), Alaska plaice (*Pseudopleuronectes quadrituberculatus*), Alaskan ronquil (*Bathymaster caeruleofasciatus*), Bering poacher (*Occella dodecaedron*), and Aleutian alligatorfish (*Aspidophoroides bartoni*).

The trammel nets produced especially large catches of masked greenling (*H. octogrammus*), rock greenling (*H. lagocephalus*), and whitespotted greenling (*H. stelleri*), in order of decreasing relative CPUE. These species were distributed throughout the bay, and all three species were caught in most sets, suggesting a considerable overlap of habitat (Fig. 21A, 22A, and 23A). Whereas yellowfin sole were more abundant than rock sole in try net catches, the reverse was true for trammel net catches (Appendix Tables 16-18). Interestingly, large adult herring were caught by the trammel nets throughout the summer, and almost the entire catch came from the Pasagshak Bay site. Uncommon but noteworthy species in trammel net sets were red Irish Lord (*H. hemilepidotus*), kelp greenling (*Hexagrammos decagrammus*; only in the last cruise), and antlered sculpin (*Enophrys diceraus*).

Kaiugnak Bay

Surface: The capelin was by far the most abundant species in the epipelagic zone of Kaiugnak Bay, followed by sand lance, sandfish, and in incidental numbers by age-0 *Hexagrammos* spp., pink salmon, and others (Appendix Tables 19-22). Sand lance of all life history stages were caught mainly in late May (in the surface trawl), and in small numbers in late June. Capelin were caught all through the bay in all cruises, although catches in early September were very small (Fig. 6B). Sandfish were caught only in the last two cruises (Fig. 7B). Interestingly, juvenile pink salmon were relatively uncommon in Kaiugnak Bay; only 11 fish were caught during the entire summer. Other surface catches included sockeye salmon smolts (undoubtedly immigrants from another estuary system since there is no lacustrine habitat in the drainage immediately around Kaiugnak Bay), tadpole sculpins (*Psychrolutes paradoxus*), juvenile prowfish (*Zaprora silenus*), threespine stickleback, and juvenile rock and flathead sole.

Midwater zone: In late May sand lance comprised the dominant mesopelagic species, albeit in small numbers (Fig. 12B, Appendix Tables 23-25). In subsequent cruises, however, capelin and sandfish were the only common midwater species. Capelin and sandfish were distributed throughout the bay, and sandfish were especially abundant in the outer bay in early September (Fig. 10B and 11B). Both capelin and sandfish tended to be most abundant in the deeper strata, although because each depth stratum is represented by only one or two hauls, Table 2B also shows a considerable catch variability. Besides capelin, sand lance, and sandfish, only larval and/or juvenile yellow Irish Lord, snake prickleback, walleye pollock, prowfish, bigmouth sculpin (*Hemitripterus bolini*), and unidentified postlarval bathymasterids were found in the midwater habitat (Appendix Tables 23-25).

Incidental catches of crustacea were generally higher in Kaiugnak Bay than in Ugak Bay. Large zooplankters retained in the midwater trawl and tow net were Euphausiacea, Hyperiidea, decapod zoea, at times large quantities of small shrimp (*Pandalus borealis* and/or *P. hypsinotus*), and many hydrozoan medusae and scyphozoans.

Nearshore zone: Sand lance overwhelmingly dominated intertidal catches all through the summer, and were especially abundant in the inner region of the bay over small gravel and sand substrate (Fig. 13B). As before the huge variability of sand lance catches reflected a highly clustered distribution. Juvenile pink salmon were next in abundance, and were caught chiefly on the exposed side of the spit enclosing the lagoon at the head of Kiavak Bay (Fig. 3 and 14B). Catches of juvenile salmonids declined sharply by late July, and none were caught in early September (Fig. 14B and 15B). Adult pink and in less abundance chum salmon were caught in late July in aggregations near a small stream feeding the head of the bay and near the Kiavak lagoon. A large number of juvenile sandfish occurred in beach seine catches, although most of these were from a single set in moderate surf on the north shore of the outer region (Fig. 3). Juvenile great sculpin comprised the bulk of intertidal cottid catches, and were most abundant in the more protected inner region of the bay (Fig. 17B). Juvenile greenling catches increased over the summer, and as in Ugak Bay masked greenling were most abundant followed by whitespotted and rock greenling (Appendix Tables 26-29). There were especially many juvenile greenling in the Kiavak lagoon, where the substrate was small rocks heavily covered with *Fucus*. Sexually dimorphic capelin were seined only in late May at a sandy beach at the head of the bay. Other beach seine catches were young-of-the-year threespine stickleback, silverspotted sculpin, tubenose poacher (*P. barbata*), crescent gunnel (*P. laeta*), a few Dolly Varden, and mainly juvenile rock sole and starry flounder.

The try net was used at three sites in Kaiugnak Bay, and only at the Kiavak site (Fig. 3) was sampling generally unimpeded by kelp clogging the net. The snake prickleback (*L. sagitta*) was the dominant species in try net catches, although only in cruises 2 and 3 and only in the outer region of the bay (Fig. 18B). Pleuronectids were next in abundance, and rock sole were consistently more abundant than yellowfin sole (Appendix Tables 30-32). The yellowfin sole was more evenly distributed through the bay than was the rock sole, which was caught almost only in the outer region (Fig. 19B and 20B). Analyzing try net catches by depth failed to indicate any consistent trends in depth utilization by rock sole and yellowfin sole as were found in Ugak Bay, although the considerably smaller catches of both species in Kaiugnak Bay may pertain to this result. Pleuronectids encountered incidentally were sand sole (*P. melanostictus*), Pacific halibut (*H. stenolepis*), butter sole (*I. isopsetta*), and flathead sole (*H. elassodon*). The greenlings were second to pleuronectids in relative abundance, and the masked greenling was consistently the dominant hexagrammid. Greenling catches increased throughout the summer, reflecting recruitment of juveniles to the nearshore zone. A total of ten cottid species were caught by the try net, including *Gymnocanthus* spp., *Triglops* sp., red and yellow Irish Lord (*H. hemilepidotus* and *H. jordani*), silverspotted sculpin, three species of *Myoxocephalus*, and, interesting from a zoogeographical perspective, the manacled sculpin (*Synchirus gilli*). Other incidental try net catches were tubenose and sturgeon poachers, penpoint gunnel (*Apodichthys flavidus*), tubesnout (*Aulorhynchus flavidus*), and Arctic shanny (*Stichaeus punctatus*).

Rocky subtidal (i.e., trammel net) catches were mostly of adult masked, rock, and whitespotted greenling (Appendix Tables 33-35). All three species were abundant throughout the bay (Fig. 21B, 22B, and 23B). The rock sole was the only pleuronectid caught by the trammel nets in Kaiugnak Bay. Other noteworthy catches were adult black rockfish (*S. melanops*; only in the outer region), kelp greenling (again, only in the last cruise), great sculpin, and Alaska ronquil (*B. caeruleofasciatus*).

Alitak Bay

Surface: In terms of numbers alone, the capelin was by far the most abundant species in the epipelagic zone, although essentially all of these were larvae and small juveniles caught in a few hauls in the Hepburn region in mid-September (Appendix Tables 36-39). Interestingly, the larvae were caught in three diurnal hauls, and all of the juveniles were caught in a few nighttime hauls. Only one capelin was caught on the surface in other cruises, a marked contrast from the night catches from other bays.

Juvenile pink salmon were the most consistently abundant epipelagic residents, and were especially abundant in the lower Deadman region and in the Hepburn region (Fig. 8B). The diurnal pink salmon catches in Alitak were notably more variable than the nocturnal catches in Ugak Bay, evinced by several instances when catches of from several hundred to over a thousand fingerlings were preceeded or followed immediately by one to several empty hauls. The mid-September catches were drastically reduced relative to earlier levels (Appendix Table 38, Fig. 8B), making us wonder whether the negligible catches reflected outmigration or to some extent perhaps diurnal aversion of surface waters by the larger juveniles. Six nocturnal tow net hauls were made in the lower Deadman and Hepburn regions, and the total catch of only three juvenile pinks suggested that the fish were either staying below the surface throughout the diel period or had mostly left the bay, or perhaps both.

Juvenile greenlings were encountered more in Alitak Bay than in the other bays, and especially large catches were made in the outer region in late June (Fig. 9).

All other surface catches were incidental. Larval sand lance and bathymasterids were caught in late June, and other catches included a few juvenile chum, sockeye and coho salmon smolts, Dolly Varden, juvenile and adult threespine stickleback, yellow Irish Lords, black rockfish, juvenile tiger rockfish (*Sebastes nigrocinctus*) and lingcod (*Ophiodon elongatus*).

Midwater zone: The capelin was substantially more abundant than any other species in the mesopelagic habitat (Appendix Tables 40-42). Capelin were all through the bay, but the largest catches were from the inner two-thirds of the bay (Fig. 10C). The largest catches were generally from the sets nearest to the bottom, although this result is occluded in Table 2C since the bottom contour of Alitak Bay is very irregular and the table is incremented by depth and not by distance from the bottom.

The juvenile sandfish population of Alitak Bay is apparently small, as none were caught on the surface and only in the outer region in cruise 4 were any appreciable numbers caught by the midwater trawl (Fig. 11C).

Other common midwater species were slender eelblenny (*Lumpenus medius*), represented by larvae and small juveniles in mid-September, adult herring, sand lance (early in the summer), and, interestingly, Alaska eelpout (*Bothrocara pusillum*) which were found only in the deepest strata of the Deadman region (Table 2C). Seventy four juvenile pink salmon were caught in an 18 m set in the outer region in cruise 3, but it is distinctly possible that they entered the trawl from the surface at the start or end of the tow. Other midwater catches were a few juvenile greenling, adult and juvenile cottids, prowfish, and smooth lumpsucker (*Aptocyclus ventricosus*).

Nearshore zone: As in the other bays, the sand lance was the numerically dominant species in the intertidal zone of Alitak Bay (Appendix Tables 43-46); about 75% of the total catch came from a single haul on a sandy beach near Shag Bluff (about 56°56' N, 153°53' W) in mid-September (Fig. 13C).

Juvenile pink and chum salmon were abundant in late May at the head of Deadman Bay. Although chum salmon appear to have been more abundant than pinks, almost the entire catch of young chum came from a single haul. Juvenile pink catches were never as great as in the other bays (cf. Fig. 14A-C).

Other salmonid catches included Dolly Varden, again found mostly in aggregations near streams throughout the bay (Fig. 16B), recent smolts of sockeye and coho salmon, and adult pink salmon in the last two cruises.

Metamorphosing juvenile greenling were first seined in late June, and were quite abundant in the last two cruises (Appendix Tables 43-46). Predictably, the juvenile greenling were caught mostly over small rock and cobble substrate with profuse growths of algae. As in the other bays, juvenile masked and whitespotted greenling were much more numerous than juvenile rock greenling.

The dominant intertidal cottid was the great sculpin, represented mostly by young of the year and other juveniles in the more protected Deadman and westside regions (Fig. 17C).

Other intertidal catches were incidental, and were similar to those from Ugak and Kaiugnak Bays (Appendix Tables 43-46). Several nighttime seine sets at the head of Deadman Bay are noteworthy, as large juvenile (probably age 1) Pacific cod (*Gadus macrocephalus*) and pollock, and adult herring were caught, indicating nocturnal use of the immediately nearshore zone by these forms.

The try net sampling in Alitak Bay was greatly hampered by especially large growths of kelp in the few areas suitable for nearshore trawling. Unfortunately, no workable try net sites were found in the Deadman region.

The sand lance was the most abundant species caught by the try net in numbers alone, but the entire catch came from a single haul near Shag Bluff. Interestingly, that haul was offshore from and nearly simultaneous with the beach seine haul that yielded over 20,000 sand lance, suggesting that the aggregation was quite large.

The most consistently abundant subtidal forms were rock sole and juvenile and small adult greenlings (Appendix Tables 47-49). Pleuronectid catches were always highest in the western half of the bay, and particularly at the Tannerhead site for rock sole (Fig. 20C), sand sole, and juvenile halibut. The catches of yellowfin sole were noticeably depressed, but were also predominantly from the western part of the bay (Fig. 19C).

Appendix Tables 47-49 show again a consistent increase of greenling catches over the summer, attributable to the change from pelagic to littoral residence by juveniles. The masked greenling was again the most abundant hexagrammid.

The remaining try net catches were similar to the incidental catches from the other bays; *Gymnocanthus* spp., the great sculpin, shorthorn sculpin (*M. scorpius*), red and yellow Irish Lord, and *Blepsias* spp. were the principal cottid species, and the crescent gunnel, snake prickleback, and Arctic shanny (*S. punctatus*) comprised the blennioid fishes.

Trammel nets set over rocky substrate produced large numbers of masked, whitespotted and rock greenlings, in order of decreasing CPUE (Appendix Tables 50-52). Masked greenling were distributed all through the bay (Fig. 22C), but the rock and whitespotted greenlings seemed to be more stratified. Rock greenling were caught almost only in the eastside region (Fig. 21C), while whitespotted greenling were chiefly in the westside and particularly Deadman regions (Fig. 23C). In retrospect, the same trend for whitespotted greenling is seen in beach seine and try net catches (Appendix Tables 45-49).

Other trammel net catches included the usually small numbers of large juvenile cod and *Myoxocephalus* spp., but also in the fourth cruise the Atka mackerel (*Pleurogrammus monopterygius*) and decorated warbonnet (*Chirolophis polyactocephalus*). Five adult sockeye salmon were caught in the trammel net set in late June near the entrance to Olga Narrows (Fig. 5).

Summary, and Comparison of Bays

The principal pelagic fish fauna in all bays was: capelin, sandfish, juvenile pink salmon, and predominantly larvae and juveniles of sand lance, herring, stichaeids, bathymasterids, cottids, and scorpaenids.

Larval, juvenile, and adult sand lance were abundant in the pelagic zone of all bays in the early part of the summer, but catches declined to only incidental occurrences in the last three cruises (late June to September). This probably reflects a general shift to benthic and/or littoral habitats in midsummer, but some outward movement may occur as well. Bottom trawling by the Alaska Department of Fish and Game (ADF&G; OCS R.U. #486) produced almost no sand lance in Ugak and Alitak bays (Kaiugnak Bay was not sampled), suggesting that the population occupies mainly littoral habitats in later summer. However, the fish may have been unsusceptible to capture by the 400 mesh Eastern otter trawl used in that survey. Barraclough, Robinson and Fulton (1968) also found an early-summer decrease in pelagic larval sand lance catches in their tow net sampling of Saanich Inlet near Vancouver Island.

The capelin was the principal pelagic species in all bays, and was represented overwhelmingly by larval and (suspected) yearling fish. Very few sexually dimorphic fish were caught in the pelagic zone, especially in the later cruises. There is strong albeit indirect evidence for diel vertical movements of capelin. Large numbers were caught on the surface in nocturnal townetting in Ugak and Kaiugnak bays, while essentially none were caught in diurnal townetting in Alitak Bay (except for larvae in the last cruise only). The midwater trawl, however, proved that capelin were abundant in Alitak Bay. Further, the only surface catches of juvenile capelin in Alitak Bay were from the few nighttime sets around Cape Hepburn. The markedly low surface catches of capelin in the last cruise in Ugak and Kaiugnak bays suggest a seasonal change in depth utilization by capelin, since they were still very abundant in the midwater strata (cf. Fig. 6A and B).

A few postlarval and small juvenile sandfish were caught in late May and June, but by the latter half of the summer they comprised the second most abundant pelagic species in the study area. Interestingly, Alitak Bay seemed to have a smaller population of juvenile sandfish than the other bays, and the overall abundance sharply declined toward the southern half of the island (cf. Fig. 11A-C). The largest catches occurred in the mouths of the bays in the last cruise, which suggests concentration in the outer regions concomitant with movement out of the nursery bays. The bottom trawling by ADF&G yielded few sandfish in Ugak and Kaiugnak bays in June, but larger numbers in late summer (James Blackburn, unpublished ms.; personal communication). Also, the mean weight of sandfish decreased from 77 gm and 132 gm in June and July, respectively, to 9.5 gm in August, suggesting that juveniles were moving from pelagic to benthic habitats. There were also many more sandfish in Ugak Bay than in Alitak Bay in that study. Diel vertical migrations of juvenile sandfish are hinted by large catches in nocturnal townetting and null catches in diurnal surface sampling, but the

Alitak Bay population was so small that the null diurnal catches could be explained by sampling variability alone.

Juvenile pink salmon were abundant in surface waters in day and night in late June and early August, but were obviously moving out of the bays in late August to mid-September. The surface trawl in cruise 1 indicated at least a few juveniles in the pelagic zone of the bays as early as late May. The largest catches of juvenile salmon were from the middle region of Ugak Bay and from the lower Deadman and Hepburn regions of Alitak Bay in late June and late July. By mid-September Ugak Bay catches were highest in the outer region, suggesting ongoing outmigration, and Alitak Bay catches were negligible in day and night, suggesting that the fish had largely left the bay by that time. However, several unmeasured factors must be considered in interpreting our catch data, including:

1) the fish caught in outer Ugak Bay may have included some outmigrants from other bays,

2) the negligible catches in Alitak Bay may be partly due to a presumed low probability of intersecting diurnal schools in the expansive outer regions of the bay,

3) larger juveniles may prefer subsurface waters (i.e., below the footrope of the tow net) or otherwise easily avoid the gear in daytime.

There was evidence for more catch variability in our diurnal sampling than in nocturnal sampling, but we cannot separate differences due to bays. Tyler (1972) discusses diel effects on catch variability in more detail.

FRI has townetted several bays on Kodiak Island annually since 1963 to provide a forecast of pink salmon runs to the island. Sampling usually took place from late June to early August. In every year but 1975, the Hepburn/Portage Bay and lower Deadman regions of Alitak Bay have hosted large concentrations of juvenile pink salmon, evinced by catches of from several hundred to several thousand per 10 minute haul (Richard Tyler, Bob Donnelly, unpublished data). Much smaller numbers have been found in the westside bays, and catches of only a few fish have regularly occurred in the outer region of the bay. In 1975, interestingly, the Hepburn area yielded only moderate catches yet the westside bays provided catches up to 15,000 fish per haul. One haul in Moser Bay yielded about 30,000 fish. While the Hepburn and lower Deadman regions of Alitak Bay usually have concentrations of juvenile pink salmon (and chum salmon, albeit in much less abundance), the 1975 results show that the distribution pattern is subject to considerable variation. The distribution pattern for Ugak Bay has historically been very similar to that found in the present survey.

Juvenile masked and whitespotted greenling were present in the epipelagic zone of all bays in early summer, although large catches occurred only in Alitak Bay in late June. Pelagic greenling catches fell to incidental numbers by late July and to negligible levels in the last cruise as the fish gradually took up residence in littoral habitats.

Many more species were encountered in the nearshore than in the pelagic zone. Juvenile sand lance and salmon were the most abundant intertidal fishes, and since they school they likely have clustered albeit probably shifting distributions. Greenlings, pleuronectids, cottids, and to a lesser degree Dolly Varden, herring, and blennioids comprised the bulk of the remaining nearshore community.

Although sand lance were found chiefly in the inner regions of Ugak and Kaiugnak Bays, the enormous sampling variability associated with the species precludes a firm statement about their distribution within the bays. In all cases, however, they were seined over sand or small gravel substrate, and probably any such beach in the study area is likely to host sand lance. We cannot infer from our catches a seasonal peak of abundance, again because of the large sampling variability. Nevertheless, because the pelagic catches of juveniles and adults declined sharply by late June, there is indirect evidence for an increase in the littoral sand lance population in early summer.

Juvenile pink and chum salmon were abundant in the littoral zone of all bays in late May and late June, but had almost entirely moved into pelagic areas by late July. An exception was the enormous intertidal catch of juvenile pinks and chum from the northwest corner of Eagle Harbor, Ugak Bay, in early August. It may be that this aggregation was a large diurnal school of typically pelagic fish that either at random or in some directed fashion ranged inshore.

Adult salmon were first encountered nearshore in late June when five sockeye and one chum were caught in the trammel nets near the entrance to Olga Narrows (Fig. 5). The main adult catches were largely of pink salmon near the mouths of streams in late July.

Because our gear types and discontinuous sampling program provided little information on the adult salmon runs to the bays, supplementary information was gleaned from the literature. Catch and escapement data compiled by FRI and ADF&G provide indirect but useful indications of timing and size of runs to various bays and even to particular river systems within the bays. The pink salmon is the principal salmonid species on Kodiak Island; catches of pinks make up an average of 84% of the total salmon catch from Kodiak in odd years and 96% in even years (Stern, unpublished ms.). Stern shows the average timing of pink runs to Kodiak as the third week of June to the first week of September, with a peak in late July/early August. In some years and near some river systems the peak catches may be in the second week of August (Manthey, Malloy, and McGuire, 1975; Bevan, Lechner, and Eaton, 1973). The main Kodiak sockeye salmon runs are to Karluk and Red rivers, but a few streams in Olga Bay (connected to Alitak Bay) also support commercially important runs. Smaller numbers of sockeye return to Ugak Bay, particularly to the Pasagshak River. Sockeye salmon return to the estuaries considerably earlier than the pink salmon. Small numbers of sockeye are in the rivers as early as late May (Gwartney, 1969), but the runs to the Olga Bay rivers usually begin in early June (Eaton, 1968; Bevan, Pedersen, and Manthey, 1975; Russell, 1972). Peak sockeye catches from the bays occur in the third week of June (Stern, unpublished ms.).

Figure 24 shows the major spawning streams in the study area by species, as identified in this study and as mapped by Atkinson, Rose, and Duncan (1967).

Dolly Varden were common in all bays and throughout the field season, usually in aggregations near the mouths of streams. A few individuals were caught by the tow net in Ugak and Alitak bays.

The greenlings (*H. octogrammus*, *H. stelleri*, and *H. lagocephalus*) were the most consistently occurring species in the nearshore zone. Yearling and suspected age-2 greenlings were caught in the intertidal and subtidal zones by the beach seine and try net, and almost all of the larger adults were caught by the trammel nets. A more detailed length frequency analysis is presented later, but the mean lengths of fish caught by beach seine, try net, and trammel net, respectively, were 125.4, 144.3, and 205.2 mm for *H. octogrammus* (n = 479,241 and 392), and 93.5, 135.5, and 248.5 mm for *H. stelleri* (n = 413,151 and 144). An a priori orthogonal comparison of lengths from beach seine and try net versus trammel net samples was highly significant for both species (for *H. octogrammus* $t = -25.97$, $p < .001$ and for *H. stelleri* $t = -35.24$, $p < .001$; data pooled over all bays and cruises), although in both cases the variances were heterogeneous. We cannot conclude whether these size differences are primarily due to a considerable degree of habitat separation between mature and younger greenling, or whether differential avoidance of active and passive gear by large and small fish had the dominant effect on catch data. We suspect that mature adults occupy a more strictly rocky, vegetated habitat and that younger age groups range more frequently into intertidal and smooth, sandy subtidal areas, but that our data perhaps exaggerated the trend because of respective catchabilities of the gear. Spawning by masked and rock greenlings was first observed in late June, indicated by ripe and running eggs and male breeding coloration. By the third cruise many whitespotted greenling were in spawning condition, and by mid-September female masked and rock greenling were spent and male breeding colors were fading. Whitespotted greenling were still in spawning condition during the last cruise. Interestingly, very few juvenile rock greenling were caught in pelagic or nearshore habitats, yet the adult population was commensurate with those of masked and whitespotted greenling. Only a few adult kelp greenling (*H. decagrammus*) were caught, and only in outer Kaiugnak and Ugak bays in the last cruise. This may be a reasonable result of sampling variability given a small population of the species in the study area, but the results suggest a larger population outside the mouths of the bays (perhaps in the large kelp beds just offshore or along the rocky outer coast) which fringes just inside the bays in later summer.

The dominant pleuronectids in the nearshore zone were mainly juveniles of the yellowfin sole and the rock sole. Catches of both species were highest in Ugak Bay, where yellowfin sole occurred mostly in the inner bay and rock sole catches increased toward the mouth of the bay. For both species the catches were highest in later summer, reflecting the influx of young of the year to the nearshore habitats. Surprisingly, no postlarvae were identified in the entire study, but the smallest age-0 fish caught in August and mid-September had apparently just completed metamorphosis. Very few flathead sole were caught in the nearshore zone. ADF&G's benthic survey, in contrast, showed the flathead sole to be the second most abundant flatfish in the deeper parts of the bays. Young halibut were caught sporadically in all bays, but a concentration of age-0 halibut was found in mid-September on the sandy habitat at Tanner Head in Alitak Bay. Consistent with this result, the shallow banks just outside Alitak Bay and near the Trinity Islands off south Kodiak Island have been found by the International Pacific Halibut Commission (IPHC, 1964; Best, 1974) to host large numbers of juvenile halibut. Butter sole were caught mainly in Pasagshak Bay within Ugak Bay, and in small numbers in outer Kaiugnak Bay. Starry flounder and sand sole were also common nearshore.

The great sculpin was the most abundant nearshore cottid, and was also frequent in the benthic samples of ADF&G. Catches were highest in the early summer when young of the year were present in the more protected regions of the bays. Large adults were rare in the intertidal zone relative to the subtidal areas. Congeners were the shorthorn sculpin and plain sculpin, the latter caught only in the subtidal zone.

Other nearshore species were already mentioned in earlier sections, and are listed in the Appendix Tables. In several cases our incidental catches constituted geographic range extensions. For information on geographic distributions we have relied heavily on Andriyashev (1954), Hart (1973), Wilimovsky (1954, 1958), Quast and Hall (1972), and various unpublished literature. With these range extensions goes the caveat that we may have missed published records documenting some or all of these species in the Kodiak area:

1) Tube-snout, *Aulorhynchus flavidus*. This species was reported by Quast and Hall (1972) to range from Baja California to southeast Alaska, and was previously reported in Kodiak waters by Tyler (unpublished).

2) Plain sculpin, *Myoxocephalus jaok*. The last range extension that we know was eastward, to Cold Bay, Alaska (Quast and Hall, 1972).

3) Manacled sculpin, *Synchirus gilli*. The last northward range extension was to Sitka, Alaska, reported by Miller and Erdman (1948).

4) *Porocottus quadrifilis*. Andriyashev (1954) mentioned that this species is restricted to the Bering Strait. Our specimens may be *P. bradfordi* which has been recorded on Kodiak Island (Rutter, 1898).

5) Bering poacher, *Occella dodecaedron*. According to Quast and Hall (1972), the southeastern extent of the range is the Alaska Peninsula.

6) Bering wolffish, *Anarhichas orientalis*. Quast and Hall (1972) reported the range as from the Sea of Okhotsk to Bristol Bay, but it appeared in our catches as well as in the incidental catches of past FRI townet sampling around Kodiak Island (Bob Donnelly, personal communication).

This section on distribution and abundance would be incomplete, or at least misleading, without a word on fishes not caught by our sampling. Regardless of the types of gear employed or the amount of effort, there is always a probability that at least one extant species is never represented in the catches. To illustrate this, in each cruise of this survey a number of species were encountered for the first time; on the last cruise, for instance, 12 species were added to the checklist (Appendix Table 1). To some extent this result may be due to seasonal changes in distribution (e.g., fish moving into the bays or into the nearshore zone), but even without considering such dynamics the same result might be expected on the basis of multinomial probabilities. In short, our results reflect the major constituents of the estuarine fish fauna, but there are perhaps many species inhabiting the pelagic and nearshore zones of the study area which were not encountered.

General Description, Age-Class Composition, and Food Habits of Major Species

Because most of our nearshore and pelagic catches were mainly of juvenile fishes, length frequency graphs for major species are broken down by cruise to reflect growth of the early age groups. When feasible the same abscissa scale is used for all graphs for a species, and the length intervals have lower boundary points (e.g., 40-44, 45-49; 70-79, 80-89, etc.). In all cases the ordinate is the percentage of the total sample contributed by the length intervals. Since seasonal growth was deemed an important factor, length data were usually pooled over all bays and gear types to provide samples sufficiently large to warrant graphing. Consequently, the following graphs are not length frequencies in the strictest sense since no allowance was made for different catchabilities by size of the various gear types. Nevertheless, they suffice to identify the major size classes represented in the samples.

We examined all stomach samples collected in this survey, and recorded for each predator specimen the prey taxa and life history stages (including the genre organic debris, parts of organisms, and unidentified material), total wet weight (± .01 gm) of stomach contents, and count and wet weight (± .001 gm) for each prey taxon/life history stage category. The data were processed by a FORTRAN program to provide the statistics needed to prepare Indices of Relative Importance (I.R.I.), similar in design to those of Pinkas et al. (1971), and useful in graphically describing three important variables of a species' food habits: frequency of occurrence of a prey category, and percent composition of a prey category in terms of numbers and total consumed biomass. The three-way I.R.I. graphs show for a sample of conspecific predators: 1) on the horizontal axis, the percent frequency of occurrence of each prey category (that is, the fraction of the entire sample of stomachs that contained at least one individual of the category), 2) on the vertical scale above the horizontal axis, the percentage of the total number of prey items in the sample contributed by each category, and 3) below the horizontal axis, the percent contribution of each category to the total weight of all identified prey items in the sample. Unless otherwise stated, all three variables are drawn so that 1 mm = 1%. Categories represented by less than 5% for frequency of occurrence and by less than 1% for the other variables were not included on the I.R.I. graphs.

Pacific herring, *Clupea harengus pallasi*

The Pacific herring is caught commercially in the Kodiak Island area, and the main fishery is on the west side of the island (Manthey, Malloy, McGuire, 1975; Reid, 1971). The Kodiak herring fishery was quite large before the late 1950's (an average of 40,000 tons were harvested annually from 1934 to 1950, and the largest catch in 1934 was nearly 121,000 tons), but processing herring for oil and meal became unprofitable causing closure of plants and a sharp decline in catches. Currently there is a limited fishery for roe herring. The average annual catch from 1970 to 1974 was only 441 tons (Manthey, Malloy, McGuire, 1975).

Most of the non-larval herring encountered in this study were large adults caught by the trammel nets in outer Ugak Bay (specifically, in Pasagshak Bay) and small adults caught in two midwater trawl hauls in outer Alitak Bay. The largest individual was 332 mm and the smallest fish were young of the year about 30-60 mm long (Fig. 25). Large fish (over about 260 mm) were nearshore in Pasagshak Bay throughout the summer, certainly well after the spawning season which according to Rounsefell (1930) is May-early June for the Kodiak-Afognak area. Svetovidov (1952) mentioned that various races of Pacific herring stay inshore to feed after spawning. According to length and age information from Rounsefell (1930) and Reid (1971), the adult herring caught by the trammel nets were from about 5 to near 20 years old. Alaska herring mature at age III or IV (Reid, 1972).

Only 11 age-0 herring were examined for food habits, and the small sample size does not warrant graphing. All of the fish had recently fed, and over 99% by numbers and weight of the pooled stomach contents consisted of calanoid copepods, followed by a few harpacticoid copepods.

Pink salmon, *Oncorhynchus gorbuscha*

The summer growth of juvenile pink salmon pooled over all bays and gear types is illustrated in Fig. 26. Several important factors affecting growth of estuarine juvenile salmon beg a more elaborate analysis, however. For example, the young fish grew so fast that much of the variance of the distributions shown in Fig. 26 is due to the growth that occurred within the approximately 2-week cruises. Also, we might expect habitat to pertain to fish size, since juvenile pinks are generally nearshore early in the summer and in epipelagic areas later (Tyler, unpublished; Manzer, 1956).

Figures 27 and 28 show the mean lengths of fish caught in the intertidal (beach seine) and epipelagic (tow net and midwater trawl) hauls from Ugak and Alitak Bays, respectively, plotted against sampling date. The means are either from single samples or are grand means from two or more samples taken on or close to the sampling date indicated.

The implied curves in Figures 27 and 28 hint exponential growth, as would be expected for very young fish. We suspect that the early-September sample means are lower than the population mean(s) at that time (that is, the last growth increment indicated was probably larger than shown). Since the peak of outmigration is in August and since timing of outmigration appears to be related to size (Tyler, unpublished), the juveniles remaining in the bays in September may represent the smallest fish of the cohort. Also, bias toward smaller fish in the later cruises may have accrued from more effective gear avoidance by the larger fish.

In a preliminary analysis, the mean lengths of fish caught intertidally were significantly less than the mean lengths of epipelagic fish in cruises 2 and 3, as expected. However, Fig. 27 shows that these differences were to some extent artifacts of our sampling since in both cruises the intertidal samples were taken earlier than the pelagic samples. Consequently, much of the disparity between means from nearshore and epipelagic samples may have been made up by the growth that occurred in the few days (10 days for cruise 2, 3 days for cruise 3) between the beach seine and tow net sampling. For example, Ugak Bay fish grew an average of 1.05 mm/day (an estimate calculated by dividing the difference between the intertidal means from cruises 2 and 3 by the 30 days separating the samples), and therefore as much as 1.05 cm of the 1.11 cm difference between intertidal and pelagic sample means from cruise 2 may be explained by growth that occurred in the 10 day interval. The fish caught intertidally in Alitak Bay in cruise 2 were obviously smaller than pelagic fish, however.

The diets of juvenile pink salmon differed greatly between nearshore and pelagic habitats (Fig. 29 and 30). Fish caught by the beach seine, pooled over all bays and cruises, fed mostly on epibenthic harpacticoid copepods. Gammaridean amphipods, fish eggs, and miscellaneous larval crustacea contributed to the diet in terms of numbers, but very little in terms of weight (Fig. 29). Pinks caught in the epipelagic zone (day and night samples combined) ate mainly calanoid copepods, barnacle cypris larvae, miscellaneous crustacean nauplii, harpacticoids, and fish eggs. Larval capelin contributed most of the weight in the entire sample, but came from the stomachs of only a few large juveniles.

The most recent and detailed study of food and feeding habits of Kodiak Island pink salmon was by Gosho (1977). He studied the diets of epipelagic juvenile pink salmon collected from Kiliuda Bay (just south of Ugak Bay) and Alitak Bay in the summer of 1971, and attempted to relate food habits with the results of concurrent zooplankton sampling. His study pointed out many factors that affect the diet of young pinks, including season, time of day, and location within the bays. The diets of fish in his samples included mainly copepodids, nauplii, decapod zoea, and planktonic eggs in the day, and barnacle cypris, insects, pteropods, copepodids, zoea, and *Oikopleura* at night.

Stern (unpublished ms.) reviewed the general life history and biology of pink salmon, as well as other salmonid species, in the Kodiak area.

Chum salmon, *Oncorhynchus keta*

Juvenile chum salmon were noticeably larger than juvenile pinks in late May when both species were abundant in beach seine samples. The chum averaged 43.5 mm, significantly more than the 37.0 mm mean for pink salmon (two sample t-test, $t_{(282\ df)} = 12.39$, $p < .001$).

There was a great disparity between the mean sizes of nearshore and pelagic fish throughout the summer, especially in cruise 2 when it resulted in a bimodal length frequency distribution (Fig. 31). A plot of means from nearshore and pelagic samples from Ugak Bay is presented in Fig. 32 (relatively few fish were caught in the other bays). For the cruise 2 (late June) samples, the difference between nearshore and pelagic means was about 5.3 cm, which is clearly significant and which explains the bimodal distribution in

Fig. 31. Nearshore fish were also smaller than pelagic residents in the last two cruises, although the differences were not as great. Unlike the situation with juvenile pink salmon, these results cannot be attributed to growth occurring between the intertidal and pelagic sampling dates.

The sample of stomachs from pelagic chum salmon was too small to show confidently a dietary shift with movement from the nearshore to the pelagic habitat, so all juveniles were pooled to provide a single prey spectrum for this species (Fig. 33). Fifty-nine of the 72 fish in the sample were caught in the intertidal zone, and as might be expected remembering the results for pink salmon, the prey spectrum is dominated by epibenthic harpacticoid copepods. Teleostei (in only a few large juveniles), gammaridean amphipods, harpacticoids, and mysids comprised the bulk of the diet in terms of weight. Calanoids were only incidental, but this is surely due to the small number of pelagic fish in the sample.

Gosho (unpublished data from 1971) found the diurnal diet of 80 pelagic juvenile chum salmon from Alitak and Kiliuda bays to consist of copepods (0-36.3% by numbers; range for 3 samples), pelagic eggs (11.8-94.8%), zoea (1.7-38.9%), winged insects (0-71.7%), harpacticoids (0-2.6%), fish larvae (0-4.0%), and *Oikopleura* (0-3.7%). The nighttime diet, based on 114 fish from Kiliuda Bay, was harpacticoids (23.9% by numbers), indicating nearshore or epibenthic feeding, decapod zoea (18.2%), *Oikopleura* (17.0%), winged insects (15.2%), pelagic eggs (7.2%), copepods (9.6%), pteropods (4.0%), thoracica cypris (1.6%), and fish larvae (1.0%).

Dolly Varden, *Salvelinus malma*

The life history of Dolly Varden is quite variable, but many stocks in the Gulf of Alaska area typically move out of lakes and enter estuarine waters in the spring, feed in marine waters through summer, and return to freshwaters for the winter (Blackett, 1968; DeLacy and Morton, 1943). Spawning is in fall, and the young remain in freshwater for 3 or 4 years before beginning the annual anadramous behaviour of adults. Dolly Varden feed very little in winter, resulting in an 8-to 31% weight loss (data taken from Eva Creek, Baranof Island, by Heiser, 1966), although this pattern probably varies greatly with stock and local food supply. In any event, most of the growth occurs in the marine environment in spring and summer.

The length frequencies of Dolly Varden caught in the present study are presented in Fig. 34, but there are insufficient data to identify even the youngest year classes. Relying on length data from Heiser (1966), the smallest fish (around 100 mm) were probably 3 or 4 years old and newcomers to the marine environment. The largest fish may have been over ten years old.

Eighty-four stomachs from Dolly Varden collected mainly from Ugak and Alitak bays in all cruises were examined for food habits, and the resulting prey spectrum is shown in Fig. 35. Only one stomach in the entire sample was empty, and several stomachs were distended after heavy feeding on gammaridean amphipods. Larval and juvenile fish comprised most of the prey weight, and the sand lance was the principal forage species. Only five juvenile pink salmon occurred in the sample, comprising .05% of the diet in terms of numbers and .18% by weight. The other teleosts consumed were juvenile sandfish, yellow Irish Lord, herring, greenling, and great sculpin. The other principal prey taxon was Gammaridea, which swamped the other categories in terms of numbers of prey organisms. Other food items were insects, hyperiidean amphipods, polychaetes, mysids, algae, fish eggs, and, not shown in Fig. 35, juvenile Natantia, Euphausidaceans, juvenile gastropods, cumaceans, and isopods.

Roos (1959) studied the food habits of Dolly Varden from Chignik Lagoon, and also found from his sample of 188 fish that amphipods were the most frequently occurring prey items (81.1% in his sample, 23% in the present study). Simenstad, Isakson, and Nakatani (in press) found that the diet of 66 Dolly Varden from Amchitka Island consisted principally of decapods, amphipods, fish (largely sand lance), and insects, in order of decreasing frequency of occurrence.

Dolly Varden have long been thought to prey heavily on juvenile salmon (Ricker, 1941; Rounsefell, 1958; Roos, 1959; Lagler and Wright, 1962), although most studies have been concerned with predation specifically on sockeye salmon in the freshwater environment. Armstrong (1965) found that young salmon comprised 28.1% by weight and 21.6% by frequency of occurrence of the diet of Dolly Varden caught in Hanus Bay, Baranof Island. Capelin, herring, and mysids were the other principal prey items. Lagler and Wright (1962), however, found little evidence of predation by Dolly Varden on juvenile salmon in Little Port Walter estuary, Baranof Island, although their sampling took place after the peak of downstream migration of the young salmon. Little predation on young salmon was indicated in the present study as well, but again, most of the Dolly Varden were caught in midsummer after most of the salmon had moved to the epipelagic habitat.

An annotated bibliography on the Dolly Varden was prepared by Armstrong and Morton (1969).

Capelin, *Mallotus villosus*

Despite the fact that the capelin is one of the most abundant and most important forage fish in the Gulf of Alaska and Bering Sea regions, surprisingly little is known about its ecology and life history. Spawning occurs in June and July in the Bering Sea (Musienko, 1970) and in September and October in southern British Columbia (Hart, 1973). In the present study, no evidence of spawning was seen within the bays, although sexually dimorphic adults (i.e., males in breeding condition) were caught occasionally in late May and mid-June in the pelagic and intertidal zones. There is a sport fishery for capelin along the exposed sandy beaches of Kodiak Island in May and June (Jim Blackburn, personal communication), which further points to these months as the spawning season. Eggs hatch in 2 to 3 weeks, and the larvae become pelagic. Fecundity, age at maturity, growth, and life span vary considerably between different areas.

The length frequency distributions of capelin caught by the midwater trawl are pictured in Fig. 36. Fish caught by the tow net were generally smaller than those caught by the midwater trawl, but it is impossible for us to separate effects due to gear selectivity. Large adults occurred in the trawl samples only in late May, and in beach seine samples in late May and June. Later in the summer large adults may have died after spawning, left the bays, or remained close to the bottom unavailable to our midwater trawl. The smallest fish indicated in Fig. 36 in the first cruise were probably one year old, since the vernal spawning season precludes their being young of the year. Two-year-old fish presumably comprise the second mode around 90 mm. In late July it seems that larger fish were caught, but by mid-September the mode decreased to 95-99 mm again.

The prey spectrum for pelagic capelin shows the principal food items to be euphausiids, larval fish, and calanoid copepods, although some fish may have been feeding close to the bottom to consume typically epibenthic forms such as polychaetes and harpacticoids (Fig. 37). Euphausiids and copepods were also the main items in capelin stomachs in other studies (Hart and McHugh, 1944; Barraclough, Robinson, and Fulton, 1968; Barraclough and Fulton, 1968).

Masked greenling, *Hexagrammos octogrammus*

This species is distributed from the Sea of Japan, through the Bering Sea, and southeast along the Aleutian coast to about Sitka. Its presumed absence from Amchitka Island (Simenstad, Isakson, and Nakatani, in press) and abundance in other Aleutian areas (Wilimovsky, 1964), however, attest a discontinuous distribution over at least part of its range. Spawning occurs in the neritic zone between early summer and fall (generally earlier in more northern waters), and young of the year inhabit the epipelagic zone of the open ocean where they grow very little before returning to littoral areas the following summer.

The masked greenling was the most abundant and smallest hexagrammid species in the estuarine bays of Kodiak Island. Three distinct size classes are apparent in Fig. 38: one-year-old juveniles, presumed two-year-olds (100-170 mm), and older fish, over about 180 mm. Gorbunova (1962) presented data from Kamchatka showing 3, 4, 5, and 6-year-old females being 18.5-19.5, 22.0-26.0, 26.0-27.0, and 28.0 cm, respectively, and Rutenberg's (1962) very small sample of Unalaska fish included 3- and 4-year-old fish 23.0 and 23.8 cm long, respectively. The greatest growth of juveniles in the present study seemed to occur between the last two cruises, after they had shifted from the pelagic to the nearshore environment (Fig. 38).

The food habits of this species should be viewed from at least three ecological perspectives: pelagic and nearshore juveniles, and adults. Only seven pelagic juvenile greenling collected for stomach analysis were positively identified to *H. octogrammus*, and their food consisted overwhelmingly of calanoid copepods, with reptantian zoea and harpacticoids in lesser amounts. The diet of 12 nearshore juveniles consisted of more epibenthic prey, as expected (Fig. 39). Gammaridean amphipods and polychaetes comprised most of the diet by weight, and Gammaridea and Harpacticoida were the principal taxa in terms of numbers of organisms. Stomachs were not saved from any adults caught by the trammel nets because of the excessive digestion expected in the duration of the sets. Hence, the adult prey spectrum (Fig. 40) is based mainly on small adults caught by the seine and try net. Gammaridea was the main prey category in adult stomachs, followed by polychaetes, small shrimp and crabs, and isopods. Many other taxa of smaller organisms were also represented.

Whitespotted greenling, *Hexagrammos stelleri*

The whitespotted greenling has about the same distribution as the masked greenling, but it extends further south along the American coast to northern California (Quast and Hall, 1972). This species was also very abundant in our pelagic and especially nearshore samples in the last three cruises.

The length frequency distributions pictured in Fig. 41 are dominated by the large numbers of age-1 juveniles caught in the pelagic and nearshore zones, especially in cruise 3. Again, the greatest growth in juveniles occurred after transition to the neritic habitats. The other age-classes represented in our data cannot be distinguished.

Stomach samples were taken from mainly juvenile whitespotted greenling. Juveniles caught in the pelagic zone of Alitak Bay in late June fed predominantly on calanoids, decapod zoea, and Euphausiacea (Fig. 42), as found also for juvenile masked greenling and salmonids. Barraclough and Fulton (1968) and Barraclough, Robinson, and Fulton (1968) also found copepods to comprise over 90% of the diet of pelagic whitespotted greenling, with amphipods, decapod larvae, ostracods, cypris larvae, fish eggs, and *Oikopleura* making up the remainder.

Gosho (unpublished data) examined 255 pelagic juvenile *Hexagrammos* spp. (probably mostly *H. stelleri*) caught in early summer, 1971, in several samples from Alitak Bay. The diurnal diet consisted largely of copepodids (31.0-92.6% by numbers), pelagic eggs (up to 6.0%), zoea (1.8-81.3%), harpacticoids (1.0-1.8%), and thoracica cypris (2.1%). The nighttime diet was mainly zoea (81.3-91.3%), fish larvae (1.0%), and thoracica cypris (1.1%).

The diet of 47 nearshore juveniles also collected from Alitak Bay but about one month later was mainly harpacticoids, gammarideans, caprellideans, and calanoids (Fig. 43). Small numbers of barnacles and polychaetes also contributed significantly to the biomass consumed.

Rock greenling, *Hexagrammos lagocephalus*

This species includes two forms (*H. lagocephalus* and *H. superciliosus*) which were earlier given specific status (Quast, 1960). Both forms were identified in our samples from Kodiak Island. The species has the widest distribution of all greenlings, ranging from northern China to southern California.

Figure 44 shows the length frequency distributions of rock greenling from Kodiak Island. Very few juveniles were caught in our survey, which contrasts results for the other congeneric species. This substantiates Gorbunova's (1962) view that the juveniles remain in the open ocean for 3 or 4 years before recruiting to the littoral zone. We have no explanation for the demonstrable decrease in mean size of adults throughout the summer (Fig. 44), but surmise that it may be due to larger fish moving into deeper water after completion of spawning in July-August. Simenstad (1971), however, found no evidence for adult dispersal or migration in an ecological study of rock greenling off Amchitka Island. Females attain a considerably larger size than males (Fig. 45), and length data from Gorbunova (1962) suggest that this is due to different mortality rates rather than different growth rates between sexes.

Only eight rock greenling were examined for food habits in this study since few fish were caught by gear other than the trammel nets (which are not a preferred source of stomach samples since digestion cannot be arrested immediately after capture). Most of these fish had gammarideans (comprising over 75% of the diet by weight) and caprellideans in their stomachs, and four or fewer fish had eaten pelecypods, hydrozoans, mysids, polychaetes, fish, isopods, and barnacle larvae. Simenstad (1971) studied in detail the food and feeding habits of rock greenling, and found the diet to consist of, by weight: 43.2% amphipods, 31.9% inanimate matter (mostly algae), 10.2% mysids, 6.4% molluscs, 4.5% fish, and 1.0% copepods. Klyashtorin (1962) found that the diet of only 20 rock greenling from the Kuril Islands was chiefly amphipods, with smaller quantities of isopods, polychaetes, molluscs, and fish.

Great sculpin, *Myoxocephalus polyacanthocephalus*

This species was the most abundant cottid in our nearshore survey, and comprised between 4 and 8% by weight of the total catch of fish and invertebrates in the benthic survey of Ugak and Alitak bays by ADF&G (R.U. 486). The great sculpin also occurs in great abundance on the continental shelf throughout the Gulf of Alaska region (Ronholt, Shippen, and Brown, 1976; Ronholt, personal communication). Young-of-the-year great sculpin were abundant in beach seine catches in the first two cruises, but were caught in less abundance relative to other age groups later (Fig. 46). Age-0 great sculpins were just under 60 mm by mid-September, so the fish with lengths centered at about 75 mm in cruise 1 were surely one- and, perhaps to some extent, two-year olds. Most of the larger fish pictured in Fig. 46 were caught by the try net and trammel nets in subtidal habitats.

Hart (1973) briefly described the great sculpin as a piscivore, but our samples and other studies suggest a considerably more diverse diet. Fish were the principal prey organisms in our sample in terms of weight

(Fig. 47), and were consumed by juveniles and adults. The category Scorpaeniformes was represented by one fish in the stomach of a large sculpin. Juvenile sand lance were the most numerous fish in the stomach contents. Majiid crabs were also an important prey category by weight. Gammaridean amphipods contributed very little to total consumed biomass, yet were the most frequently occurring prey items. Prey represented in small quantities were nematods (possibly parasites), corophiids, caprellideans, shrimp, echinoids, pelecypods, flabelliferan isopods, algae, and polychaetes. Simenstad, Isakson, and Nakatani (in press) found about 100 crabs in the stomachs of only four offshore great sculpins, while the diet of nearshore fish was mainly amphipods and isopods with smaller quantities of fish and gastropods.

Snake prickleback, *Lumpenus sagitta*

The snake prickleback was the most abundant blennioid fish in our survey. represented by large numbers of postlarvae and small juveniles in the pelagic zone and by larger juveniles and adults in nearshore (particularly try net) samples. Figure 48 provides length frequency information and shows the overall decline in adult abundance in the catches of later summer. The prey spectrum for 41 nearshore juveniles and adults is shown in Fig. 49. Gammarideans and harpacticoids were the main items, although polychaetes also contributed considerably to the diet in terms of weight. Barraclough, Robinson, and Fulton (1968) found copepods to be the principal food of young-of-the-year pricklebacks inhabiting the pelagic zone near Vancouver Island.

Pacific sandfish, *Trichodon trichodon*

Age-0 sandfish were second only to capelin in abundance in our pelagic samples. The species is distributed from Kamchatka, through the Bering Sea, to California (Quast and Hall, 1972), although there are major discontinuities in its range. No postlarval sandfish were reported in the extensive pelagic sampling in the Strait of Georgia (Barraclough, Robinson, and Fulton, 1968), yet there is an adult population along both coasts of Vancouver Island (Hart, 1973). Ronholt, Shippen, and Brown (1976) found adult sandfish in the Gulf of Alaska in 9.1% of the bottom trawls between 1 and 100 m and in 2.5% of the trawls between 101 and 200 m. Sandfish spawn in late winter and early spring.

The growth of the age-0 cohort is clearly illustrated in Fig. 50. The largest fish caught was 190 mm, but adults can attain 305 mm (Clemens and Wilby, 1961).

Sixteen juvenile sandfish were examined for food habits, and crab zoea and larval fish comprised the bulk of their diet by weight (Fig. 51).

Pacific sand lance, *Ammodytes hexapterus*

The Pacific sand lance has a complex life history, inhabiting pelagic, benthic, and nearshore habitats in various times of the year. The length frequency distributions shown in Fig. 52 are misleading, because we did not measure many postlarvae in the first two cruises. Postlarval catches were large in those cruises, but decreased later in the summer as the small juveniles recruited to the nearshore zone. Barraclough, Robinson, and Fulton (1968) also found a decrease in epipelagic larval sand lance catches in the early summer. The dominant size class shown in Fig. 52 was probably made up of mainly one-year-old fish, which supports Andriyashev's (1954) statement that catches of sand lance in the nearshore zone are mainly of the second age group (1+). Although Andriyashev's data was for the closely related European form, which he called *A. h. marinus*, the life histories of the Barents Sea and north Pacific forms are probably very similar. The Barents Sea form lives to four years, and allegedly matures in the third year. According to Andriyashev, juveniles and adults move to shallower water in the spring and early summer, and presumably the younger age groups move closer to shore than large adults. In the late summer and fall they return to deeper water. Spawning is in late winter.

The prey spectrum of 86 juvenile and adult sand lance caught in the intertidal zone is pictured in Fig. 53. Primarily pelagic organisms such as calanoids (contributing about 75% of the biomass), zoea, larvaceans, and nauplii were the principal food items, which is surprising considering where the samples were taken. Andriyashev (1954) mentioned that the food of *A. h. marinus* from the Barents Sea is mainly planktonic crustaceans such as calanoids, barnacle larvae, and euphausiids, rather than benthic or epibenthic organisms as might be expected. Further, Simenstad, Isakson, and Nakatani (in press) also showed a high incidence of copepods in sand lance caught off Amchitka Island, and suggested that this species may transfer a significant amount of trophic energy from the pelagic to nearshore areas.

Rock sole, *Lepidopsetta bilineata*

The rock sole is one of the principal flatfish species in the shallower waters of the entire Gulf of Alaska region, and particularly in the area around the Alaska Peninsula (Alverson, Pruter, and Ronholt, 1964; Best, 1969a,b, 1974; Int. Pac. Halibut Comm., unpublished data). It was the most abundant flatfish in our nearshore samples from Kodiak Island.

Almost all of the rock sole caught in this study were measured. Young of the year were caught in the latter half of the summer, and a large recruitment of age-0 fish to the nearshore zone was apparent in the last cruise (Fig. 54). The dominant size class indicated consists of 1-, 2-, and perhaps some 3-year-old fish, based on age/length information from Musienko (1957) collected in the Bering Sea and from Forrester and Thomson (1969) collected in Hecate Strait. An abundant cohort of fish around 260 mm (probably 4-year-olds) is indicated by our data, but this may be due to try net size-selectivity (most of the fish over about 150 mm were caught by the try net). Very few fish over about 340 mm were caught in this study (Fig. 54). Applying age/length information from Forrester and Thomson (1969) and Chitton and Smith (1971), this size corresponds to 5- to 7-year-old fish, depending on sex. Since the youngest age at maturity is about 4 years (Forrester, 1969) it is clear that there are few mature fish in the extreme nearshore zone of the estuarine bays around Kodiak.

The food of 114 juvenile and adult rock sole collected mainly from Ugak Bay in the last three cruises was largely sand lance by weight, but amphipods, polychaetes, and bivalves in terms of numbers and frequency of occurrence (Fig. 55). The bivalves and sand lance were consumed almost only by adult rock sole. Other items included algae, cumaceans, mysids, isopods, and fish eggs. Shubnikov and Lisovenko (1964) described the diet of Bering Sea rock sole as 62% polychaetes, 37% molluscs, and 13% crustaceans (mostly Natantia). Simenstad, Isakson, and Nakatani (in press) examined 20 rock sole from the offshore sand and gravel community around Amchitka Island and found amphipods, ophiuroids, cumaceans, hermit crabs, *Oikopleura*, gastropods, and bivalves to be the most frequently occurring prey items. Forrester (1969) mentioned that rock sole eat mostly polychaetes and at larger sizes mostly fish, of which sand lance is the most important.

Yellowfin sole, *Limanda aspera*

This species and the rock sole comprise the especially abundant flatfishes in the nearshore zones of the estuarine bays around Kodiak Island. The yellowfin sole was generally more abundant than the rock sole in our try net catches, but was almost completely absent from the intertidal zone. Yellowfin sole abundance increased toward the deeper subtidal zone, although this trend was only demonstrable and unoccluded by sampling variability in Ugak Bay where the highest catches occurred (Table 3).

The length frequency diagrams for yellowfin sole also show a recruitment of young of the year by late summer (Fig. 56), as found for the rock sole. Large adults were caught almost only in midsummer, and only small numbers of fish over about 200 mm were encountered in the last cruise. This may be due to offshore movement by larger fish toward the end of summer. According to age/length data summarized by Kitano (1969), most of the fish in our samples (i.e., less than about 240 mm) were about 5 years old or younger. Moiseev (1953) reported that yellowfin sole in Peter the Great Bay mature in the third or fourth year (20-23 cm), and Fadeev (1963) showed a wider variation of age at maturation for Bering Sea fish: 4-7 years (14-28 cm) for males and 5-10 years (19-36 cm) for females. If these maturity data can be roughly applied to our length frequency results, it seems evident that most of the nearshore fish are immature.

The food habits of yellowfin sole are pictured in Fig. 57. Small bivalves were the most frequently occurring items, but they contributed relatively little to the total consumed biomass. Fish (mostly sand lance) and echiuroids comprised most of the weight of prey, and were eaten almost exclusively by a few adult sole. An analysis of 548 yellowfin sole from offshore waters in the southeastern Bering Sea by Skalkin (1963) showed the diet to consist mainly of gammaridean and hyperiidean amphipods, mysids, euphausiids, small bivalves, ascidians, echiuroids, and pandalid shrimp. There were notable differences in diet between area and depth in that study.

Other Species

Basic statistics on length distributions (pooled over all bays, cruises, and gear types) for all other species caught in this study are presented in Table 4. Also, the prey spectra for four of these are provided without comment: coho salmon, Fig. 58; Pacific cod, Fig. 59; starry flounder, Fig. 60; sand sole, Fig. 61.

Physical Data

Mean pelagic surface temperatures are presented in Table 5. To some extent the means and standard deviations reflect the fact that three types of thermometers were used at different times during field work. The surface waters of Alitak and Kaiugnak bays warmed to about 11°C by late July and cooled about 1°C by mid-September. The late-June mean for Ugak Bay is quite high, and is surely due to the week of very warm and calm weather that followed pelagic sampling of the other bays and immediately preceded townetting in Ugak Bay. Ugak Bay surface temperatures also fell slightly by early September.

Midwater temperatures are tabulated by bay, cruise, and depth stratum in Table 6. All data for the last two cruises were taken by the Beckman salinometer, and are presumed reliable despite the few suspiciously high temperatures at depth. The deepest strata of Alitak Bay were generally colder than the same strata in the other bays, probably because Alitak Bay is a true fjord (i.e., the Deadman Bay region is much deeper than the mouth of Alitak Bay, and serves as a sink for cold water).

As in the epipelagic zone, temperatures in the nearshore zone rose in all bays to about 11.4°C by late July/early August, and dropped about 1°C in the last cruise (Table 7).

Salinities were also measured by more than one technique; all nearshore values are based on lab analysis of bottled samples and most pelagic salinities were read in the field from the Beckman salinometer (Table 8). The nearshore salinities were lowest, which would be expected since many of our beach seine sites were close to river mouths. There was considerable variation of epipelagic salinity readings, probably reflecting various degrees of mixing of fresh and salt waters with particular weather and sea states. The surface salinities were always slightly less than the midwater salinities.

Deposition of Data

All data collected in this project have been properly coded, formatted (EDS File Type 023), placed on 7-track magnetic tape, and sent to EDS/NODC with full documentation as part of the OCSEAP data base.

INTERPRETATIONS RELEVANT TO OIL DEVELOPMENT

While it is not an objective of this study to assess or predict the impact of petroleum resource development on the estuarine fish fauna of Kodiak Island, some of our results have direct bearing on the matter. There are numerous potential impacts of resource development of the outer continental shelf but this discussion will pertain only to the most obvious: direct spillage of oil or refined products into the marine environment.

The epipelagic and nearshore zones are perhaps the most critical estuarine habitats regarding oil pollution as they would probably receive the most immediate and direct effects. In the event of a spill or well blow-out, oil will remain on the surface for a period leaching toxins into the epipelagic zone. Depending on currents and wind, it would eventually drift inshore. The principal epipelagic inhabitants are juvenile salmonids, greenling, capelin, and sandfish. Salmonids should be of particular concern because of their economic importance and because they are strictly surface-dwelling fish. They might easily avoid a mass of oil floating into a bay, but in so doing they would perhaps leave the bay prematurely or move to another, inferior part of the bay. Many nearshore fishes might also easily avoid an inshore drift of contaminants but their ultimate fate would then depend on their success as refugees. Stationary or territorial fishes such as spawning greenling, homing salmon bound for a particular stream mouth, and littoral fishes with definite home ranges (Gibson, 1967) would be disadvantaged.

Spawning and juvenile rearing are two important uses of estuaries which warrant discussion. If juvenile fish are especially susceptible to the inimical effects of petroleum hydrocarbons, as suggested by Nelson-Smith (1972), Struhsaker (1977), and Evans and Rice (1974), the use of estuarine bays as nursery or rearing areas by numerous species takes on special importance. Our pelagic catches were mainly juveniles of capelin, sandfish, sand lance, salmonids, greenling, bathymasterids, stichaeids, herring, scorpaenids, and cottids. Larvae of some of these forms were also caught in large numbers, but the peak of larval abundance is probably in spring as in other north Pacific waters. Nearshore catches were principally juveniles of salmon, sand lance, greenling, cottids, flatfishes, herring and capelin. Postlarval and juvenile fish of many species recruit to nearshore habitats from the pelagic zone during spring and summer. Among these are sand lance, greenling, cottids, flatfishes, and most intertidal fish. Others, including herring, capelin, and salmonids, live as juveniles in the nearshore zone and move to pelagic waters by the end of summer.

Fish are most sensitive to oil pollution during periods of physiological stress, such as during spawning. Spawning fish are not only affected themselves, but hydrocarbons incorporated into their gonadal products can reduce gametic, embryonic, and larval survival (Struhsaker, 1977). In this regard, critical estuarine species would include those which spawn en masse in the nearshore zone, such as herring, capelin, greenling, and salmon. Salmon spawn mostly in freshwater, of course, but pink and chum salmon spawn to some extent in intertidal areas at the mouths of streams. Most other species that spawn in part in the estuaries do so in the winter and early spring. These include flatfishes, gadids, cottids, rockfishes, and blennioid fishes.

Oil will have direct effects on fishes of all life history stages, but also indirect effects through depletion of prey populations or through ingestion of toxins incorporated into prey organisms. This study identified some of the major prey groups that should be considered in this regard. Most of the pelagic fishes examined relied heavily on calanoid copepods (nauplii, copepodids, and adults), decapod zoea, barnacle cypris, and pelagic eggs. Larger plankters such as euphausiids, hyperidean amphipods, and fish larvae were also important prey. We did not catch enough large fish in the pelagic zone to determine the incidence of predation on juvenile capelin, salmon, sandfish, and sand lance. Nearshore fish consumed a large array of epibenthic and benthic prey including harpacticoid copepods, gammaridean amphipods, settled cypris, juvenile gastropods and pelecypods, polychaetes, and various life history stages of shrimp and crabs. The sand lance was the most important nearshore forage fish.

RECOMMENDATIONS FOR FURTHER RESEARCH

More baseline information is needed before the estuarine bays of Kodiak Island are sufficiently understood to permit assessment of the potential impact of offshore oil development. Additional work would stem largely from two needs: 1) to use a wide assortment of gear to sample fish of all life history stages, and 2) to sample over a larger time frame.

The present study employed five types of gear but nevertheless large adults and especially larval fish were probably not caught in proportion to their true abundance in the bays. Further study should employ smaller gear, perhaps Bongo nets, to sample larval and juvenile fish in nearshore and pelagic habitats, and larger gear, perhaps longlines and/or purse seines, to sample adult pelagic fish. The trammel nets were found to be effective for a wide range of fish size and morphology, but in the present study limitations of field time permitted their use only in areas unworkable by the try net. Ideally, trammel nets would be fished in all nearshore habitats to reflect the abundance of adult fish in the entire nearshore zone.

Larval fish should be given special consideration in a baseline assessment as they comprise a major fraction of the estuarine fauna. A large effort should first be placed on larval identification. This would include preparation of a reference collection containing series of larval stages of as many species as possible. Larval fish should be sampled systematically and quantitatively to provide information on seasonality, distribution (geographic and vertical), relative abundance, and development.

At least three temporal aspects of fish ecology must be considered in baseline work: annual, seasonal, and diel. This project covered only one season in one year, and it certainly should not be used as the sole indication of the Kodiak nearshore and pelagic estuarine fish fauna. There are often major year-to-year variations in marine communities, and consequently sampling should occur over at least two years and preferably more.

Sampling should also be done in all seasons of the year, although inclement weather conditions would make year-round sampling difficult and would perhaps result in major data gaps. The present data give little information about the estuarine fish communities of fall, winter, and spring. Major faunal changes were identified in the summertime sampling of the present study, but equally important changes probably take place in other seasons as well. Many fish might move into deeper water or completely out of the bays with the onset of winter, thus greatly changing the species composition of the nearshore zone. Also, sampling in winter and spring would be required to determine which species spawn in the bays at that time. This information would be correlated with the results of the vernal larval sampling to give a fairly complete picture of reproduction and early life history of most species in the bays. Seasonal changes in food and feeding habits should also be monitored.

There are often dramatic diel changes in the species composition of marine communities resulting from vertical migrations or on- and offshore movements. Several cases of diel movements were evinced in this study, but limitations of field time precluded more nighttime sampling. Subsequent study should include considerable nighttime work to identify the species making major diel movements and the combined effects of these movements on the species composition in various habitats.

Lastly, some effort should be made to determine the uniqueness of the estuarine fish fauna. This would include a small sampling effort in pelagic and nearshore habitats just outside the mouths of the bays and off the outer coast between bays. This approach would perhaps indicate a gradation from estuarine to oceanic fish communities, and would help to identify further critical species, life history stages, and ecological relationships which are typically if not strictly estuarine.

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Table 1. The sampling effort, in terms of number of standard hauls, applied in each bay and cruise by gear type. The actual number of sets, when different, is in parentheses

Cruise	Gear	Ugak Bay	Kaiugnak Bay	Alitak Bay	Gear total
1	Surface trawl[1]	16	5	10 (9)	31 (30)
	Mid-water trawl	9.5 (8)	5	13 (11)	27.5 (24)
	Beach seine	16	9	8	33
2	Tow net	20	10	26	56
	Beach seine	14	6	14	34
	Try net	26	9	21	56
	Trammel net	8 (3)	2 (1)	6 (4)	16 (8)
3	Tow net	20	10	29	59
	Mid-water trawl	23	7	21 (18)	51 (48)
	Beach seine	14	7	16	37
	Try net	15	8	19	42
	Trammel net	3 (2)	2	4	9 (8)
4	Tow net	20	10	36	66
	Mid-water trawl	19	7	18	44
	Beach seine	13	9	21	43
	Try net	20	12	21	53
	Trammel net	4	3 (2)	7 (6)	14 (12)

[1]The midwater herring trawl was used on the surface in Cruise 1, and those catches were analyzed separately from the regular mid-water samples.

Table 2. Depth distribution of principal midwater species as determined by diurnal midwater trawling. Values are mean catch per unit of effort (mean number of fish/haul) in each stratum. NS = Not sampled

Cruise (dates)	Species	Depth strata			
		9-20m	21-60m	61-100m	>100m
A: Ugak Bay					
1	Capelin	26.4	14.8	NS	Not
(5/25-5/26)	Sand lance	60.8	6.6	NS	applicable
3	Capelin	54.6	75.7	109.0	
(7/18-7/21)	Sandfish	16.0	40.9	85.3	
	Sand lance	0	3.6	0	
4	Capelin	42.8	398.6	709.0	
(8/29-9/2)	Sandfish	775.9	228.6	1517.3	
B: Kaiugnak Bay					
1	Capelin	0	0	2.0	NS
(5/27)	Sand lance	33.0	18.0	0	NS
3	Capelin	0	138.3	3.0	NS
(7/25)	Sandfish	0.5	1.7	0.5	NS
4	Capelin	0	0	767.0	208.0
(9/5)	Sandfish	0	16.0	169.0	377.0
C. Alitak Bay					
1	Capelin	0	638.4	549.7	213.5
(5/28-5/30)	Sand lance	0	0	.7	0
	Alaska eelpout	0	0	0	1.0
3	Capelin	33.3	3254.3	52.3	101.0
(7/29-7/31)	Alaska eelpout	0	0	.7	17.0
4	Capelin	0	94.2	492.3	1593.0
(9/8-9/12)	Alaska eelpout	0	0	0	10.7
	Sandfish	0	20.2	0.3	0
	Sandlance	0	10.7	0	0

Table 3. Depth distribution of rock sole and yellowfin sole in Ugak Bay as determined by nearshore trawling with a try net. Values are mean catch per unit of effort (mean number of fish/haul)

Cruise (dates)	Species	Depth of haul		
		4 m	9 m	13 m
2 (6/19-6/21)	Yellowfin sole	1.3	1.5	12.7
	Rock sole	6.3	7.5	6.3
3 (7/18-7/22, 8/2)	Yellowfin sole	6.8	13.3	67.5
	Rock sole	26.6	3.5	3.5
4 (8/29-9/2)	Yellowfin sole	14.7	14.6	29.5
	Rock sole	15.4	13.1	6.8

Table 4. Lengths of incidental species, all bays, cruises, and gear types combined

Species	Mean total length, mm	Range, mm	Standard deviation, mm	Sample size
Rajidae				
R. binoculata	520 (to tip of pelvic fins)			1
Salmonidae				
O. kisutch	188.8	35 - 734	143.57	111
O. nerka				
Juveniles	118.8	59-187	26.74	41
Adults	633.6	557-671	45.93	5
Osmeridae				
H. pretiosus				
Juveniles	66.6	52-104	11.87	26
Adults	179.5	163-197	91.20	16
Gadidae				
G. macrocephalus	167.9	48-258	57.93	59
M. proximus	270.5	261-280	13.44	2
T. chalcogramma	85.3	35-206	41.99	44
Zoarcidae				
B. pusillum	153.2	95-185	19.99	54
Gasterosteidae				
G. aculeatus	47.3	21-92	26.2	72
Aulorhynchus flavidus	72			1
Scorpaenidae				
S. melanops	90.8	39-281	65.65	29
S. nigrocinctus	57			1
Hexagrammidae				
H. decagrammus	350.2	172-447	99.73	6
O. elongatus	91.0	87-95	5.66	2
P. monopterygius	265			1
Cottidae				
A. fenestralis	75.0	27-112	20.33	19
B. cirrhosus	66.1	18-185	24.15	220
B. bilobus	134.6	101-215	35.36	8
Gymnocanthus spp.	107.8	20-275	49.04	266
E. bison	94.4	52-169	16.03	7
E. diceraus	118.0	86-150	45.26	2
H. hemilepidotus	310.0	150-362	89.98	5
H. jordani	93.8	27-277	54.21	85
L. armatus	210.8	41-398	68.39	74

Table 4. Lengths of incidental species, all bays, cruises, and gear types combined - Continued

Species	Mean total length, mm	Range, mm	Standard deviation, mm	Sample size
Cottidae - Continued				
N. pribilovius	64			1
P. quadrifilis	53.5	40-67	19.09	2
P. paradoxus	48			1
S. gilli	37			1
H. bolini	78			1
M. jaok	132.8	83-409	67.93	27
M. scorpius	273.3	109-467	93.53	63
T. pingeli	70.5	38-170	30.72	19
Agonidae				
P. barbata	81.0	28-183	25.51	160
A. acipenserinus	179.1	26-285	94.03	125
A. bartoni	67			1
O. dodecaedron	100.8	61-127	28.08	4
Cyclopteridae				
A. ventricosus	200			1
L. cyclopus	47.5	43-52	6.36	2
Bathymasteridae				
B. caeruleofasciatus	181.3	78-231	69.80	4
B. signatus	79.7	72-90	9.29	3
Stichaeidae				
L. medius	65.4	49-120	30.58	5
C. polyactocephalus	240			1
A. purpurescens	107.0	106-108	1.41	2
S. punctatus	107.4	91-116	9.61	5
Pholidae				
P. laeta	129.9	47-202	32.34	126
Apodichthys flavidus	324			1
Anarhichadidae				
A. orientalis	94			1
Zaproridae				
Z. silenus	113.6	59-163	37.45	8
Pleuronectidae				
H. elassodon	130.3	37-297	56.24	39
H. stenolepis	113.9	50-1015	144.38	57
I. isolepis	192.8	107-343	56.48	35
P. quadrituberculatus	282.0	179-385	145.66	2
P. melanostictus	192.4	42-507	100.68	98
P. stellatus	215.0	32-553	102.81	155

Table 5. Mean pelagic surface temperatures (°C) by cruise and bay, with standard deviation and sample sizes

Cruise (dates)	Ugak Bay	Kaiugnak Bay	Alitak Bay	Cruise mean
1 (5/21-6/3)	No information	No information	$\overline{T}$ = 5.3 S.D. = 1.209 n = 17	5.3
2 (6/16-6/30)	$\overline{T}$ = 12.5 S.D. = 0.924 n = 18	$\overline{T}$ = 8.9 S.D. = 0.564 n = 9	$\overline{T}$ = 9.3 S.D. = 1.154 n = 22	10.4
3 (7/15-8/7)	$\overline{T}$ = 10.3 S.D. = 1.013 n = 29	$\overline{T}$ = 11.4 S.D. = 0.180 n = 17	$\overline{T}$ = 10.6 S.D. = 0.747 n = 37	10.7
4 (8/25-9/16)	$\overline{T}$ = 9.7 S.D. = 0.529 n = 38	$\overline{T}$ = 10.4 S.D. = 0.508 n = 17	$\overline{T}$ = 10.1 S.D. = 0.281 n = 53	10.0
Bay means	10.5	10.5	10.1[1]	

[1]The mean for Alitak Bay is based on the last three cruises only, for comparability with other bays.

Table 6. Mean midwater temperatures (°C) by depth, cruise, and bay

Cruise 1 (5/21-6/3):

No information available for Ugak and Kaiugnak bays

Alitak Bay[1]		
Depth, m	$\bar{T}$	n
31-50	2.9	1
51-70	3.1	1
71-90	2.6	1
91-110	2.2	1
131-150	3.4	1

Cruise 2 (6/16-6/30): No midwater trawling

Cruise 3 (7/15-8/7):

Ugak Bay			Kaiugnak Bay			Alitak Bay		
Depth, m	$\bar{T}$	n	Depth, m	$\bar{T}$	n	Depth, m	$\bar{T}$	n
9	7.8	1	9	10.6	1	9	9.6	1
14-30	7.2	8	14-30	10.3	2	14-30	9.9	2
31-50	5.1	2	51-70	7.5	1	31-50	6.9	4
51-70	6.1	1	91-110	5.7	1	51-70	5.3	1
71-90	7.0	1				91-110	2.4	1

Cruise 4 (8/25-9/16):

Ugak Bay			Kaiugnak Bay			Alitak Bay		
Depth, m	$\bar{T}$	n	Depth, m	$\bar{T}$	n	Depth, m	$\bar{T}$	n
9	9.1	2	9	10.1	1	9	10.0	2
14-30	8.4	5	14-30	9.9	2	14-30	9.8	5
51-70	8.4	2	31-50	7.6	1	31-50	9.3	5
71-90	7.8	1	51-70	6.5	1	51-70	6.9	1
			91-110	6.5	2	91-110	3.2	3
						111-130	2.4	1

[1] Alitak Bay, Cruise 1 temperatures are possibly inaccurate because of problems with the bathythermograph slides.

Table 7. Mean nearshore surface temperatures (°C) by cruise and bay, with standard deviations and sample sizes

Cruise (dates)	Ugak Bay	Kaiugnak Bay	Alitak Bay	Cruise means
1 (5/21-6/3)	$\overline{T}$ = 7.4 S.D. = 0.850 n = 13	$\overline{T}$ = 7.0 S.D. = 1.061 n = 9	$\overline{T}$ = 7.0 S.D. = 0.716 n = 5	7.2
2 (6/16-6/30)	$\overline{T}$ = 7.8 S.D. = 1.235 n = 40	$\overline{T}$ = 9.2 S.D. = 1.759 n = 13	$\overline{T}$ = 10.2 S.D. = 1.618 n = 33	8.9
3 (7/15-8/7)	$\overline{T}$ = 11.5 S.D. = 1.592 n = 21	$\overline{T}$ = 12.2 S.D. = 0.269 n = 11	$\overline{T}$ = 10.9 S.D. = 0.990 n = 26	11.4
4 (8/25-9/16)	$\overline{T}$ = 9.6 S.D. = 1.222 n = 32	$\overline{T}$ = 11.6 S.D. = 0.769 n = 16	$\overline{T}$ = 10.1 S.D. = 0.623 n = 40	10.2
Bay means	9.0	10.3	10.2	

Table 8. Mean nearshore and pelagic salinities (parts per thousand) by bay (initialed) and cruise number

Bay/cruise	Habitat	Mean salinity (°/oo)	Range	Sample size
U 1	Nearshore	19.6	0.6 - 30.5	5
U 2	Nearshore	12.3	1.3 - 32.1	8
U 2	Surface	12.8	1.7 - 27.9	3
U 3	Nearshore	17.6	7.2 - 24.3	3
U 3	Midwater	33.2	31.0 - 35.8	12
U 3	Midwater	32.9[1]	31.0 - 33.6	11
U 4	Surface	24.0	10.4 - 30.6	16
U 4	Midwater	32.8	28.9 - 33.6	11
K 2	Nearshore	29.2	26.3 - 32.0	2
K 3	Nearshore	27.9	27.0 - 29.3	3
K 3	Midwater	33.1	32.4 - 33.6	4
K 4	Surface	29.9	29.1 - 30.6	10
K 4	Midwater	33.6	33.0 - 34.3	7
A 1	Nearshore	21.0	11.3 - 30.6	2
A 1	Surface	29.7	27.7 - 32.0	3
A 2	Nearshore	30.0	26.0 - 31.8	7
A 2	Surface	31.4		1
A 3	Nearshore	31.5		1
A 3	Surface	31.7	26.2 - 33.0	27
A 3	Midwater	33.1	32.6 - 33.7	9
A 4	Surface	32.4	30.7 - 32.9	35
A 4	Midwater	33.3	31.1 - 34.7	17

[1]Excluding the suspiciously high value of 35.8°/oo immediately above.

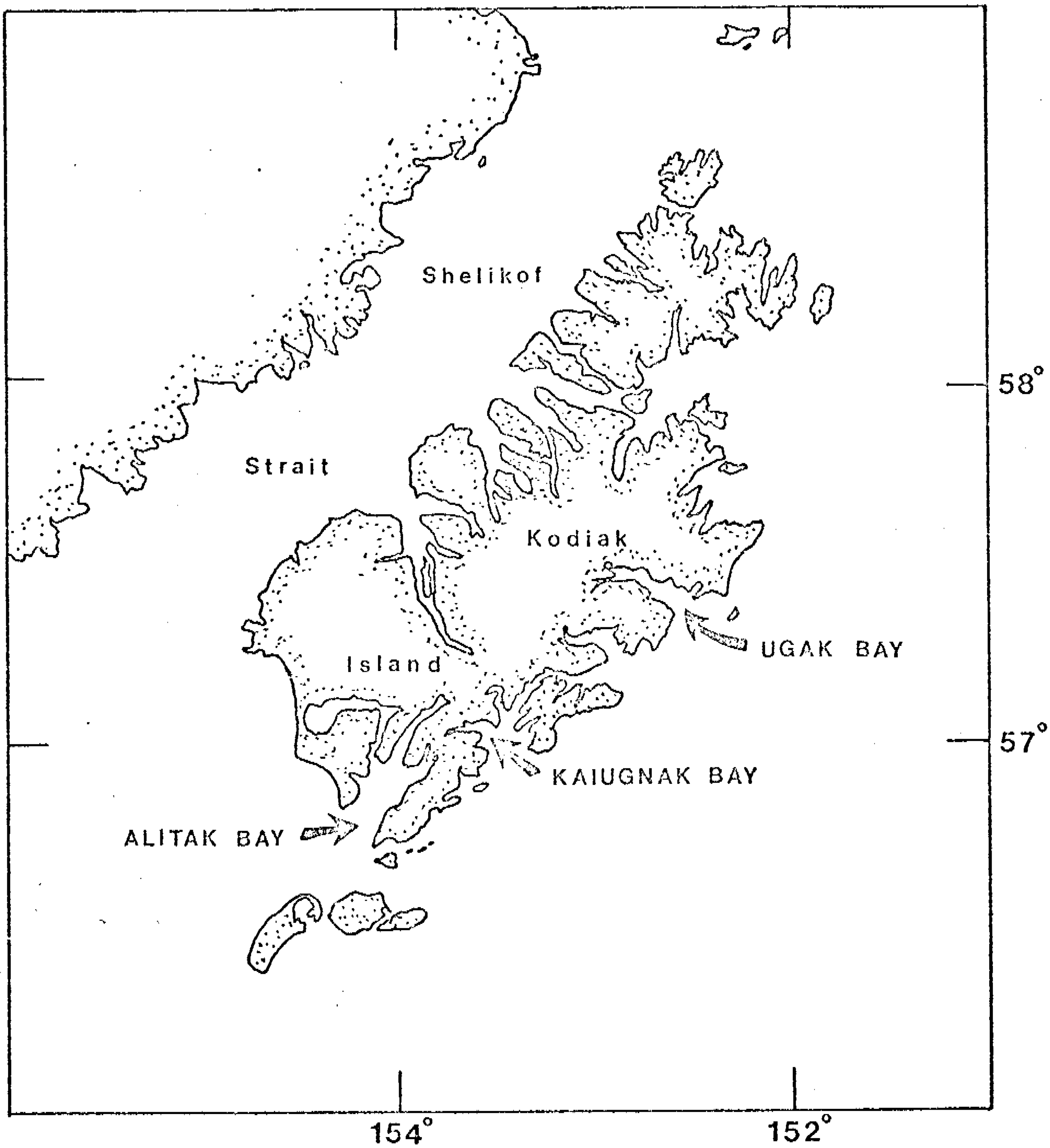


Fig. 1. Base map showing Kodiak Island and location of study bays.

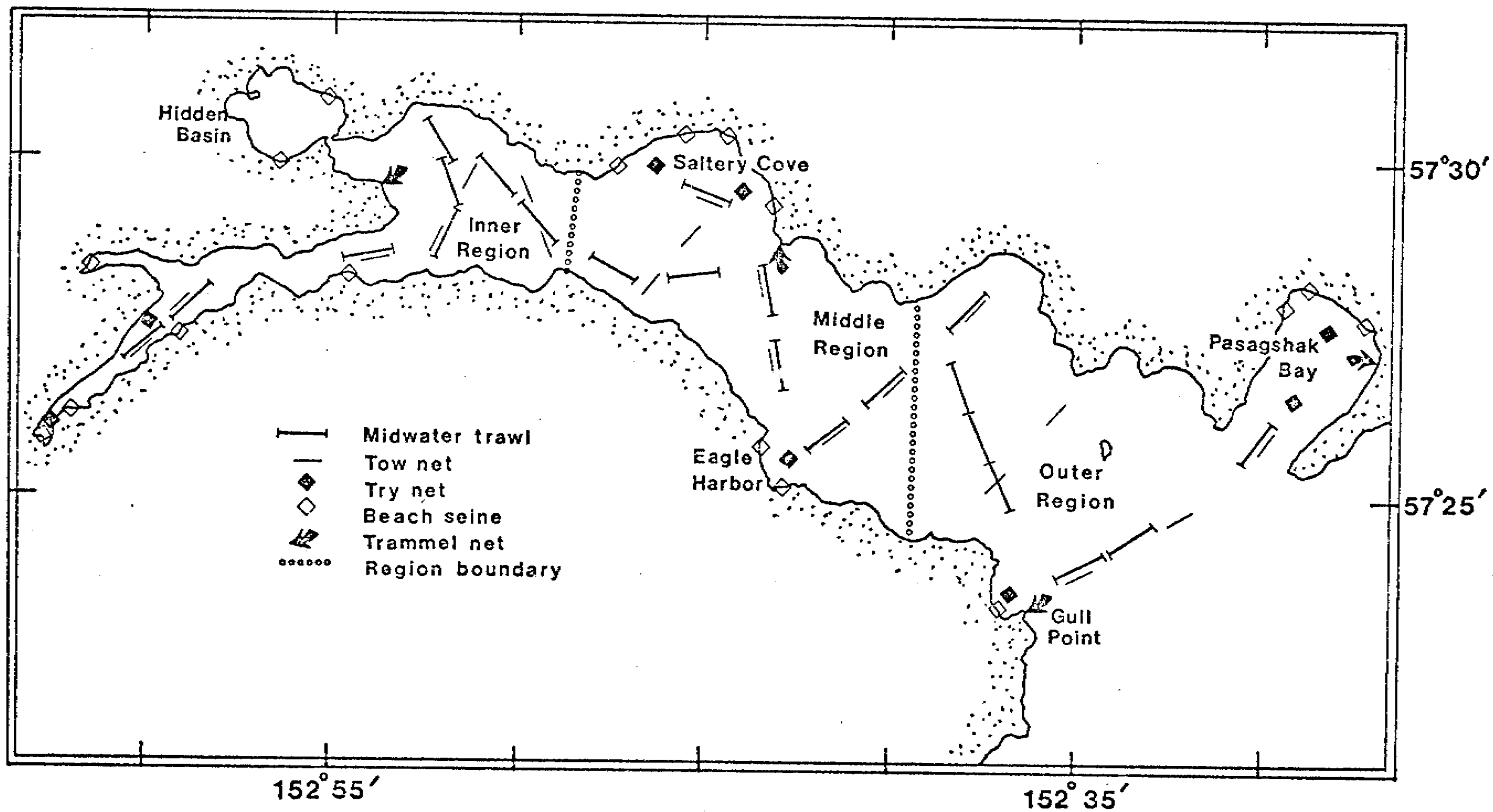


Fig. 2. Location of sampling sites and transects in Ugak Bay. Not all sites were sampled in each cruise.

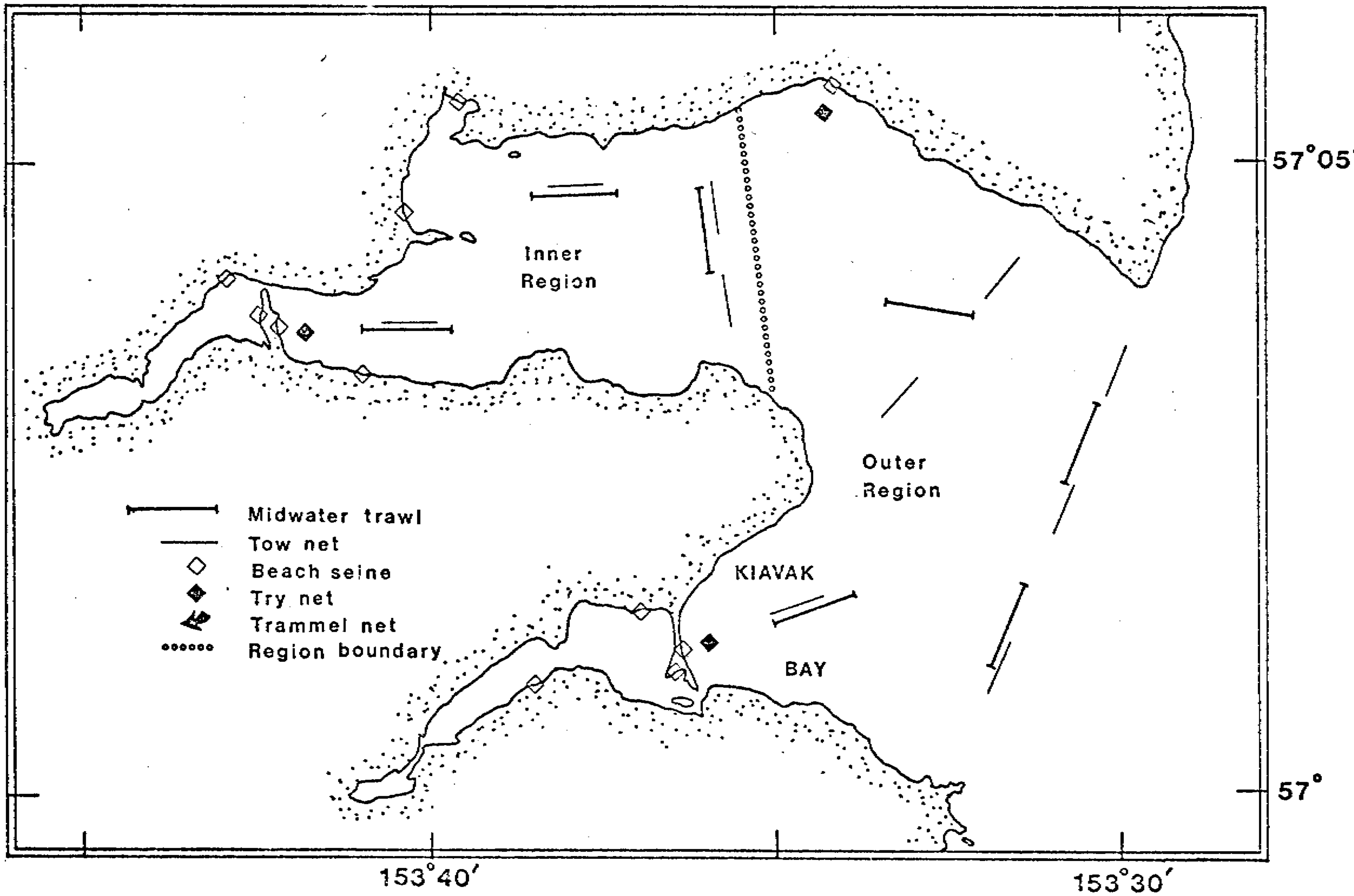


Fig. 3. Location of sampling sites and transects in Kaiugnak Bay. Not all sites were sampled in each cruise.

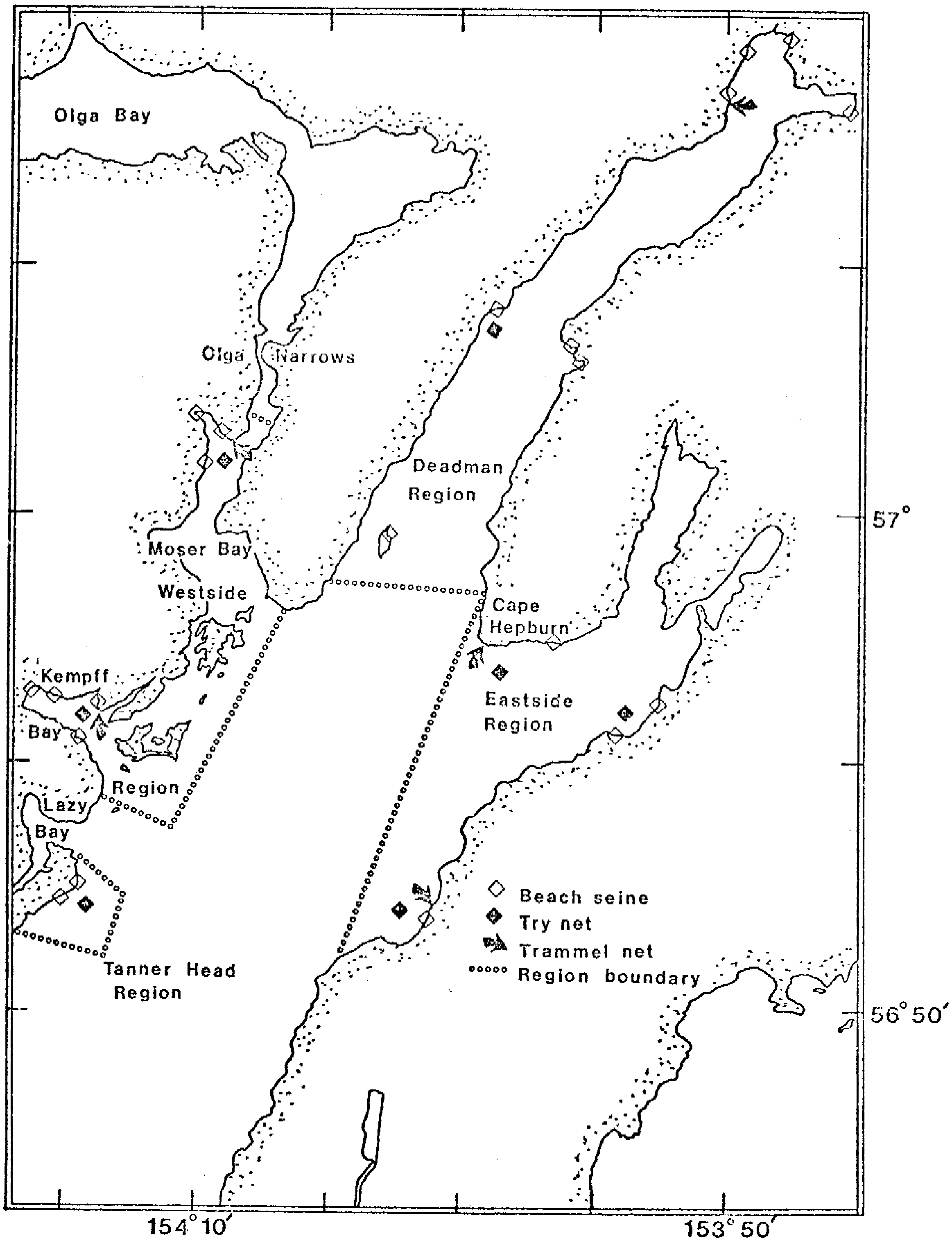


Fig. 4. Location of nearshore sampling sites in Alitak Bay. Not all sites were sampled in each cruise.

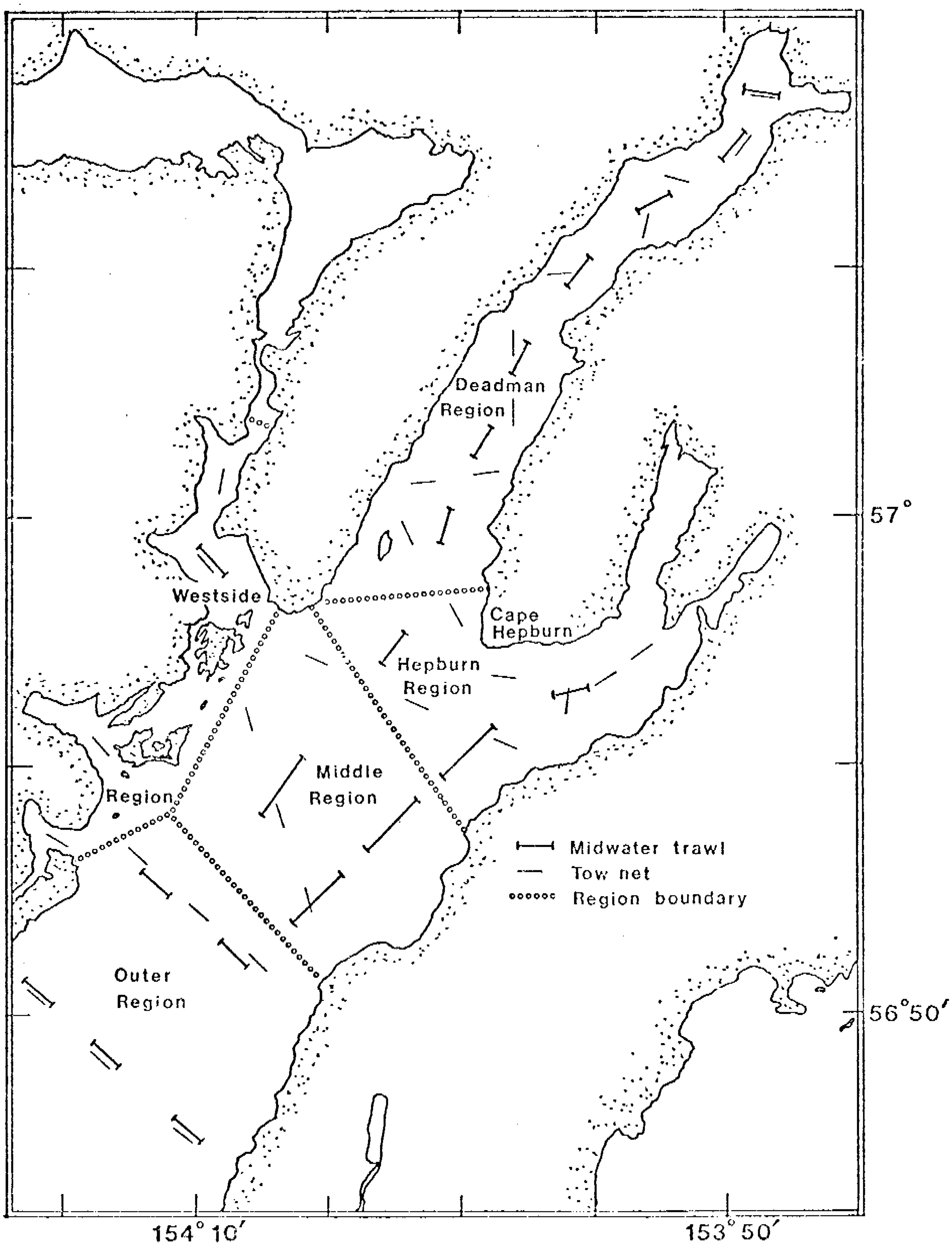


Fig. 5. Location of pelagic sampling sites and transects in Alitak Bay. Not all sites were sampled in each cruise.

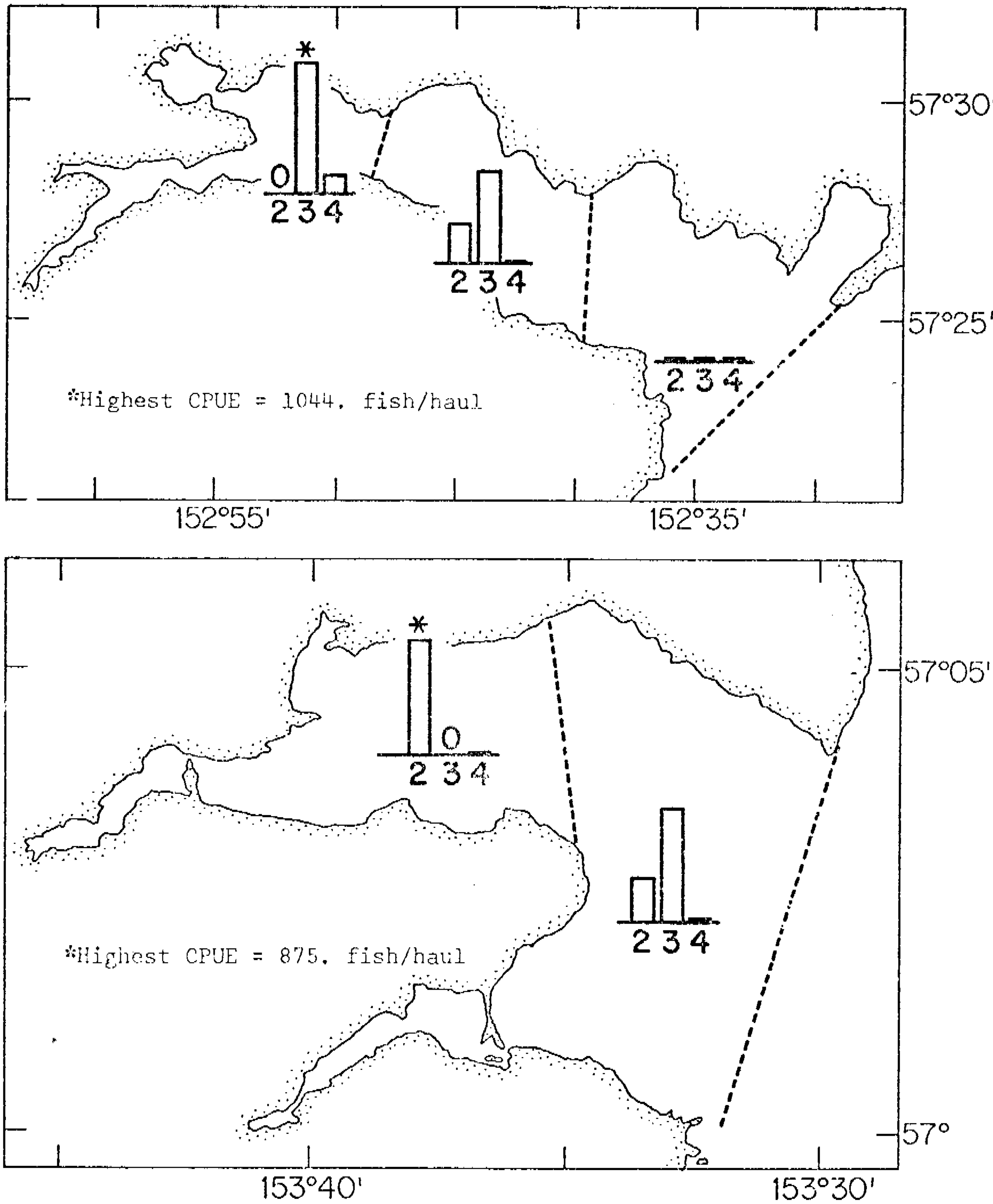


Fig. 6A & B. Townet CPUE of capelin in cruises 2-4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars. The diurnal catches in Alitak Bay were too small to warrant graphing.

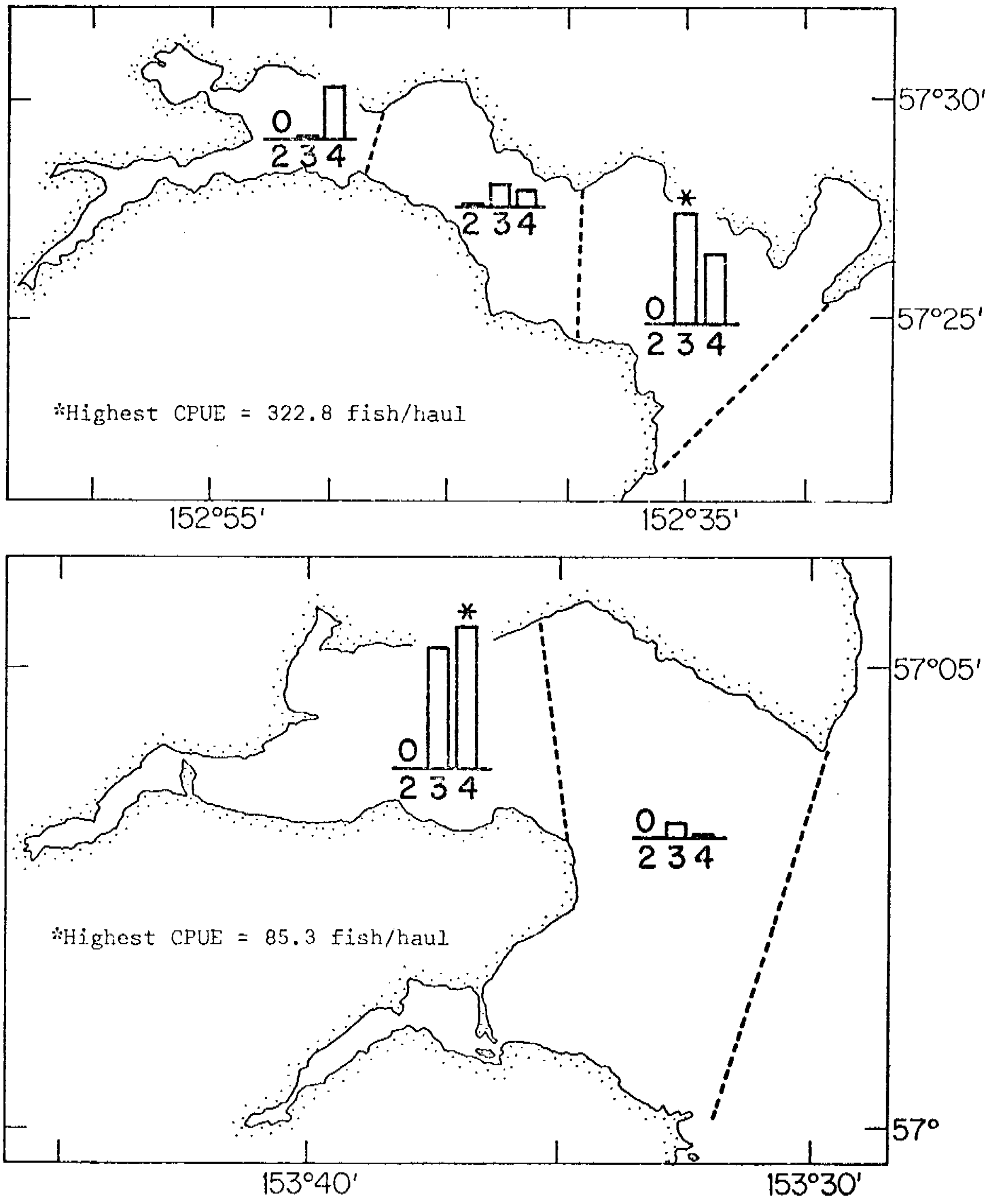


Fig. 7A & B. Townet CPUE of Pacific sandfish in cruises 2-4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars. The diurnal catches in Alitak Bay were too small to warrant graphing.

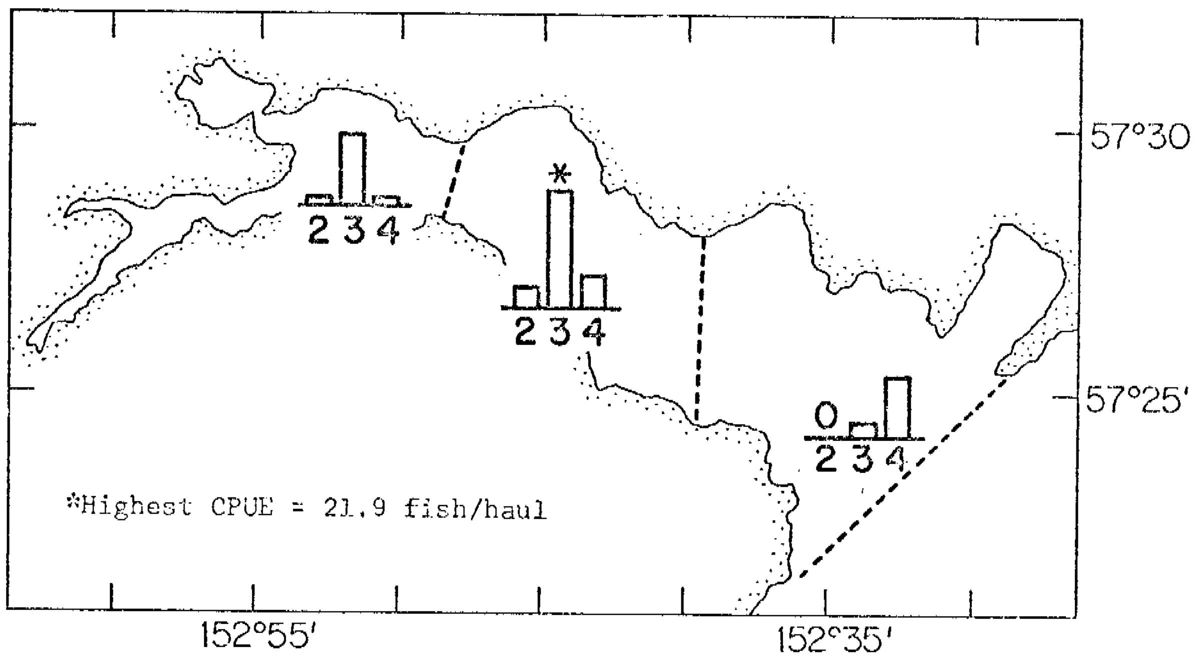


Fig. 8A. Townet CPUE of age 0 pink salmon in cruises 2-4 and in various regions of Ugak Bay. The cruise numbers are indicated below the bars. Catches in Kaiugnak Bay were too small to warrant graphing.

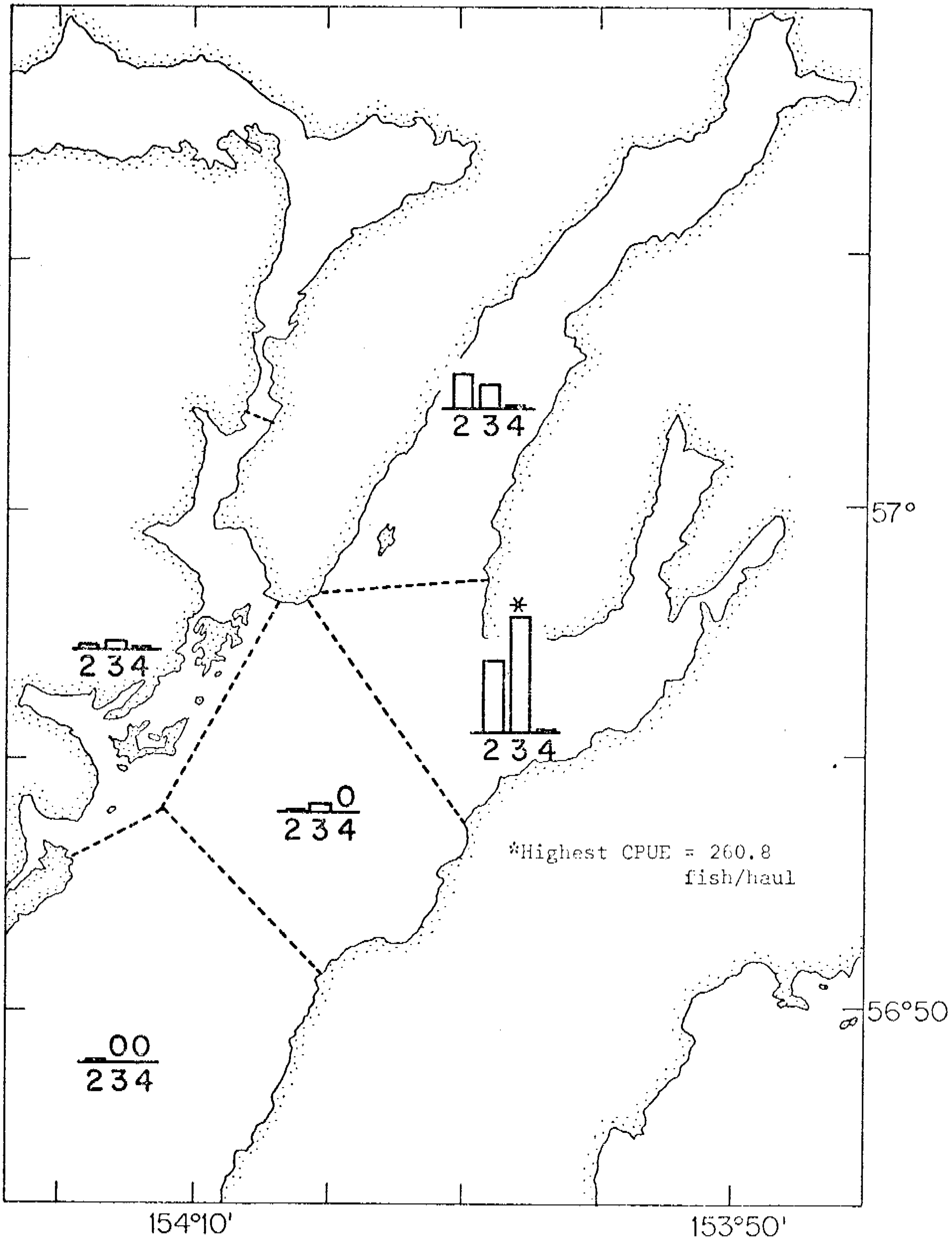


Fig. 8B. Townet CPUE of age 0 pink salmon in cruises 2-4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars.

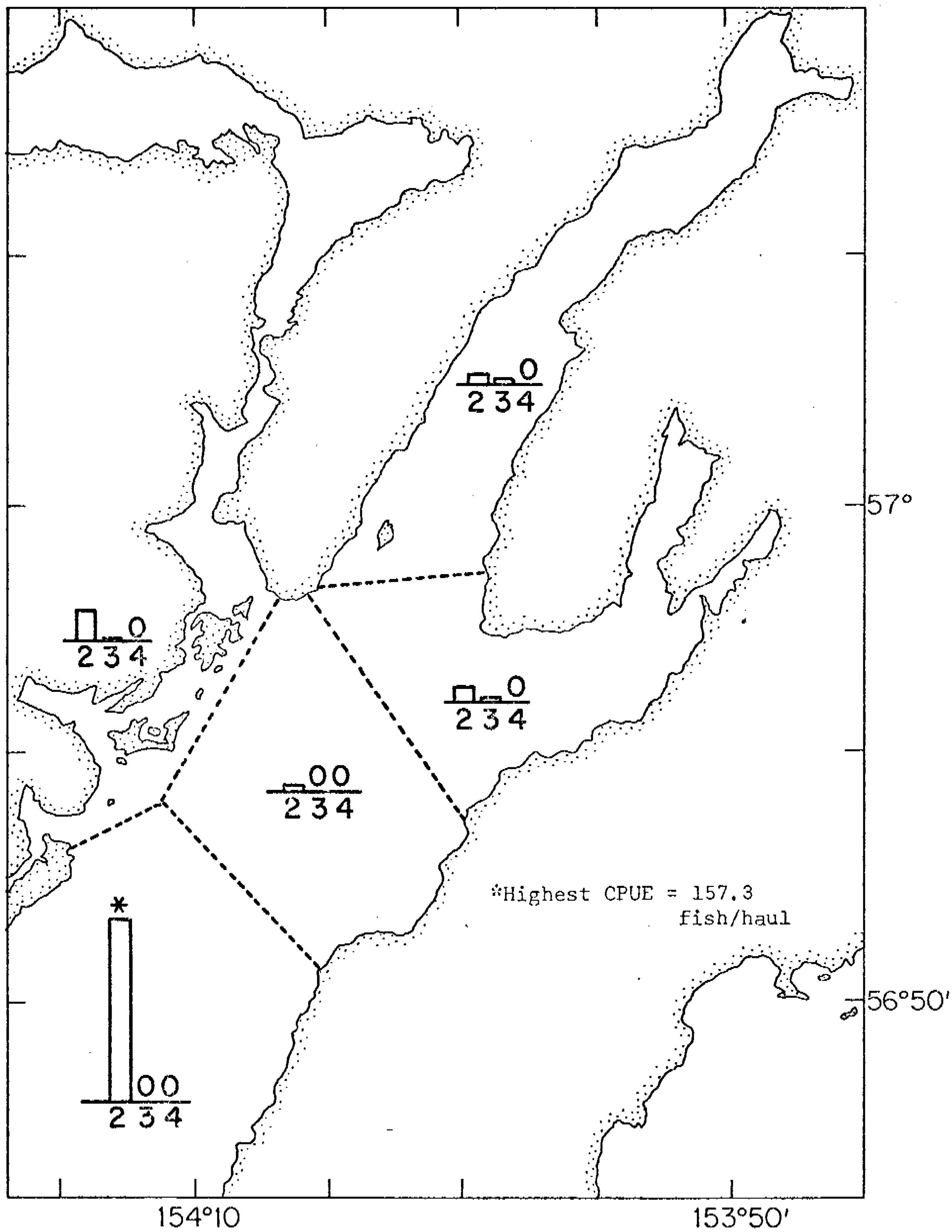


Fig. 9. Townet CPUE of age 1 greenlings (*Hexagrammos* spp.) in cruises 2-4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars. Catches in Ugak and Kaiugnak Bays were too small to warrant graphing.

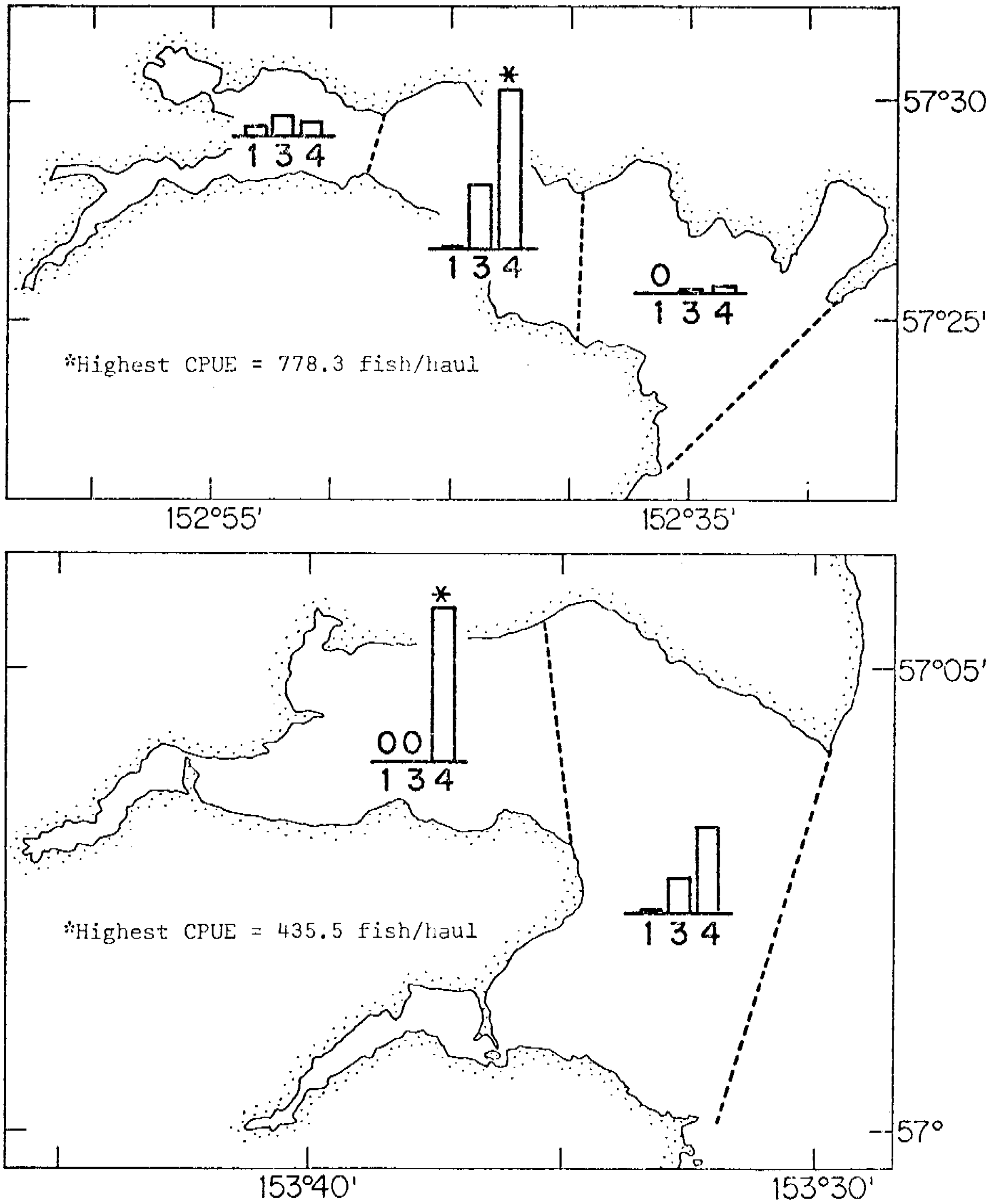


Fig. 10A & B. Midwater trawl CPUE of capelin in cruises 1, 3, and 4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars.

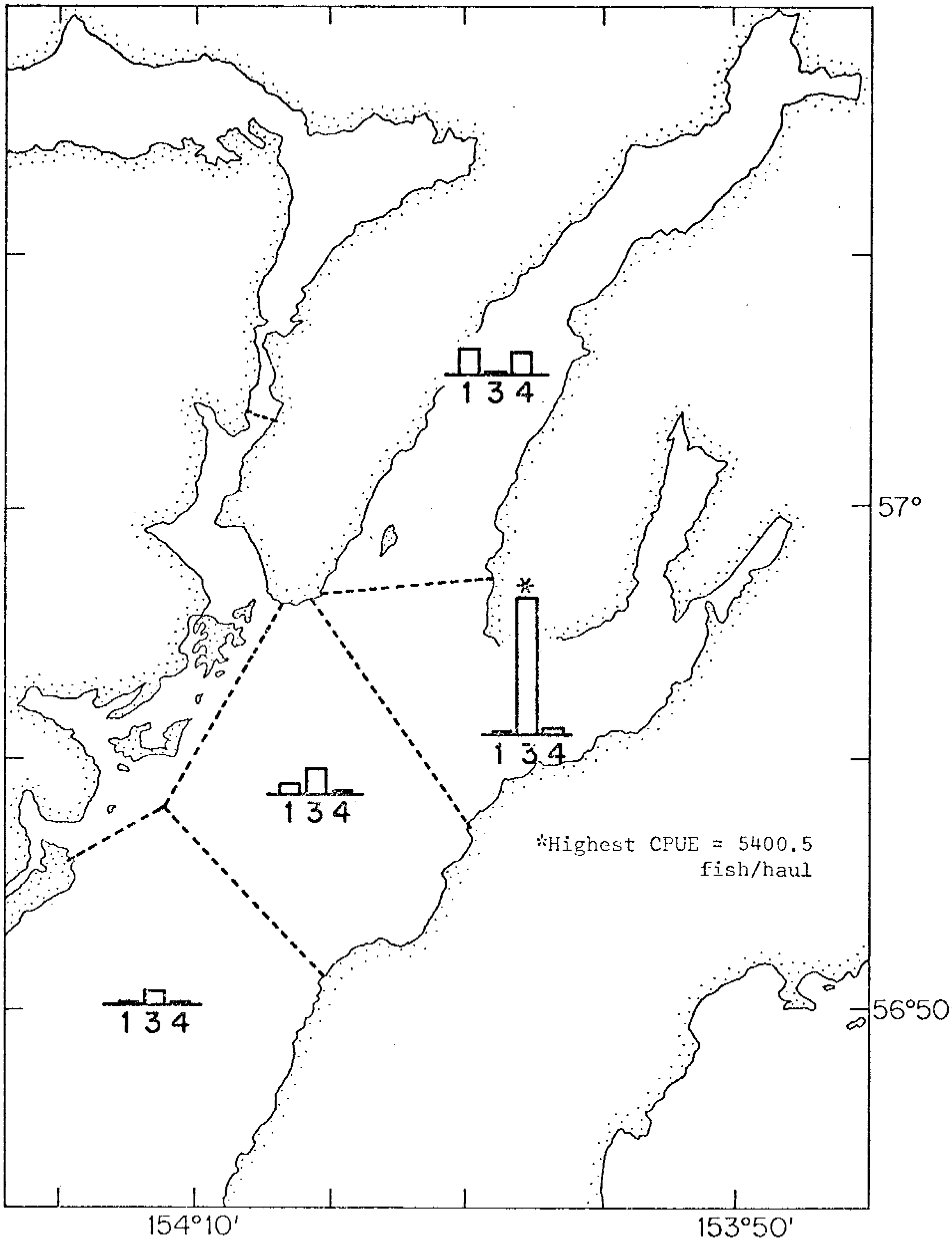


Fig. 10C. Midwater trawl CPUE of capelin in cruises 1, 3, and 4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars.

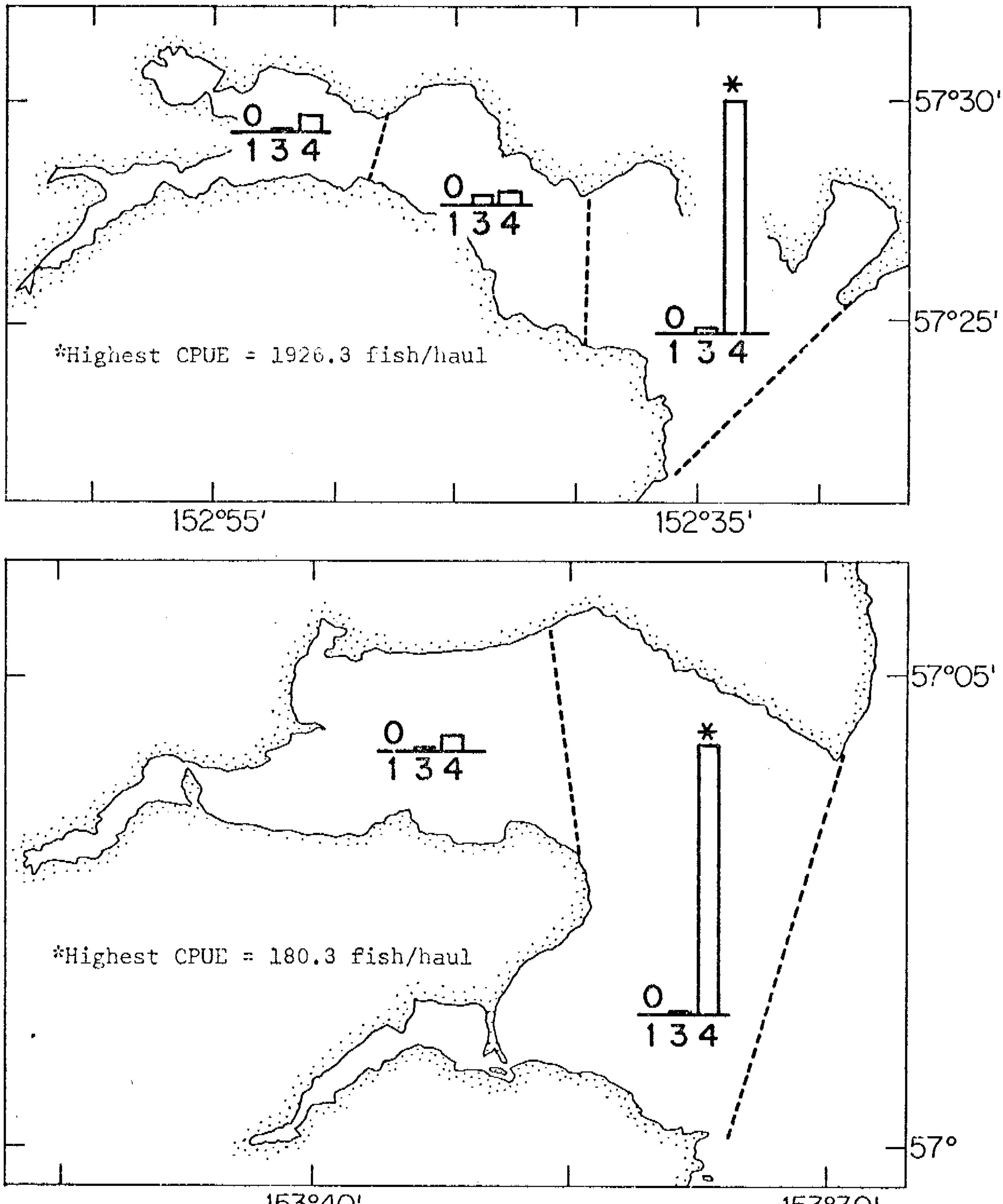


Fig. 11A & B. Midwater trawl CPUE of Pacific sandfish in cruises 1, 3, and 4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars.

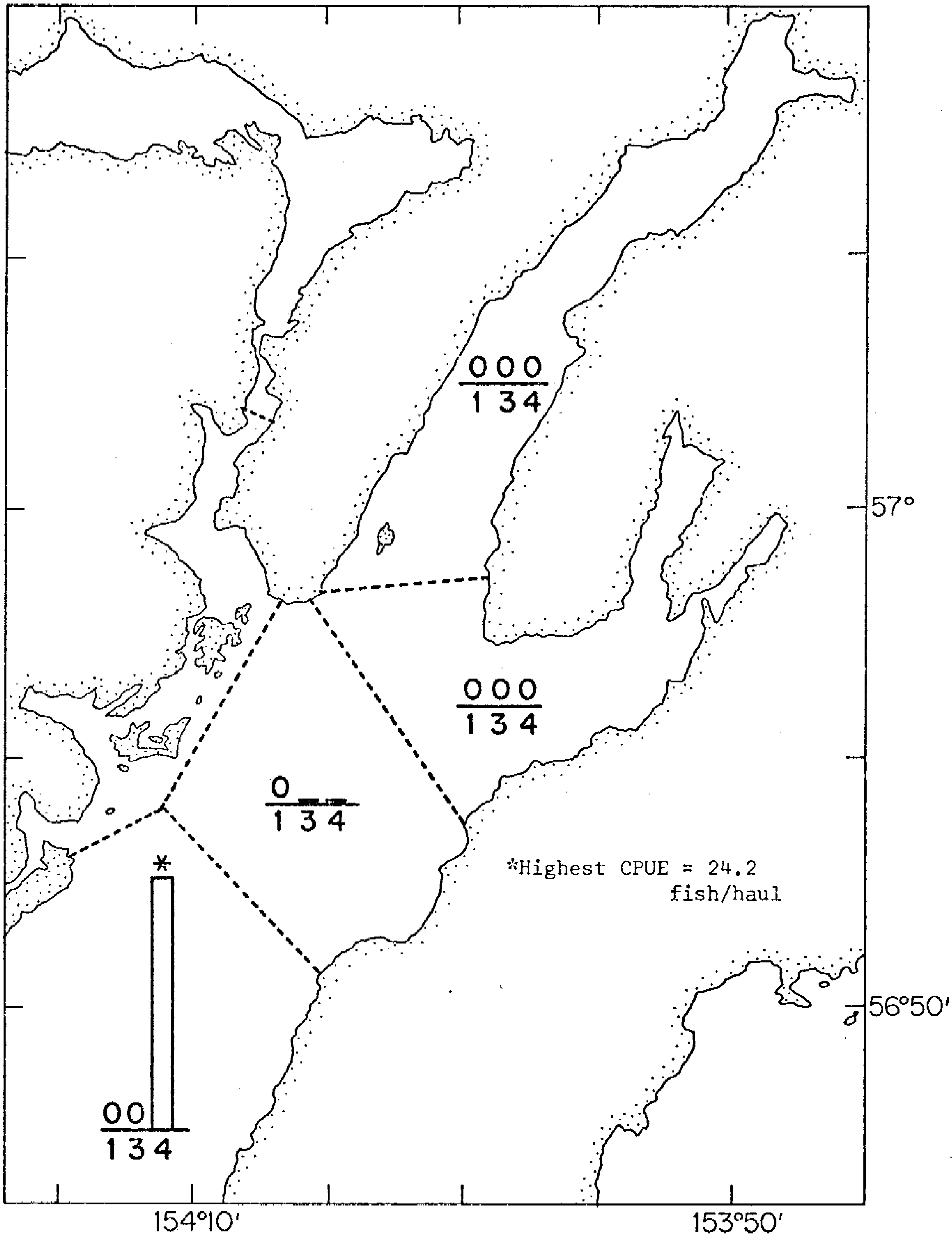


Fig. 11C. Midwater trawl CPUE of Pacific sandfish in cruises 1, 3 and 4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars.

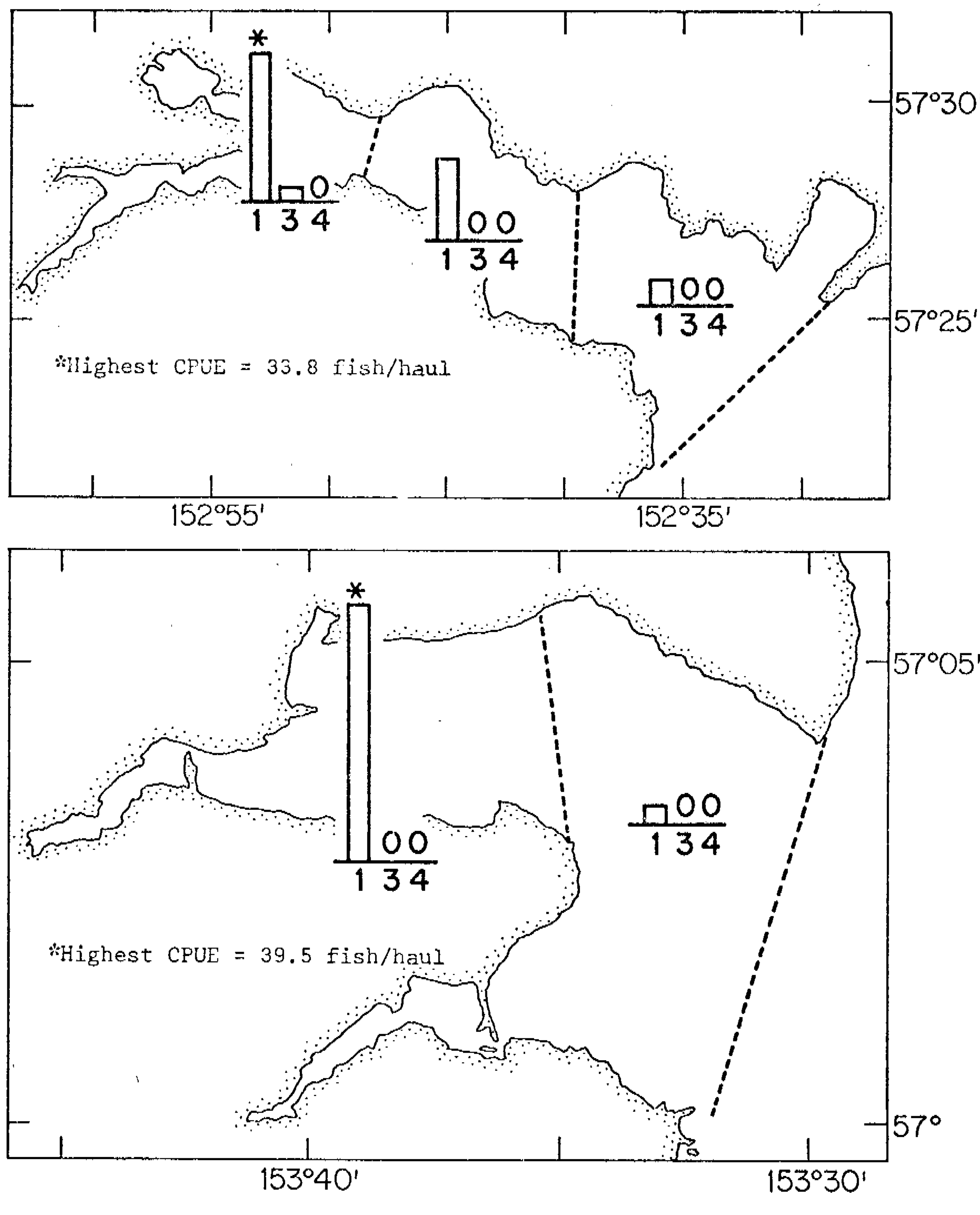


Fig. 12A & B. Midwater trawl CPUE of sand lance in cruises 1, 3, and 4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars. Catches in Alitak Bay were too small to warrant graphing.

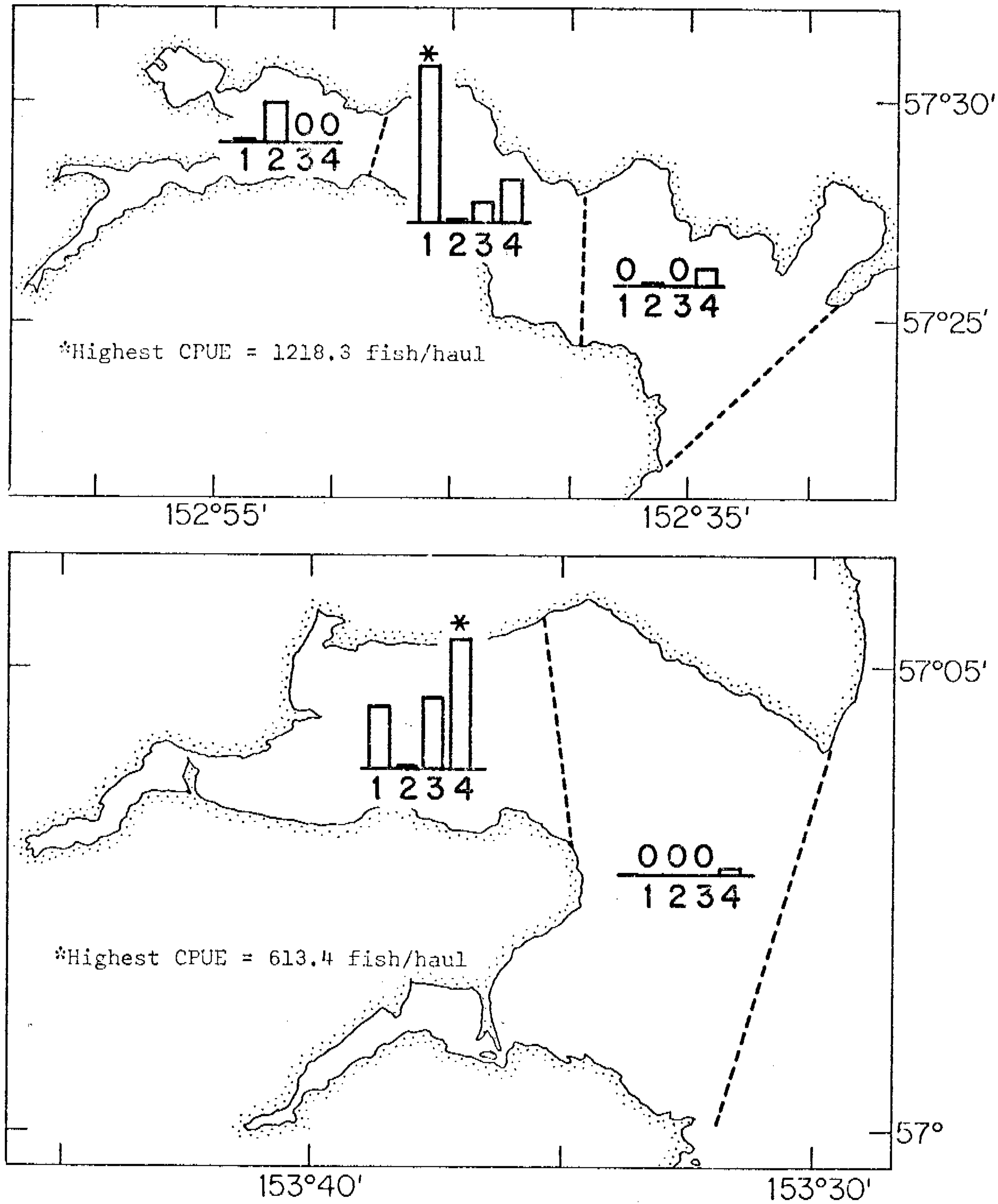


Fig. 13A & B. Beach seine CPUE of sand lance in cruises 1-4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars.

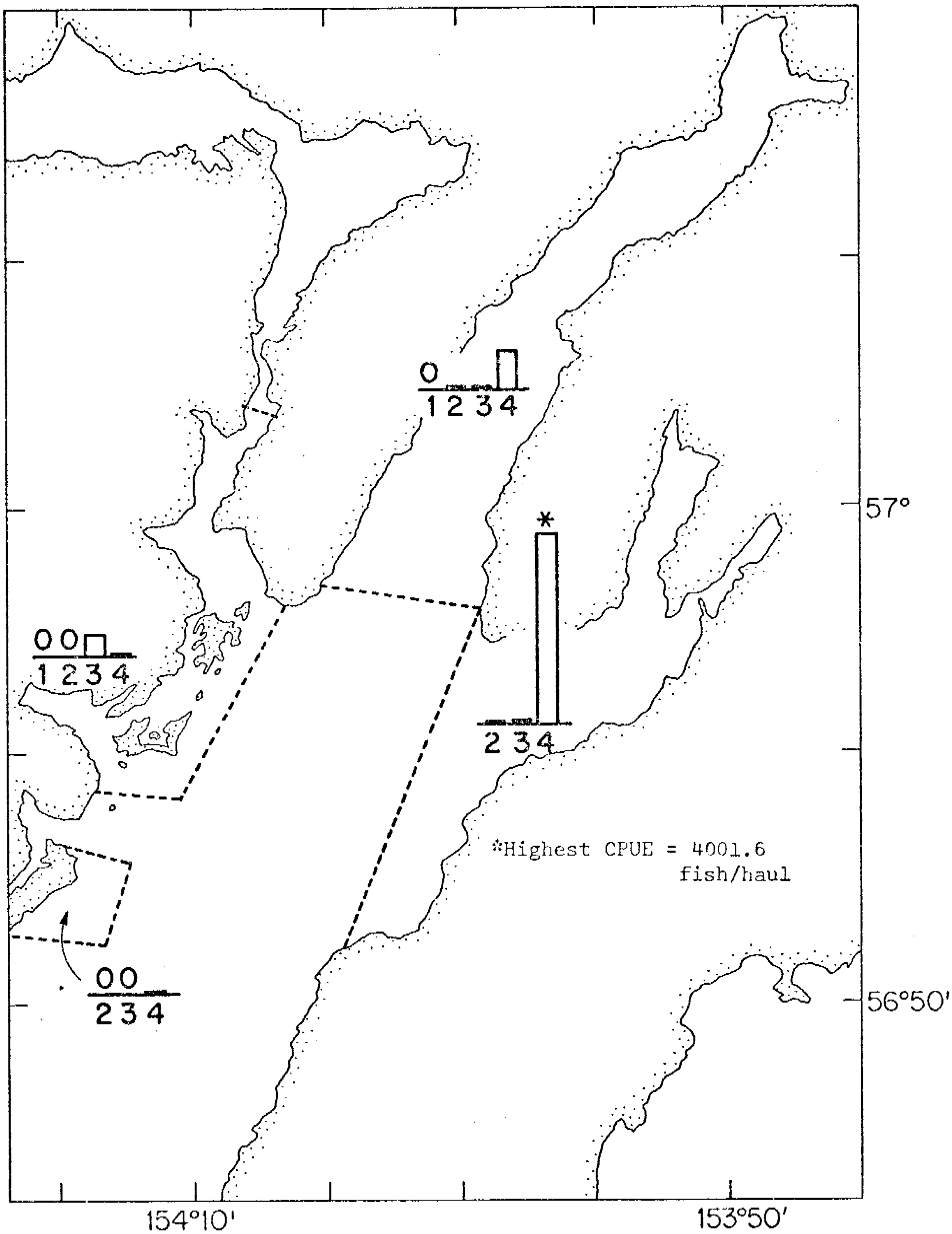


Fig. 13C. Beach seine CPUE of sand lance in cruises 1-4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars.

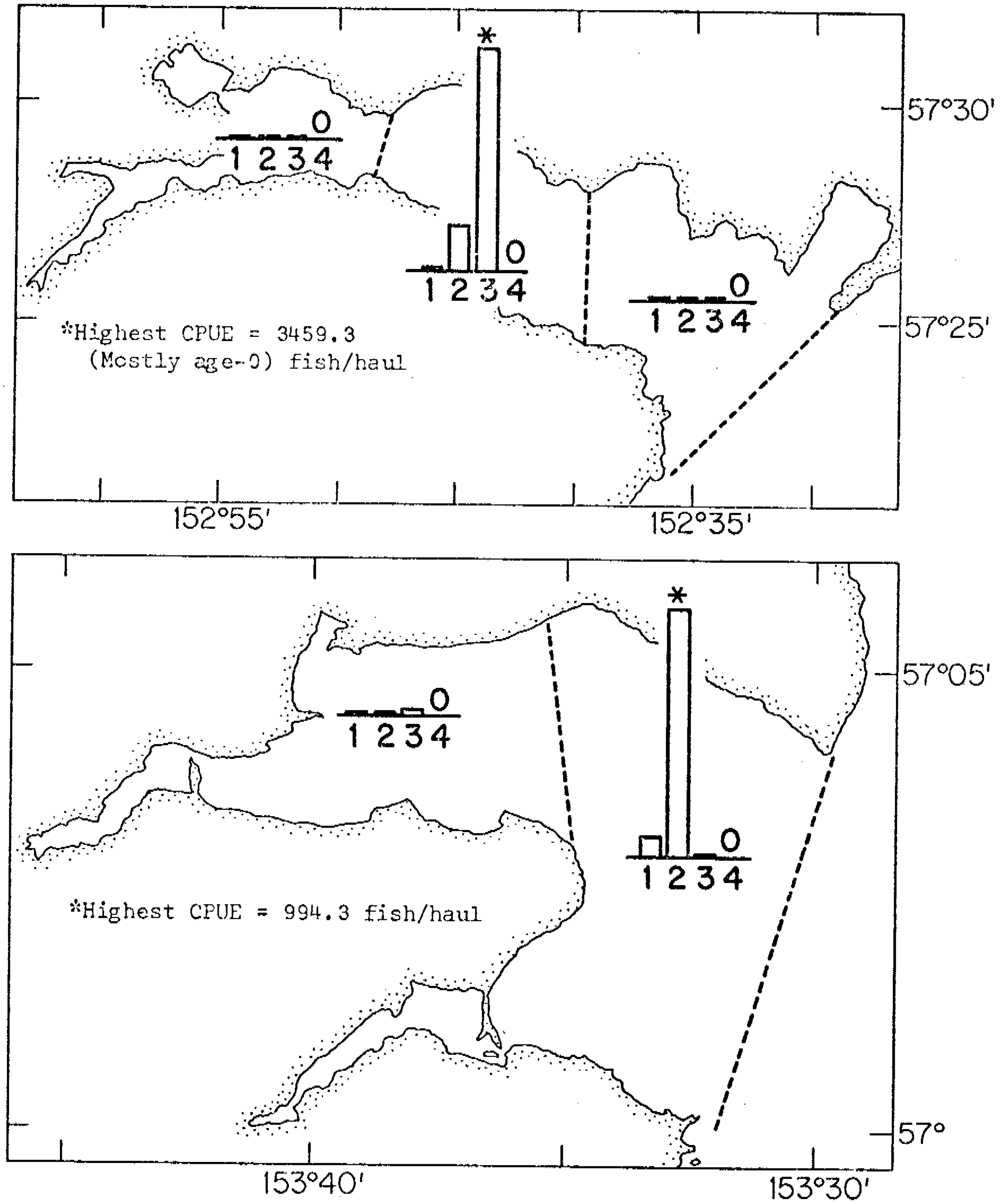


Fig. 14A & B. Beach seine CPUE of pink salmon in cruises 1-4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars.

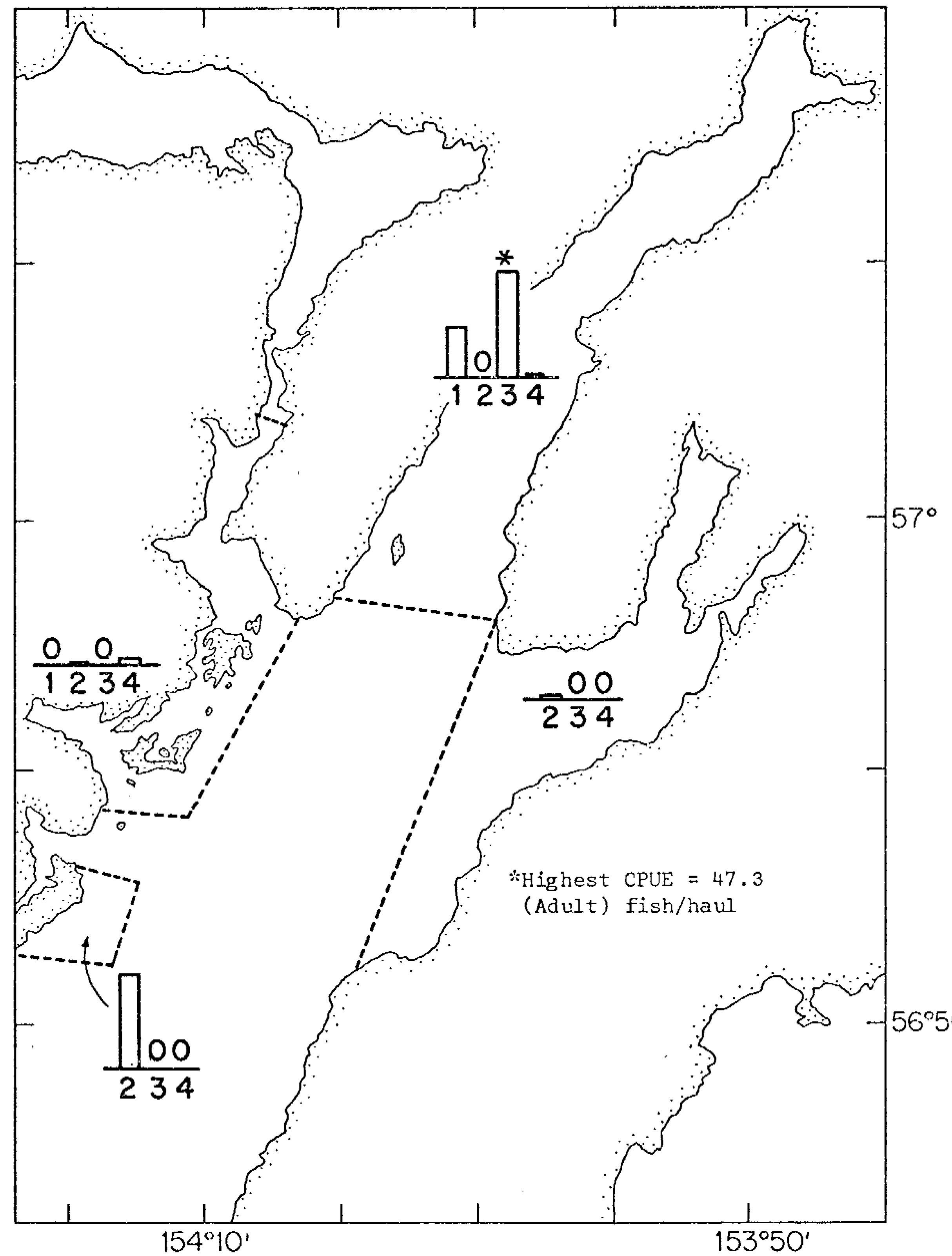
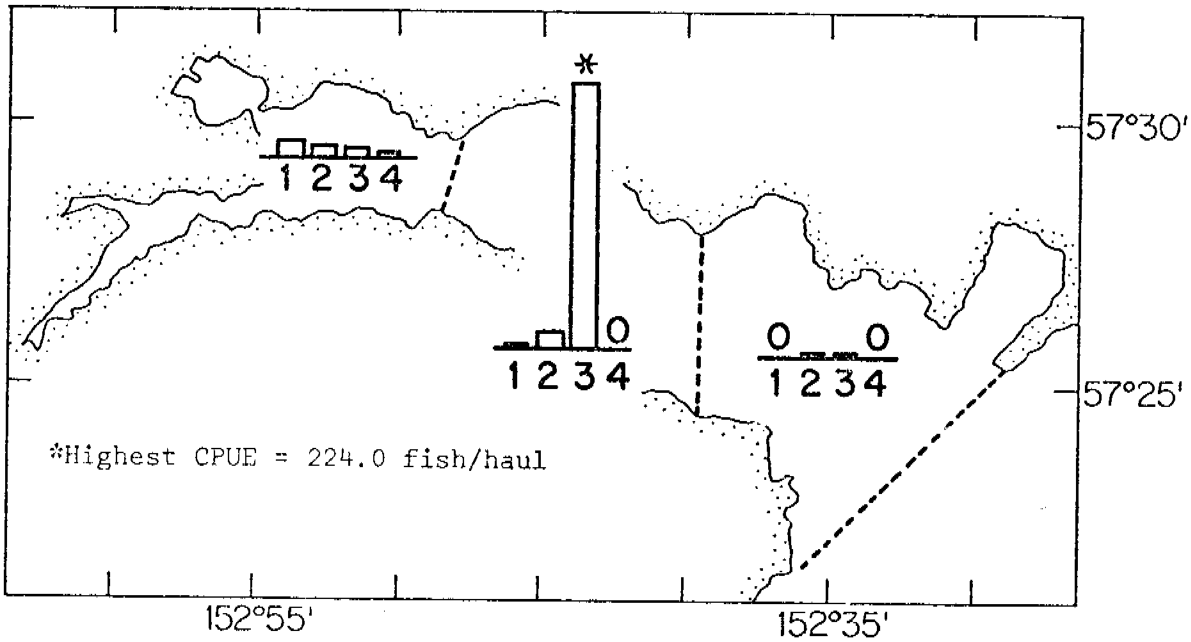


Fig. 14C. Beach seine CPUE of pink salmon in cruises 1-4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars.



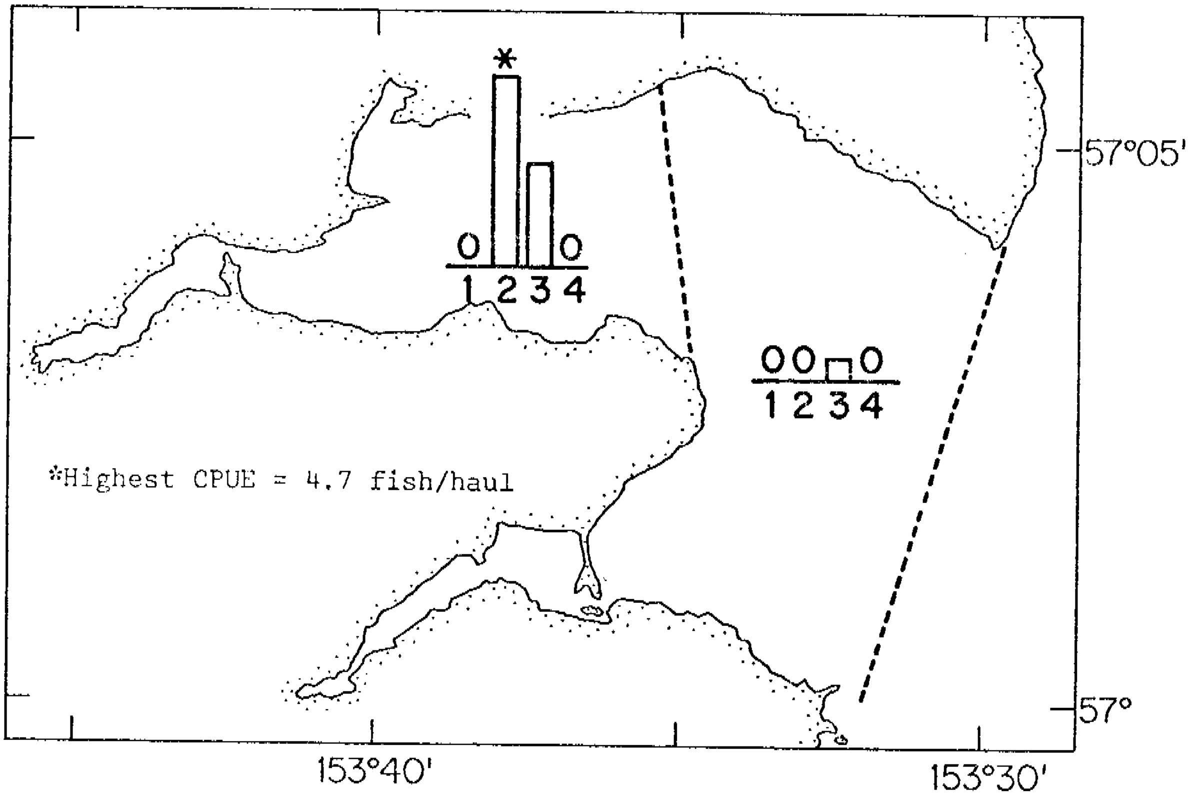


Fig. 15A & B. Beach seine CPUE of chum salmon in cruises 1-4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars. Catches in Alitak Bay were entirely from one cruise and region, and do not warrant graphing.

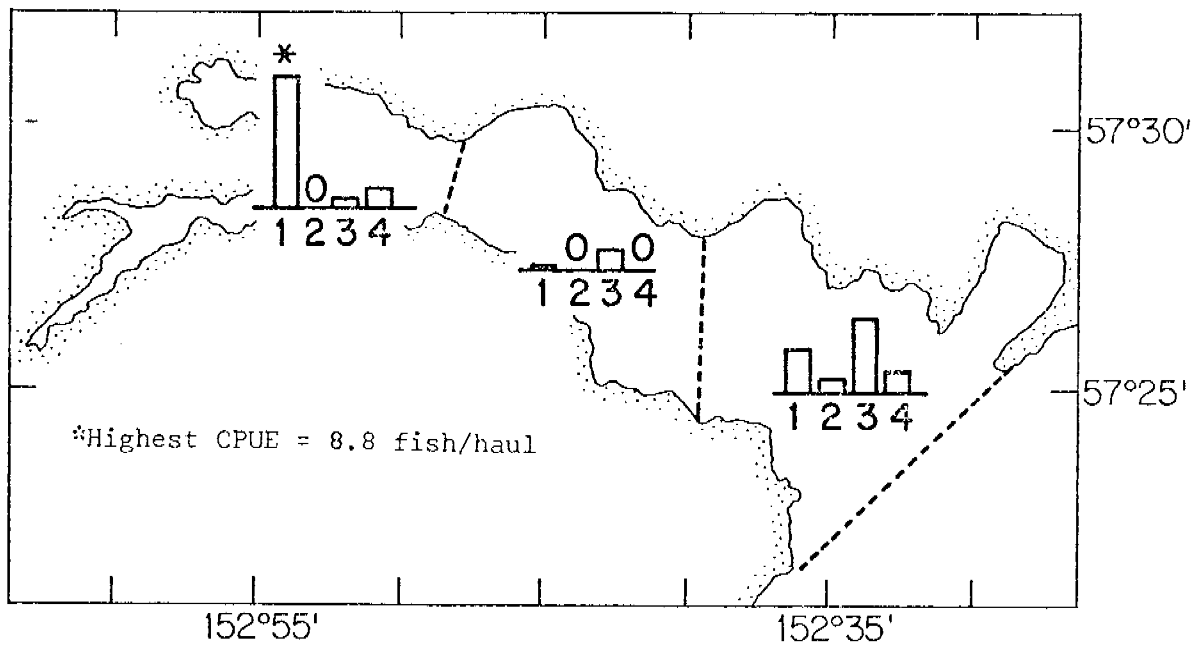


Fig. 16A. Beach seine CPUE of Dolly Varden in cruises 1-4 and in various regions of Ugak Bay. Catches in Kaiugnak Bay were too small to warrant graphing. The cruise numbers are indicated below the bars.

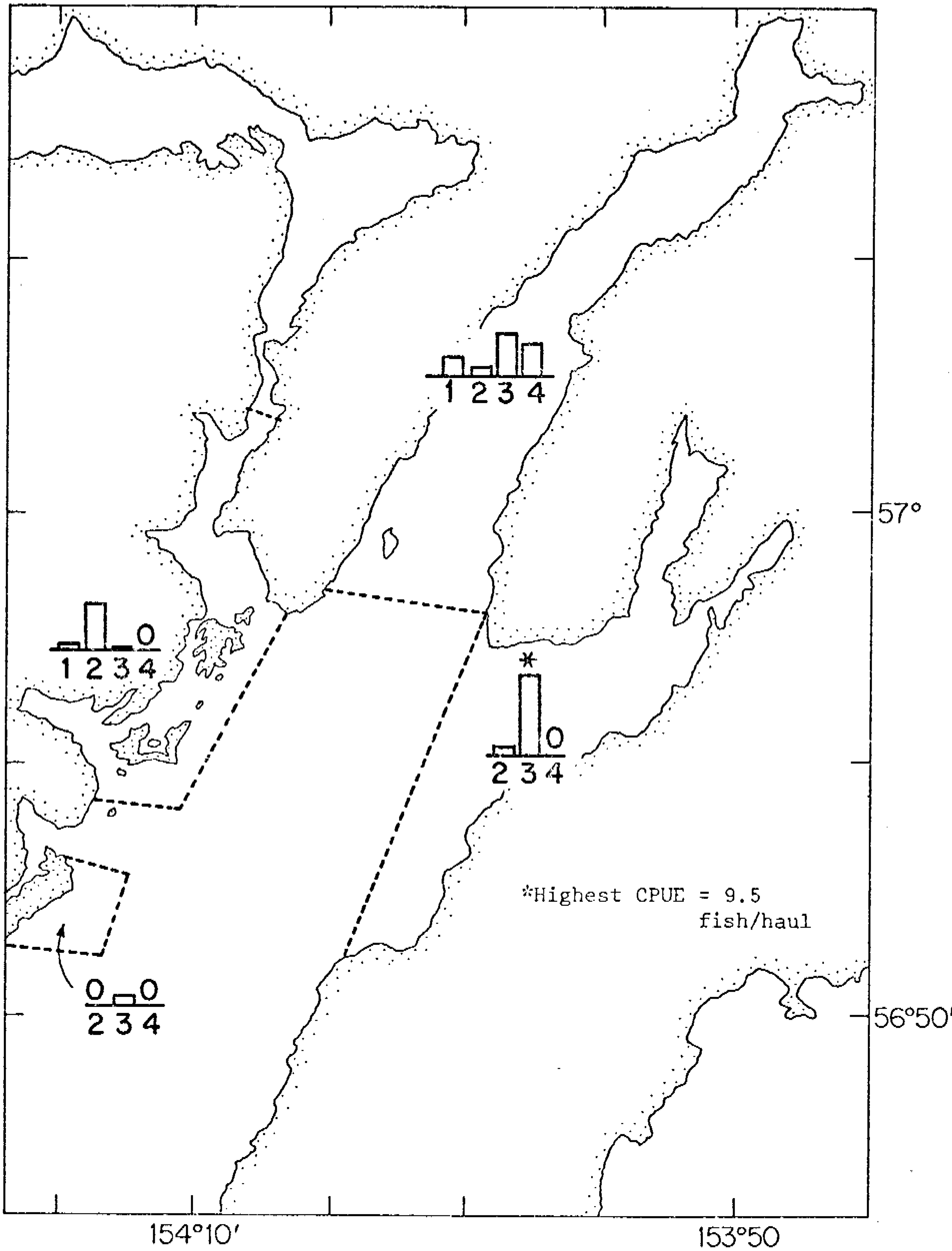


Fig. 16B. Beach seine CPUE of Dolly Varden in cruises 1-4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars.

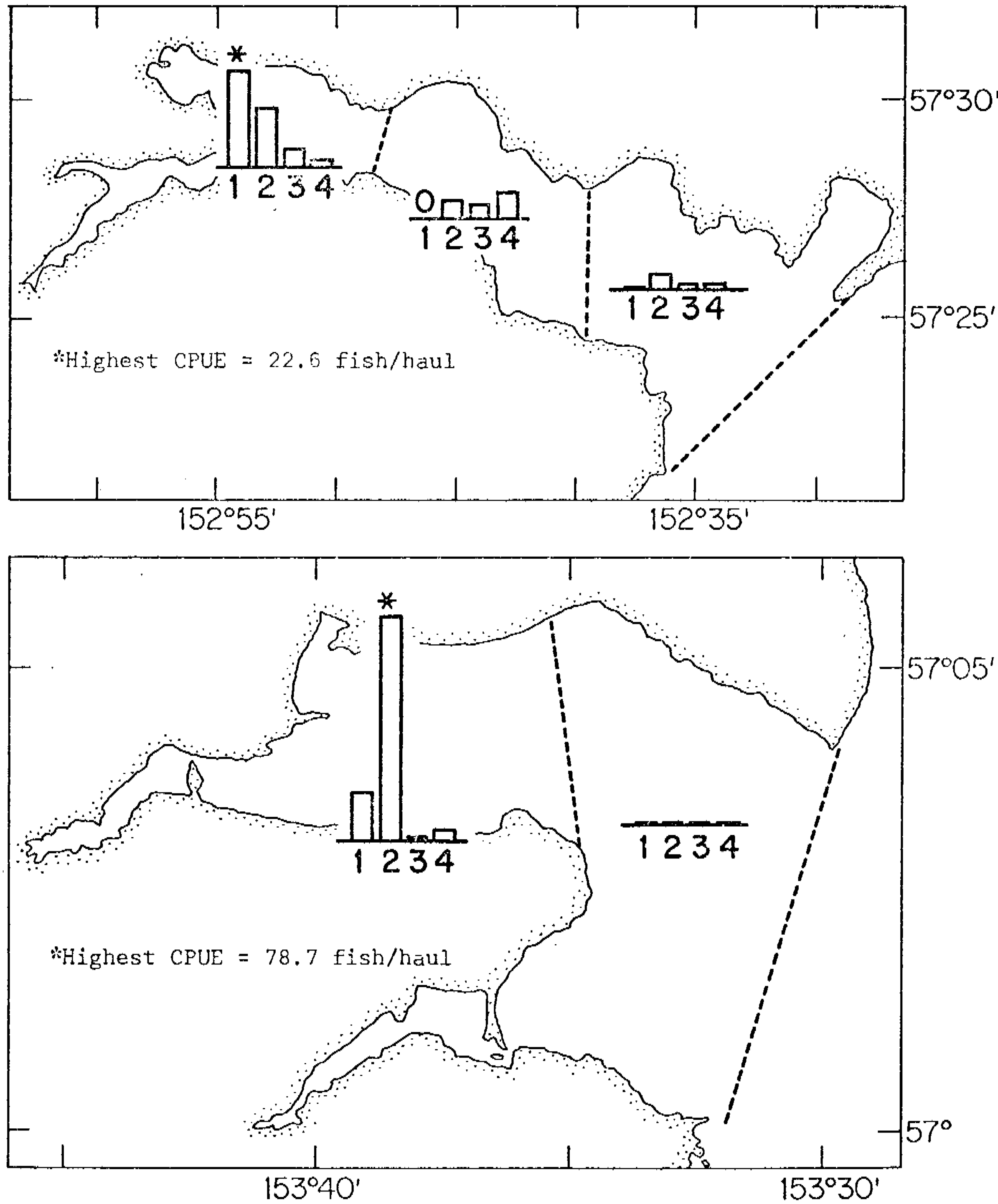


Fig. 17A & B. Beach seine CPUE of great sculpin in cruises 1-4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars.

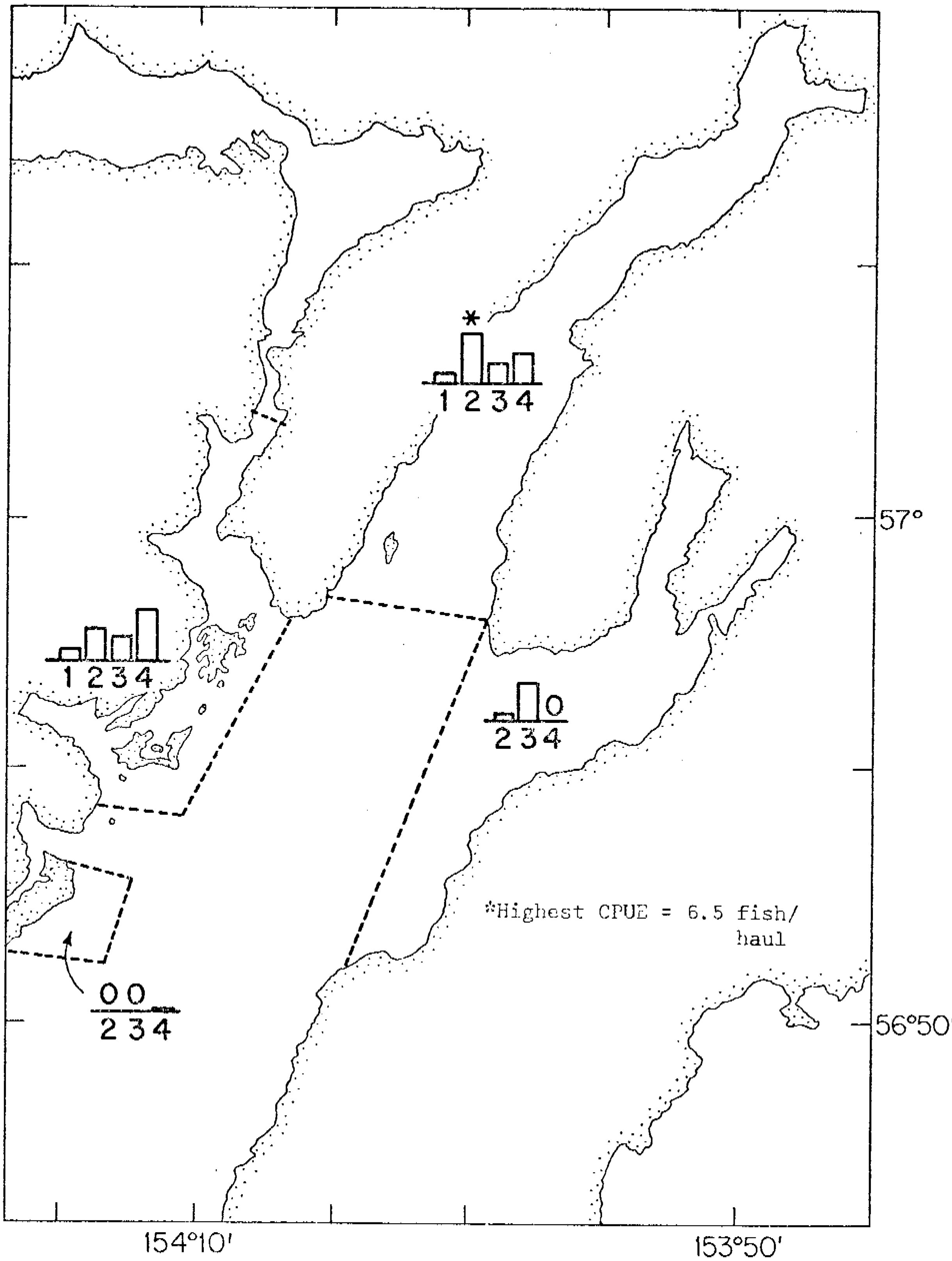


Fig. 17C. Beach seine CPUE of great sculpin in cruises 1-4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars.

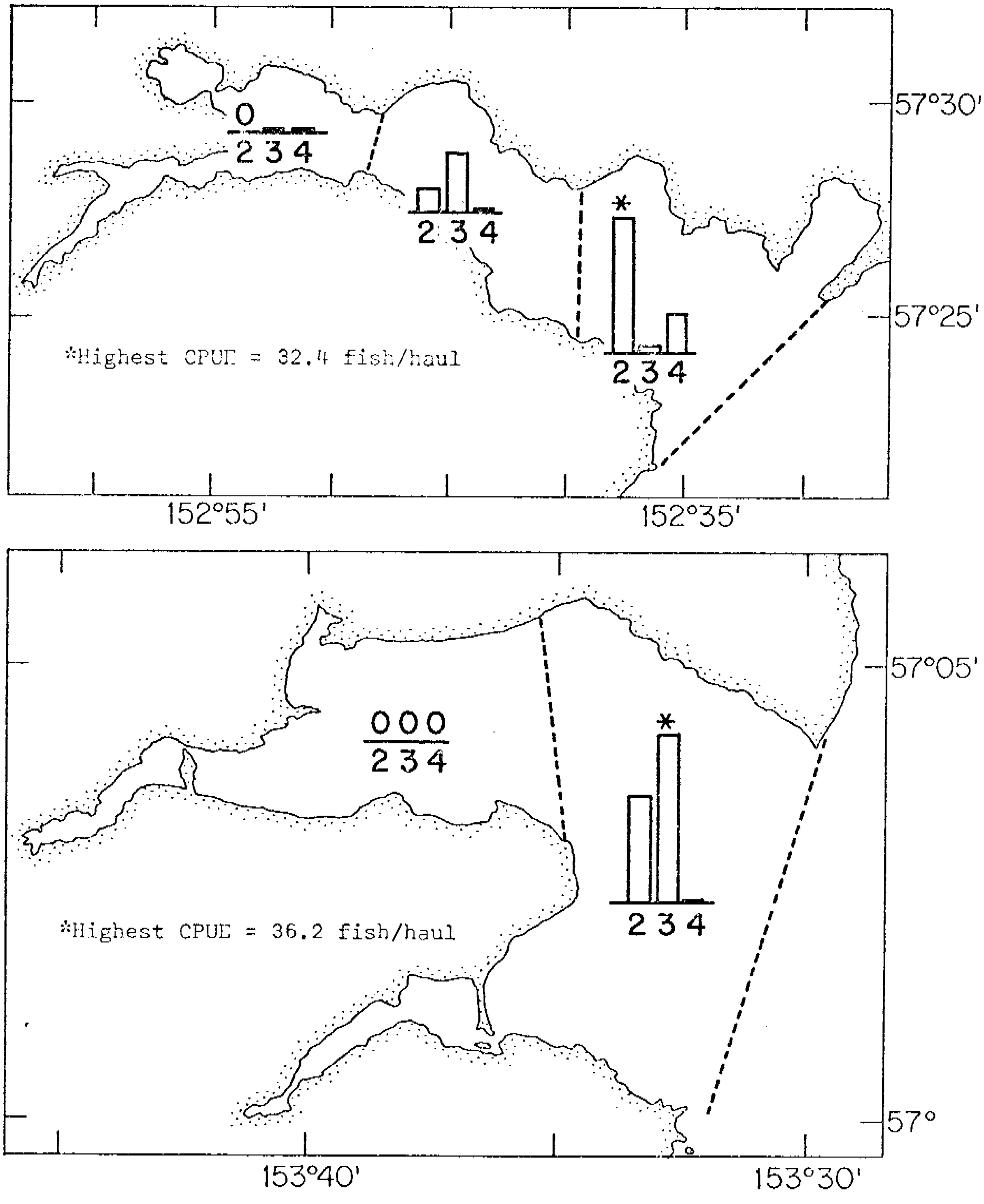


Fig. 18A & B. Try net CPUE of snake prickleback in cruises 2-4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars. Catches in Alitak Bay were too small to warrant graphing.

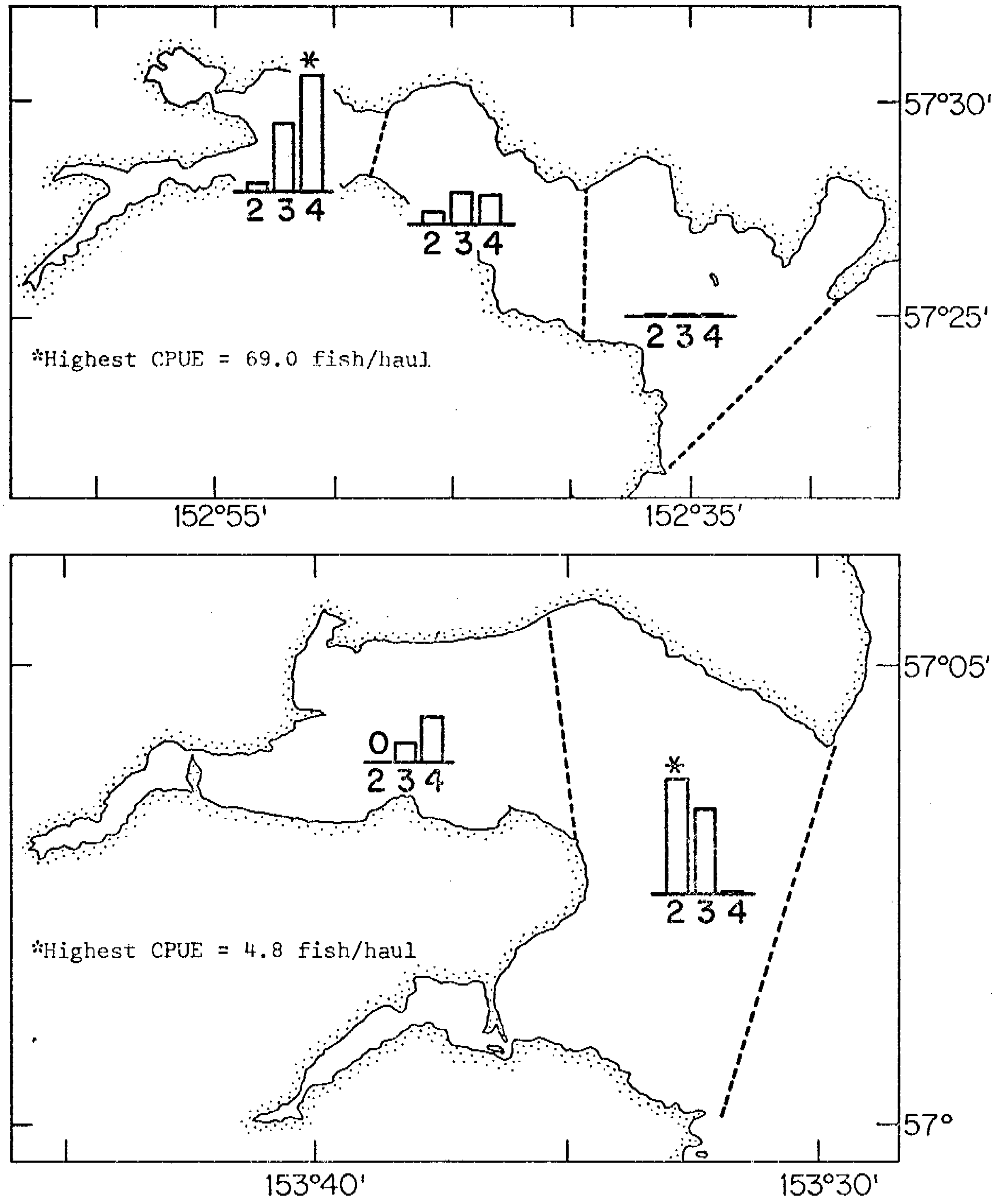


Fig. 19A & B. Try net CPUE of yellowfin sole in cruises 2-4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars.

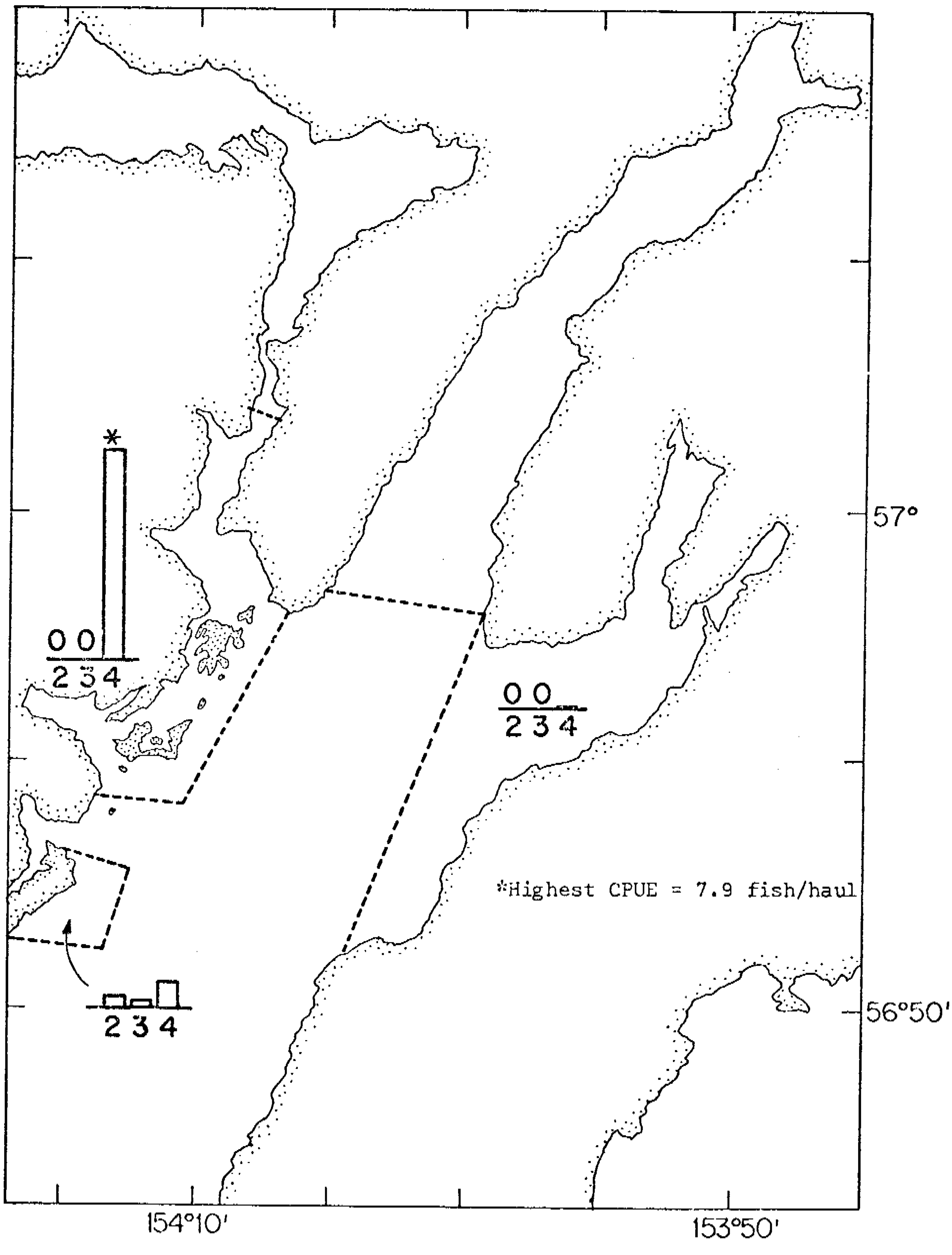


Fig. 19C. Try net CPUE of yellowfin sole in cruises 2-4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars.

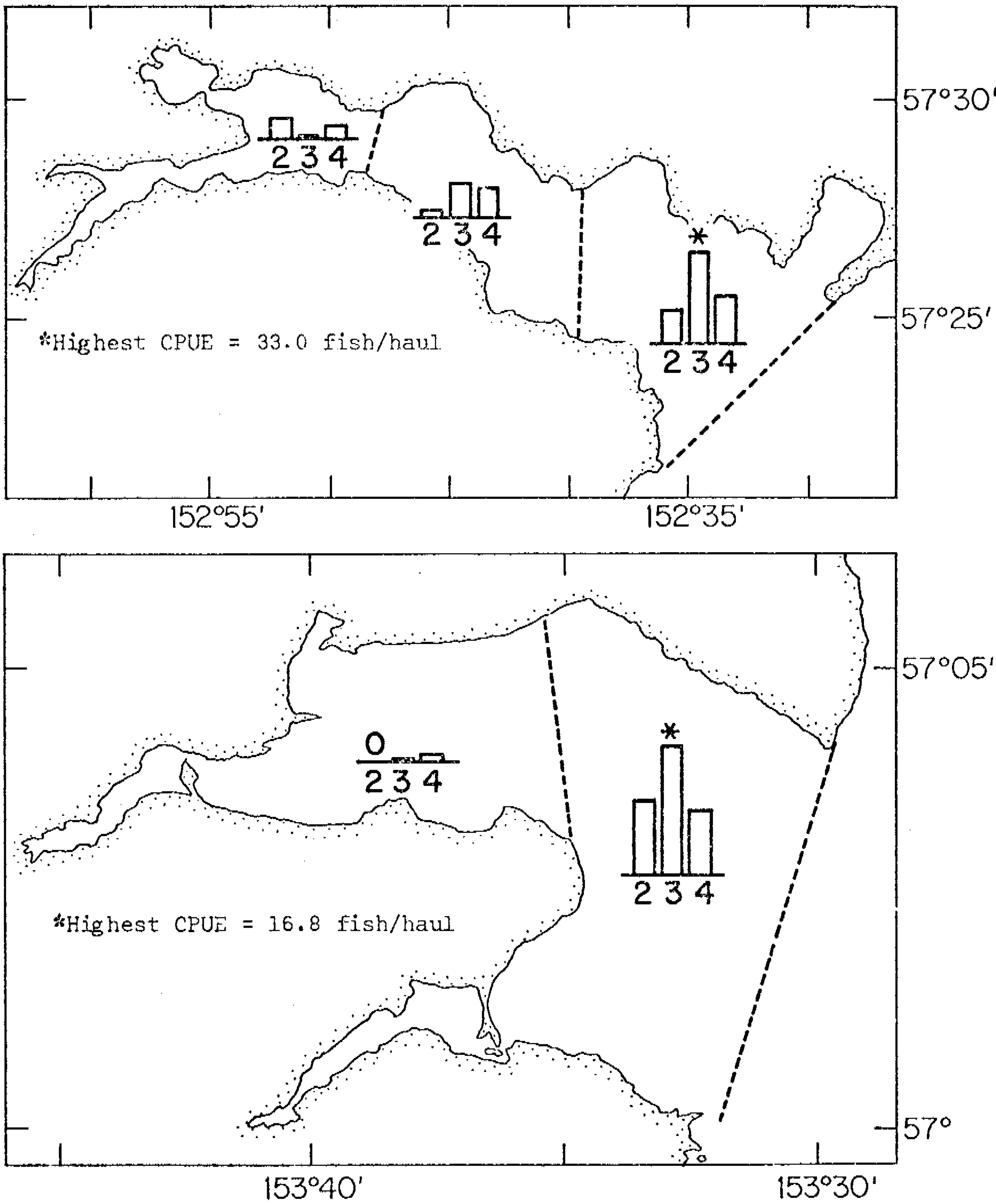


Fig. 20A & B. Try net CPUE of rock sole in cruises 2-4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars.

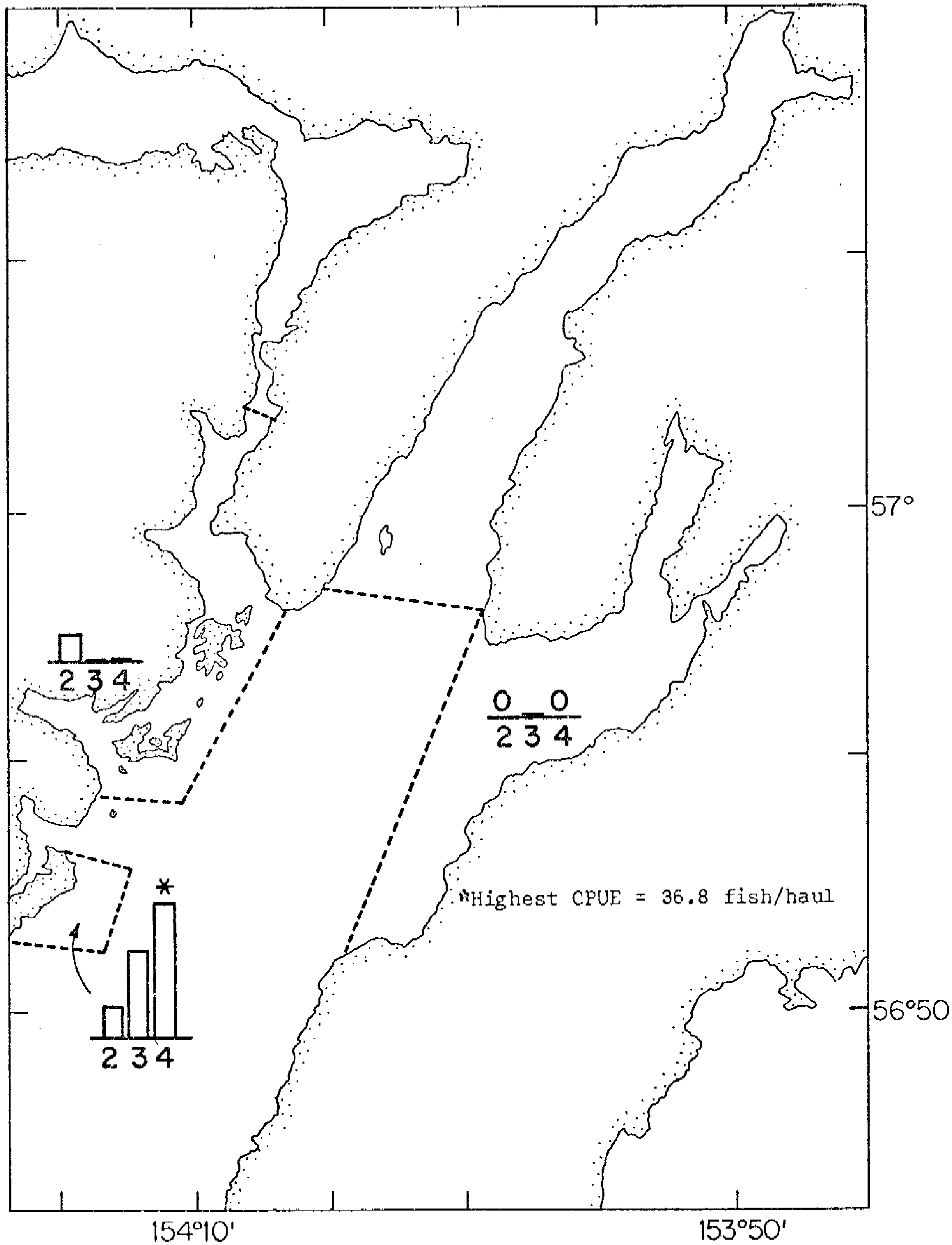


Fig. 20C. Try net CPUE of rock sole in cruises 2-4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars.

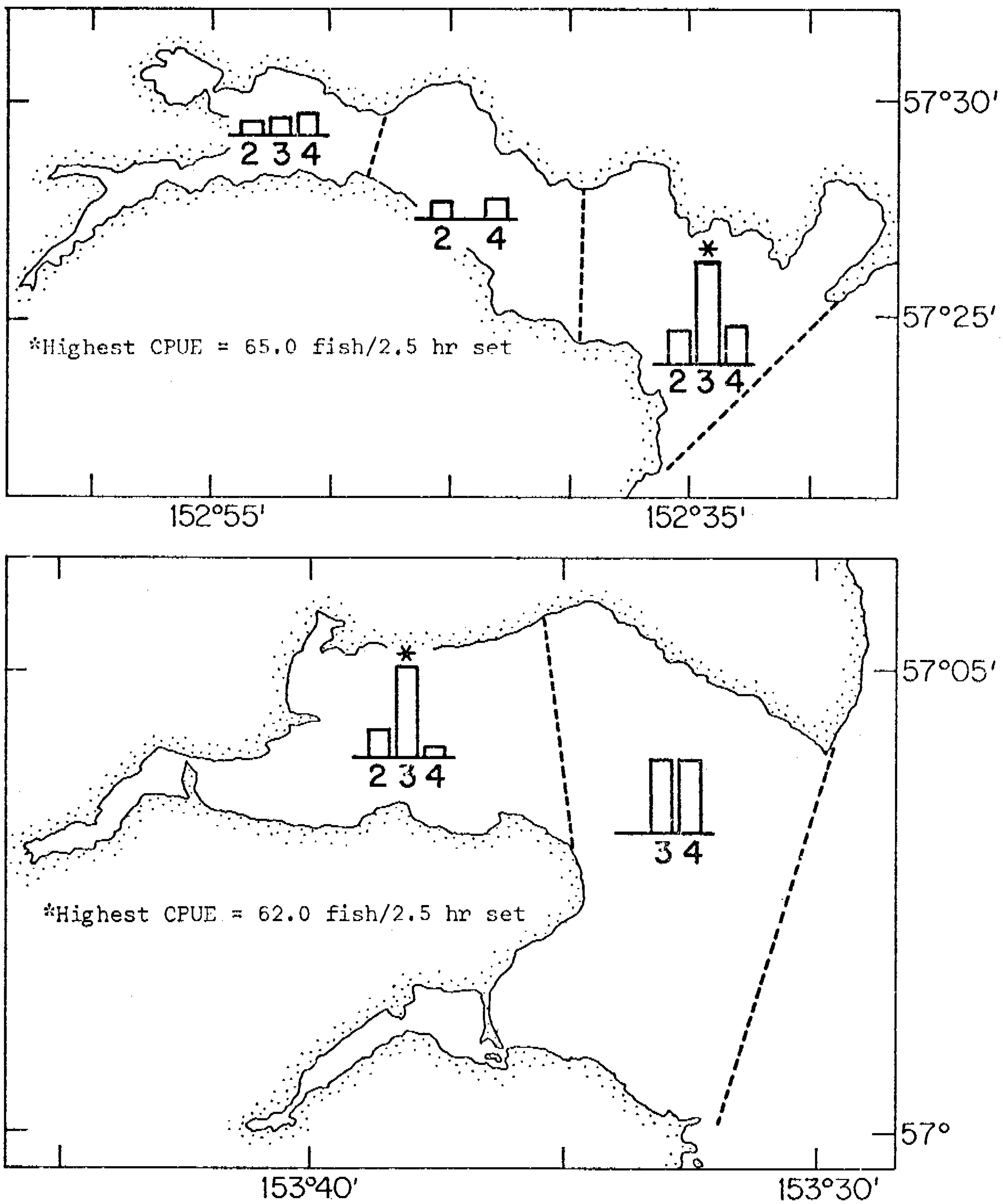


Fig. 21A & B. Trammel net CPUE of rock greenling in cruises 2-4 and various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars.

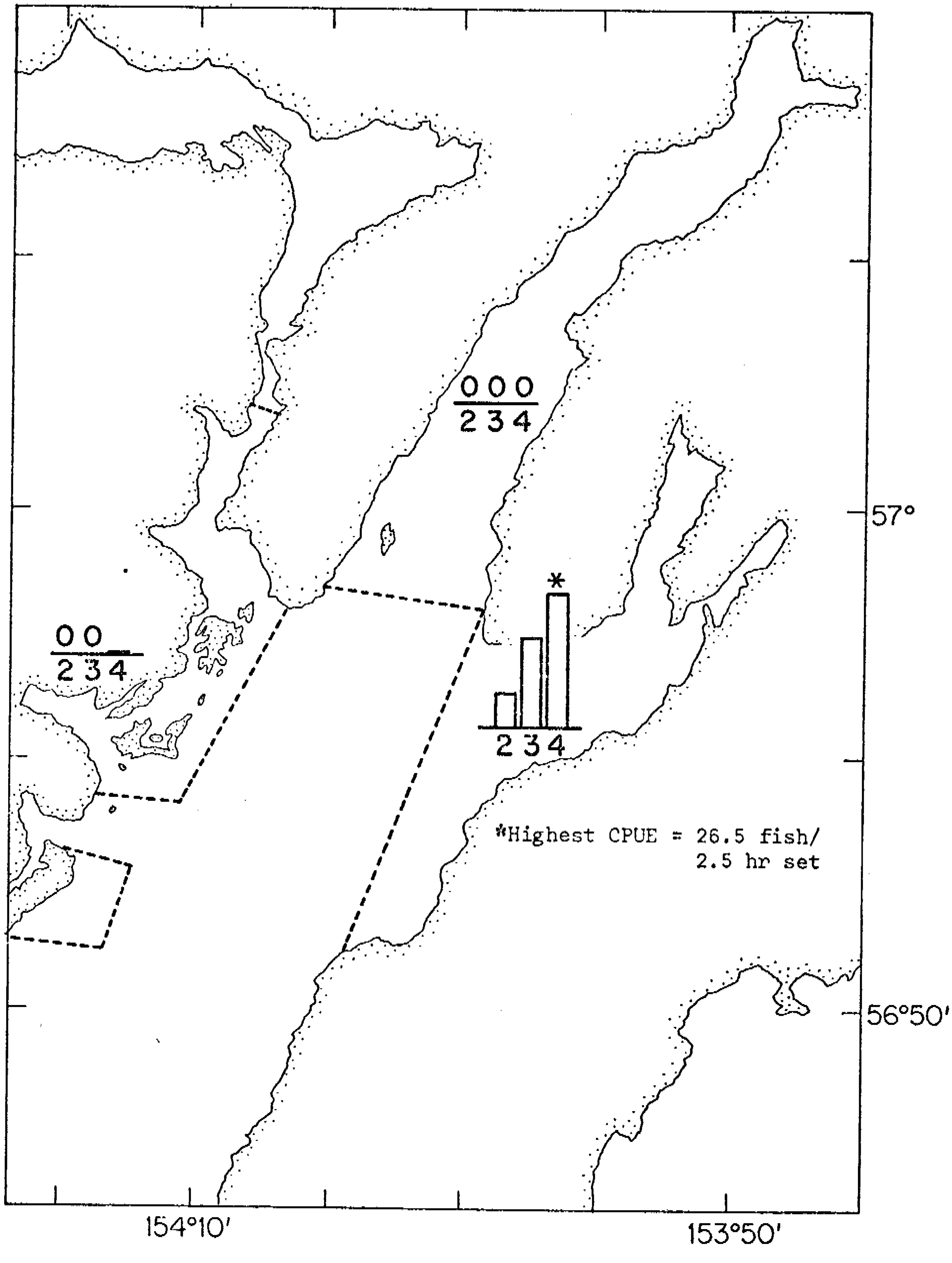


Fig. 21C. Trammel net CPUE of rock greenling in cruises 2-4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars.

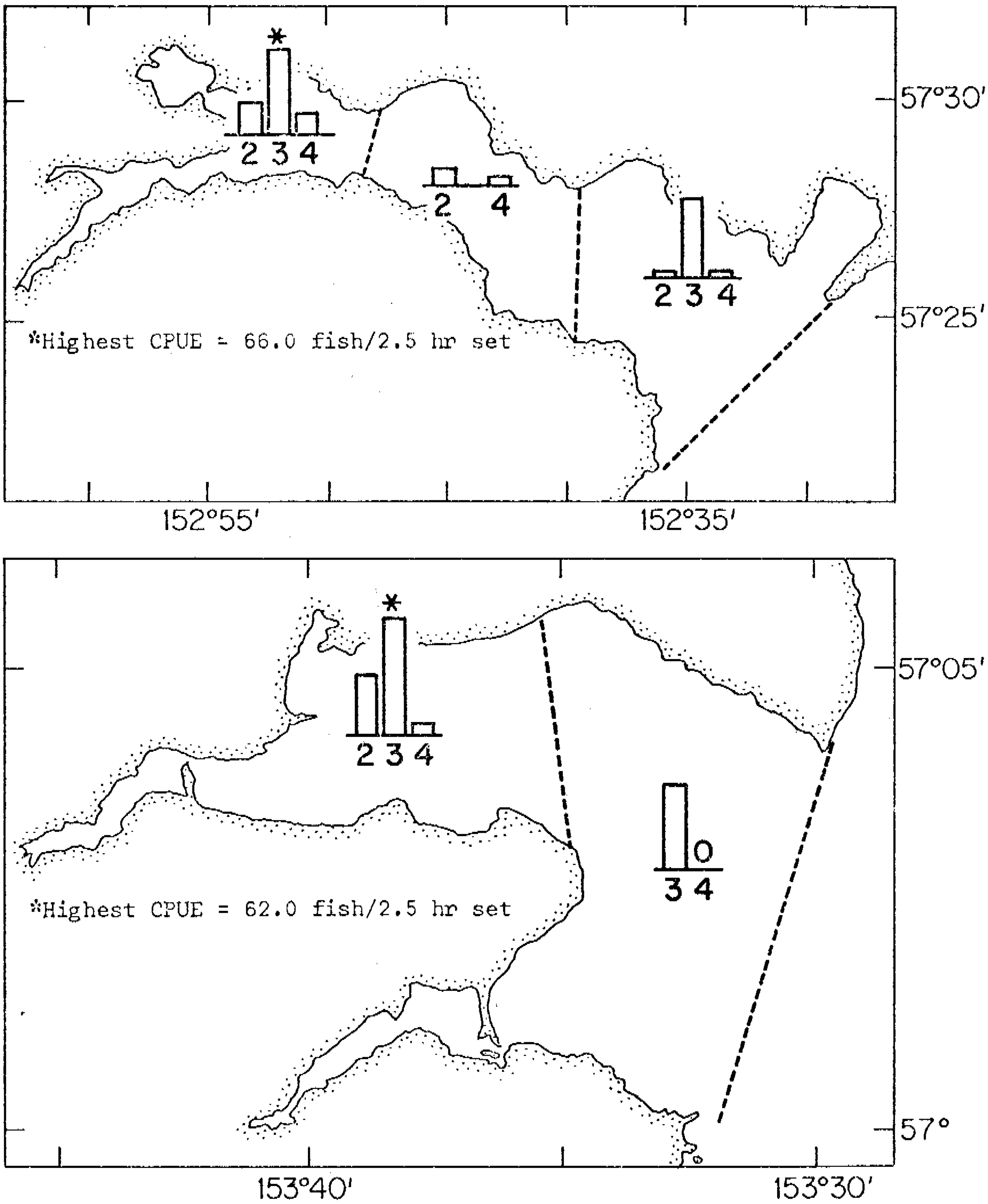


Fig. 22A & B. Trammel net CPUE of masked greenling in cruises 2-4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars.

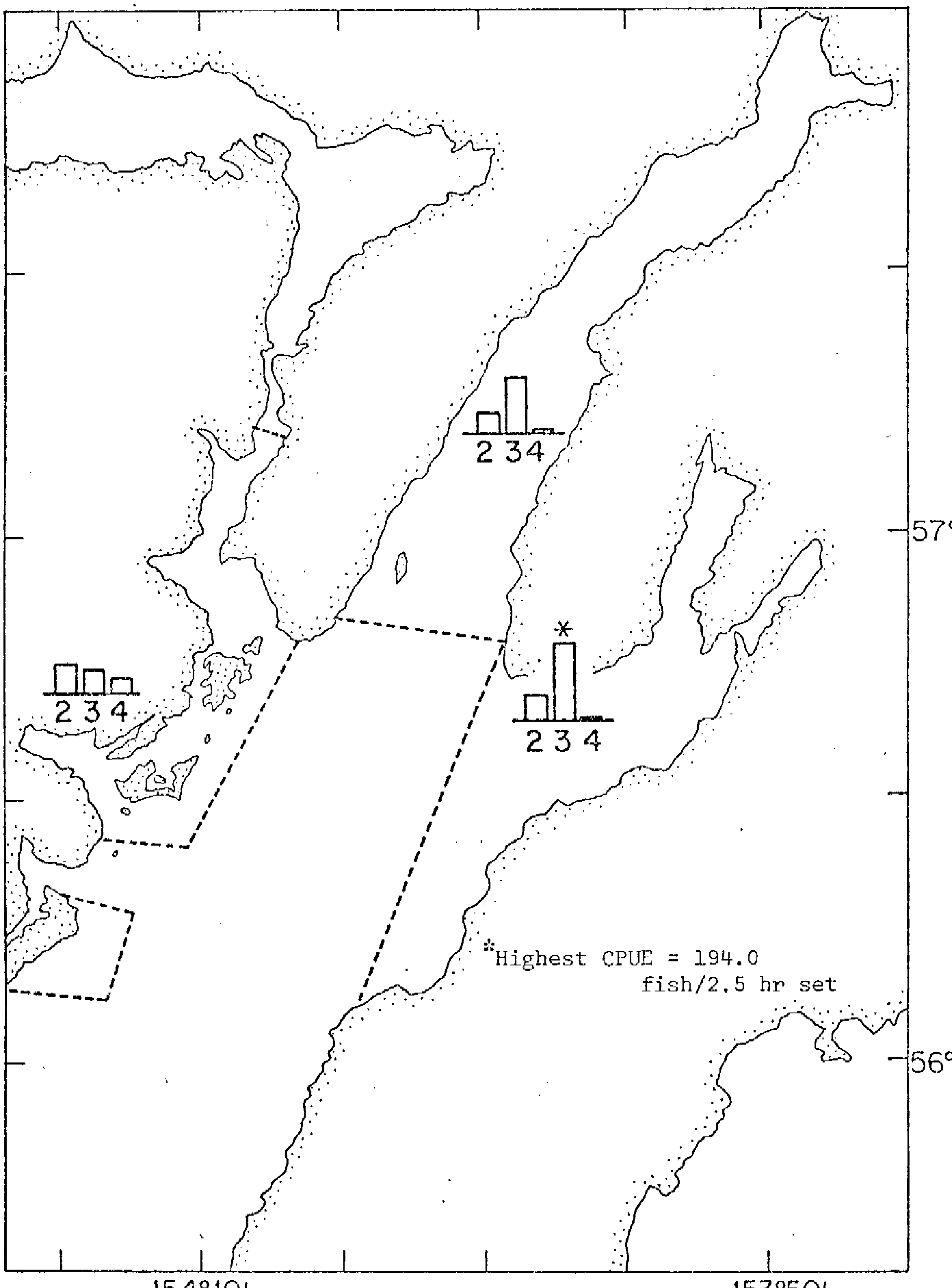


Fig. 22C. Trammel net CPUE of masked greenling in cruises 2-4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars.

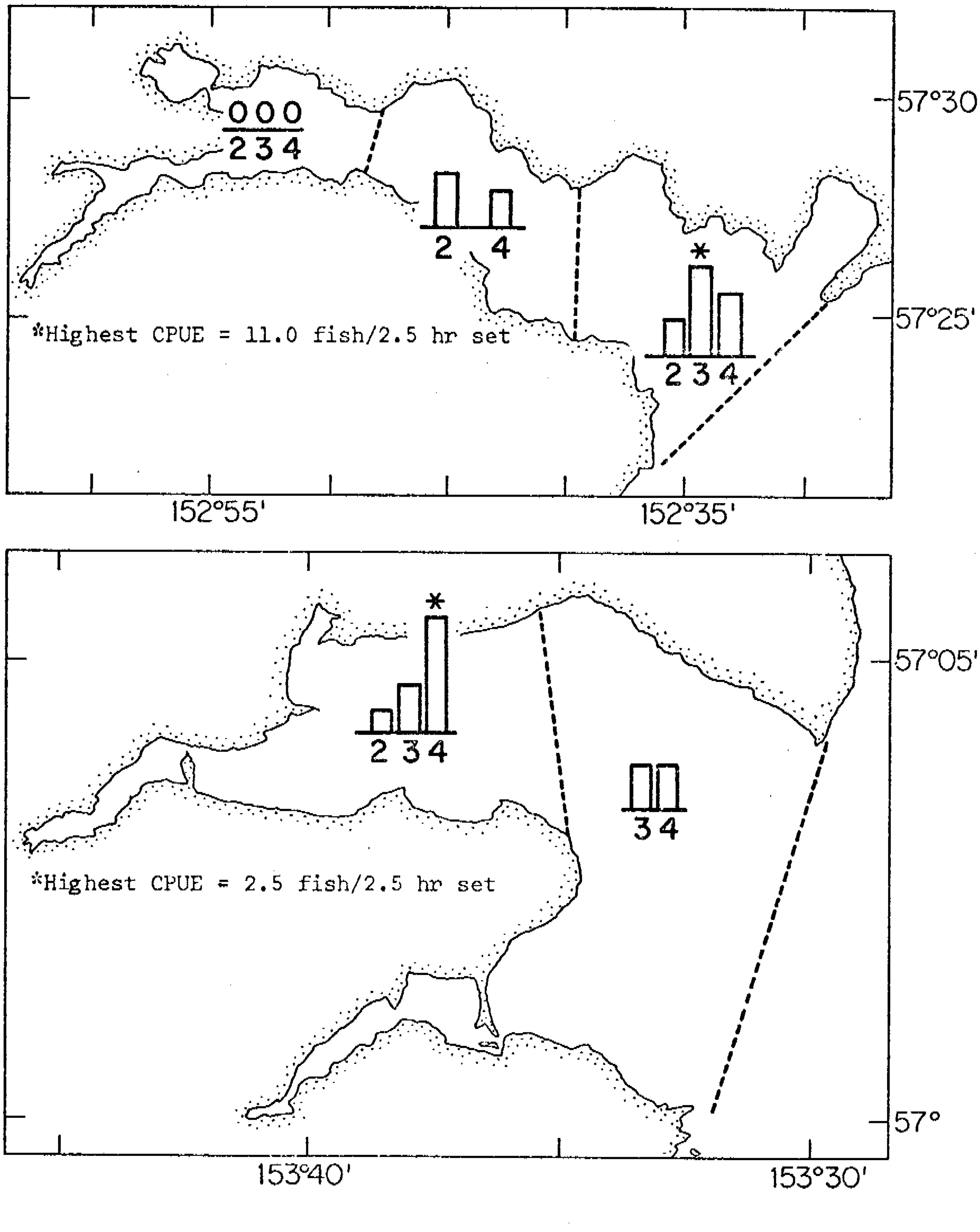


Fig. 23A & B. Trammel net CPUE of whitespotted greenling in cruises 2-4 and in various regions of Ugak Bay (A, top) and Kaiugnak Bay (B, bottom). The cruise numbers are indicated below the bars.

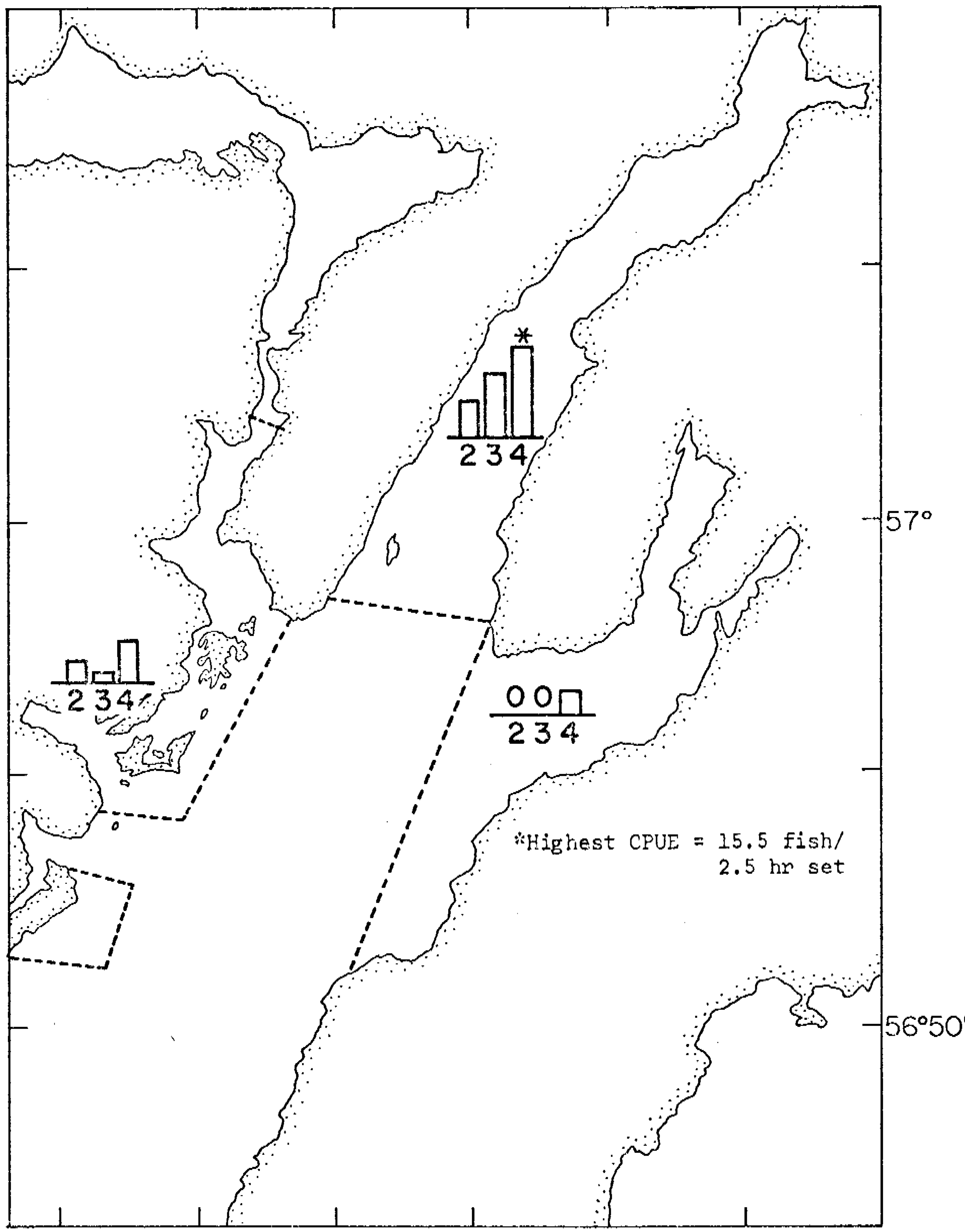


Fig. 23C. Trammel net CPUE of whitespotted greenling in cruises 2-4 and in various regions of Alitak Bay. The cruise numbers are indicated below the bars.

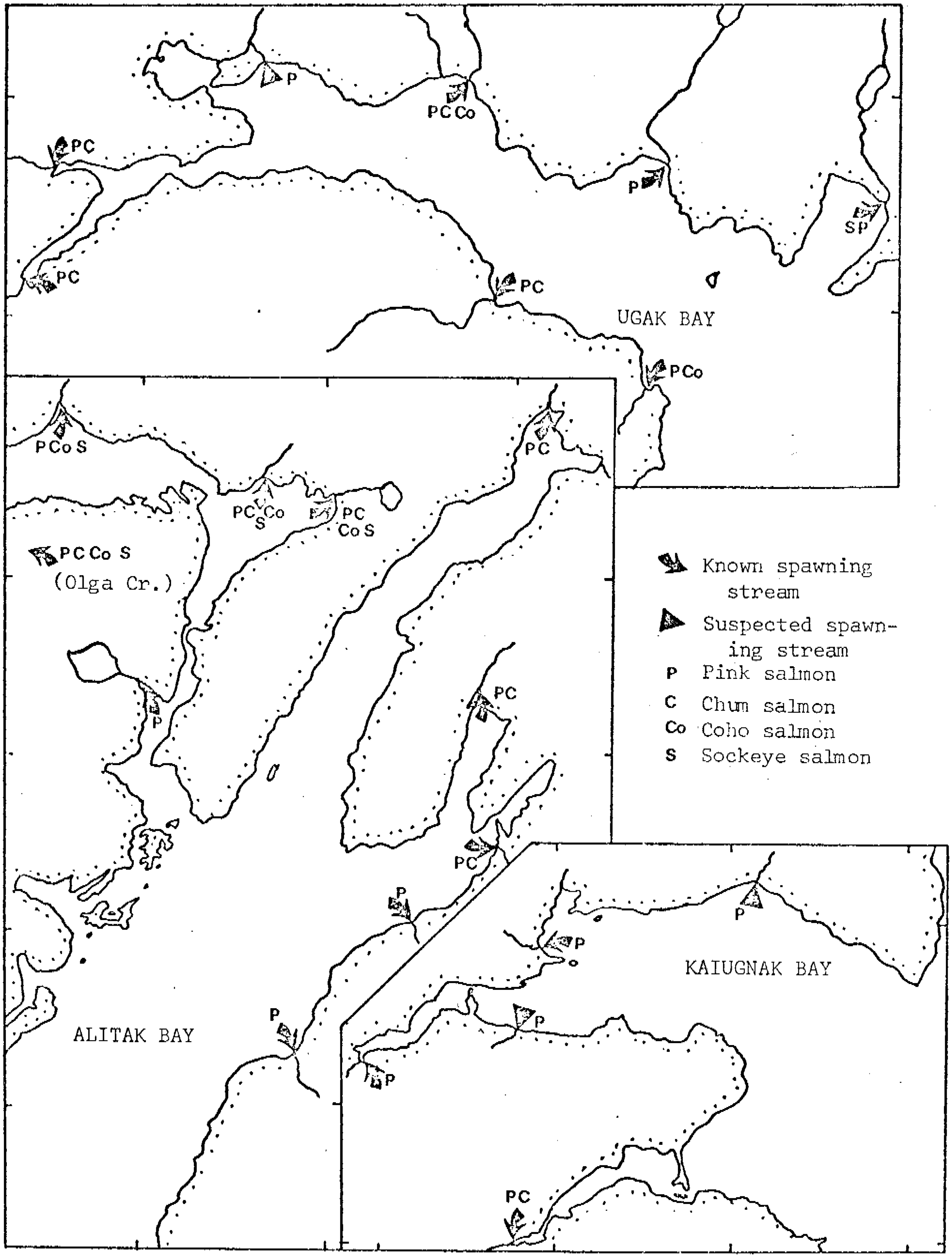


Fig. 24. Major salmon spawning streams in the study area as found in the present study and as shown in Atkinson, Rose, and Duncan (1967).

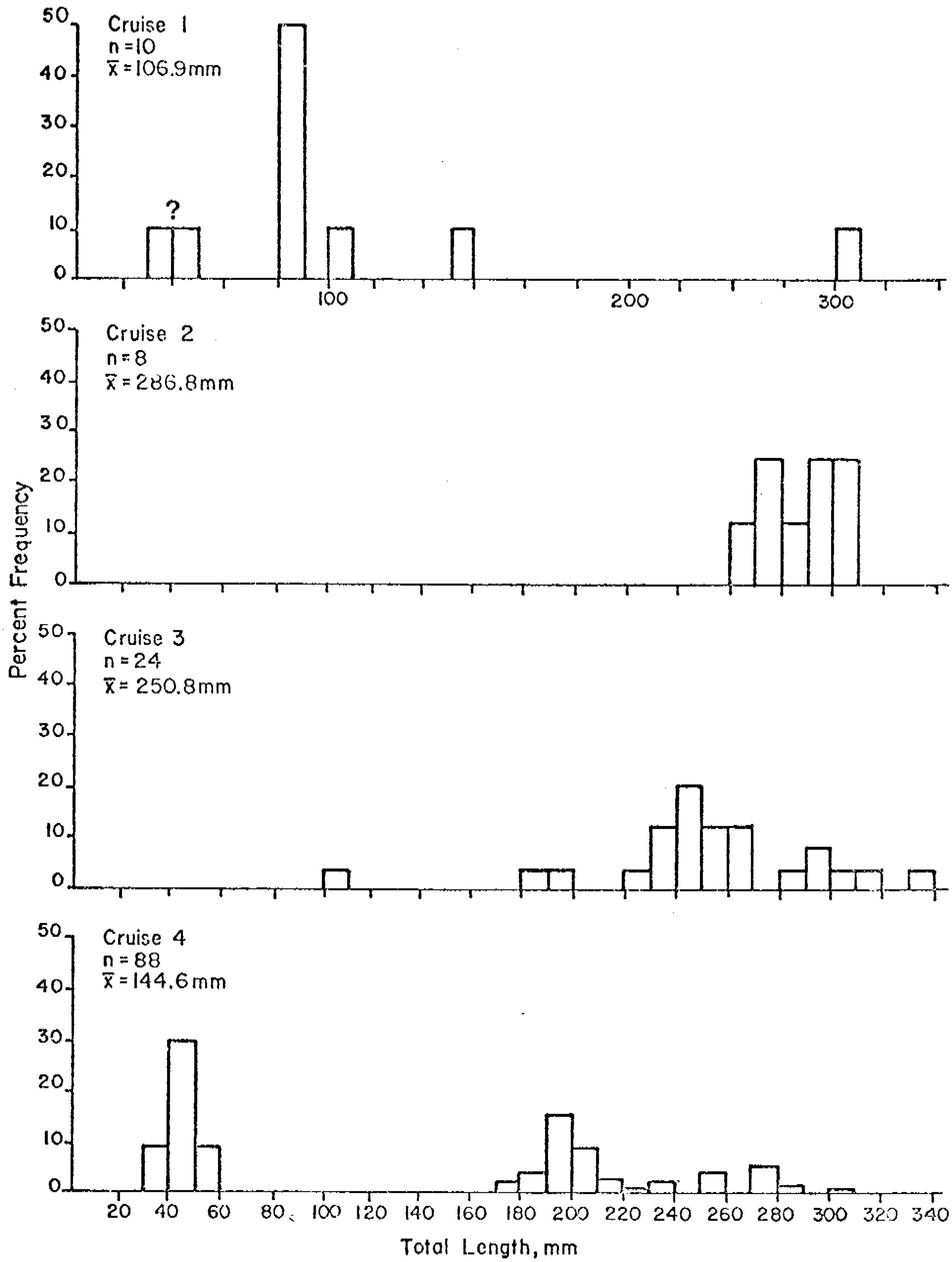


Fig. 25. Lengths of Pacific herring, *Clupea h. pallasi*, pooled over all bays and gear types. The occurrence of fish around 40 mm in late May is dubious, and probably is a case of mistaken larval identification.

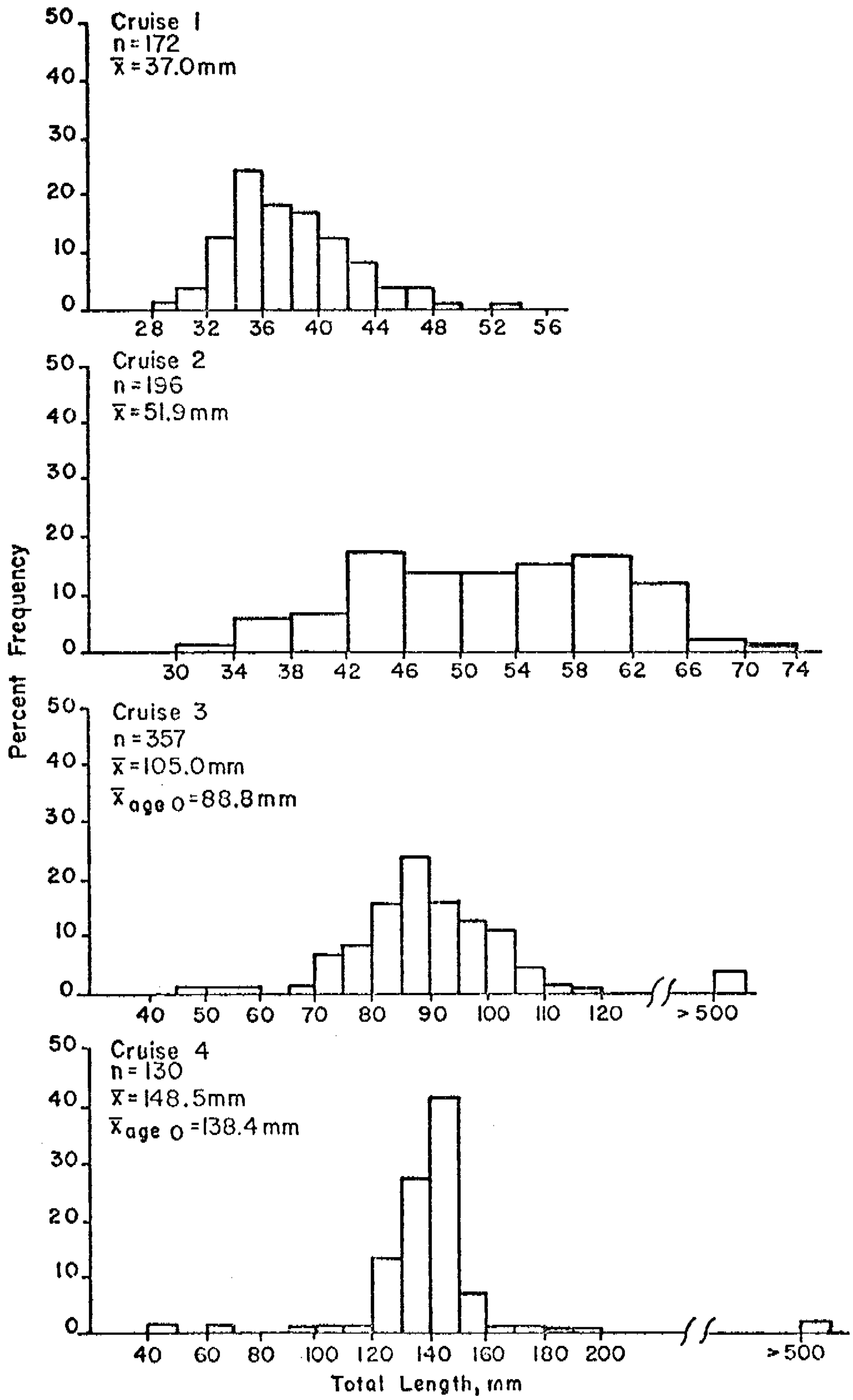


Fig. 26. Lengths of pink salmon, *Oncorhynchus gorbuscha*, pooled over all bays and gear types.

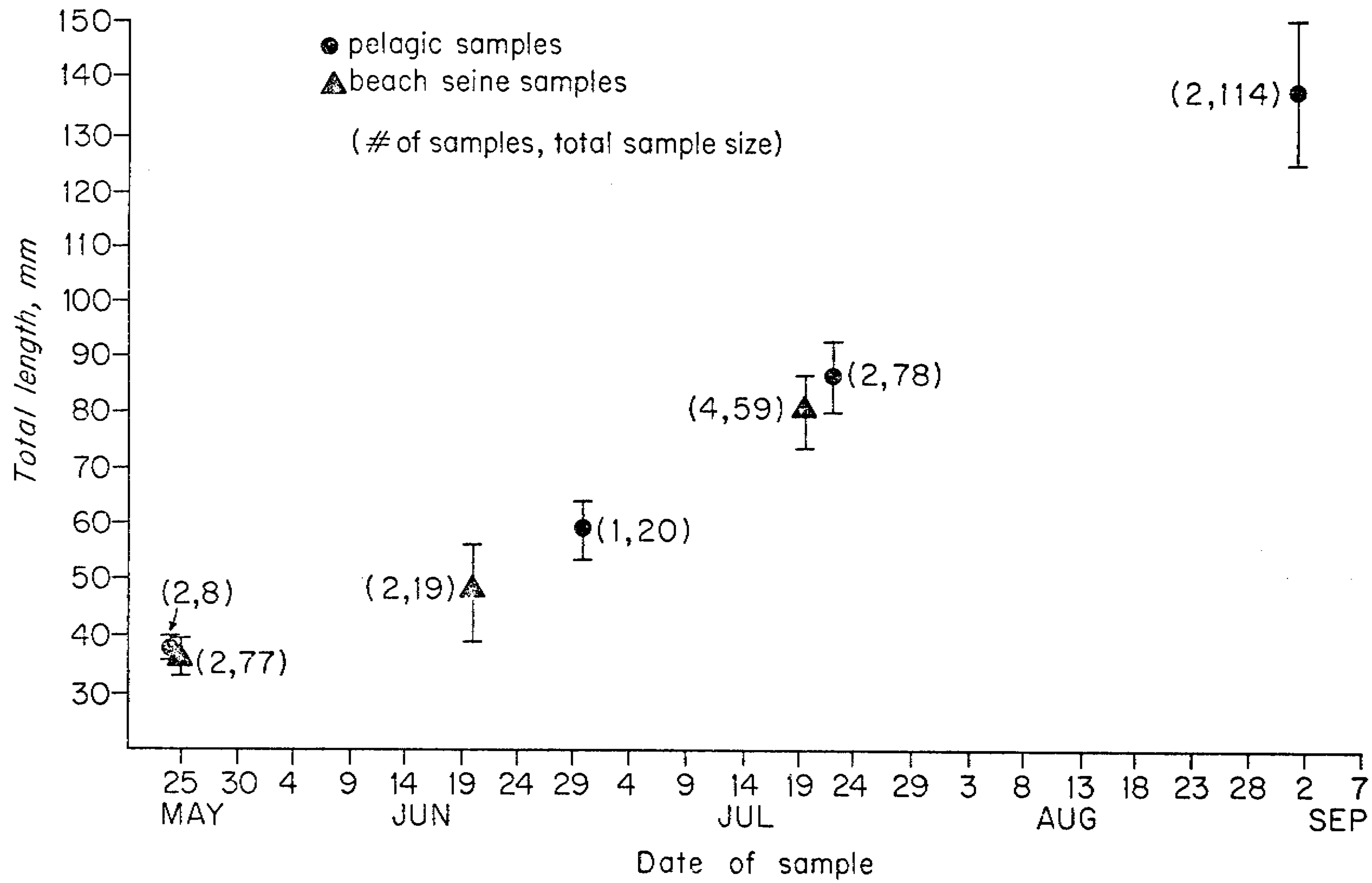


Fig. 27. Plot of grand means of total length for various intertidal and pelagic samples of juvenile pink salmon, Ugak Bay. One standard deviation is drawn on each side of the means. In the multiple sample cases, the standard deviation is Sp (the pooled-sample S.D.), and the samples were taken within two days of the date indicated.

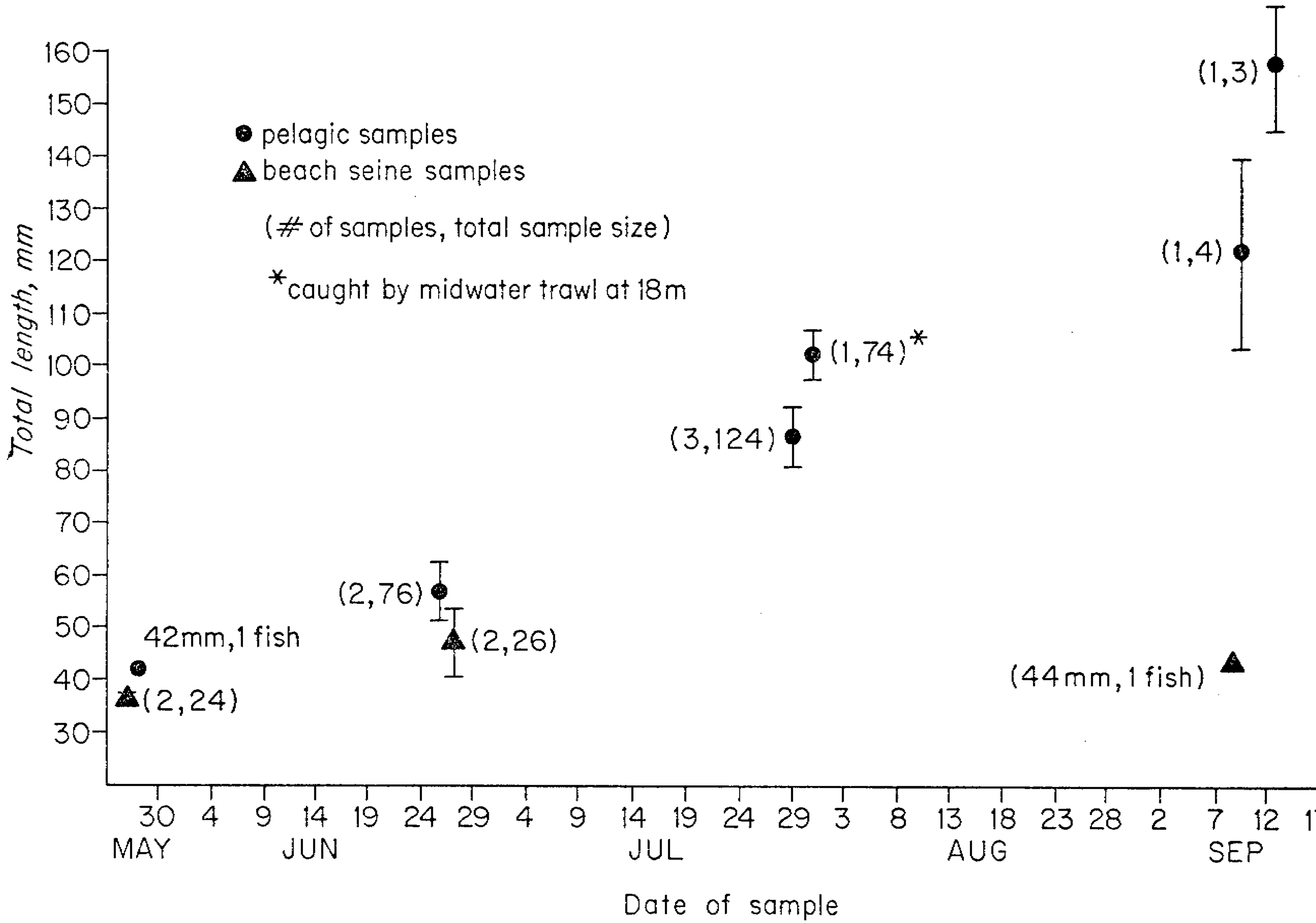


Fig. 28. Plot of grand means of total length for various intertidal and pelagic samples of juvenile pink salmon, Alitak Bay. One standard deviation is drawn on each side of the means. In the multiple sample cases, the standard deviation is Sp (the pooled sample S.D.), and the samples were taken within two days of the date indicated.

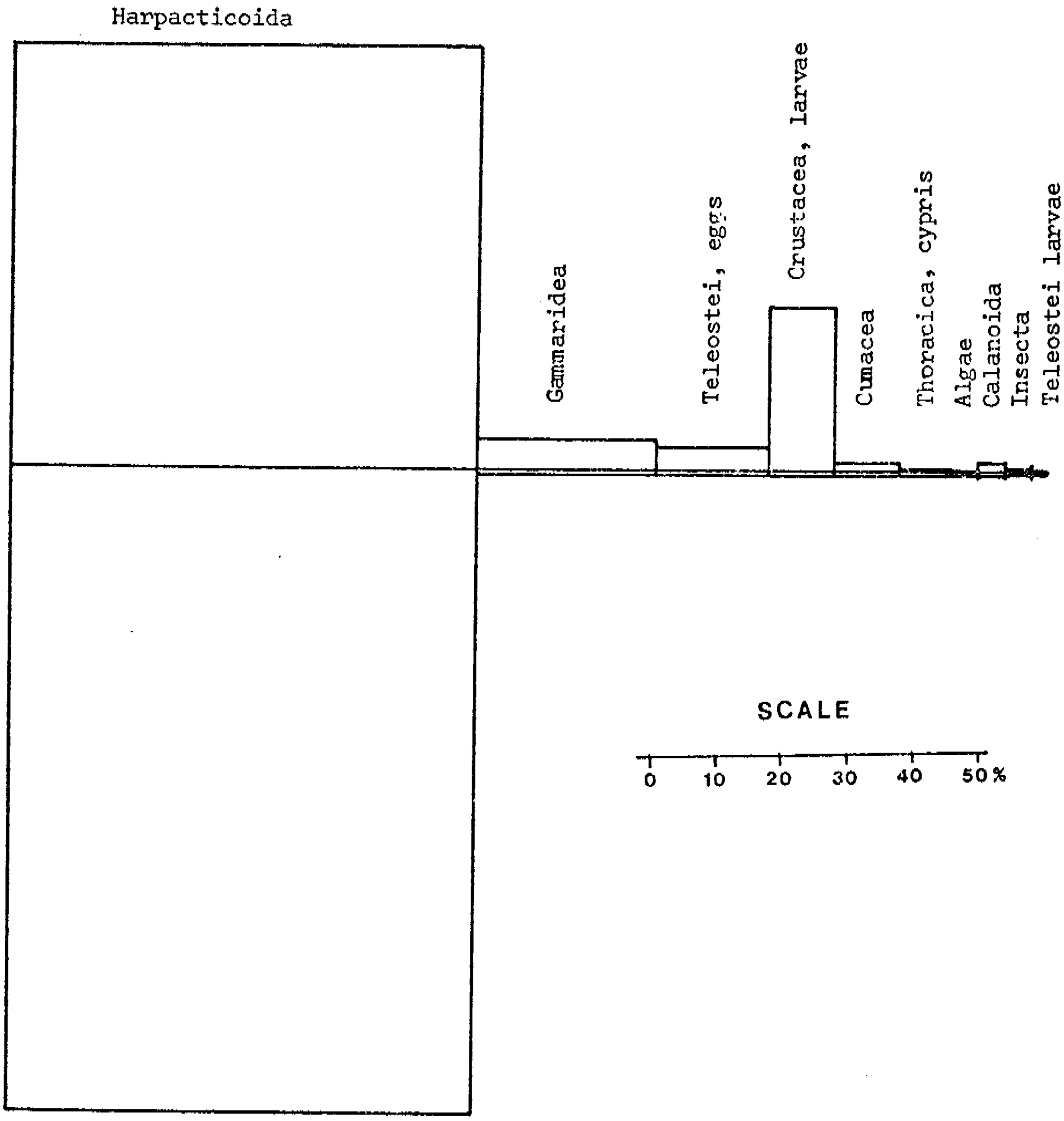


Fig. 29. Prey spectrum of 48 juvenile pink salmon caught from late May to late July in the intertidal zone of all three study bays. There were no empty stomachs, and unidentified material comprised 6.6 percent of the total weight of contents.

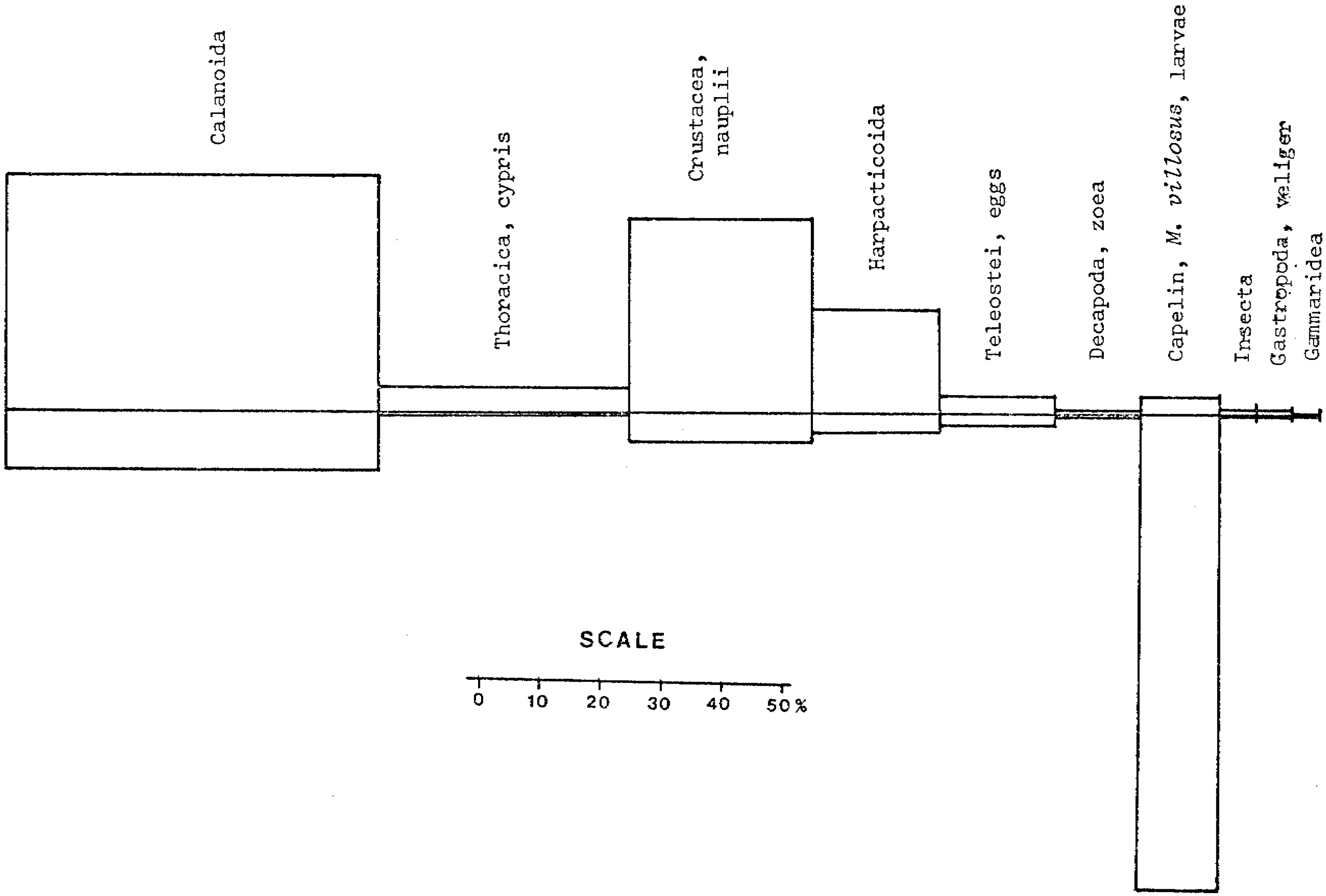


Fig. 30. Prey spectrum of 70 juvenile pink salmon caught from late June to mid-September in the epipelagic zone of Ugak and Alitak bays. There were no empty stomachs, and unidentified material comprised 21.2 percent of the total weight of contents.

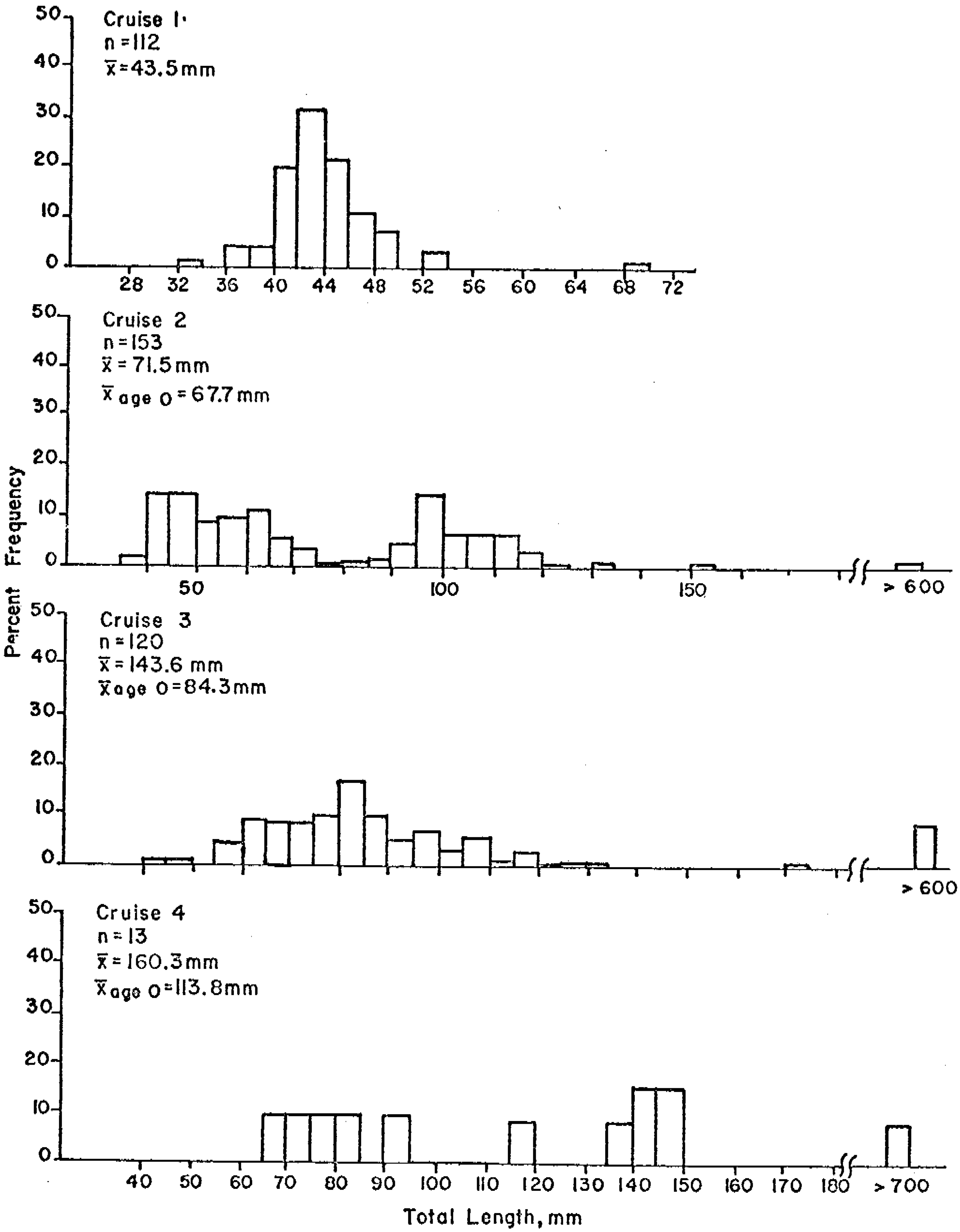


Fig. 31. Lengths of chum salmon, *Oncorhynchus keta*, pooled over all bays and gear types.

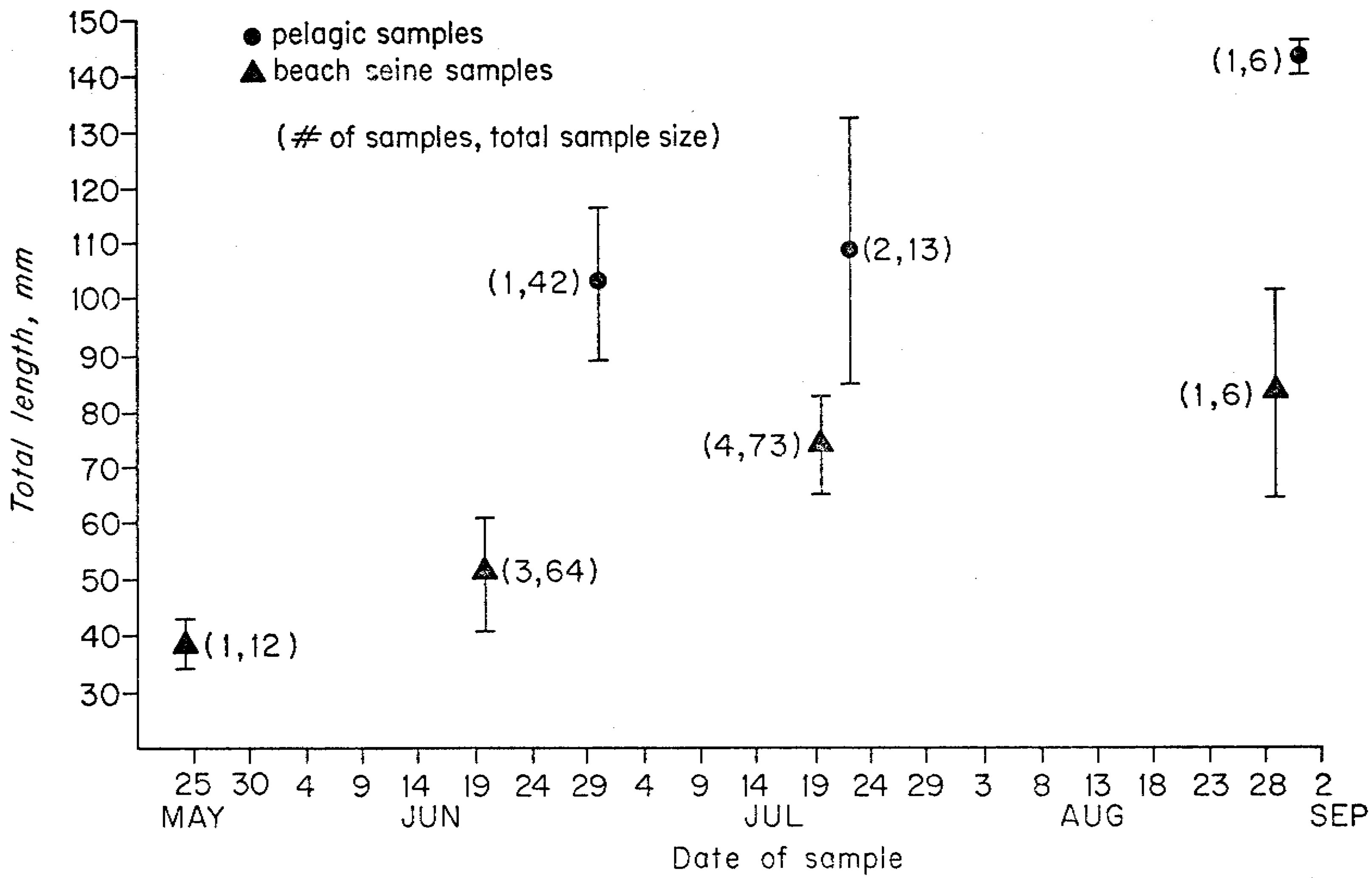


Fig. 32. Plot of grand means of total length for various intertidal and pelagic samples of juvenile chum salmon, Ugak Bay. One standard deviation is drawn on each side of the means. In the multiple sample cases, the standard deviation is Sp (pooled-sample S.D.), and the samples were taken within two days of the date indicated.

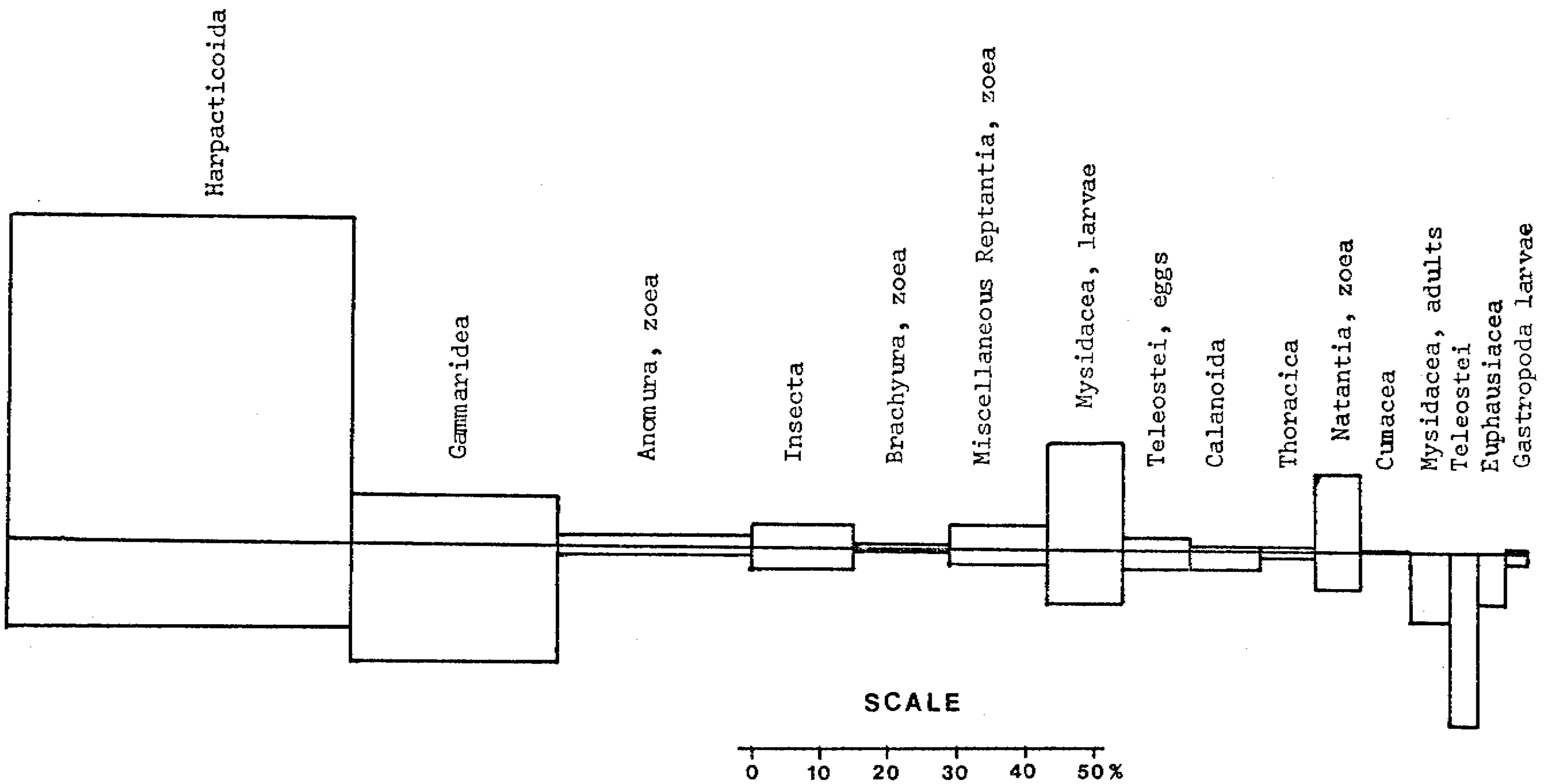


Fig. 33. Prey spectrum of 72 juvenile chum salmon (13 from pelagic zone, 59 from intertidal zone), collected from late May to late July in Ugak and Alitak bays. There were no empty stomachs, and unidentified material comprised 47.6 percent of the total weight of contents.

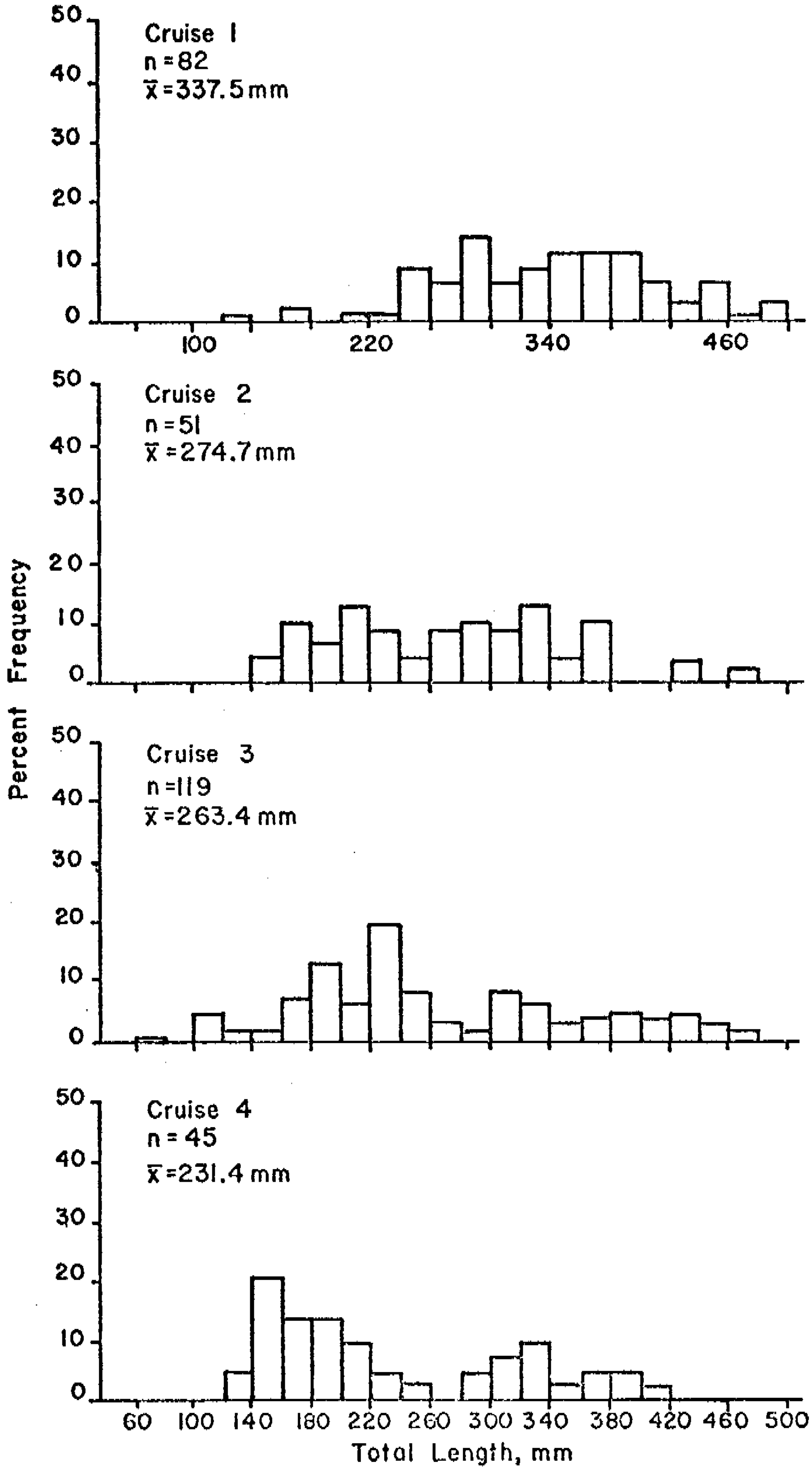


Fig. 34. Lengths of Dolly Varden, *Salvelinus malma*, pooled over all bays and gear types.

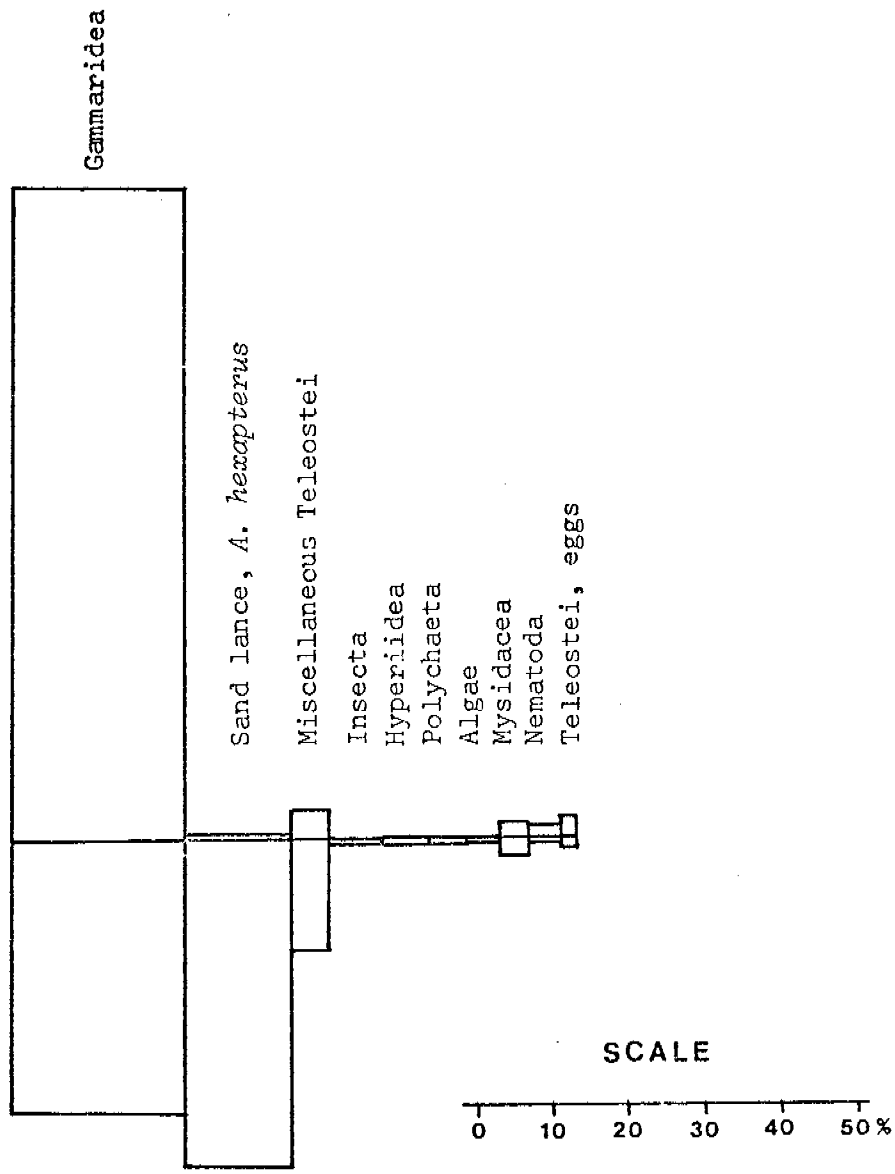


Fig. 35. Prey spectrum of 84 Dolly Varden, pooled over all bays and cruises. There was 1 empty stomach, and unidentified material comprised 30.0 percent of the total weight of contents.

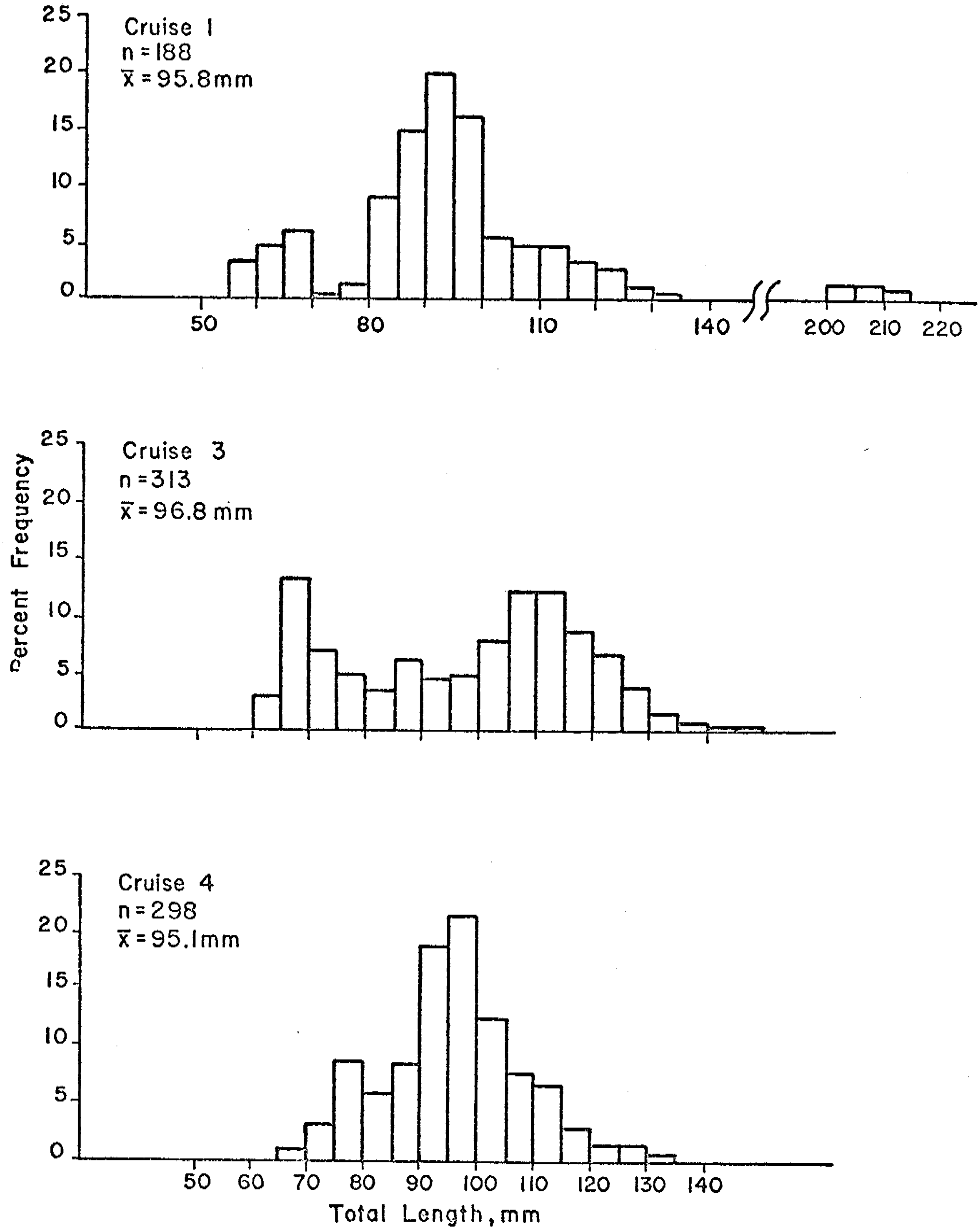


Fig. 36. Lengths of capelin, *Mallotus villosus*, caught by the mid-water trawl, pooled over all bays.

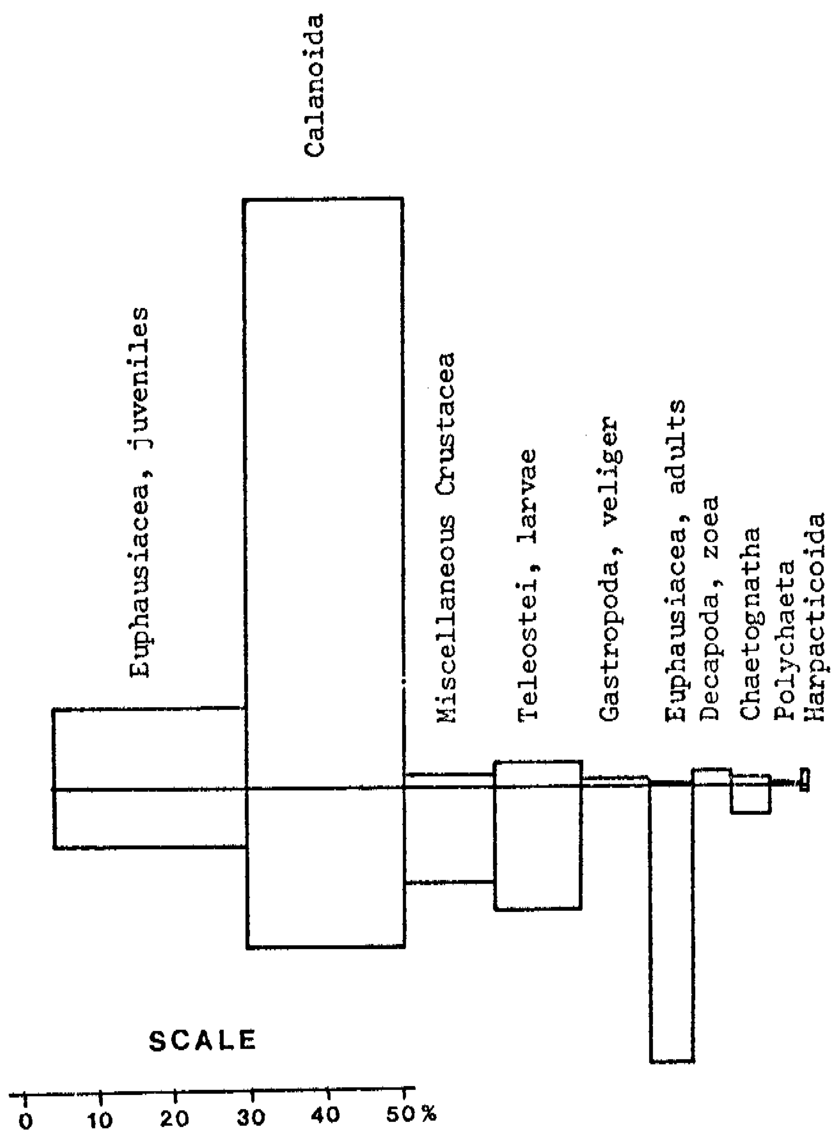


Fig. 37. Prey spectrum of 83 pelagic capelin caught in Alitak Bay in late May, and in Ugak Bay in the last three cruises. There were 2 empty stomachs, and unidentified material comprised 56.4 percent of total weight of contents.

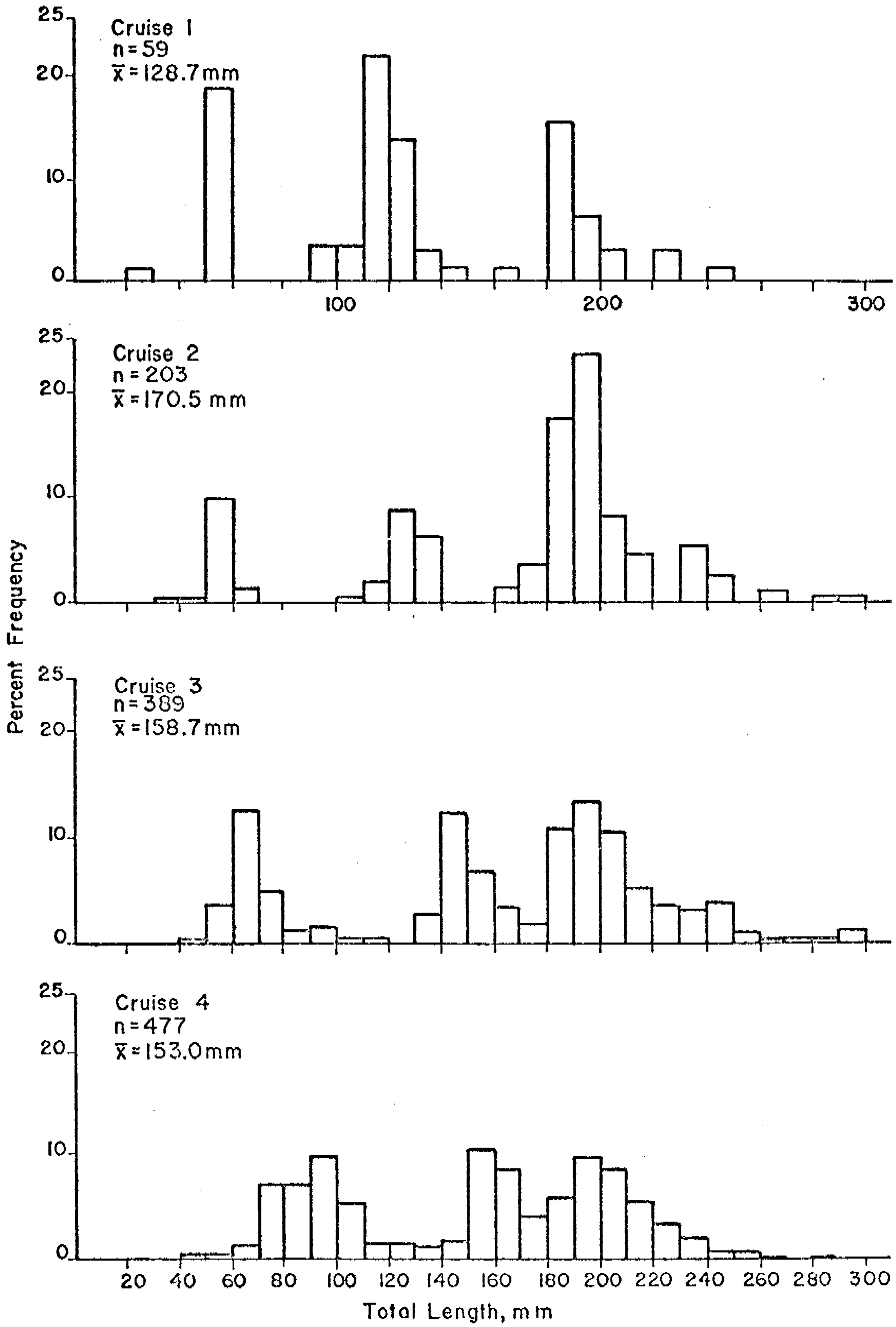


Fig. 38. Lengths of masked greenling, *Hexagrammos octogrammus*, pooled over all bays and gear types.

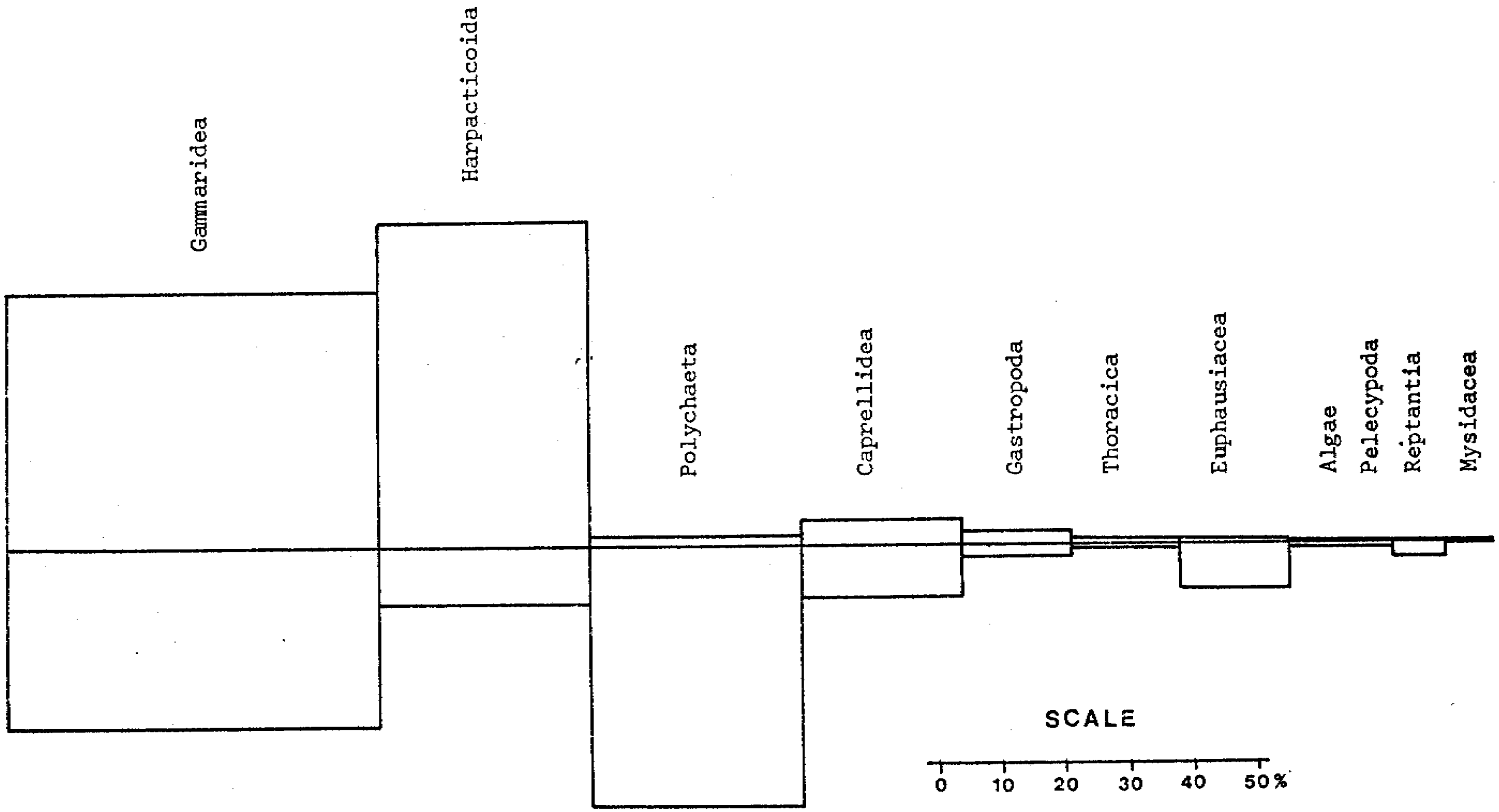


Fig. 39. Prey spectrum of 12 juvenile masked greenling caught in the nearshore zone from Alitak and Kaiugnak bays. There were no empty stomachs, and unidentified material comprised 42.0 percent of total weight of contents.

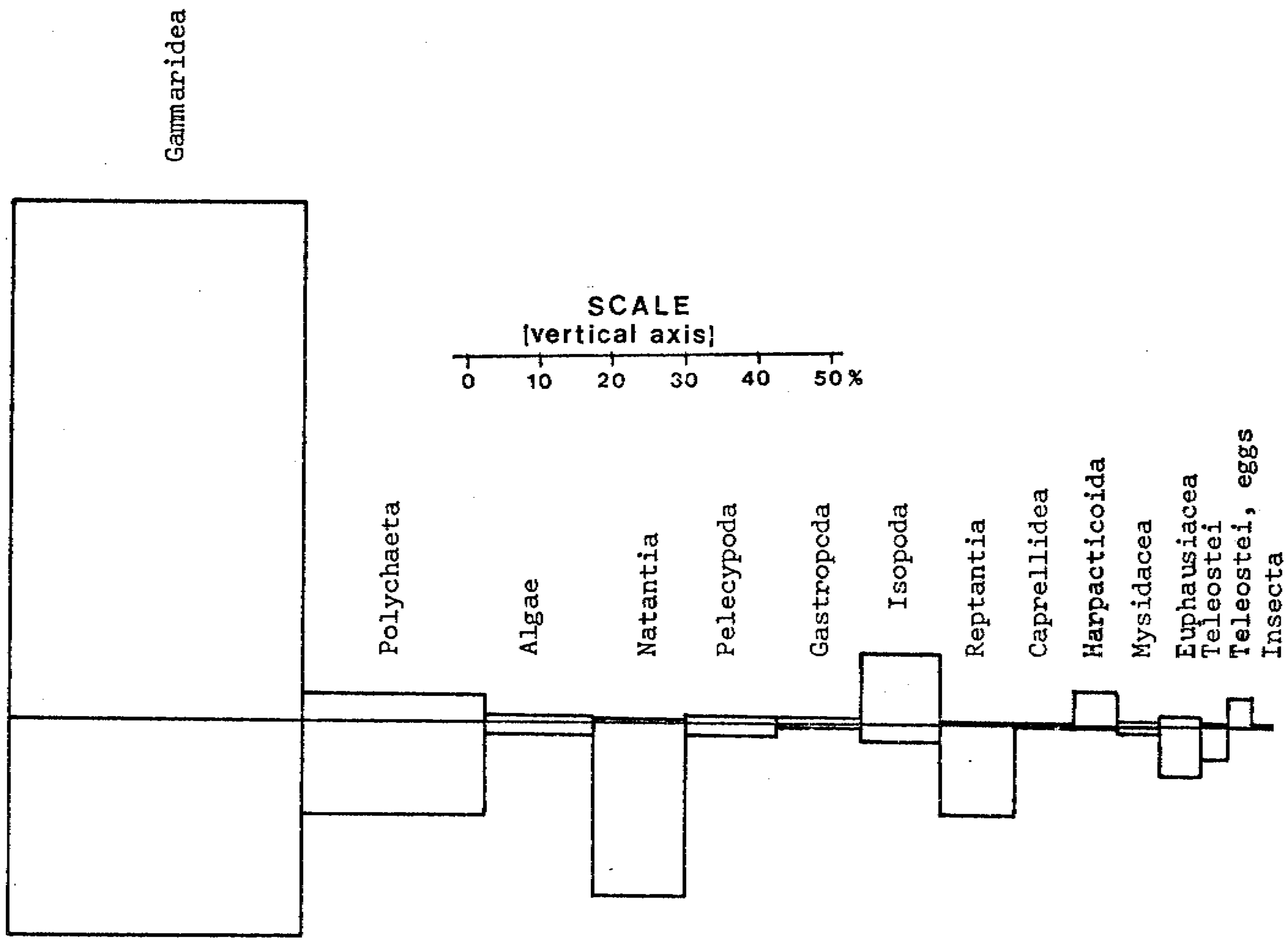


Fig. 40. Prey spectrum of 97 adult masked greenling, pooled over all bays and gear types. 1 mm = 2 percent for frequency of occurrence (horizontal axis). There were no empty stomachs, and unidentified material comprised 32.8 percent of total weight of contents.

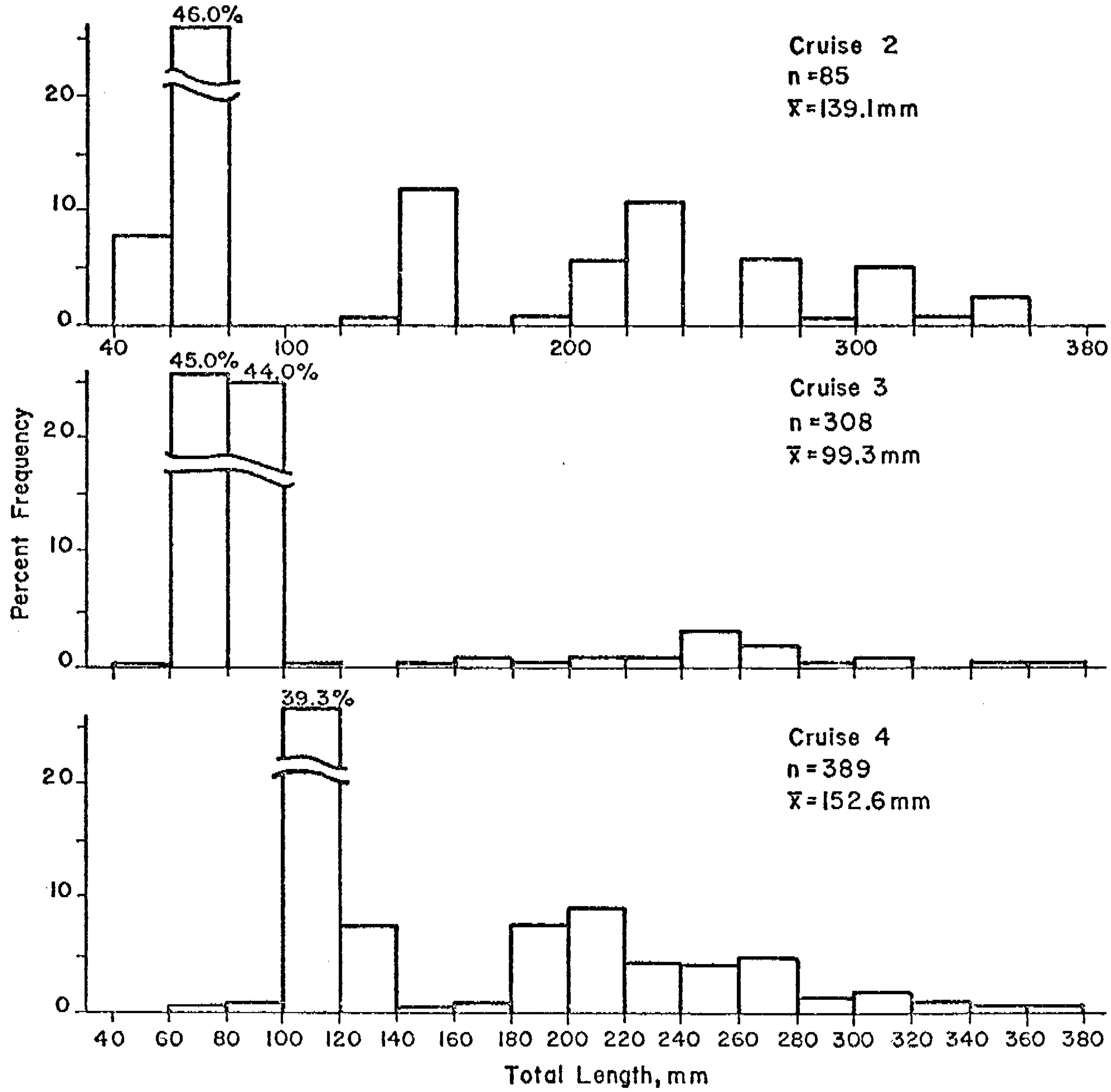


Fig. 41. Lengths of whitespotted greenling, *Hexagrammos stelleri*, pooled over all bays and gear types.

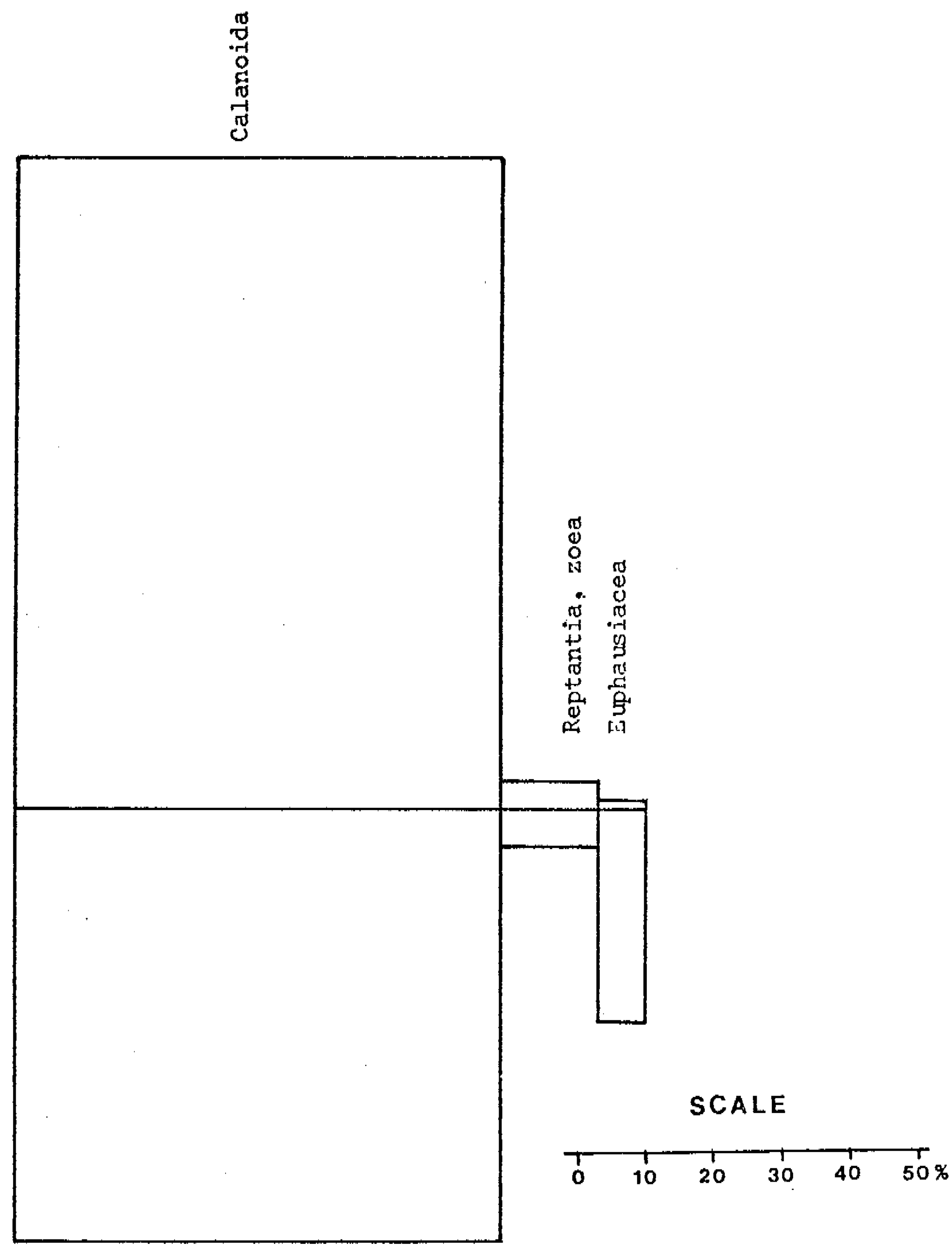


Fig. 42. Prey spectrum of 14 pelagic juvenile white-spotted greenling collected from Alitak Bay in late June. There were no empty stomachs, and unidentified material comprised 41.0 percent of total weight of contents.

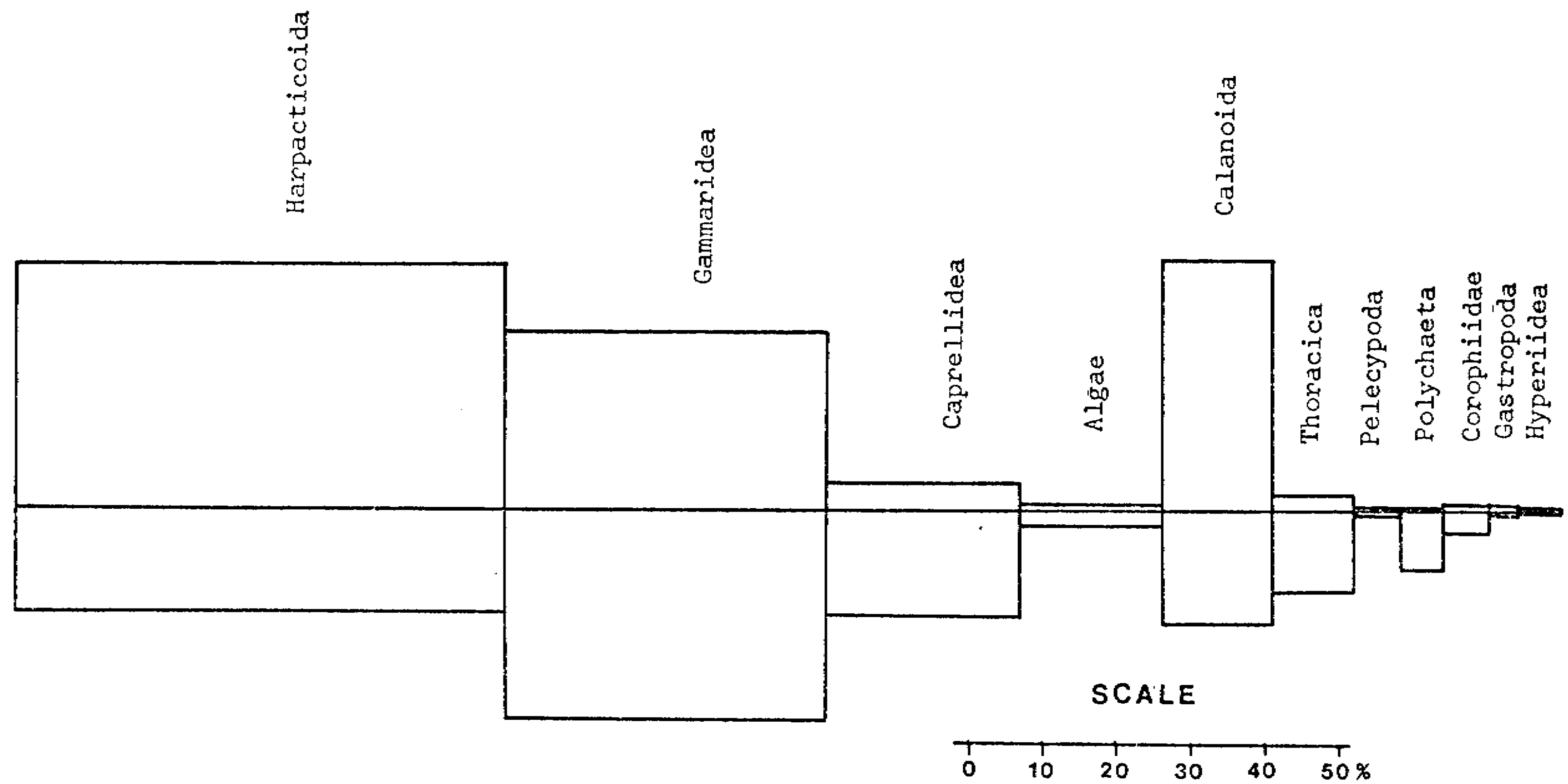


Fig. 43. Prey spectrum of 47 juvenile whitespotted greenling caught in the intertidal zone of Alitak Bay in early August. There were no empty stomachs, and unidentified material comprised 50.4 percent of total weight of contents.

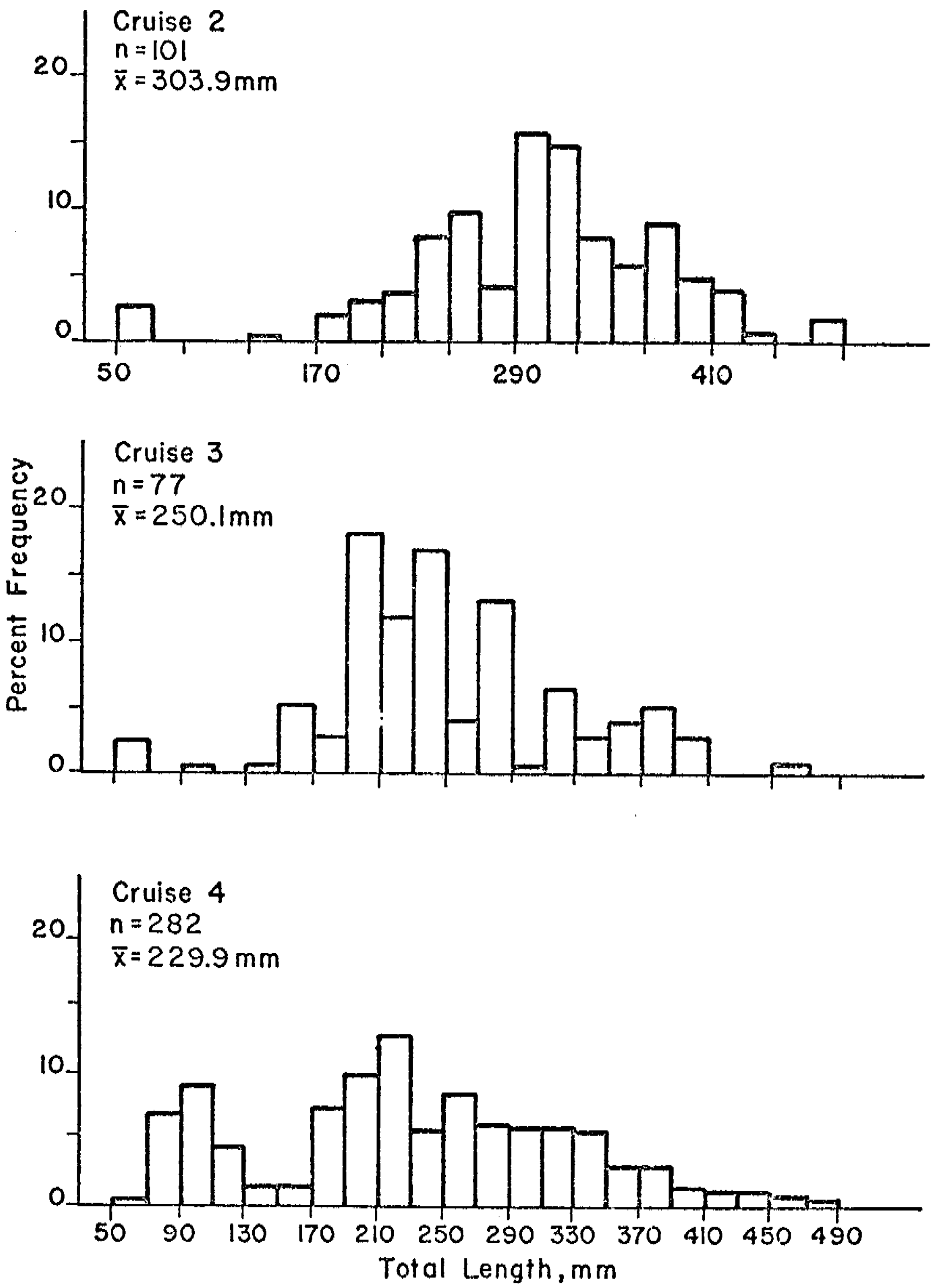


Fig. 44. Lengths of rock greenling, *Hexagrammos lagocephalus*, pooled over all bays and gear types.

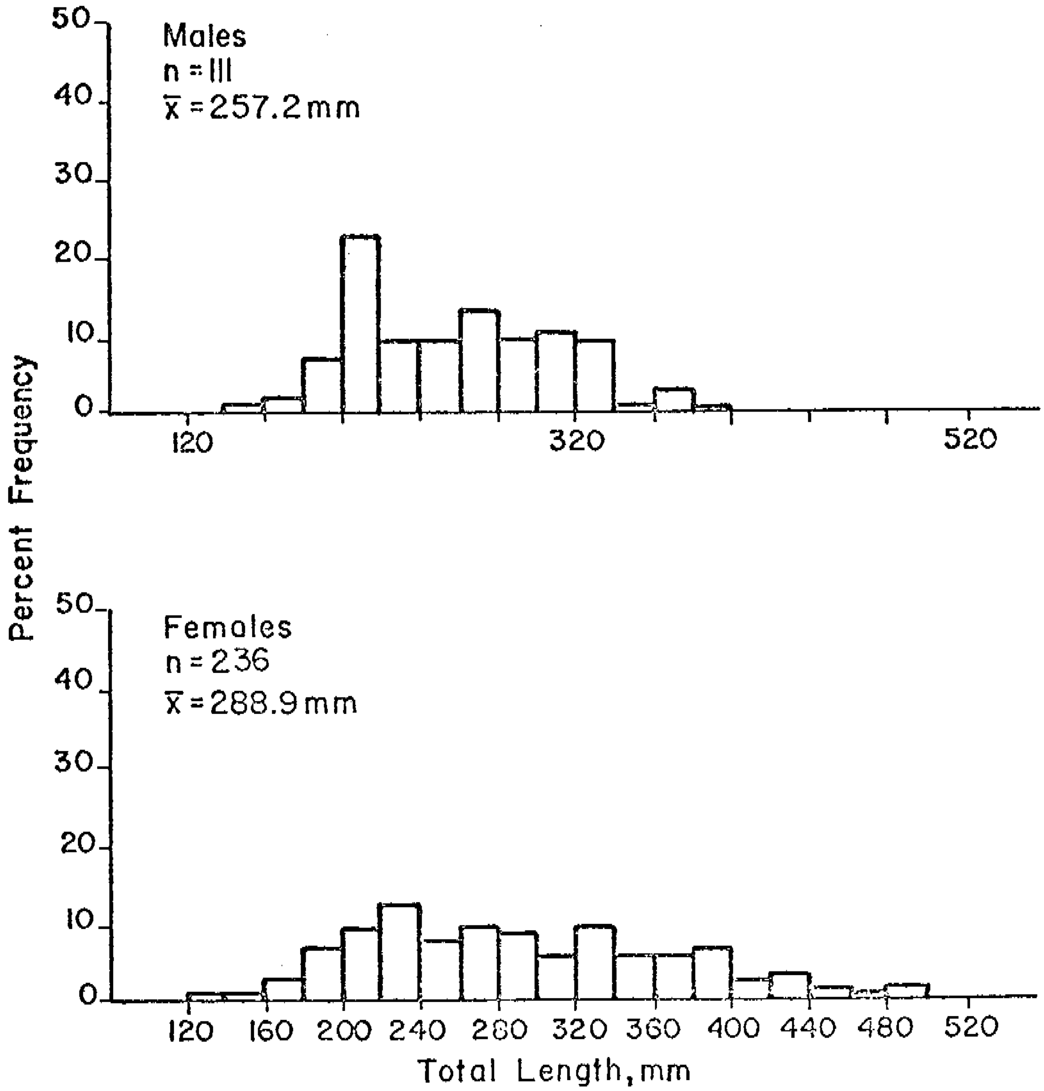


Fig. 45. Lengths of male and female rock greenling, pooled over all bays, gear types, and cruises.

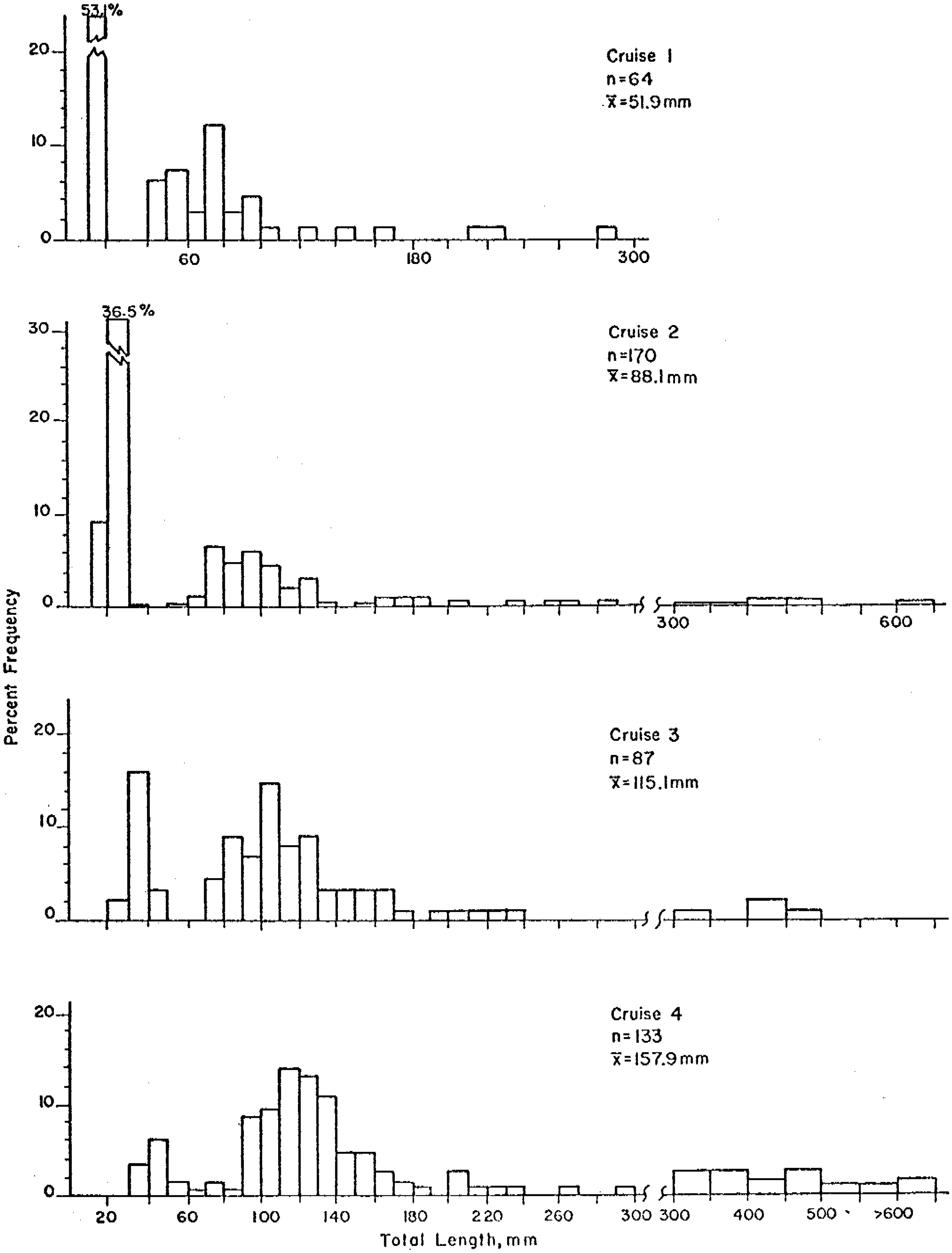


Fig. 46. Lengths of great sculpin, *Myoxocephalus polyacanthocephalus*, pooled over all bays and gear types.

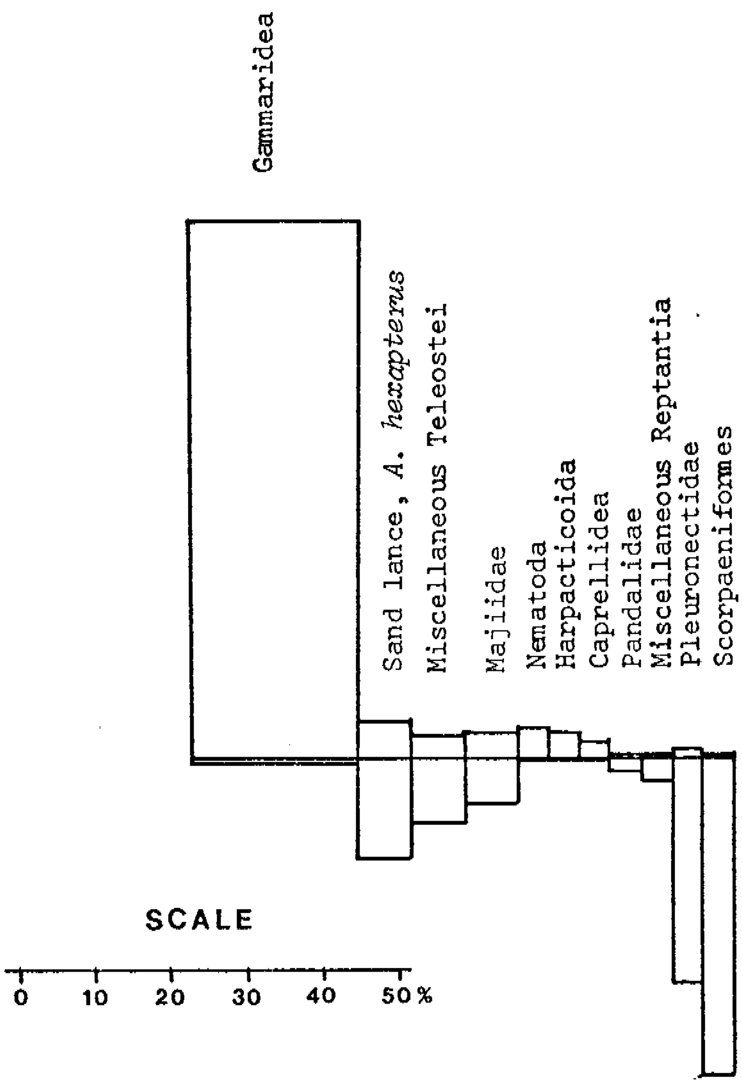


Fig. 47. Prey spectrum of 16 juvenile and 11 adult great sculpins, collected from all bays and cruises. There were no empty stomachs, and unidentified material comprised 10.1 percent of total weight of contents.

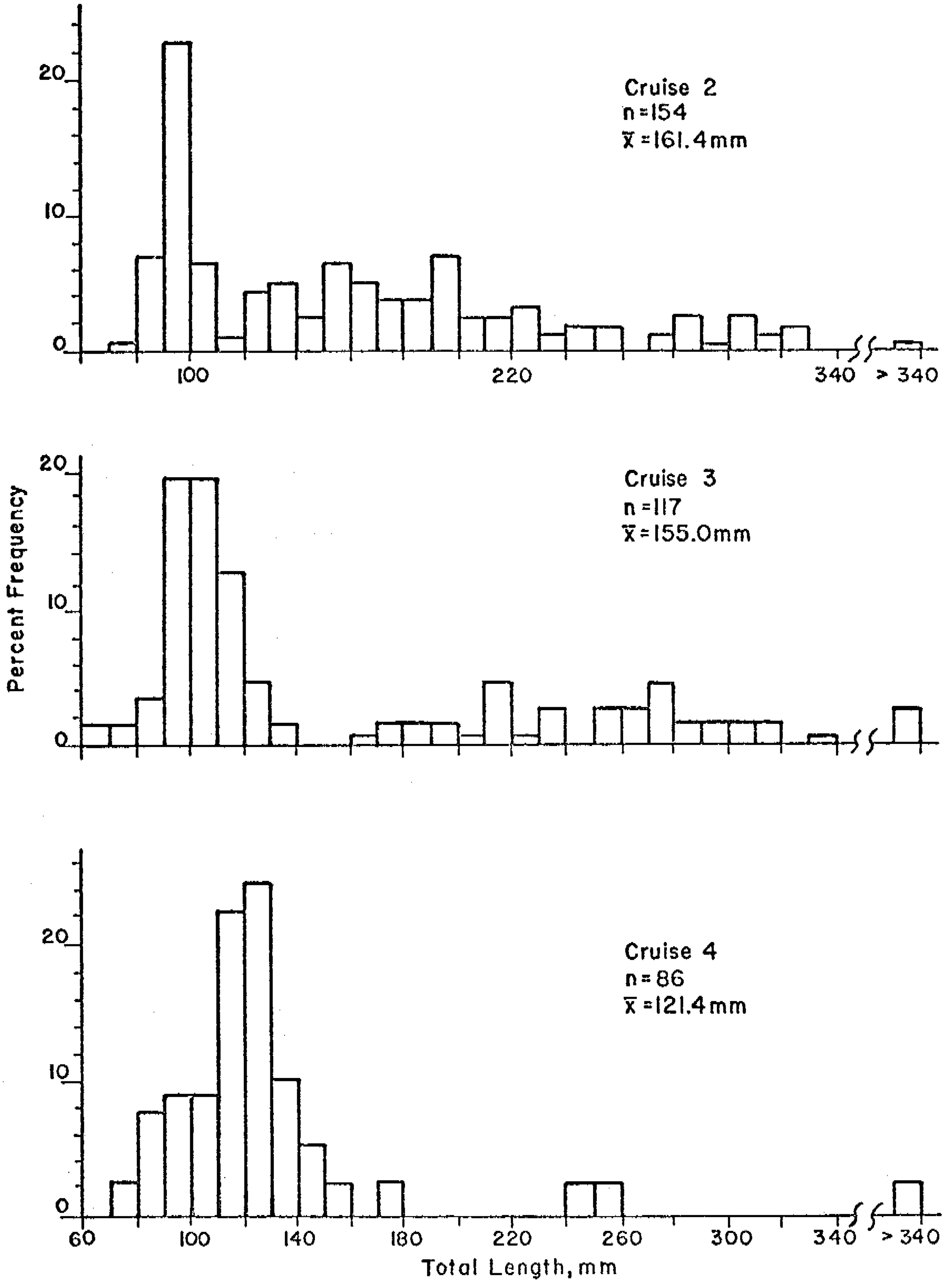


Fig. 48. Lengths of snake pricklebacks, *Lumpenus sagitta*, pooled over all bays and gear types.

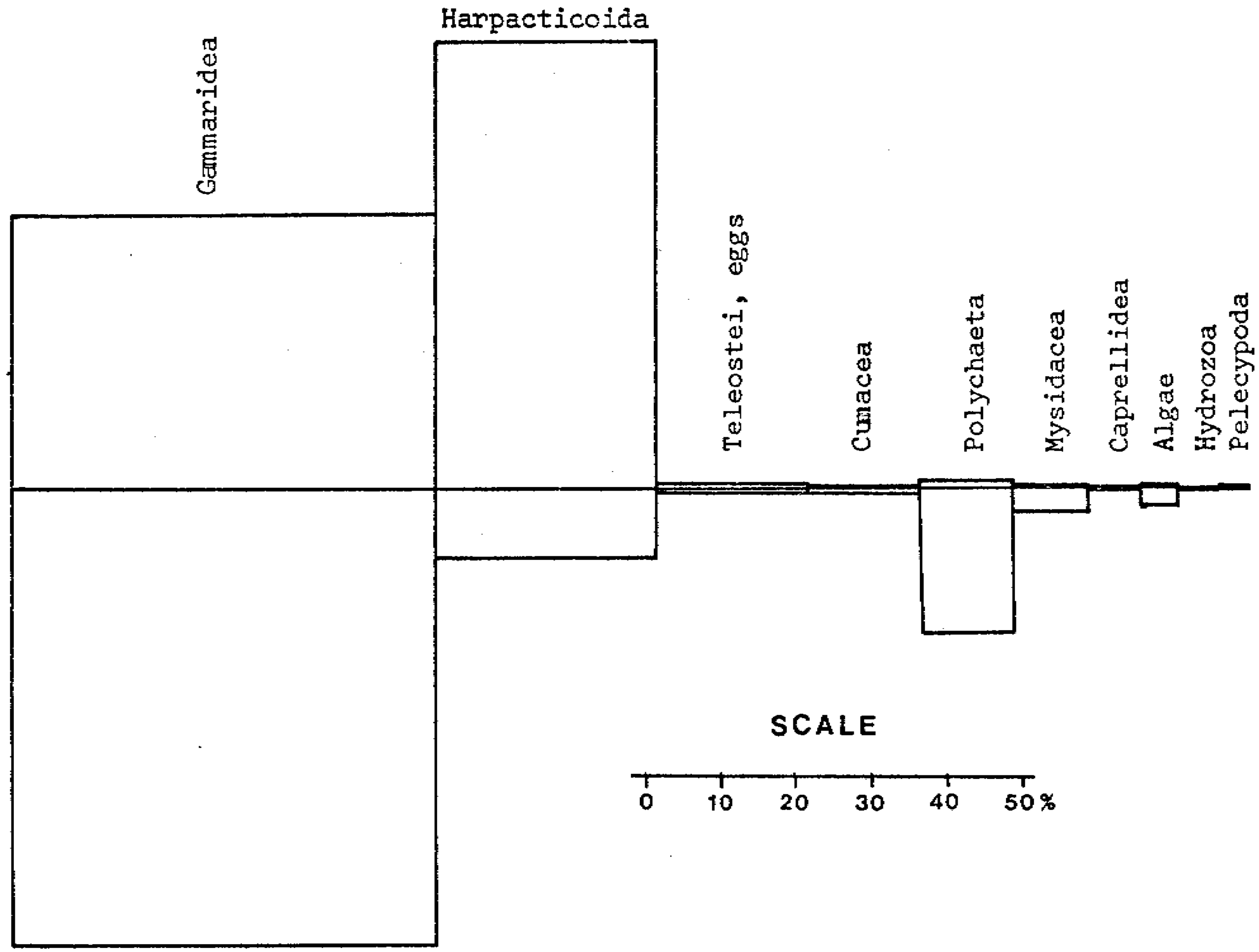


Fig. 49. Prey spectrum of 41 juvenile and adult snake pricklebacks collected mainly from Ugak Bay in late June and late July. There were no empty stomachs, and unidentified material comprised 45.6 percent of total weight of contents.

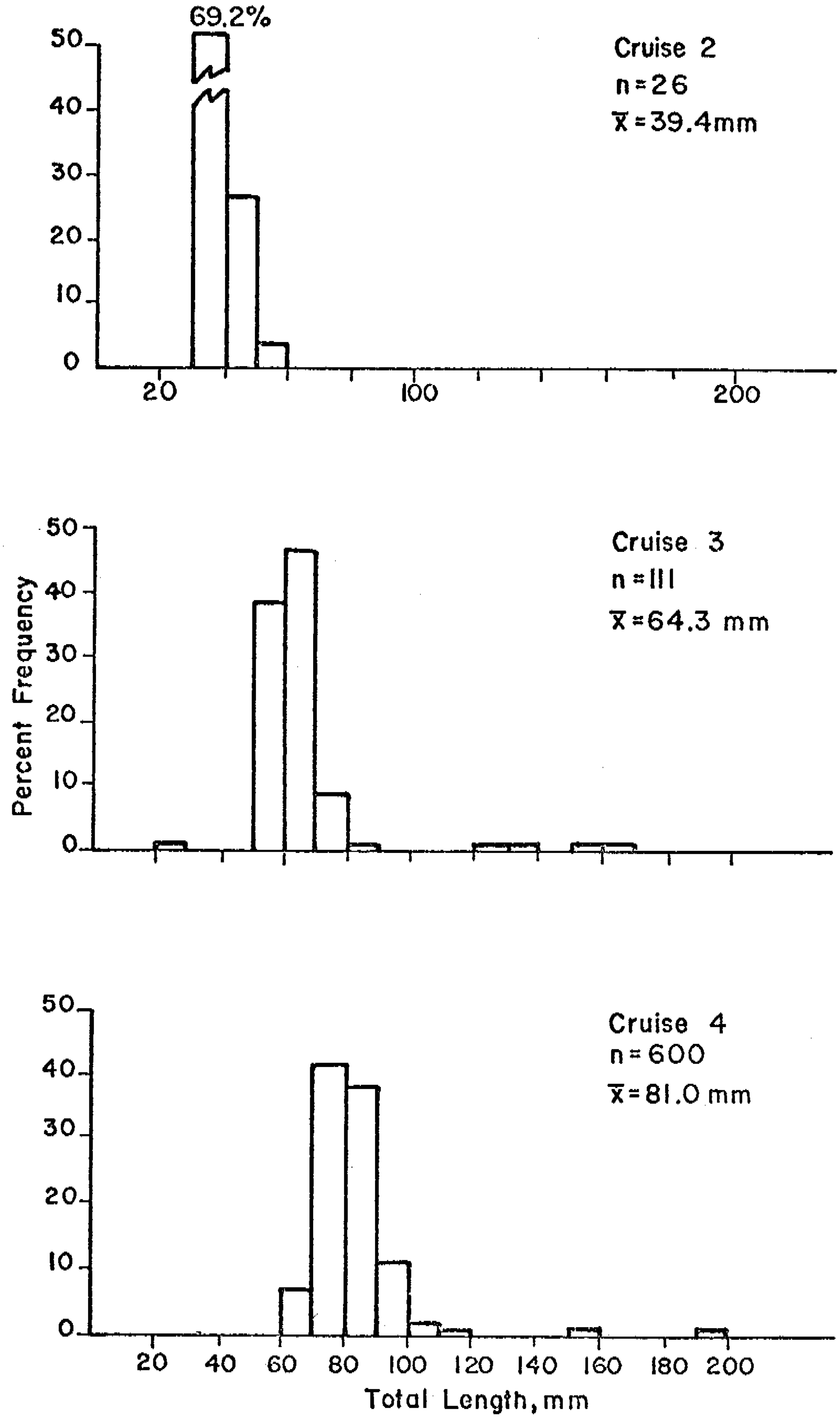


Fig. 50. Lengths of Pacific sandfish, *Trichodon trichodon*, pooled over all bays and gear types.

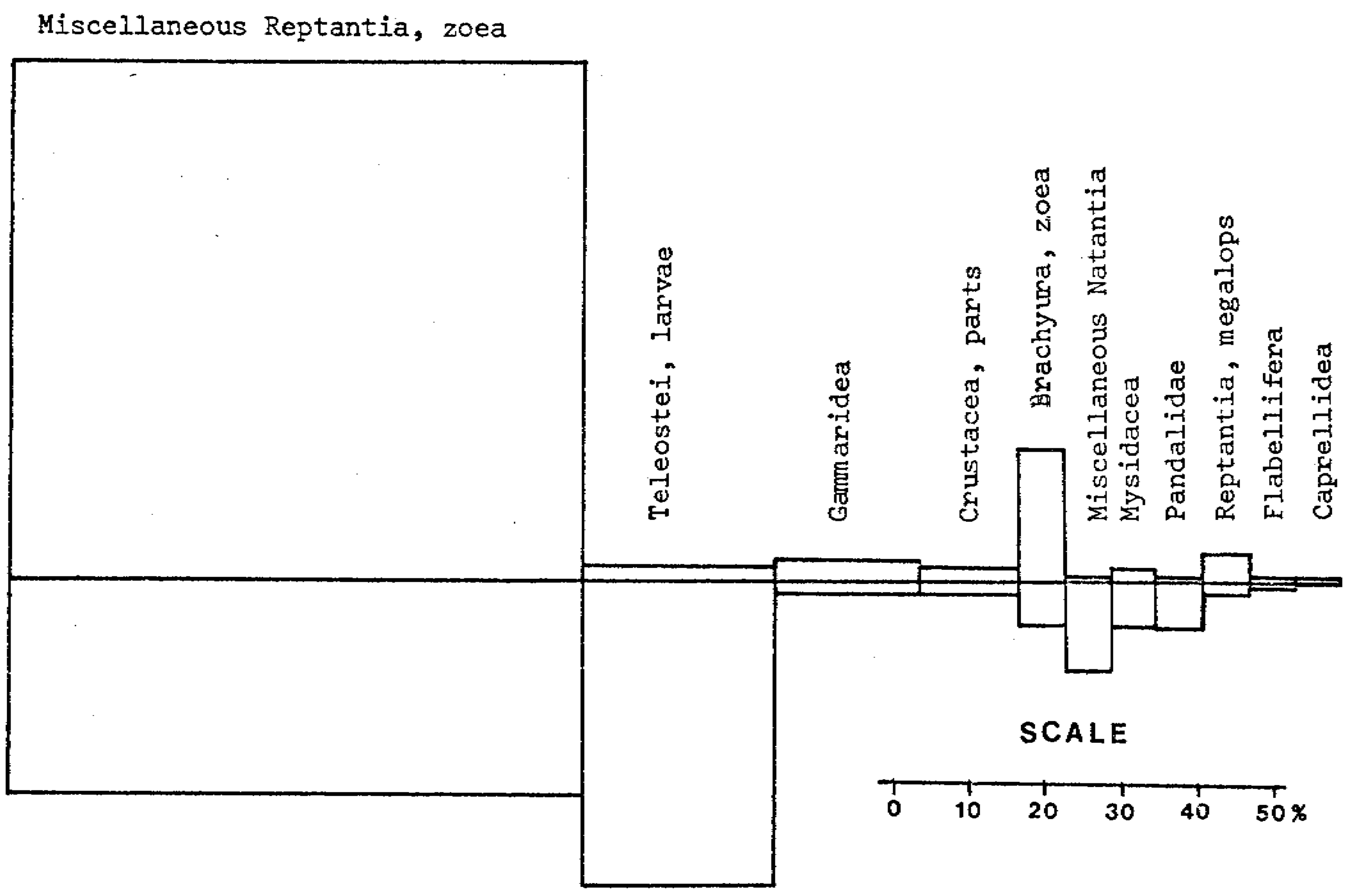


Fig. 51. Prey spectrum of 16 juvenile Pacific sandfish caught by midwater trawl in Ugak Bay in late August. There were no empty stomachs, and unidentified material comprised 36.9 percent of total weight of contents.

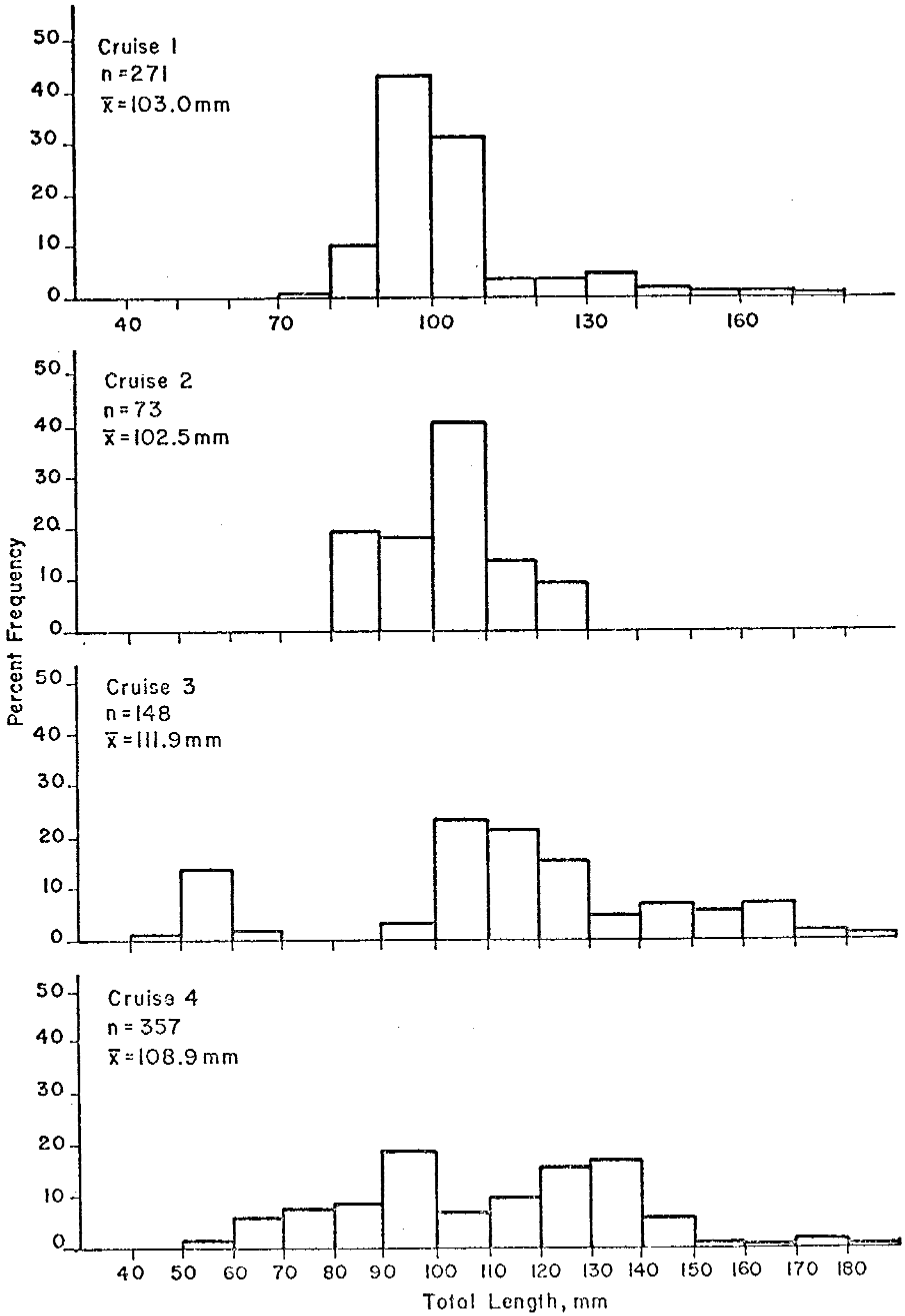


Fig. 52. Lengths of sand lance, *Ammodytes hexapterus*, pooled over all bays and gear types. No postlarvae were measured in the first two cruises.

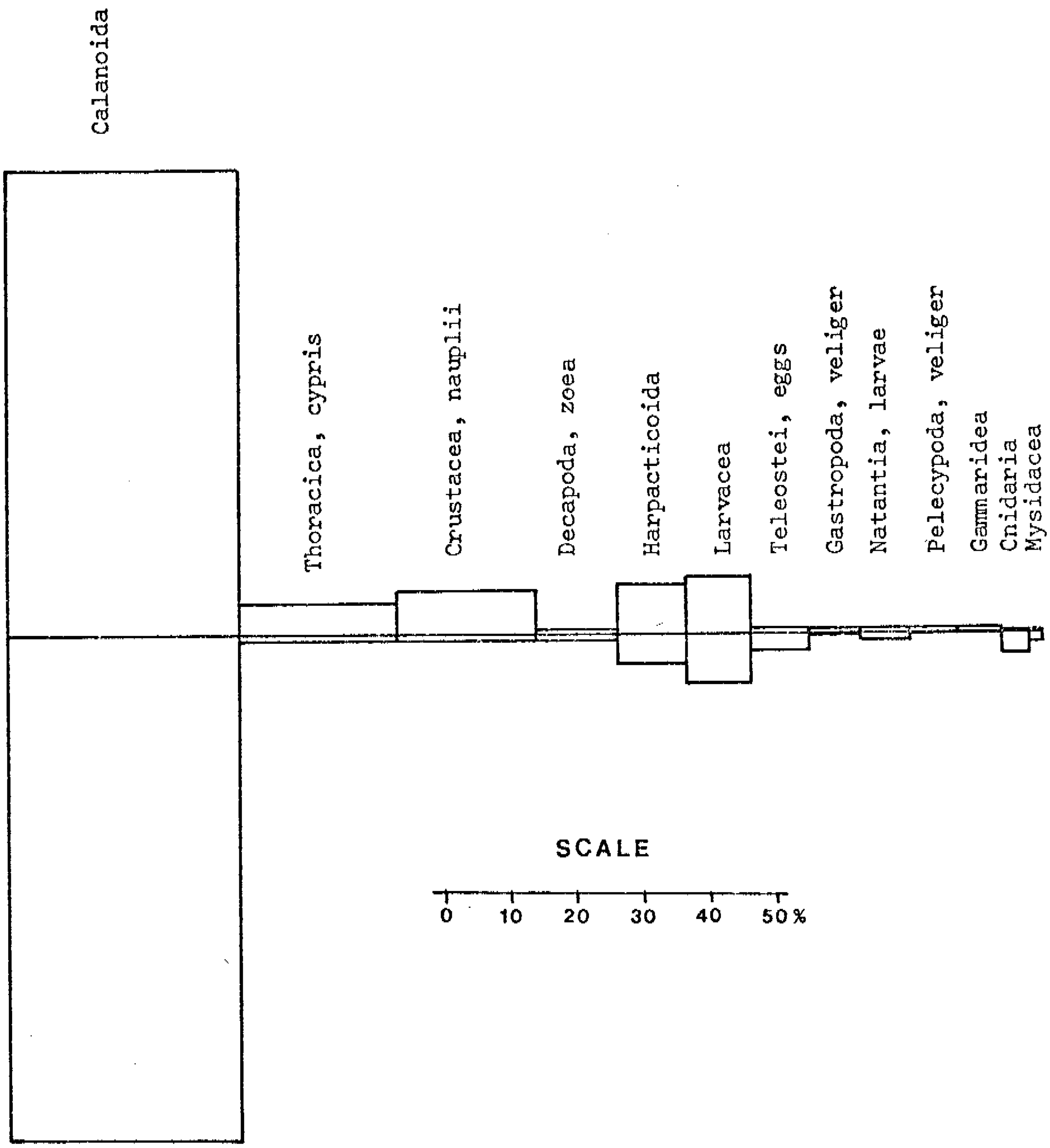


Fig. 53. Prey spectrum of 86 juvenile and adult sand lance caught in the intertidal zone of all bays, late June - mid-September. There were no empty stomachs, and unidentified material comprised 53.6 percent of total weight of contents.

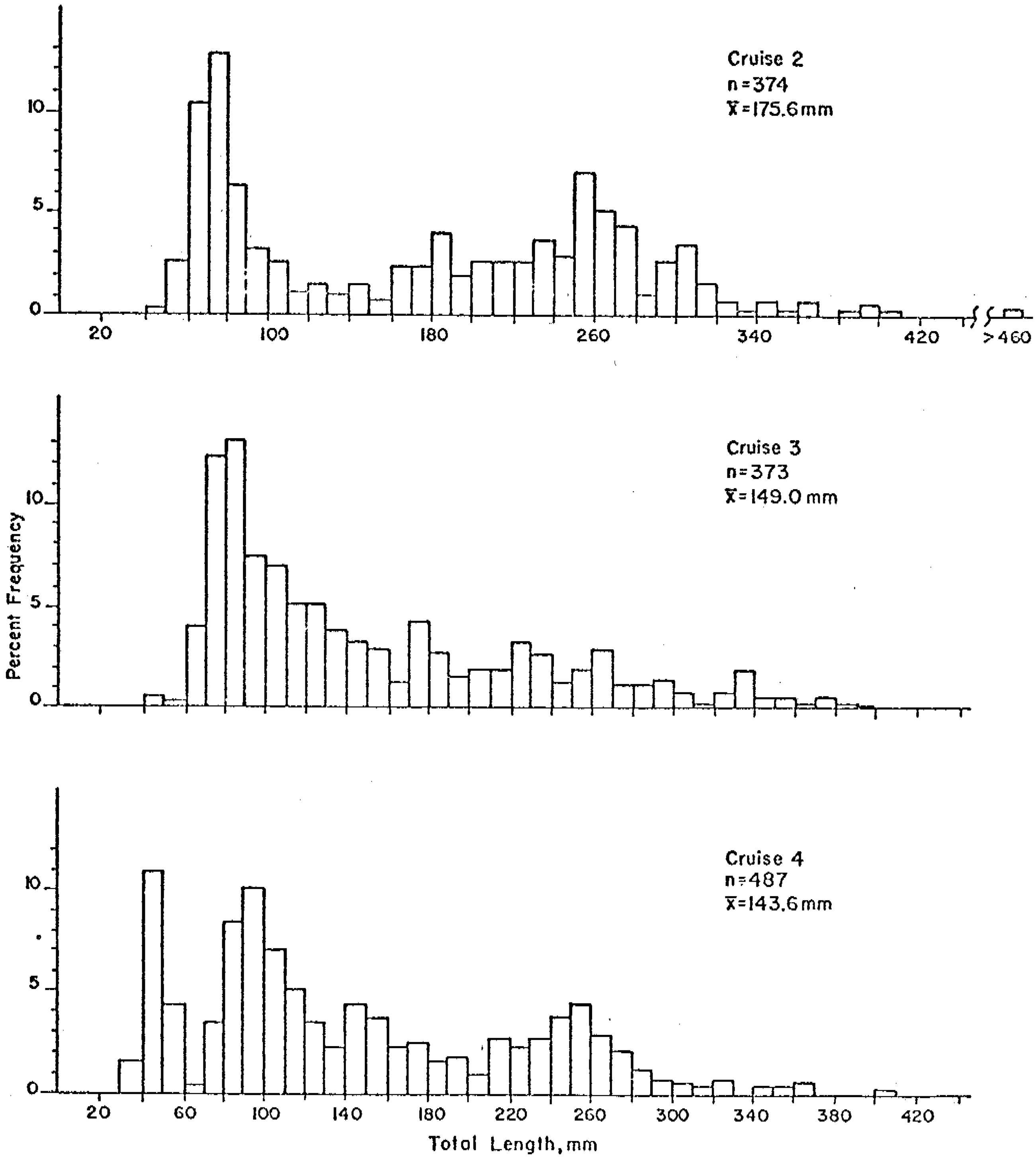


Fig. 54. Lengths of rock sole, *Lepidopsetta bilineata*, pooled over all bays and gear types.

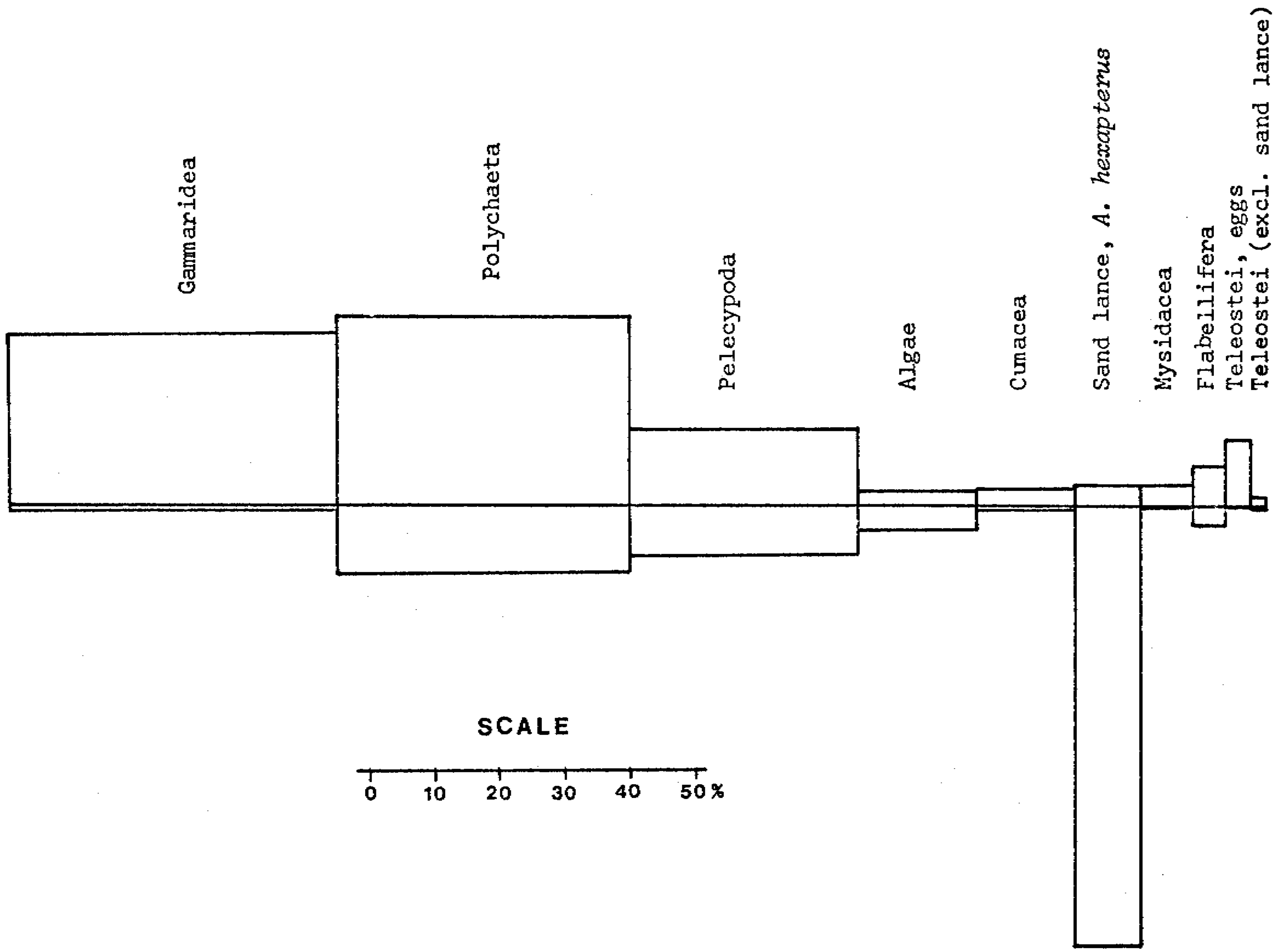


Fig. 55. Prey spectrum of 114 juvenile and adult rock sole caught mainly in Ugak Bay in late June to mid-September. There was 1 empty stomach, and unidentified material comprised 21.0 percent of total weight of contents.

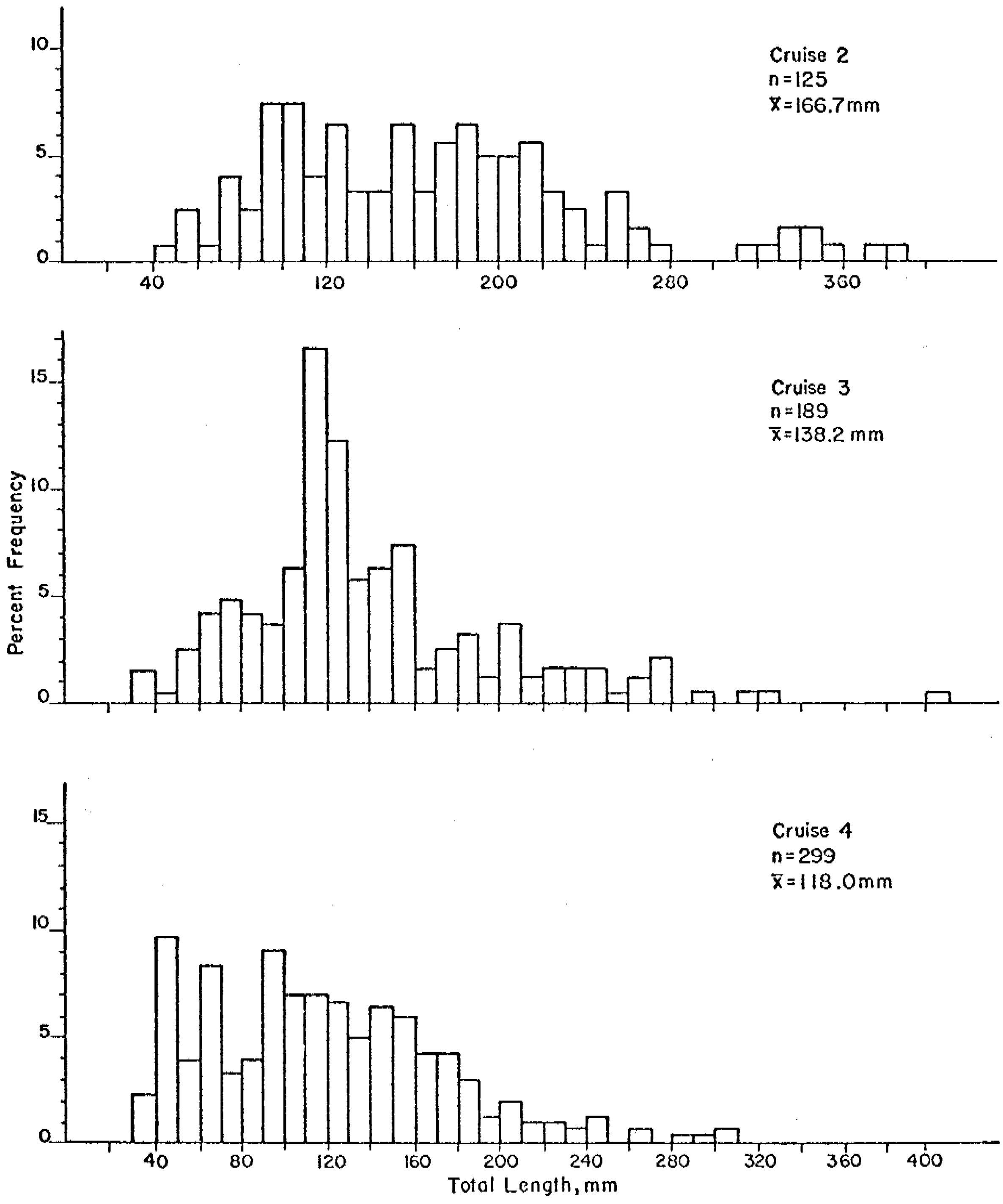


Fig. 56. Lengths of yellowfin sole, *Limanda aspera*, pooled over all bays and gear types.

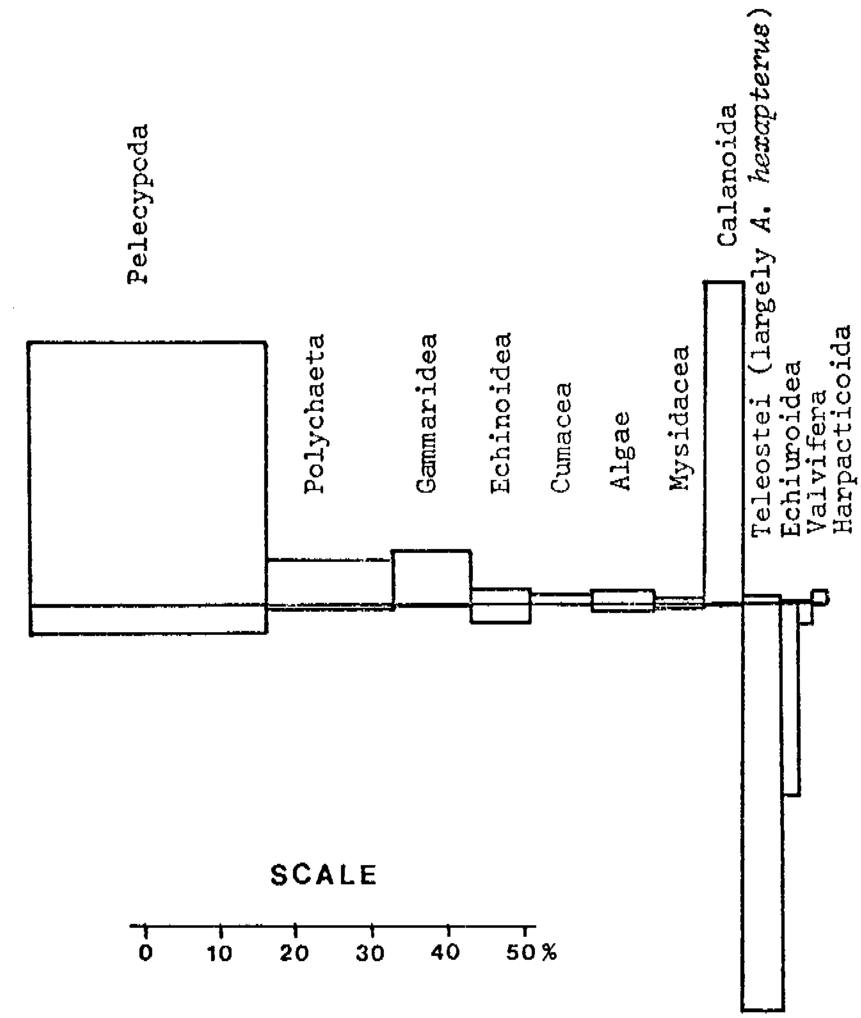


Fig. 57. Prey spectrum of 59 juvenile and adult yellowfin sole, *Limanda aspera*, caught in Ugak Bay from late June to early September. There were no empty stomachs, and unidentified material comprised 25.7 percent of total weight of contents.

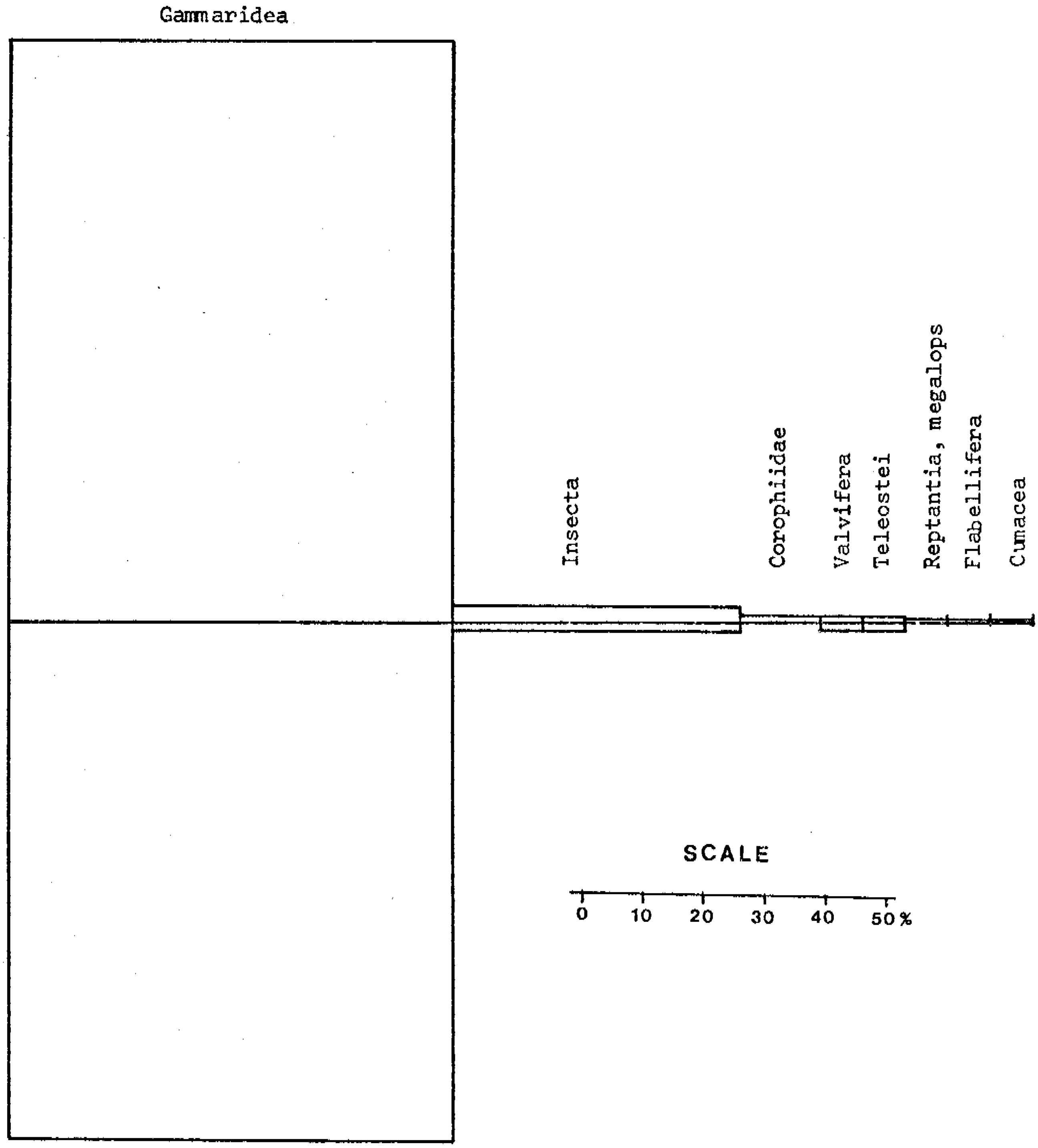


Fig. 58. Prey spectrum of 15 juvenile coho salmon, *Oncorhynchus kisutch*, caught in the intertidal zone of Alitak Bay in late June. There were no empty stomachs, and unidentified material comprised 24.8 percent of total weight of contents.

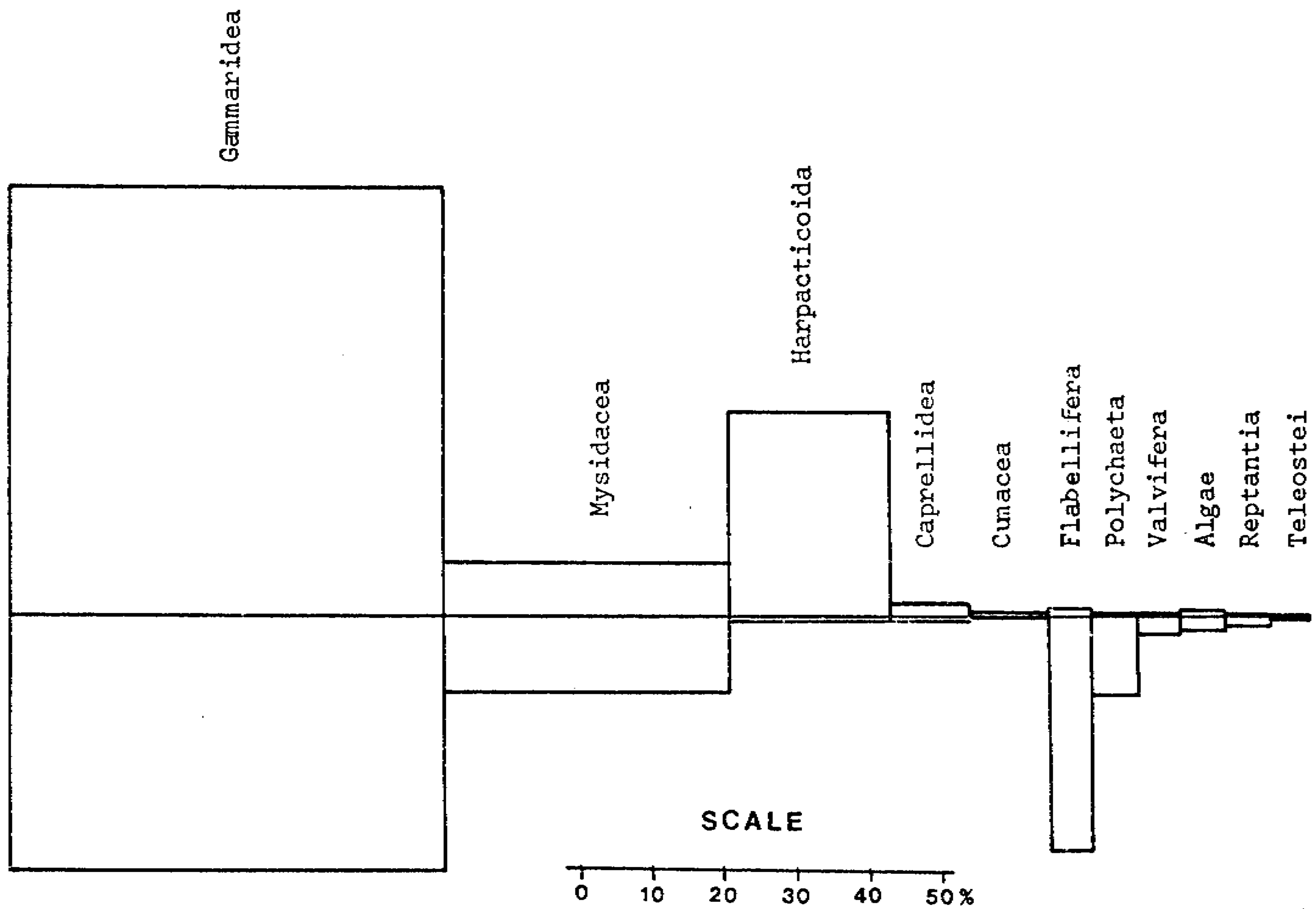


Fig. 59. Prey spectrum of 18 juvenile (Age 1+) Pacific cod, *Gadus macrocephalus*, caught in the nearshore zone of Alitak Bay in late May and June. There were no empty stomachs, and unidentified material comprised 56.9 percent of total weight of contents.

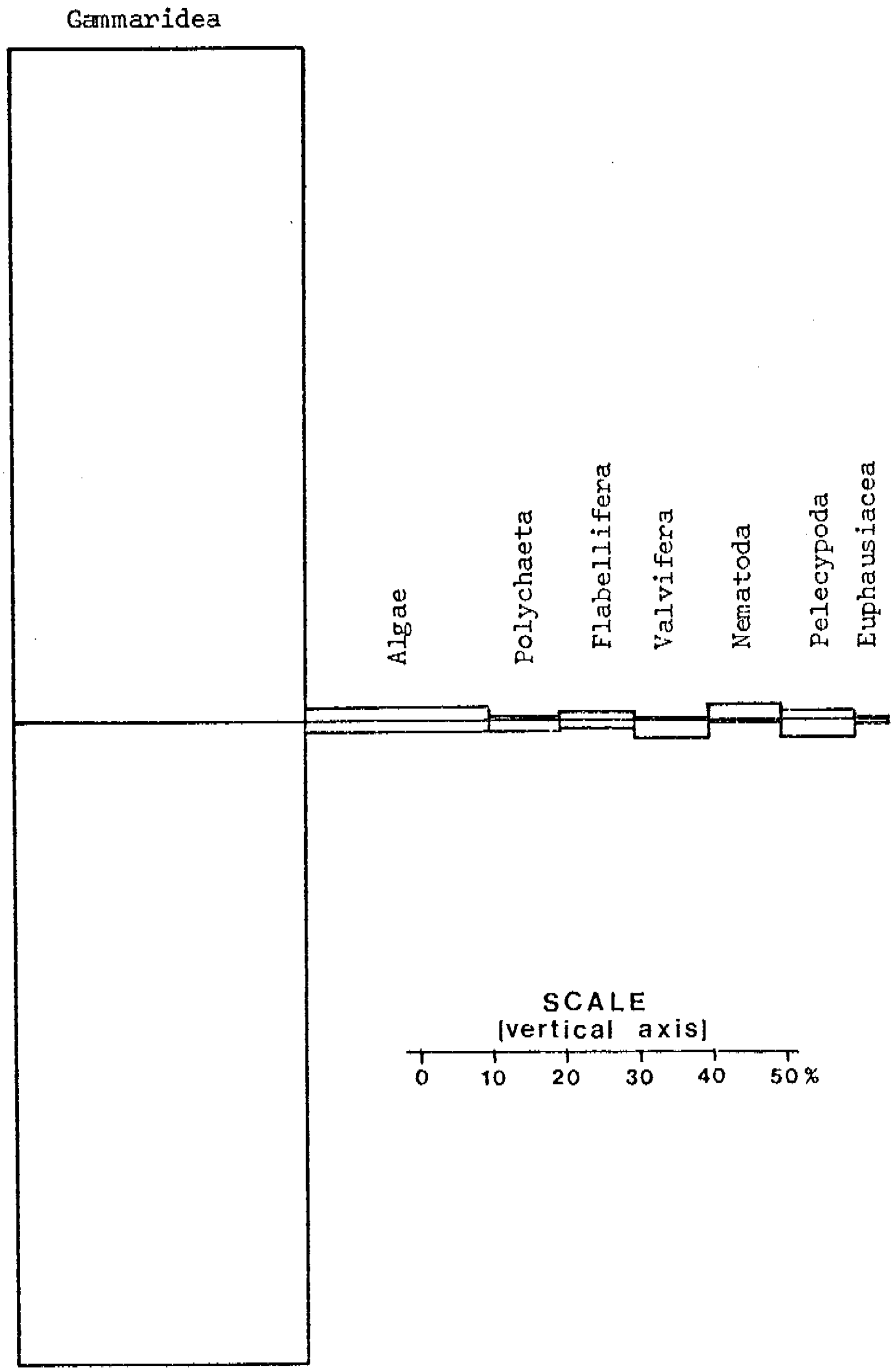


Fig. 60. Prey spectrum of 10 starry flounder, *Platichthys stellatus*. 1 mm = 2 percent for frequency of occurrence (horizontal axis). There were no empty stomachs, and unidentified material comprised 21.6 percent of total weight of contents.

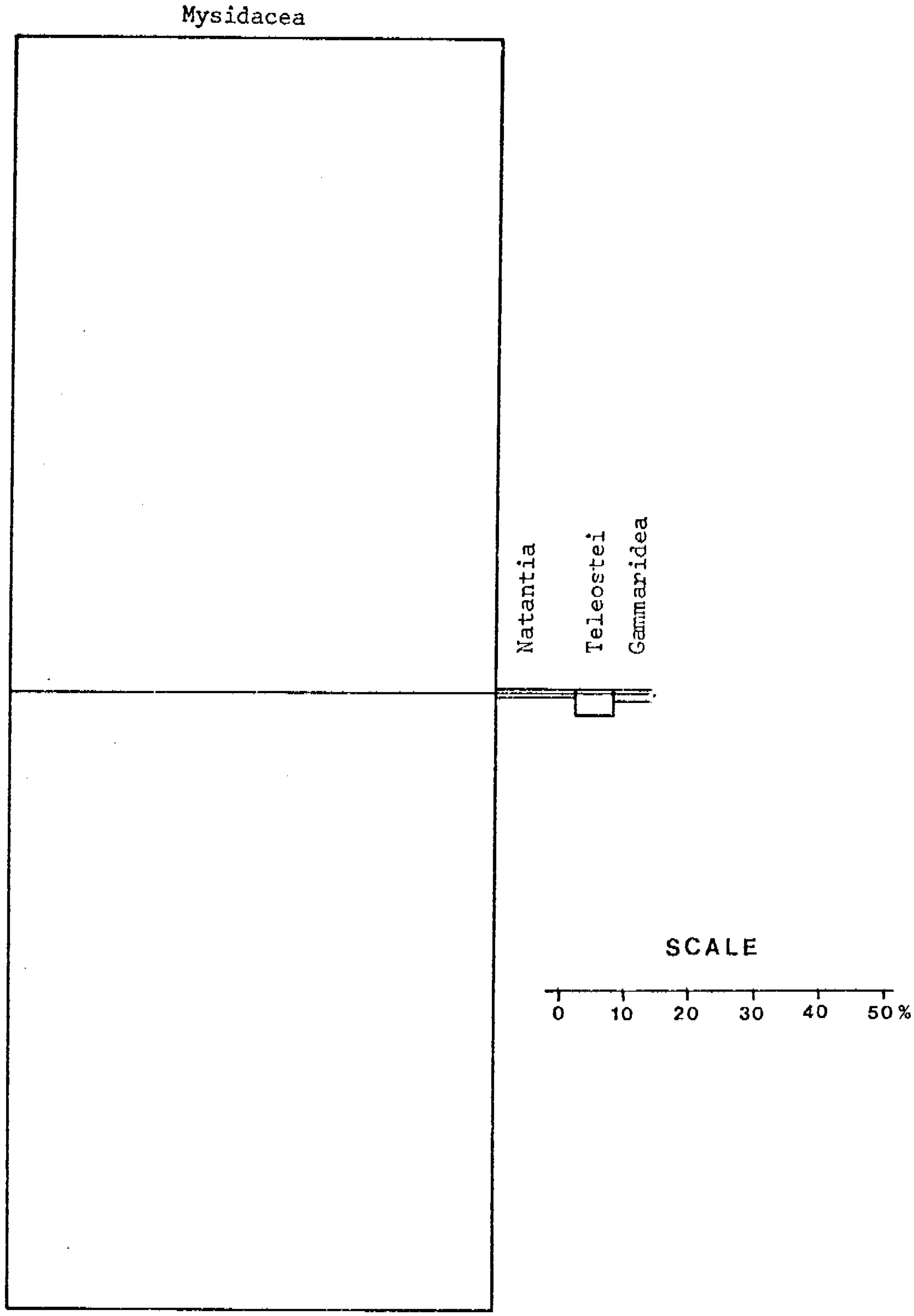


Fig. 61. Prey spectrum of 16 sand sole, *Psettichthys melanostictus*, caught in Ugak Bay from late June to early September. There were no empty stomachs, and unidentified material comprised 12.9 percent of total weight of contents.

APPENDICES

Appendix Table 1. Checklist of all species caught, their occurrence by cruise, bay, and gear type, and their relative abundance[1,2]

Species	Occurrence by cruise	Occurrence by bay	Occurrence by gear type	Relative abundance
Rajidae				
Big skate *Raja binoculata*	3	U	Try	R
Unidentified Osteichthyes	1	U,K	M,B	
Clupeidae				
Pacific herring *Clupea harengus pallasi*	1,2,3,4	U,K,A	T,M,B,Tr	A
Salmonidae				
Pink salmon *Oncorhynchus gorbuscha*	1,2,3,4	U,K,A	T,M,B	V
Chum salmon *Oncorhynchus keta*	1,2,3,4	U,K,A	T,M,B,Tr	A
Coho salmon *Oncorhynchus kisutch*	2,3,4	U,K,A	T,M,B	C
Sockeye salmon *Oncorhynchus nerka*	2,3,4	U,K,A	T,B,Tr	I
Dolly Varden *Salvelinus malma*	1,2,3,4	U,K,A	T,B,Tr	C
Osmeridae				
Surf smelt *Hypomesus pretiosus*	1,4	U	B	I
Capelin *Mallotus villosus*	1,2,3,4	U,K,A	T,M,B,Try	V
Gadidae				
Pacific cod *Gadus macrocephalus*	1,2,3,4	U,A	T,B,Try,Tr	I
Pacific tomcod *Microgadus proximus*	4	U	Try	R
Walleye pollock *Theragra chalcogramma*	1,2,3,4	U,K,A	T,M,B,Try	I

Appendix Table 1. Checklist of all species caught, their occurrence by cruise, bay, and gear type, and their relative abundance - Continued

Species	Occurrence by cruise	Occurrence by bay	Occurrence by gear type	Relative abundance
Zoarcidae				
Alaska eelpout *Bothrocara pusillum*	1,3,4	A	M	I
Gasterosteidae				
Threespine stickleback *Gasterosteus aculeatus*	1,3,4	U,K,A	T,M,B	C
Tube-snout *Aulorhynchus flavidus*	4	K	Try	R
Unidentified Scorpaeniformes	1,2	U,K	M,B,Try	
Scorpaenidae				
Black rockfish *Sebastes melanops*	2,3,4	U,K,A	T,B,Try,Tr	I
Tiger rockfish *Sebastes nigrocinctus*	4	A	T	R
Hexagrammidae				
Unidentified *Hexagrammos*	1,2,3	U,K,A	T,M,B	
Kelp greenling *Hexagrammos decagrammus*	4	U,K	Try,Tr	R
Rock greenling *Hexagrammos lagocephalus*	2,3,4	U,K,A	T,B,Try,Tr	A
Masked greenling *Hexagrammos octogrammus*	1,2,3,4	U,K,A	T,M,B,Try,Tr	A
Whitespotted greenling *Hexagrammos stelleri*	1,2,3,4	U,K,A	T,M,B,Try,Tr	A
Lingcod *Ophiodon elongatus*	4	A	T,Try	R
Atka mackerel *Pleurogrammus monopterygius*	4	A	Tr	R

Appendix Table 1. Checklist of all species caught, their occurrence by cruise, bay, and gear type, and their relative abundance - Continued

Species	Occurrence by cruise	Occurrence by bay	Occurrence by gear type	Relative abundance
Cottidae				
Unidentified Cottidae	1,2,3,4	U,K	T,M,B,Try	
Padded sculpin *Artedius fenestralis*	3,4	U,A	B	I
Crested sculpin *Blepsias bilobus*	2,4	U,A	T,M,Try,Tr	R
Silverspotted sculpin *Blepsias cirrhosus*	1,2,3,4	U,K,A	T,M,B,Try	C
Buffalo sculpin *Enophrys bison*	2,3,4	U,K	B,Try	R
Antlered sculpin *Enophrys diceraus*	4	U,A	Try,Tr	R
Soft sculpin *Gilbertidia sigalutes*	3,4	U	T,M	R
Gymnocanthus spp. (*G. galeatus* and *G. pistilliger*)	2,3,4	U,K,A	B,Try	C
Red Irish Lord *Hemilepidotus hemilepidotus*	2,4	U,K,A	Try,Tr	R
Yellow Irish Lord *Hemilepidotus jordani*	1,2,3,4	U,K,A	T,M,B,Try,Tr	I
Pacific staghorn sculpin *Leptocottus armatus*	1,2,3,4	U,A	B,Try,Tr	I
Unidentified *Myoxocephalus*	1,3	U,K,A	M,B,Tr	
Plain sculpin *Myoxocephalus jaok*	2,3,4	U,K,A	T,B,Try,Tr	I
Great sculpin *Myoxocephalus polyacanthocephalus*	1,2,3,4	U,K,A	T,B,Try,Tr	A

Appendix Table 1. Checklist of all species caught, their occurrence by cruise, bay, and gear type, and their relative abundance - Continued

Species	Occurrence by cruise	Occurrence by bay	Occurrence by gear type	Relative abundance
Shorthorn sculpin *Myoxocephalus scorpius*	2,3,4	U,K,A	B,Try,Tr	I
Eyeshade sculpin *Nautichthys pribilovius*	3	A	Tr	R
Porocottus quadrifilis	2	U	B	R
Tadpole sculpin *Psychrolutes paradoxus*	3	K	T	R
Manacled sculpin *Synchirus gilli*	4	K	Try	R
Unidentified *Triglops*	1,2	U,K,A	M,Try	
Ribbed sculpin *Triglops pingeli*	3,4	U,A	M,Try	I
Bigmouth sculpin *Hemitripterus bolini*	3	K	M	R
Agonidae				
Aleutian alligator fish *Aspidophoroides bartoni*	4	U	Try	R
Bering poacher *Occella dodecaedron*	2,4	U	Try	R
Tubenose poacher *Pallasina barbata*	1,2,3,4	U,K,A	T,B,Try	C
Sturgeon poacher *Agonus acipenserinus*	2,3,4	U,K,A	T,M,B,Try,Tr	C
Cyclopteridae				
Unidentified Cyclopteridae	3	U	T	
Smooth lumpsucker *Aptocyclus ventricosus*	4	A	M	R

Appendix Table 1. Checklist of all species caught, their occurrence by cruise, bay, and gear type, and their relative abundance- Continued

Species	Occurrence by cruise	Occurrence by bay	Occurrence by gear type	Relative abundance
Unidentified *Liparis*	1	U	B	
Ribbon snailfish *Liparis cyclopus*	3,4	U,A	Try	R
Trichodontidae				
Pacific sandfish *Trichodon trichodon*	1,2,3,4	U,K,A	T,M,B,Try	V
Bathymasteridae				
Unidentified Bathymasteridae	1,2	U,K,A	T,M,B	
Alaskan ronquil *Bathymaster caeruleofasciatus*	2,3,4	U,K	Try,Tr	R
Searcher *Bathymaster signatus*	3,4	U	Try	R
Anarhichadidae				
Bering wolffish *Anarhichas orientalis*	2,3	U,K	T,M	R
Stichaeidae				
Unidentified Stichaeidae	1,2	U,K,A	T,M,Try	
High cockscomb *Anoplarchus purpurescens*	1,4	U,K	B,Tr	R
Decorated warbonnet *Chirolophis polyactocephalus*	4	A	Tr	R
Unidentified *Lumpenus*	3,4	A	M	
Stout eelblenny *Lumpenus medius*	4	U,A	M,Tr	C
Snake prickleback *Lumpenus sagitta*	1,2,3,4	U,K,A	T,M,B,Try	A

Appendix Table 1. Checklist of all species caught, their occurrence by cruise, bay, and gear type, and their relative abundance - Continued

Species	Occurrence by cruise	Occurrence by bay	Occurrence by gear type	Relative abundance
Arctic shanny *Stichaeus punctatus*	2,4	K,A	Try	R
Pholidae				
Penpoint gunnel *Apodichthys flavidus*	3	K	Try	R
Crescent gunnel *Pholis laeta*	1,2,3,4	U,K,A	B,Try	C
Zaproridae				
Prowfish *Zaprora silenus*	3,4	K,A	T,M	R
Ammodytidae				
Pacific sand lance *Ammodytes hexapterus*	1,2,3,4	U,K,A	T,M,B,Try	V
Pleuronectidae				
Unidentified Pleuronectidae	4	A	Try	
Flathead sole *Hippoglossoides elassodon*	3,4	U,K	T,M,Try	I
Pacific halibut *Hippoglossus stenolepis*	2,3,4	U,K,A	Try,Tr	I
Butter sole *Isopsetta isolepis*	2,3,4	U,K	Try	I
Rock sole *Lepidopsetta bilineata*	1,2,3,4	U,K,A	T,M,B,Try,Tr	A
Yellowfin sole *Limanda aspera*	2,3,4	U,K,A	M,B,Try,Tr	A
Starry flounder *Platichthys stellatus*	1,2,3,4	U,K,A	B,Try,Tr	C
Alaska plaice *Pleuronectes quadrituberculatus*	2,3	U	Try	R

Appendix Table 1. Checklist of all species caught, their occurrence by cruise, bay, and gear type, and their relative abundance - Continued

Species	Occurrence by cruise	Occurrence by bay	Occurrence by gear type	Relative abundance
Pleuronectidae (Continued)				
Sand sole *Psettichthys melanostictus*	1,2,3,4	U,K,A	B,Try	I

[1]Nomenclature is standardized according to Bailey, Reeve, M., et al. (1970).

[2]Symbols:

Cruise; cruise number

Bay; U = Ugak Bay, K = Kaiugnak Bay, A = Alitak Bay.

Gear type; T = tow net, M = midwater trawl, B = beach seine, Try = try net, Tr = trammel net.

Relative abundance categories were arbitrarily defined on the basis of total catch in numbers over the entire study: R = rare (1-10), I = infrequent (11-100), C = common (101-500), A = abundant (501-15000), V = very abundant (> 15001).

Appendix Table 2. Cumulative tow net catches of all species from three regions of Ugak Bay, Cruise 2

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L=larvae, J=juveniles, A=adults).

Species	Life history stages	Inner (7 hauls)		Middle (7 hauls)		Outer (6 hauls)		Total (20 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
M. villosus	J,A			2291	327.29	2	.33	2293	114.65
O. keta	J			119	17.00	13	2.17	132	6.60
O. gorbuscha	J	1	.14	28	4.00			29	1.45
O. kisutch	post-smolt			4	.57	21	3.50	25	1.25
O. nerka	post-smolt	9	1.29			3	.50	12	.60
S. malma	A			5	.71	1	.17	6	.30
T. trichodon	J			5	.71			5	.25
Hexagrammos spp.	J	1	.14					1	.05
H. jordani	A					1	.17	1	.05
A. orientalis	J			1	.14			1	.05
Unidentified Stichaeidae	J					1	.17	1	.05

Appendix Table 3. Cumulative tow net catches of all species from three regions of Ugak Bay, Cruise 3.

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L=larvae, J=juveniles, A=adults).

Species	Life history stages	Inner (7 hauls)		Middle (7 hauls)		Outer (6 hauls)		Total (20 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
M. villosus	J,A	7308	1044.00	4492	641.71	29	4.83	11829	591.45
T. trichodon	J	2	.29	453	64.71	1937	322.83	2392	119.60
O. gorbuscha	J	93	13.29	153	21.86	13	2.17	259	12.95
L. sagitta	J	5	.71	31	4.43			36	1.80
O. kisutch	post-smolt	22	3.14	11	1.57			33	1.65
O. nerka	post-smolt			17	2.43	1	.17	18	.90
O. keta	J	6	.86	7	1.00	3	.50	16	.80
S. malma	A			4	.57			4	.20
G. aculeatus	J	4	.57					4	.20
Hexagrammos spp.	J	1	.14			2	.33	3	.15
T. chalcogramma	J			1	.14	1	.17	2	.10
A. hexapterus	L,J	1	.14	1	.14			2	.10
B. cirrhosus	J	1	.14					1	.05
G. sigalutes	J			1	.14			1	.05
H. jordani	A			1	.14			1	.05
Unidentified Cyclopteridae	J			1	.14			1	.05

Appendix Table 4. Cumulative tow net catches of all species from three regions of Ugak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L=larvae, J=juveniles, A=adults).

Species	Life history stages	Inner (7 hauls)		Middle (7 hauls)		Outer (6 hauls)		Total (20 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
T. trichodon	J	1009	144.14	393	56.14	1271	211.83	2673	133.65
M. villosus	L,J	875	125.00	50	7.14	192	32.00	1117	55.85
O. gorbuscha	J	5	.71	44	6.29	65	10.83	114	5.70
S. melanops	J			5	.71	5	.83	10	.50
O. keta	J	1	.14	5	.71			6	.30
O. nerka	post-smolt	2	.29	3	.43	1	.17	6	.30
G. aculeatus	J	3	.43	2	.29			5	.25
O. kisutch	post-smolt			4	.57			4	.20
L. sagitta	J			2	.29	2	.33	4	.20
A. hexapterus	J	3	.43					3	.15
T. chalcogramma	J	1	.14					1	.05
Hexagrammos spp.	J	1	.14					1	.05
B. bilobus	J	1	.14					1	.05
H. jordani	J					1	.17	1	.05
P. barbata	J			1	.14			1	.05
A. acipenserinus	J					1	.17	1	.05

Appendix Table 5. Cumulative surface trawl catches of all species from three regions of Ugak Bay, Cruise 1

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L=larvae, J=juveniles, A=adults).

Species	Life history stages	Inner (7 hauls)		Middle (6 hauls)		Outer (3 hauls)		Total (16 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
A. hexapterus	L,J,A	1431	204.43	932	155.33	5	1.67	2368	148.00
M. villosus	L,J,A	92	13.14					92	5.75
O. gorbuscha	J			6	1.00	1	.33	7	.44
Unid. Stichaeidae	L	6	.86	1	.17			7	.44
C. h. pallasi	J	6	.86					6	.38
Unid. Scorpaeniformes	L	4	.57	1	.17			5	.31
H. jordani	J	5	.71					5	.31
B. cirrhosus	J	1	.14	1	.17	1	.33	3	.19
G. aculeatus	A	1	.14					1	.06
Triglops sp.	L					1	.33	1	.06
T. trichodon	L					1	.33	1	.06
Unidentified Bathymasteridae	L			1	.17			1	.06

Appendix Table 6. Cumulative midwater trawl catches of all species from three regions of Ugak Bay, Cruise 1

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L=larvae, J=juveniles, A=adults).

Species	Life history stages	Inner (4.5 hauls)		Middle (2 hauls)		Outer (3 hauls)		Total (9.5 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
A. hexapterus	A	152	33.78	37	18.50	16	5.33	205	21.58
M. villosus	L,A	178	39.56	6	3.00			184	19.37
Triglops sp.	L,J	2	.44	3	1.50	8	2.67	13	1.37
H. jordani	J	5	1.11			6	2.00	11	1.16
Unid. Scorpaeniformes	L,J	3	.67					3	.32
Unid. Bathymasteridae	L	1	.22	1	.50			2	.21
Unid. Osteichthyes	L			1	.50			1	.11
C. h. pallasi	J	1	.22					1	.11
O. gorbuscha	J	1	.22					1	.11
H. octogrammus	J	1	.22					1	.11
B. cirrhosus	J			1	.50			1	.11

Appendix Table 7. Cumulative midwater trawl catches of all species from three regions of Ugak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L=larvae, J=juveniles, A=adults).

Species	Life history stages	Inner (9 hauls)		Middle (8 hauls)		Outer (6 hauls)		Total (23 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
M. villosus	J,A	988	109.78	2528	316.00	90	15.00	3606	156.78
T. trichodon	J,A	1	.11	546	68.25	285	47.50	832	36.17
L. sagitta	L,J,A	31	3.44	53	6.63			84	3.65
A. hexapterus	L,J	34	3.78					34	1.48
H. elassodon	J	16	1.78					16	.70
H. jordani	L,J	9	1.00	1	.13			10	.43
O. gorbuscha	J	6	.67					6	.26
G. sigalutes	J	3	.33	1	.13			4	.17
T. chalcogramma	J			2	.25	1	.17	3	.13
O. kisutch	post-smolt					2	.33	2	.09
L. bilineata	A	1	.11	1	.13			2	.09
C. h. pallasi	A	1	.11					1	.04
O. keta	J	1	.11					1	.04
B. cirrhosus	J			1	.13			1	.04
T. pingeli	A			1	.13			1	.04
A. acipenserinus	J			1	.13			1	.04

Appendix Table 8. Cumulative midwater trawl catches of all species from three regions of Ugak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (7 hauls)		Middle (6 hauls)		Outer (6 hauls)		Total (19 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	To	CPUE
T. trichodon	J	980	140.00	597	99.50	11558	1926.33	13135	691.32
M. villosus	J	455	65.00	4670	778.33	177	29.50	5302	279.05
L. sagitta	A	4	.57					4	.21
T. chalcogramma	J	2	.29					2	.11
B. bilobus	A	2	.29					2	.11
G. sigalutes	J	2	.29					2	.11

Appendix Table 9. Cumulative beach seine catches of all species from three regions of Ugak Bay, Cruise 1

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (5 hauls)		Middle (6 hauls)		Outer (5 hauls)		Total (16 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
A. hexapterus	A	4	.80	7310	1218.33			7314	457.13
O. gorbuscha	J	205	41.00	53	8.83	195	39.00	453	28.31
M. polyacanthocephalus	J	113	22.60			4	.80	117	7.31
O. keta	J	65	13.00	17	2.83			82	5.13
S. malma	A	44	8.80	1	.17	14	2.80	59	3.69
M. villosus	A			36	6.00			36	2.25
Myoxocephalus spp. (probably *M. polyacanthocephalus*)	J	16	3.20			4	.80	20	1.25
H. pretiosus	A					17	3.40	17	1.06
Unidentified Scorpaeniformes	L,J	17	3.40					17	1.06
P. stellatus	A,J	1	.20	2	.33	7	1.40	10	.63
B. cirrhosus	J,A	7	1.40					7	.44
H. octogrammus	A	4	.80					4	.25
P. laeta		3	.60					3	.19
L. armatus	J,A	1	.20	1	.17			2	.13
Unidentified Bathymasteridae	J					2	.40	2	.13
G. aculeatus	A			1	.17			1	.06
P. barbata	A			1	.17			1	.06
Liparis sp.	J	1	.20					1	.06
L. bilineata	A			1	.17			1	.06
P. melanostictus	A			1	.17			1	.06

Appendix Table 10. Cumulative beach seine catches of all species from three regions of Ugak Bay, Cruise 2

CPUE values are mean catches per unit of effort, cumulative catch/ number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (7 hauls)		Middle (3 hauls)		Outer (4 hauls)		Total (14 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
A. hexapterus	A	2107	301.00	93	31.00	2	.50	2202	157.29
O. gorbuscha	J	17	2.43	2099	699.67	2	.50	2118	151.29
O. keta	J	71	10.14	38	12.67	15	3.75	124	8.86
M. polyacanthocephalus	J,A	93	13.29	12	4.00	15	3.75	120	8.57
P. stellatus	A	3	.43	2	.67	14	3.50	19	1.36
L. bilineata	J,A	1	.14	6	2.00	11	2.75	18	1.29
L. sagitta	A					12	3.00	12	.86
O. kisutch	J					8	2.00	8	.57
H. jordani	J	6	.86					6	.43
H. octogrammus	J,A	5	.71					5	.36
B. cirrhosus	J	5	.71					5	.36
S. malma	A					4	1.00	4	.29
L. armatus	A,J	1	.14			3	.75	4	.29
P. barbata	J	3	.43	1	.33			4	.29
E. bison	J			2	.67	1	.25	3	.21
P. laeta		3	.43					3	.21
P. melanostictus	A			1	.33	2	.50	3	.21
S. melanops	J	2	.29					2	.14
P. quadrifilis		2	.29					2	.14
O. nerka	Post-smolt	1	.14					1	.07
M. villosus	A			1	.33			1	.07
Unidentified Scorpaeniformes	L	1	.14					1	.07
H. lagocephalus	J	1	.14					1	.07
Unidentified Cottidae		1	.14					1	.07
Gymnocanthus sp.	J	1	.14					1	.07

Appendix Table 11. Cumulative beach seine catches of all species from three regions of Ugak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (8 hauls)		Middle (3 hauls)		Outer (3 hauls)		Total (14 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
O. gorbuscha	J,A	23	2.88	10378	3459.33	13	4.33	10414	743.86
O. keta	J,A	51	6.38	672	224.00	13	4.33	736	52.57
A. hexapterus				463	154.33			463	33.07
L. sagitta	A			309	103.00	43	14.33	352	25.14
M. villosus	J					300	100.00	300	21.43
M. polyacanthocephalus	J	52	6.50	10	3.33	3	1.00	65	4.64
L. bilineata	J	5	.63	7	2.33	26	8.67	38	2.71
H. stelleri	J	19	2.38	6	2.00	9	3.00	34	2.43
P. laeta	A	28	3.50					28	2.00
S. malma	A	3	.38	4	1.33	15	5.00	22	1.57
H. octogrammus	J	21	2.63					21	1.50
B. cirrhosus	J	11	1.38					11	.79
P. melanostictus						9	3.00	9	.64
P. barbata	J	3	.38	5	1.67			8	.57
L. armatus	A	1	.13	3	1.00	3	1.00	7	.50
P. stellatus	J	5	.63					5	.36
G. aculeatus	J,A	4	.50					4	.29
O. nerka	post-smolt	2	.25					2	.14
E. bison	J					2	.67	2	.14
O. kisutch	J					1	.33	1	.07
A. fenestralis	A	1	.13					1	.07
Myoxocephalus sp.	J	1	.13					1	.07
A. acipenserinus	A					1	.33	1	.07

Appendix Table 12. Cumulative beach seine catches of all species from three regions of Ugak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (7 hauls)		Middle (2 hauls)		Outer (4 hauls)		Total (13 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
C. h. pallasi	L	1200	171.43					1200	92.31
A. hexapterus	A,J			649	324.50	480	120.00	1129	86.85
M. villosus	L	200	28.57					200	15.38
H. preticsus	J					55	13.75	55	4.23
L. bilineata	J,A	3	.43	11	5.50	31	7.75	45	3.46
P. barbata	J,A	35	5.00	8	4.00	1	.25	44	3.38
T. trichodon	J			1	.50	41	10.25	42	3.23
H. octogrammus		29	4.14					29	2.23
M. polyacanthocephalus	J,A	11	1.57	12	6.00	4	1.00	27	2.08
B. cirrhosus	J	10	1.43	12	6.00	1	.25	23	1.77
H. lagocephalus	J	8	1.14	10	5.00	2	.50	20	1.54
P. stellatus	A	1	.14			12	3.00	13	1.00
S. malma	A	7	1.00			5	1.25	12	.92
Gymnocanthus spp.	J	4	.57	8	4.00			12	.92
H. stelleri	J	6	.86	5	2.50			11	.85
P. laeta	A	10	1.43					10	.77
O. keta	J	6	.86					6	.46
G. macrocephalus	J					5	1.25	5	.38
G. aculeatus	J	3	.43					3	.23
S. melanops	J	1	.14			2	.50	3	.23
A. fenestralis	J	3	.43					3	.23
L. armatus	A,J	2	.29			1	.25	3	.23
P. melanostictus	A					2	.50	2	.15
O. kisutch	J	1	.14					1	.08
H. jordani	J	1	.14					1	.08
M. scorpius	J	1	.14					1	.08

Appendix Table 13. Cumulative try net catches of all species from three regions of Ugak Bay, Cruise 2

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (4 hauls)		Middle (12 hauls)		Outer (10 hauls)		Total (26 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
L. sagitta	A,J			69	5.75	324	32.40	393	15.12
L. bilineata	J,A	26	6.50	18	1.50	129	12.90	173	6.65
L. aspera	J,A	10	2.50	91	7.58	14	1.40	115	4.42
I. isolepis	A					45	4.50	45	1.73
P. melanostictus	A			1	.08	17	1.70	18	.69
Gymnocanthus spp.	J,A	2	.50	4	.33	5	.50	11	.42
H. octogrammus	A	2	.50	7	.58			9	.35
P. barbata	A			3	.25	6	.60	9	.35
M. polyacanthocephalus	A,J	3	.75	3	.25	2	.20	8	.31
A. acipenserinus	A,J					6	.60	6	.23
P. stellatus	A					3	.30	3	.12
Unidentified Cottidae	J			2	.17			2	.08
H. jordani	J			2	.17			2	.08
L. armatus	A					2	.20	2	.08
Triglops sp. (probably *T. pingeli*)				2	.17			2	.08
H. stenolepis	A					2	.20	2	.08
R. binoculata	A					1	.10	1	.04
M. villosus	A					1	.10	1	.04
M. jaok	A	1	.25					1	.04
O. dodecaedron						1	.10	1	.04
P. quadrituberculatus	A			1	.08			1	.04

Appendix Table 14. Cumulative try net catches of all species from three regions of Ugak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (6 hauls)		Middle (7 hauls)		Outer (2 hauls)		Total (15 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
L. aspera	J,A	242	40.33	141	20.14	1	.50	384	25.60
L. bilineata	J,A	6	1.00	96	13.71	66	33.00	168	11.20
L. sagitta	A,J	1	.17	105	15.00	3	1.50	109	7.27
Gymnocanthus spp.	A	53	8.83	4	.57			57	3.80
T. pingeli	A			32	4.57			32	2.13
P. melanostictus	J					13	6.50	13	.87
H. elassodon		13	2.17					13	.87
M. jaok	J,A	12	2.00					12	.80
H. octogrammus	A,J	9	1.33	2	.29	1	.50	12	.80
M. polyacanthocephalus	A,J	7	1.17	1	.14	3	1.50	11	.73
P. laeta	A	10	1.67					10	.67
P. stellatus	A					8	4.00	8	.53
H. stelleri	A	2	.33	2	.29	1	.50	5	.33
L. armatus	A					5	2.50	5	.33
T. chalcogramma	J			4	.57			4	.27
B. cirrhosus	J,A			4	.57			4	.27
P. barbata	A	1	.17	2	.29			3	.20
A. acipenserinus	A			1	.14	2	1.00	3	.20
H. lagocephalus	J,A			1	.14	1	.50	2	.13
H. jordani	A			2	.29			2	.13
M. scorpius	A	2	.33					2	.13
G. macrocephalus	J	1	.17					1	.07
B. caeruleofasciatus	A	1	.17					1	.07
B. signatus	J			1	.14			1	.07
H. stenolepis	J			1	.14			1	.07
P. quadrituberculatus	J			1	.14			1	.07

Appendix Table 15. Cumulative try net catches of all species from three regions of Ugak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (3 hauls) No.	Inner (3 hauls) CPUE	Middle (9 hauls) No.	Middle (9 hauls) CPUE	Outer (8 hauls) No.	Outer (8 hauls) CPUE	Total (20 hauls) No.	Total (20 hauls) CPUE
L. aspera	J,A	207	69.00	170	18.89	5	.63	382	19.10
L. bilineata	J,A	11	3.67	112	12.44	118	14.75	241	12.05
Gymnocanthus spp.	A	77	25.67	13	1.44			90	4.50
L. sagitta	J,A	1	.33	5	.56	75	9.33	81	4.05
P. barbata	J			14	1.56	28	3.50	42	2.10
A. acipenserinus	A,J			14	1.56	20	2.50	34	1.70
H. stelleri	J,A	8	2.67	16	1.78	5	.63	29	1.45
B. cirrhosus	J,A			20	2.22	5	.63	25	1.25
T. trichodon	J			2	.22	19	2.38	21	1.05
P. melanostictus	A,J			12	1.33	7	.88	19	.95
H. octogrammus	J,A	4	1.33	14	1.56			18	.90
P. stellatus	A			11	1.22	6	.75	17	.85
L. armatus	A	5	1.67	7	.78	1	.13	13	.65
M. jaok	J,A	10	3.33	2	.22			12	.60
H. jordani	J,A	7	2.33	2	.22			9	.45
H. elassodon	J,A	7	2.33	1	.11			8	.40
H. lagocephalus	J,A			5	.56			5	.25
P. laeta	A,J	1	.33	1	.11	2	.25	4	.20
S. melanops	J	2	.67	1	.11			3	.15
M. scorpius	A	2	.67	1	.11			3	.15
O. dodecaedron	A					3	.38	3	.15
H. stenolepis	J			3	.33			3	.15
I. isolepis	A			1	.11	2	.25	3	.15
M. proximus	A					2	.25	2	.10
T. chalcogramma	J			1	.11	1	.13	2	.10
L. cyclopus	J					2	.25	2	.10
B. signatus	J			1	.11	1	.13	2	.10
G. macrocephalus	A			1	.11			1	.05
E. bison	J			1	.11			1	.05
M. polyacanthocephalus	J					1	.13	1	.05
T. pingeli	J			1	.11			1	.05
A. bartoni	J	1	.33					1	.05
B. caeruleofasciatus	J	1	.33					1	.05
A. purpurescens	A	1	.33					1	.05
L. medius	A	1	.33					1	.05

Appendix Table 16. Cumulative trammel net catches of all species from three regions of Ugak Bay, Cruise 2

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (4 hauls)		Middle (2 hauls)		Outer (2 hauls)		Total (8 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
H. octogrammus	A	105	26.25	29	14.50	9	4.50	143	17.88
H. lagocephalus	A	38	9.50	23	11.50	46	23.00	107	13.38
L. bilineata	A			13	6.50	33	16.50	46	5.75
A. acipenserinus	A			6	3.00	24	12.00	30	3.75
C. h. pallasi	A	1	.25			3	1.50	4	.50
P. stellatus	A					4	2.00	4	.50
L. armatus	A			2	1.00	1	.50	3	.38
M. polyacanthocephalus	A	2	.50	1	.50			3	.38
S. malma	A	2	.50					2	.25
G. macrocephalus	A	2	.50					2	.25
H. hemilepidotus	A					2	1.00	2	.25

Appendix Table 17. Cumulative trammel net catches of all species from two regions of Ugak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/ number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = arvae, J = juveniles, A = adults)

Species	Life history stages	Inner (1 haul)		Outer (2 haul)		Total (3 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
H. octogrammus	A	66	66.00	58	29.00	124	41.33
H. lagocephalus	A	10	10.00	65	32.50	75	25.00
L. bilineata	A	8	8.00	14	7.00	22	7.33
C. h. pallasi	A			21	10.50	21	7.00
A. acipenserinus	A	1	1.00	19	9.50	20	6.67
H. stelleri	A	7	7.00	5	2.50	12	4.00
L. aspera	A	4	4.00			4	1.33
G. macrocephalus	A			2	1.00	2	.67
P. stellatus	A			2	1.00	2	.67
L. armatus	A			1	.50	1	.33
M. polyacantho-cephalus	A	1	1.00			1	.33

Appendix Table 18. Cumulative trammel net catches of all species from three regions of Ugak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (1 haul)		Middle (1 haul)		Outer (2 hauls)		Total (4 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
H. lagocephalus	A	14	14.00	13	13.00	43	21.50	70	17.50
H. octogrammus	A	18	18.00	9	9.00	8	4.00	35	8.75
H. stelleri	A	4	4.00	11	11.00	15	7.50	30	7.50
A. acipenserinus	A	1	1.00	5	5.00	22	11.00	28	7.00
L. bilineata	A,J			13	13.00	15	7.50	28	7.00
C. h. pallasi	A					19	9.50	19	4.75
G. macrocephalus	A	1	1.00	10	10.00			11	2.75
H. decagrammus	A					4	2.00	4	1.00
M. polyacanthocephalus	A					3	1.50	3	.75
S. malma	A	1	1.00			1	.50	2	.50
L. armatus	A			1	1.00	1	.50	2	.50
O. keta	A	1	1.00					1	.25
E. diceraus	A	1	1.00					1	.25
M. scorpius	A					1	.50	1	.25
L. aspera	A	1	1.00					1	.25
P. stellatus	A					1	.50	1	.25

Appendix Table 19. Cumulative tow-net catches of all species from two regions of Kaiugnak Bay, Cruise 2

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L=larvae, J=juveniles, A=adults)

Species	Life history stages	Inner (4 hauls)		Outer (6 hauls)		Total (10 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
M. villosus	J	3500	875.00	2033	338.83	5533	553.30
A. hexapterus	L			250	41.67	250	25.00
Hexagrammos spp.	J	12	3.00	10	1.67	22	2.20
Unid. Stichaeidae	L	4	1.00			4	.40
Unid. Bathymaster-idae	L			2	.33	2	.20
O. gorbuscha	J	1	.25	1	.17	2	.20
H. jordani	J	1	.25	1	.17	2	.20
Unid. Cottidae	J			1	.17	1	.10
M. polyacantho-cephalus		1	.25			1	.10

Appendix Table 20. Cumulative tow-net catches of all species from two regions of Kaiugnak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (4 hauls)		Outer (6 hauls)		Total (10 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
M. villosus	J,A			4943	823.83	4943	494.30
T. trichodon	J	291	72.75	25	4.17	316	31.60
O. gorbuscha	J,A	2	.50	3	.50	5	.50
O. nerka	post-smolt			4	.67	4	.40
Hexagrammos spp.	J	1	.25	3	.50	4	.40
A. hexapterus	J			4	.67	4	.40
O. kisutch	post-smolt			3	.50	3	.30
T. chalcogramma	J			3	.50	3	.30
B. cirrhosus	J			2	.33	2	.20
G. aculeatus	J			1	.17	1	.10
P. paradoxus	J			1	.17	1	.10
L. bilineata	J	1	.25			1	.10

Appendix Table 21. Cumulative tow-net catches of all species from two regions of Kaiugnak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (4 hauls)		Outer (6 hauls)		Total (10 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
T. trichodon	J	341	85.25	12	2.00	353	35.30
M. villosus	J	15	3.75	125	20.83	140	14.00
O. gorbuscha	J	2	.50	2	.33	4	.40
Z. silenus	J			3	.50	3	.30
G. aculeatus	J			2	.33	2	.20
H. elassodon	J	1	.25	1	.17	2	.20
T. chalcogramma	J	1	.25			1	.10
S. melanops	J			1	.17	1	.10

Appendix Table 22. Cumulative surface-trawl catches of all species from two regions of Kaiugnak Bay, Cruise 1

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (2 hauls) No.	Inner (2 hauls) CPUE	Outer (3 hauls) No.	Outer (3 hauls) CPUE	Total (5 hauls) No.	Total (5 hauls) CPUE
A. hexapterus	L,J,A	511	255.50	47	15.67	558	111.60
Unid. Bathymaster-idae	L	1	.50	1	.33	2	.40
Unid. Stichaeidae	L	1	.50			1	.20

Appendix Table 23. Cumulative midwater trawl catches of all species from two regions of Kaiugnak Bay, Cruise 1

CPUE values are mean catches per unit of effort, cumulative catch/ number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (2 hauls)		Outer (3 hauls)		Total (5 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
A. hexapterus	A,J	79	39.50	8	2.67	87	17.40
Unid. Bathymasteridae	L	1	.50	4	1.33	5	1.00
H. jordani	J	2	1.00	1	.33	3	.60
M. villosus	J			2	.67	2	.40
L. sagitta	L			1	.33	1	.20

Appendix Table 24. Cumulative midwater trawl catches of all species from two regions of Kaiugnak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (3 hauls)		Outer (4 hauls)		Total (7 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
M. villosus	J,A			421	105.25	421	60.14
T. trichodon	J	2	.67	5	1.25	7	1.00
T. chalcogramma	J	1	.33	3	.75	4	.57
A. orientalis	J			2	.50	2	.29
Unidentified Cottidae	J			1	.25	1	.14
H. bolini	J			1	.25	1	.14

Appendix Table 25. Cumulative midwater trawl catches of all species from two regions of Kaiugnak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (3 hauls)		Outer (4 hauls)		Total (7 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
M. villosus	J			1742	435.50	1742	248.86
T. trichodon	J	26	8.67	721	180.25	747	106.71
T. chalcogramma	J	2	.67	16	4.00	18	2.57

Appendix Table 26. Cumulative beach seine catches of all species from two regions of Kaiugnak Bay, Cruise 1

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (4 hauls)		Outer (5 hauls)		Total (9 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
A. hexapterus	A	1242	310.50			1242	138.00
O. gorbuscha	J	3	.75	437	87.4	440	48.89
M. villosus	A	74	18.50			74	8.22
M. polyacanthocephalus	J,A	71	17.75	3	.60	74	8.22
Myoxocephalus spp.	J	61	15.25	4	.80	65	7.22
H. octogrammus	A			39	7.80	39	4.33
Unidentified Osteichthyes	L	1	.25	12	2.40	13	1.44
B. cirrhosus	J	1	.25	9	1.80	10	1.11
S. malma	A	1	.25	7	1.40	8	.89
L. sagitta		3	.75			3	.33
C. h. pallasi	J	1	.25			1	.11
G. aculeatus		1	.25			1	.11
Unidentified Scorpaeniformes	L			1	.20	1	.11
A. purpurescens	A			1	.20	1	.11
L. bilineata	A	1	.25			1	.11

Appendix Table 27. Cumulative beach seine catches of all species from two regions of Kaiugnak Bay, Cruise 2

CPUE values are mean catches per unit of effort, cumulative catch/ number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (3 hauls)		Outer (3 hauls)		Total (6 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
O. gorbuscha	J	10	3.33	2983	994.33	2993	498.83
T. trichodon	J			315	105.00	315	52.50
M. polyacanthocephalus	J,A	236	78.67	3	1.00	239	39.83
H. octogrammus				65	21.67	65	10.83
Hexagrammos spp.	J	19	6.33			19	3.17
O. keta	J	14	4.67			14	2.33
A. hexapterus	A	7	2.33			7	1.17
L. bilineata	A	1	.33	3	1.00	4	.67
Unidentified Cottidae	J			2	.67	2	.33
P. barbata	J,A	1	.33	1	.33	2	.33
S. malma	A			1	.33	1	.17
A. acipenserinus	A			1	.33	1	.17
P. laeta	A			1	.33	1	.17

Appendix Table 28. Cumulative beach seine catches of all species from two regions of Kaiugnak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (4 hauls)		Outer (3 hauls)		Total (7 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
T. trichodon	J			2205	735.00	2205	315.00
A. hexapterus	A	1373	343.25			1373	196.14
G. aculeatus	J,A	1	.25	419	139.67	420	60.00
O. gorbuscha	A,J	94	23.50	32	10.67	126	18.00
H. octogrammus	J,A	6	1.50	76	25.33	82	11.71
B. cirrhosus	J	1	.25	46	15.33	47	6.71
H. stelleri	J	15	3.75	17	5.67	32	4.57
P. barbata	J			14	4.67	14	2.00
O. keta	J	11	2.75	2	.67	13	1.86
P. laeta	A			9	3.00	9	1.29
M. polyacanthocephalus	J	5	1.25	2	.67	7	1.00
L. bilineata	J	7	1.75			7	1.00
S. malma	A			4	1.33	4	.57
H. lagocephalus	A			4	1.33	4	.57
L. sagitta	A			2	.67	2	.29
P. stellatus	A			1	.33	1	.14

Appendix Table 29. Cumulative beach seine catches of all species from two regions of Kaiugnak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/ number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (5 hauls) No.	Inner (5 hauls) CPUE	Outer (4 hauls) No.	Outer (4 hauls) CPUE	Total (9 hauls) No.	Total (9 hauls) CPUE
A. hexapterus	A,J	3067	613.40	125	31.25	3192	354.67
H. octogrammus	J,A	23	4.60	85	21.25	108	12.00
B. cirrhosus	J			28	7.00	28	3.11
M. polyacanthocephalus	J,A	21	4.20	5	1.25	26	2.89
H. lagocephalus	J,A	23	4.60	1	.25	24	2.67
H. stelleri	J,A	11	2.20	12	3.00	23	2.56
P. barbata	A	3	.60	9	2.25	12	1.33
P. laeta	A			11	2.75	11	1.22
M. scorpius	A,J			4	1.00	4	.44
P. stellatus	J	4	.80			4	.44
L. bilineata	A	2	.40			2	.22
S. malma	A	1	.20			1	.11
Unidentified Cottidae	J	1	.20			1	.11

Appendix Table 30. Cumulative try net catches of all species from two regions of Kaiugnak Bay, Cruise 2

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (3 hauls)		Outer (6 hauls)		Total (9 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
L. sagitta	J,A			128	21.33	128	14.22
L. bilineata	J			58	9.67	58	6.44
L. aspera	J			29	4.83	29	3.22
Gymnocanthus spp.	J,A	2	.66	17	2.83	19	2.11
H. lagocephalus	A			7	1.17	7	.78
P. melanostictus	J,A			6	1.00	6	.67
H. octogrammus	J,A	4	1.33			4	.44
Triglops sp. (probably *T. pingeli*)				2	.33	2	.22
H. stelleri	A			1	.17	1	.11
H. hemilepidotus	A			1	.17	1	.11
I. isolepis	A			1	.17	1	.11
P. stellatus	A			1	.17	1	.11
M. polyacanthocephalus	A			1	.17	1	.11

Appendix Table 31. Cumulative try net catches of all species from two regions of Kaiugnak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (3 hauls)		Outer (5 hauls)		Total (8 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
L. sagitta	J			181	36.20	181	27.63
L. bilineata	J,A	1	.33	84	16.80	85	10.63
B. cirrhosus	J			33	6.60	33	4.13
H. octogrammus	A,J	11	3.67	14	2.80	25	3.13
L. aspera	J	2	.67	21	4.20	23	2.88
H. lagocephalus	A,J	2	.67	20	4.00	22	2.75
H. stelleri	J	3	1.00	6	1.20	9	1.13
Gymnocanthus spp.	A			9	1.80	9	1.13
T. chalcogramma	J			6	1.20	6	.75
H. jordani	A	3	1.00			3	.38
P. stellatus	J			3	.60	3	.38
I. isolepis	J			2	.40	2	.25
M. jaok	A	1	.33			1	.13
P. barbata	J			1	.20	1	.13
Apedichthys flavidus	A			1	.20	1	.13
H. stenolepis	J			1	.20	1	.13

Appendix Table 32. Cumulative try net catches of all species from two regions of Kaiugnak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (3 hauls)		Outer (9 hauls)		Total (12 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
L. bilineata	J,A	2	.67	77	8.56	79	6.58
H. octogrammus	J,A	24	8.00	20	2.22	44	3.67
H. lagocephalus	A,J			40	4.44	40	3.33
H. stelleri	J,A	10	3.33	26	2.89	36	3.00
B. cirrhosus	J	10	3.33	22	2.44	32	2.67
L. aspera	J	6	2.00	1	.11	7	.58
Gymnocanthus spp.	J,A	2	.67	4	.44	6	.50
P. melanostictus	J,A			6	.67	6	.50
M. polyacanthocephalus	A,J	1	.33	4	.44	5	.42
P. stellatus	A	3	1.00	1	.11	4	.30
H. jordani	J	2	.67	1	.11	3	.25
P. barbata	J			3	.33	3	.25
I. isolepis	J			3	.33	3	.25
L. sagitta	J			2	.22	2	.17
Aulorhynchus flavidus	J			1	.11	1	.08
H. decagrammus	A			1	.11	1	.08
H. hemilepidotus	A			1	.11	1	.08
M. scorpius	A			1	.11	1	.08
S. gilli	A			1	.11	1	.08
A. acipenserinus	A			1	.11	1	.08
S. punctatus	A	1	.33			1	.08
H. elassodon	J	1	.33			1	.08
H. stenolepis	J			1	.11	1	.08

Appendix Table 33. Cumulative trammel net catches of all species from Kaiugnak Bay, Cruise 2 (2 standard hauls were made in Inner Region only)

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (2 hauls)	
		No.	CPUE
H. octogrammus	A	65	32.50
H. lagocephalus	A	35	17.50
H. stelleri	A	1	.50
B. caeruleofasciatus	A	1	.50
L. bilineata	A	1	.50

Appendix Table 34. Cumulative trammel net catches of all species from two regions of Kaiugnak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (1 haul)		Outer (1 haul)		Total (2 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
H. lagocephalus	A	62	62.00	47	47.00	109	54.50
H. octogrammus	A	94	94.00	15	15.00	109	54.50
S. melanops	A			3	3.00	3	1.50
H. stelleri	A	1	1.00	1	1.00	2	1.00
L. bilineata	A	1	1.00	1	1.00	2	1.00
Myoxocephalus sp.	A			1	1.00	1	.50
M. polyacanthocephalus	A	1	1.00			1	.50
A. acipenserinus	A	1	1.00			1	.50
B. caeruleofasciatus	A			1	1.00	1	.50

Appendix Table 35. Cumulative trammel net catches of all species from two regions of Kaiugnak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Inner (2 hauls)		Outer (1 haul)		Total (3 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
H. lagocephalus	A	15	7.50	46	46.00	61	20.33
H. octogrammus	A	12	6.00			12	4.00
H. stelleri	A	5	2.50	1	1.00	6	2.00
S. melanops	A			1	1.00	1	.33
E. decagrammus	A			1	1.00	1	.33
M. polyacanthocephalus	A	1	.50			1	.33
L. bilineata	A	1	.50			1	.33

Appendix Table 36. Cumulative tow net catches of all species from five regions of Alitak Bay, Cruise 2

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L=larvae, J=juveniles, A=adults)

Species	Life history stages	Deadman (10 hauls)		Hepburn (5 hauls)		Westside (4 hauls)		Middle (4 hauls)		Outer (3 hauls)		Total (26 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
O. gorbuscha	J	806	80.60	825	165.00	20	5.00	1	.25	2	.67	1654	63.62
Hexagrammos spp.	J	61	6.10	52	10.40	101	25.25	20	5.00	472	157.33	706	27.15
Unid. Bathymasteridae	L									25	8.33	25	.96
A. hexapterus	L									25	8.33	25	.96
O. keta	J			5	1.00							5	.19
S. malma	A	5	.50									5	.19
H. jordani	J	1	.10			1	.25	1	.25	1	.33	4	.15
O. kisutch	post-smolt	3	.30									3	.12
O. nerka	post-smolt	2	.20									2	.08

Appendix Table 37. Cumulative tow net catches of all species from five regions of Alitak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L=larvae, J=juveniles, A=adults)

Species	Life history stages	Deadman (10 hauls)		Hepburn (5 hauls)		Westside (4 hauls)		Middle (4 hauls)		Outer (6 hauls)		Total (29 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
O. gorbuscha	J	565	56.50	1304	260.80	58	14.50	10	2.5			1937	66.79
Hexagrammos spp.	J	1	.10	2	.40	54	13.50					57	1.97
G. aculeatus	J,A					24	6.00					24	.83
O. keta	J	5	.50			2	.50					7	.24
C. h. pallasi	J					1	.25					1	.03
O. nerka	post-smolt	1	.10									1	.03
S. malma	A					1	.25					1	.03
M. villosus	A					1	.25					1	.03
B. cirrhosus	J	1	.10									1	.03
Z. silenus	J							1	.25			1	.03

Appendix Table 38. Cumulative tow net catches of all species from five regions of Alitak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L=larvae, J=juveniles, A=adults)

Species	Life history stages	Deadman (10 hauls)		Hepburn (12 hauls)		Westside (3 hauls)		Middle (5 hauls)		Outer (6 hauls)		Total (36 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
M. villosus	L,J	2	.20	6697	558.08			1	.20			6700	186.11
G. aculeatus	J,A	1	.10	11	.92			2	.40	3	.50	17	.47
O. gorbuscha	J	4	.40	3	.25	1	.33					8	.22
S. melanops	J							1	.20	1	.33	2	.06
O. kisutch	post-smolt			1	.08							1	.03
G. macrocephalus	J			1	.08							1	.03
S. nigrocinctus	J									1	.33	1	.03
H. lagocephalus	J							1	.20			1	.03
O. elongatus	J							1	.20			1	.03
B. bilobus	A					1	.33					1	.03
H. jordani	J			1	.08							1	.03
P. barbata	A			1	.08							1	.03
A. hexapterus	A							1	.20			1	.03

Appendix Table 39. Cumulative surface trawl catches of all species from two regions of Alitak Bay, Cruise 1

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L=larvae, J=juveniles, A=adults).

Species	Life history stages	Deadman (7 hauls)		Hepburn (3 hauls)		Total (10 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
O. gorbuscha	J	1	.14			1	.10
O. keta	J	1	.14			1	.10

Appendix Table 40. Cumulative midwater trawl catches of all species from four regions of Alitak Bay, Cruise 1

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Deadman (5 hauls)		Hepburn (3 hauls)		Middle (2 hauls)		Outer (3 hauls)		Total (13 hauls)	
		No.	CPUE	No.	CPUE	No. m	CPUE	No.	CPUE	No.	CPUE
M. villosus	A,L	5680	1136.00	193	64.33	1250	625.00	60	20.00	7183	552.54
Hexagrammos spp.	J			2	.67			1	.33	3	.23
B. pusillum	A	2	.40							2	.15
A. hexapterus	A					2	1.00			2	.15
Unid. Bathymasteridae	L							2	.67	2	.15
O. gorbuscha	J			1	.33					1	.08
T. chalcogramma	A							1	.33	1	.08
L. sagitta	J					1	.50			1	.08
Myoxocephalus sp.	A					1	.50			1	.08

Appendix Table 41. Cumulative midwater trawl catches of all species from four regions of Alitak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Deadman (6 hauls)		Hepburn (4 hauls)		Middle (6 hauls)		Outer (5 hauls)		Total (21 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
M. villosus	J,A	332	55.33	21602	5400.50	5786	964.33	2829	565.80	30549	1454.71
O. gorbuscha	J					74	12.33			74	3.52
B. pusillum	A	53	8.83							53	2.52
Lumpenus sp. (probably *L. medius*)	L	8	1.33							8	.38
O. keta	J					5	.83			5	.24
T. trichodon	A					2	.33	1	.2	3	.14
C. h. pallasi	A					1	.17			1	.05
B. cirrhosus	J			1	.25					1	.05
L. aspera	A	1	.17							1	.05

Appendix Table 42. Cumulative midwater trawl catches of all species from four regions of Alitak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Deadman (6 hauls)		Hepburn (3 hauls)		Middle (4 hauls)		Outer (5 hauls)		Total (18 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
M. villosus	J,A	5688	948.00	754	251.33	217	54.25	162	32.40	6821	378.94
Lumpenus sp. (probably *L. medius*)	J	424	70.67	225	75.00					649	36.06
L. medius	L					72	18.00	100	20.00	172	9.56
C. h. pallasi	A							128	25.60	128	7.11
T. trichodon	J,A					1	.25	121	24.20	122	6.78
A. hexapterus	J,A							64	12.80	64	3.56
B. pusillum	A	32	5.33							32	1.78
T. chalcogramma	J							2	.40	2	.11
Z. silenus	J							2	.40	2	.11
H. stelleri	J							1	.20	1	.06
B. bilobus	A							1	.20	1	.06
H. jordani	A							1	.20	1	.06
A. ventricosus	A	1	.17							1	.06

Appendix Table 43. Cumulative beach seine catches of all species from two regions of Alitak Bay, Cruise 1

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Deadman (6 hauls)		Westside (2 hauls)		Total (8 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE
O. keta	J	778	129.67			778	97.25
O. gorbuscha	J	137	22.83			137	17.13
H. octogrammus	A	13	2.17	5	2.50	18	2.25
S. malma	A	15	2.50	1	.50	16	2.00
G. macrocephalus	J	14	2.33			14	1.75
Myoxocephalus spp.	J	2	.33	11	5.50	13	1.63
M. polyacanthocephalus	J,A	7	1.17	2	1.00	9	1.13
T. chalcogramma	A,J	7	1.17			7	.88
C. h. pallasi	A	2	.33			2	.25
M. villosus	A	2	.33			2	.25
L. sagitta	A	2	.33			2	.25
G. aculeatus	A	1	.17			1	.13
H. stelleri	A	1	.17			1	.13
P. stellatus	A			1	.50	1	.13

Appendix Table 44. Cumulative beach seine catches of all species from four regions of Alitak Bay, Cruise 2

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Deadman (4 hauls)		Eastside (4 hauls)		Westside (4 hauls)		Tannerhead (2 hauls)		Total (14 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
A. hexapterus	A	147	36.75	2	.50					149	10.64
O. gorbuscha	J			6	1.50	1	.25	74	37.00	81	5.79
M. polyacanthocephalus	J	25	6.25	3	.75	14	3.50			42	3.00
P. stellatus	A	2	.50	6	1.50	10	2.50	17	8.50	35	2.50
O. keta	J	14	3.50	5	1.25	4	1.00	8	4.00	31	2.21
S. malma	A	5	1.25	4	1.00	22	5.50			31	2.21
H. octogrammus	J,A	19	4.75	2	.50	9	2.25			30	2.14
O. kisutch	J	18	4.50			4	1.00			22	1.57
P. laeta	A,J	3	.75	1	.25	9	2.25	1	.50	14	1.00
L. bilineata	J			7	1.75			7	3.50	14	1.00
L. armatus	A	3	.75	1	.25	4	1.00	2	1.00	10	.71
G. macrocephalus		9	2.25							9	.64
M. scorpius	A					4	1.00			4	.29
B. cirrhosus	A	3	.75							3	.21
Hexagrammos spp.	J					2	.50			2	.14
H. lagocephalus	J	2	.50							2	.14
O. nerka	post-smolt			1	.25					1	.07
L. aspera	A					1	.25			1	.07
P. melanostictus								1	.50	1	.07

Appendix Table 45. Cumulative beach seine catches of all species from four regions of Alitak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance
(L = larvae, J = juveniles, A = adults)

Species	Life history stages	Deadman (6 hauls)		Eastside (4 hauls)		Westside (4 hauls)		Tannerhead (2 hauls)		Total (16 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
A. hexapterus	J,A	276	46.00	150	37.50	1790	447.50			2216	138.50
O. gorbuscha	A	284	47.33							284	17.75
H. stelleri	J,A	122	20.33	9	2.25	120	30.00			251	15.69
H. octogrammus	J,A	125	20.83	5	1.25	38	9.50			168	10.50
S. malma	A	31	5.17	38	9.50	1	.25	2	1.00	72	4.50
L. bilineata	J,A			26	6.50			17	8.50	43	2.69
M. polyacanthocephalus	J,A	13	2.17	18	4.50	11	2.75			42	2.63
P. laeta	A,J	5	.83			15	3.75			20	1.25
Gymnocanthus spp.	J,A			14	3.50	1	.25	1	.50	16	1.00
E. cirrhosus	A,J	6	1.00	1	.25	8	2.00			15	.94
A. fenestralis	J,A			9	2.25	3	.75			12	.75
G. aculeatus	J					9	2.25			9	.56
P. barbata	J,A	4	.67	3	.75					7	.44
L. armatus	A			4	1.00	1	.25	1	.50	6	.38
H. jordani	J,A	4	.67							4	.25
M. scorpius	A,J	1	.17			3	.75			4	.25
P. stellatus	A,J					1	.25	2	1.00	3	.19
L. sagitta	A			1	.25					1	.06

Appendix Table 46. Cumulative beach seine catches of all species from four regions of Alitak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Deadman (7 hauls)		Eastside (5 hauls)		Westside (6 hauls)		Tannerhead (3 hauls)		Total (21 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
A. hexapterus	J,A	6312	901.71	20008	4001.60	77	12.83	18	6.00	26415	1257.86
H. stelleri	J	74	10.57	8	1.60	127	21.17			209	9.95
H. octogrammus	J,A	95	13.57	1	.20	67	11.17			163	7.76
C. h. pallasi	L	2	.29	108	21.60					110	5.24
M. polyacanthocephalus	J,A	25	3.57			37	6.17	1	.33	63	3.00
L. bilineata	J,A	1	.14	27	5.40	2	.33	28	9.33	58	2.76
S. malma	A	29	4.14							29	1.38
Gymnocanthus spp.	J			17	3.40	2	.33	5	1.67	24	1.14
L. armatus	A,J					2	.33	13	4.33	15	.71
O. gorbuscha	A,J	4	.57			10	1.67			14	.67
P. stellatus	J,A					2	.33	12	4.00	14	.67
O. kisutch	post-smolt, A	11	1.57	1	.20					12	.57
M. scorpius	A,J	1	.14			11	1.83			12	.57
P. barbata	J	2	.29			5	.83	1	.33	8	.38
P. laeta	A	2	.29			6	1.00			8	.38
B. cirrhosus	J	1	.14			5	.83	1	.33	7	.33
P. melanostictus	J							7	2.33	7	.33
T. trichodon	J							6	2.00	6	.29
H. jordani	J,A	3	.43			2	.33			5	.24
A. fenestralis	J					3	.50			3	.14
S. melanops	J					1	.17			1	.05
H. lagocephalus	J					1	.17			1	.05
L. sagitta	A	1	.14							1	.05

Appendix Table 47. Cumulative try net catches of all species from three regions of Alitak Bay, Cruise 2

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Eastside (7 hauls)		Westside (6 hauls)		Tannerhead (8 hauls)		Total (21 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
L. bilineata	J,A					71	8.88	71	3.38
H. octogrammus	A	8	1.14	4	.67			12	.57
H. stelleri	A			2	.33	6	.75	8	.38
L. sagitta	A,J					6	.75	6	.29
L. aspera	J					4	.50	4	.19
P. melanostictus	J,A					4	.50	4	.19
S. melanops	J	2	.29	1	.17			3	.14
G. macrocephalus	J			2	.33			2	.10
Gymnocanthus spp.	J					2	.25	2	.10
P. laeta	A	2	.29					2	.10
T. chalcogramma	A			1	.17			1	.05
H. lagocephalus	A					1	.13	1	.05
B. bilobus	A			1	.17			1	.05
H. hemilepidotus	A	1	.14					1	.05
Triglops sp. (probably *T. pingeli*)	J					1	.13	1	.05
Unidentifed Stichaeidae	J					1	.13	1	.05
S. punctatus		1	.14					1	.05
H. stenolepis	J					1	.13	1	.05

Appendix Table 48. Cumulative try net catches of all species from three regions of Alitak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/ number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Eastside (8 hauls)		Westside (5 hauls)		Tannerhead (6 hauls)		Total (19 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
L. bilineata	J	3	.38	1	.20	148	24.67	152	8.00
H. octogrammus	A,J	42	5.25	12	2.40	2	.33	56	2.95
H. stelleri	J,A	3	.38	1	.20	11	1.83	15	.79
Gymnocanthus spp.	J,A			1	.20	8	1.33	9	.47
H. jordani	A,J	2	.25	3	.60	2	.33	7	.37
H. lagocephalus	A	3	.38	1	.20			4	.21
G. macrocephalus	J	1	.13			2	.33	3	.16
H. stenolepis	J					3	.50	3	.16
P. melanostictus	A					3	.50	3	.16
M. scorpius	A	1	.13	1	.20			2	.11
M. polyacanthocephalus	J	1	.13					1	.05
N. pribilovius	J	1	.13					1	.05
L. cyclopus	J			1	.20			1	.05
L. sagitta	J					1	.17	1	.05
P. laeta	A	1	.13					1	.05
L. aspera	J					1	.17	1	.05
P. stellatus	J					1	.17	1	.05

Appendix Table 49. Cumulative try net catches of all species from three regions of Alitak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Eastside (8 hauls)		Westside (7 hauls)		Tannerhead (6 hauls)		Total (21 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
A. hexapterus	A,J	948	118.50			3	.50	951	45.29
L. bilineata	J,A			6	.86	221	36.83	227	10.81
H. octogrammus	J,A	99	12.38	8	1.00			107	5.10
H. stelleri	J,A	7	.88	47	6.71	28	4.67	82	3.90
L. aspera	J,A	1	.13	55	7.86	6	1.00	62	2.95
H. stenolepis	J					51	8.50	51	2.43
Gymnocanthus spp.	J,A	2	.25	19	2.71	21	3.50	42	2.00
A. acipenserinus	J					17	2.83	17	.81
H. jordani	J,A	2	.25	8	1.14	4	.67	14	.67
Unidentified Pleuronectidae	J					12	2.00	12	.57
B. cirrhosus	J	5	.63			1	.17	6	.29
P. melanostictus	A,J					6	1.00	6	.29
M. polyacanthocephalus	J,A	3	.38	1	.14	1	.17	5	.24
H. lagocephalus	A	4	.50					4	.19
M. scorpius	J,A	1	.13	3	.43			4	.19
P. barbata	J	2	.25			2	.33	4	.19
T. chalcogramma	J					3	.50	3	.14
T. pingeli		3	.38					3	.14
S. punctatus	A	3	.38					3	.14
P. stellatus	A	3	.38					3	.14
G. macrocephalus	J	1	.13			1	.17	2	.10
P. laeta	A			2	.29			2	.10
S. melanops	J	1	.13					1	.05
O. elongatus	J					1	.17	1	.05
B. bilobus	A	1	.13					1	.05
E. diceraus	J	1	.13					1	.05
M. jack	J			1	.14			1	.05

Appendix Table 50. Cumulative trammel net catches of all species from three regions of Alitak Bay, Cruise 2

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Deadman (2 hauls)		Eastside (1 haul)		Westside (3 hauls)		Total (6 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
H. octogrammus	A	104	52.00	66	66.00	247	82.33	417	69.50
H. stelleri	A	14	7.00			11	3.67	25	4.17
M. scorpius	A	1	.50			8	2.67	9	1.50
H. lagocephalus	A			7	7.00			7	1.17
L. aspera	A	1	.50			6	2.00	7	1.17
O. nerka	A					5	1.67	5	.83
C. h. pallasi	A					4	1.33	4	.67
L. bilineata	A			1	1.00	3	1.00	4	.67
P. stellatus	A					4	1.33	4	.67
S. malma	A					3	1.00	3	.50
M. polyacantho-cephalus	A	1	.50	1	1.00	1	.33	3	.50
L. armatus	A					2	.67	2	.33
O. keta	A					1	.33	1	.17
H. stenolepis	A	1	.50					1	.17

Appendix Table 51. Cumulative trammel net catches of all species from three regions of Alitak Bay, Cruise 3

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Deadman (1 haul)		Eastside (1 haul)		Westside (2 hauls)		Total (4 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No	CPUE
H. octogrammus	A	146	146.00	194	194.00	131	65.50	471	117.75
H. lagocephalus	A			18	18.00			18	4.50
H. stelleri	A	11	11.00			3	1.50	14	3.50
M. scorpius	A					7	3.50	7	1.75
S. malma	A	2	2.00	1	1.00	4	2.00	7	1.75
L. aspera	A	3	3.00					3	.75
G. macrocephalus	A			1	1.00			1	.25
L. armatus	A					1	.50	1	.25
M. polyacanthocephalus		1	1.00					1	.25
P. stellatus	A					1	.50	1	.25

Appendix Table 52. Cumulative trammel net catches of all species from three regions of Alitak Bay, Cruise 4

CPUE values are mean catches per unit of effort, cumulative catch/number of hauls. Life history stages represented in the entire bay's catch are in order of decreasing relative abundance (L = larvae, J = juveniles, A = adults)

Species	Life history stages	Deadman (2 hauls)		Eastside (2 hauls)		Westside (3 hauls)		Total (7 hauls)	
		No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
H. octogrammus	A	16	8.00	40	20.00	128	42.67	184	26.29
H. stelleri	A	31	15.50	8	4.00	20	6.67	59	8.43
H. lagocephalus	A			53	26.50	1	.33	54	7.71
G. macrocephalus	J,A	4	2.00	3	1.50	3	1.00	10	1.43
M. scorpius	A					10	3.33	10	1.43
P. stellatus	A	1	.50			2	.67	3	.43
M. polyacanthocephalus	A			1	.50	1	.33	2	.29
P. monopterygius	A	1	.50					1	.14
B. bilobus	A					1	.33	1	.14
H. jordani	A					1	.33	1	.14
C. polyactocephalus	A	1	.50					1	.14
L. aspera	A					1	.33	1	.14

Quarterly Report

Contract #03-5-022-69
Research Unit #486
Reporting Period April 1, 1977 - June 30, 1977
Number of Pages: 2

Demersal Fish and Shellfish Assessment in Selected Estuary Systems of Kodiak Island

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June 30, 1977

I. Task Objectives

A. Determine the spatial and temporal (June-September) distribution, relative abundance and inter-relationships of the various demersal finfish and shellfish species in the study area.

B. Determine the growth rate and food habits of selected demersal fish species.

C. Conduct literature survey to obtain and summarize an ordinal level documentation of commercial catch, stock assessment data, distribution as well as species and age group composition of various shellfish species in the study area.

D. Obtain basic oceanographic and atmospheric data to determine any correlations between these factors and migrations and/or relative abundance of various demersal fish and shellfish species encountered.

II. Field or Laboratory Activities

No field activities were conducted during this quarter. Data analyses, report preparation and proposal preparation for FY 78 conducted during the quarter.

III. Results

Project extension proposals are being submitted. Data analyses are not sufficiently complete to warrant submission.

IV. Preliminary Interpretation of Results

N/A

V. Problems Encountered/Recommended Changes

None

VI. Estimate of Funds Expended

A.	Personnel		23.79[1]
B.	Travel and Subsistance		3.01
C.	Contractual Services		56.81
D.	Commodities[2]		4.63
E.	Equipment		3.35
		Total	91.59
		Overhead	9.44
		Grand Total	101.03

[1]Includes benefits
[2]Includes expendable fishing gear, i.e. trawls and seines.

QUARTERLY REPORT

Contract 03-5-022-56
Task Order No. 30
Research Unit No. 502
Reporting Period: 4/1 - 6/30/77

TRAWL SURVEY OF THE BENTHIC EPIFAUNA OF THE CHUKCHI SEA AND NORTON SOUND

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June 30, 1977

I. TASK OBJECTIVES

To conduct a survey of the benthic epifaunal invertebrates of the Chukchi Sea/Norton Sound areas.

II. SHIP OR LABORATORY ACTIVITIES

A. No ship activity.

B. Scientific party - not applicable.

C. Methods - laboratory analysis:

1. Verification of field identifications is near completion at the Institute of Marine Science, University of Alaska, Fairbanks.

2. Examination of starry flounder predator-prey relationships is in progress.

D. Sample localities - not applicable.

E. Data collected or analyzed:

1. Invertebrates from 270 hauls have been analyzed.

2. Three hundred ten (310) starry flounder stomachs were examined. Methods of stomach analysis included frequency of occurrence, numerical, and volumetric.

III. RESULTS

Data on distribution and abundance, predator-prey relationships and reproductive notes have been examined and are being keypunched. An extensive report on the food of the starry flounder is in preparation and based on 133 stomachs examined in the field using the frequency of occurrence method of analysis and 177 stomachs examined using volumetric and numerical methods of analysis.

IV. PRELIMINARY INTERPRETATION OF RESULTS

The combined areas show that Mollusca, Arthropoda, and Echinodermata, in that order, were the dominant phyla based on number of species.

Starry flounder from Norton Sound feed mainly upon the deposit-feeding clam *Yoldia hyperborea*, the Greenband cockle *Serripes groenlandicus*, and the small brittle star *Amphipholis pugetana*. Starry flounder from the Chukchi Sea concentrated on the worm *Echiurus echiurus* and the prickleback fish *Lumpenus fabricii*.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

No problems were encountered nor were there any recommended changes in order to meet the task objectives.

Quarterly Report

Contract #03-5-022-69
Research Unit #512
Reporting Period April 1, 1977 -
June 30, 1977
Number of Pages: 4

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

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June 30, 1977

I. Task Objectives

A. Determine the spatial and temporal (May-September) distribution, relative abundance and inter-relationships of the various pelagic and demersal finfish and shellfish species in the study area.

B. Determine when, where, at what rate and in what relative abundance pelagic fish species (primarily salmonids) migrate into and through the study area.

C. Determine the growth rate and food habits of selected pelagic and demersal fish species.

D. Survey the literature to obtain and summarize an ordinal level documentation of commercial catch, stock assessment data, distribution, as well as species and age group composition of various shellfish species in the study area.

E. Survey the literature to inventory and characterize salmon spawning streams as well as timing of fry and smolt migrations.

F. Obtain basic oceanographic and atmospheric data to determine any correlations between these factors and migrations and/or relative abundance of various pelagic and demersal fish and shellfish species encountered.

II. Field or Laboratory Activities

No field activities were conducted during the quarter. Data analyses, report preparation and proposal preparation for FY 78 have been conducted during the quarter.

III. Results

Project extension proposals are being submitted. Data collected during March has been tabulated, Table 1. Predominant taxa captured during March otter trawling were snow crab (*Chionoecetes bairdi*), yellow Irish Lord (*Hemilepidotus jordani*), rock sole (*Lepidopsetta bilineata*), Pacific halibut (*Hippoglossus stenolepis*), yellowfin sole (*Limanda aspera*), great sculpin (*Myoxocephalus polyacanthocephalus*) and butter sole (*Isopsetta isolepis*). A thorough discussion of results will be presented later.

IV. Preliminary Interpretation of Results

Very little difference between winter (March) and summer (June through September) is apparent in table 1. A more detailed discussion will be presented later.

V. Problems Encountered/Recommended Changes

None.

VI. Estimate of Funds Expended

A.	Personnel	93.25[1]
B.	Travel and Subsistance	5.99
C.	Contractual Services	76.04
D.	Commodities[2]	30.99
E.	Equipment	14.24
	Total	220.51
	Overhead	22.77
	Grand Total	243.28

[1]Includes benefits.
[2]Includes expendable fishing gear, i.e. trawls and seines.

Table 1. Preliminary tabulation of otter trawl catch in kilograms per 20 minute haul in lower Cook Inlet in June, July, August, September 1976 and March 1977.

Taxa	June	July	Aug.	Sept.	March
Spiny dogfish				0.4	
Big skate[1]				1.3	1.0
Black skate			0.3		
Longnose skate		0.5		0.6	
Starry skate[1]					
Pacific herring			T	0.3	T
Capelin	T	T	T	T	
Eulachon		T	T	T	0.1
Pacific cod	8.9	6.9	7.0	2.4	3.2
Pacific tomcod	T	T		T	0.2
Walleye pollock	0.9	16.2	24.2	2.4	0.6
Shortfin eelpout		T	T		T
Wattled eelpout	T	T			
Pacific sandfish	0.3	0.1	0.1	T	0.3
Searcher	T	T	0.4	0.3	T
Daubed shanny	T		T	T	T
Snake prickleback	T	T		T	
Pacific sand lance				T	T
Rockfish spp		T	T		0.1
Masked greenling	T				
Whitespotted greenling	0.3	T	T	0.3	T
Atka mackerel					T
Sculpin spp	3.0	2.4	T[2]		
Spinyhead sculpin		T	T	T	T
Gymnocanthus spp		0.2	0.9	0.3	0.2
Red Irish Lord	T		T		
Yellow Irish Lord	1.1	5.6	15.2	1.3	15.4
Bigmouth sculpin		0.3	0.2		0.1
Northern sculpin			T		T
Thorny sculpin		T		T	T
Staghorn sculpin				0.1	0.1
Blackfin sculpin		0.2	T		0.2
Great sculpin	4.4	2.9	7.2	5.2	4.6
Eyeshade sculpin			T		
Tadpole sculpin	T		T		
Scissortail sculpin			0.1		0.4
Ribbed sculpin		T	T	0.1	T
Sea poacher (spp)	T	T			
Northern spearnose poacher			T	T	
Sturgeon poacher	.7	.2	.1	.1	1.5
Smooth and Aleutian alligatorfish		T	T	T	T
Gray starsnout		T	T	T	
Fourhorn poacher			T		
Tubenose poacher					T

Table 1. (cont.)

Taxa	June	July	Aug.	Sept.	March
Sawback poacher			T		0.1
Snailfish spp	T	T	T	T	T
Pleuronectidae spp	0.6[3]				
Arrowtooth flounder	0.5	3.4	7.6	2.3	1.0
Rex sole	T	0.2	0.4	1.3[3]	0.2
Flathead sole	0.2	0.5	1.9	3.0	0.3
Pacific halibut	10.1	5.3	8.6	5.1	7.5
Butter sole	4.8	7.0	4.1	7.4	4.4
Rock sole	2.1	2.7	10.3	11.4	12.0
Yellowfin sole	2.2	7.0	4.7	22.1	6.1
Dover sole		.2	.2	T	T
Starry flounder	0.1	0.2	1.9	6.5	1.0
Alaska place	0.4	T	0.2	0.9	0.1
Sandsole	0.2		T		
King crab	5.3	4.6	8.6	6.8	1.9
Snow crab	11.8	25.5	23.2	10.8	30.2
Dungeness crab	0.5				
Shrimp	T	T	0.7	0.9	T

[1]Egg case captured, identification tentative for starry skate.
[2]Apparently a new species of sculpin.
[3]Identification dubious. Originally identified as Dover sole but were in wrong place and wrong size and aggregated as Dover never were.

QUARTERLY REPORT

Contract No. 03-5-022-56
Task Order No. 29
Research Unit No. R.U. 517
Reporting Period: 4/1 - 6/30/77

THE DISTRIBUTION, ABUNDANCE AND DIVERSITY OF THE EPIFAUNAL BENTHIC ORGANISMS IN TWO BAYS (ALITAK AND UGAK) OF KODIAK ISLAND, ALASKA

Principal Investigator

Dr. Howard M. Feder
Professor of Marine Science and Zoology
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

Assisted by: Associate Investigators

Max Hoberg and Stephen C. Jewett
Research Assistants
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

June 30, 1977

I. TASK OBJECTIVES

A. A quantitative inventory census of dominant benthic invertebrate epifaunal species.

B. A description of spatial distribution patterns of selected benthic invertebrate epifaunal species.

C. Observations of biological interrelationships between segments of the benthic biota.

II. LABORATORY ACTIVITIES

A. Laboratory work:

1. Verification of specimens from Legs I, II, III, and IV were completed.

B. Investigators:

1. Stephen Jewett, Institute of Marine Science Research Assistant, assessed data on distribution and abundance, trophic relationships and reproduction activity.

C. Methods - the method employed in verification of specimens from Leg IV (3-18 March 1977) was the same as the previous 3 Legs (see previous Quarterly Report).

D. Sample localities - not applicable.

E. Data collected or analyzed during Leg IV (3-18 March 1977) - 23 stations were occupied in Ugak Bay and 21 stations were occupied in Alitak Bay.

III. RESULTS AND INTERPRETATION OF RESULTS

Seven (7) outer Alitak Bay stations were eliminated on Leg IV due to heavy concentrations of ovigerous female King crab. All crab eggs were in the eyed-egg condition. The trawl was completely full in a 10-minute tow in this area. One (1) station was eliminated due to presence of crab gear. Two (2) Ugak Bay stations contained many recently molted adult male snow crab (carapace width 145-170 mm).

Little feeding data was obtained due to the active reproducing period of many species. Starry flounder and yellowfin sole were the dominant fishes in terms of biomass. Stomachs were periodically examined and found to be empty. Both species had ripe gonads. Great sculpin was the only fish found to be feeding; many of these had ripe gonads. Male snow crab stomachs were not examined due to the near pre- or post-molt condition. Twenty-nine (29) King crab stomachs were obtained, however, feeding was minimal.

The following species of crustaceans were carrying eggs in the advanced condition (eyed):

Snow crab - *Chionoecetes bairdi*
King crab - *Paralithodes camtschatica*
Pink shrimp - *Pandalus borealis*
Coon-stripe shrimp - *Pandalus hypsinotus*
Humpy shrimp - *Pandalus goniurus*
Rock shrimp - *Argis* sp.
Eualus binnguis

IV. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

No problem encountered; no recommended changes.

RECEPTORS (BIOTA)

MICROBIOLOGY

RECEPTORS (BIOTA)

MICROBIOLOGY

Quarterly Report

Contract # 03-5-022-85
Research Unit 29
Period 4/1 - 6/30

Assessment of Potential Interactions of Microorganisms and Pollutants Resulting from Petroleum Development on the Outer Continental Shelf in the Beaufort Sea

Submitted by: Ronald M. Atlas
Principal Investigator
Department of Biology
University of Louisville
Louisville, Kentucky 40208

July 1, 1977

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 Schedule

No field activities were scheduled during this quarter.

B. Laboratory Activities

Taxonomic testing of 500 microorganisms isolated on oil agar, (presumed hydrocarbon utilizers) was carried out. Methods employed for taxonomic testing have been described in previous reports.

III. Results

Taxonomic data on 500 microorganisms isolated from Beaufort Sea samples on oil agar was completed and deposited at NIH in file 100252. Cluster analyses on this data have been performed.

IV. Interpretation of Results

No new interpretation of analyses were made during this period.

V. Problems Encountered

None.

VI. Estimate of Funds

It is estimated that 75% of this year's funds were expended as of July 1, 1977.

Quarterly Report

Contract # 03-6-022-35109
Research Unit 30
Period 4/1 - 6/30

Assessment of Potential Interactions of Microorganisms and Pollutants Resulting from Petroleum Development in Cook Inlet

Submitted by: Ronald M. Atlas
Principal Investigator
Department of Biology
University of Louisville
Louisville, Kentucky 40208

July 1, 1977

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 Schedule

No field activities were scheduled during this quarter.

B. Laboratory Activities

Microorganisms from the samples collected in Cook Inlet during April were enumerated according to procedures described in previous reports. Additionally hydrocarbon degrading microorganisms were enumerated by a most probable number (MPN) procedure.

For MPN determinations dilutions of samples were added to 60 cm^3 stoppered serum vials containing 10 cm^3 Bushnell Haas broth and 50 μm^3 Cook Inlet crude oil spiked with 1 ^{14}Cn-hexadecane (s.p. act. = 0.4 $\mu Ci/cm^3$ oil). Poisoned controls were prepared by adding 0.2 cm^3 concentrated hydrochloric acid to the vials. A 3 tube MPN procedure was used. After incubation at 5 C for 6 weeks the solutions were acidified with 0.2 cm^3 concentrated hydrochloric acid and the $^{14}CO_2$ produced was recovered. $^{14}CO_2$ was recovered by purging the vials with air and trapping the $^{14}CO_2$ in 1 cm^3

hyamine hydroxide in percolation tubes, 0.5 cm x 10 cm, containing glass beads. The hyamine hydroxide was washed from the tubes into scintillation vials with 3 1 cm^3 portions of methanol. The counting solution was 10 cm^3 Omnifluor + toluene (New England Nuclear). Counting was with a Beckman liquid scintillation Counter. Counts greater than or equal to 2 times control were considered as positive; counts less than 2 times control were considered as negative. The most probable number of hydrocarbon degrading microorganisms was determined from the appropriate MPN Tables and recorded as number per cm^3 for water samples or number per g dry wt. for sediment samples.

III. Results

A. Enumeration of Microorganisms

Figure 1 shows the locations of sites samples during the April Discoverer cruise. The latitudes, longitudes, depths, temperatures, and salanities are shown in Table 1 for water samples and in Table 2 for sediment samples.

The viable counts of heterotrophic microorganisms are shown in Tables 3 and 4 for water and sediment samples respectively. Tables 3 and 4 also show the incidence of pigmentation in the total heterotrophic populations enumerated at 4 C. Heterotrophic populations were higher at the upper end of the Inlet than near the entrances to Cook Inlet. Presumed *Vibrio* spp. were found in much higher numbers in sediment than in water samples. The percentages of the heterotrophic microbial populations in water that were pigmented were higher than those in sediment samples.

The estimation of numbers of hydrocarbon utilizing microorganisms enumerated at 5 C by plate count methods is shown in Table 5, and by MPN procedures in Table 6. The plate counts showed much higher estimates of hydrocarbon utilizers in sediment than in water samples. Within Cook Inlet higher plate counts were found at the upper end of the Inlet for water samples but sediment samples showed similar plate counts throughout the Inlet. The MPN estimates generally did not show large differences of hydrocarbon utilizers between water and sediment samples collected at a given site. The MPN estimates showed the highest numbers of hydrocarbon utilizers near shore and at the upper end of the Inlet and the lowest numbers along a central transect of the Inlet.

B. Taxonomic Analyses

Data gathering for taxonomic studies of heterotrophic microbial populations isolated from samples collected during October in Cook Inlet have been completed. The data has been deposited at NIH in file 100245. Descriptive Data on 393 strains is contained in this file. Cluster analyses have not yet been run on this data.

Taxonomic data on 74 microorganisms isolated from the Gulf of Alaska on oil agar media has also been completed and deposited at NIH in file 100252. File 100252 also contains information on Beaufort Sea microorganisms isolated on oil agar. Cluster analyses have been performed on this data.

IV. Interpretation of Results

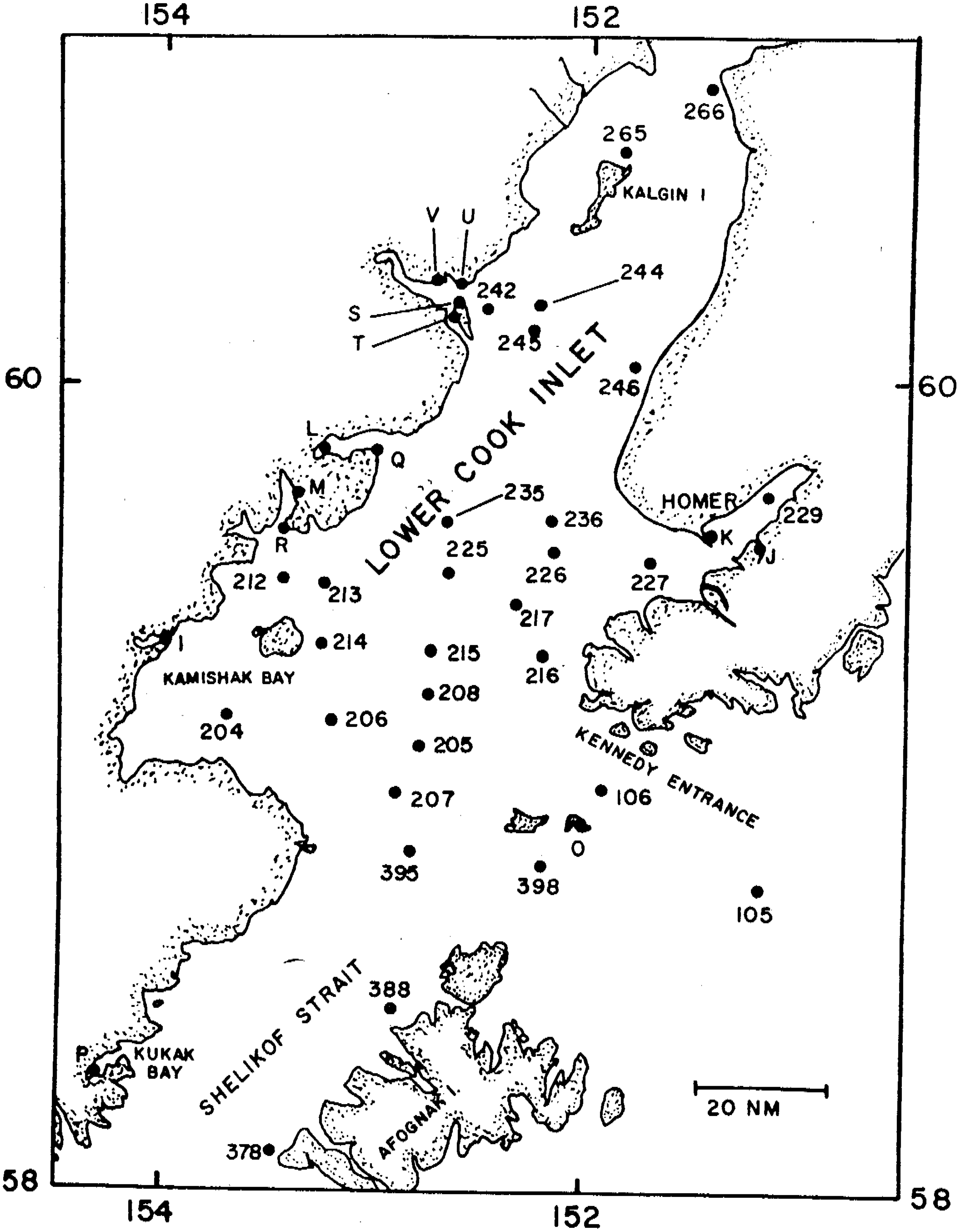
No new interpretation of analyses was made during this period.

V. Problems Encountered

Problems have been encountered in obtaining results of nutrient analyses performed at University of Alaska.

VI. Estimate of Funds

It is estimated that 75% of this year's funds were expended as of July 1, 1977.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KALGIN I
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LOWER COOK INLET
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KAMISHAK BAY
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KENNEDY ENTRANCE
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378

Table 1. Sample Locations and Abiotic Parameters of Water Samples, Cook Inlet, April, 1977.

Sample #	Station	Date	Latitude (N)	Longitude (W)	Depth (m)	Temp. (°C)	Salinity (°/oo)	Remarks
GW 402	266	4/5/77	60°41.2'	151°25.0'	1	1.0	21.0	
GW 403	265	4/5/77	60°34.3'	151°51.4'	1	1.0	27.4	
GW 405	245	4/6/77	60°06.8'	152°14.0'	1	2.9	26.0	
GW 406	S	4/6/77	60°10.7'	152°36.0'	1	2.8	24.5	Offshore
GW 407	S	4/6/77	60°10.7'	152°36.0'	0	4.5	24.0	Beach
GW 411	U	4/7/77	60°12.7'	152°36.5'	1	6.0	15.0	Offshore
GW 415	242	4/7/77	60°09.5'	152°25.0'	1	2.3	30.1	
GW 417	246	4/8/77	60°03.0'	151°46.2'	1	2.5	25.5	
GW 420	227	4/9/77	59°33.5'	151°36.4'	1	4.4	31.4	
GW 421	K	4/9/77	59°36.1'	151°25.0'	1	5.3	25.3	Offshore
GW 425	229	4/9/77	59°37.6'	151°18.0'	1	4.2	31.3	
GW 426	216	4/10/77	59°18.2'	152°14.1'	1	5.0	31.5	
GW 428	226	4/10/77	59°33.5'	152°18.7'	1	4.7	31.5	
GW 429	225	4/10/77	59°31.4'	152°41.5'	1	3.7	31.3	
GW 431	214	4/10/77	59°18.2'	153°14.3'	1	3.3	31.1	
GW 432	204	4/10/77	59°14.2'	153°39.7'	1	2.7	30.8	
GW 433	206	4/10/77	59°09.8'	153°08.2'	1	4.9	31.5	
GW 434	212	4/11/77	59°32.4'	153°21.8'	1	2.3	30.6	
GW 435	215	4/11/77	59°21.9'	152°48.7'	1	3.4	31.2	
GW 438	205	4/12/77	59°06.3	152°43.1'	1	5.0	31.6	
GW 439	207	4/12/77	58°59.9'	152°52.0'	1	4.8	31.7	
GW 440	395	4/13/77	58°53.0'	152°54.0'	1	4.6	26.5	
GW 441	106	4/13/77	59°00.4'	152°00.0'	1	4.7	31.5	
GW 442	105	4/14/77	58°50.0'	151°20.0'	1	4.6	27.8	
GW 444	388	4/14/77	58°28.6'	153°10.0'	1	4.7	24.4	
GW 445	378	4/14/77	58°02.0'	153°29.0'	1	4.5	26.3	

Table 2. Sample Locations and Abiotic Parameters of Sediment Samples, Cook Inlet, April, 1977.

Sample #	Station	Date	Latitude (N)	Longitude (W)	Depth (m)	Temp. (°C)	Salinity (°/oo)	Remarks
GB 410	242	4/6/77	60°09.5'	152°25.0'	39.0	2.3	30.2	
GB 411	U	4/7/77	60°12.7'	152°36.5'	3.0	6.0	15.0	Offshore
GB 420	227	4/9/77	59°33.5'	151°36.4'	89.0	4.4	31.5	
GB 421	K	4/9/77	59°36.1'	151°25.0'	3.5	-	-	
GB 425	229	4/9/77	59°37.6'	151°18.0'	67.0	4.1	31.3	
GB 428	226	4/10/77	59°33.5'	152°18.7'	60.0	4.7	31.5	
GB 429	225	4/10/77	59°31.4'	152°41.5'	39.0	4.4	31.5	
GB 431	214	4/10/77	59°18.2'	153°14.3'	49.0	3.3	31.1	
GB 434	212	4/11/77	59°32.4'	153°21.8'	27.0	2.5	30.7	
GB 435	215	4/11/77	59°21.9'	152°48.7'	76.0	4.6	31.5	
GB 438	205	4/12/77	59°06.3'	152°43.1'	148.0	5.4	32.1	
GB 440	395	4/13/77	58°53.0'	152°54.0'	172.0	-	-	
GB 442	105	4/14/77	58°50.0'	151°20.0'	118.0	7.5	32.6	
GB 444	388	4/14/77	58°28.6'	153°10.0'	168.0	-	-	
GB 445	378	4/14/77	58°02.0'	153°29.0'	95.0	5.0	32.0	

Table 3. Viable Counts for Water Samples (per ml) - Cook Inlet, April, 1977.

Sample #	Marine Agar 2216 4 C	Marine Agar 2216 20 C	TCBS (Vibrio) 4 C	TCBS (Vibrio) 20 C	Pigmented Bacteria (%)	Orange Pigmented Bacteria (%)
GW 402	1.2×10^3	5.1×10^3	1.5×10^1	5.0×10^0	37.7	0.2
GW 403	5.8×10^2	1.5×10^3	9.0×10^0	1.0×10^1	29.9	1.7
GW 405	4.7×10^2	1.3×10^3	9.4×10^0	1.0×10^1	10.6	0.0
GW 406	8.8×10^2	2.8×10^3	1.2×10^1	5.0×10^0	24.7	6.5
GW 407	5.6×10^2	7.1×10^2	4.5×10^1	5.0×10^0	12.4	1.2
GW 411	1.9×10^3	4.7×10^3	3.0×10^1	1.0×10^1	10.3	5.0
GW 415	1.5×10^2	2.9×10^2	1.8×10^0	2.0×10^0	23.4	6.3
GW 417	1.3×10^3	2.0×10^3	6.5×10^1	1.5×10^1	12.4	0.0
GW 420	1.8×10^2	9.0×10^1	1.0×10^1	1.6×10^0	22.8	0.0
GW 421	6.1×10^2	7.9×10^2	4.5×10^1	2.5×10^1	16.7	0.0
GW 425	1.1×10^2	1.7×10^2	1.2×10^1	4.0×10^0	23.2	0.0
GW 426	7.2×10^1	-	3.0×10^0	-	11.4	0.0
GW 428	6.4×10^1	-	5.0×10^0	-	25.0	0.0
GW 429	5.4×10^1	2.3×10^1	8.0×10^0	3.0×10^0	14.8	0.0
GW 431	7.4×10^1	-	0.9×10^0	-	27.0	0.0
GW 432	6.4×10^1	-	3.0×10^0	-	43.8	0.0
GW 433	2.8×10^1	-	0.6×10^0	-	42.9	0.0
GW 434	1.9×10^2	-	1.0×10^1	-	22.4	0.0
GW 435	3.2×10^1	-	0.6×10^0	-	25.0	0.0
GW 438	1.2×10^2	-	1.7×10^0	-	47.5	0.0
GW 439	1.2×10^2	-	1.0×10^0	-	53.4	1.7
GW 440	4.8×10^1	-	2.0×10^0	-	25.0	0.0
GW 441	9.3×10^2	-	1.4×10^0	-	13.7	0.0
GW 442	2.4×10^2	-	0.0×10^0	-	70.0	1.7
GW 444	2.8×10^1	-	1.0×10^1	-	10.7	0.0
GW 445	9.8×10^1	-	1.5×10^1	-	47.0	0.0

Table 4. Viable Counts for Sediment Samples (per gram of dry weight) - Cook Inlet, April, 1977.

Sample #	Marine Agar 2216		TCBS		Pigmented Bacteria	Orange Pigmented Bacteria	Remarks
	4 C	20 C	4 C	20 C	(%)	(%)	
GB 410	4.5×10^5	4.2×10^5	5.0×10^3	2.5×10^3	5.1	0	sand
GB 411	1.6×10^7	3.3×10^7	1.9×10^5	3.8×10^4	15.5	0	clay
GB 420	1.1×10^7	8.2×10^6	1.3×10^5	8.5×10^4	12.6	0	clay
GB 421	1.1×10^8	1.3×10^8	4.0×10^5	9.4×10^4	18.3	0	black clay
GB 425	1.3×10^7	1.8×10^7	1.1×10^5	2.3×10^4	32.1	0	clay
GB 428	5.1×10^4	-	4.4×10^3	-	5.0	2.0	sand, shell
GB 429	3.8×10^5	2.2×10^5	1.0×10^3	9.5×10^2	9.0	0	clay
GB 431	1.0×10^6	-	1.8×10^4	-	0	0	clay
GB 434	3.9×10^5	-	1.2×10^5	-	1.2	0	clay, sand
GB 435	1.4×10^5	-	2.9×10^3	-	15.5	0	sand
GB 438	1.6×10^5	-	1.9×10^4	-	17.3	0	sand
GB 440	6.0×10^5	-	3.2×10^4	-	9.8	0	clay
GB 442	5.9×10^5	-	2.7×10^4	-	0	0	clay
GB 444	2.5×10^6	-	4.4×10^4	-	0	0	clay
GB 445	2.1×10^6	-	5.2×10^4	-	1.0	0	sand

Table 5. Hydrocarbon Utilizer Counts at 5 C

April 1977

Sample #	Station	Water CFU/ml	Sediment CFU/g dry wt.
402	266	8.0×10^{1}	-
403	265	1.2×10^{1}	-
405	245	5.7×10^{1}	-
406	S*	4.0×10^{1}	-
407	S	2.0×10^{1}	-
415	242	2.0×10^{0}	1.9×10^{4}
411	U	1.5×10^{1}	1.9×10^{3}
417	246	1.3×10^{1}	-
420	227	6.0×10^{0}	9.7×10^{3}
421	K	$<1.0 \times 10^{-2}$	3.3×10^{4}
425	229	$<1.0 \times 10^{-2}$	1.7×10^{4}
426	216	3.6×10^{0}	-
428	226	3.0×10^{-1}	3.2×10^{2}
429	225	1.0×10^{-1}	$<10^{0}$
431	214	4.8×10^{0}	$<10^{0}$
432	204	$<1.0 \times 10^{-2}$	-
433	206	3.5×10^{-1}	-
434	212	1.3×10^{0}	2.7×10^{3}
435	215	1.0×10^{-2}	2.0×10^{3}
438	205	1.0×10^{-1}	$<10^{0}$
439	207	3.0×10^{-1}	-
440	395	2.0×10^{-1}	1.9×10^{3}
441	106	4.0×10^{1}	-
442	105	6.8×10^{2}	4.5×10^{3}
444	388	$<1.0 \times 10^{-2}$	1.6×10^{4}
445	378	$<1.0 \times 10^{-2}$	4.4×10^{3}

*1 meter

CFU = Colony Forming Unit

Table 6. Most Probable Numbers of Hydrocarbon Utilizers at 5 C, April, 1977

Sample #	Station	Water MPN	Sediment MPN
402	266	20.0	-
403	265	20.0	-
405	245	1.1	-
406	S*	20.0	-
407	S	20.0	-
415	242	2.8	3.0
411	U	75.0	1100.0
417	246	2.8	-
420	227	4.0	210.0
421	K	210.0	460.0
425	229	1100.0	1500.0
426	216	2.8	-
428	226	120.0	110.0
429	225	2.8	6.4
431	214	2.0	21.0
432	204	21.0	2.8
433	206	2.8	-
434	212	1.4	2.8
435	215	2.0	2.8
438	205	1.4	4.3
439	207	1.1	-
440	395	0.7	0.7
441	106	93.0	-
442	105	93.0	210.0
444	388	1.1	-
445	378	-	-

*1 meter

MPN = Most Probable Number

Quarterly Report

Task Numbers A-27; B-9
Contract #03-5-022-68
Research Unit 190-E
Reported Period 1 April to 30 June, 1977

Number of pages 39

Study of Microbial Activity in the Lower Cook Inlet and Analysis of Hydrocarbon Degradation by Psychrophilic Microorganisms

SUBMITTED BY:

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Robert P. Griffiths
Co-Investigator
Research Associate
Department of Microbiology
Oregon State University
Corvallis, OR 97331

Date Submitted

June 30, 1977

I. Task Objectives

a. To measure the relative levels of microbial activity in the waters and sediments of the Lower Cook Inlet and to measure the concentration of bacteria found in the same samples using epifluorescent microscopy (Task A-27).

b. To study hydrocarbon degradation by psychrophilic hydrocarbon degrading bacteria (Task B-9).

c. To study the effects of crude oil on growth and metabolism of natural marine microbial populations.

d. To coordinate the above studies with Dr. Atlas and his associates (R U #29).

II. Field and Laboratory Activities

A. Field trip schedule

During this period, we participated in one field trip in the Lower Cook Inlet and a cruise on board the NOAA ship Discoverer from April 3 to April 16, 1977.

B. Scientific party

All of the personnel involved in this project are in the Department of Microbiology, Oregon State University. Dr. Griffiths and Mr. McNamara participated in the field trip mentioned above and conducted related laboratory studies at Oregon State University.

C. Personnel

Dr. Richard Y. Morita, Principal Investigator
Dr. Robert Griffiths, Co-Prinicpal Investigator
Mr. Thomas McNamara, Technician (Research Assistant, Unclassified)

C. Methods

Substrate uptake and bacterial concentration determinations

The methods used were essentially the same as those described on pages 8 to 11 in our second annual report. In most of the samples analyzed, the relative microbial activities were determined using a single concentration of glucose or glutamic acid.

Desulfovibrio concentrations in sediments

Subsamples of a 10^{-3} dilution were added to screw top test tubes so that no air would be introduced to the semisolid anaerobic medium. Serial dilutions were made in the range of 10^{-5} to 10^{-6} in most cases. The medium used was a modification of marine desulfovibrio medium PM 10 E (ZoBell and Morita, Deep Sea Research 3:66-73, 1955). This medium contained the following ingredients: Na formaldehyde sulfoxylate, 0.1 g; K_2HPO_4, 0.5 g; NH_4Cl, 1 g; Na_2SO_4, 1 g; $CaCl_2 \cdot 2H_2O$, 0.1 g; $MgSO_4 \cdot 7H_2O$, 2 g; Ca lactate, 5 g; yeast extract, 1 g; NaCl, 30 g; Na citrate 1 g; agar 3 g, H_2O 1 liter. The medium was adjusted to a pH of 7.5 and sterilized by autoclaving at 30 psi for 15 min. Prior to use, the medium was steamed for one hour to drive off gases within the medium.

The test tubes were kept at 4 C or below during transport to our laboratory at Oregon State University. These tubes were incubated at 8 C for four weeks before they were checked for growth. The incubation temperature was then increased to 25 C and checked again for growth after an additional two weeks incubation.

Crude oil degradation potential in sediments

These experiments were conducted on sediment samples that were brought back to the laboratory at Oregon State. The samples were kept at or below 4 C between the time they were collected and the start of the experiment. Ten ml subsamples of the sediment were placed into 50 ml serum bottles. To this was added 0.1 ml of Cook Inlet Crude oil which contained 0.37 µCi prestane and 0.37 µCi hexadecane. The bottles were sealed with rubber stoppers fitted with a plastic bucket containing fluted filter paper. Duplicate subsamples and one acidified control were used to determine crude oil mineralization in each of the sediments analyzed. The samples were incubated at 8 C for 31 days. At the end of the incubation period, the evolved $^{14}CO_2$ was collected and assayed for radioactivity.

Nitrogen fixation and nitrogen fixing bacterial concentrations in sediments

Nitrogen fixation in the sediments was determined in the field by using the acetylene reduction method (Stewart et al, 1967, Proc.

N.A.S.-U.S. 58:2071 - 2078). Ten ml subsamples of sediment were added to respective 50 ml serum bottles: one control and two duplicate samples were used for each analysis. After the bottles were sealed with a rubber stopper, the samples were gassed for one min with He at a flow rate of 10 cc/sec. Ten ml of acetylene was then added to each bottle and the bottles were allowed to incubate for 24 hr before incubation was terminated with one ml of 50% trichloracetic acid (TCA). The controls were treated in the same way before incubation and were used to determine the amount of ethylene that was released abiotically. After the incubation was terminated, the tops of the rubber stoppers were sealed with silicone cement. The bottles were kept at or below 4 C until they could be assayed for ethylene in our laboratory at Oregon State University. The analysis for ethylene was made on a Hewlett Packard model 5830A gas chromatograph. The column used was 1.9 meter of 1/8" stainless steel tubing packed with Porapak R 80-100 mesh and the oven temperature was 40 C. The carrier gas was nitrogen flowing at a rate of 29 cc/min. The resulting levels of ethylene were normalized using incubation times and gram dry weight conversions.

The concentration of nitrogen fixing bacteria in the sediments will be determined by plate counts on fixed nitrogen deficient agar plates. These data are still in the process of being analyzed and will be presented in the next quarterly report.

D. Sample locations

The locations and sampling dates for stations taken in the Cook Inlet during the spring Discoverer cruise are given in Figure 1 and Table 1.

E. Data collected

During this reporting period, 44 water and 15 sediment samples were analyzed from the Cook Inlet area for relative microbial activity and percent respiration. Fifteen sediment samples were analyzed for nitrogen fixation rates and 12 sediment samples were analyzed for crude oil degradation potential. All samples collected were analyzed for bacterial concentrations using epifluorescent microscopy.

III. Results

Relative microbial activity in seawater

Distinct geographical trends were seen in relative microbial activity in offshore water samples when either labeled glucose or glutamic acid was used in uptake determinations (Figures 2 and 3; Table 2). The highest levels of activity were seen in the northern-most stations sampled (24.7 and 52.4 μg glutamic acid/liter/h). Somewhat lower values offshore were observed to the southwest of Kalgin Island (6.8 to 14.6 μg glutamic acid/liter/h). The values found in Kamishak Bay, stations 215 and 225 in the center of the inlet, and those found in Kachemak Bay were still lower, and values seen in the south and southeastern sections were the lowest (0.5 to 2.0 μg glutamic acid/liter/hr). This is very similar to the pattern of relative microbial uptake that was seen in water samples analyzed during our fall, 1976 cruise in the same area (Figure 4).

As we have observed in the past, the values that we observed at the surf line were higher than those observed in water samples taken 10 m offshore (Table 3). These values in turn, were higher than those observed further offshore.

If one compares the levels of relative microbial uptake during the fall and spring cruises, there are some apparent differences (Table 4). The average value for all beach (onshore) water samples analyzed during the fall cruise was 30 μg glucose/liter/h and it was 7.8 in the spring. The same values for glutamic acid uptake were 85.5 μg/liter/h in the fall and 31.5 in the spring. If one discounts the measurement made in the atypical sample number GW322 in the fall series, the average uptake of both substrates in offshore waters was about the same during both sampling periods. The average ratio of glucose to glutamic acid uptake was somewhat higher during the spring sampling period.

If the average values for the same stations occupied during the two cruises are compared, much the same pattern is seen. The difference seen in the glucose to glutamic acid ratios are somewhat less in the fall than that found in the spring. When the uptake of both substrates is compared seasonally for all common offshore stations, the correlation coefficients are 0.59 and 0.69 respectively for glucose and glutamic acid. Unfortunately, there were not enough common beach (onshore) stations to make a similar comparison, thus, the apparent differences seen there are subject to question.

Relative microbial activity in sediments

There were not enough common stations occupied during the two sampling periods to make statistically significant seasonal comparisons in sediment sample measurements. However, comparisons can be made of all sediment samples analyzed during both cruises (Table 5). If the sediment samples that were analyzed from the Shelikof Strait (which were different from Cook Inlet sediments) are omitted from the average values observed during the spring cruise, the average levels of glucose uptake were the same during both cruises. The average uptake of glutamic acid was somewhat higher during the spring cruise. The glucose to glutamic acid ratio average was also higher in the spring sediments. When the uptake of glucose and glutamic acid were compared in the same samples, the correlation coefficients were 0.70 in the fall and 0.85 in the spring.

The relative microbial activity in the sediments as measured by glutamic acid uptake was the lowest (0.08 to 0.16 μg/g dry weight/hr) in samples taken in the northern half of Kamishak Bay and in the open ocean (Figure 6, Table 6). Somewhat higher values (0.30 to 1.57 μg/g dry weight/hr) were observed at station 204 in Kamishak Bay (southwest of Kalgin Island), stations 227, 229 and K in Kachemak Bay and stations U and V in Tuxedni Bay (southwest of Kalgin Island). Of the stations sampled in Cook Inlet, the beach sediments showed the highest values. The two sediment samples taken from the Shelikof Strait gave values which were about one order of magnitude higher than anything else observed in this region (9.2 and 10.5 μg/g dry weight/hr). A similar pattern of relative microbial activity was also seen as measured by glucose uptake.

Percent respiration in all samples

In general, during the spring cruise, the lowest respiration percentages with glutamic acid were observed in the water samples taken from the northern stations (Figure 5). With one exception, the range of values observed in this region ranged from 31 to 39%. The values observed in Kamishak Bay ranged from 41 to 48%. Values of 52 to 56% were observed at stations 206, 225, and 236. Percent respiration values greater than 61% were seen in water samples taken from stations to the south and southeast. A similar but less well defined pattern was observed during the fall cruise in this area (Figure 7).

When the average glucose respiration percentages for all water samples taken during both sampling periods are compared, there was little difference seen (Table 4). When the same parameter is compared for common stations, there was little difference seen. The average percent glutamic acid respiration observed in the spring was somewhat lower than those observed in the fall (Table 4).

There was no significant geographical trends observed in the respiration percentages observed in the sediments. When the average respiration percentages for both substrates were compared for the two sampling periods, there were no significant differences noted (Table 5).

Comparison of relative microbial activity as measured by simple uptake and heterotrophic potential calculations.

In our seventh quarterly report, we presented data which showed a high correlation between estimating relative microbial activity using glutamic acid uptake at one concentration and the more complex and time consuming estimates using heterotrophic potential calculations which require uptake measurements at four concentrations. Since the later method requires 3 to 4 times the manhours and materials of the former, we recommended making most of our microbial activity measurements be made using the single concentration method.

This is the approach that we took during the spring Cook Inlet study and the result was a much higher resolution due to the larger number of samples obtained from offshore stations. We did make a few heterotrophic potential measurements in order to establish an estimate of the correlation between the two methods (Table 7). The observed correlation coefficients was 0.998 for offshore water samples and 1.000 for sediments.

The ratio of glutamic acid uptake as measured by the maximum potential uptake rate (Vmax) to the actual uptake at the concentrations used was about 2 for both water and sediment samples. Thus, the potential maximum uptake rate for glutamic acid was roughly twice the actual rate at the concentrations studied. These ratios held true for the data collected during both the fall and spring cruises.

In situ rates of nitrogen fixation in sediments

At the time of this study, there were no data available on the in situ rates of nitrogen fixation in the Cook Inlet sediments. In fact, very little is known generally about this primarily bacterial function in marine sediments. It was our intention to evaluate the extent of nitrogen fixation in these sediments and to initiate experiments which would evaluate the effects of Cook Inlet crude oil on this process. The geographical variations in nitrogen fixation in the sediments collected during the spring cruise are given in Figure 8. The highest rates were observed in Kachemak Bay with somewhat lower values observed at stations 395 and 388 (Table 8).

From the values observed for nitrogen fixation in Kachemak Bay, we calculated the annual rate of nitrogen fixation in the sediments of this bay. This calculation was made based on several assumptions which were; (1) that the average level of nitrogen fixation is 1 ng/g dry wt. sediment/hr, (2) that most of the nitrogen fixation is taking place in the top of two cm of the sediment, and (3) the area of Kachemak Bay was 100 sq miles. Within the framework of these assumptions, the amount of nitrogen fixed annually in the sediments of Kachemak Bay would be 2×10^4 kg. If this was also utilized in bacterial biosynthesis, this would result in an annual bacterial biomass of about 4×10^5 kg bacteria (roughly 400 tons). Presumably, this biomass would be available to higher trophic levels including species of commercial value. If this process was drastically altered by the presence of crude oil in the sediments, effects at all trophic levels might be seen.

An attempt to obtain information about this process was made in the field by adding crude oil to two sediment samples and assaying for nitrogen fixation. In neither case was there a change in rate when compared to the nitrogen fixation rates in the untreated samples. Sediment samples were returned to our laboratory at Oregon State University for further analyses. An experiment as conducted to determine the long term effects of crude oil on nitrogen fixation in untreated samples (without added substrate) and in samples treated with sucrose. The experiment was designed to determine if crude oil might in some way effect growth of nitrogen fixing bacteria. Although the results of such an experiment are certainly equivocal, it should give at least an indication of gross effects of crude oil on the system.

We first wanted to determine what effects the additional storage time had had on the observed nitrogen fixation rates in the sediment samples that we had brought back to Oregon State for further analyses. The correlation coefficient between the field and laboratory rates in four samples was 0.96 (Table 8). We thus concluded that the storage of the sediments had little effect on this function.

A comparison of samples with no treatment and those to which Cook Inlet crude oil was added showed very little difference in all four samples tested (Table 9). This was true in samples that had been incubated for one or ten days. In all four samples, the addition of sucrose significantly increased the rate of nitrogen fixation after extended incubation. The effects of crude oil on this stimulation gave mixed results. In sample number 411, the crude oil greatly inhibited the sucrose stimulation and in sample number 444, the stimulation was somewhat reduced by the presence of crude oil. In sample number 425, the sucrose stimulation appeared to be greatly enhanced and in sample 440, crude oil appeared to be slightly stimulative. Obviously more work needs to be done in order to obtain a better understanding of the dynamics of this system. It must also be kept in mind that in these experiments we are not actually measuring nitrogen fixation but are indirectly measuring nitrogenase activity through the reduction of the acetylene.

Concentrations of *Desulfovibrio* sp. in the sediments

Many of the sediments that were collected were analyzed for the presence of presumptive *Desulfovibrio* sp. Only one sediment (Station #214) showed no evidence of these organisms at the lowest dilution used (10^{-3}). The other sediments all showed growth of these organisms at this dilution and/or at higher dilutions. The estimated concentrations of these organisms are shown in Figure 9. The highest concentrations observed were seen in Tuxedni Bay beach sediments, station K at Homer, station 227 in the Cook Inlet, and station 388 in the Shelikof Strait.

Crude oil degradation potentials as compared to relative microbial activity

Crude oil degradation potentials were measured in sediment samples that were returned to our laboratory at Oregon State University. The rates observed in these experiments were compared with relative uptake rates of glutamic acid, glucose and acetate in the same samples. The correlation coefficients were very low and thus there did not appear to be a correlation between crude oil degradation potentials and the uptake of any three of these substrates in sediments. The levels of radioactivity released as CO_2 in the ^{14}C labeled crude oil experiments are given in Figure 10.

<u>Direct counts of bacterial concentrations in water and sediment samples</u>

The average value for bacterial concentrations in the sediments was 2.5×10^9 bacteria per g dry weight sediment (Table 11). This is lower than the average value of 4.9×10^9 observed in the sediments during the October cruise. The average concentration of bacteria in the water samples analyzed was 3.0×10^6 cells/ml. The average value for water samples taken from common stations during the October cruise was 1.1×10^6 cells/ml. This is roughly twice the concentration observed in water samples taken from the same stations during the October cruise.

VI. Preliminary interpretation of results

A. General comments

The information from relatively high resolution microbial activity measurements coupled with data on the hydrography and currents of the Cook Inlet is starting to produce an overall picture that will be valuable in managing the development of crude oil reserves in this region.

From the data presented, it is obvious that the forces acting in the Lower Cook Inlet can only be understood in terms of the broader factors acting on the entire region. If we had restricted our study to only the Lower Cook Inlet, we would not have been able to interpret our data in terms of the wider patterns which directly affect this area.

In summary, we found the relative microbial activity in the waters to the north was very high even though very little primary productivity is taking place in the area. This high activity was directly related to the suspended particulate load in these waters. As the tidal current velocities decrease to the south in the wider portions of the inlet, the surface water becomes less turbid and presumably, the particles are starting to settle out of the water column. We are curious as to where this highly active suspended matter found in the northern water mass settles. An analysis of microbial activity in the Cook Inlet sediments indicate that little of this material settles out into the sediments of this area but rather is deposited in the sediments of the <u>Shelikof Strait</u>. The high microbial activity sediments of the Shelikof Strait undoubtedly is very important to the whole food chain in this region. If the studies of crude oil - suspended matter interactions currently being conducted by Drs. Jole Cline and Richard Feely (PMEL) show that significant quantities of crude oil can become associated with these particles, it is quite likely that crude oil would be introducted to these very active sediments of the Shelikof Strait.

There are two distinct water masses present in the Cook Inlet; one to the north that is very turbid and of relatively low salinity and one to the south and southeast which is more typical of open ocean water. We have found that both of these water masses have characteristic patterns of microbial activity and respiration. Glutamic acid uptake studies in surface waters have shown that the relative microbial activity is very high and the respiration percentages are very low in the northern water mass. The reverse pattern is seen in the water mass to the south. Intermediate values were observed in regions where these two water masses meet in the area to the north and east of Augustine Island. This is the same region in which a gyre has been observed by other investigators. In general, the patterns of surface water microbial activity and respiration reflect the net surface circulation patterns reported by Miller and Allen (RU #436) (Environmental Assessment of the Alaskan Continental Shelf, Oct.-Dec., 1976 Principal Investigators' Reports, Vol. 3, page 782).

B. The use of microbial parameters as indicators of water mass and particle transport

As far as we know, this is the first study made in which patterns of microbial activity in marine waters have been used to characterize more than one distinct water mass and to indicate regions of interaction between those water masses. The two water masses in question are clearly shown in Figure 11 from surface salinity data. This same type of pattern has been reported by Kinney et. al., 1969, (Prevention and Control of Oil Spills, API-EPA Proceedings, page 336). This is also the same type of pattern that one would expect from the current data presented by Miller and Allen (RU #436), (Oct.-Dec., 1976 OCSEAP Principal Investigators' Reports Vol. 3, page 782). Since these observations were taken at various times, it would appear that this is a relatively consistant phenomenon in this region. This same general pattern was observed in the relative levels of glutamic acid uptake in surface water microbial populations during both the fall and spring cruises (Figures 3 and 4). Consistancies between the patterns of respiration percentages observed during these two sets of observations also supports the idea that the position of these two water masses is relatively constant. The high levels of microbial activity seen in the northern waters was related to the high suspended matter load found in these waters. If the surface current data observed by Miller and Allen were in effect during our observations, one would expect this water to have a net movement to the southwest, through Kamishak Bay to the west of Augustine Island and to the south and southwest through the Shelikof Strait. The relative microbial activity in the surface waters follows the same pattern with values becoming lower as the water moves south. During this time, it is presumed that the highly active suspended matter is settling out of the water column. Our studies of microbial activity in the sediments indicate that most of this material does not settle out in the sediments of Kamishak Bay but that it is deposited in the sediments of the Shalikof Strait.

The respiration percentages for glutamic acid shows a similar pattern. The low values associated with the northern water mass are replaced with higher values in the waters to the southwest as the water moves through Kamishak Bay. The high values to the southeast reflect the influx of ocean water pushing into the inlet moving from the southeast to the northwest. Intermediate values were observed at stations #206, 225 and 236 in area in which mixing between these two water masses probably takes place.

When one compares the patterns resulting from the glutamic uptake data and the respiration percentage data, there are some differences. Of these two sets of data, the respiration percentages more closely follows the surface salinity data than does the uptake data. The most probable explaination for this phenomenon is that the respiration percentages reflect the types of nutrients available to the microbial population. Under many conditions, the respiration percentages are inversely related to microbial activity (the correlation coefficient typically runs from about -0.4 to -0.5). This relatively low correlation reflects at least two possible situations which would cause an exception to this relationship. It is possible to have a population which has all of the nutrients it requires for growth but the nutrients are avaliable at very low concentrations thus the microbial activity would be low and the percent respiration would also be low. The reverse situation can also occur, namely, there might be a deficiency in one or more growth factors in a water sample but in general, the levels of other available nutrients is high resulting in a high level of activity and a high respiration percentage. It is also possible that the level of respiration observed in a given sample reflects the types of organisms present rather than their physiological state. The taxonomical studies being conducted by Dr. Atlas may help to clarify this point.

Even with these discrepancies in detail, both sets of data show that there is an area of mixing in the general region of the "null zone" which has been described by Miller and Allen.

The correlation that we found between suspended matter load and microbial activity suggests that the tidal currents may play a role in determining the level of microbial activity observed in a given location at a given time. After analyzing our data from the fall cruise, we concluded that the tidal currents were not a significant factor in affecting microbial activity. We now have data that suggests that the tidal state may indeed be a factor, particularly in relatively shallow regions where sediment can be introducted into the water column by mixing. Water samples taken at stations U and V in Tuxedni Bay illustrate this point. These stations were taken during a strong flood tide. Station U was taken near the mouth of the bay and V one mile further up the bay. The water flowing from station U to station V was flowing over a rather extensive mud flat area. The uptake observed at V was more than twice that observed at station U.

C. Seasonal variation in microbial parameters

When seasonal variations are compared in water samples taken from common offshore stations, there were very few differences seen in the resulting data. The average relative microbial uptake was somewhat higher in the spring when measured with glutamic acid but was about the same with glucose (this is reflected in the glutamic acid/glucose ratios). These data suggest that there might be a slightly different type of organic nutrient available in the spring than in the fall. The percent respiration with glutamic acid was somewhat lower in the spring water samples. This might also be a reflection of a slightly different nutrient composition in the spring.

In the onshore (beach) water samples, the average value for glutamic uptake was about the same during both seasons if the atypical values observed at Homer are omitted from the average. The uptake of glucose was again somewhat lower in the spring. This may reflect a decrease in the amount of carbohydrate available to the spring microbial populations. It is not known at this time what these differences mean in terms of the interactions between the microbial populations and crude oil.

Of perhaps equal interest were some of the differences seen at specific locations between the two seasons. The uptake of both glucose and glutamic acid was exceptionally high in the water samples taken in the Homer boat basin in the fall (five times greater than any other samples tested). During the spring sampling, the level of microbial activity was much lower for this station and the other stations sampled in Kachemak Bay. These differences probably reflect differences in the amount of organic material that was being released into the bay from Homer at these two times of year.

There were also differences in the patterns of microbial activity in the interface between the two water masses. It is not known at this time if this is a seasonal phenomenon or if these differences reflect much shorter term fluctuations. The studies that we have proposed to conduct during FY78 should help determine the seasonality of these fluctuations.

D. The presence of Desulfovibrio sp. in Cook Inlet sediments

Of potential interest to those planning to construct metal structures that come into contact with sediments is the presence of a group of anaerobic bacteria known as Desulfovibrio. The growth of this organism may produce considerable corrosion of most metals. These organisms are also known to grow in drilling muds with the resulting release of H_2S. Except for the sediment analyzed from station 214, all samples tested showed significant concentrations of this organism in Cook Inlet sediments (10^3 to 10^6 bacteria per ml sediment). In most dilution tubes, growth was visable within four weeks incubation at 8 C.

E. Crude oil degradation potentials in sediments

A study was designed to see if there were any correlations between crude oil degradation potentials in sediments and the uptake of glutamic acid, glucose, or acetate in the same sediments. This study was initiated because we did find a correlation between crude oil degradation potentials in surface waters with glucose uptake rates during October, 1976 Cook Inlet cruise. We did not find any significant correlation between any of these parameters in the sediments taken during the April, 1977 cruise. The highest correlation coefficient observed (0.57) was found to exist between crude oil degradation and the ratio of glutamic acid uptake to glucose uptake in the same samples.

F. Relative levels of microbial uptake using two methods

We have reported previously that there was a very high correlation between the uptake of glutamic acid at one concentration and heterotrophic potential (V_{max}) determinations made using four substrate concentrations. In our last two reports, we recommended dropping the V_{max} determinations in favor of simple uptake measurements at one substrate concentration. The high correlation coefficients observed between these two methods during this cruise again confirms the validity of this approach. For this and reasons listed below, we will continue measuring both glutamic acid and glucose uptake in all water and sediment samples.

G. Correlations between glutamic acid uptake and other parameters in sediment samples

Correlation coefficients were determined between rates of glutamic acid, glucose and acetate uptake and the measurements of total viable counts, total ferminative bacterial concentrations, the concentrations of total vibrios, and sucrose positive vibrios (Table 10). This was done in order to determine whether the uptake of these three substrates could be used to characterize any of these other groups of organisms. In most cases, glucose and acetate showed about the same correlation with all of the other paramenters with which it was compared, thus, it was not surprising to find that the correlation coefficient between glucose and acetate uptake was 0.97.

The correlation of all parameters were different with glutamic acid than with glucose. This probably reflects the activity of different populations. These data support our decision to routinely assay relative microbial activity using both of these substrates.

In our study, Lib X medium was used for determining total viable counts. The counts observed on this medium correlated very well with relative microbial activity as measured with glucose uptake but relatively poorly when glutamic acid was used (Table 10). The reverse trend was seen in sediment samples collected during the October cruise when another medium was used to determine total viable bacterial counts. Both of these media are selective for certain bacterial populations. These observations support the idea that these two substrates are measuring different bacterial populations and that both sets of data should be collected.

H. Correlations of our past studies with Dr. Atlas

We have had a chance to examine the data reported by Dr. Atlas (RU #29/30) in his 1977 annual report and have observed the following correlations.

1. NEGOA

On the average, we found that the relative level of microbial activity in the offshore water samples was lower than in any other area we have studied. Dr. Atlas has reported that both plate counts and direct counts indicate that the cell concentrations were lower in the offshore water samples than in the Cook Inlet samples. He found that the cell concentrations were also very low in the sediments but we found relatively high levels of activity especially in the sediments to the west of Kayak Island.

2. Cook Inlet (fall, 1976 cruise)

Dr. Atlas reported that viable bacterial counts were higher in the northern Cook Inlet than in the waters to the south. This is the same trend that we have seen in relative microbial activity measurement.

There was a correlation coefficient of 0.85 between his measurements of crude oil degradation potential in water samples and glucose uptake measurements made by us. This trend was not observed in the Beaufort Sea samples analyzed during the summer, 1976 Glacier cruise.

3. Beaufort Sea

In the summer, 1975 study, he reported that the viable counts were higher in the water and sediment of Prudhoe Bay than they were in the samples collected near Barrow. We saw a similar trend in the relative microbial activity data.

Dr. Atlas reported that both direct counts and viable plate counts indicate that the number of bacteria present in the water is lower in the winter than in the summer. This observation is supported by our measurements of relative microbial activity. He also reported that the plate counts indicated that the bacterial concentrations were higher in the sediments studied in the summer of 1975 than in the average winter of 1976. Our direct count data reflects this same trend but the average relative level of microbial activity was one order of magnitude lower in the winter sediment samples. It is quite likely that bacteria were selectively removed from the water column during the freezing process and were still viable but also relatively inactive.

In addition, he reported that the average concentration of bacteria in the sediments was much higher in the samples analyzed in the summer of 1976 than those analyzed in the summer of 1975. Our relative microbial activity data reflects the same trend.

4. Generalized trends

Dr. Atlas has found that the concentration of bacteria in the sediments is much higher than that found in the water column. We have also observed this in our microbial activity measurements. On a volume to volume basis, we find that the activity is roughly four orders of magnitude higher in the sediments.

V. Problems encountered, recommended changes, acknowledgements

A. Problems encountered

Thanks to the excellent logistical support supplied by the Juneau regional office, no serious logistical problems were encountered. Our main problem again centers around the lack of sufficient funds to provide the manpower required to continue our work on hydrocarbon utilization by bacterial isolates taken from the Cook Inlet. The personnel currently available under the present funding schedule are occupied primarily with field study obligations. Because of the long term nature of the work that must be done, enough manpower must be available to insure that these studies are continued at Oregon State during the field operations. Funds have just been received (6/13/77) to remedy this situation.

B. Recommended changes.

None at the present time. See our FY78 OCSEAP research proposal for recommended changes in our research goals for FY78 and beyond.

C. Acknowledgements

We would like to thank the officers and crew of the NOAA ship Discoverer for their assistance during the April, 1977 cruise in the Cook Inlet. We would also like to thank the Chief Scientist (Dr. Jole Cline) for his role in coordinating the requirements of the scientists with the operation of the ship.

We would also like to thank Dr. John Baross of our laboratory (not funded by NOAA) for his analyses of total viable bacterial counts, total viable fermentative bacteria, total vibrio viable counts and sucrose positive vibrio counts in the Cook Inlet sediment samples.

Table 1. Summary of water depth, temperature, and salinity data and positions of stations sampled during the April, 1977 Cook Inlet cruise. Sediment samples having the same number as the listed water samples were taken at the same locations. (*) those stations at which temperature and salinity were determined using a portable field salinometer of relatively low accuracy. (a) those beach samples taken 10 meters offshore. (b) those beach samples taken in the surf line.

Station number	Water Sample number	Depth of water column (meters)	Temperature Surface	Temperature Bottom	Salinity 0/00 Surface	Salinity 0/00 Bottom	Lat. North	Long. West
D *	GW401 (b)	shore	6.5	--	16.5	--	57 39.0	152 31.0
266 *	402	36	1.0	--	21.0	--	60 41.2	151 25.0
265	403	39	0.44	0.38	27.38	27.41	60 34.3	151 51.4
244	404	56	2.21	2.36	30.08	30.21	60 09.6	152 15.0
245 *	405	46	2.9	--	26.0	--	60 06.8	152 14.0
S *	406 (a)	shore	2.8	--	24.5	--	60 10.7	152 36.0
S *	407 (b)	shore	4.5	--	24.0	--	"	"
T *	408 (a)	shore	2.8	--	25.0	--	60 09.3	152 38.0
T *	409 (b)	shore	4.0	--	25.0	--	"	"
242	410	39	2.35	2.33	30.19	30.19	60 09.5	152 25.0
U *	411 (a)	shore	6.0	--	15.0	--	60 12.7	152 36.5
V *	412 (a)	shore	4.0	--	22.0	--	60 13.7	152 46.8
V*	413 (b)	shore	2.0	--	23.0	--	"	"
242	415	33	2.29	2.31	30.11	30.10	60 09.5	152 25.0
242	416	33	2.28	2.29	30.08	30.08	"	"
246 *	417	15	2.5	--	25.5	--	60 03.0	151 46.2
235	418	40	2.81	2.83	30.60	30.64	59 40.8	152 38.6
236	419	48	4.06	3.96	31.41	31.37	59 40.9	151 14.1
227	420	90	4.46	4.36	31.41	31.49	59 33.5	151 36.4
K *	421 (a)	shore	2.5	--	25.5	--	59 36.1	151 25.0
K *	422 (b)	shore	5.0	--	26.0	--	"	"
J *	423 (a)	shore	4.6	--	26.8	--	59 35.3	151 10.7
J *	424 (b)	shore	5.0	--	25.0	--	"	"
229	425	66	4.16	4.11	31.25	31.33	59 37.6	151 18.6
216	426	86	4.95	4.97	31.46	31.46	59 18.2	152 14.1
217	427	74	4.64	4.47	31.47	31.51	59 27.0	152 23.2
226	428	60	4.66	4.66	31.46	31.47	59 33.5	152 18.7
225	429	39	3.68	4.44	31.25	31.48	59 31.4	152 41.5
213	430	33	3.13	3.13	30.98	30.98	59 30.0	153 13.2
214	431	49	3.28	3.27	31.10	31.09	59 18.2	153 14.3
204	432	36	2.72	2.95	30.79	30.91	59 14.2	153 39.7
206	433	39	4.89	4.95	31.51	31.53	59 09.8	153 08.2
212	434	27	2.30	2.48	30.59	30.66	59 32.4	153 21.8
215	435	76	3.41	4.62	31.16	31.51	59 21.9	152 48.7
212	436	22	2.38	2.39	30.68	30.70	59 33.4	153 24.5
208	437	104	4.92	5.39	31.62	31.92	59 14.7	152 45.5
205	438	148	5.00	5.42	31.64	32.14	59 06.3	152 43.1

Table 1 (Continued)

Station number	Water Sample number	Depth of water column (meters)	Temperature Surface	Temperature Bottom	Salinity 0/00 Surface	Salinity 0/00 Bottom	Lat. North	Long. West
207	GW439	148	4.82	5.28	31.67	31.92	58 59.9	152 52.0
395	440	170	--	--	--	--	58 53.0	152 54.0
106	441	202	4.75	5.56	31.49	32.08	59 00.4	152 00.6
105	442	118	4.74	7.49	31.29	32.63	58 50.0	151 20.7
398	443	122	4.69	5.32	31.74	32.11	58 48.8	152 11.9
388	444	169	--	--	--	--	58 28.6	153 10.9
378	445	95	4.22	4.98	31.72	31.95	58 02.0	153 29.5

Table 2. Relative levels of microbial activity and percent respiration of glutamic acid and glucose observed in all water samples collected during April cruise.

		Substrate Uptake		Percent Respiration	
Station number	Sample number	Glucose ng/l/h	Glutamic Acid ng/l/h	Glucose	Glutamic Acid
D	GW401	6.7	38.8	51	76
266	402	8.5	52.4	15	36
265	403	2.7	24.7	17	34
244	404	1.6	14.6	15	31
245	405	1.6	11.7	27	35
S	406	2.6	15.2	19	38
S	407	3.3	25.7	20	44
T	408	2.4	13.5	15	34
T	409	1.1	8.3	17	34
242	410	1.9	15.5	16	32
U	411	7.9	67.7	23	58
V	412	39.7	129	15	50
V	413	18.0	78.9	16	39
242	415	1.8	9.3	5	27
242	416	--	17.9	--	33
246	417	11.5	66.5	14	34
235	418	2.0	6.8	16	34
236	419	0.3	0.9	34	52
227	420	0.4	0.9	26	61
K	421	3.7	8.0	47	53
K	422	6.7	28.1	22	54
J	423	0.5	1.8	41	49
J	424	1.0	4.8	25	58
229	425	0.9	0.9	36	67
216	426	0.3	2.0	47	61
217	427	0.3	1.0	39	64
226	428	0.3	0.7	42	61
225	429	0.6	1.5	36	55
213	430	0.3	1.8	40	41
214	431	0.3	0.5	35	42
204	432	0.8	3.0	34	48
206	433	0.4	0.6	31	56
212	434	1.1	3.8	32	54
215	435	0.5	1.5	37	62
212	436	0.6	2.0	26	40
208	437	0.2	0.8	36	61
205	438	1.0	2.7	36	64
207	439	1.0	2.0	39	67
395	440	0.2	0.7	45	68
106	441	0.2	0.5	39	45
105	442	0.4	2.0	45	72
398	443	0.7	2.9	49	70
388	444	2.0	2.6	16	70
378	445	0.8	2.2	30	62

Table 3. A comparison of glutamic acid uptake in water samples taken in the surf zone and 10 meters offshore.

Glutamic acid uptake (ng/l/h)

Surfline	Offshore
14	4.9
26	5.8
39	21
8.3	0.9
256	236
51	50
3.5	2.1
7.3	0.4
3.3	2.6
2.4	1.1
40	18
6.7	3.7
1.0	0.5

Table 4. Comparison of average values observed in water samples collected during both the October and April cruises. All uptake values are reported as ng substrate taken up per liter of seawater per h.

A Comparison of all stations.

		Fall	Spring
1. Glucose:			
Glucose uptake	offshore	3.0 (1.2 W/O GW322)	1.5
	onshore	30 (20 W/O GW316 and GW317)	7.8
glucose percent respiration		28	29
2. Glutamic acid:			
glutamic acid uptake:	offshore	7.5	7.9
	onshore	85.5 (31.8 W/O GW316 and GW317)	31.5
glutamic acid percent respiration		58	50
glutamic acid/glucose ratios all samples		3.4	4.4

B Comparison of common stations (average figures). Offshore samples only.

		Fall	Spring
1. Glucose: uptake		3.2	1.9
	W/O GW322	(1.2)	(1.5)
percent respiration		31	33
2. Glutamic acid: uptake		8.1	9.9
percent respiration		57	54
Glutamic acid/glucose ratio		3.6	4.0

Correlation Coefficient between fall and spring samples taken at the same station.	glucose = 0.59	glutamic acid = 0.69

Table 5. Comparison of average values observed in sediment samples collected during both the October and April cruises. All uptake values are reported as μg substrate taken up per gr. dry weight sediment per hr.

	Fall	Spring
Comparison of all samples taken		
1. Glucose: uptake	0.012	0.066 0.012 W/O GB444 & GB445
Glucose percent respiration	28	26
2. Glutamic acid: uptake	0.22	1.25 0.39 W/O GB444 & GB445
Glutamic acid percent respiration	46	46
Glutamic acid/glucose ratios	25	33
Correlation coefficient between glucose and glutamate uptake within the same samples	0.702	0.845

Table 6. Relative levels of microbial activity and respiration percentages observed using glucose, glutamic acid and acetate in all sediment samples collected during the April cruise.

		Substrate Uptake			Percent Respiration		
Station number	Samples number	Glucose ng/g/hr dry wt.	Acetate ng/g/hr dry wt.	Glutamic acid μg/g/hr dry wt.	Glucose	Acetate	Glutamic acid
D	GB401	0.6	1.8	0.01	36	73	48
U	" 411	24.0	19.2	0.89	16	75	45
V	412	18.0	7.5	0.66	14	70	37
227	420	18.4	5.7	0.36	16	54	49
K	421	44.8	13.3	1.57	22	32	54
229	425	12.8	6.0	0.30	19	60	45
213	430	3.7	6.7	0.14	36	49	41
214	431	2.0	4.9	0.08	19	63	40
204	432	13.2	7.3	0.37	22	55	46
212	434	6.4	4.6	0.16	32	57	41
212	436	5.1	13.3	0.17	26	62	45
395	440	11.6	9.3	0.27	16	62	45
105	442	1.4	6.3	0.11	23	61	42
388	444	618	72.4	9.22	65	84	57
378	445	211	22.1	10.50	35	44	60

Table 7. A comparison between relative microbial activity measured using simple uptake at one concentration of glutamic acid and the multiconcentration method used to calcualte V_{max} values.

Station number	Sample number	Vmax	Glutamic acid at one concentration	Ratio
		Water		
265	GW403	53.9	24.7	2.2
246	" 417	126	66.5	1.9
214	431	1.2	0.5	2.4
212	434	6.6	3.8	1.7
215	435	2.4	1.5	1.6
212	436	5.7	2.0	2.9
Average				2.1

Correlation Coefficient = 0.998

		Sediment		
212	GB434	0.22	0.16	1.4
212	GB436	0.32	0.17	1.9
388	GB444	20.4	9.22	2.2
Average				1.8

Correlation Coefficient = 1.000

Table 8. Rates of nitrogen fixation observed in sediments collected during the April cruise. The unit of measurement is ng nitrogen fixed per g dry weight of sediment per h.

		Nitrogen fixation rates ng/g dry wt./hr	
Station number	Sample number	Field	Laboratory
D	GB401	0.06	
U	411	0.09	
V	412	0.02	
227	420	0.52	0.65
K	421	1.36	
J	424	0.11	
229	425	0.90	0.90
204	432	0.05	
212	434	0.02	
215	435	0.00	
212	436	0.03	
208	437	0.01	
395	440	0.43	0.39
105	442	0.00	
388	444	0.33	
Average		0.28 ng/g/hr	0.50
Correlation coefficient lab vs. field on four samples		0.96	
Average rate observed in five sediments taken from Yaquina Bay, Oregon		1.07 ng/g/hr	

Table 9. The effects of crude oil on nitrogen fixation rates in sediment samples taken from the Cook Inlet area. Quantities of ethylene production are given as pmoles ethylene produced over the incubation period given per 0.3 ml atmosphere within the reaction vessel. Treatments used (1) no additives, (2) sucrose added, (3) crude oil added, (4) sucrose and crude oil added.

		pmoles ethylene	
Sample number	Treatment	1 day	10 days
411	1	17	66
	2	0	5726
	3	13	86
	4	5	2194
425	1	60	203
	2	70	4233
	3	56	242
	4	73	7343
440	1	38	163
	2	37	1095
	3	26	126
	4	64	1494
444	1	30	149
	2	34	250
	3	33	133
	4	30	199

Table 10. Correlation coefficients observed between measurements made in 16 sediment samples collected during the April cruise.

	Total plate counts	Total fermentative organisms	Total *Vibrio* counts	Total sucrose + *Vibrio* counts	Glutamic acid uptake rates	Glucose uptake rates
Total fermentative organisms	0.98					
Total *Vibrio* counts	0.96	0.99				
Total sucrose + *Vibrio* counts	0.97	0.97	0.97			
Glutamic acid uptake rates	0.61	0.65	0.61	0.59		
Glucose uptake rates	0.92	0.92	0.87	0.86	0.84	
Acetate uptake rates	0.94	0.92	0.87	0.86	0.77	0.97

Table 11. Concentrations of bacteria in water and sediment samples collected during the April cruise as determined by epiflourescent microscopy.

WATER

Sample number	Cells/ml x 10^5	Sample number	Cells/ml x 10^5
GW401	2.4	GW423	1.1
402	17.4	424	1.0
403	23.3	425	1.4
404	10.9	426	2.2
405	17.4	427	1.4
406	19.6	428	1.3
407	32.7	429	0.9
408	14.1	430	1.0
409	12.4	431	1.7
410	12.4	432	1.8
411	17.0	433	1.7
412	96.4	434	1.1
413	138	435	0.8
415	1.0	436	5.7
416	1.1	437	0.9
417	121	438	0.8
418	6.5	439	1.0
419	1.2	440	0.8
420	1.0	441	5.3
421	1.2	442	2.0
422	1.3	443	0.7
Average (all stations) 3.0×10^6		444	1.4
Average (common stations) 1.1×10^6		445	2.0

SEDIMENTS

	Cells/ml x 10^9
GB401	0.4
411	4.8
412	7.1
420	3.6
421	3.1
425	4.8
430	5.9
431	7.3
432	9.2
434	7.2
436	8.9
440	5.8
442	3.3
444	2.1
445	3.1
Average	2.5×10^9

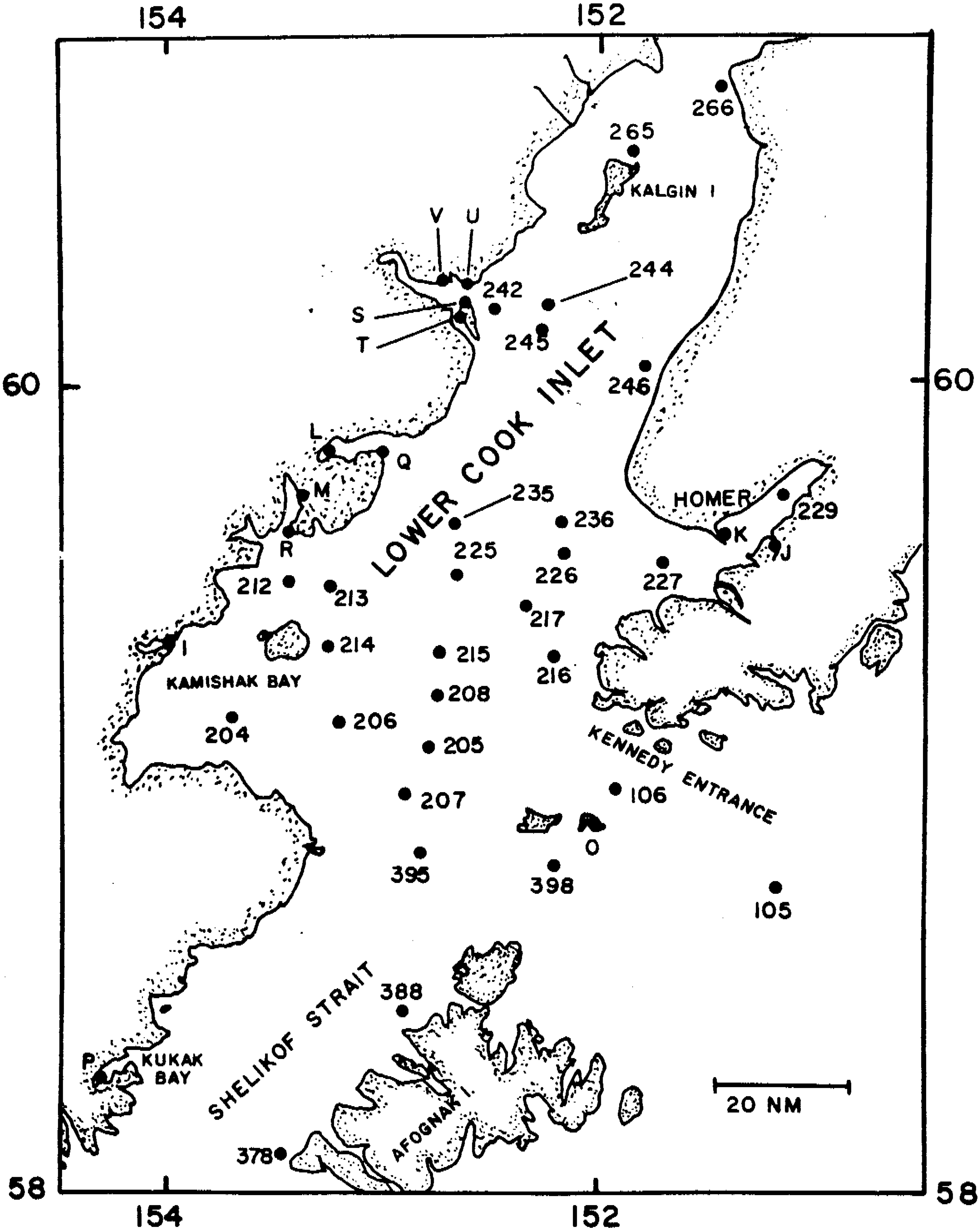

Figure 1. Station locations and numbers for stations occupied in the Cook Inlet area.

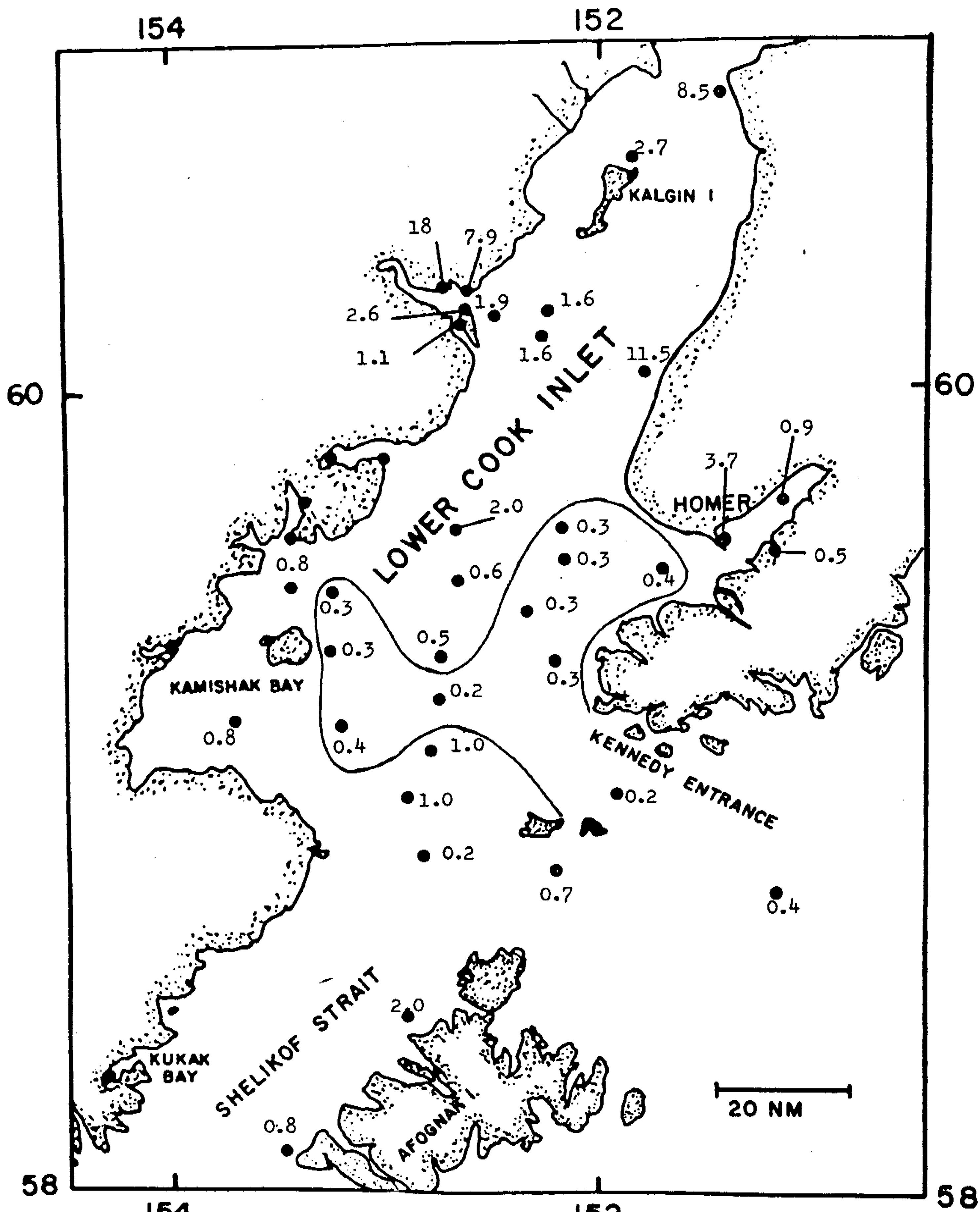

Figure 2. Relative microbial activity in water samples as measured using glucose during the April cruise. The units are reported as ng/liter/h.

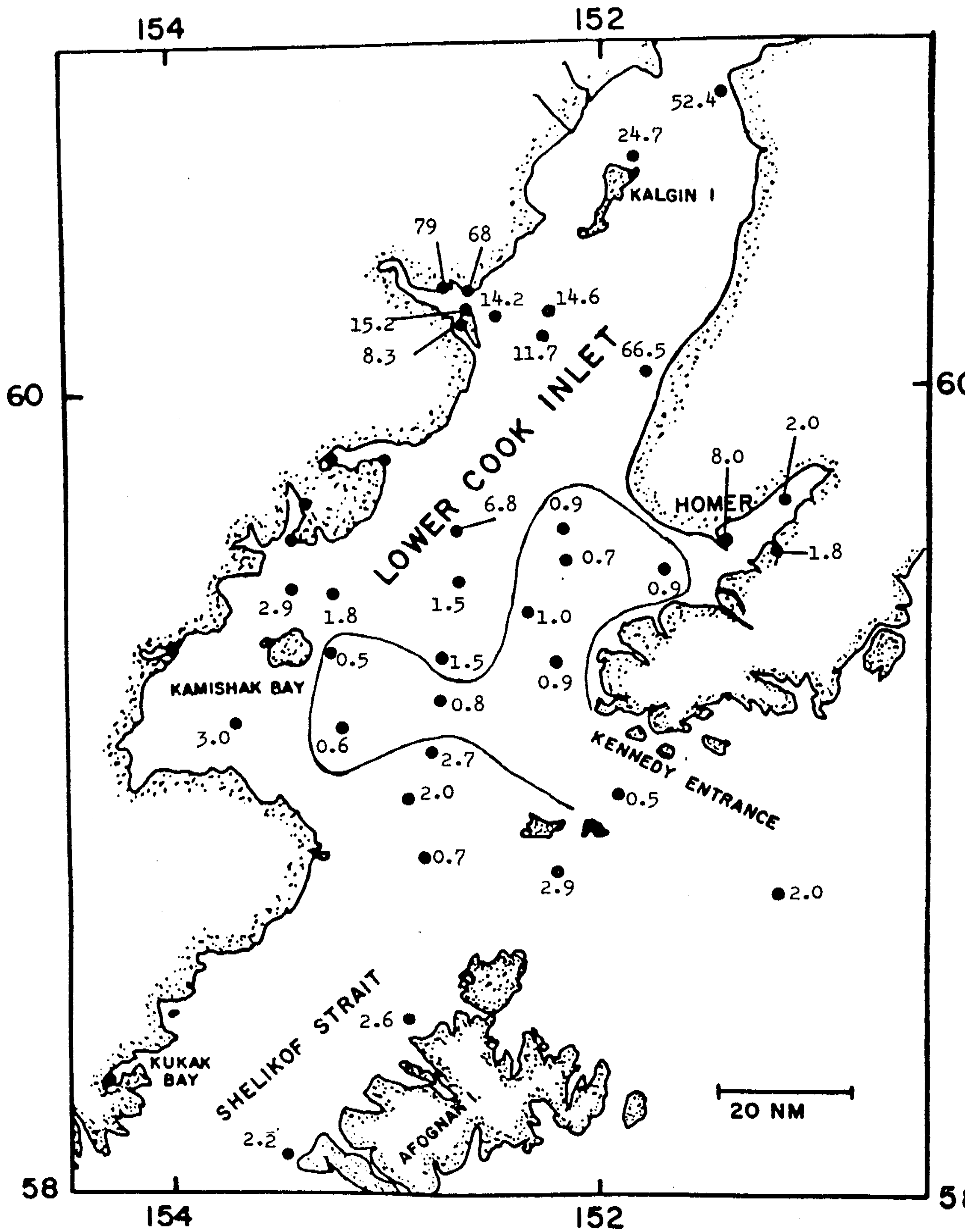

Figure 3. Relative microbial activity in water samples as measured using glutamic acid during the April cruise. The units are reported as ng/liter/h.

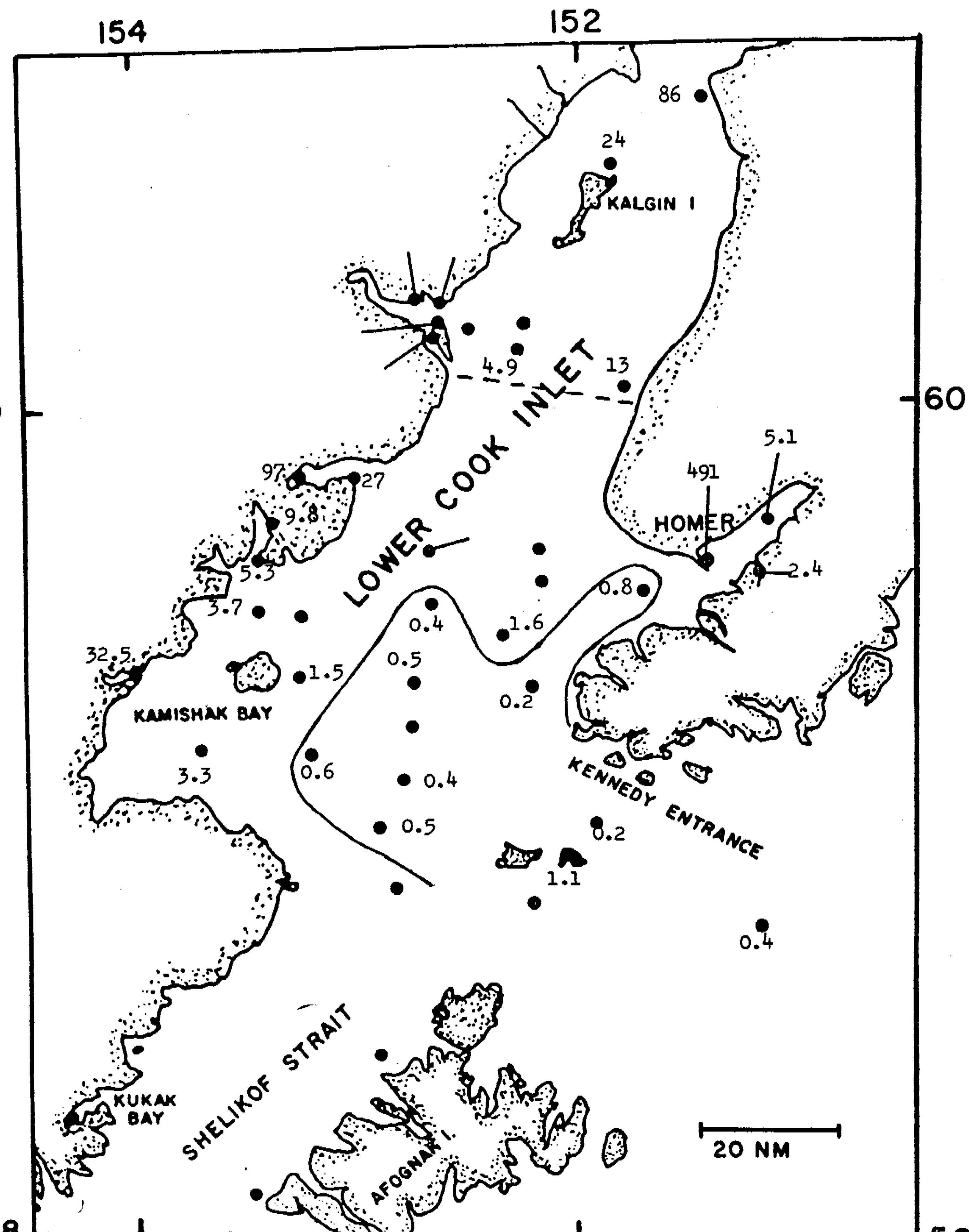

Figure 4. Relative microbial activity in water samples as measured using glutamic acid during the October cruise. The units are reported as ng/liter/h.

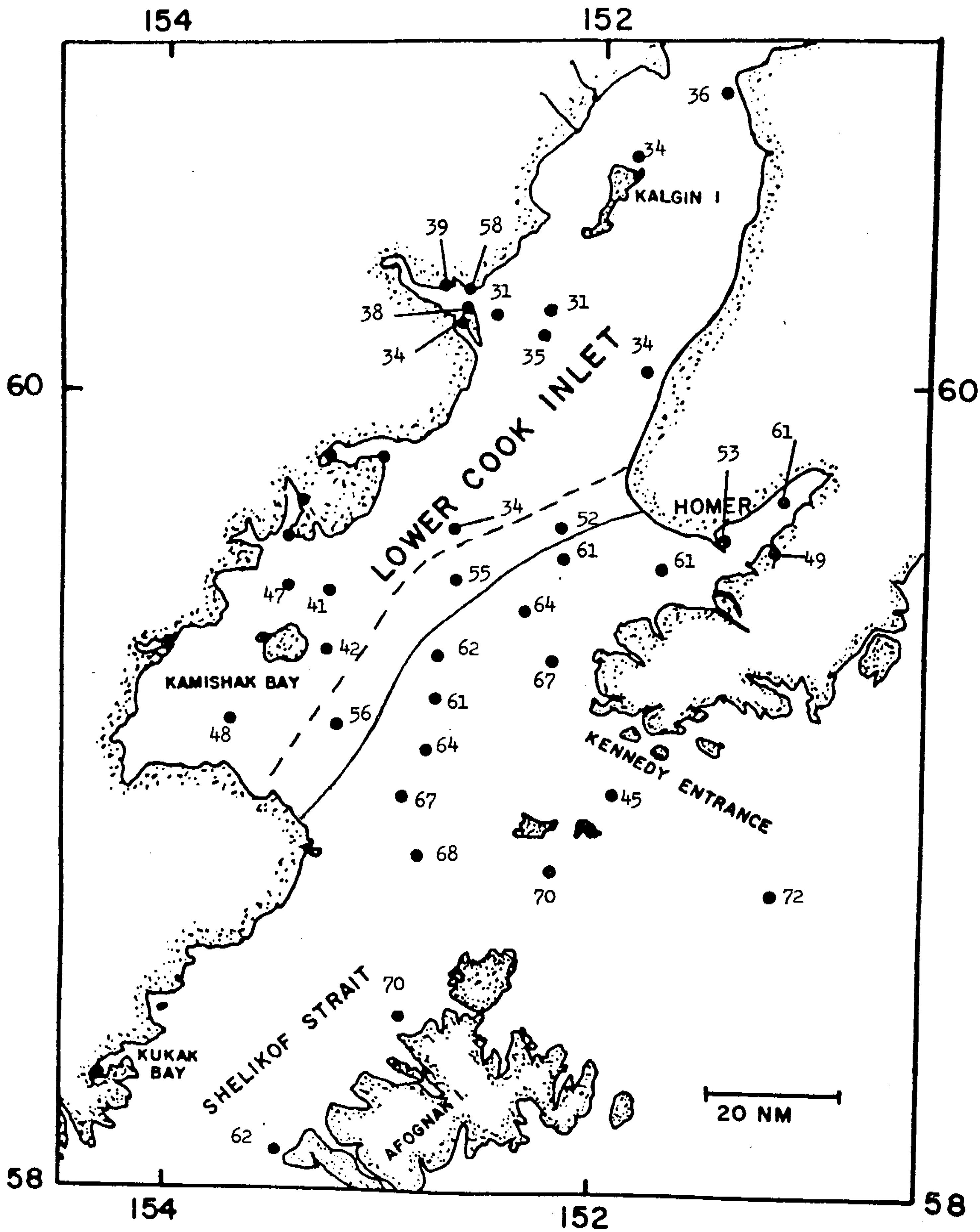

Figure 5. Respiration percentages observed in water samples as measured using glutamic acid during the April cruise.

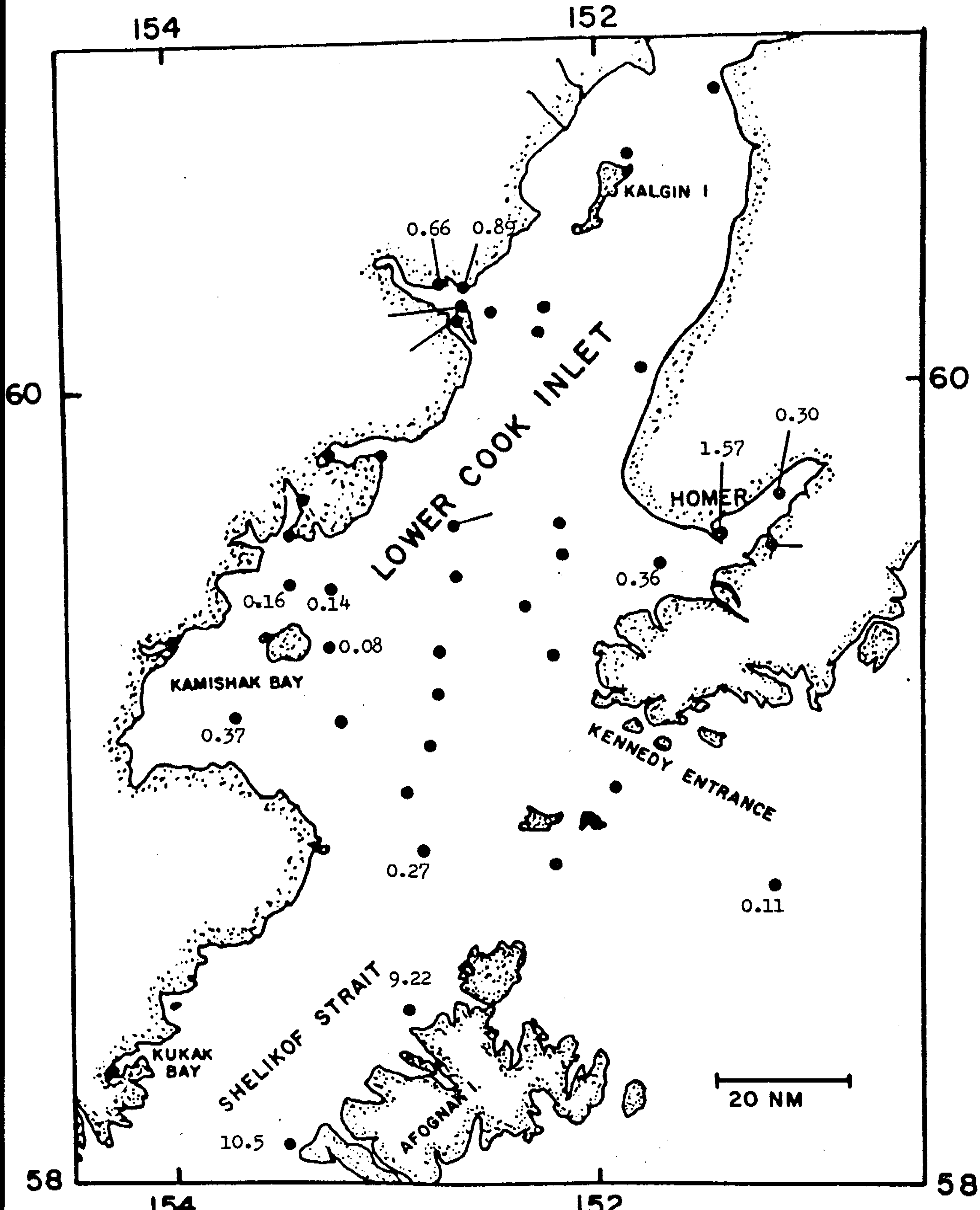

Figure 6. Relative microbial activity in sediment samples as measured using glutamic acid during the April cruise. The units are reported as µg/gram dry weight/h.

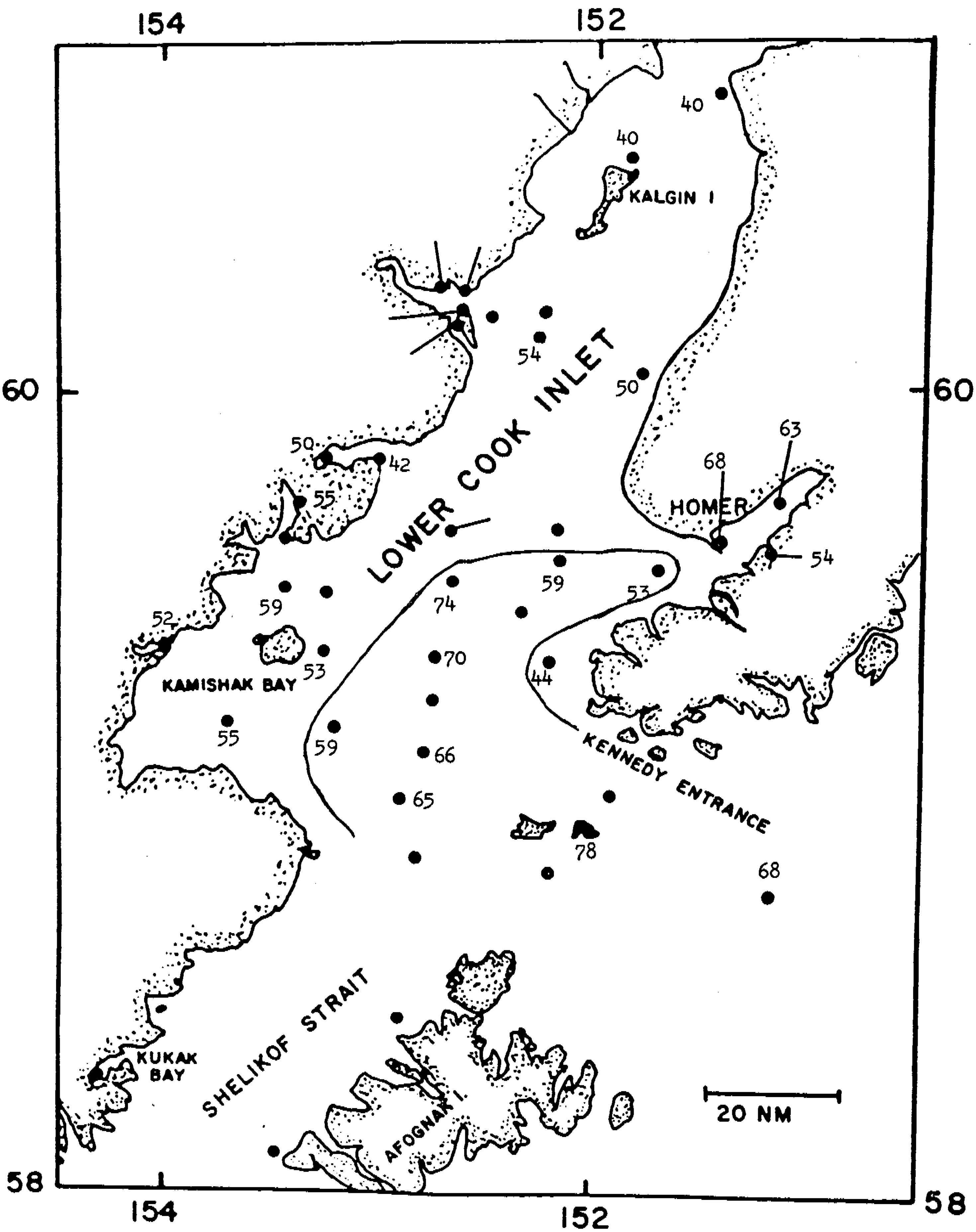

Figure 7. Respiration percentages observed in water samples as measured using glutamic acid during the October cruise.

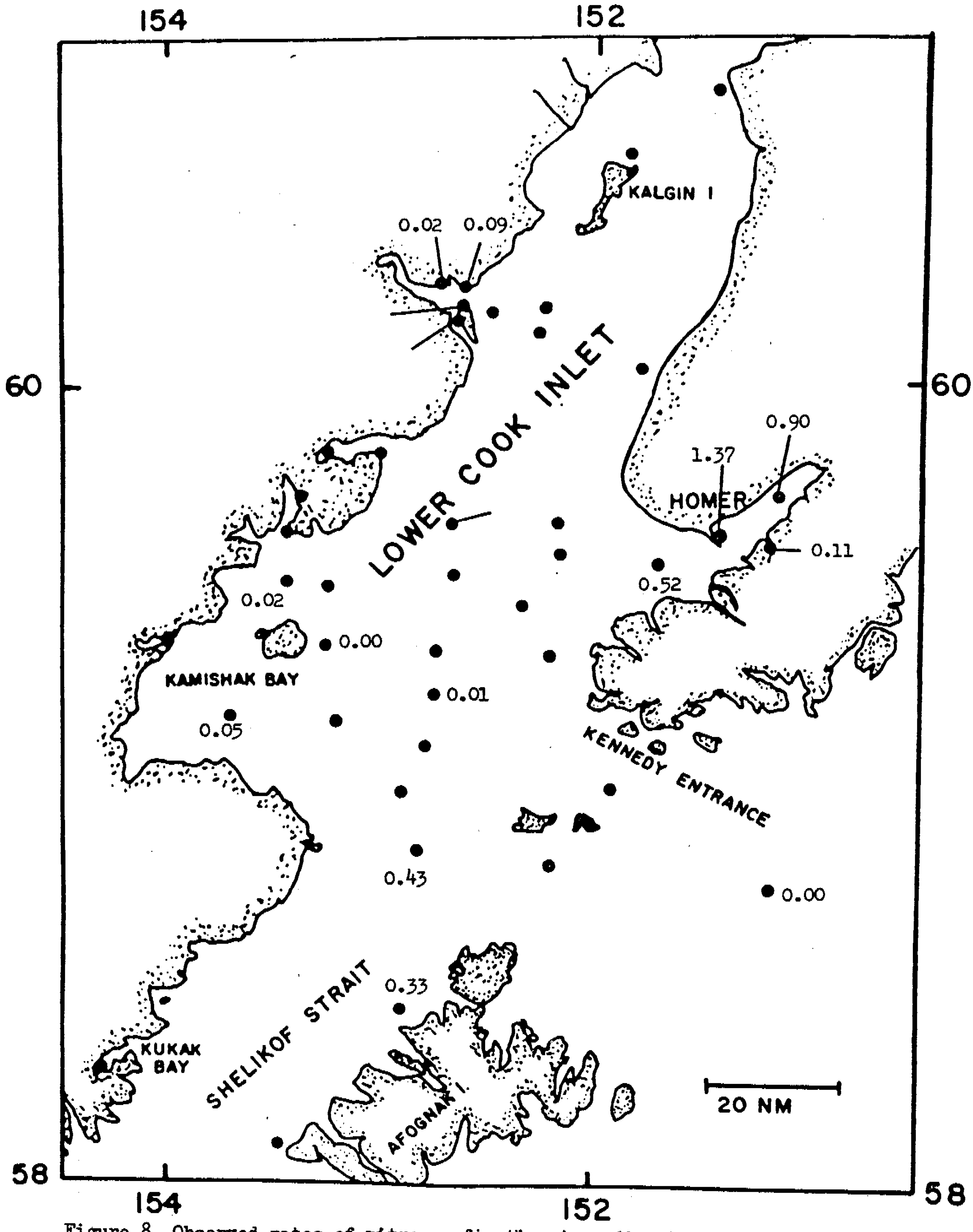

Figure 8. Observed rates of nitrogen fixation in sediment samples collected during the April cruise. The unit of measurement used was ng nitrogen fixed/gram dry weight of sediment/h.

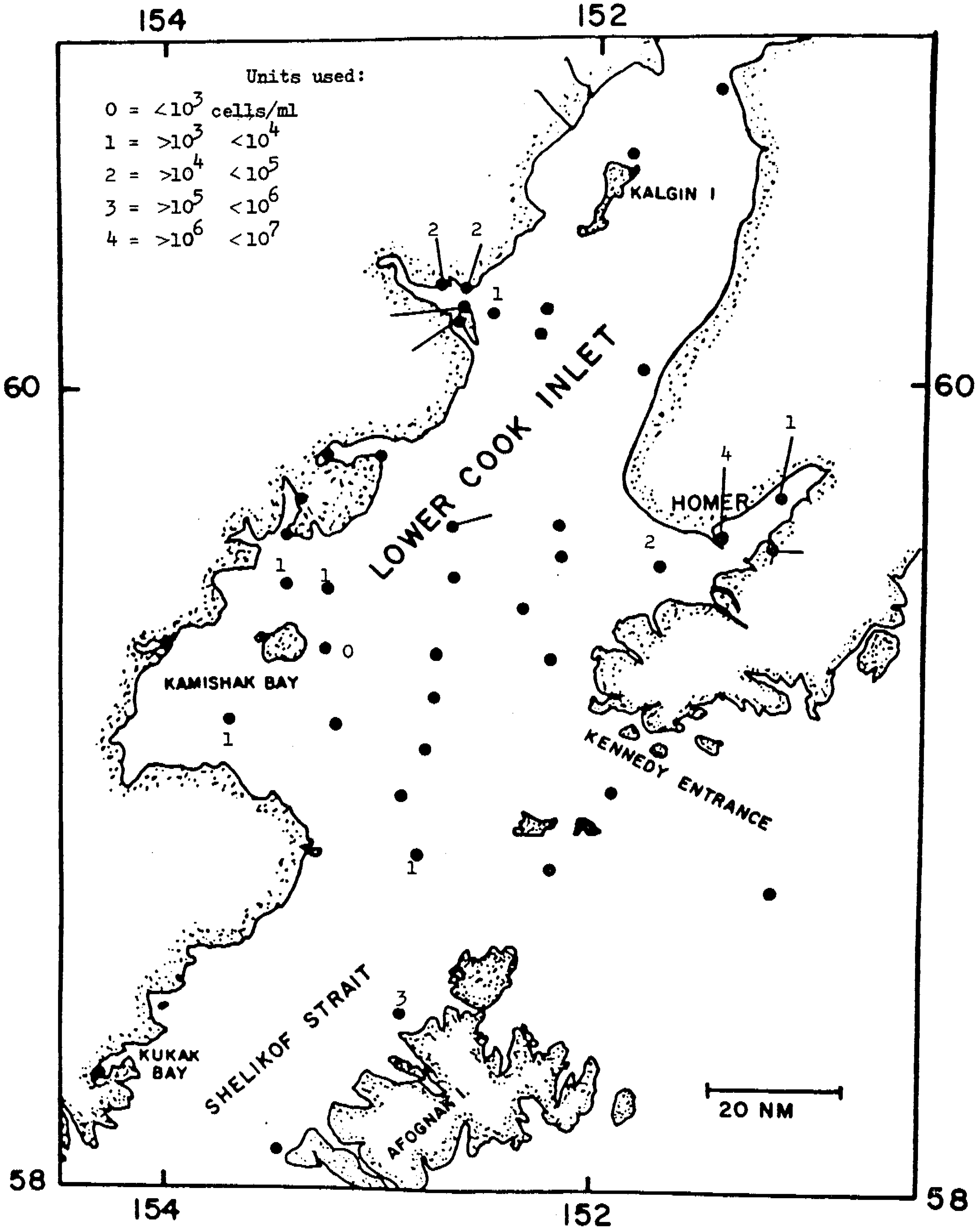

Figure 9. Relative concentrations of Desulfovibrio sp. present in sediments analyzed during the April cruise.

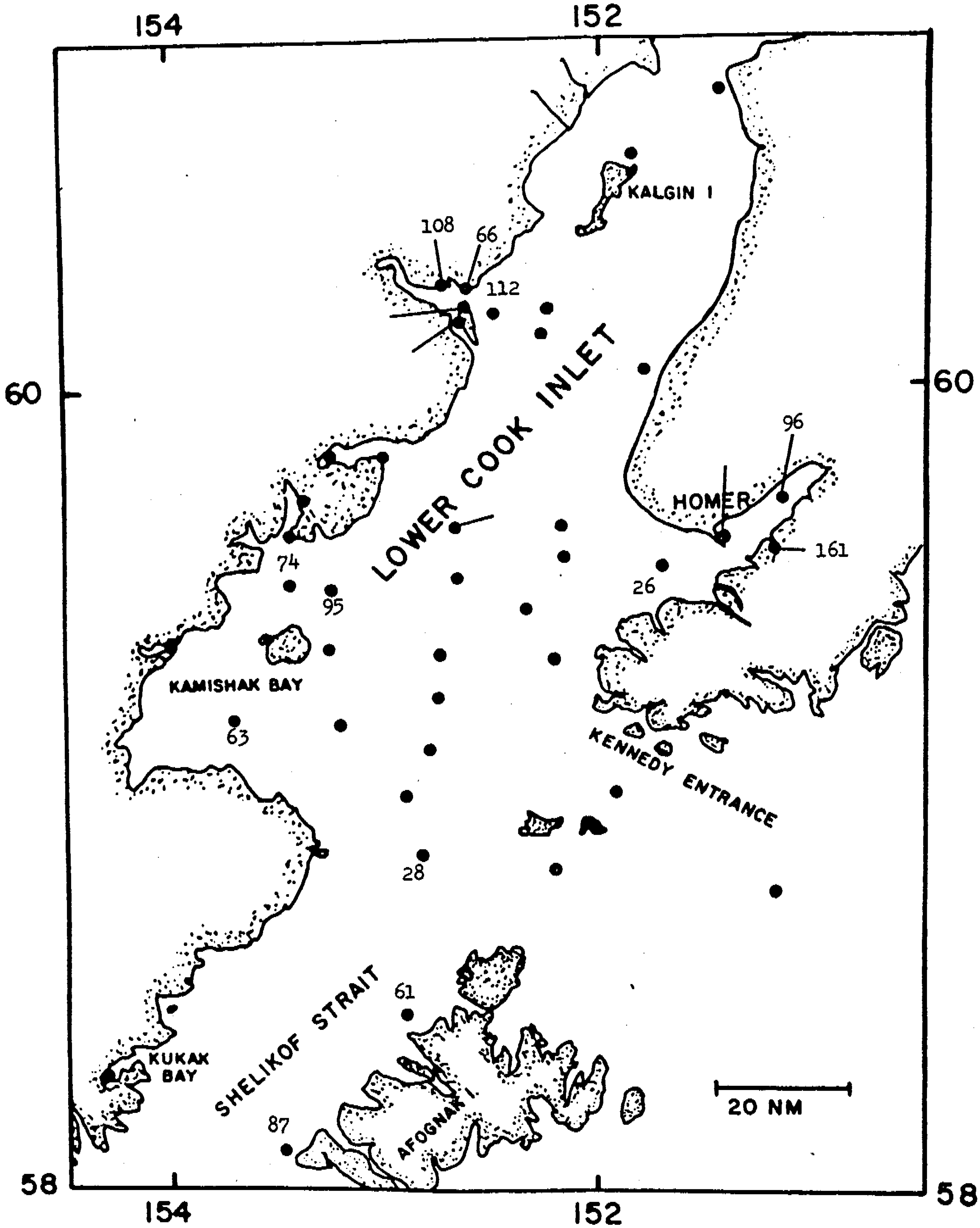

Figure 10. Crude oil degradation potential measurements in sediments collected during the April cruise. Units reported as DPM/ gr. dry weight.

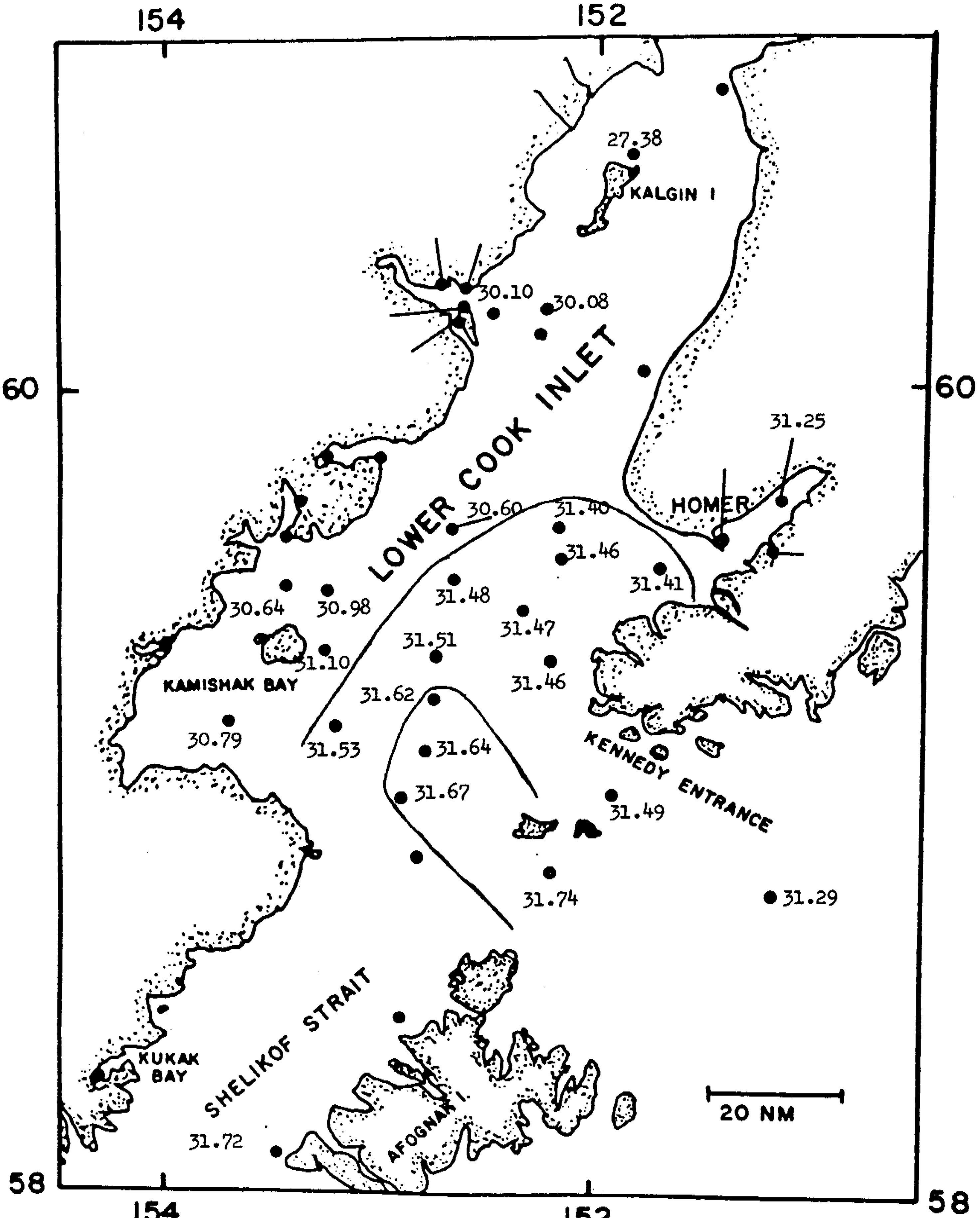

Figure 11. Salinity measurements made in surface water samples analyzed during the April cruise. The unit used is parts per thousand.

DETERMINE THE FREQUENCY AND PATHOLOGY OF MARINE FISH DISEASES IN THE BERING SEA, GULF OF ALASKA, AND BEAUFORT SEA

by

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OUTER CONTINENTAL SHELF ENERGY ASSESSMENT PROGRAM
Sponsored by
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ABSTRACT

Tissue specimens from fish and invertebrates with suspected pathological conditions from the Gulf of Alaska (GOA) and the Norton Sound/Chukchi Sea areas were examined microscopically for histopathological characteristics. Five species of fish from the GOA were found to have tumors. Of these tumors, the pseudobranchial tumors of Pacific cod (Gadus macrocephalus) and walleye pollock (Theragra chalcogramma) and the epidermal tumors of rock sole (Lepidopsetta bilineata) have been characterized previously by us. The remaining tumors, the epithelial tumors of Pacific Ocean perch (Sebastes alutus) and epidermal papillomas of flathead sole (Hippoglossoides elassodon), which had never before been reported in Alaskan waters, were studied extensively. The tumors on all five species had in common the presence of tumor-specific X-cells.

OBJECTIVES

Determine the frequency, geographical distribution, and biological and pathological characteristics of marine fish and macro-invertebrates in Alaskan waters. Also, characterize the microorganisms isolated from diseased animals using standard microbiological procedures.

FIELD AND LABORATORY ACTIVITIES

Ship or field trip schedule

No field trips were undertaken during this quarter, although a 4-week trip aboard the Polish ship the R.V. Professor Siedlecki is planned in July.

Scientific party

Name	Role	% time
Bruce B. McCain, PhD	Principal investigator, coordinates field and laboratory activities, participates in histopathological and microbiological analyses, and writes progress reports and manuscripts.	40

Harold O. Hodgins, PhD	Principal investigator, supervises NMFS investigations and reviews all reports and manuscripts.	10
Mark S. Myers	Performs histopathological analyses of tissue specimens, and participates in data processing.	50
William D. Gronlund	Participates in data processing and analyses of biological data.	25
Katherine King	Invertebrate pathologist, participates in data processing, analyses of biological data, and histopathological examination of invertebrate tissue specimens.	50
S.R. Wellings, MD, PhD	Coordinates histopathological analyses of tissue specimens. (Dept. Pathology, School of Medicine, Univ. Calif.,Davis)	Consultant

Methods

Laboratory activities were mainly concerned with processing the specimens and data obtained during Leg I of Cruise MF-77-1. Tissue specimens from animals with the main pathological conditions to be examined histologically were matched with the photographic colored slides showing the gross appearance of the lesions. Histological procedures were performed and stained sections were examined for histopathology.

The Haul Data and Individual Data Sheets for fish and invertebrates were key punched onto computer cards and analyzed. A new lesion location code and computer format were developed by PMEL (Mr. Dean Dale), approved by OCSEAP personnel, and the data was transcribed to new data sheets and then transferred to computer cards for further analysis.

Sample collection localities

NEGOA

Data collected and/or analyzed

Number and type of samples

Fish and invertebrate specimens processed for histology (58)

Histological slides prepared (350)

Number and type of analyses

Histological slides examined and interpreted (230)

RESULTS

The January-February cruise of the R.V. Miller Freeman in the NEGOA resulted in the finding of tumors in five species of demersal fish; including pseudobranchial tumors of Pacific cod and pollock, epidermal papillomas of rock sole and flathead sole, and, the previously unreported epidermal tumors of Pacific Ocean perch. Because the histopathology of the tumors in Pacific cod, pollock, and rock sole has already been described by us as part of our baseline studies in the Bering Sea, our efforts during the past quarter have emphasized the characterization of the Pacific Ocean perch and flathead sole tumors.

The Pacific Ocean perch tumors, which were located on the inside of the opercula, on the gills, or on the skin surface near the head, had as their predominant cell type, a cell morphologically identical to the X-cells found in the other two types of tumors mentioned above. The tumors were composed of nests of X-cells supported by a thin fibrous stroma and the entire tumor was enclosed by a thin layer of squamous epithelial cells underlaid by a narrow band of connective tissue. The tumors were not invasive; the larger tumors often contained areas of focal necrosis.

The epidermal papillomas on flathead sole were much more heterogeneous in their gross and microscopic morphology than similar tumors on other flatfish species. Some flathead sole tumors had varying forms of the typical papillary arrangement of X-cells and epithelial cells, while one tumor contained large numbers of necrotic X-cells accompanied by a marked lymphocytic infiltration. The latter tumor may be the first documentation of a flatfish epidermal papilloma being sloughed or rejected.

Continued histological examination of tissue from invertebrates from the Norton/Chuckchi areas has revealed no significant histopathology.

PRELIMINARY INTERPRETATION OF RESULTS

At present, at least five species of demersal fish in the GOA have been found by us to have tumors. Other species may likely have significant diseases. For example, three gadids, Pacific cod, walleye pollock, and Atlantic cod (G. morhua), are known to have pseudobranchial tumors; therefore, other gadids in the GOA, such as hake (Merluccius productus) may have such tumors. One species of Sebastes in the GOA, Pacific Ocean perch, has been found with X-cell-containing tumors; it is possible that other of the many species of rockfishes may also have such tumors.

Unfortunately, all of the Pacific Ocean perch tumors were found in one haul, the only haul in which this species was captured during the leg of the cruise in which we participated. Since 4 of 19 (26%) fish had tumors, the prevalence of this tumor may be quite high; however, more extensive examination of this species needs to be performed in order to determine the prevalence, geographical distribution, and effects on the host fish of these tumors.

It seems clear from our limited sampling in the GOA that additional baseline fish disease studies are necessary, both for further defining known diseases and for finding additional species with pathological conditions.

PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES -- None

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ESTIMATE OF FUNDS EXPENDED

Salaries	$25,200
Travel	1,900
Services	1,200
Supplies	2,800
GRAND TOTAL	$31,100

QUARTERLY REPORT

Contract
Task Order No. 1
Quarter Ending June, 1977
Research Unit No. 427

BERING SEA ICE-EDGE ECOSYSTEM STUDY: NUTRIENT CYCLING AND ORGANIC MATTER TRANSFER

Dr. V. Alexander
Dr. R. Ted Cooney

University of Alaska
Institute of Marine Science
Fairbanks, Alaska 99701

30 June 1977

I. TASK OBJECTIBES

To study the dynamics of phytoplankton and zooplankton along ice margins, especially during the period of retreating ice pack, in the Bering Sea. The purpose is to assess the significance of the ice edge in the seasonal production regime. Comparative studies during ice-free periods allow estimates of the relative importance of non-ice-dominated periods. The role of populations of organisms on and adjacent to the underside of the ice is included. Transfer rates of carbon from the lowest trophic level to grazers is being studies. All of the above will be examined and interpreted in the light of potential impact of development.

II. FIELD ACTIVITIES

A. The major cruise activity during this quarter has been two legs aboard the *Surveyor*. The dates were March 12 - April 7 for Leg II and April 13 - May 2 for Leg III. An additional cruise aboard the *Discoverer*, Leg IV, was undertaken from May 20 - June 11.

Helicopter activities utilizing a UH1H helicopter flying from Nome were carried out during the first week of April. The purpose was to determine the extent, patchiness and intensity of ice-related primary production along the Bering Sea shelf, and this was to tie in with simultaneous work being done on the *Surveyor*.

B. Phytoplankton personnel aboard during Leg II of the *Surveyor* cruise were David Brickell and Tom Chapman. Zooplankton personnel were Ted Cooney, Liz Clark and Ken Coyle. Phytoplankton personnel aboard Leg III of the *Surveyor* were David Brickell, Tom Chapman, and Linda Schandelmeier and zooplankton personnel on this leg were Ken Coyle, Pat Wagner, and Liz Clark. Personnel for the *Discoverer* cruise included David Brickell and Lewis Molot for phytoplankton studies and Ken Coyle and Sid Bertz representing zooplankton efforts.

For the helicopter work, Carl Tobin was the scientific party.

C. Sampling was carried out as before, primarily using the rosette sampler with Niskin bottles for the phytoplankton and nutrient work. Diving operations were included for sampling and observing under-ice and in-ice algal production. One difference from previous work was the availability of sophisticated pigment analysis equipment including a new prototype *in situ* fluorometer for monitoring chlorophyll levels in the sea water column, and also a new Turner-Designs fluorometer for continuous monitoring of surface chlorophyll concentration. This made it possible to carry out the survey portion of the work in a more efficient manner. Also, we had on board instrumentation for measuring incoming radiation and light levels within the water column and under ice.

Animal plankton and micronekton were sampled in vertical closing 1-m net tows (25-m increments between the sea bed and surface), in horizontal or open double oblique bongo tows, and with a 2-m Tucker (NIO) midwater trawl. A small double-net newston trawl was also used when ice conditions and weather permitted. For grazing experiments, animals were quickly removed from catches gently sorted, and introduced into experimental containers. Catches for counts, species identification, and dry weight determination were preserved in 10 percent buffered seawater. A small number of under-ice samples were obtained by divers towing the newston nets under the pack.

For the UH1H helicopter work, sampling was done by SIPRE corer, and samples were taken by slicing from the end of the core in contact with the seawater, thawing it and analyzing for the concentration of chlorophyll *a*. Samples were taken from the water below the ice for nutrient analysis.

D. Cruise Track

Tracklines for two legs of the *Surveyor* cruise (II & III) included a transect of stations at 60 mile intervals approaching the ice edge, a series of 48 to 72 hour stations along the ice edge and stations at 60 mile intervals directly away from the ice edge. From Unimak Pass, *Surveyor* II cruise track approaches the western ice edge at 59°N/173°W, where the first of four 72 hour ice stations was occupied. Succeeding stations were occupied within the ice in an easterly direction at 58°N/170°W, 58°N/165°W, and 58°N/162°W into Bristol Bay. The ice was sampled by Sipre coring at four mile intervals from the edge at ice station II into the pack ice with the aid of the ship's helicopter. Stations again were occupied at 60 mile intervals in a transect departing the eastern ice edge towards Unimak Pass.

The *Surveyor* III cruise track followed a reverse path with a transect to the eastern ice edge in Bristol Bay, three 72 hour ice stations running to the western ice edge, and again stations at 60 mile intervals away from the western ice edge at 59°N/174°W toward Unimak Pass.

Discoverer VI cruise track extends from Unimak Pass to St. Paul Island with stations at 60 mile intervals, and continues with stations 50 miles apart to the ice edge northwest of St. Mathew Island. Five ice stations were occupied southeast along the ice edge to Nunivak Island and a transect departing the ice edge with stations at 60 mile intervals to Unimak Pass.

The pack ice study in the northern Bering Sea was accomplished with the aid of a UH1H helicopter in an area between Norton Sound and St. Lawrence Island. Concentrated sampling centered at approximately 64°N/166°W with trackline radiating from south to west of this location and stations sampled at 20 mile intervals.

E. Total number of samples and types

	STATIONS/SAMPLES			
	SV-II	SV-III	DS VI	UN1H
Chlorophyll - by fluorometer	16/130	14/112	19/142	89/89
- for calibration	4/ 31	4/ 28	8/ 36	
Nutrients	16/132	14/117	23/168	16/16
Primary Productivities:				
24 hr. experiments	14/ 72	14/ 72	17/ 85	
6 hr. experiments	3/ 15	2/ 10	2/ 10	
fractioning	3/ 15	2/ 10	2/ 10	
nutrient depletion	1/ 5	3/ 4	5/ 32	
pH and Alkalinity	14/ 72	14/ 72	17/ 85	
Oxygen	12/ 85	10/ 83	5/ 47	
Preserved phytoplankton	15/ 87	14/ 97	16/ 74	
Phytoplankton net tows		12/ 12	23/ 23	
60-cm bongo net	/ 24	/ 23	/ 14	
50-cm neuston net	/ 7	/ 2	/ 0	
1-m net	/ 37	/ 40	/ 54	
2-m Tucker trawl	0	0	/ 15	
105 KHZ Analogtraces	/ 25	/ 15	/ 16	
105 KHZ tape recordings	/ 16	/ 15	/ 12	

	STATIONS/SAMPLES			
	SV-II	SV-III	DS VI	UN1H
Light profiles	10-	6-	3-	
Daily light integrations	18 days	15 days	12 days	
Surface Chlorophyll monitoring	150 hrs.	120 hrs.	160 hrs.	
Ice sampling stations	3-	3-	5-	
Particle Counts			23/72	
Lugol experiments			1/ 3	
Grazing experiments			5/26	

In addition, the usual CTD parameters plus fluorometer chlorophyll concentrations were recorded on mga tape for all hydrocast stations. The current status of all samples collected on OCS cruises to date are:

1. All nutrient samples collected during 1976 have been analyzed.
2. Chlorophyll data for all cruises up to the current year have been analyzed.
3. Phytoplankton samples for all 197o work have been counted.
4. Alkalinity data for all 1976 cruises is complete.
5. All primary productivity data for 1976 is worked up completely.
6. Synthesis work on the phytoplankton productivity and distribution data has been initiated, includijg cluster analysis for phytoplankton population structure, and regional and seasonal alanysis for the primary productivity data.
7. Modeling of the ice edge community by Dr. Katherine Green has involved completion of the phytoplankton portion and incorporation of all 1975 cruise data on primary production and chlorophyll.
8. All zooplankton and micronekton samples gathered in 1976 have been processed.
9. Statistical analyses and data description are currently being prepared for zooplankton collected in the southeastern Bering Sea during the 1975-76 field season as part of a final report.

III. RESULTS AND INTERPERTATION

Laboratory analyses of this year's samples are not complete therefore the following results are preliminary and based on field observations.

A. *Surveyor*, Leg II - March 12-April 7, 1977

Phytoplankton activity appeared to be minimal with very low chlorophyll concentrations in the water column at all stations including those not affected by ice cover. The water over the shelf appeared to be well mixed to approximately 50 m depth. The 1% light depth occurred at about 25 meters. The only station showing a slight increase in chlorophyll concentration occurred with a bottom depth of 28 meters where the mixed layer occurred within the euphotic zone.

Light beneath the pack ice was measured to be less than 1% of the sub-surface light, while slush-ice allowed approximately 10% light penetration. Obviously ice cover does restrict phytoplankton growth in the water column beneath it through light limitation. Those areas not covered by ice did not, however, have any greater standing crop of phytoplankton as estimated by chlorophyll concentration. This suggests that production in the water column at this time is restricted by yet other factors: either not enough incident radiation to initiate a bloom, or that wind mixing is carrying the cells out of the euphotic zone. Based on previous data it is doubtful that nutrient limitation is responsible.

Ice appears to contribute to initial production at the ice edge by maintaining the plant cells in the well-lighted surface zone. Slush, resulting from collisions of ice chunks during storms, was observed to contain great quantities of plant cells. Buoyed by the slush these cells were exposed to maximum light and appeared in sufficient quantities to give an observable tint to the surface slush over large areas. This coloration was documented with aerial photographs from the helicopter. This early cruise was requested to describe the contintuancy and abundance of animal plankton and micronekton prior to the onset of the spring bloom. In cases where a two layered water column was present, at least 90 of the animal plankters (both number and kind) occurred in the deeper (>90 m) and warmer (>1.0°C) layer; there was little evidence of vertical migration at night across the well developed thermocline. Several well defined sonic scattering layers were present and most clearly defined during the daylight hours. The under-ice community in the water column (neustons tows was very sparse). We observed no fish eggs.

Freezing conditions and the fact that the vessel was operating in the "closed" pack greatly hampered the net sampling efforts.

B. *Surveyor*, Leg III - April 13-May 2, 1977

In general, phytoplankton activity in the vicinity of the ice edge showed only a slight increase since last leg. This was in sharp contrast to our observations of the ice edge bloom phenomenon last year at this time when a truly explosive bloom was occurring in the surface waters near the ice edge. Significant chlorophyll was observed only at the easternmost ice station in relatively shallow water (about 60 meters) and again at the deep water station quite far from the ice edge. Other ice appeared to have a moderate quantity of algal growth. Light measurements at the ice stations indicated that 1% light depth occurred in the vicinity of 50 meters.

This appeared to be the result of less sediment in the water column than on the previous leg. At those stations where moderate chlorophyll concentrations were observed, chlorophyll appeared relatively uniform throughout the water column in contrast to the sharp stratification in the near surface waters as previously observed. We have felt that one major influence of partial ice cover has been the enhancement of primary productivity by exerting a stabilizing influence on the water column, allowing a bloom to begin by restricting the influence of wind mixing. This hypothesis is supported by our observation of a narrow, vertical band of production which moves down the water column away from the ice edge as the surface waters are nutrient depleted. One possible explanation for the absence of a bloom at this time may relate to the fact that there is less ice cover this year than in previous years. Considerably more of the shelf is exposed to wind mixing, including the "ice edge" area; therefore, the ice cover is freer to shift about. It appears that the water is being exposed to frequent wind mixing and that the ice cover is not effectively stabilizing the water column to allow a bloom to begin.

Seventy different phytoplankton species were identified from preliminary examination of tows and ice samples. A detailed analysis of the preserved samples will undoubtedly yield other species. Diatoms comprised approximately 90% of the phytoplankton population, with members of other groups present in varying amounts at different stations. The species composition of the phytoplankton changed slightly at each area sampled, with some new species added and others dropping out, or with relative abundances of the species shifting. Stations with low phytoplankton numbers seemed to contain larger percentages of dinoflagellates relative to the number of diatoms. Microflagellates, which are an important part of the phytoplankton population, could not be accurately surveyed with the microscope available.

A diverse population of diatoms was found living in and under the ice and in slush. *Thalassiosira spp.*, *Melosira sulcata*, and *Nitzschia spp.* (*Fragilariopsis*) were abundant in the ice, and more than 20 genera were represented in a cursory and very preliminary examination. Unlike the earlier situation, the animal plankton community appeared to be somewhat more randomly distributed in the water column during the daylight hours with some evidence of vertical migration to the surface in the evening. Samples taken after sonic layers had moved into the surface waters suggest that large amphipods and euphausiids were probably responsible for backscattering at 105 KHZ at this time.

Observations made along transects to each from the edge zone seemed to indicate the pelagic fauna occurring at the edge is identical with or closely related to the communities of the open shelf well removed from the ice.

C. *Discoverer*, Leg VI

Whereas little phytoplankton activity was observed during the earlier cruises aboard the *Surveyor*, we did observe the beginning stages of an ice bloom on this cruise. The character of the bloom appeared to be less intense than that observed in other years and is probably related to the variation in the extent and nature of ice cover.

The more southerly areas not covered by ice this year do not appear to have the well defined bloom that was observed in these same areas as the ice front receeded in the past.

The *in situ* fluorometer played a valuable role in this season's research. A deep chlorophyll layer near the bottom has been observed over the shelf area in past years, notably aboard the *Alpha Helix* cruise in 1974. With the *in situ* fluorometer we were able to observe the sinking of a tongue of cold chlorophyll-rich surface water from the vicinity of the ice edge as we proceeded from the ice edge toward open water.

The ice itself showed little evidence of phytoplankton activity which is probably associated with melt conditions. Since the plant cells occur in brine cells and channels of the ice it appears that once the ice begins to melt that the cells are no longer able to thrive in the lower salinity melt water or that the cells are flushed from the ice.

On this third and last cruise, zooplankton and micronekton populations were observed to participate more actively in diel vertical migrations than had been the case earlier in the spring. During the evening tows, the animals tended to concentrate near the surface while during the day, populations appeared to be more dense at depth.

Several grazing experiments were conducted to further test the feasibility of techniques planned for extensive shipboard experimental work this coming year.

D. UH1H Helicopter Work

The pack ice sampled from the UH1H helicopter in the northern Bering Sea showed ice thickness to vary from 1 to 3 meters over small areas.

Chlorophyll *a* concentrations were extremely variable and patchy throughout the ice with some concentrations being 5 to 7 times that found in open water. Nutrient samples were taken from water just under the ice. Nutrient and chlorophyll data will be correlated with that of the ice edge.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

Our shifting requirement to examine more closely some quite restricted regimes for extended times has caused some difficulties in integrating with the marine bird and mammal surveys. We recommend that in the future, work at the ice edge be arranged so that each leg would have a primary mission and that other work would be accepted on a "not-to-interfere" basis only. The legs could then alternate, plankton and higher trophic levels, with enough overlap (observers) to maintain continuity if desired. This will be an increasingly more important consideration as the plankton experimental work develops this coming year.

CONTAMINANT BASELINES

CONTAMINANT BASELINES

QUARTERLY REPORT

Contract #01-6-022-11469
Research Unit #43

Reporting Period
April 1, 1977 - June 30, 1977

Stephen N. Chesler
Harry S. Hertz
Willie E. May
Stephen A. Wise

Trace Organic Analysis Group
Bioorganic Standards Section
Analytical Chemistry Division
National Bureau of Standards
Washington, D. C. 20234

June 30 1977

I. TASK OBJECTIVES

The task reported herein relates to serving as a quality assurance laboratory for hydrocarbon analyses of marine waters, sediments and tissues. This objective is being met by: 1) Conducting a second series of interlaboratory comparisons on sediment; 2) Conducting an interlaboratory comparison study on tissue samples of *Mytilus* homogenized by NBS; 3) Acting as a sample-split coordinating-laboratory (10% of all samples collected by NOAA P.I.'s will be sent for NBS analysis and/or redistribution); 4) Acting as a consultant laboratory to other NOAA P.I.'s involved in hydrocarbon analysis.

II. FIELD AND LABORATORY ACTIVITIES

Laboratory activities during this quarter included NBS analysis of the second sediment intercomparison material and experiments on homogenizing *Mytilus* samples for the upcoming round robin exercise.

Revised Milestone Chart

1) Send homogenized *Mytilus* tissue to participating laboratories. 8/77
2) NBS report to NOAA on results of second sediment intercomparison exercise. 10/77
3) Return of mussel intercomparison exercise

results to NBS and completion of detailed laboratory analysis by NBS. 11/77

4) NBS report to NOAA on results of *Mytilus* intercomparison exercise. 2/78

III. RESULTS

A. Second Sediment Intercomparison Exercise

NBS has completed its laboratory analysis of the second sediment intercomparison sample (supplied by Dr. Kaplan). Results of this exercise will be discussed in the next quarterly report. At that time we will have completed evaluation of the data received from the participating laboratories. The following laboratories have not yet submitted results of their analyses:

Dr. John Farrington, Woods Hole Oceanographic Institution

Dr. Isaac R. Kaplan, UCLA

Dr. David Schultz, USGS-Reston

B. *Mytilus* Homogenization Studies

Large scale (∿ 1 kg) homogenization, freezing and thawing studies of both Alaskan and Santa Barbara *Mytilus* samples have been satisfactorily completed. *Mytilus* samples were homogenized using an ultrasonic probe and then aliquoted for freezing and subsequent analysis. Hydrocarbon levels were consistent over the various aliquots and over the sample storage period (one day to one month).

IV. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

The problems we encounter continue to be the same as mentioned in earlier reports. We still have not received any sample splits from the other hydrocarbon investigators.

V. ESTIMATED FUNDS EXPENDED

Approximately $102K have been spent through June 30, 1977.

Quarterly Report

Research Unit: #152
Reporting Period: 4/1/77 - 6/30/77
Number of Pages: 13

The Distribution, Composition, Transport and Hydrocarbon Adsorption Characteristics of Suspended Matter in the Gulf of Alaska, Lower Cook Inlet and Shelikof Strait

Principal Investigators: Richard A. Feely, Oceanographer
Joel D. Cline, Oceanographer

Pacific Marine Environmental Laboratory
3711 15th Avenue N.E.
Seattle, Washington 98105

June 30, 1977

I. Task Objectives

The major objectives of the suspended matter program include: (1) determination of the seasonal variability of the distribution and composition of suspended matter in Lower Cook Inlet and Shelikof Strait; (2) an investigation of the processes controlling resuspension and redistribution of bottom sediments; and (3) an investigation of the adsorptive characteristics of Cook Inlet suspended matter for crude oil.

II. Field or Laboratory Activities

A. Field Activities

1. Ship Schedule

   a. DISCOVERER Cruise (RP-4-Di-77A-III, 14-31 March 1977)

   b. DISCOVERER Cruise (RP-4-Di-77A-IV, 4-16 April 1977)

   c. MILLER FREEMAN Cruise (RP-4-MF-77B-III, 6-11 June 1977)

2. Participants from PMEL

   a. Dr. Richard A. Feely, Oceanographer

   b. Dr. Joel D. Cline, Oceanographer

   c. Ms. Jane Fisher, Oceanographer

   d. Ms. Joyce Quan, Physical Science Technician

   e. Ms. Marilyn Pizzello, Physical Science Aid

3. Methods

   a. Particulate Matter - Water samples were collected in 10-liter top-drop Niskin bottles and filtered under vacuum through preweighed 0.4 μm Nuclepore and Selas silver filters. The filters were removed from the filtration apparatus, placed into individually marked petridishes, dried in a desiccator for 24 hours and stored for shipment to the laboratory.

b. Nephelometry - The vertical distribution of suspended matter was determined with a continuously recording integrating nephelometer. The instrument is interfaced into 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 7044A X-Y Recorder. The signals from the CTD-Rosette system and the nephelometer were also simultaneously interfaced into the ship's data acquisition system. This resulted in computor listings of conductivity, temperature, depth, salinity, sigma T and light scattering for all of the stations.

c. Petroleum Hydrocarbon-Suspended Matter Interactions - Gram quantities of suspended matter were extracted from Lower Cook Inlet using a continuous flow centrifuge (operating conditions: 500 ml/min @ 17,000 rpm). The suspended matter was placed into 500 ml glass bottles with aluminum lined plastic caps and returned to the laboratory for subsequent interaction studies with Cook Inlet crude oil. In addition, water samples from station 3 were placed into 250 ml and 1000 ml separatory funnels to which 10 μl, 20 μl, and 30 μl aliquots of Cook Inlet crude oil were subsequently added. The mixtures were placed into a subambient temperature bath (maintained at 4.0°C) and shaken for one hour. The samples were then allowed to stand for about two hours until all the oil-sediment flocculents had settled. The flocculents were separated from the water and both were subsequently extracted with methylene chloride and returned to the laboratory for gravimetric and GC-MS analysis.

4. Sample Locations

Figures 1 and 2 show the locations of the suspended matter stations in the northeastern Gulf of Alaska (DISCOVERER Cruise RP-4-Di-77A-III) and Lower Cook Inlet and Shelikof Strait (DISCOVERER Cruise RP-4-Di-77A-IV). In Figure 1 stations B and D are the locations of the arrays which contain the current meters, nephelometers, and sediment traps.

5. Data Collected

Particulate matter samples were collected from 8 stations in the northeastern Gulf of Alaska and 57 stations in Lower Cook Inlet. Samples were taken from several preselected depths, depending on location. Nominally, these depths included: surface, 10 m, 20 m, 40 m, 60 m, 80 m, 100 m, and 5 m above the bottom. At two stations in the northeastern Gulf, WIST I and WIST II (Figure 1), single arrays consisting of a nephelometer mounted in the weight, two and four Aanderaa current meters, respectively, and one and three sediment traps, respectively, were deployed on 17 March 1977. With the exception of one nephelometer, all of the equipment was successfully recovered on 8 June 1977.

B. Laboratory Activities

1. Methods

The major (Mg, Al, Si, K, Ca, Ti, and Fe) and trace (Cr, Mn, Ni, Cu, Zn, and Pb) element chemistry of the particulate matter is being determined by x-ray secondary emission (fluorescence) spectrometry utilizing a Kevex® Model 0810A-5100 x-ray energy spectrometer and the thin-film technique (Baker and Piper, 1976). The inherent broad band of radiation from an Ag x-ray tube is used to obtain a series of characteristic emission lines from a single element secondary target which then more efficiently excites the thin-film sample. Se and Zr secondary

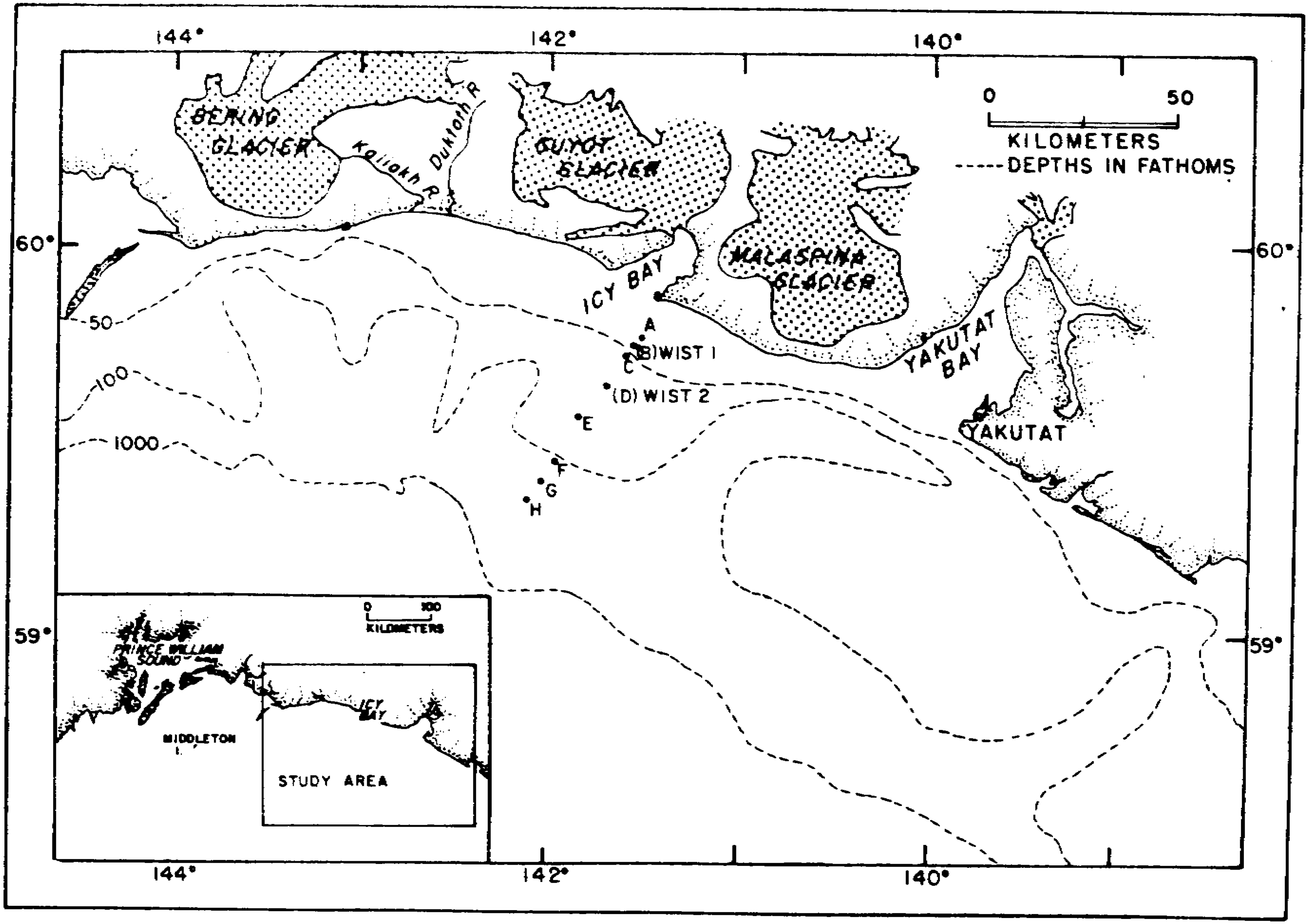

Figure 1. Locations of suspended matter stations in the northeastern Gulf of Alaska (RP-4-Di-77A-III, 14-31 March 1977).

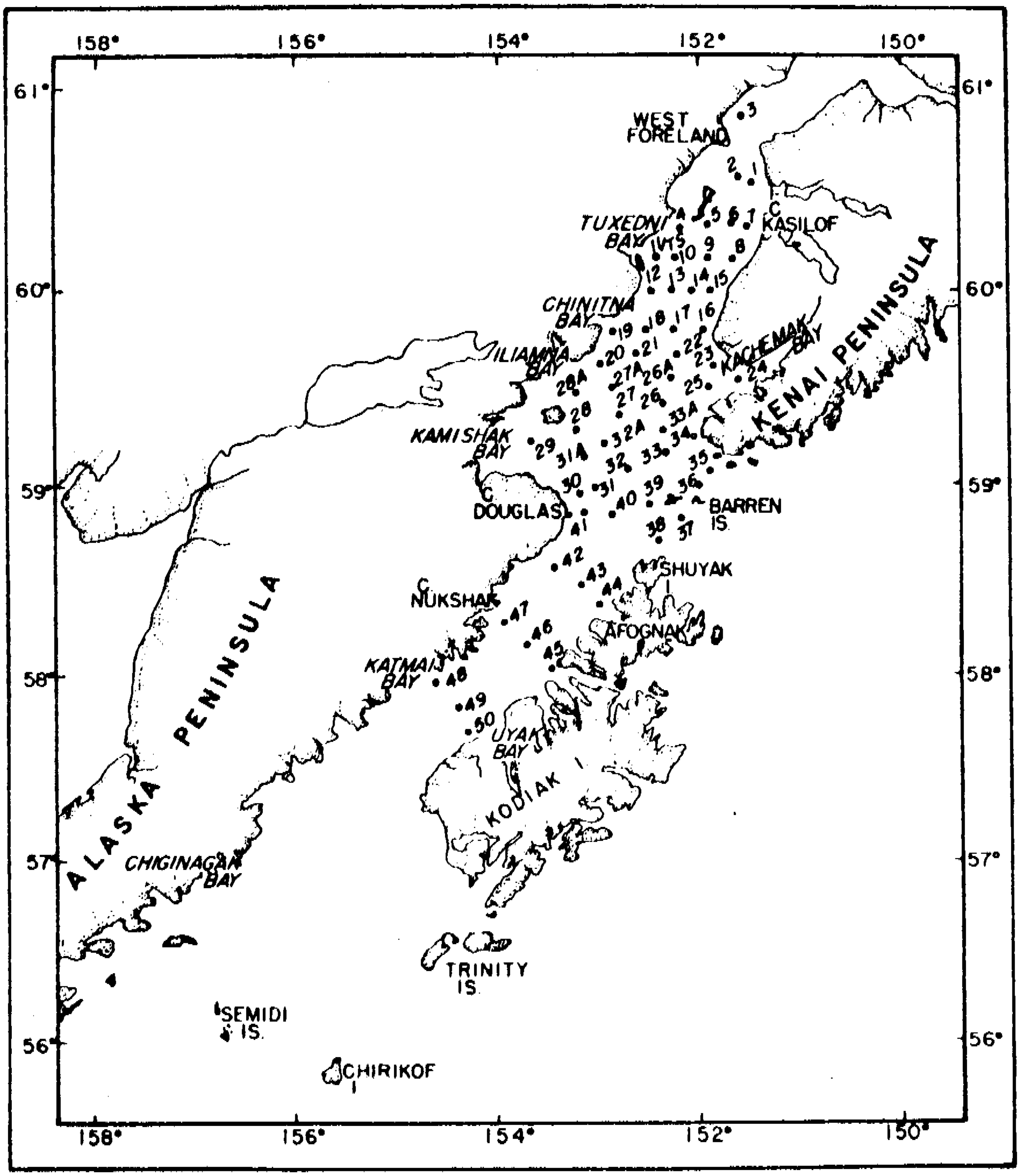

Figure 2. Locations of suspended matter stations in Lower Cook Inlet and Shelikof Strait (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

targets are used to analyze the samples for both major and trace elements. Standards are prepared by passing suspensions of finely ground USGS standard rocks (W-1, G-2, GSP-1, AGV-1, BCR-1, PCC-1) and NBS trace element standards through a 37 μm mesh polyethylene screen followed by collection of the size fractionated suspensates on Nuclepore® filters identical to those used for sample acquisition. The coefficient of variation for 10 replicate analyses of a largely inorganic sample of approximately mean mass was less than 3 percent for the major constituents and as high as 5 percent for the trace elements. However, when sampling precision is considered, the coefficients of variation increase, averaging 12 and 24 percent for major and trace elements, respectively.

Analysis of total particulate carbon and nitrogen is carried out with a Hewlett Packard model 185B C-H-N analyzer. In this procedure, particulate carbon and nitrogen compounds are combusted to CO_2 and N_2 (micro Dumas method), chromatographed on Poropak® Q, and detected sequentially with a thermal conductivity detector. NBS acetanilide is used for standardization. Analyses of replicate surface samples yield coefficients of variation ranging from 2 to 10 percent for carbon and 7 to 14 percent for nitrogen.

2. Data Collected

To date, we have completed three out of four cruises in the Gulf of Alaska and Lower Cook Inlet which were scheduled for the present fiscal year. At this point, approximately 300 samples have been collected and weighed for suspended loads. In addition approximately 100 samples have been collected for elemental analysis of particulate material and 20 grams of suspended matter from Lower Cook Inlet have been collected for the crude oil suspended matter interaction studies.

III. Results

A. Particulate Matter Distributions and Transport

The data on the distribution of suspended matter in Lower Cook Inlet and Shelikof Strait are complete and will be described below. The work on the elemental composition of the suspended matter and crude oil-suspended matter interaction studies is presently underway and will be described in a future report.

Figures 3 and 4 show the distribution of suspended matter at the surface and 5 m above the bottom during the spring cruise in Lower Cook Inlet (RP-4-Di-77A-IV, 4-16 April 1977). The surface and near-bottom suspended matter distribution patterns are remarkably similar, indicating that Cook Inlet is characterized by unusually high horizontal gradients and no vertical gradients during the winter season. On the eastern side, the inflowing Gulf of Alaska water has suspended matter concentrations ranging between 0.5 and 5.0 mg/ℓ. On the western side, the outflowing turbid water, which contains mechanically abraded rock debris from Upper Cook Inlet and has particulate concentrations ranging from 5.0 to 200 mg/ℓ, is transported past Augustine Island to Kamishak Bay, where a portion of the suspended material settles out and the remaining material is transported around Cape Douglas into Shelikof Strait and is dispersed.

Figure 5 shows a vertical cross-section of the distribution of suspended matter from Kachemak Bay to Kamishak Bay in Lower Cook Inlet. The figure shows that suspended matter concentrations are lowest in the center of Cook Inlet with particulate concentrations increasing rapidly near the coast, especially in the vicinity of Kamishak Bay. Particulate concentrations are uniform with depth throughout most of the region which suggests that the water column is vertically mixed. This is supported by the

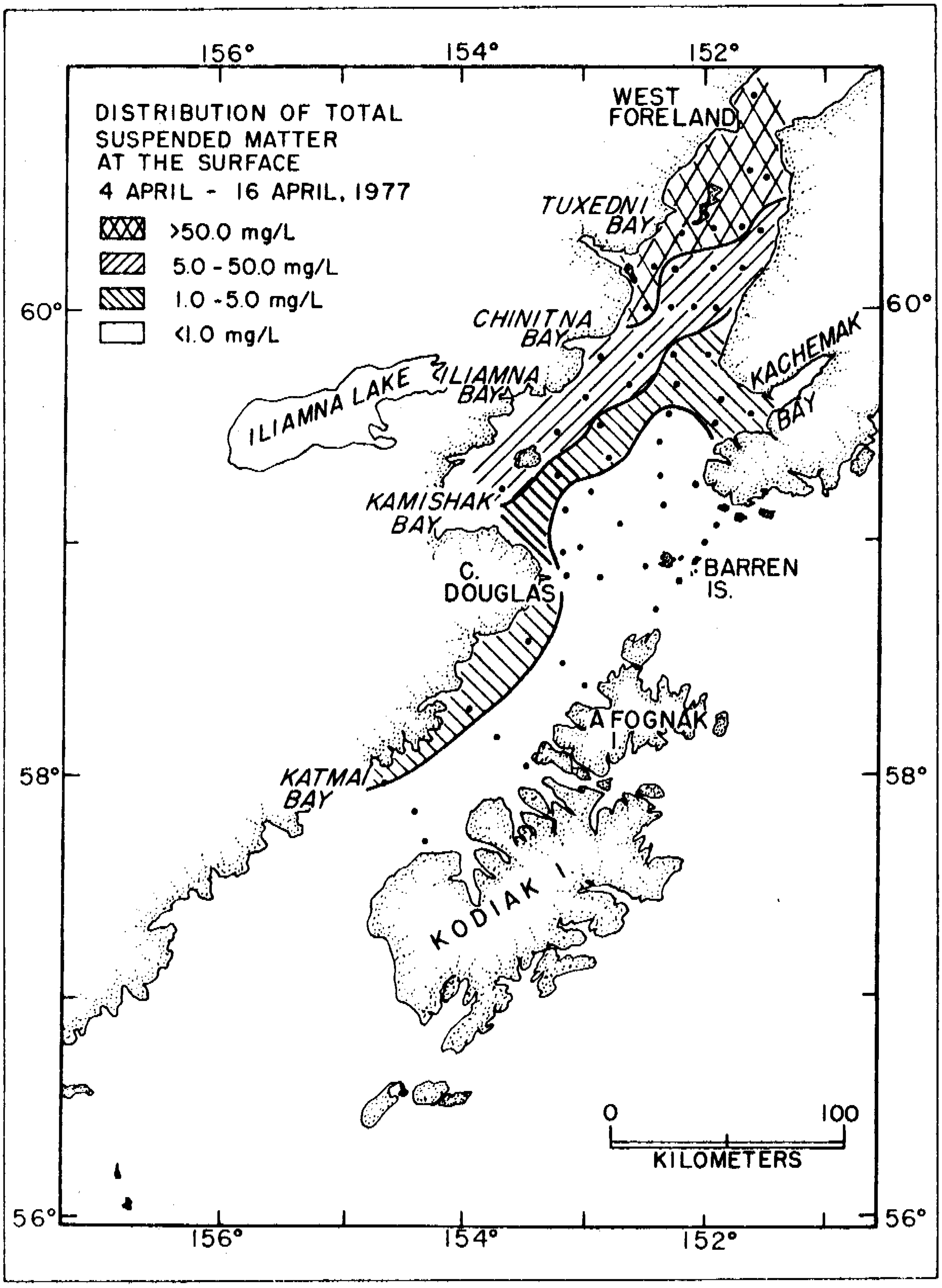

Figure 3. Distribution of total suspended matter at the surface in Lower Cook Inlet and Shelikof Strait (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

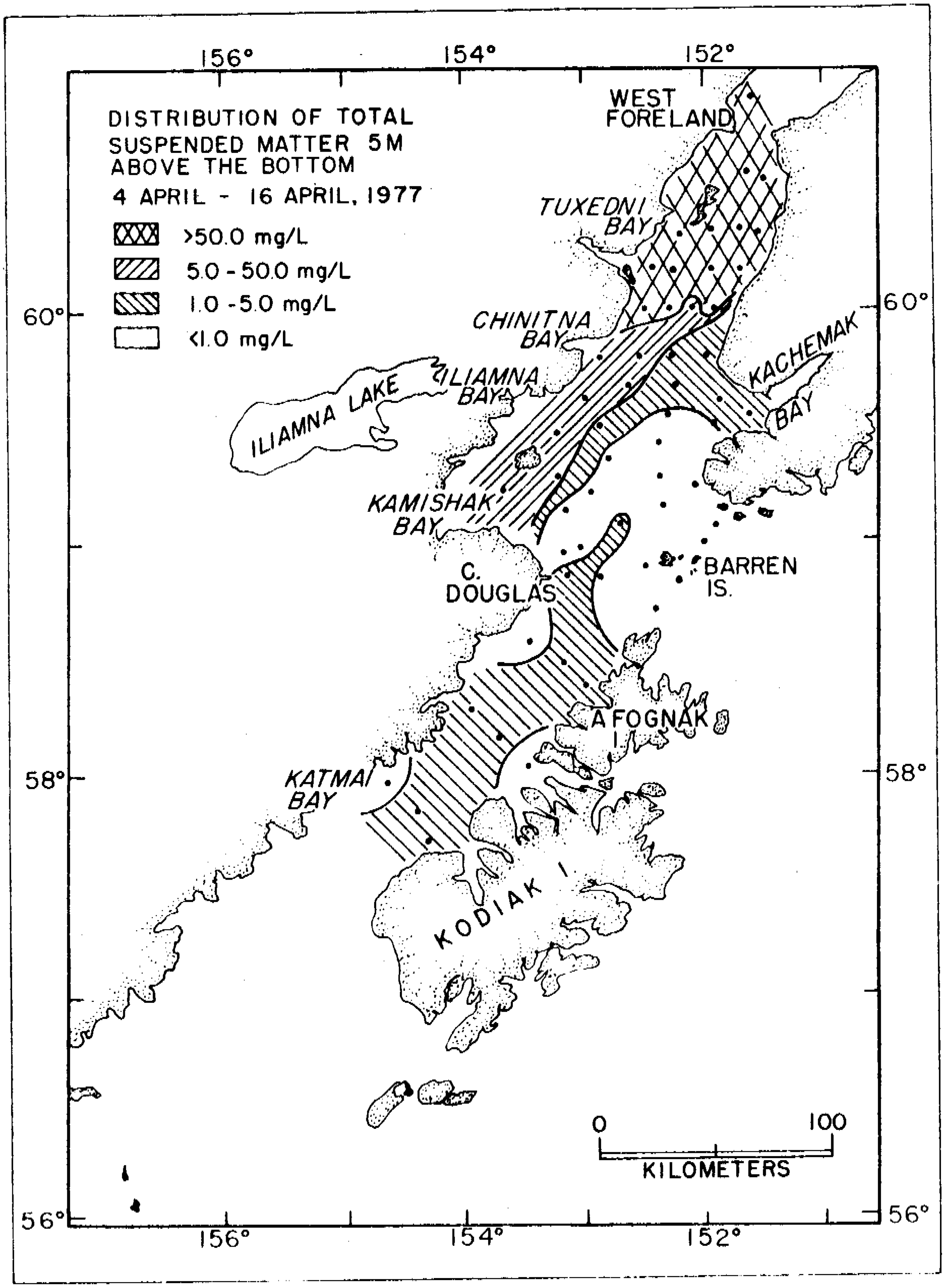

Figure 4. Distribution of total suspended matter 5 m above the bottom in Lower Cook Inlet and Shelikof Strait (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

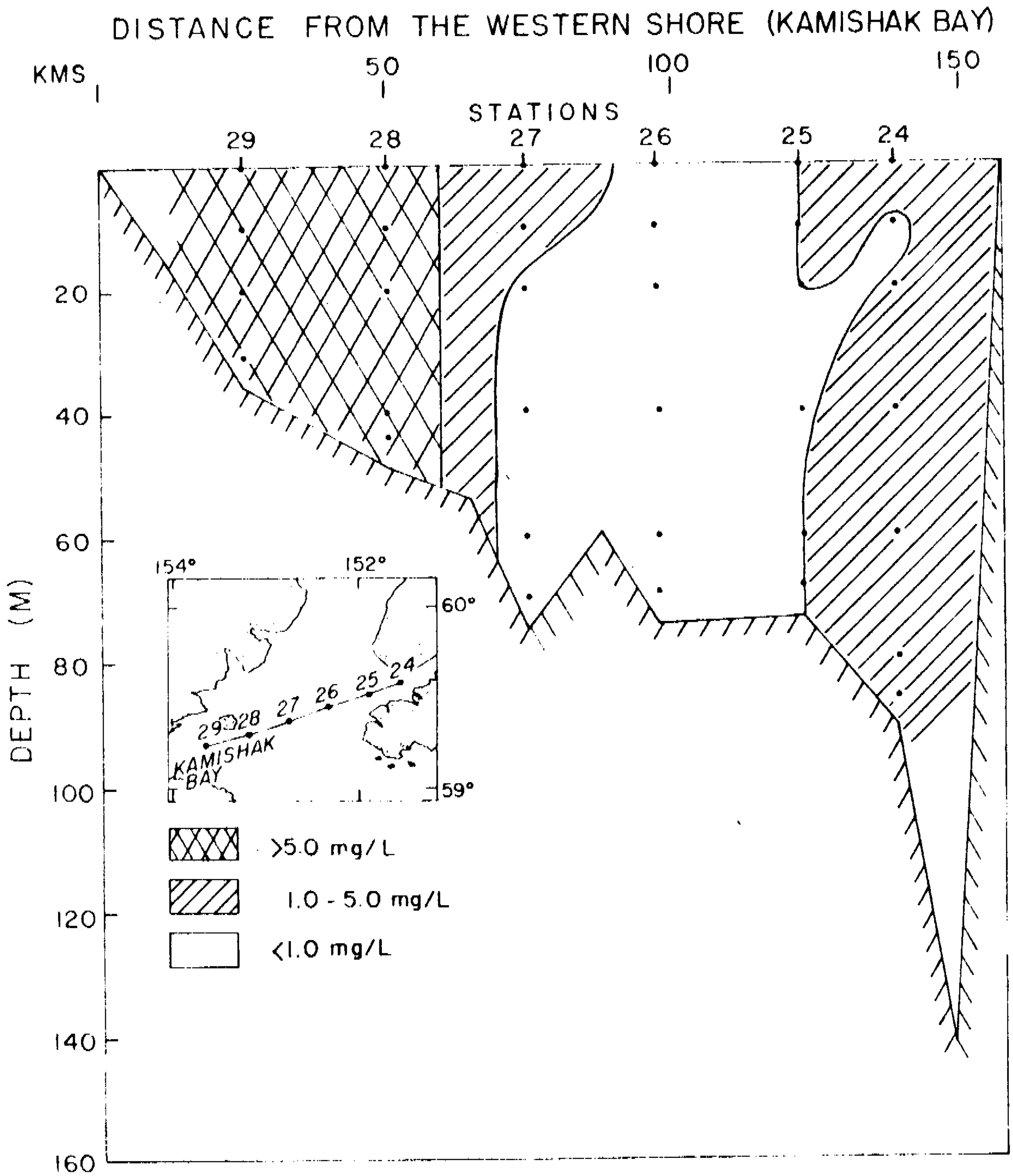

Figure 5. Vertical cross section of the distribution of total suspended matter for stations 24 thru 29 in Lower Cook Inlet (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

temperature and salinity distributions which are also uniform with depth. Apparently, the turbulence which is caused by tidal mixing is sufficient to keep the water column well mixed with respect to suspended matter.

B. Temporal Variability of Suspended Matter

In order to obtain some information about high frequency variations in suspended matter concentrations in Lower Cook Inlet, a 36-hour time series experiment was conducted at station 11. Water samples were collected every two hours from the surface and 5 meters above the bottom. The results of these experiments are presented in Figure 6. As shown in the figure, concentrations of suspended matter are highly variable both at the surface and near the bottom. At the surface, particulate concentrations range from 40 to 90 mg/ℓ. The surface maxima have a 12-hour period and appear to reach their peak shortly after the tidal currents have come to maximum velocity. Near the bottom the suspended matter concentrations are more highly variable and may reach concentrations in excess of 130 mg/ℓ. The near-bottom particulate maxima do not show any consistent periodicity and most probably reflect local variations in amount of material that is resuspended into the water column by bottom currents.

IV. Preliminary Interpretation of the Results

The distribution patterns of particulate material in Lower Cook Inlet show a direct relationship to water circulation. The inflowing relatively nonturbid Gulf of Alaska water moves along the eastern coastline until it reaches Kalgin Island where it mixes with the highly turbid brackish water from Upper Cook Inlet. Under the influence of tidal currents and coriolis forces the turbid water moves southwest along the western coast into Shelikof Strait where the particulate matter disperses and settles to the bottom. This counterclockwise circulation

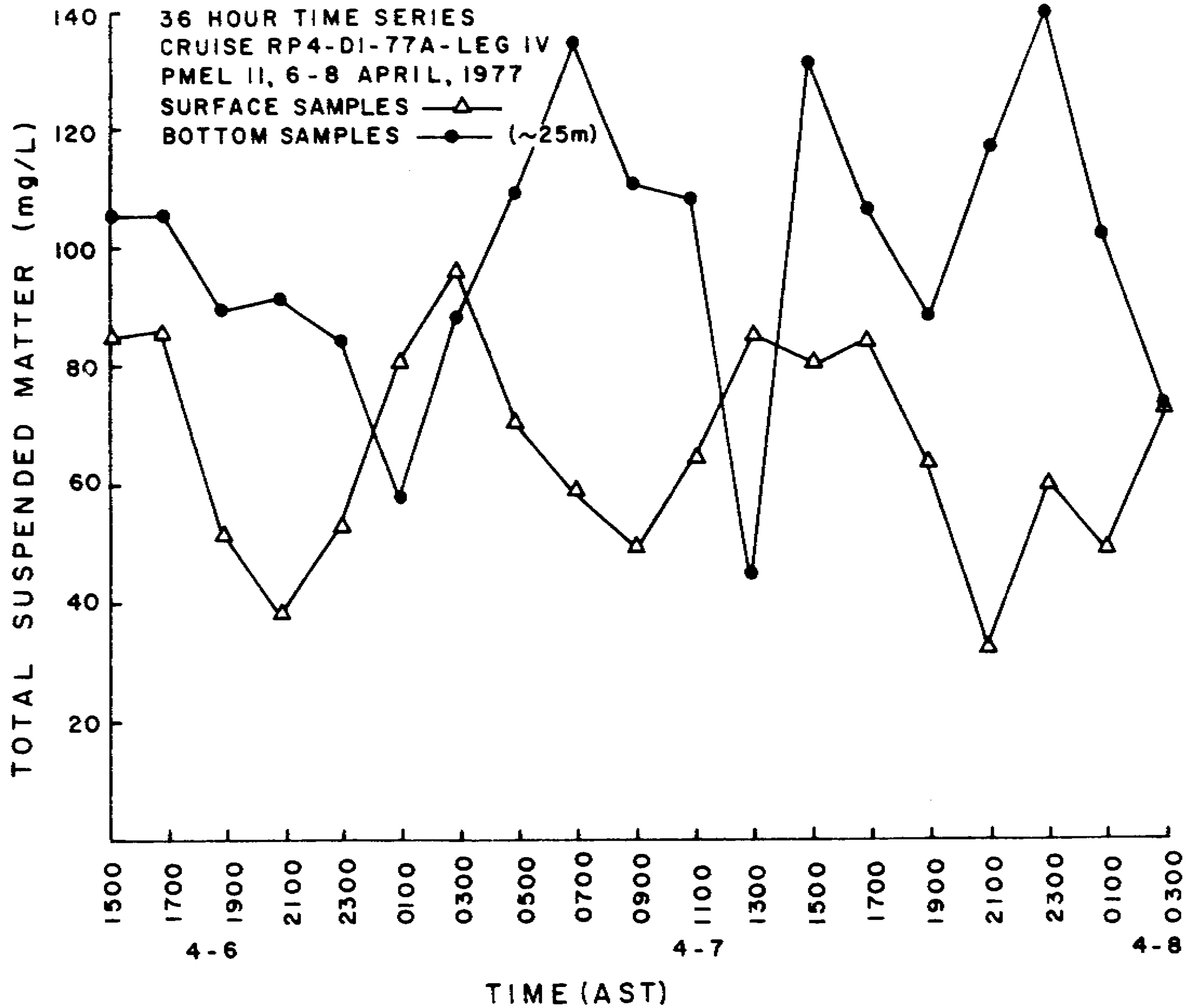

Figure 6. Temporal variability of total suspended matter at the surface and 5 meters above the bottom at station 11 in Lower Cook Inlet (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

pattern gives rise to extremely large horizontal gradients in suspended matter. However, tidal mixing is extensive and rapid; and, therefore, no vertical suspended matter gradients are observed during the winter months in the central regions of Lower Cook Inlet.

V. Problems Encountered

We have no significant problems to report at this time.

VI. Estimate of Funds Expended

	Allocated	Expended	Balance
Salaries and Overhead	$159.2K	$ 94.2K	$65.0K
Travel and Per Diem	9.8K	5.8K	4.0K
Major Equipment	40.0K	40.0K	0
Expendable Supplies	28.8K	28.8K	0
Shipping	2.2K	1.5K	0.7K
Publications	1.0K	1.0K	0
Ranked FY 76 Funds	20.0K	20.0K	0
	$261.0K	$191.3K	$69.7K

References

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Sharp, J. H. Improved analysis for "particulate" organic carbon and nitrogen from seawater, Limnol. and Oceanogr., 19(6): 984-989, 1974.

Quarterly Report

Research Unit: 153
Reporting Period: 1 April - 30 June 1977
Number of Pages: 7

Identification of Natural and Anthropogenic Petroleum Sources Utilizing Low Molecular Weight Hydrocarbons, C_1-C_4

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June 30, 1977

I. Task Objectives

During the past year, regional studies into the distributions of the low molecular weight hydrocarbons (LMWH) were conducted in Bristol Bay and the northeast Gulf of Alaska. The principal focus of the program was to provide baseline information on the temporal and spatial variations as a prelude to the probable development of OCS petroleum resources. Our responsibility to these objectives will be largely met at the close of the current field season, although important seasonal data in some areas will be lacking.

Studies of the abundances and distributions of LMWH this year have focused on lower Cook Inlet, Shelikof Strait, Kodiak Island shelf, and the Tarr Bank-Kayak Island area. The first of two cruises (subject of this report) concentrated on LCI and the Tarr Bank-Kayak Island region of the northeast Gulf of Alaska.

Objectives of the study in LCI were to assess the baseline concentrations of LMWH and to identify significant anthropogenic and natural sources of hydrocarbons. These sources might include subsurface natural seepage, spillage or leakage from production platforms, or input from transportation activities. If point sources of petroleum hydrocarbons are identified, the distribution of LMWH provides valuable information about the dispersion characteristics of the dissolved fraction. The objective of the program in the Tarr Bank-Kayak Island region was to assess the composition of hydrocarbons in pore waters and relate these findings to the compositions observed in the overlying water column. During previous surveys, unusually high near-bottom concentrations of methane were observed, although the origin of this gas was unknown. Analyses of interstitial water for LMWH will elucidate the sources and whether the gases are the result of microbial activity or thermogenic processes.

II. Field Activities

A. Ship Schedule

The distribution and abundances of LMWH were evaluated in LCI, Shelikof Strait, and the Tarr Bank-Kayak Island shelf region during April 1977. The cruise was divided into two legs, the first being devoted to LMWH and suspended matter studies in LCI and Shelikof Strait, the second focusing on benthic sources of LMWH in the Tarr Bank region.

Vessel: R/V DISCOVERER

Cruise Date: 4-22 April 1977

Cruise No.: RP-4-DI-77A-IV

B. Scientific Compliment

The scientific compliment included (LMWH only):

Dr. Joel Cline, PMEL, Cruise Leader

Mr. Anthony Young, PMEL, Oceanographer

Ms. Marilyn Pizzello, PMEL, Technician

Mr. Brad Echert, NOS, Electronic Technician

Mr. Rob Martinez, PMEL, Technician

Mr. James Cimato, BLM, Observer

Mr. Varis Grundmanis, UW, Graduate Student

C. Methods

1. Analysis of waters for LMWH: LMWH are stripped from a 1-liter volume of seawater using a modified procedure recommended by Swinnerton and Linnenbom (1967). Hydrocarbon components, methane, ethane, ethene, propane, propene, iso- and n-butanes, are removed in a continuous stream of He and trapped on activated alumina at -196°C. After a nominal 10-minute stripping time, the

trap is warmed to 100°C and the components flushed into the gas chromatograph for analysis.

Chromatography of the components is effected on a column of Poropak^R Q (8' x 3/16"), 60-80 mesh, in series with a small column of activated alumina (3/16" x 2") impregnated with 1% silver nitrate by weight. This dual column configuration results in sharper peaks, better separation of olefins, and reduced component retention times. Chromatography of LMWH components through C_4 is accomplished in less than six minutes. Detection of the component hydrocarbons as they emerge from the column is performed with a flame ionization detector.

2. Analysis of pore waters for LMWH: Interstitial water samples were taken with a harpoon sampler similar to that described by Sayles et al. (1973). Its obvious advantage is that dissolved gases in pore waters can be sampled without contaminating or exposing the sediment to ambient degassing. This instrument acts as a large syringe with a spring loaded master cylinder providing the suction. Full 1-1/2 meter penetration triggers the suction and at each of the seven sampling ports interstitial water is drawn through a Whatman filter into a 20 ml stainless steel sample loop. Each sample loop is detachable from the harpoon and can be interfaced with the previously described aqueous stripping procedure. Analysis of LMWH in pore waters is similar to that described above for seawater, only the stripping chamber has been reduced in volume to accommodate smaller interstitial water samples.

D. Sampling Protocol

The sampling grid for LCI and Shelikof Strait is shown in Figure 1. Station sampling in the Tarr Bank area is shown in Figure 2.

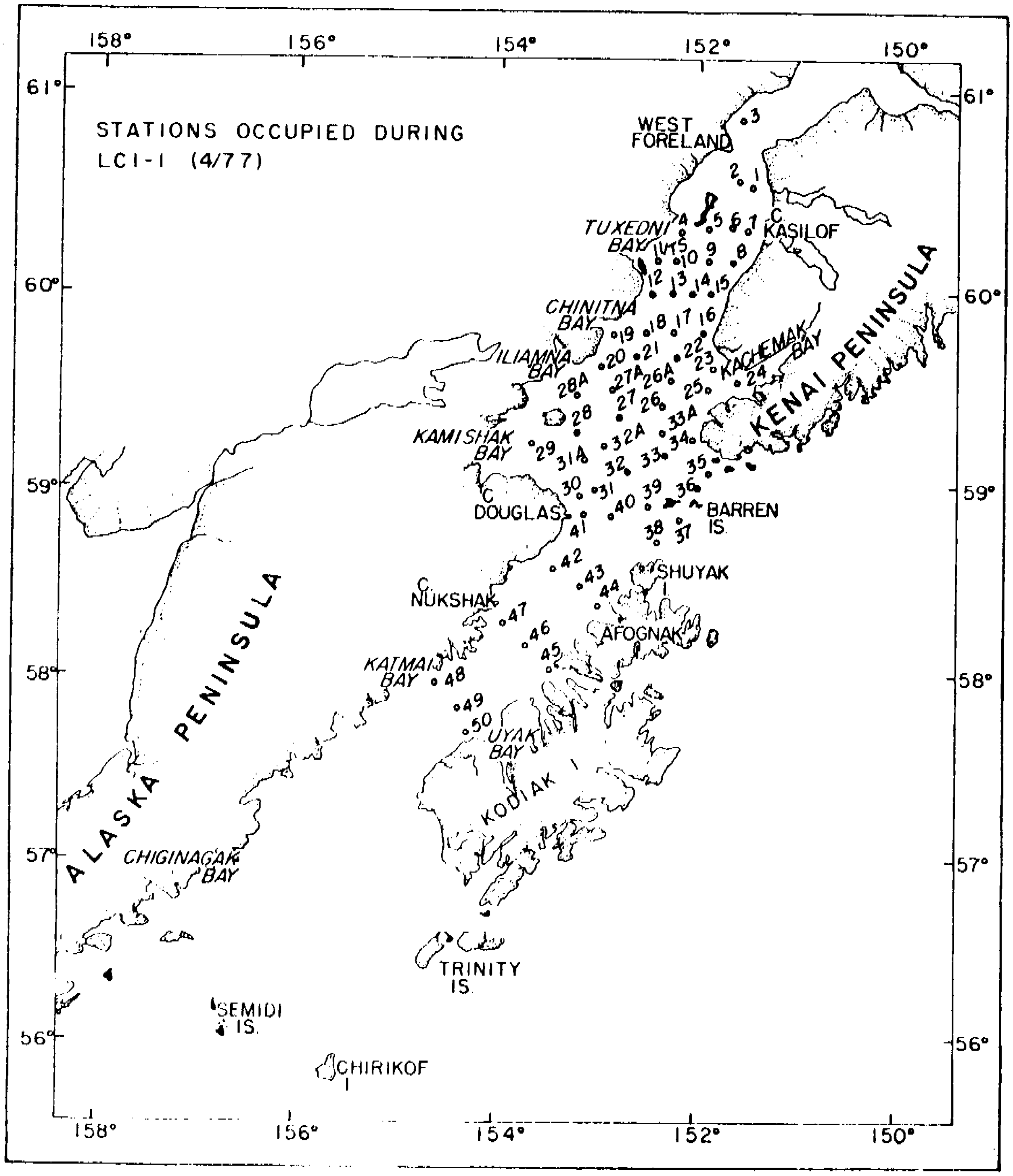

Figure 1. Stations occupied in lower Cook Inlet and Shelikof Strait during April 1977 (RP-4-DI-77A-IV).

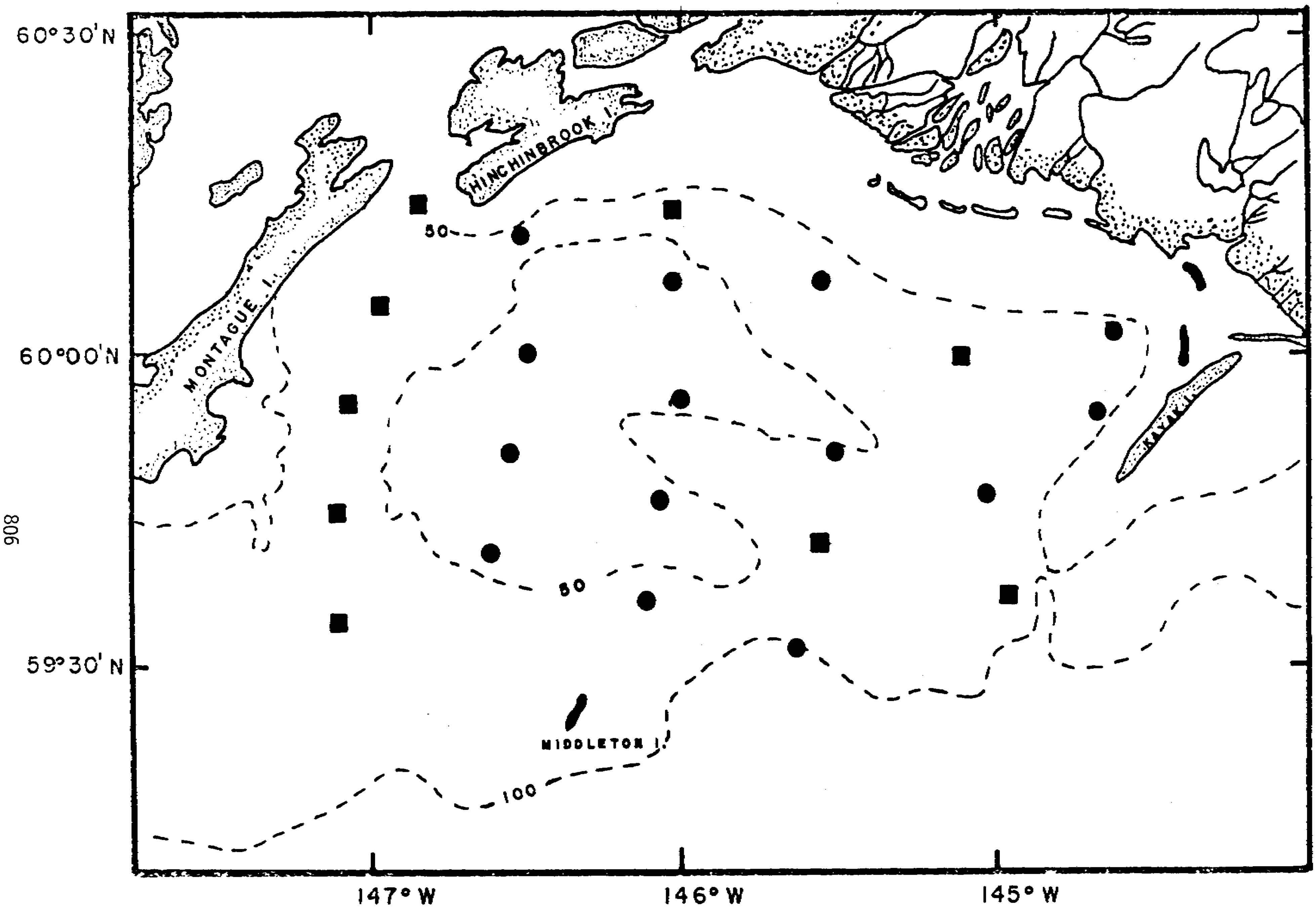

Figure 2. Proposed station locations on Tarr Bank. core + water samples ■ water samples ●

E. Data Collected and Analyzed

1. LCI and Shelikof Strait

   No. Stations: 44

   No. Samples Analyzed: 141

   Trackline Miles: 560 n.m.

2. Tarr Bank-Kayak Island

   No. Stations: 19

   No. Core Stations: 8

   No. Samples Analyzed (water): 89

   No. Samples Analyzed (pore water): 41

   Trackline Miles: 260 n.m.

III. Results

All the analyses have been completed, but the graphical and tabular information is not available for presentation at this time. These data together with the results of the June-July cruise will be discussed in the semi-annual report (Oct. 1, 1977).

IV. Problems Encountered

Considerable difficulty was encountered in the analysis of LMWH in Cook Inlet. Part of the difficulty was traceable to the high suspended loads in Cook Inlet, which decreased the stripping efficiency. Also, water samples taken north of Kalgin Island contained visable quantities of oil (i.e., tar balls), resulting in massive contamination of the aqueous stripper. The cleanup trap (Tenax GC) has been increased in length and accumulating contaminants now can be backflushed from the trap. It is hoped that future problems of this type can be averted.

V. Estimate of Funds Expended

	Allocated	Expended to Date	Balance
Salaries and Overhead	$41,238	$22,935	$18,303
Travel and Per Diem	4,140	4,140	0
Major Equipment	8,400	7,800	600
Expendable Supplies	5,100	3,900	1,200
Shipping	1,000	700	300
Publications	1,000	250	750
Banked FY76 Funds	4,000	4,000*	0
Totals	$64,878	$43,725	$21,153

*The FY76 banked monies have been redistributed within the salary and expendable supply categories.

QUARTERLY REPORT

APRIL-JUNE 1977

NATURAL DISTRIBUTION AND ENVIRONMENTAL BACKGROUND OF TRACE HEAVY METALS IN ALASKAN SHELF AND ESTUARINE AREAS

RU #162

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Professor of Marine Science
Institute of Marine Science
University of Alaska
Fairbanks, Aaska 99701

June 25, 1977

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I. TASK OBJECTIVES

The primary objective of this program is to characterize the trace metal contents of seawater, sediment, and selected indigenous biota in the three originally specified study areas (Gulf of Alaska, S. Bering Sea, Beaufort Sea) plus those regions added through later contract modifications (Lower Cook Inlet, Norton Sound). This program also incorporates sediment grain-size analysis, clay mineralogy analysis and "previous work" literature searches as described in the original Work Statement.

II. FIELD AND LABORATORY ACTIVITIES

A. Field Work

1. S. Bering Sea

   OSS *Surveyor*, March 15-May 1, 1977, Personnel: None from this R.U.

   Marine mammal samples were collected for us by Dr. Fay. See cruise report for that R.U.

2. NEGOA

   NEGOA specific study site. R/V *Acona*, 6-14 April 1977, Personnel: T. Manson, T. Owens, D. Heggie.

   Hydrographic data, suspended sediment and core samples were taken at four stations in Yakutat Bay. Major vessel malfunction caused curtailment of the cruise and no stations could be occupied in Icy Bay.

3. Lower Cook Inlet

   Specific study site - Kachemak Bay. 2-7 May 1977 (no sampling platform), Personnel: T. Manson.

   Sediment, *Fucus* and *Mytilus* samples were collected from four intertidal localities thus:

a. Inner Bay (Mud Bay)
b. Outer Bay (N.W. of spit)
c. Anchor Point
d. Bluff Point

Macoma samples collected in inner bay only.

4. S. Bering Sea

OSS *Discoverer*, 19 May-14 June 1977. Personnel: None from this R.U.

Marine mammal samples were collected for us by Dr. Fay.

5. Lower Cook Inlet

R/V *Acona*, Personnel: T. Manson.

Intertidal sampling trip. Cruise in progress at time of preparation of this report.

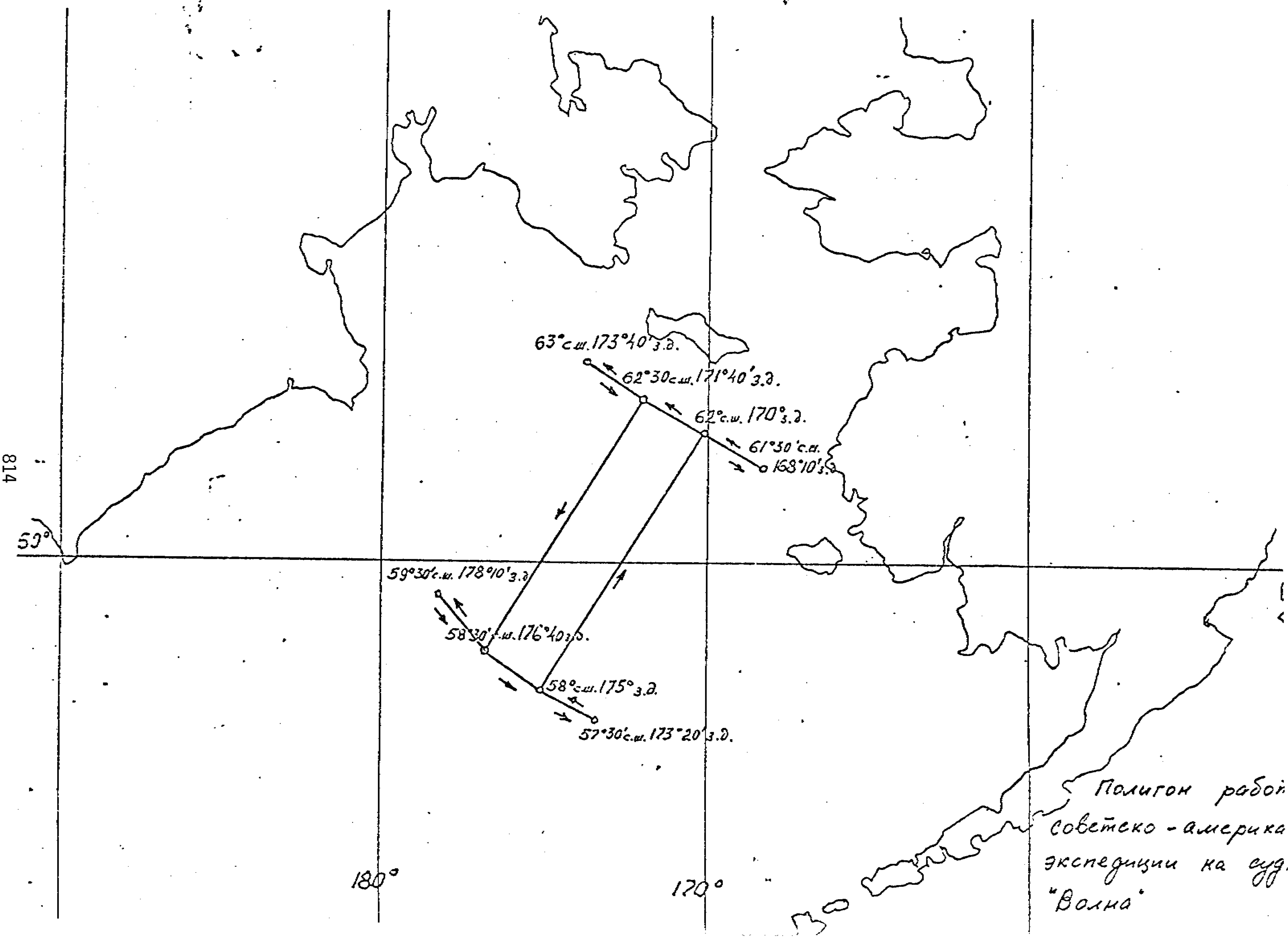
6. S-N Bering Sea

U.S.S.R. hydromet vessel *Volna*.

Preparations for participation on this cruise are currently in progress. Work will comprise surface and euphotic zone dissolved heavy metals. One scientist from the heavy metal program will participate in order to collect from this previously unsampled region. It is hoped that an opportunity will be afforded to compare our analysis techniques with the Soviets and that further cooperative cruises in later years will result. The tentatively scheduled area of operations for this initial cruise is shown on the accompanying chart (Fig. 1).

B. Scientific Parties

As noted above.


63°с.ш.173°40'з.д.
62°30с.ш.171°40'з.д.
62°с.ш.170°з.д.
61°30'с.ш.
168°10'з.д.
59°
59°30'с.ш.178°10'з.д.
58°30'с.ш.176°40'з.д.
58°с.ш.175°з.д.
57°30'с.ш.173°20'з.д.
180°
170°
Полигон работ
советско-америка
экспедиции на суд.
"Волна"

C. Field Collection Methods

1. Marine mammals. Individuals dissected shipboard and separate tissue samples stored frozen in polyethylene bags.
2. Intertidal benthos. Hand collected and stored in frozen polyethylene.
3. Core samples. Taken using Haps corer as described in Annual Report.
4. Water samples. New sampling system installed for 6-14 April R/V *Acona* cruise. Niskin go-flo bottles on Kevlar line. This equipment intended to eliminate (a) sea surface contamination, (b) contamination from metallic hydro wire.

   Special preparations are currently in hand for water collection in the Bering Sea on board the Soviet hydromet vessel *Volna* in July-August. The primary set of samples will be collected from the surface water column down to approximately 50 m. A pumping system and associated in-line filter is being prepared in order to avoid the problem of potential contamination from shipboard sampling bottles and from the hydrowire. It is hoped also that it will be possible to collect surface film samples and a special screen sample is being constructed for this. Analyses for Cu and Pb will be performed shipboard *via* anodic stripping voltammetry.

D. Sample Localities

1. Marine mammal samples. See Table I and cruise reports from that R.U.
2. NEGOA specific study sites. See 1976-1977 Annual Report for charts showing standard station localities.

TABLE I

Localities and types of marine mammal tissue samples collected for heavy metal analysis.

Date (1977)	Sample No.	Species (seal)	Sex	Weight (kg)	Lat. (N)	Long. (W)
3.29	14	Bearded	F	32.3	58 25.18	104 50.06
4.24	28	Spotted	M	89.9	58 54.2	169 13.6
4.24	29	Ring	M	59.9	58 40.1	169 40.3
4.24	30	Spotted	M	84.0	58 40.1	169 28.8
4.26	32	Spotted	M	118.0	59 22.5	173 43.0

TABLE II

Localities of intertidal benthic sampling stations. May 1977 Lower Cook Inlet (Kachemak Bay).

Date (1977)	Station No.	Location	Lat. (N)	Long. (W)
5.4	1	Inner Bay	59 40	151 26
5.5	2	Anchor Point	59 46	151 52
5.6	3	N.W. Outer Bay	59 38	151 30
5.7	4	Bluff Point - Diamond Creek	59 40	151 42

3. Lower Cook Inlet benthos. Sample localities listed above and in Table II.

E. Laboratory Analysis Program

1. Marine mammal tissue samples. We are currently experimenting with new dissolution techniques. The basis of this method will be use of a low temperature plasma asher when permission has been obtained to purchase (see below). Low temperature teflon bombs have already been obtained and are being tested. When this system is fully operational, dissolution of biota samples will be greatly speeded (this is presently the time limiting analysis step) and our procedures will be in line with OCS investigators in other parts of the country.

2. Dissolved and particulate organic carbon. These parameters are required as essential ancillary data for coastal specific study site research as described in the Annual Report. A new ampoule sealing rig has been installed and the analyser is currently being calibrated using standards.

3. Soluble Cd analysis. The anodic stripping voltammetry method used for this metal is being updated and refined.

4. Soluble Cu analysis. The electroanalytical technique employed for this metal is being readied for use at sea on the *Volna* cruise.

5. Silver in seawater by neutron activation analysis (Dr. D. E. Robertson). It is not possible to measure Ag by this direct counting method because of an interference from high levels of ^{46}Sc produced in the activated samples. We are, therefore,

developing a rapid radiochemical separation of ^{110m}Ag (252d) from the neutron irradiated sediment samples by lithium metaborate fusion, followed by solvent extraction of the ^{110m}Ag with dithizone in strong acid solution. The separated silver will then be counted in a NaI(Tl), high efficiency well crystal.

6. Hg species in sediments (Dr. H. V. Weiss).

   a. Elemental and readily reducible mercury in sediment samples was determined as follows: 100 ml distilled water was added to weighed quantity of sediment in an aeration vessel. The mixture was treated as for the determination of Hg in seawater (see methods in Annual Reports) except that the reducing agent was not added. Subsequently the analysis was repeated on the same material after the addition of stannous chloride. The responses were quantified by the method of standard additions.

   b. For reducible and organic species of mercury extractable into seawater, sediment was shaken for 1 hour together with 150 ml of unacidified bottom seawater of known mercury content. After separation by centrifugation, half of the seawater was immediately analysed for reducible mercury. The remainder of the water was acidified with 0.5 ml of nitric acid, irradiated with U.V. light, and analysed for mercury as before.

7. Sediment size analysis (Dr. C. M. Hoskin). S. Bering Sea sediment samples collected on the June 1975 *Discoverer* cruise have been fractionated into 1/4 Ø sizes from -0.75 to 10.

Norton Sound samples (OSS *Discoverer* Leg IV, 8-24 September 1976) are presently being analysed for gravel (< -1 Ø), Sand (-1 -4 Ø) and mud (> 4 Ø). These data will be discussed in a later report.

8. Thermal analysis of clay samples (Dr. A. S. Naidu). A set of ten random clay samples collected from the S. Bering Sea have been selected for x-ray diffraction analysis and subsequent step-wise heat treatment. For this study, the < 2 μm size fraction of magnesium saturated clays mounted on porous porcelain slides were taken. As noted in the 1976-77 Annual Report, the x-ray diffractiograms on these samples both before and after glycol solvation were already available and these latter have also been used to identify the constituent mineral types. The thermal treatment consisted of subjecting the magnesium saturated clay slides to step-wise heating at 300 C for one hour followed by 550 C for a second hour period using a calibrated muffle furnace. Diffractograms were obtained at the end of each heating period.

III. RESULTS

A. Extractable trace metals of NEGOA sediments.

Data for the last of the samples collected on the *Silas Bent* cruise are given in Table III.

B. Extractable contents of Norton Sound and Chukchi Sea sediments.

These data for sediments collected on the *Discoverer* cruise (Leg IV, 8-24 September 1976) are given in Tables IV and V.

TABLE III

N.E. Gulf of Alaska
Silas Bent - 31 August-17 September 1975.
Heavy metal contents of sediment extracts (mg/kg).

Station	Cd	Cu	Ni	Zn	Fe	Mn
5	<0.25	7.5	4.5	14	1880	53
40	<0.25	19.7	7.1	21	3640	101
52	<0.25	23.6	3.7	23	4020	116
55	<0.25	16.9	5.2	22	3770	99
57	<0.25	12.5	2.6	12	2000	91
58	<0.25	17.5	4.8	17	3400	83

TABLE IV

Norton Sound
OSS *Discoverer* - Leg IV, 8-24 September 1976.

Station	Cd	Cu	Ni	Zn	Fe	Mn
N1	<0.1	<0.3	<1.3	6.2	750	8
N4	<0.1	0.5	2.5	5.0	3050	48
N5	<0.1	0.5	2.9	5.0	2840	86
N6	<0.1	2.0	3.3	5.7	3080	121
N9	<0.1	1.1	4.3	8.0	4250	79
N12 D	<0.1	0.6	1.4	5.1	1610	230
N13	<0.1	0.5	1.8	6.0	2090	283
N15	<0.1	<0.3	<1.3	5.1	1780	75
N17	0.1	2.2	4.2	9.1	2960	193
N20	<0.1	<0.3	<1.3	3.5	970	58
N21	<0.1	0.3	<1.3	3.5	1220	52
N23	<0.1	0.6	1.8	6.6	2070	70
N26	<0.1	<0.3	<1.3	2.5	570	60
N28 A	<0.1	<0.3	<1.3	2.5	750	20

TABLE V

S. Chukchi Sea
OSS *Discoverer* - Leg IV, 8-24 September 1976.
Heavy metal contents of sediment extracts (mg/kg).

Station	Cd	Cu	Ni	Zn	Fe	Mn
C3	<0.1	<0.3	1.6	3.8	1280	11
C5	<0.1	0.6	1.8	3.7	1490	20
C6	<0.1	<0.3	1.4	6.0	2130	134
C7	<0.1	0.4	1.4	3.5	910	12
C7A	<0.1	0.6	1.8	4.6	2280	54
C9	<0.1	<0.3	1.3	2.6	950	74
C10	<0.1	<0.3	<1.3	2.6	620	25
C12	<0.1	<0.3	1.8	3.4	1200	6
C13	<0.1	0.4	1.8	3.7	1590	10
C14	<0.1	0.3	1.8	3.9	1490	13
C15	<0.1	0.3	<1.3	3.3	1220	29
C16	<0.1	<0.3	<1.3	3.4	970	5
C19	<0.1	<0.3	<1.3	3.5	1270	22
C20	<0.1	<0.3	<1.3	2.8	830	29
C22	<0.1	<0.3	1.4	4.3	1560	16
C23	<0.1	<0.3	<1.3	0.9	300	2
C24	<0.1	<0.3	1.9	3.9	1510	10
C25	<0.1	<0.3	<1.3	3.7	1340	17
C29	<0.1	<0.3	<1.3	3.8	1020	10

C. Intertidal benthos.

Heavy metal contents of *Mytilus* and *Fucus* collected by the intertidal biology group from E and W Gulf, Kodiak and S. Bering Sea are given in Tables VI and VII. Accuracy and precision data are given in Table VIII.

D. Mercury species in NEGOA sediment samples (Dr. H. V. Weiss).

Sediments collected in the Gulf of Alaska on *Discoverer* Leg III November-December 1975 cruise have been analysed for the following mercury species:

i) elemental
ii) readily reducible
iii) extractable into seawater both as reducible and organic (after UV oxidation).

These data are given in Table IX.

E. Total contents of heavy metals in S. Bering Sea sediments (Dr. D. E. Robertson).

Total concentrations of As, Ba, Co, Cr, Fe, Sb, and Sc are given in Table X. Co, Cr, Fe, and Sb distributions are shown in Figures 2-5.

F. Clay mineral compositions of shelf sediments (Dr. A. S. Naidu).

Clay mineral compositions of an additional suite of samples from the S. Bering Sea are given in Table XI. Tables XII and XIII give clay mineral compositions of the less than 2 and 1 μm fractions of NEGOA and N.W. Gulf sediments, respectively, following various chemical treatments. The "weighed peak area percent" unit is as *per* Biscaye (1965). Most of the "expandable component" fraction is considered to be degraded (i.e., depotassicated) illite.

TABLE VI

Heavy metal contents of *Mytilus* (μg/g dry weight).

Sample Location	Cd	Cu	Ni	Zn
Low Cape	5.8	10.1	3.6	76.9
Lagoon Point	5.8	9.6	1.3	101.8
Unimak - Cape Lupin	7.3	9.8	0.8	90.0
Cape Pagshak	2.5	9.3	1.6	115.3
Unimak - Sennett Point	5.0	10.8	1.8	130.5
Eider Point	4.0	9.8	1.3	121.5

TABLE VII

Heavy metal contents of *Fucus* (μg/g dry weight).

Sample location	Cd	Cu	Ni	Zn
Boswell Bay	2.9	13.2	13.2	12.7
Port Dick	2.9	2.5	8.3	10.2
Katalia	1.9	9.2	18.3	12.6
Sundstrom Island	2.3	2.0	5.3	8.0
Spectacle Island	3.8	1.4	6.0	9.7
Makushin Bay	3.8	0.8	7.1	10.4
La Touche Point	2.9	2.0	9.2	7.3
Lagoon Point	3.9	1.5	6.7	17.3
Unalaska - Eider Point	5.5	1.5	4.9	17.3
Unimak - Cape Lupin	6.4	2.0	10.8	21.6
Unimak - Sennett Point	5.3	2.0	3.2	17.3
Cape Pagshak	3.5	1.8	4.3	22.7

TABLE VIII

Accuracy data for biota analysis.

A. NBS Standard #1571 Orchard Leaves

Element	This study	NBS Certified
Cd	--	0.11 ± 0.02
Cu	10 ± 1	12 ± 1
Ni	1.3 ± 0.2	1.3 ± 0.2
Zn	25 ± 5	25 ± 3

B. NBS Standard #1577 Bovine Liver

Element	This study	NBS Certified
Zn	133 ± 12	130 ± 10

TABLE IX

N.E. Gulf of Alaska
Discoverer - Leg III, 23 November-2 December 1975.
H. V. Weiss, Analyst
Mercury species in sediment.

Station	Total Mercury (ng/g)	Hg (%)			Extractable into Seawater (%)		
		Sample wt (g)	Elemental	Readily Reducible[a]	Sample wt (g)	Reducible	Organic[b]
2	67.1	4.5	<0.06[c]	0.30	28.1	<0.01	0.45
5	33.4	2.2	<0.28	0.90	28.3	<0.02	1.20
7	48.5	2.4	<0.18	0.18	22.2	1.03	<0.02
8	34.3	4.5	<0.12	0.28	25.9	0.85	<0.02
25	31.3	1.6	<0.40	0.64	25.7	<0.02	<0.02
26	29.8	3.9	<0.18	1.01	37.3	0.34	0.34
29	23.2	3.6	<0.24	0.86	25.9	<0.03	0.03
30	10.8	3.1	<0.60	<0.60	41.9	1.85	17.6
33	39.4	2.7	<0.18	0.51	25.9	<0.02	<0.02
39	65.0	2.4	<0.12	0.62	28.0	<0.01	0.77
44	32.6	2.4	0.31	0.31	24.8	<0.02	3.07
48	46.0	2.2	0.22	0.65	21.3	<0.02	0.65
49	51.4	3.3	<0.12	0.39	26.4	0.19	0.01
50	60.3	3.8	<0.08	0.33	27.0	0.17	0.83
51	50.0	3.7	<0.10	0.20	26.2	<0.02	0.20
52	53.3	4.8	<0.08	0.38	28.5	0.38	<0.01
53	46.8	3.2	<0.14	0.21	28.0	<0.02	0.21
54	42.3	6.0	<0.08	0.47	27.2	0.24	<0.02
56	31.6	3.5	<0.18	0.32	20.8	0.32	0.63
57	59.5	2.5	<0.14	0.34	28.4	<0.01	<0.01
58	35.5	2.7	<0.20	1.41	25.1	<0.02	0.85
59A	59.2	5.0	<0.06	0.34	26.2	0.17	0.34
60	57.4	2.7	<0.12	0.35	24.3	<0.01	<0.01
61	45.2	3.8	<0.18	0.71	23.0	0.03	0.03
62	28.0	3.8	<0.18	0.40	26.4	0.02	0.20
68	54.5	2.1	<0.18	0.92	26.5	0.01	0.55
69	51.6	4.1	<0.10	0.39	41.0	0.10	4.10
110	19.2	1.8	<0.58	0.58	15.5	4.74	6.77

[a]Corrected for elemental mercury

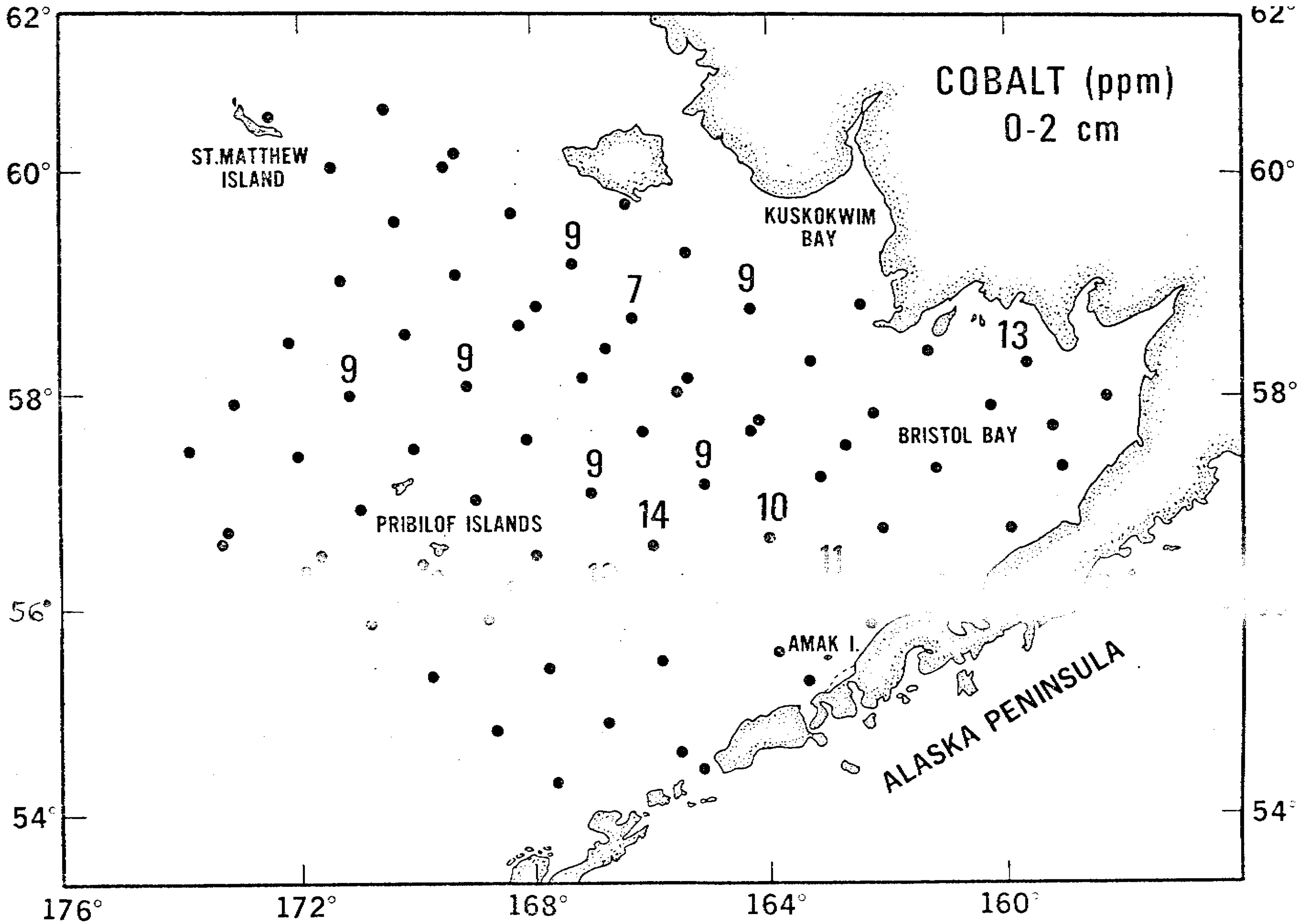
[b]Corrected for reducible mercury

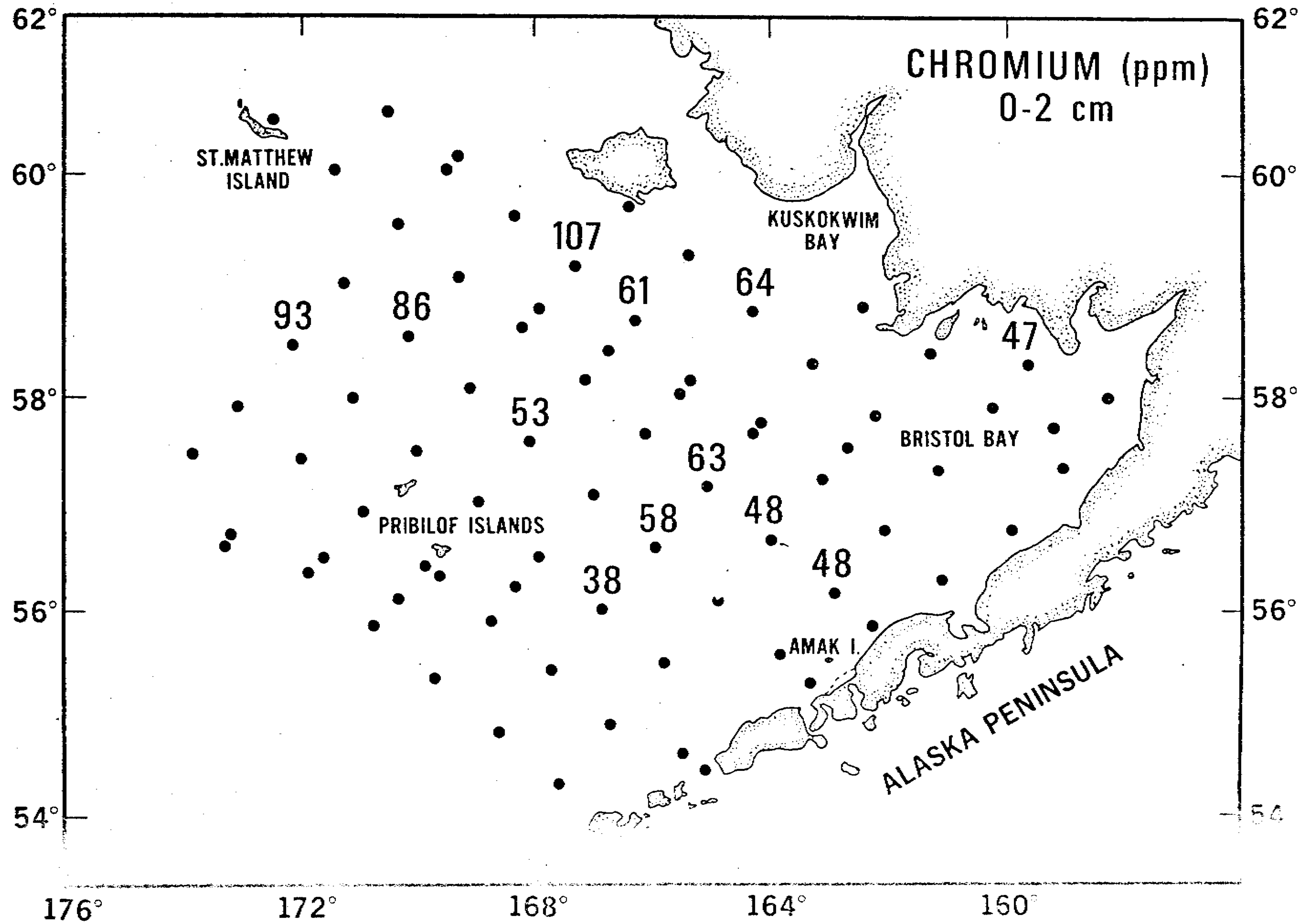
[c]Claculated on the basis of 0.2 ng detection limit.

TABLE X

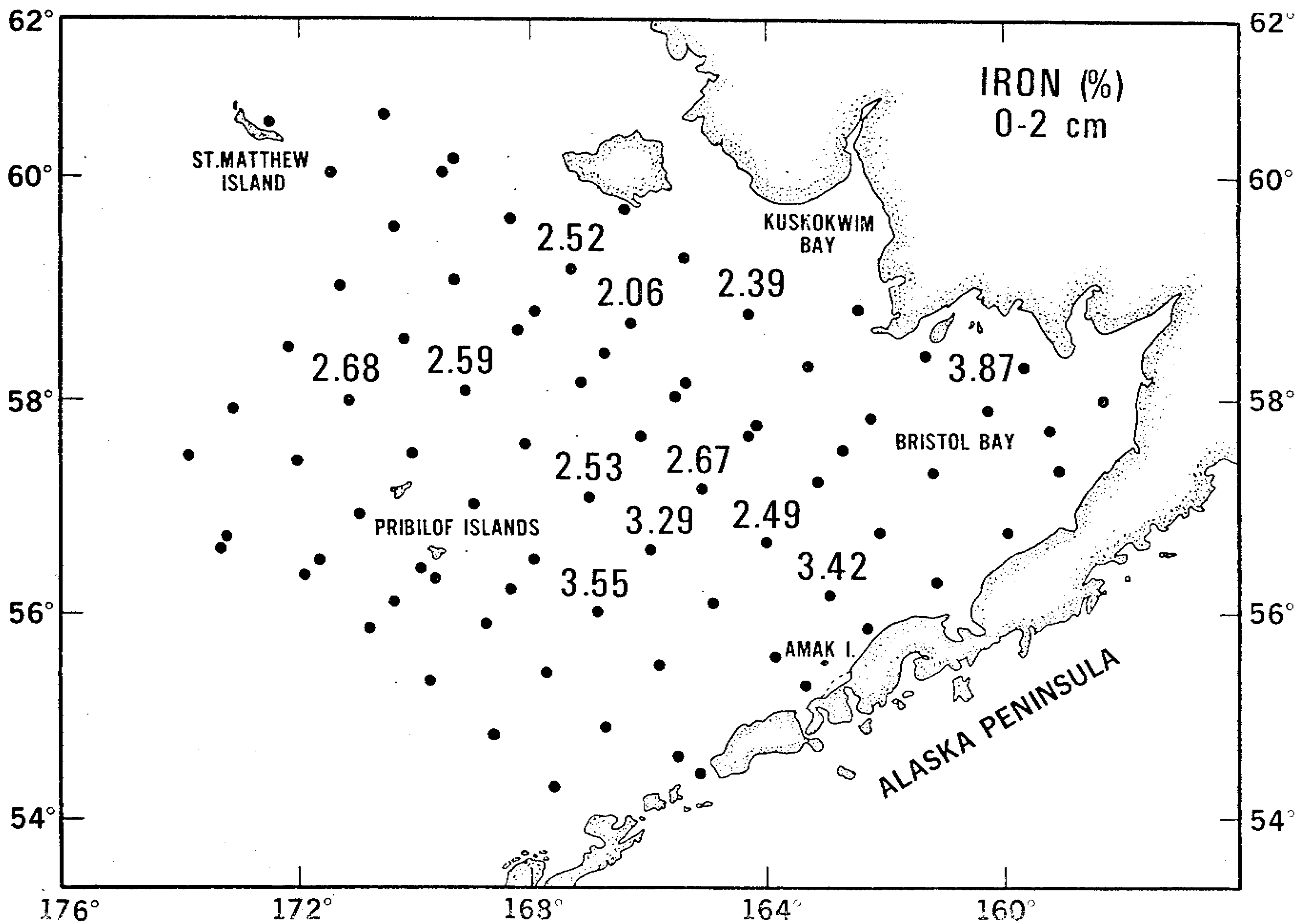
S. Bering Sea
Discoverer - 2-19 June 1975.
D. E. Robertson, Analyst.
Total heavy metal contents of bottom sediments (μg/g) except Fe%)

Station	Interval (cm)	As	Ba	Co	Cr	Fe(%)	Sb	Sc
8	0-2	4.1±0.4	370±230	13	47±5	3.87	0.46±0.13	13
	4-6	5.1±0.3	230±210	10	32±4	2.87	0.56±0.22	11
	8-10	4.1±0.4	310±220	14	46±4	4.21	0.68±0.14	14
	12-14	3.9±0.4	<210	7.2	25±4	2.11	0.36±0.08	8
12	0-3	4.3±0.5	650±170	11	48±5	3.42	0.86±0.17	13
19	0-2	3.7±0.4	440±140	10	48±4	2.49	0.63±0.12	12
28	0-3	2.9±0.5	490±170	9	63±4	2.67	0.56±0.14	12
29	0-4	7.2±0.5	530±220	14	58±5	3.29	0.96±0.18	12
30	0-4	3.4±0.5	200±190	10	38±5	3.55	0.55±0.13	15
	4-8	2.1±0.5	<260	11	36±5	3.53	0.50±0.13	15
	8-12	1.5±0.5	<370	10	46±5	3.42	0.34±0.13	14
37	0-2	4.1±0.6	430±190	9.1	53±4	2.53	0.61±0.11	10
	4-6	3.1±0.5	500±150	8.9	59±4	2.44	0.44±0.11	11
	8-11	5.8±0.4	750±150	11	60±5	2.73	0.79±0.14	10
41	0-2	3.0±0.4	480±140	8.9	64±5	2.39	0.52±0.12	10
43	0-2	3.2±0.5	<420	7.0	61±5	2.05	0.57±0.10	8
56	0-2	0.7±0.6	<260	9	86	2.59	0.63±0.08	10
	4-6	4.3±0.6	460±280	8	73	2.24	0.69±0.08	9
	8-10	2.8±0.6	570±440	10	95	2.87	0.74±0.09	11
	12-18	4.0±0.7	<500	9	79	2.47	0.82±0.14	10
59	0-2	4.0±0.4	1070±340	9	107	2.52	0.73±0.08	10
	4-6	3.8±0.4	<350	8	115	2.20	0.72±0.09	9
64	0-2	2.7±0.8	1030±340	9	93	2.68	0.48±0.09	10
	4-6	3.6±0.6	500±270	9	85	3.81	0.50±0.11	11
	8-10	2.9±8.6	<280	10	102	3.07	0.71±0.07	11
	12-14	3.6±0.6	810±300	8	76	2.47	0.68±0.09	10
	16-20	4.6±0.5	400±260	11	101±5	3.36	0.75±0.19	13
	10-24	6.5±0.4	600±240	11	92±5	3.27	1.02±0.17	13


COBALT (ppm)
0-2 cm
ST.MATTHEW ISLAND
KUSKOKWIM BAY
BRISTOL BAY
PRIBILOF ISLANDS
AMAK I.
ALASKA PENINSULA
9
7
9
9
9
13
9
9
14
10
62°
60°
58°
56°
54°
176°
172°
168°
164°
160°



CHROMIUM (ppm)
0-2 cm
ST.MATTHEW ISLAND
KUSKOKWIM BAY
BRISTOL BAY
PRIBILOF ISLANDS
AMAK I.
ALASKA PENINSULA
107
61
64
93
86
47
53
63
48
58
48
38
62°
60°
58°
56°
54°
176°
172°
168°
164°
160°


IRON (%)
0-2 cm
ST.MATTHEW ISLAND
KUSKOKWIM BAY
PRIBILOF ISLANDS
BRISTOL BAY
AMAK I.
ALASKA PENINSULA
2.52
2.06
2.39
2.68
2.59
3.87
2.53
2.67
3.29
2.49
3.42
3.55
62°
60°
58°
56°
54°
176°
172°
168°
164°
160°

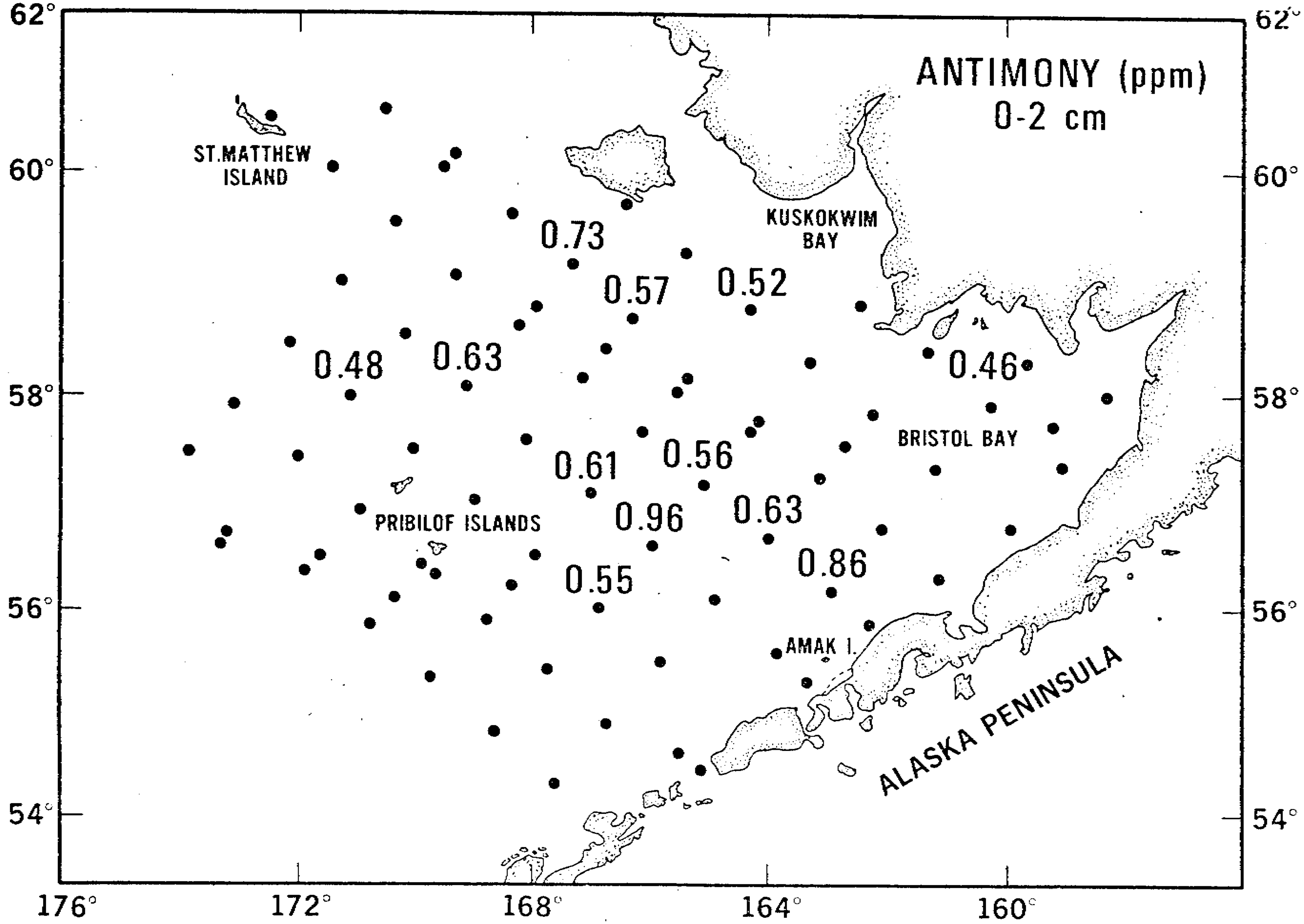

ANTIMONY (ppm)
0-2 cm
ST.MATTHEW ISLAND
KUSKOKWIM BAY
BRISTOL BAY
PRIBILOF ISLANDS
AMAK I.
ALASKA PENINSULA
0.73
0.57
0.52
0.48
0.63
0.46
0.61
0.56
0.96
0.63
0.55
0.86
62°
60°
58°
56°
54°
176°
172°
168°
164°
160°

TABLE XI

S. Bering Sea
Discoverer, 2-19 June 1975.
A. S. Naidu, Analyst.
Clay mineralogy (weighted peak area percents).

Station No.	Expandable component[a]	Illite	Kaolinite	Chlorite
16	40	22	5	33
17	41	29	3	27
18	36	35	5	24
30	31	29	3	37
36	32	28	3	35
37	16	46	4	34
66	31	41	3	25

[a]See text for definition

TABLE XII

A. S. Naidu, Analyst.
Clay mineralogy of < 1 and 2 μm fractions (weighted peak area percents).

Sample No.	Treatment	Expandable component <2 μm	Expandable component <1 μm	Illite <2 μm	Illite <1 μm	Kaolinite <2 μm	Kaolinite <1 μm	Chlorite <2 μm	Chlorite <1 μm	Kaolinite +Chlorite <1 μm
1	a	1	t	45	42	0	-	54	-	58
	b	0	-	45	45	0	-	55	-	55
	c	2	-	47	41	0	-	51	-	59
3	a	4	6	45	47	0	t	51	47	-
	b	0	0	47	51	0	t	53	49	-
	c	5	7	45	40	0	t	50	53	-
4	a	3	7	45	44	0	t	52	49	-
	b	t	0	57	50	0	t	43	50	
	c	6	6	44	43	0	t	50	51	-
5	a	5	-	41	-	0	-	54	-	-
	b	0	-	53	-	0	-	47	-	-
	c	7	-	42	-	0	-	51	-	-
6	a	4	2	47	48	0	-	49	-	50
	b	t	-	46	56	0	-	54	-	44
	c	7	8	39	44	0	-	54	-	48
7	a	10	7	32	38	0	t	58	55	-
	b	-	0	-	43	0	t	-	57	-
	c	8	3	37	37	0	t	55	60	-
25	a	4	6	58	54	0	t	38	41	-
	b	0	0	66	61	0	t	34	39	-
	c	4	7	57	54	0	t	39	39	-
28	a	2	2	51	48	0	t	47	51	-
	b	t	0	56	54	0	t	44	46	-
	c	t	2	52	47	0	t	48	51	-
31	a	2	2	43	48	0	-	55	-	50
	b	0	-	44	51	0	-	56	-	49
	c	3	-	39	39	0	-	58	-	61
32	a	3	5	35	37	0	0	62	58	-
	b	t	0	46	44	0	0	54	56	-
	c	3	3	39	34	0	0	58	63	-

TABLE XII. Cont'd

Sample No.	Treatment	Expandable component <2 µm	Expandable component <1 µm	Illite <2 µm	Illite <1 µm	Kaolinite <2 µm	Kaolinite <1 µm	Chlorite <2 µm	Chlorite <1 µm	Kaolinite +Chlorite <1 µm
39	a	6	5	44	38	0	0	50	58	-
	b	t	0	50	43	0	0	50	57	-
	c	4	4	40	36	0	0	56	60	-
40	a	6	t	38	45	0	-	56	-	-
	b	0	-	36	43	0	-	64	-	57
	c	5	t	35	41	0	-	60	-	59
41	a	4	6	46	31	0	0	50	63	-
	b	t	6	47	41	0	0	53	59	-
	c	5	3	45	37	0	0	50	60	-
42	a	5	5	35	32	0	0	60	63	-
	b	0	0	47	38	0	0	53	62	-
	c	3	1	40	37	0	0	57	63	-
43	a	5	7	36	37	0	0	59	56	-
	b	t	0	46	47	0	0	54	53	-
	c	4	5	42	34	0	0	54	60	-
48	a	4	5	40	36	0	-	56	-	59
	b	0	-	51	50	0	-	49	-	50
	c	7	3	37	40	0	-	57	-	57
50	a	5	5	34	37	0	0	61	59	-
	b	0	0	45	40	0	0	55	60	-
	c	5	3	41	39	0	0	54	58	-
52	a	2	6	48	51	0	0	50	44	-
	b	1	0	53	56	0	0	46	44	-
	c	2	4	56	48	0	0	42	48	-
57	a	6	-	44	53	0	-	50	-	47
	b	0	-	48	52	0	-	52	-	48
	c	5	?	42	42	0	-	53	-	58
58	a	5	7	42	36	0	0	53	56	-
	b	0	1	52	47	0	0	48	52	-
	c	3	3	37	31	0	0	60	65	-

Treatments:

a - Glycol saturation
b - K^{+} glycolated
c - Mg^{++} glycolated

TABLE XIII

N.W. Gulf of Alaska

A. S. Naidu, Analyst.

Clay mineralogy of <1 and 2 µm fractions (weighted peak area percents).

Sample No.	Treatment	Expandable component <2 µm	Expandable component <1 µm	Illite <2 µm	Illite <1 µm	Kaolinite <2 µm	Kaolinite <1 µm	Chlorite <2 µm	Chlorite <1 µm	Chlorite+ Kaolinite <1 µm
104	a	6	5	54	53	0	0	40	41	-
	b	0	0	53	54	0	0	47	46	-
	c	7	9	37	43	0	0	54	51	-
119	a	7	8	60	54	0	-	33	-	38
	b	0	-	64	64	0	-	36	-	36
	c	11	3	53	58	0	-	36	-	39
120	a	9	10	55	52	0	0	36	38	-
	b	0	0	57	62	0	0	43	38	-
	c	7	9	54	49	0	0	39	42	-
121	a	10	8	53	49	0	0	37	43	-
	b	0	0	53	48	0	0	47	42	-
	c	9	7	47	45	0	0	44	48	-
124	a	13	12	47	39	0	0	40	49	-
	b	0	0	47	54	0	0	53	46	-
	c	9	10	39	39	0	0	52	51	-
134	a	7	10	45	44	0	0	48	46	-
	b	0	0	48	55	0	0	52	45	-
	c	10	8	45	47	0	0	45	44	-
135	a	13	14	52	45	0	0	35	41	-
	b	0	2	58	49	0	0	42	49	-
	c	19	11	37	43	0	0	44	46	-

Treatments:

a - Glycol saturation
b - K^{+} glycolated
c - Mg^{++} glycolated

IV. PRELIMINARY INTERPRETATION

A. Extractable heavy metal contents of sediments.

The data set given in Table III completes the NEGOA analysis program. Previous results were given in Table V and Tables XXX and XXI of the 1974-75 and 1976-77 Annual Reports respectively. An initial summary and interpretation was included in the N.E. Gulf Synthesis Report. This will be updated and included in the next quarterly report. Meaningful interpretation of these data has been hampered because of the paucity of sediment size fractionation data available for this area. Tables IV and V give data for Norton Sound and the S. Chukchi Sea respectively for samples collected on the September 1976 *Surveyor* cruise. A simple size fractionation (gravel, sand, mud) is being currently obtained for all these samples. For the S. Bering Sea samples (extract chemistry data given in Table XXXIV of the 1976-77 Annual Report), a detailed size analysis program is being conducted. All these data will be discussed in the next quarterly report.

B. Intertidal benthic biota.

The data for heavy metal contents of *Mytilus* and *Fucus* given in Tables VI and VII respectively completes the general survey undertaken in conjunction with Zimmerman's group. This work covered beach sites on the N.E. and N.W. Gulf, Kodiak Island and S. Bering Sea. Multiple data is available only for the N.W. Gulf region and this was discussed at the Synthesis Meeting. An update will be included in the next report.

C. Mercury species in NEGOA sediments (H. V. Weiss).

The results of the analyses together with the total mercury content of these sediments appear in Table IX. Either none or only a small fraction of the mercury associated with the sediments is in the elemental or readily reducible form with the exception of one sediment (#110) only small quantities of these species were extractable into seawater. In contradistinction to the other sediments which were mud-like in character, #110 consisted of sand; apparently this composition allowed for release of essentially half of the mercury and that which was released was substantially readily reducible. Some sediments give evidence that an organic moiety is also extracted into seawater.

D. Clay mineral compositions of shelf sediments (Dr. A. S. Naidu).

The data of Table XI are additional to the listing given as Table LVI on p. 129 of the 1976-77 Annual Report. An interpretation was included at that time.

With reference to the thermal studies of the S. Bering Sea clay samples, Dr. Naidu has prepared the following summary:

> "These heat treatments, in conjunction with earlier analysis on chemically untreated and treated samples have permitted, at least on a tentative way, to decipher the presence of various mixed-layer clay mineral phases. In attempting to recognize such mixed-layer components, criteria proposed by several investigators have been followed (Howes, 1967; Reynolds and Howes, 1970; Millot, 1970).
>
> As of this report writing, it would seem that most of the clay samples examined from the southeast Bering Sea, do have recognizable amounts of mixed-layer components, and that these are most likely in the form of verniculite-chlorite or illite-verniculite mixed-layer minerals are observed only occasionally.

The great enhancement of the 14 Å d basal peaks subsequent to the heating of the clays at 550°C/1 hr suggests the presence of a thermally stable chlorite which most likely is also the Mg-chlorite type.

References

Biscay, P. E. 1965. Mineralogy and sedimentation of recent deep-sea clay in Atlantic ocean and adjacent seas and oceans. *Geol. Soc. Amer. Bull.* 76:803-832.

Howes, J. 1967. Order of mixed-layering in illite/montmorillonites. *Clays and Clay Minerals* 15:64-74.

Millot, G. 1970. Geology of clays. Springer-Verlag, New York-Berlin (English transl. by W. R. Farrand and Hélène Raquet). 429 pp.

Reynolds, R. C. and J. Hower. 1970. The nature of interlayering in mixed-layer illite-montmorillonites. *Clays and Clay Minerals* 18:25-26."

V. PROBLEMS ENCOUNTERED

A. There has been no official acceptance of the specific study sites proposed for FY 77 so we are uncertain as to the emphasis to be given to particular areas.

B. We have encountered considerable problems in operating our field work program in Icy Bay. Bad weather and ship breakdowns have been the principal culprits.

C. The delay in funding the "mammal modification" to the project (this has now been officially approved with only 3 months work time available), coupled with the new emphasis on biota analysis has caused laboratory problems. We have attempted to improve this phase of the program by obtaining a plasma furnace to speed up the time-limiting dissolution step but have not secured the necessary official approval as yet.

D. The first batch of "archived" marine mammal samples proved unsuitable for heavy metal analysis work.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: June 30, 1977

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 refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 1	2	3	4
Discoverer Leg II #808	6/2/75	6/19/75	*	*	None	*
Silas Bent Leg I #811	8/31/75	9/14/75	None	None	None	None
Discoverer Leg IV #812	10/8/75	10/16/75	*	*	None	*
Miller Freeman	8/16/75	10/20/75	None	None	Unknown	None
Discoverer Leg III #810	9/12/75	10/3/75	None	None	None	*
North Pacific	4/25/75	8/7/75	None	None	Unknown	None
Intertidal Biota		1975	None	None	Unknown	None
Discoverer #816	11/12/75	12/2/75	*	*	None	*
Contract 03-5-022-34	Last	Year	*	None	None	None
USCGC Glacier	8/18/76	9/3/76	*	None	None	None
Discoverer	9/10/76	9/24/76	*	None	None	None

Note: [1] Data Management Plan has been approved by M. Pelto, we await approval by the Contract Officer.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 5	6	7	8
Discoverer Leg II 808	6/2/75	6/19/75	*	None	None	None
Silas Bent Leg I 811	8/31/75	9/14/75	None	None	None	None
Discoverer Leg IV 812	10/8/75	10/16/75	*	*	None	None
Miller Freeman	8/16/75	10/20/75	None	Lost	*	*
Discoverer Leg III 810	9/12/75	10/3/75	None	*	None	None
North Pacific	4/25/75	8/7/75	None	Lost	Lost	Lost
Intertidal Biota		1975	None	None	*	*
Discoverer 816	11/23/75	12/2/75	*	None	None	None
Contract 03-5-022-34	Last	year	*	None	*	*
Glacier	8/18/76	9/3/76	*	*	None	None

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 9	10		
Discoverer Leg II 808	6/2/75	6/19/75	*	*		
Silas Bent Leg I 811	8/31/75	9/14/75	*	*		
Discoverer Leg IV 812	10/8/75	10/16/75	*	*		
Miller Freeman	8/16/75	10/20/75	none	none		
Discoverer Leg III 810	9/12/75	10/3/75	none	none		
North Pacific	4/25/75	8/7/75	none	none		
Intertidal Biota		1975	none	none		
Discoverer 816	11/23/75	12/2/75	*	*		
Contract 03-5-022-34	Last	year	*	none		
Moana Wave	3/76	4/15/76	*	none		
Beaufort Sea Sediments	-	-	*	*		
Acona	4/6/77	4/14/77	9/30/77			

* Suitable format for magnetic tape submission was received 3/21/77. Formating of data will proceed, delivery date is unknown at this time. These data have been submitted in tabular form in the Annual and Quarterly Reports for T/O 12 including the Final report of contract 03-5-022-34.

QUARTERLY REPORT

Contract 03-5-022-56
Task Order No. 5
Quarter Ending: 30 June 1977

AROMATIC HYDROCARBONS IN RECENT SEDIMENTS OF THE BEAUFORT SEA: DISTRIBUTION AND SOURCES

R.U. 275

Principal Investigator

Dr. David G. Shaw
Associate Professor
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June 30, 1977

AROMATIC HYDROCARBONS IN RECENT SEDIMENTS OF THE BEAUFORT SEA: DISTRIBUTION AND SOURCES

SHAW, David G., SMITH, Eleanor R., and MCINTOSH, Douglas J., Institute of Marine Science, University of Alaska, Fairbanks, Alaska 99701

Analysis of aliphatic and aromatic hydrocarbon fractions in nearshore surficial sediments of the western Beaufort Sea by gas chromatography shows the predominance of a suite of compounds probably of terrigenous plant origin including n-C_{23}, n-C_{25}, and n-C_{27}. A typically marine assemblage including n-C_{15}, n-C_{17}, n-C_{19}, pristane and phytane is also present at lesser concentrations.

Further analysis of the aromatic fraction by combined gas chromatography mass spectrometry using single ion monitoring was carried out to determine the relative abundances of polycyclic aromatics and their alkyl homologs. Sediments from Prudhoe Bay contained $C_{14}H_{10}$ (anthracene and/or phenanthrene) and the C_1 and C_2 homologs in the ratio 0.3:0.3:1.0; the corresponding ratio for Iko Bay (300 km to the west) is 0.5:0.8:1.0. However sediments from Cape Simpson, an intermediate location, contained $C_{14}H_{10}$ at a concentration two orders of magnitude less than the other two locations and undetectably small amounts of the homologs. The potential local sources of these aromatics include the weathering of coal, shale and asphalt deposits which are known to occur on land near the Beaufort Sea coast and which are likely to also exist at submarine locations; petroleum spills associated with industrial activity; pyrolysis products of petroleum and modern plant material; and biosynthesis. However, the relative abundances of alkyl homologs in sediments differ markedly from the patterns of Alaskan coals, asphalt from an adjacent seep area, and diesel engine exhaust.

I. FIELD AND LABORATORY ACTIVITIES

A. Field

1. A field party working out of Homer obtained samples of sediment and a wide variety of biota of Kachemak Bay. This was done in coordination with trace metal collections.

2. On a cruise of the USNOSS *Discoveror* in the Bering Sea biological materials from the pelagic food web of the area. Experiments to quantify the importance of bio-sedimentation of oil droplets by zooplankton were also conducted.

3. On a cruise of the R/V *Acona* in Cook Inlet samples of biota, water, sediment and seston were collected.

B. Laboratory

Work continues in this area without either spectacular breakthroughs of catastrophic setbacks.

II. RESULTS

Attached is an informational copy of an abstract prepared for presentation at a meeting of the Geological Society of America in November 1977.

Quarterly Report

Contract: RK6 - 6074
Reserarch Unit: 413
Reporting Periods: 1 April 1977 - 1 July 1977

Trace Metal Content of Bottom Sediment in Northern Bering Sea

Jeffrey J. Patry
Brad Larsen
Hans Nelson
Chris Heropoulos

Pacific-Arctic Branch of Marine Geology
345 Middlefield Road
Menlo Park, California 94025

July, 1977

INTRODUCTION

The activities of the past quarter include: (1) preparation and statistics analysis of individual bulk data sets residing on computer files, (2) merging of appropriate data files after comparison of statistics of individual data files to create the best total bulk data set of surface samples,(3) statistical analysis of the total bulk data set, (4) preparation for station plotting of the data set, (5) error analysis of replicate emission spec analysis, (6) preliminary work on 3-dimensional graphic plotting of the total surface sample bulk data set.

Sample Sets

At the beginning of the quarter three separate data sets, TMBULK 1, TMBULK 2, and TMBULK 3 existed on computer files. These data files are composed of geochemical values derived from emission spec analysis of 345 surface samples collected from 1968 to 1976. TMBULK 1 is composed of grab samples collected before 1976 in Chirikov Basin and Norton Sound. TMBULK 2 was formed using a weighted average program to combine the analytic values of size splits of bulk grab and box core samples collected in Chirikov Basin in 1968 and 1969. TMBULK 3 contains the analytic values of the Soutar-Van Veen bulk samples collected in Norton Sound during 1976. These TMBULK 3 samples were the most carefully collected subset of bulk samples; they come from a chemically clean device that causes minimal disturbance of surface samples. The surface sampling by template to 1 cm depth duplicated standard baseline techniques developed by Ian Kaplan of UCLA for thier BLM-NOAA research throughout the western North American OCS research. The samples were frozen immediately upon collection and preserved in that manner until analysis in Menlo Park, California.

Statistical Analysis of Individual Data Sets

General

Fischer-K statistics were generated for each of the individual data sets using the U.S.G.S. Statpac system Fisher-K statistics program (D0010) written by Gary I. Selner and Robert Terrazas. Prior to running Fischer-K statistics the analytical values were transformed to Log_{10} values by use of the U.S.G.S. Statpac system transformation generator program (D0001) written by George van Trump.

The Fischer-K statistics were run on unqualified values only and used unbiased equations as defined in the program. Unqualified values were chosen because: (1) the data sets were analyzed by emission spec in different years and the increasing precision of emission spec techniques has lowered the limit of detection for several elements. The newer data sets may therefore contain data values lower than those of older data sets and since the older data sets cannot be made more precise, qualified values were eliminated for uniformity of the data sets, (2) elements contained either predominately qualified values or unqualified values, therefore elimination of the few qualified values has minimal effect on the statistics for the elements reported in Table 1. Elements containing many qualified values are not reported but the unqualified values for these elements will be hand plotted to see if they represent reasonable geologic anomalies.

Data Sets TMBULK 1 - 3

Because TM BULK 1 contains the most samples, 296, and covers both Chirikov Basin and Norton Sound, it is the most statistically accurate of the individual data sets and it has been used as a datum for comparison of the other individual data sets. The geometric mean is considered to be the most accurate measure of central tendancy for geochemical values (Meisch, 1970). Comparison of geometric means shows that TM BULK 2 varies considerably from TM BULK 1 whereas TM BULK 3 generally varies little from TM Bulk 1. The discrepancies noted in TM BULK 2 are due to two causes: (1) there are not enough samples to be statistically significant, (2) loss or concentration of elements may have occurred during size splitting of the bulk sample prior to emission spec analysis. For these reasons the data of TM BULK 2 is seen as questionable and has not been used in the total bulk set (T BULK SET).

A surface sample total bulk data set, T BULK SET was created by merging the elements common to TM BULK 1 and TM BULK3. TM BULK 2 may be added to the total bulk set after plotting contour maps of the total bulk set if the areal distribution of the limited number of values make a logical geologic pattern. In addition, several subsurface, pre-Holocene, samples were selected out prior to generating Fischer-K statistics on the total bulk data set.

Subsurface bulk data set

Pre-Holocene subsurface samples were selected out of the total bulk data set and were statiscally analyzed in the same manner as the other data sets. Comparison of the geometric means of the subsurface sample bulk data set and the total bulk data set show that the pre-Holocene samples have predominately lower values than the total bulk set or TM BULK 1 (Table 4). The low values in the subsurface sample bulk data, in part, account for the increase in the geometric mean noted for the total surface sample bulk data set. The possible explanation for the low geometric mean values for Pre-Holocene samples may be linked to different sediment sources for the pre-Holocene samples and the modern bulk surface samples.

Data Set (T Bulk Set)

The total bulk data set was statistically analyzed in the same manner as the individual data sets. Table 1 shows that the geometric mean values for the total bulk data set are generally higher than those for TM BULK 1 or TM BULK 3. The two most probable explanations for the increased geometric mean values are: (1) increased number of samples has increased the statistical accuracy of the geometric means, (2) the Pre-Holocene subsurface samples removed contained lower concentrations of the reported elements than the surface samples, thus increasing the geometric mean values (see Table 4).

Error Analysis of Emission Spec Analysis

Two characteristics must be considered in an error analysis; precision and accuracy. Precision can be determined by comparing replicate analysis of several elements for a single sample. Additionally replicate samples were run independently using neutron activation by Dave Robertson of Battalle Northwest. Accuracy is measured by comparing replicate emission spec analysis of U.S.G.S. standard rocks to the published standard rock values. The emission spec replicate analyses of standard rocks were inserted randomly within Norton Basin sample sets.

Precision of Emission Spec Analysis

Precision measures the grouping or closeness of replicate analytic values and is independent of accuracy. The precision analysis of emission spec values was done by comparing the anlytic values of replicate samples to the mean values of these samples and taking the percent difference for each of the 8 replicates. The percent differences were averaged and appear under the replicate sample number in table 4. The average percent errors for the three replicate samples were averaged to give the average percent error for each element for emission spec analysis (Table 4).

All of the reported elements have better than 75 percent precision, except Zn, and most of the elements have precision greater than 85 percent. This means that for a given element replication of the analysis would result in a value within 25 percent of other replicates for all elements, except Zn, and within 15 percent of replicate values for most of the elements.

Comparison of the geometric means of elements common to emission spec and neutron activation analysis replicates shows that both methods give values of the same magnitude (Table 2). The standard deviations of emission spec analysis are generally higher than those for neutron activation analysis indicating that neutron activation tends to give more reproducible results than does emission spec analysis (Table 2). It must be noted that the number of replicates, three and eight for neutron activation and emission spec respectively, are low and the comparison of standard deviations may not be statistically accurate. Reproducibility varies for different elements, as will be discussed under 'accuracy' below. A list of relative reliability for emission spec analyses of different elements has been produced (Table 4).

Accuracy of Emission Spec Analysis

Four U.S.G.S. standard rock samples were each analyzed twice using emission spec techniques. Percent error for each replicate emission spec analysis of a standard rock was calculated and then the percent error was averaged for each element (Table 3). The average percent error varies considerably for the reported elements; the elements are ranked by increasing percent error in Table 4.

Emission spec analysis has an 'accepted' error of approximately 25 percent. The reported elements break naturally into three groups of increasingly greater percent error. The most reliable elements, 9 to 30 percent error, are Y, Ca, Ba, K, Cr, Cu, Na, Co, Nb, Ni, V, and Zn in increasing percent error (Table 4). These element values should represent good baseline values for the Northern Bering Sea.

A second group, 35 to 65 percent error, represent reasonable baseline values because even with significant percent error the values of elements in this group are of the same order of magnitude as the published values for U.S.G.S. standard rocks and neutron activation analysis (see Fe, Mg, Mn in Table 2). This group includes Sr, Al, Sc, Zr, Ti, Ga, Pb, Re, Mn, Mg, and La in increasing percent error (Table 4). The third group, 80 percent error and up, represents elements that do not lend themselves to emission spec analysis.

While these elements, Yb, Sn, and B do not give good analytic values, they may still give high value trends in certain areas that may point out geologic anomalies. The actual magnitude of these anomalies will be unknown but possibly selected samples from these areas could be analyzed by other methods to yield the numerical values of the anomalies.

The average standard deviations were calculated for elements of the U.S.G.S. standard rock replicates (Table 4).

Preliminary Work on 3-dimensional Graphics

A contract has been set up with the Lawrence Berkeley Laboratory computer center for the purpose of utilizing the 3-dimensional surface display graphics package. Two types of plots are seen as useful: (1) 3-dimensional scalor plot which gives plots of the actual values as rods in a 3-dimensional perspective view integrating latitude and longitude, (2) 3-dimensional contour plots that give interpolated values to unsampled areas and give visual accentuation to anomalies.

A complete listing of the software documentation and a complete card deck for the necessary programs and subroutines have been obtained. The total surface sample bulk data set may be amended to add TM BULK 2 after station plotting of the data set and comparison of the regional geology with values in TM BULK 2. 3-dimensional graphics plotting should begin in late July with the plotting of selected test elements. In early August these test graphics will be evaluated and a complete series of areal plots for each element will be made if the graphic techniques prove suitable.

TABLE 1 Geometric Means, Geometric Deviations, Maximum and Minimum Values for Semi-Quantitative Emission Spectrographic Analysis of All Norton Basin bulk data sets.-

Data Set	#Samples / #Elements (# of Qualified Values)	TOTAL - BULK SET (TBulkset) 312 / 10: Geometric Mean	Geometric Mean	Minimum Value	Maximum Value	Pre-1976 Surface Grab Samples (TMBulk 1) 296 / 10: Geometric Mean	Geometric Deviation	Minimum Value	Maximum Value
Toxic Elements	Pb(1)	19.0613	1.59529	.845097	2.69897	17.09779	1.30868	.845098	1.69897
	Cu(0)	14.2027	2.01937	.477120	2.84509	12.23211	1.77521	.477121	1.69897
	Zn(1)	76.7828	1.61446	1.30102	3.0000	69.02246	1.51119	1.176091	2.30103
Petroleum Index Elements	Cr(0)	47.6043	1.81517	.99999	3.0000	43.43114	1.67397	1.0000	2.17609
	Ni	22.6943	1.88605	.30102	3.17609	19.40804	1.64759	.4771213	[illegible]
	V(0)	96.1676	1.48447	1.47712	2.30102	95.36285	1.47573	1.477121	2.30103
Indicators of Change in chemical environment	Ba(0)	582.8164	1.58368	1.99995	3.30103	600.8508	1.45514	2.176091	3.17609
	Fe(2)	2.3244	1.53832	.99999	.15490	2.15965	1.47480	.154902	.84509
	Mn(0)	446.3106	1.78390	3.17609	3.84509	385.8647	1.60375	2.176091	3.17609
	Co(0)	12.1423	1.70380	.69896	1.99999	111.24098	1.64413	.301030	1.84509
Heavy Metals	Sn(260)	6.80136	2.32868	.477120	1.99999	NV	NV	NV	NV
	Zr(1)	162.991	1.51427	1.30102	3.0000	149.2371	1.42379	1.698970	2.69897
Major Elements	Mg(1)	0.79673	1.01473	.84509	.82390	0.74405	1.78842	.698970	.84509
	Ca(1)	1.68074	1.96385	.69897	.99999	1.72958	1.91385	.698970	1.0000
	Ti(0)	0.46068	1.57794	.30000	.30102	0.41418	1.54240	0.0000	1.0000
	Al(0)	5.96760	1.35554	.15490	.99999	6.77093	1.76284	.301030	1.0000
	Na(0)	1.87660	1.60826	.11519	.47712	2.04322	1.41692	.154902	.47712
	K(0)	1.61928	1.58812	.30000	.69896	1.65656	1.39377	.052287	.47712
Minor Elements	Sr(0)	230.784	1.70733	1.47712	3.0000	237.7685	1.59928	1.69897	3.0000
	Y(0)	27.3438	1.49763	.99999	2.1760	24.61036	1.40590	1.0000	1.69897
	Sc(0)	13.3131	1.50513	.69896	1.69897	13.04778	1.49636	.69897	1.69897
	Nb(6)	11.7001	1.39435	.84509	1.47712	11.32454	1.40776	.69897	1.47712
	B(1)	76.0388	1.69394	.69896	2.30102	85.31570	1.46578	1.47712	2.17609
	La(0)	44.5794	1.62456	.99999	2.30103	41.76027	2.56449	1.17609	2.0000
	Ga(31)	15.2316	1.41418	.47712	1.47712	13.93048	1.40070	[illegible]	.477121
	Yb(0)	3.7030	1.40669	.15531	1.17609	3.57460	1.47780	0.0000	.845098
	Be(0)								

Data Set	Element	Size Split - Bulk Data (TMBulk 2) 15 / 30: Geometric Mean	Geometric Deviation	Minimum Value	Maximum Value	Soutar-Van Veen Samples (TMBulk 3) 34 / 54: Geometric Mean	Geometric Deviation	Minimum Value	Maximum Value	Pre-Holocene subsurface sample (bulk data set) 10 / 10: Geometric Mean	Geometric Deviation	Minimum Value	Maximum Value
Toxic Elements	Pb(1)	33.6435	1.70826	1.157137	2.12493	17.29920	1.35973	.84509	1.47712	21.058	1.1937	.47712	1.4771
	Cu(0)	57.8722	1.68079	1.462397	2.25123	15.25660	1.91286	.44712	1.69897	8.6970	1.7477	.47712	1.3010
	Zn(1)	131.9997	-----	2.120573	-.12057	87.04448	1.63786	1.47712	2.69897	51.507	1.9299	1.1760	2.1760
Petroleum Index Elements	Cr(0)	81.6855	1.33383	1.653212	2.12493	59.65216	1.37805	2.30103	1.9999	31.446	1.6906	.99999	1.8450
	Ni	20.3121	1.40216	1.102661	1.56427	25.54745	1.57788	.84509	1.69897	12.179	1.8384	.47712	1.4771
	V(0)	74.4744	1.25212	1.698970	[illegible]	105.6225	1.36317	1.69897	2.30103	72.078	1.3946	1.6989	2.1760
Indicators of Change in chemical environment	Ba(0)	581.001	-.22619	2.564271	2.90309	682.6062	1.49182	2.30103	3.0000	747.05	1.3468	2.6989	3.0000
	Fe(2)	2.1915	1.31579	.176090	.52287	2.50554	1.57660	.154092	.69896	1.5764	1.5451	.15490	.47712
	Mn(0)	409.9770	1.50897	2.425967	3.02802	647.2658	1.65385	2.30103	3.17609	290.81	1.4651	2.1760	2.6989
	Co(0)	7.5971	1.50182	.635483	1.22184	10.39004	1.44497	.698969	1.30101	7.3670	1.6706	.30102	1.11760
Heavy Metals	Sn(260)	NV	NV	.059738	1.08778	2.99999	1.0000	.47712	.477120				
	Zr(1)	176.8481	1.18860	1.903276	2.26324	231.9734	1.46657	1.99999	2.845098	110.44	1.5744	1.6989	2.3010
Major Elements	Mg(1)	0.7861	1.25978	.124938	.246672	1.016155	1.64173	.477120	.698970	.41577	1.5092	.15490	.69897
	Ca(1)	1.4899	1.40761	.397939	.791816	1.51134	1.5562	.477120	.522878	1.2004	1.9640	.30103	.69896
	Ti(0)	0.2971	1.22576	.47065	1.5788	.59308	1.31652			.30780	1.5229	.30103	.82390
	Al(0)	4.7909	1.20279	.564270	.801631	5.19419	1.21261	.477120	.845098	5.7570	1.3008	.47712	.99999
	Na(0)	1.3490	1.19496	.066946	.335791	1.67397	1.27798	.1589021	.477120	2.0146	1.4340	.15531	.47712
	K(0)	1.6184	1.20191	.066946	.335791	1.85097	1.3679	.154902	.477120	1.8410	1.2534	.17609	.47712
Minor Elements	Sr(0)	205.5496	1.39710	2.124938	2.564271	263.6207	1.64460	1.845098	3.0000	215.83	1.6182	1.9999	2.8450
	Y(0)	19.39637	1.13941	1.176090	1.397939	32.7341	1.47327	1.176090	1.84509	19.445	1.4210	.9999	1.4771
	Sc(0)	9.91577	1.22460	.083850	1.124938	17.67155	1.34021	.845097	1.47712	11.837	1.5320	.69896	1.3010
	Nb(6)	8.37922	1.10084	.059738	.999999	10.18678	1.30553	.8450978	1.30103	10.786	1.3136	.84509	1.1760
	B(1)	38.39772	1.35516	1.176090	1.751326	65.7779	1.38057	1.47712	2.17609	99.375	1.3570	1.8450	2.1760
	La(0)	37.60230	1.20622	1.517638	1.612783	60.3127	1.42274	1.30103	1.99999	38.286	1.5370	1.3010	1.8450
	Ga(31)	13.35251	1.17889	1.020028	2.331868	18.4833	1.49719	.477121	1.47712	15.430	1.2706	.9999	1.3010
	Yb(0)	2.08198	1.44131	.221848	.397939	3.51836	1.42083	.176091	.84509	3.7041	1.4209	.17609	.69897
	Be(0)							.158325	.69897				

Table 2 - Comparison of Emission Spec and Neutron Activation Values for Elements Common to Both Analyses

Statistic	Geometric Mean		Standard Deviation	
Methods	Emission Spec	Neutron Activation	Emission Spec	Neutron Activation
#Replicates	8	3	8	3
Zn ppm	59.1668	58.2847	22.9128	2.3563
Cr ppm	41.2835	53.4329	9.6824	1.9067
Ni ppm	25.7683	26.5664	4.8414	2.3556
V ppm	122.475	76.5172	25.000	4.7148
Fe %	1.86121	2.30485	0.1732	0.0917
Mn ppm	319.7807	307.6673	66.1437	183.426
Mg ppm	.70001	.305677	0.0968	1.3294
Ga ppm	11.8978	10.000	4.6351	0.000
Yb ppm	2.8517	1.28062	0.2839	0.6041

Table 3. % Error Between Analysis for Emission Spec Values and U.S.G.S. Rock Standard Values[1]

U.S.G.S. Rock Names	Error AGV-2[2]	% Error G2[2]	% Error GSP[2]	% Error BC R[2]	Avg. % Error of Standard rocks vs. all 8 emission spec Replicates
E.S. #Replicates	2	2	2	2	
Pb	42.0	51.0	36.0	70.0	49.75
Cu	16.0	7.0	10.0	39.0	17.25
Zn	19.0	25.0	28.0	46.0	29.50
Cr	2.0	43.0	20.0	1.0	16.50
Ni	5.0	42.0	32.0	21.0	25.00
V	25.0	21.0	13.0	41.0	25.00
Fe	56.0	43.0	54.0	48.0	50.25
Mn	NC	NC	NC	NC	NC
Co	24.0	9.0	33.0	21.0	21.75
Ba	17.0	6.0	15.0	4.0	10.50
Sn[3]	67.0	89.0	178.0	4.0	84.50
Zr	0.0	18.0	100.0	34.0	38.00
Y	6.0	13.0	1.0	19.0	9.75
Nb	27.0	7.0	18.0	48.0	24.00
B	500.0	525.0	267.0	200.0	398.0
La	100.0	56.0	5.0	92.0	63.25
Ga	48.0	31.0	36.0	50.0	41.25
Ce	NC	100.0	27.0	NC	63.50
Yb	76.0	100.0	67.0	79.0	80.50
Sc	12.0	89.0	41.0	9.0	37.75
Mg	54.0	61.0	48.0	57.0	55.00
Ca	2.04	23.0	1.0	13.0	9.76
Ti	29.0	50.0	33.0	43.0	38.75
Al	43.0	35.0	34.0	38.0	37.50
Na	30.0	26.0	7.0	8.0	17.75
K	4.0	33.0	10.0	18.0	16.25

Table 4. Comparison of accuracy of emission spec analysis of U.S.G.S. Standard Rocks and Precision of Replicate analysis of bulk samples from Norton Basin

	U.S.G.S. Standard Rocks Accuracy	Emission spec replicate data			
	Average	Average	% Difference from mean of 8 replicate bulk samples		
Sample	% Error	%Precision	ANC 68-235	ANC 68-216	ANC 68-120
Y ppm	9.75	20.94	23.63	20.2	19.0
Ca %	9.76	11.55	13.25	10.0	11.4
Ba ppm	10.50	13.13	15.0	9.0	15.4
K %	16.25	8.19	7.38	0.0	17.2
Cr ppm	16.50	15.91	22.13	16.0	9.6
Cu ppm	17.25	13.23	13.5	12.8	13.4
Na %	17.75	15.39	18.38	13.4	14.4
Co ppm	21.75	12.19	12.38	12.8	11.4
Nb ppm	24.00	20.26	22.38	20.2	18.2
Ni ppm	25.00	16.78	17.75	14.4	18.2
V ppm	25.00	18.07	20.0	16.4	17.8
Zn ppm	29.50	51.40	17.0	14.2	20.2
Sr ppm	37.50	6.53	11.38	8.2	0.0
Sc ppm	37.75	15.90	16.5	17.8	13.4
Zr ppm	38.00	19.68	22.63	23.0	13.4
Ti %	38.75	30.08	35.63	37.8	16.8
Ga ppm	41.25	13.15	31.25	0.0	8.2
Pb ppm	49.75	12.40	14.0	13.4	9.8
Fe %	50.25	6.73	13.5	0.0	20.2
Mn ppm	NC	22.78	13.75	18.2	16.8
Mg %	55.00	12.98	14.75	14.2	10.0
La ppm	63.25	21.29	28.88	11.4	23.6
Yb ppm	80.50	8.79	7.38	19.0	0.0
Sn ppm	84.50	NC	NC	NC	NC
B ppm	398.00	2.25	6.75	0.0	0.0

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August 2, 1977

Research Unit No. 500

Dr. Herbert E. Bruce
ERL/OCSEAP
National Oceanic and Atmospheric
Administration
P.O. Box 1808
Juneau, Alaska 99802

Dear Dr. Bruce:

This letter will serve as our First Quarterly Report on "Activity-Directed Fractionation of Petroleum Samples" covering the period February 15 to June 30, 1977.

Weathered and fresh Prudhoe Bay crude oil was obtained for this study from Jeff Short of Auke Bay Fisheries Laboratory.

A 20-gram sample of the fresh oil was fractionated into a pentane-soluble fraction and pentane-insoluble fraction. The pentane insolubles accounted for three percent of the total oil. This fraction was completely soluble in tetrahydrofuran (THF); hence, no THF-insoluble fraction was obtainable.

A portion of the pentane-soluble fraction was subfractionated by liquid chromatography using activated silica gel to give five subfractions. A sixth subfraction was obtained by exhaustively extracting the eluted silica gel with acetonitrile in a Soxhlet apparatus. The eluting solvents used to obtain each subfraction and the percent of the total oil represented by each are given in Table 1. Significant losses occurred because of the evaporation of the more volatile components during the determination of residue weights.

In vitro mammalian cell toxicity assays and Ames *Salmonella* mutagenicity assays are being carried out on the whole oil, pentane insolubles, pentane solubles, and fractions 1 and 2 from pentane solubles. Insufficient material was available for bioassaying fractions 3 to 6. Larger amounts of oil will be fractionated to obtain sufficient amounts of these latter fractions.

Although the program has gotten off to a slow start, we expect to accelerate the program during the next quarter. Work planned for the next quarter includes (1) completion of the initial *in vitro* bioassays including the bioassay of standard reference compounds, (2) fractionation of larger amounts of fresh oil, (3) subfractionation of the initial fractions, (4) bioassay of subfractions, and (5) fractionation of weathered oil.

If you have any questions concerning this work, please do not hesitate to contact me.

Sincerely yours,

J. Scott Warner
Senior Research Scientist
Organic, Analytical, and
Environmental Chemistry

JSW:pao

xc: Dr. Rudolph J. Engelmann
ERL/OCSEAP
National Oceanic and
Atmospheric Administration
Boulder, Colorado 80302

TABLE 1. FRACTIONATION OF PRUDHOE BAY OIL

Description of Fraction	Percent of Total Oil
Pentane Insolubles	3
Pentane Solubles	84
Silica Gel Fractions (using given eluting solvents)	
(1) Petroleum Ether	54
(2) 20% Methylene Chloride in Pet. Ether	14
(3) 20% Methylene Chloride in Pet. Ether	2
(4) Methylene Chloride	2
(5) Acetonitrile	2
(6) Acetonitrile (soxhlet extraction)	3

EFFECTS

EFFECTS

QUARTERLY REPORT

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"EFFECTS OF OILING ON TEMPERATURE REGULATION IN SEA OTTERS"

Dr. Gerald L. Kooyman, Principal Investigator

Northwest and Alaska Fisheries Center Auke Bay Laboratory
National Marine Fisheries Service, NOAA
P.O. Box 155, Auke Bay, Alaska 99821

PROGRESS REPORT ON NOAA CONTRACT #03-7-022-35130

TO SUPPORT RESEARCH ENTITLED

"EFFECTS OF OILING ON TEMPERATURE REGULATION IN SEA OTTERS"

I. Personnel engaged in research study.

A. Dr. Gerald L. Kooyman, Principal Investigator

B. Dr. Walter Garey, Research Physiologist concerned with all aspects of the conduct of the study.

C. Jack Sarno, Developmental Research Technician involved with the design, fabrication and operation of metabolic chamber and its associated instrumentation.

D. Michael Castellini and Randall Davis, UCSD graduate students working with the experimental runs and data analyses.

E. Noel Muller and Valerie Paul, UCSD undergraduate volunteers assist during the experimental runs.

F. Michael Bergey, animal caretaker and pool cleaning.

II. Metabolic chamber and instrumentation.

A. Metabolic chamber fixtures and fittings, corroded from previous use, were refurbished.

B. The cooling system capacity of the chamber was doubled by the addition of a new compressor-evaporator.

C. The heating system capacity was doubled.

D. A new chamber lid was constructed, which incorporated an elongated lucite dome (for animal freedom of movement).

E. The system controlling unit was extensively modified to permit control of the increased heating and cooling capacities.

F. The resolution of the digital display of the oxygen analyzer was expanded to four digits.

G. The oxygen analyzer sensor was cleaned and recalibrated at the factory.

H. Four single channel temperature telemetry transmitters of the FM pulse-interval-ratio type were purchased.

I. An appropriate FM telemetry demodulator-receiver was obtained.

J. A Wright respirometer having a 10,000 liter capacity was purchased and an elapsed time device, as well.

K. The metabolic chamber and its associated instrumentation performed excellently, while we utilized a human subject in 33.5°C water during a checkout experimental run. As one example, the 200 gallons of chamber water was held ± 0.03°C.

III. Obtaining, transport and maintenance of experimental animals.

A. On 12 May 1977 two sea otters (M ♀ weighing 26.5 kg and B ♀ weighing 12.9 kg) were efficiently collected under our permit #PRT 2-183, off Monterey, California by personnel of the California Fish and Game and the U. S. Fish and Wildlife departments.

B. Within three hours the animals were flown to San Diego and transferred to a pool, 20 ft. x 40 ft., of circulating sea water at Scripps Institution of Oceanography.

C. The otters ate immediately upon introduction to the pool and have been maintained since then on a five times/day feeding of squid, sea urchin, crab and occasionally abalone.

D. One animal, B, has gained weight over this period, but the other, M, has sustained a weight loss.

E. Because of concern over the weight loss the otters were transported to Sea World for an assessment of M's health status.

F. A diagnosis of pneumonia was made and the animal was given Keflex, a wide spectrum antibiotic. (In retrospect, we believe that this animal had this respiratory disease at the time of capture. Pneumonia is commonly manifested in the wild otter population off Monterey.)

G. Under the regimen of the antibiotic, animal M registered a significant gain in weight within three days. The prognosis for a complete recovery is good, and we expect the period of confinement at Sea World to be two weeks or less.

IV. Experiments

A. Upon their initial exposure to the metabolic chamber, both animals adjusted quickly and favorably.

B. Within a few minutes they floated quietly on the water and gave steady state oxygen consumption values. The recordings displayed far less fluctuation than those of our human subject at "total rest" and they were many times more stable than those we have made of resting northern fur seals.

C. Through an entire experimental run of approximately six hours the otters exhibit both quiet periods and active ones devoted to grooming and swimming.

V. Experimental results and observations

Average Oxygen Consumption ($\dot{V}O_2$) ml/min · kg

Animal	T_{H_2O} °C	Day or Night	$\dot{V}O_2$ of Entire Run	$\dot{V}O_2$ of Quiet Periods	$\dot{V}O_2$ of Grooming Periods
B	5	Night	22.3	15.8	27.8
M	5	Night	24.6	15.4	27.1
B	20	Day	17.0	13.7	21.4
M	20	Day	12.4	11.9	14.4
B	20	Night	19.1	15.4	24.8
M	20	Night	14.6	13.0	16.5

A. The resting oxygen consumptions of sea otters are about 2.5 times greater than mammals generally of similar size and weight.

B. On the basis of one experiment it is suggested that the overall oxygen consumption is two times greater in water of 5°C than at 20°C.

VI. Upcoming Work

A. We will continue to obtain control values of oxygen uptakes in animals exposed to 5, 15 and 25°C waters.

B. We plan to record simultaneously with the oxygen consumption the deep body and subcutaneous temperatures via FM telemetry.

C. Experimental runs are to be made following the oiling of a portion of the dorsal pelage with Prudhoe crude oil.

D. The oiled pelage of each animal will be cleaned with a different potentially effective detergent.

E. We will consider replacing the removed natural pelage oil with a reasonable substitute.

F. Repetitive experimental runs will be made during a recovery period, lasting over days and weeks, until each animal has regained a pre-oiled temperature regulating ability and status.

VII. Time schedule

A. Provided that our animals remain healthy, we would expect to complete the above work by 1 October, 1977.

B. The rest of the schedule is dependent upon the rate of recovery of the otters. Until they are close to normal we will not make another collection because of the considerable caretaking effort that would occur.

C. We project that the second collection of otters will take place this fall, if all goes reasonably well with the first experiments. In that case this phase of the project should be complete by next summer.

VII. Problems and concerns

A. Although high quality facilities and care are provided for our otters, their well being will remain our principal concern.

B. The best placement of the telemetry "pills" are a matter of deliberation. The otters often specifically reject a one-half vitamin capsule sequestered in food fed to them. Thus we doubt if they will swallow (and not crush) the telemetry pill.

C. Reputably, otters clear their gastro-intestinal tract within three hours after eating and could pass a successfully introduced telemetry pill, thus greatly limiting its temperature sensing period.

D. Aided by a marine mammal veterinarian, we shall investigate on an anesthetized otter the possibilities and practicalities of implanting a telemetry pill in the vaginal tract and another subcutaneously.

E. The first hours of exposure to water following oiling predictably will be the most critical period of our experiment. Accordingly, we will be particularly attentive to the animal's functional status during that time.

VIII. Budget

A. Overall, the level of expenditures is within the limit of the proposed budget.

B. The costs for modifying the anesthesia apparatus and for the telemetry pills have exceeded our estimates by $300. and $400. respectively. However, the pro-rated food costs for supporting our otters are less than originally projected, because we are presently maintaining two animals rather than the four anticipated. During some of the upcoming months we may be caring for three otters at one time.

C. As of now, we expect that the costs of this research study will be covered by the cost-reimbursement amount of the contract.

QUARTERLY REPORT

Contract No.
Research Unit #72
Report Period - April 1, 1977 to July 1, 1977
Number of Pages - 8

ACUTE AND CHRONIC TOXICITY, UPTAKE AND DEPURATION, AND SUBLETHAL METABOLIC RESPONSE OF ALASKAN MARINE ORGANISMS TO PETROLEUM HYDROCARBONS

by

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June 15, 1977

INTRODUCTION:

The third quarter has been a rough one for us. The quarter started off with the death of Loren Cheatham, Research Chemist, and delays in hiring personnel and availability of experimental animals compounded our problems. Our research unit has rebounded now, and we are essentially fully staffed, although we have fewer experienced people than originally planned. Personnel problems have caused cancellation of some experiments and delays in others, but we have added or modified other experiments to provide $500k-worth of oil-effects research relating to OCSEAP goals.

Two experiments have been added: the effects of temperature on animal sensitivity and uptake, and the comparison of sensitivities between tolerant and sensitive species to static and flow-through exposures. We feel these experiments have high priority, and are expansions or refinements of previous experiments which can be completed without further R&D.

I. Task Objectives and Third Quarter Progress

1. Determine the acute toxicity of the water-soluble fraction (WSF) of crude oil (1.3 man years):

a. Continue experiments with species not tested previously. Static tests will be phased out and flow-through tests phased in.

Progress: Tests were completed earlier in FY 77, and a manuscript is being revised.

b. Continue experiments with larvae, especially tests with molting larvae. Tests will be static. Larvae of previously untested species (such as mussels, barnacles, snails, and sea urchins) will be tested with WSF, toluene and naphthalene.

Progress: Tests with several species were cancelled because of administratitive delays in hiring key personnel.

Toxicity tests with coonstripe shrimp larvae before, during, and after molting from Stage I to II were completed with both toluene and naphthalene. Molting animals were more sensitive than nonmolting animals when exposed to toluene, but no change was observed for napththalene. Manuscript synthesis is in progress.

c. Determine sensitivity changes of several salmonid species when transferred to seawater at time of normal seaward migration.

Progress: Like the pink salmon tested previously, chum, sockeye, and Dolly Varden smolts were more sensitive in seawater than in freshwater when exposed to toluene and naphthalene.

2. Determine which components of oil account for toxicity (3.25 man years):

a. Assess the toxicity role of phenols and heterocycles by determining quantities in oil and WSF's, and determining the acute toxicity to three species of the major compounds found in the WSF. Toxicity tests will be static.

Progress: All bioassay and uptake tests have been completed. Detailed analyses by National Analytical Laboratory at Seattle are in progress. Some phenols and cresols are present. Toxicity and uptake tests with phenol and cresol have been completed with shrimp and fish. Evaluation of data is incomplete.

b. Determine toxicity of a natural WSF and a synthetic WSF to three species with flow-through tests to determine whether the synthetic WSF accounts for all the toxicity. Compounds that are difficult to analyze, or that may be in trace quantitites, can probably be eliminated as major components responsible for toxicity. Future tests will be with altered synthetic WSF's.

Progress: This test, scheduled to begin this quarter, was postponed by Cheatham's death. A replacement chemist has been hired and experiments will resume next quarter after appropriate training. Project will extend into FY 78.

c. Determine time-dependent toxicity recovery curves with mono- and dinuclear aromatics to three species with flow-through tests. Tests will be with individual compounds and with combined mixtures. This will be a beginning effort to assess the relative toxicity importance of mono- and dinuclear aromatics.

Progress: The R&D for flow-through exposures has been developed for compounds used singlely, and the apparatus is in use. We are behind schedule in conducting exposures to two compounds simultaneously, since we have learned that this is logistically far more complicated than expected. This experiment should be on line next quarter, but will extend into FY 78 before completion. (Four-day exposures are too short, animals of the required sizes are difficult to obtain, and analyses of two compounds requires use of GC which is out of commission and undergoing repairs). Personnel in this project were reprogrammed for 2 months into larvae experiments when a federal hiring freeze delayed the hiring of key personnel.

3. Determine the effects of short-term exposures to WSF's on the survival of tagged marine organisms that are returned to the natural environment. Scallops will be tagged, exposed, and returned to pens in Auke Bay, with exposed and non-exposed starfish also being introduced into the pens. Their survival will be monitored for up to 3 months. Tests with pure aromatic fractions will also be used. (1.3 man years).

Progress: On schedule. Scallops have been tagged, exposed to toluene, and returned to pens in Auke Bay. Exposed and control starfish were also placed in the pens. Divers have been making observations since June 10. Tests with additional exposures will probably be conducted in July and August.

4. Determine the effects of WSF's of oil and pure aromatics on the metabolic rate of invertebrate species. Oxygen uptake will be monitored by a blood-gas analyzer, and heart rate will be measured. Experiments will be coordinated with uptake-depuration experiments (tissue burden experiments) to assess the animal's oil uptake capacity. (2 man years).

Progress: Behind schedule. Data acquisition with king crab juveniles began on schedule, but problems in locating adequate numbers of certain sizes caused us to switch to a different species (Hemigrapsus nudus). Data acquisition with second species is underway. Results with king crab: Heart rate was affected by benzene and toluene in different ways. Benzene caused a marked depression while toluene did not show a similar depression but caused frequent cardiac arrests.

5. Determine the tissue burden of several species exposed to oil or labelled aromatics, and their ability to rid themselves of hydrocarbons. Analysis will be by NOAA National Analytical Laboratory or by liquid scintillation. (1 man year).

a. Larvae will be tested with WSF's spiked with labelled isotopes. The form of the isotope (parent hydrocarbon versus metabolite) will be checked by the method of Roubal et al. (1976). No determination of metabolite identity will be attempted.

Progress: Data acquisition completed. Coonstripe shrimp larvae (Stages I, II, and I molting to II) were exposed to labelled toluene and naphthalene. Analyses of live versus dead larvae (killed with O_2 deprivation) and of molted skins and bodies of Stage II, were completed. Roubal samples for metabolites were taken. Manuscript synthesis in progress.

b. The tissue burden of animals was to be determined by exposure in long-term flow-through tests (see Objective 3). Mono- and dinuclear aromatic hydrocarbon concentrations were to be determined by GC runs per sample, and verified by two GC-MS determinations per series of 12.

Progress: Cancelled--no chemist available to do the R&D.

c. Determine the aromatic hydrocarbon uptake depuration pattern in salmonid smolts when exposed in seawater and in freshwater.

Progress: The uptake, metabolism, and depuration of radio-labelled toluene, naphthalene, and methylnaphthalene were determined with pink salmon and chum salmon fry acclimated to freshwater and to seawater. Effects of salinity on uptake, metabolism and depuration were investigated by exposing fish (freshwater and saltwater simultaneously) to the toxicants for 24 hours and sampling for isotopic and metabolite analyses by the Roubal method during exposure and during the clean water depuration phase. Manuscript synthesis is in progress.

6. Determine the pathway and rate of elimination of labelled mono- and diruclear aromatics in fish; identify the labelled compounds as "parent" or "metabolite". Gills and excretory organs will be treated separately. Isotopes will be introduced via a WSF. Isotope form (parent hydrocarbon introduced versus metabolite) will be determined using the method of Roubal et al. (1976). (0.4 man years).

Progress: On schedule. Project leader Thomas hired. Apparatus constructed. R&D in progress. Data acquisition scheduled for next quarter.

7. Determine the rate of byssal thread extrusion of mussels exposed to WSF, toluene, and naphthalene.

Progress: Static tests were completed previously and manuscript synthesis is in progress. Follow-up flow-through experiments have been cancelled because project leader was hired by another agency.

8. Determine the effect of temperature on fish and shrimp sensitivity to toluene and naphthalene, and the effect on uptake-depuration. Tests are flow-through. Roubal samples will be taken.

Progress: On schedule. Complex apparatus has been constructed, and is being tested. Data acquisition is scheduled for next quarter. (This is one of the added projects).

9. Compare sensitivities of tolerant and sensitive species to toluene and naphthalene when exposed in static and flow-through tests.

Progress: On schedule. Apparatus set up. Data acquisition has begun. Tests with pink salmon fry are complete. Tests will probably extend into the fall FY 78 quarter because of limited animal availability. (This is another added experiment). Qualified pesonnel are available to conduct this experiment, but not for some of those that have been cancelled or delayed.

Part III. Interpretation of Results

Interpretations will be supplied in reviewed manuscripts. Manuscript synthesis has not progressed since Cheatham's death, when supervision of ongoing experiments became the highest priority. Rice will complete two manuscripts begun by Cheatham.

Part IV. Problems Encountered

1. We have experienced severe personnel problems this quarter. The unexpected death of our chemist (Loren Cheatham) not only left us without a valuable team member, but created a severe morale problem. Cheatham's death coincided with the transfer of our other senior chemist, Jeff Short, to another program. Our remaining chemist (Sue Way) had personal problems which required considerable leave away from the job. These events left us with no chemists and a deficiency in supervisory personnel. To compound difficulties, a federal hiring freeze was imposed. These problems have resulted in the delay of several chemically oriented projects and cancellation of one.

To correct these deficiencies, we have hired a permanent GS-9 chemist, (Lindsay) a GS-5 temporary chemist, and a student chemist on a work study project. The hiring of two other experienced technicians was hampered by the hiring freeze. One (Brodersen) was eventually hired, but only after weeks of delay, which required the cancellation of one larvae experiment. Another (Taylor) was not hired on schedule because of delays, and eventually accepted a position with another agency. We are now fully staffed, but with fewer experienced people than planned. All activities are again underway, training people and collecting data, but it will be several months before manuscript synthesis regains full momentum.

2. Field studies continue to prove expensive and relatively unproductive. The many uncontrollable variables in the environment require much preliminary R&D before productive studies can be implemented.

3. Animals for experiments have generally been available earlier than in previous years, due to a mild winter. This compounded our problems, since it occurred at a time when we were short-staffed. For the first time, we were unable to locate adequate numbers of juvenile king crabs. Uncompleted experiments with shrimp will probably have to be finished after September 15 as a result of problems collecting and holding small shrimp during summer.

Part V. Estimate of Funds Expended for FY 77

Budget Summary as of June 1, 1977.

	Annual Plan	Costs to June 1, 1977
Salary Costs	$ 216.4k	$209.3k 1/
Travel	30.1	19.9
Contracts	68.0	39.2
Equipment & Supplies	99.4	122.5
Other Direct & Indirect Costs	86.1	86.1 1/
Total	$ 500.0k	$477.0k

1/ Salary and overhead costs projected through September 30.

Note: We have hired a few unbudgeted extra temporary employees to make up for lost man hours and will probably not have any salary lapses.

SUBLETHAL EFFECTS OF PETROLEUM HYDROCARBONS AND TRACE METALS, INCLUDING BIOTRANSFORMATIONS, AS REFLECTED BY MORPHOLOGICAL, CHEMICAL, PHYSIOLOGICAL, PATHOLOGICAL, AND BEHAVIORAL INDICES

by

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Bureau of Land Management

April 1 to June 30, 1977

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ABSTRACT

The responses of marine organisms to environmental contaminants are reflected in a number of changes detectable at population and organismal levels, as well as at cellular, subcellular, and molecular levels. The general scope of this study is to evaluate effects on various levels by investigating behavioral, morphological, chemical, and pathological changes in subarctic and arctic marine animals exposed to petroleum hydrocarbons and trace metals.

Behavior

Studies were conducted to assess the effect of the saltwater soluble fraction (SWSF) of Prudhoe Bay crude oil (PBCO) on the reproductive behavior of an intertidal dorid nudibranch (Onchidoris bilamellata). As a part of the reproductive process nudibranchs apparently release a sex pheromone which attracts other individuals of the same species to form breeding aggregations. The results of these studies indicate that exposure of nudibranchs to the SWSF for 24 hr at less than 15 ppb significantly reduces their ability to locate other reproductively receptive individuals. This inability to locate an aggregation appears to be the result of impaired chemoreception.

Chemistry

The challenge phase of a study on accumulation and distribution of 1-methylnaphthalene in coho salmon (Oncorhynchus kisutch) and starry flounder (Platichthys stellatus) for 3-4 weeks under flow-through conditions was completed. A study on the accumulation and distribution of 1-methylnaphthalene and aromatic metabolites in coho salmon force-fed 1-methylnaphthalene is presently underway.

Provisional data from the coho salmon experiment indicate that, on an equivalent exposure basis, substantially less methylnaphthalene is accumulated in salmon muscle, liver, and gills from the SWSF of PBCO than from methylnaphthalene alone. Thus, the degree of accumulation of the alkylated naphthalenes from SWSF of petroleum appears to be strongly dependent on the composition of the total soluble hydrocarbon fraction. These findings point to the importance of obtaining detailed information on the hydrocarbon composition of exposure waters in both the laboratory and field situation. Data from the starry flounder work is being processed.

Postlarval shrimp (Pandalus danae) were exposed to a water-borne solution of naphthalene containing ^{14}C and ^{3}H labels. The shrimp were exposed to approximately 20 ppb for 10 hr and then were allowed to depurate in clean water for 12 hr. Animals were sacrificed after exposure and depuration. Twelve shrimp were removed after the 10 hr exposure and were fed to juvenile whitespotted greenlings (Hexagrammos stelleri). After 16 hr the greenlings were sacrificed for analysis of the tissues and organs. The samples are being analyzed by the extraction method of Roubal et al. (1977a), liquid scintillation spectrometry, and high performance liquid chromatography (HPLC).

Salt-water-adapted coho salmon, and rainbow trout (Salmo gairdneri) in fresh water, were force-fed [^{14}C]-1-methylnaphthalene and ^{3}H-naphthalene, respectively. Concentrations of the parent hydrocarbons and their metabolites in skin increased with time, reaching maximum values at 24 hr after the treatment and subsequently declined. Rates of decline of naphthalene and methylnaphthalene were significantly greater ($P<0.05$) than those of corresponding metabolites, resulting in preferential retention of the metabolites in skin. Epidermal mucus of the test fish contained small amounts of naphthalene and considerably larger amounts of the metabolites at least up to 48 hr. Because mucus exists in a state of continuous flux (turnover), the evidence suggests that epidermal mucus may be involved in excretion of hydrocarbons and their metabolites.

Aryl hydrocarbon hydroxylase (AHH) activity was determined in multiple samples of livers from starry flounder and rock sole (Lepidopsetta bilineata). For the first time, the pH and temperature parameters have been determined for the analysis of AHH activity for livers of starry flounder. Results of the pH effects on the AHH activity in vitro are suggestive of more than one enzyme. Detailed findings will be reported in a subsequent report.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-Contaminated Sediment

English sole (Parophrys vetulus) held on PBCO-contaminated sediments for over 4 mo had a higher frequency of liver abnormalities and weight loss than did control fish on uncontaminated sediment. During the first mo of the experiment, the fish in both groups (initially 35 fish/group) lost an average of about 3 to 4% of body weight. However, by 4 mo, the percentages of oil-exposed and control fish weighing less than their starting weights were 69 and 27%, respectively. No mortalities resulting from exposure to sediments were observed until after 4 mo of exposure. At that time, one of the oil-exposed group died and two of the oil-exposed group were severely emaciated and appeared moribund, whereas none of the controls were so affected. The severe liver abnormality, observed in 21% of the oil-exposed fish and none of the controls which were sampled, was characterized as extensive hepatocellular lipid vacuolization.

Effects of Petroleum on Fish Disease Resistance

Ratios of spleen weight to body weight were significantly ($P<0.05$) lower in rainbow trout that received high doses of PBCO in diet (1,000 ppm for 10 mo) than in non-oil fed controls. Nevertheless, antibody formation was not significantly affected by the same exposure regimen.

Morphology

The effects of a minor field spill of petroleum in Puget Sound are highlighted in this reporting period. Blindness was observed in coho salmon in rearing pens adjacent to the spill. The fish were free of any indication of bacteriological infection or other disease. The changes in the eye included hydration, which parallels our previous laboratory studies (Hawkes 1977), and cloudiness or possible early cataract formation. A known source of diesel fuel spillage was indicated as the primary causative agent. Both water and tissue samples showed the presence of petroleum components.

OBJECTIVES

In this multidisciplinary approach to evaluate the effects of petroleum on marine organisms, there is a series of objectives.

The specific objectives performed during the current quarterly reporting period of April 1 to June 30, 1977 are as follows:

Behavior

To determine if the SWSF of PBCO inhibits chemotactic behavior related to reproduction of the dorid nudibranch. (This study was not detailed in the OCSEAP FY 77 proposal, thus, an introductory statement is presented under the Preliminary Interpretation of Results section).

Chemistry

To determine the distribution and bioconcentration of 1-methylnaphthalene in coho salmon and starry flounder exposed to ppb of 1-methylnaphthalene for

3-4 weeks. To determine the distribution and levels of accumulation of 1-methylnaphthalene and total metabolites versus time after force-feeding 1-methylnaphthalene to salmon.

To determine uptake and depuration rates and the metabolic conversion of petroleum hydrocarbons by invertebrates. Studies this quarter were (1) to quantify and identify the metabolites formed by juvenile shrimp, (2) to identify any changes in metabolites after depuration, (3) to determine if any biological exchange of the ^3H label takes place, and (4) to make a preliminary determination of the magnitude of transfer of metabolites from one food web level to another.

To evaluate the importance of fish skin and its accessory structures in accumulation, metabolism, and excretion of petroleum constituents. Specific objectives of the studies were to determine concentrations of hydrocarbons and their metabolic products in skin and mucus of salmonid fish force-fed hydrocarbons.

To identify possible influences of lead and cadmium on the metabolism of petroleum aromatic hydrocarbons; also to determine levels of hydrocarbon metabolites formed in relation to metal administrations, employing HPLC and complementary techniques (coho salmon and starry flounder to be used as experimental animals).

To measure the specific activities of AHH in different marine phyla from Norton Sound and the Chukchi Sea, and to examine petroleum dose to response of AHH systems in different phyla.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-Contaminated Sediment

To characterize the long-term pathological effects of exposing flatfish to petroleum hydrocarbons in sediment.

Effects of Petroleum on Fish Disease Resistance

To determine if exposure to petroleum hydrocarbons affects disease resistance and immune responses in salmonid fish.

Morphology

To identify effects of an accidental diesel fuel spill on nearby penned coho salmon; particularly, to characterize eye changes resulting in apparent blindness. (This study was not detailed in the OCSEAP FY 77 proposal, but was undertaken because of the opportunity to observe effects of petroleum on coho salmon exposed under field conditions.)

FIELD OR LABORATORY ACTIVITIES

Ship or field trip schedule

Chemistry

Infrequent field trips were made to points in Puget Sound and the Columbia River to obtain live bottom fishes for tests on laboratory parameters of AHH analyses. Species collected were the same species found in Alaskan waters.

Morphology

Water and tissue samples were collected at Squaxin Island, Puget Sound on April 28, 1977.

On May 3, 1977 water and sediment samples were taken by divers at 4 depths in two locations after introduction of diesel fuel under circumstances that had occurred intermittently during the prior 3 mo. Zero time, 1 hr, 2 hr, and 3-3/4 hr samples were obtained.

After 1 mo without petroleum exposure, tissue and water samples were again taken (June 10, 1977).

Scientific party

Name	Role	% time
D. Malins, PhD, DSc	Principal investigator; hydrocarbon metabolism	15
W. Roubal, PhD	Research chemist; hydrocarbon metabolism	75
D. Lazuran	Sample preparation; assistant to Dr. Roubal	100
Various NOAA National Analytical Facility (NNAF) personnel	GC processing of submitted samples	as required
J. Parker	Fish feeding	as required
H. Sanborn	Oceanographer; invertebrate zoology	as required
C. Short	Graduate student; assistant to Mr. Sanborn	75
U. Varanasi, PhD	Research chemist; metal/hydrocarbon studies on skin/mucus	90
D. Gmur	Technical assistant to Dr. Varanasi	100
W. Reichert, PhD	Chemist, studies on metals/hydrocarbons	75
D. Federighi	Chemist, assistant to Dr. Reichert	100
E. Gruger, Jr., PhD	Research chemist; coordinator of chemical analyses/enzyme-hydrocarbon studies	25
L. Folmar	Research Fishery Biologist, assistant to Dr. Gruger, enzyme studies	40
D. Dungan	Chemist, assistant to Dr. Gruger, enzyme studies	100
D. Weber	Principal investigator; behavioral studies	50
N. Karrick	Principal investigator; chemical investigations	25
H. Hodgins, PhD	Principal investigator; physiological and pathological studies	25

B. McCain, PhD	Microbiologist; effects of petroleum in sediments on flatfish, coinvestigator with Dr. Hodgins	40
M. Myers	Fishery Research Biologist; part-time assistant to Dr. McCain	25
K. King	Fishery Research Biologist; part-time assistant to Dr. McCain	25
M. Schiewe	Fishery Research Biologist; disease resistance tests	50
E. Warinsky	Biological Aide; part-time assistant to Mr. Schiewe	100
L. Rhodes	Biological Aide; part-time assistant to Dr. McCain	25
J. Hawkes, PhD	Fishery Research Biologist, electron microscopy	100
C. Stehr	Technician; assistant to Dr. Hawkes	43
S. Gazarek	Technician, asistant to Dr. Hawkes	43

Methods

Behavior

Adult dorid nudibranchs were exposed to the SWSF of PBCO (Roubal et al. 1977b) for 1 or 3 days in 2,000 ml flow-through aquaria supplied with filtered seawater at 13.6° $\pm$ 0.6°C. Water samples were analyzed by gas chromatography (GC) for petroleum components.

Following SWSF exposure, the nudibranchs were assayed for a chemotactic behavioral response consisting of movement out of the initial chamber in a choice apparatus (Fig. 1). The "stimulus" chamber contained an aggregate of four control nudibranchs. The "stimulus" and "blank" chambers were alternated side-for-side on a random schedule. A positive response denoted selection of the arm leading to the stimulus chamber; a negative response denoted movement toward the blank arm.

Chemistry

Fish were exposed to 1-methylnaphthalene in flow-through water using the equipment of Roubal et al. (1977b). Excised tissues were processed preparatory to automated GC (Roubal et al. 1977a, MacLeod et al. 1976). Fish force-fed [^{14}C]-1-methylnaphthalene received this compound in a salmon-oil carrier. Excised tissues were digested by the methods of MacLeod et al. (1976) and the hydrocarbons and metabolite fractions were assayed for radioactivity by scintillation counting.

^{14}C- and ^{3}H-Naphthalene were administered to shrimp in a water-borne solution under flow-through conditions. The shrimp were removed from the naphthalene exposure and depuration tanks at appropriate times, then washed in clean seawater, and prepared for each specific analysis. Whole shrimp were solubilized for determination of total radioactivity. Whole shrimp were extracted using the method of Roubal et al. (1977a) to determine the relative contributions of parent material and metabolites. A group of 50 shrimp were frozen and extracted for metabolite identification using HPLC.

Twelve shrimp that had been exposed for 10 hr were fed to a juvenile whitespotted greenling. After 16 hr the greenling was sacrificed and the gut removed. The gut sample and the remaining tissue and organs were frozen separately and later extracted subsequent to determinations of the metabolites by HPLC. All of the radioactive samples are quantitated by liquid scintillation spectrometry.

For mucus studies, lightly anesthetized rainbow trout (150 $\pm$ 50 g) were each force-fed a gelatin capsule containing 114 μg (74.6 μCi) of [^{3}H]-1,4,5,8-naphthalene, and coho salmon (210 $\pm$ 80 g) in saltwater were each force-fed 336 μg (4.73 μCi) of [^{14}C]-1-methylnaphthalene. Four fish were sampled at each period of 4, 16, 24, 48, and 168 hr after force-feeding.

Samples of skin and mucus were collected as previously described (Malins et al. 1977) and analyzed for concentration of naphthalenes and their metabolic products (expressed as naphthols) by the method of Roubal et al. (1977a).

Coho salmon and starry flounder were exposed to lead or cadmium for 2 weeks and then injected intraperitoneally with ^{14}C-labeled naphthalene. A parallel group of fish undergoing the same exposure conditions had polynuclear aromatic hydrocarbons (PAH) included in their diet. Liver and gall bladder samples were taken from each fish and extracted to obtain metabolites of naphthalene. Identification of metabolites will be done in the near future.

Hook and line method was employed for catching experimental bottomfishes from Puget Sound waters. Experimental flatfish were caught by net in Columbia River. Livers were taken from freshly caught fish and immediately frozen and held for analyses of AHH enzyme activities. The activities of AHH in fish livers were determined by a method of DePierre et al. (1975) as adapted by Gruger et al. (1977).

Pathology

Pathological Changes in Flatfish from Exposure to Oil-Contaminated Sediment

English sole in aquaria containing sediment with or without PBCO (initially 35 fish in each group) were examined daily for mortalities and behavioral differences. At monthly intervals, all the fish in both groups (each fish was identified by a brand) were measured for length and weight, and at least 3 fish from each group were (1) bled for hematological tests, (2) autopsied and tissue specimens of major organs preserved for histological procedures, and (3) sampled for muscle, skin, and liver tissues which were frozen for hydrocarbon analyses.

Effects of Petroleum on Fish Disease Resistance

The ability to form antibodies was compared among groups of rainbow trout (mean wt. 40 g) which were maintained on diets containing (1) a high level of PBCO (1,000 ppm), (2) a low level of PBCO (10 ppm), and (3) no PBCO (control) for 10 mo prior to testing. A reduction in spleen size of oil-treated fish was noted and spleen/body weight ratios were, therefore, measured.

Ten fish on each diet were immunized with a vaccine prepared from *Vibrio anguillarum* and, in one experiment, antibody titers were determined. The number of antibody forming cells was measured in another experiment using five similarly immunized fish from each group and a Jerne plaque procedure (Chiller et al. 1969).

Morphology

Tissue samples collected at the diesel oil spill site in Puget Sound were prepared for histology and for electron microscopy using procedures reported previously (Hawkes 1977). Whole fish and mussels, *Mytilus edulis*, were frozen in dry ice and transferred to 0° freezers in the laboratory.

In addition, water samples were taken at the pen containing the most affected fish (from pen closest to spill site) and the pen containing the least affected fish (from pen farthest from spill site). Glassware used for collecting water for hydrocarbon analyses was cleaned with dichloromethane, and samples were obtained at the surface, 6 in below surface, 10 ft below surface, and 6 in above sediment bottom; sediment was also collected for hydrocarbon analyses. All of these analyses will be done by NNAF.

Bacteriological studies were done on 5 fish: kidney tissue was plated on trypticase soy agar and was negative for *Aeromonas salmonicida*, the agent of furunculosis, and for V. anguillarum, the bacterium causing marine vibriosis. There was also no evidence of kidney disease or any other infectious disease.

Sample collection localities

Chemistry

All exposures of fish to hydrocarbons and trace metals were conducted at the Mukilteo facility.

The postlarval shrimp used in this experiment were reared in the laboratory from captured gravid shrimp.

Rainbow trout were obtained from a hatchery, Trout Lodge, in Tacoma and maintained at the NWAFC laboratory in Seattle. Coho salmon were obtained from NWAFC, Manchester.

The bottomfish for AHH analyses were obtained at Manchester, Washington (Puget Sound water) and Hammond, Oregon (seawater at mouth of Columbia River).

Morphology

All samples were taken at Squaxin Island, Puget Sound, where coho salmon were being held in floating pens prior to tagging and release.

Data collected and/or analyzed

Chemistry

Number and type of samples or observations

Starry flounder exposed to 1-methylnaphthalene under flow-through conditions were sampled weekly (10 exposed fish plus 10 controls per sample period) for a period of 4 weeks of exposure followed by a 2 week period of depurating tissues for a total of 120 fish sampled. In addition, weekly water samples were collected for a total of 12 samples (test water and control). Coho salmon force-fed [^{14}C]-1-methylnaphthalene were collected at 4, 16, and 24 hr intervals from initial feeding (6 fish per sampling) for a total of 18 fish.

In addition, 11 water samples were taken, and 150 shrimp and 1 fish were sampled for studies on naphthalene metabolism.

Samples of epidermal mucus and skin were obtained from 4 fish at each of five time intervals; i.e., a total of 20 fish each of coho salmon and rainbow trout were sampled. Three or four duplicate samples were analyzed from certain fish. The total number of individual samples was 107 for skin and 38 for mucus for the rainbow trout experiment and 30 for skin and 40 for mucus for the coho salmon.

A total of 6 starry flounder, 4 rock sole, and 1 Pacific cod (*Gadus macrocephalus*) were obtained for AHH analyses.

Number and type of analyses

Duplicate 10 g composite samples of muscle and single composite samples of gills and liver were prepared from groups of the 10 fish (above) for automated GC analysis of 1-methylnaphthalene, for a total of 48 analyses. Individual fish force-fed [^{14}C]-1-methylnaphthalene were analyzed for the parent hydrocarbon and metabolite content of tissues via scintillation counting. Kidney, blood, brain, muscle, and liver were used for a total of 180 analyses.

There were 37 metabolite extractions (Roubal et al. 1977a), 6 HPLC separations, 5 solubilized shrimp analyses, 10 water analyses, and 1,000 total scintillation samples counted and data analyzed for the research with shrimp.

Samples were digested in NaOH and hexane for partitioning of the parent hydrocarbon from its metabolic products. Each fraction was analyzed by liquid scintillation spectroscopy for ^{3}H and ^{14}C (Roubal et al. 1977a).

Qualititative analyses of the metabolites were conducted using thin-layer chromatography (Roubal et al. 1977a, Jerina et al. 1970). Data was statistically treated to fit probability functions (Eberhardt and Gilbert 1973).

There were 27 analyses of hepatic AHH activities and profiles of optimum pH, 9 analyses of hepatic AHH activities and profiles of optimum temperature, 4 analyses of hepatic AHH activities in fish for species screening, and 9 analyses of proteins in cell-free liver homogenates for AHH.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-Contaminated Sediment

Number and type of samples: Blood for hematology (40); sediment samples for hydrocarbon analyses (10); tissue samples for hydrocarbon analyses (40); tissue samples for histology (151).

Number and type of analyses: Hematology: hematocrit (40), hemoglobin (40), total blood cell count (40), differential white cell count (40); hydrocarbon analyses of sediment (4); hydrocarbon analyses of tissues (4); microscopic examination of histological specimens (151).

Effects of Petroleum on Fish Disease Resistance

Number and type of samples: Anterior kidneys for lymphoid cells for Jerne plaque procedure (30); spleens for lymphoid cells for Jerne plaque procedure (30); blood serum for antibody titrations (40); blood red cell suspensions for hematocrits (20); blood white cells for differential counts (20); whole fish and spleens for spleen/somatic weight ratios (20).

Number and type of analyses: Jerne plaque determinations for antibody forming cells (12); antibody titrations (40); hematocrit determinations (20); white blood cell differential counts (20); spleen/somatic weight ratios (20).

Morphology

Number and type of samples: Tissue samples (300); water samples (96); sediment samples (12); whole fish (frozen) (100).

Number and type of analyses: Microscopic observations (20); GC and mass spectroscopic analysis on tissue and water (4); bacteriological analysis (5).

RESULTS

Behavior

As shown in Table 1, control nudibranchs displayed a marked preference for an aggregate of conspecifics in the stimulus arm of the testing apparatus. (When considering only dorids which displayed overt behavior, 94% responded positively to the stimuli.) For nudibranchs exposed to the SWSF of PBCO there was a definite reduction in movement toward the aggregate. There was no apparent direct relation between concentration and chemotactic response in either the 1-day or 3-day exposure groups. The positive response percentage for the pooled 1-day exposure group was statistically compared with the positive control percentage using an arcsin transformation test for equality of two percentages (Sokal and Rohlf 1969). The results from the 1-day exposed animals are significantly different from controls (P=0.05). Upon pooling data from both the 1- and 3-day exposure groups there is an equal distribution of nudibranchs which moved either toward the blank or stimulus arm in the test apparatus. For this preliminary series of tests the 50-50 distribution is interpreted as random movement.

Of the exposed animals which did not move the pooled data is similar to controls; however, there is an indication that nudibranchs exposed to the SWSF for 3 days may have reduced mobility. This is counterbalanced by comparisons of average times required for the test animals to complete the behavioral assay which did not differ between control and SWSF-exposed groups.

Chemistry

Methylnaphthalene was found to accumulate in coho muscle, liver, and gills to a substantially different degree, depending on whether it was present in exposure water alone (as a water-soluble hydrocarbon) or as part of a complex mixture (as a component of the SWSF of PBCO). For example, on an equivalent experimental conditions basis, the bioconcentration factors for methylnaphthalene were 4,700 and 33 for the single and mixed exposures, respectively. The data and interpretations are provisional and subject to verification prior to the next reporting period. The data reported on the starry flounder is presently being processed and interpreted.

The data from the experiment with shrimp are being processed and no conclusions or results are available.

Concentrations of both naphthalene and its metabolites in skin of the force-fed rainbow trout increased steeply with time, reaching maximum values of 322 and 17 ppb, respectively, at 24 hr and subsequently declined to 10 and 2.5 ppb, respectively, at 168 hr (Table 2). Statistical treatment of the data revealed that rates of change in concentration of naphthalene and its metabolites (Table 2) were significantly different ($P<0.05$). Naphthalene concentration increased more rapidly than the metabolites and thus at 24 hr, 95.6% of the total radioactivity in the skin was represented by naphthalene. There was also a more rapid decrease in naphthalene concentration, however, at 168 hr: the metabolites represented 17.7% of the total radioactivity in the skin.

At each sampling time, epidermal mucus of the test fish contained considerably larger concentrations of metabolites than naphthalene (Table 2). Concentrations of naphthalene and the metabolites were 45 and 130 ppb, respectively, at 24 hr after the force-feeding.

Skin of saltwater adapted coho salmon contained substantial amounts of 1-methylnaphthalene (931 ppb) and its metabolites (86 ppb) at 24 hr after force-feeding of [^{14}C]-1-methylnaphthalene. At 24 hr the skin of the test fish contained 4.1% of the administered dose, of which 7.1% was attributable to the metabolites. At 48 hr, however, as much as 38.5% of the total radioactivity in the skin was represented by the metabolites.

As in rainbow trout, epidermal mucus of saltwater coho salmon exposed to 1-methylnaphthalene contained relatively higher concentrations of the metabolites than the parent hydrocarbon--up to 48 hr after the initial treatment (Table 3).

Work has been completed on administering radioactive naphthalene to coho salmon previously exposed to 200 ppb of lead and cadmium for 3 weeks in seawater. Another group of coho was fed an aromatic hydrocarbon mixture (phenanthrene, 33%; 2-methylnaphthalene, 33%; 2,6-dimethylnaphthalene, 33%), at a level of 50 ppm for 1 week. The influence of the metal exposures on hydrocarbon metabolism in coho will be evaluated shortly by HPLC analysis of metabolites. At present, starry flounder are being challenged under comparable experimental conditions for the assessment of alterations of metabolites in relation to metal exposures.

Hepatic AHH in four starry flounder was found to be more active than that which we have found in coho and chinook salmon. Mean values of AHH activity for the flounder were 27.0 $\pm$ 6.9 nmoles/mg protein, which may be compared to salmon at 0.5 - 2.7 nmoles/mg protein (Gruger et al. 1977).

Rock sole hepatic AHH activity was about one-fifth that of the flounder. Determinations in vitro of the parameters for AHH activity analyses of starry flounder showed two pH optima, one at 7.0 and the other at 7.5. Optimum temperature of the AHH activity for the flounder was 25°C, the same as for AHH of salmonids.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-Contaminated Sediment

English sole have been exposed to PBCO-contaminated sediments for over 4 mo. The sediment was collected near Sequim, Washington, and combined with oil by previously described procedures (OCSEAP Annual Report RU 73/74, April 1977). Analyses for petroleum hydrocarbons in the sediment showed that about 26% of the total petroleum hydrocarbons in the oil initially combined with the sediment actually absorbed to the sediment. Once the sediment was placed in the aquarium and exposed to flowing seawater for 2 days, about 22% of the total hydrocarbons was lost, and an additional 10% was lost during the next 2 weeks (Table 4).

The hematological changes in the oil-exposed group, involving significantly higher hematocrit values and hemoglobin concentrations, observed during the first mo of exposure, were no longer evident by the third mo.

The weight loss by both groups of fish followed a pattern somewhat similar to the hematological changes, in that there was a gradual decrease in average weight until after about 2 mo of exposure. The average weight loss in the oil-exposed group was more pronounced (Table 5). By 4 mo, the percentages of oil-exposed and control fish weighing less than their starting weights were 69 and 27%, respectively.

During the first 4 mo of the experiment, there were no mortalities in either group resulting from exposure to sediment. However, shortly after 4 mo, in the oil-exposed group, 1 fish died and 2 fish were moribund and were sacrificed. In all three cases, the fish were extremely emaciated with no gross signs of microbial infection.

The most characteristic feature of livers in oil-exposed fish which were severely abnormal was extensive hepatocellular lipid vacuolization. Mild to moderate vacuolization was observed in livers from both groups, but only the oil-exposed group had the severe form, representing 21% of the fish sacrificed and examined histologically.

Effects of Petroleum on Fish Disease Resistance

The results of experiments in which antibody formation was assessed after long-term exposure of rainbow trout to PBCO are shown in Tables 6 and 7. The ability to form antibodies, reflected by agglutination titer (Table 6), appears to slightly decline as a result of oil exposure; however, the difference is not statistically significant. The number of antibody-forming cells in the spleens and anterior kidneys (Table 7) did not differ between high-oil exposure and control groups. An increase was observed, however, in the low oil-treatment group, but it is not clear whether this difference reflects stimulation or simply individual variation and the small sample size in these preliminary tests.

Comparison of the ratio of spleen weight to body weight in high-oil-treated versus control fish showed that a significant difference did exist (Student's t test, $P<0.05$) between the two groups. The average ratio of spleen weight (in mg) to body weight (in g) for control fish was 0.69 while the ratio was 0.49 for the high-oil-treatment group. There was no difference in hematocrits and differential leukocyte counts performed on blood from these same groups.

Morphology

A number of tests were done to determine the cause of blindness and stunted growth in the oil-exposed coho salmon from floating pens in Puget Sound. Approximately 80% of the fish examined from the most affected pen had eye abnormalities. There was no evidence of any bacteriological infection, such as marine vibriosis, furunculosis, or kidney disease.

The source of the petroleum was the diesel engines and bilge of a boat which was frequently moored about 4 ft from the most severely affected group of fish. When the engines were running, tidal flow moved the spilled petroleum directly through one pen, but all the pens received some exposure, judging from the first-hand observations of the resulting oil slick and its dispersion. Water samples were taken by divers at the most affected penned area, both at the surface where there was an obvious oil slick and at the depth of the fish in the pens. Petroleum hydrocarbons were found in samples from both depths.

Preliminary chemical analyses of 2 water samples and of 2 tissue samples provided a spectrum of petroleum components both in the surface water and at 6 in below the surface. Tissue samples show the presence of trace amounts of naphthalene and 1-methylnaphthalene as well as other peaks not normally found in unexposed salmon. Work is proceeding completing the tissue, water, and sediment analyses, including water sample analyses from the least affected pens.

The blind fish had cloudy eyes, readily apparent from visual inspection. The cornea, however, appeared normal; an obvious cloudy zone ranging from 1-3 mm in diameter was observed on the anterior surface of the lens. With

250 X magnification, the opaque area was observed not to be uniform but to consist of white streaks which seemed to radiate from a central point. Clear bands were interspersed between the broader cloudy zones. The entire lens periphery was abnormally soft and deformable. Some fish samples from the pen farthest from the source of petroleum had very small (1.5 mm) cloudy lens areas, but 80-90% were free of eye abnormalities. In some species, cloudiness and cataract formation is preceded by lens hydration (Patterson and Fournier 1976) and similar hydration was found by us in on-going laboratory studies with rainbow trout.

Other tissues showed some changes: there were hemorrhagic foci in the livers of some of the most affected fish, as well as some distention of their gall bladders. The following tissues were prepared for light and electron microscopy: liver, gill, skin, intestine, eye, pituitary, and kidney. Sectioning and examination is in process.

PRELIMINARY INTERPRETATION OF RESULTS

Behavior

The movement of a nudibranch toward an aggregate of other mating conspecifics is thought to be a chemotactic response mediated by a sex pheromone. As little as 1 day of exposure to the SWSF of PBCO at a concentration of less than 15 ppb significantly decreased the percentage of nudibranchs responding to the aggregate. This effect of SWSF exposure appears to involve the chemoreceptive system and is not a general narcosis as evidenced by equal rates of movement for both SWSF-exposed animals and control animals.

In other studies on chemotactic behavior of gastropods, feeding response was inhibited by petroleum hydrocarbon concentrations as low as 1 ppb (Jacobson and Boylan 1973). For the nudibranchs, inhibition of the chemotactic response, which is an integral part of the reproductive process, could have more serious consequences.

The effect of the SWSF of the crude oil on egg laying and embryonic development of dorid nudibranchs will be reported next quarter.

Chemistry

The results of the study on coho salmon exposed to 1-methylnaphthalene under flow-through conditions show that substantial bioconcentrations occur for this compound with exposure levels as low as 1.8 ppb. It appears that competition between hydrocarbons of a complex mixture for tissue sites may be an important factor governing accumulation of hydrocarbons; however, the nature of such competitions are not adequately understood.

Provisionally, our findings imply that the actual hydrocarbon composition of the SWSF of crude oils will dictate the degree of accumulation of the alkylated naphthalene components in key tissues, such as liver, gills, and muscle. Emphasis is therefore placed on obtaining detailed hydrocarbon analyses of exposure waters in both laboratory and field exposure situations. The latter circumstance would include arctic and subarctic areas impacted by petroleum.

No interpretation of the influence of metals on aromatic hydrocarbon metabolism are possible until the HLPC studies of metabolite formation are completed.

A survey of the literature (Varanasi and Malins 1977) shows that the skin of fish, a primary site of contact to environmental pollutants, has been largely overlooked in studies concerning fate and effect of petroleum in aquatic environments. Considering that the skin of certain marine fish species frequently develop epidermal neoplasms (Hodgins et al. 1977), whereas others do not, information on the role of skin in hydrocarbon metabolism in different fish species is of considerable interest. Results of our force-feeding studies show that skin of freshwater rainbow trout and saltwater coho salmon accumulate significant concentrations of naphthalenes and their metabolic products regardless of the nature of the compound and salinity of the medium. Rates of increase and decline in concentration of the parent hydrocarbons in skin were more rapid than those of the metabolites. Therefore, the relative proportion of metabolites increased significantly with time in the skin of the test fish in both experiments. Our results demonstrating the tendency of skin to preferentially retain metabolites of naphthalene are in agreement with findings of other workers (Sanborn and Malins 1977, Lee et al. 1977) showing that the parent hydrocarbon is more rapidly discharged either directly or via biotransformation to its metabolic products; also, small but detectable concentrations of metabolites persist in tissues of crustacea and fish over a long period.

Our results, which demonstrated that epidermal mucus of rainbow trout and coho salmon contained detectable levels of naphthalene and their metabolites for several days after the initial exposure to naphthalene by force-feeding, suggest a role for epidermal mucus of fish in the excretion of xenobiotics. In view of the fact that epidermal mucus of a fish exists in a continuous state of flux (that is, small amounts of mucus are continuously sloughed off and replaced), the continuous presence of naphthalene and, more importantly, the metabolites of naphthalenes in the mucus of test fish for several days strongly suggests that epidermal mucus of fish is involved in excretion of hydrocarbons and their metabolites. It is known that relatively more water-soluble metabolites of hydrocarbons are excreted in urine of fish. Epidermal mucus comprising glycoproteins and hydroxylated components

(Harris and Hunt 1973) may serve as an additional vehicle for the removal of water-soluble metabolites of aromatic hydrocarbons.

The properties of the AHH system have been examined for the first time for starry flounder. The two pH optima found for the flounder suggest the possible presence of more than one AHH enzyme acting on a single substrate, viz., benzo[a]pyrene. The AHH system is vital for the metabolism of aromatic hydrocarbons in fish. Implications of the findings will be further discussed in the next report.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-Contaminated Sediment

Exposure of English sole to oil-contaminated sediment appeared to have marked detrimental effects. The most obvious expressions of these effects were increased weight loss and liver alterations in certain oil-exposed fish as compared to control fish on uncontaminated sediment. Both groups of fish suffered an initial weight loss presumably due to the stress of captivity and a new diet. However, the oil-exposed group was more adversely affected during this period, as indicated by their hematological changes and greater loss of weight. After this period of adaptation, some oil-exposed fish did not recover and continued to lose weight.

The mechanisms by which the oil-soaked sediments exerted their pathological effects are not clear. One possible effect may have been the disruption of feeding behavior by reducing appetite, or interference with the sensory organs used during feeding. Also, in view of the extensive hepatocellular lipid vacuolization observed in about 20% of oil-exposed fish, metabolic defects in key organs, such as the liver, caused by petroleum components may have contributed to the loss of body weight.

Effects of Petroleum on Fish Disease Resistance

The preliminary data on antibody formation after months of exposure to PBCO in diet indicates that no marked alteration of this function occurs in rainbow trout. These results are consistent with previous observations that exposure to PBCO did not markedly reduce resistance of trout to laboratory-induced bacterial infection. The reduced spleen size in the oil-treated fish compared to controls does, however, point out a potentially detrimental change. Reduced spleen size could reflect changes in relative numbers of specific cell types which could affect the formation and maturation of hematopoetic cells and certain types of immunocompetent cells.

Morphology

The data indicate that exposure to petroleum from an intermittent diesel fuel spill caused blindness in coho salmon. Analyses of samples taken are still in process, however, and more definitive interpretation awaits their completion.

Cloudy lenses of fishes, which are easily observable, may be one indicator of biologically unsafe levels of petroleum in the environment. Understanding the etiology of the lens changes may enable earlier detection, that is, detection of changes that occur before blindness.

Because we had encountered eye problems in laboratory studies with petroleum-exposed rainbow trout, we were able to respond quickly and appropriately to reports of petroleum contamination in a field situation.

PROBLEMS ENCOUNTERED AND RECOMMENDED CHANGES

Behavior

In studies designed to assess the effect of petroleum hydrocarbons on the chemosensory systems of marine organisms, we suggested in the RU 73/74 proposal for FY 77 that lower invertebrates be investigated, specifically the avoidance behavior of the sea cucumber, Parastichopus californicus. Due to factors other than oil exposure the results of the sea cucumber experiments were generally inconclusive. Emphasis was, therefore, shifted to the chemosensory responses of the dorid nudibranch in relation to petroleum exposure and reproductive behavior. An introductory statement concerning this marine gastropod and its mating behavior is given below.

O. bilamelleta is a widely distributed dorid nudibranch that occurs throughout most temperate coastal waters of the northern hemisphere (Thompson and Brown 1976). Individuals of this species are hermaphroditic and form aggregations during mating and deposition of egg masses. Dorids mate intertidally in the marine environment, and also readily near the water surface in a laboratory situation. A nudibranch's ability to find mates and form breeding aggregations is thought to be through a sex pheromone, or chemical attractant, released by conspecific individuals (Crozier 1918, Audesirk and Audesirk 1977).

Chemistry

Turnaround time between receipt of proposed samples by NNAF and receipt of data is too long. In one instance this delay resulted in rerunning a portion of an experiment--a costly and time-consuming delay. Steps are being taken to prevent these delays.

We have encountered problems with the rearing of mollusc larvae. The problem has been related to temperature control and is in the process of being remedied.

Another problem concerned a loss of frozen samples from Norton Sound and Chukchi Sea which were collected for AHH analysis. Apparently during rough weather the electric plug to a freezer on the R.V. Miller Freeman became disconnected and all these samples were ruined. As a consequence, samples for AHH analysis, which are representative of species of the above areas, were collected in Washington waters.

ESTIMATE OF FUNDS EXPENDED

Salaries, EC, Sluc, Overhead	$192.7
Travel and transportation	7.6
Services	14.8
Supplies and equipment	57.3
GRAND TOTAL	272.4

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Meetings

U. Varanasi presented a paper on the effect of water-borne calcium on uptake and retention of lead^{210} in skin of rainbow trout and coho salmon at the 61st Annual Meeting of Federation of American Biological Societies, held April 1977 at Chicago, Illinois.

A paper is in preparation entitled, "Effects of Long-term Exposure of Flatfish to Sediment Contaminated with Alaskan Crude Oil," by B.B. McCain, H.O. Hodgins, W.D. Gronlund, and J.W. Hawkes. It has been submitted for presentation at a forthcoming symposium entitled, "Recovery Potential of the Northern Marine Environment Following Oil Spills," to be held October 11-14, 1977, at the Bedford Institute of Oceanography, Darthmouth, N.S., Canada.

J. Hawkes presented papers on the morphological effects of petroleum on fish tissues at the Cordova Fisheries Institute, Cordova, Alaska (April 1977), at a joint seminar with the University of Alaska and Auke Bay NMFS Laboratory, and at a poster session at the International Symposium on Pathobiology of Environmental Pollutants--Animal Models and Wildlife as Monitors, at the University of Connecticut, Storrs (June 1977).

W.T. Roubal presented a paper at the American Petroleum Institute's 1977 Oil Spill Conference (Prevention, Behavior, Control, Cleanup) entitled "Flow-through System for Chronic Exposure of Aquatic Organisms to Seawater-Soluble Hydrocarbons From Crude Oil: Construction and Applications."

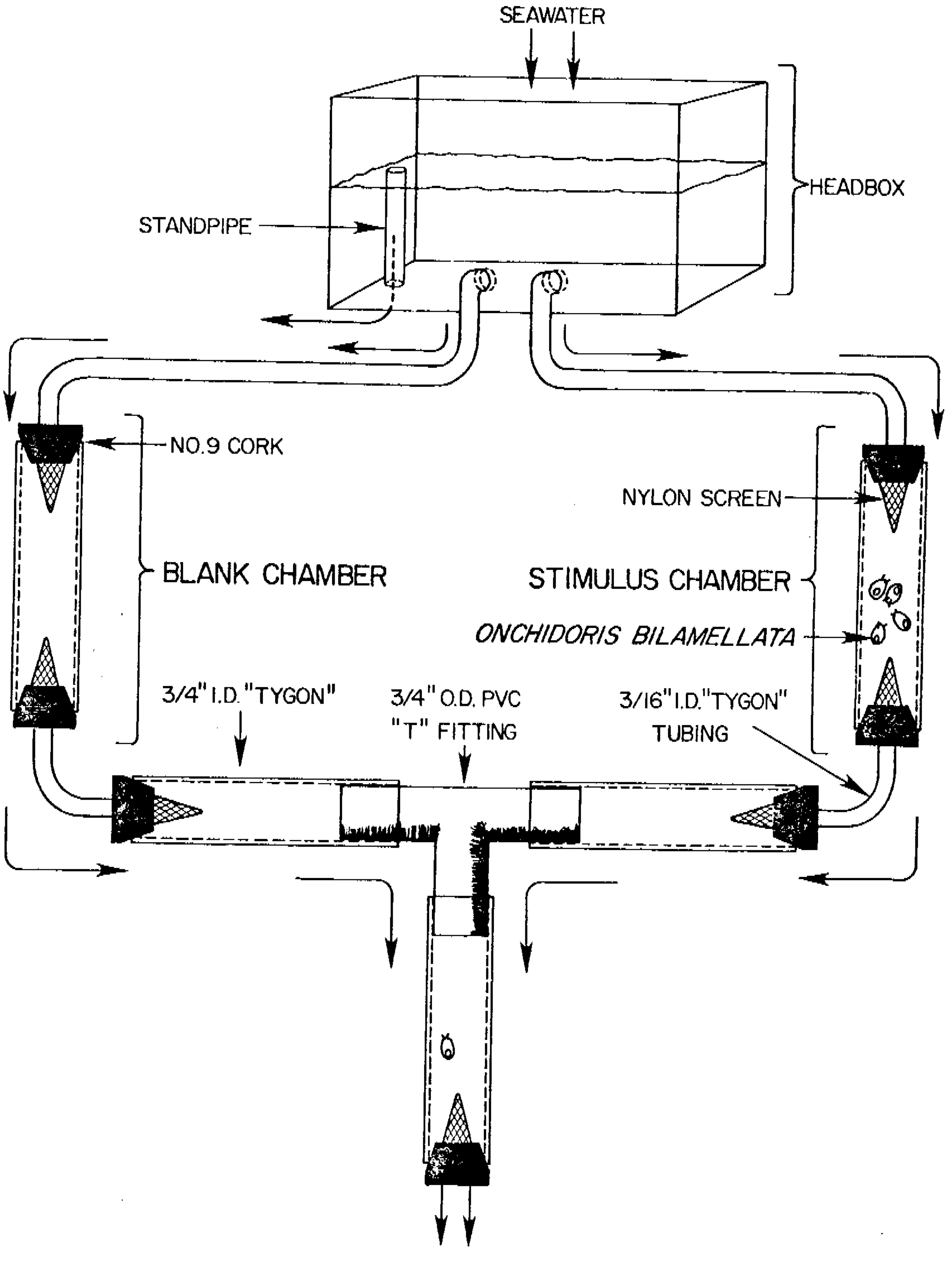

FIGURE 1. Testing apparatus for chemotactic response of dorid nudibranch. Choice chamber is "T" fitting in lower center of diagram.

TABLE 1. Chemotactic responses of control and SWSF-exposed dorid nudibranchs to an aggregate of reproductive conspecifics.

Days SWSF exposure (ppb±range)	Response			Time for choice min:sec	
	N pos. (%)	N neg. (%)	No movement (%)	pos.	neg.
Control	16 (84.2)	1 (5.2)	2 (10.5)	3:57	6:07
1 day at:					
(13±3)	5 (62.5)	3 (37.5)	0	3:28	3:04
(61±18)	5 (62.5)	2 (25.0)	1 (12.5)	3:04	3:27
(420±243)	5 (62.5)	3 (37.5)	0	4:18	5:26
Total (SWSF)	15 (62.5)	8 (33.3)	1 (4.2)	3:52	4:00
3 day at:					
(13±3)	1 (11.1)	6 (66.7)	2 (22.2)	3:50	5:01
(61±18)	2 (25.0)	4 (50.0)	2 (25.0)	2:15	4:09
(420±243)	4 (57.1)	3 (42.9)	0	3:38	2:45
Total (SWSF)	7 (29.2)	13 (54.2)	4 (16.7)	3:33	4:08
Total SWSF exposed	22 (45.8)	21 (43.8)	5 (10.4)	3:42	4:04

TABLE 2. Concentrations of naphthalene and its metabolites in skin and epidermal mucus of rainbow trout (Salmo gairdneri) force-fed naphthalene[a]

Time elapsed after treatment (hr)	Skin		Mucus	
	Naphthalene ppb[c]	Metabolites[b] ppb	Naphthalene ppb	Metabolites ppb
4	35±13.0	4.7±1.2	2± 0.7 [0.01][e]	70± 5.2 [0.46]
16	173±21.0	16.0±1.4	13± 2.1 [0.09]	83±16.0 [0.55]
24	322±32.0	17.0±1.2	45±37.0 [0.29]	130± 5.3 [0.89]
48	76±13.0	6.2±1.0	45±23.0 [0.30]	118±28.0 [0.78]
168	10± 1.0	2.5±0.4	29±21.0 [0.19]	41±22.0 [0.27]

[a] Fish were force-fed 114 μg of [^{3}H]-1,4,5,8-naphthalene.
[b] Concentration of metabolites was based on molecular weight of naphthol.
[c] Concentrations are based on dry weight of tissue; the concentration of both naphthalene and metabolites in water was less than 0.1 ppb at all times.
[d] Mean±S.E. (Sokal and Rohlf 1969).
[e] Concentrations in brackets are also given on a wet weight basis because epidermal mucus contained 99.34% water. The data fit lognormal distribution.

TABLE 3. Concentrations of 1-methylnaphthalene and its metabolites in skin and epidermal mucus of saltwater adapted coho salmon (Oncorhynchus kisutch) force-fed 1-methylnaphthalene[a,b]

Time elapsed after treatment (hr)	Skin		Mucus	
	1-Methyl-naphthalene ppb	metabolites ppb	1-Methyl-naphthalene ppb	metabolites ppb
4	347± 93[d,e]	91±16	n.d.[h]	152±100 [4.1][f]
16	767±290	118± 4	289±112 [7.8]	367± 68 [9.9]
24	931±320	86±30	--[g]	--
48	72± 31	45±31	135 [3.6]	693±100 [18.6]
168	--	--	n.d.	n.d.

[a] These results are provisional. Experiment is still in progress.
[b] Fish were fed 4.73 μCi (336 μg) of [^{14}C]-1-methylnaphthalene.
[c] Concentration of the metabolites was calculated using molecular weight of 1-methylnaphthol.
[d] All concentrations are given on dry weight basis; values represent Mean±S.E. (Sokal and Rohlf 1969).
[e] Concentrations of either 1-methylnaphthalene or metabolites in water was less than 0.1 ppb.
[f] Concentrations in brackets are given on a wet weight basis because epidermal mucus contained 97.31% water.
[g] Not done.
[h] Not detected.

TABLE 4. Result of analyses for petroleum hydrocarbons in oil-contaminated sediment to which English sole were exposed

Hydrocarbons	Concentration (ng/g wet wt) of sediment collected at various times			
	0-time	2 days	7 days	16 days
Biphenyl	156.7	112.7	107.2	104.2
Naphthalene	219.0	120.1	46.5	50.7
2-Methylnaphthalene	597.6	396.7	356.4	373.4
1-Methylnaphthalene	389.9	282.6	271.8	274.6
2,6-Dimethylnaphthalene	195.2	118.1	144.8	116.5
2,3,5-Trimethylnaphthalene	117.8	90.1	86.8	80.7
Fluorene	147.1	14.2	13.9	13.8
Phenanthrene/anthracene	293.7	226.6	230.4	202.7
Total saturated hydrocarbons (μg/g wet wt)	264	198	183	191
Total unsaturated hydrocarbons (μg/g wet wt)	263	211	163	182

TABLE 5. Weight changes in English sole in aquaria with and without oil-contaminated sediment over a period of 4 months.

Description of Value	Oil-exposed	Control
Number of fish per group	16	15
Average weight change per fish after 6 weeks	-1.78 g	-0.98 g
" " " " " " 14 weeks	-1.21 g	+0.54 g
Average % weight change per fish after 6 weeks	-7.1%	-3.8%
" " " " " " " 14 weeks	-4.8%	+2.1%
Dead or moribund fish after 4 months	3 (19%)	0

TABLE 6. Effect of long-term peroral exposure to PBCO on antibody formation in rainbow trout. Antibody formation was assessed by measuring agglutinating antibody titer to V. anguillarum bacterin 21 days after immunization. Results represent the geometric mean titers ($\log_2$) of 10 fish from each exposure regime.

Level of PBCO added in diet	Mean antibody titer against V. anguillarum bacterin
High (1,000 ppm)	4.3
Low (10 ppm)	5.2
None, immunized	5.7
None, non-immunized	<1

TABLE 7. Effect of long-term peroral exposure to PBCO on antibody formation in rainbow trout. Antibody formation was assessed by determining the number of plaque forming cells per 10^6 lymphoid cells in a modified Jerne plaque assay. Results represent a 5-fish pool from each exposure regime.

Source of lymphoid cells	Number of plaque forming cells/10^6 lymphoid cells PBCO oil exposure		
	High (1,000 ppm)	Low (10 ppm)	Control
Anterior kidney	275	3,556	107
Spleen	193	577	218

QUARTERLY REPORT

Contract No. : R7120810
Research Unit No. : RU-77
Reporting Period : Apr 1 - Jun 30, 1977
Number of Pages : 11
Final report on background data on marine birds, 43 p.

ECOSYSTEM DYNAMICS, EASTERN BERING SEA

Co-Principal Investigators

Taivo Laevastu and Felix Favorite
National Marine Fisheries Service
Northwest and Alaska Fisheries Center

I. Task Objectives

Formulation, programming, testing and use of a Numerical Dynamic Marine Ecosystem (DYNUMES) model for the eastern Bering Sea. Use of this model to: (a) summarize the quantitative aspects of the marine ecosystem and its components, as well as its dynamics in the area, (b) present the seasonal distributions and migrations of major species and/or ecological groups, (c) quantify the trophodynamics of the ecosystem in the area including interspecies interactions, (d) investigate and demonstrate the effects of the environment (e.g., currents) and its anomalies (e.g., temperature, ice cover) on the ecosystem, (e) investigate and demonstrate quantitatively the various possible effects of man, specially the offshore oil and gas developments, on the ecosystem and compare these possible effects with the effects of environmental influences (anomalies) and natural ecosystem internal fluctuations, and (f) investigate and quantify any other oil development aspects which are otherwise difficult to investigate empirically.

II. Field or Laboratory Activities

A. Ship or Field Trip Schedules - N/A

B. Scientific Party

Co-principal Investigators:

T. Laevastu (half-time)

F. Favorite (N/C)

K. Larson, Technician (part-time)

P. Livingston, Technician (part-time)

C. Methods

Design and program a complete, quantitative dynamic, interactive numerical ecosystem model to run on large, available computers. Use all available, up-to-date necessary knowledge on the composition, dynamics and quantitative trophic interactions of the Bering Sea ecosystem, and obtain input data from available literature as well as new data created by other Research Units of OCSEAP. Verify and tune the model and use it for investigation and demonstration of the effects of offshore oil developments, by changing necessary input and/or interaction parameters.

Present version of the model (DYNUMES) includes the following ecological groups and major single species:

Mammals

1. Fur seal
2. Sea lion
3. Bearded seal
4. Ring and ribbon seals
5. Harbor seals
6. Baleen (true) whales
7. Toothed whales (including porpoises, dolphins)
8. Walrus

Birds

9. Murres
10. Shearwaters
11. Other marine birds ("lumped" group)

Fish

12-14 Pollock (3 age groups)

15. Other gadids ("lumped")
16. Herring
17. Other pelagic fish (capelin, smelts, etc.)
18. Yellowfin
19. Other flatfish
20. Other demersal fish (sculpins, etc.)

Plankton, benthos

21. Benthos ("fish food benthos")

22. Euphausids

23. Copepods

24. Squids

25. Phytoplankton (consumption only)

D. Sample localities/ship or aircraft tracklines - N/A

E. Data collected or analyzed

1. Number and type of samples/observations - N/A

2. Number and types of analyses - About 20 computer runs have been made to structure the 25-component submodel. Tuning and verification is in progress. The monthly and annual dynamics (distributions, abundance, consumption, etc.) of the 25 components in the model are being assessed.

A final report on background data on marine birds (Sanger and Baird, 1977) replacing the preliminary report submitted in September 1976 was submitted as part of the Annual Report.

3. Miles of trackline - N/A

F. Milestone Chart and Data Submission Schedule

1. Update of schedule

FY 77. Third quarter (July to September (incl.)):

a. Complete tuning, evaluation, alterations and documentation of the model. (Updating the input data base with new data will be completed in FY 78.)

b. Complete a report with preliminary results from the 25-component model and selected graphic outputs (seasonal and monthly distributions, consumptions, etc.)

c. Commence incorporating (programming) the effects of environmental anomalies (digitization of input fields). Qualitative determination of the effects will be effected in FY 78.

d. Commence optimization of the model and its adaption to the largest available computer (CDC 7600, ERDA, Lawrence Rad. Lab., Berkeley) (see V below), and initiate documentation (including running instructions) of the operational model (to be completed in FY 78).

FY 78

a. Update the input data base with all available new data.

b. Program in space and time variable food composition as function of food availability, and investigate the extent and effects of natural starvation.

c. Separate dominant fish groups into juveniles and adults, and introduce size-dependent feeding.

d. Provide zooming subroutines for detailed investigation of small-scale effects of oil development in Bristol Bay and in St. George Basins.

e. Complete model optimization and documentation; at this stage the 25-component submodel will be considered operational.

f. Determine qualitatively and quantitatively the effects of environmental conditions and intervention by man on the trophodynamics and interspecies competition.

g. Determine quantitatively the effects of drastic environmental changes (e.g. the extent of ice cover) and increase in mortality and/or avoidance behavior as might be caused by an oil spill.

2. Justification of slides in schedule - N/A

III. Results

An extensive report on the present submodel is in preparation and will be submitted in September. Therefore, only a few preliminary model results are listed below as examples:

a. The ecosystem internal consumption is considerably higher than assumed heretofore in conventional population dynamics approaches. This requires that the growth rates are high, which is possible if the bulk of the fish biomass is juveniles. The annual turnover rate varies between 1.0 (demersal species) to ca 1.6 (pelagic species).

b. The bulk of the biomass of most species (excluding salmon) is found in prefishery juveniles (Figure 1) where the ecosystem internal consumption (Figure 2) and growth rates are also high. Most of the juvenile consumption is by other fish. The fishing mortality in most species is rather insignificant as compared to mortalities as a result of ecosystem internal consumption.

c. Mammals consume considerably more fish in the eastern Bering Sea than are caught by man (examples on Figures 2 and 3). The consumption of pelagic fish by birds (examples on Figure 3) is also higher than removal by the fishery.

d. It has become apparent that the spatial and temporal variations of grazing on juveniles may determine largely the year-class strength of adults, rather than the size of spawning stock or survival of eggs and very young larvae (which obviously can also become limiting factors).

e. The results of preliminary model runs also suggest a conclusion derived from the 8-component submodel that starvation may be one of the important controlling factors in the marine ecosystem.

IV. Preliminary Interpretation of Results

Although final interpretation will be presented in the September quarterly report, two preliminary general interpretations of the results with respect to offshore gas and oil development that require further documentation are:

a. Any effects of oil development in the eastern Bering Sea on marine fish are expected to be small in relation to internal ecosystem interactions.

in most cases, it would scarcely be possible to distinguish these effects from natural fluctuations of the ecosystem. The latter has only a gross equilibrium and reacts quickly to a great number of different factors inside, as well as outside of the system. The only exceptions might be at the boundaries (i.e., coast) where the ecosystem's third dimension (depth) is lost and where ill effects can accumulate in a narrow important zone (e.g., crab, herring and capelin spawning, benthos, etc.), and in offshore areas where extensive oil spills in the vicinity of spawning sites might occur (e.g., from March to June in St. George Basin area, pollock eggs and larvae; from June-August in the Bristol Bay Basin, yellowfin sole eggs and larvae).

b. As there are great quantities of birds and mammals in the eastern Bering Sea, which are competitive with man in the harvest of fish resources, modest detrimental (accidental) effects of oil development on mammals and birds do not have noticeable negative effects on the rest of the ecosystem. The DYNUMES model permits the objective evaluation of the trade-offs associated with such interactions.

V. Problems Encountered/Recommended Changes

a. The present model has been extended to the core limits of the available computer (CDC 6400). The extended model must be run on the largest available computers (CDC 7600, ERDA, Lawrence Rad. Lab. in Berkeley, California).

b. The ecosystem proved to be much more sensitive to minor changes of abundance, distribution, and interaction of its components than previously anticipated. This necessitated more computer runs than previously planned for debugging, tuning, and verification. Computer costs have increased proportionately.

VI. Estimate of Funds Expended

$31 K

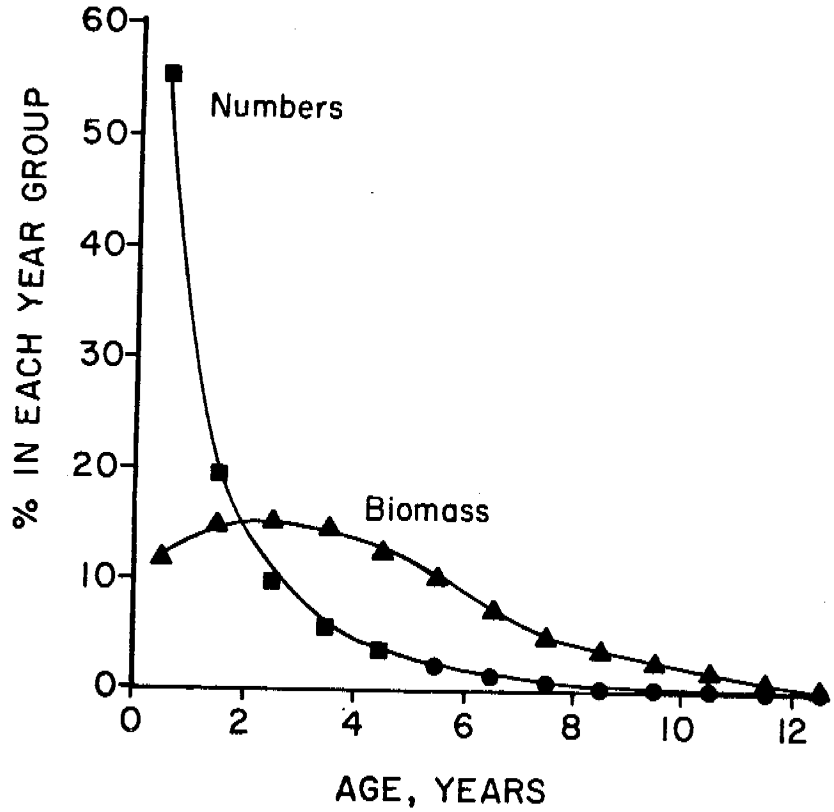

Figure 1.--Biomass vs. numbers of individuals in different year classes of Pacific herring in the eastern Bering Sea.

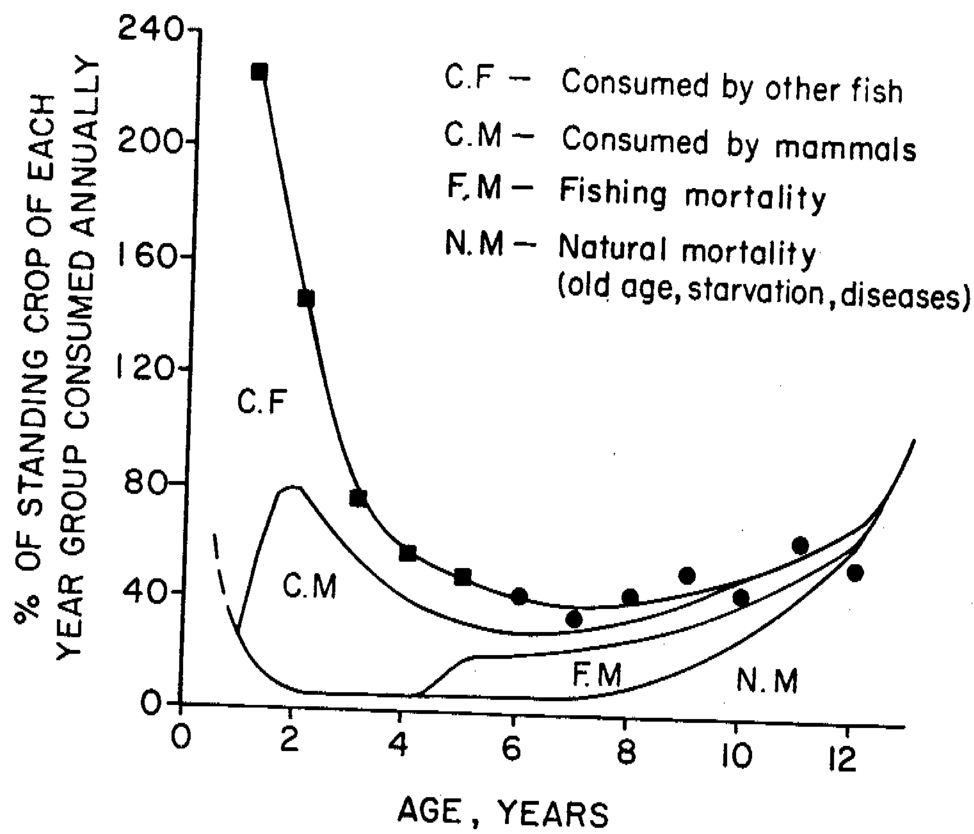

Figure 2.--Consumption vs. mortality with age in Pacific herring in the eastern Bering Sea.

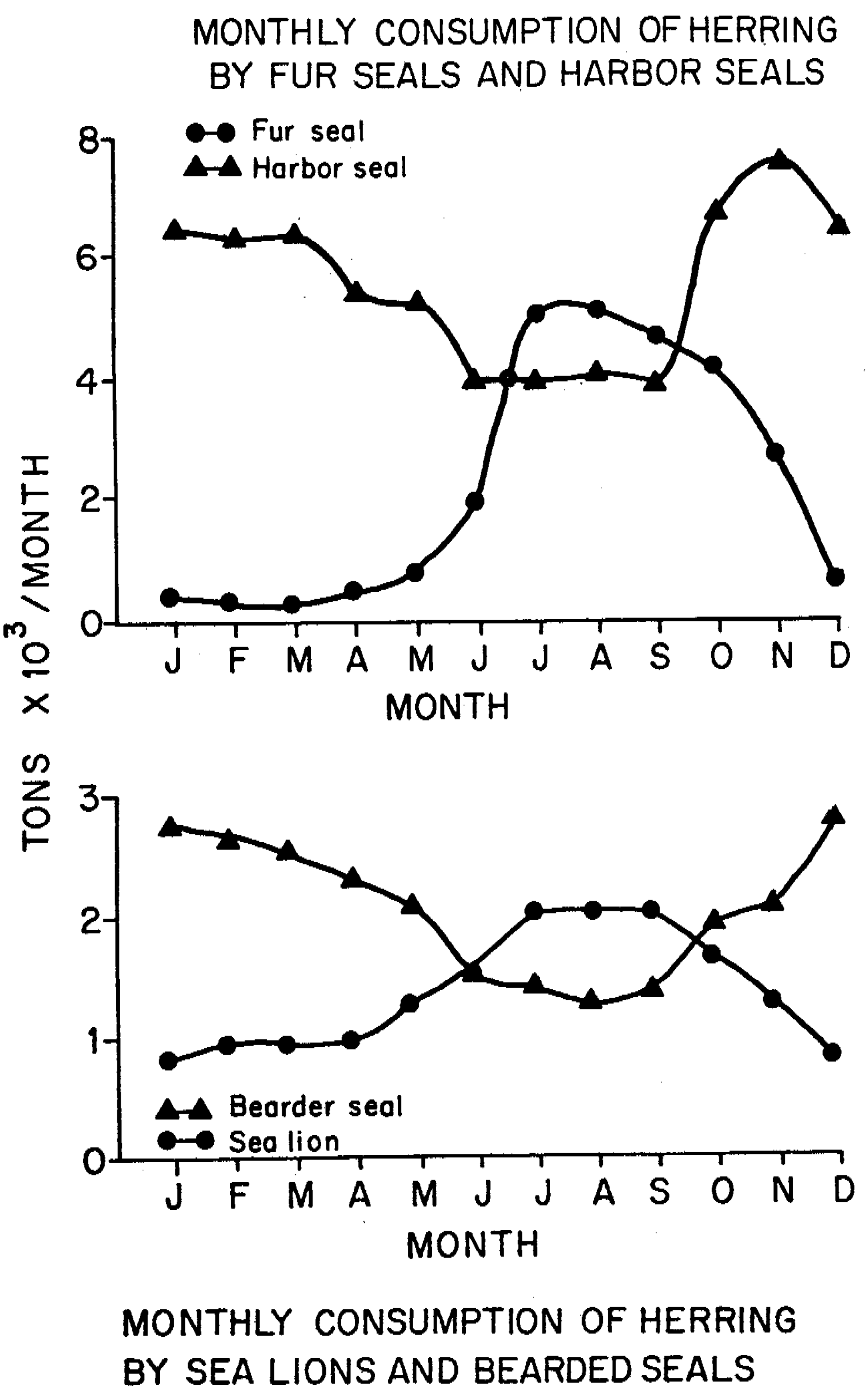

Figure 3.—Consumption of herring by selected mammals.

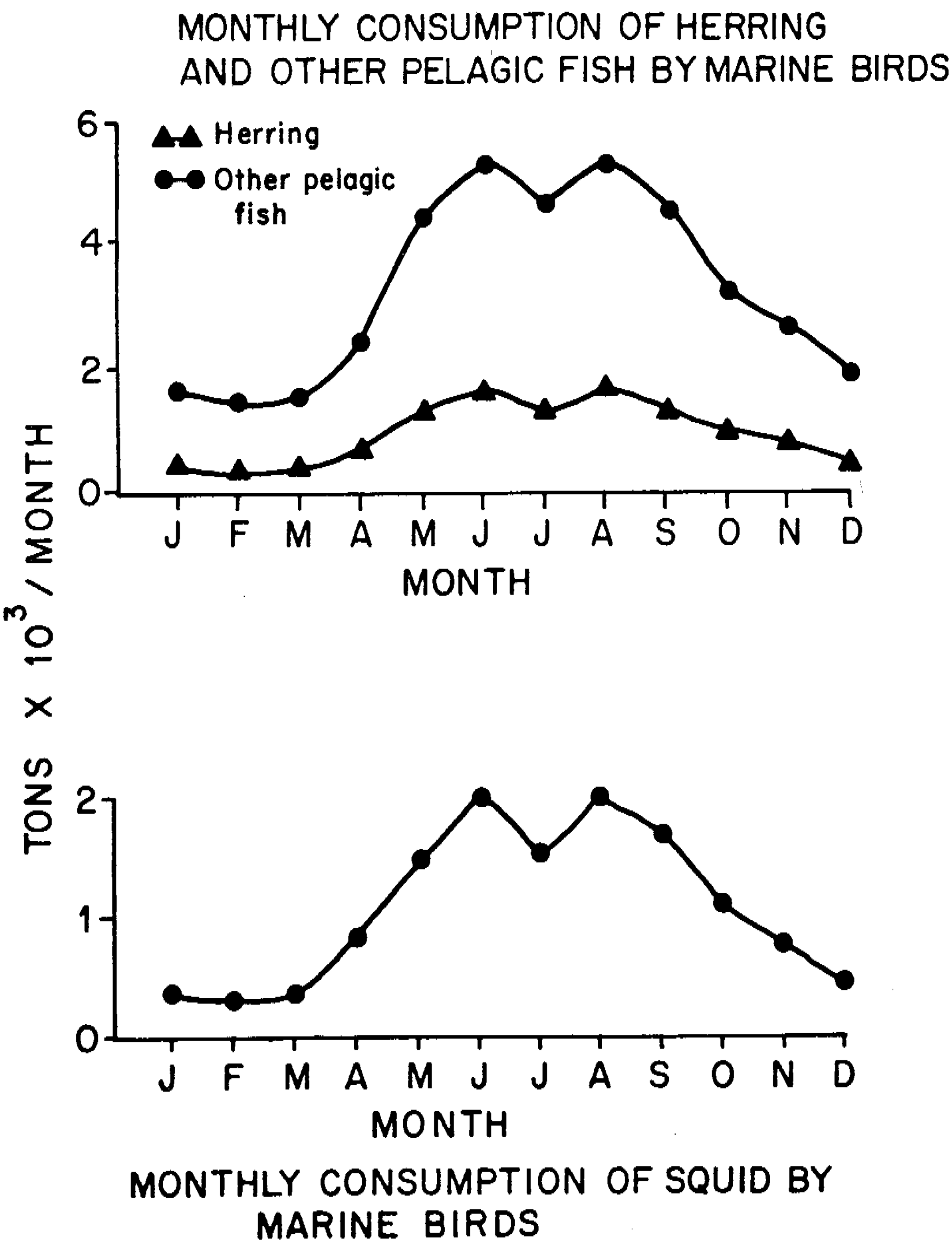

Figure 4.—Consumption of selected nekton by marine birds.

Quarterly Report

RU # 96 - 77

Quarter Ending - 30 June, 1977
Number of Pages - 2

EFFECTS OF PETROLEUM EXPOSURE ON HATCHING SUCCESS AND CHICK SURVIVAL OF THE GULF OF ALASKA HERRING GULL GROUP (Larus argentatus x Larus glaucescens)

by

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31 June 1977

QUARTERLY REPORT

I. Task Objectives this quarter:

To continue field investigations on the effects of petroleum exposure on the breeding ecology of the Gulf of Alaska Herring Gull group (*Larus argentatus* x *Larus glaucescens*).

II. Field and Laboratory Activities:

A. Field Trip Schedule

The investigators are currently in the field at Dry Bay, mouth of the Alsek River, 75 km south of Yakutat, Alaska, and have been on site since 4 May 1977. We will remain on site through the completion of the 1977 gull reproductive season in August.

B. Laboratory Activities

(none)

C. Methods

We are examining a mixed colony of Herring and Glaucous-winged Gulls at Dry Bay. We are conducting a reproductive survey of control and experimental colonies. The normal control group is composed of two groups: Group A, 90 nests in a rectanglular shape fronting the Alsek River and Group B, with 22 nests in rough circular shape in the middle of the island. Both groups are located on a flat gravel island near the mouth of the river. Methods are as previously described (RU 96-76).

The experimental colony is composed of 53 nest sites adjoining the control colonies. The experimental colony is similar in population composition and nest site selection.

North Slope Crude Oil has been delivered to completed clutches in the experimental colony with the following variables: dosage in microliter amounts of 20, 50, and 100 ul of petroleum exposure, and time of delivery in relation to stage of incubation. Thirty (30) eggs in ten (10) clutches have received ten (10) microliters each of North Slope Crude. Sixty (60) eggs in twenty (20) nests have received fifty (50) microliters each of North Slope Crude. Sixty (60) eggs have received one hundred (100) microliters of North Slope Crude. Group I received treatment immediately after clutch completion and onset of incubation; Group II received treatment after one week of incubation; and Group III received treatment after 2 weeks of incubation. Six eggs in three nests have received two hundred (200) microliters each at the close of the incubation period, that is, at pipping, approximately 26 days after onset of incubation.

C. Methods continued

We are constructing enclosures around gull nest sites in the experimental colony and exposing chicks to various amounts on North Slope Crude on body parts including: feet and legs; breast and abdomen; and head and capital regions.

We are supporting our investigations with additional data on petroleum toxicity to eggs of the following species: Sterna paradisaea, Sterna aleutica, Calidris minutilla, and Larus canus. These species show gradients in egg volume, nesting habitat and distance from marine environments.

III. Results:

Results are pending. We cannot determine effects until the completion of the breeding season.

IV. Preliminary Interpretation of Results:

None feasible at this time.

V. Problems Encountered/Recommended Changes

None.

July 1, 1977

QUARTERLY PROGRESS REPORT

TASK TITLE: Transport, retention, and effects of the water-soluble fraction of Cook Inlet crude oil in experimental food chains

RU #389

Jeannette A. Whipple
Principal Investigator

Thomas G. Yocom
Task Leader

I. Abstract of Quarter's Accomplishments

Chronic exposures of the water-soluble fraction (WSF) of Cook Inlet crude oil to organisms in a simple experimental food chain were begun during the quarter. An alga (Dunaliella), the littleneck clam (Protothaca staminea), and the starry flounder (Platichthys stellatus) were exposed to concentrations of petroleum hydrocarbons of approximately 100 ppb through the water column; in addition, clams were fed oil-contaminated Dunaliella and flounder were fed oil-contaminated clams.

The effects of WSF on spawning clams and shrimp were being determined during the quarter as were the growth rates of clams fed various concentrations of Dunaliella.

A proposal to renew this project under BLM funding was submitted to the OCS project review office in Juneau following a meeting with experimenters from the Northwest Fisheries Center and the Auke Bay Fisheries Laboratory to coordinate research efforts.

II. Task Objectives:

The objectives of this study are to determine the accumulation and passage of petroleum constituents in experimental marine food chains and the effects of petroleum exposure on the test organisms. The specific objectives are:

1. To determine the accumulation, retention and transfer of petroleum constituents in experimental food chains consisting of up to four trophic levels including primary producers, consumers and primary and secondary carnivores. Exposure will be either from water-soluble fractions of petroleum or introduced only in food to distinguish the effectiveness of petroleum accumulation from food and water exposure pathways. Adult and larvae food chains will be studied.

2. To determine mortality of experimental animals under various exposure conditions including mortality in eggs and larvae from exposed adults.

3. To determine morphological and behavioral abnormalities caused by selected exposure conditions.

4. To predict potential effects of crude oil on populations and communities in terms of reproductive success, energy utilization and growth.

5. To recommend maximum allowable levels of petroleum components in the water column and fish food organisms and, if possible, to identify components of crude oil with the greatest potential for adverse biological effects.

III. Research Activities

A. Field Activities

Field activities were limited to the collection of clams for laboratory experiments. Littleneck clams (*Protothaca staminea*) were taken at Hog Island in Tomales Bay, California, and Japanese littleneck clams (*Tapes semidecussata*) were taken from San Francisco Bay near Berkeley.

B. Laboratory Activities

1. Scientific Party

   a. Jeannette A. Whipple - Chief, Physiology Investigations; principal Investigator; also in charge of experiments dealing with effects of water-soluble hydrocarbons on spawning clams and flounder and their subsequent offspring.

   b. Thomas G. Yocom - Fishery Biologist; Task Leader; planning and supervision of experiments, also in charge of acute and chronic studies with flounder.

   c. Pete Benville, Jr. - Research Chemist; development of water and tissue samples for water-soluble hydrocarbons and metabolic by-products.

   d. D. Ross Smart - Biological Technician; plans and conducts experiments on the acute and chronic effects of water-soluble hydrocarbons on clams and shrimp; assists in other experiments.

   e. Meryl H. Cohen - Biological Aide; assists in development of analytical techniques; assists in studies on phytoplankton, clams, and flounder; in charge of laboratory equipment.

   f. Martha E. Ture - Biological Aide; care and maintenance of experimental animals; in charge of experiments on phytoplankton.

C. Methods

Following is a list of experimental outlines for work begun during the quarter and presently under way.

EXPERIMENT 1D5: Effects of short-term exposure through water column (total WSF) on adult clams prior to spawning and subsequent effects on the early developmental stages.

OBJECTIVES:

1. To determine effects on spawning adults, their gametes prior to spawning, fertilization success, hatching success and larval survival through yolk absorption.

2. To establish the pattern of uptake, the maximum accumulation levels and accumulation rate during exposure in adults and gonads prior to spawning.

3. To establish the rates and patterns of depuration after exposure (1) in adults and (2) their eggs and larvae.

4. To determine obvious cytological, histological, physiological and behavioral effects and to attempt correlations of these effects with WSF component levels in adult and early developmental stages.

HYPOTHESES:

1. Spawning clams are in an energy-deficit state because their surplus energy reserves are utilized in the production of gametes. Furthermore, estuarine and inshore clams often undergo a wide range of environmental stresses during spawning. Adult clams prior to spawning may be the most vulnerable life stage to stresses induced by the WSF fraction.

2. Neither adults nor gametes may possess enzymes for detoxification of WSF components. The gametes have high lipid content in which many WSF components are soluble. Thus, toxic WSF components may accumulate to high levels in the gonads prior to spawning.

3. There may be a reduction in survival throughout the later developmental stages (larval) as a consequence of the high levels in the gametes.

4. Reduction in survival at various developmental stages would be a direct measure of the potential influence of chronic low levels of the WSF on rates of larval recruitment and resultant year-class strength.

CONSTANTS: Adults; containers during exposure and depuration period.

1. Acclimation: Ripe clams will be collected from the field and acclimated for a short period (approx. 1 week).

2. Light: photoperiod, intensity, and wave-length distribution will approximate that in the natural environment as closely as possible.

3. Temperature - $14 \pm 0.5^{o}C$.

4. Salinity - 30 ppt

5. Oxygen - saturation

6. pH and ammonia - pH not less than 7.5; ammonia not greater than .1 ppm.

7. Containers - 133 liters (35 gallons).

8. Filtration of seawater (Inflow) - Reduction of ambient levels of oil components to approximate zero-level. Double-sand filtration, followed by charcoal filtration; other filtration as necessary.

9. Flow rates - 1 liter/min; turnover rate once every 2-3 hours. Must sustain O_2 near saturation.

10. Time of exposure - Open flow: 5 days exposure, followed by no exposure until oil components undetectable.

11. Exposure techniques - as appropriate. See Attachment.

12. Measurement techniques - as appropriate. See Attachment.

13. No food

INDEPENDENT (TREATMENT) VARIABLES: Adults

1. Concentrations of WSF: 0 (Control), approx. 500 ppb WSF (Equivalent: 100 ppb of 6 simplest monoaromatics).

   2 levels; = 2 tanks. 0 vs Exposed.
   (20 males, 20 females/tank; total of 40 males, 40 females combination).

Control	Exposed
40	40

DEPENDENT (MEASUREMENT) VARIABLES: Adults

SAMPLING TIMES HRS	SAMPLING TIMES DAYS	MEASUREMENTS (Each sampling time)	
0	0	Physical-chemical factors - Tanks	
START	EXPOSURE	Concentrations:	Gonads, liver, gall bladder and bile
6	1/4	**Mortality**:	Adults; gametes in gonads
24	1	Autopsy	Color pattern
48	2	Morphology:	Gross morphological differences in organs and gametes
72	3		
		Cytology-Histology:	Tissue sections (EM light microscope)
96	4		Gametogenesis & maturation
			Lipid content & distribution
120	5		Cell membrane structure
			Histopathology - gonads, liver
CEASE	EXPOSURE		
		Physiology:	
144	6		Sperm motility, viability
			Mucus production
168	7		
		Behavior:	
			Activity - gaping, etc.
			Spawning activity

CONSTANTS: Fertilized egg to Veliger larvae-settlement, if possible - early developmental stages.

1. Eggs artificially fertilized according to techniques of Loosanoff and Davis, 1960. Also try hydrogen peroxide.

2. Rearing conditions as used in previous experiments with other larvae using static system (Struhsaker, 1971).

3. Surviving larvae will be held for a month after end of experiment to determine possible delayed effects.

INDEPENDENT (TREATMENT) VARIABLES: Early developmental stages.

1. Source of fertilized eggs; test cross.

   Eggs and spermatozoa from adults exposed to 500 ppb WSF and adult controls.

	Replicate crosses
a. Control female eggs X Control male spermatozoa	(#1♀ x #1♂) (#2♀ x #2♂)
b. Control female eggs X Exposed male spermatozoa	(#1♀ x #1♂) (#2♀ x #2♂)
c. Exposed female eggs X Control male spermatozoa	(#1♀ x #1♂) (#2♀ x #2♂)
d. Exposed female eggs X Exposed male spermatozoa	(#1♀ x #1♂) (#2♀ x #2♂)

   Four crosses x 2 replicates/cross x 2 replicate cont./ cross = 4 x 2 x 2 = 16 containers

   200 fertilized eggs/container.

DEPENDENT (MEASUREMENT) VARIABLES: Early developmental stages.

SAMPLING TIMES		MEASUREMENTS (each sampling time)
HRS	DAYS	Behavior: Swimming, feeding, etc.
0	0	
		Mortality: At hatching; through trochophore; Veliger
6		to settlement
12		Morphological effects:
		Developmental sequences & rates
18		Developmental stages - preserved series
		Abnormalities
24	1	
		Cytological-Histological effects in early developmental
48	2	stages.
		Tissue sections
72	3	Lipid content of stage
		Caloric value of stage (energy content)
96	4	
		Physiological effects - energy utilization
120	5	Growth rate of larvae and Veligers
Continue until settled ~ 11-14 days		

ANALYSIS: Multivariate techniques; analysis covariance, comparison of concentrations of total WSF identifiable components on time, correlations of uptake and depuration with mortality, etc.

PROCEDURE:

1. Get supplies together (Meryl)

   a. 6 dozen, 2-L beakers - Order and pick up if possible
   b. 4 dozen, 6-inch fingerbowls - " " " " "
   c. Check to see if all e-M chemicals are here and mix solutions (see Joyce Hawkes).
   d. Small jars and foil for frozen samples - need approx. 64 small (about 2 oz. jars).
   e. Hydrogen peroxide
   f. Check out oxygen meter, refractometer and thermometer. Stop watch.
   g. Check out dissection equipment - need new scalpel blades

2. Collect clams - Need 100 large adult clams for this experiment (Ross, et al).

3. Dissect 10 clams and examine for ripeness, do autopsy (JW)

4. Try to induce spawning in 10 clams - check out larvae (JW)

5. Acclimate remaining clams for 1 week (JW)

6. Set up experimental tanks (Ross)

7. Take 0 time sample, adjust physico-chemical constants (Ross)

8. Take water samples, physico-chemical data 2X daily; 8:30 am and 4:00 pm (Meryl)

9. Take clam sample 1X daily at 1:00 p.m. (JW)

10. Try to induce spawning in controls vs. exposed

11. Autopsy four clams/treatment; freeze tissues (JW)

12. Preserve 1 clam/treatment for histological work. EM. (JW)

PHYSIOLOGY INVESTIGATIONS

OCSEAP PROJECT

Preliminary Phytoplankton Experiments

EXPERIMENT 1E: Feeding experiments: Clams and Phytoplankton

A. OBJECTIVES:

1E1: To determine which species of phytoplankton results in adequate tissue maintenance and growth. To determine which species of littleneck will be the best experimental animal for food chain studies.

1E2: To perform static bioassay on species of phytoplankton selected, to determine analytical techniques for measuring uptake, and to determine other parameters to be measured for physiological and behavioral effects during food chain studies.

1E3: To establish conditions comparable to those used in food chain studies and to determine effects on phytoplankton within that system - control vs. exposed at chronic level.

1E4: If time permits, repeat 1E3 with addition of clams.

B. Exp. 1E1:

1. CONSTANTS:

a. Physical-chemical conditions that will also be established in food chain, long-term tests.

1) Temperature - 12-13°C.
2) Salinity - 30 ppt
3) Oxygen - Saturation level for temperature/salinity =5.9 ppm O_2
4) Light - Photoperiod = 12 hrs dark, 12 hrs light; Intensity = 125 fc
5) pH - Not less than 7.5

b. Tank - Volume = 35 gals, 133 liters; all glass.

c. Open flow conditions - to maintain good exp. conditions above, except when feeding phytoplankton, stop flow for 1 or 2 hrs (to be determined).

d. Phytoplankton density - Stock = 1.33 liters at 10^6 cells/ml. Tank = Final density of 10^4 cells/ml.

2. TREATMENT (INDEPENDENT) VARIABLES:

a. Species of Clam: Juvenile Japanese littleneck (*Tapes semidecussata*); Juvenile Common littleneck (*Protothaca staminea*)

b. Species of Phytoplankton: *Dunaliella salina*
Nephroselmis sp.

c. Time - 0, 1, 2, 3, 4 weeks

Treatment combinations = 2 X 2 X 5 = 20

5 clams/treatment combination = 100 clams; 50 species

3. MEASUREMENT (DEPENDENT) VARIABLES:

a. For initial sample and clams during test: weekly

From each Tank:		Shell				TISSUE			
TIME	No.	Volume	Length	WW	DISSECTION	DW	Cal/gm	WW/DW	% Water
0	5/5								
1 week	5/5								
2 weeks	5/5								
3 weeks	5/5								
4 weeks	5/5								

b. Feeding Period; Daily

1) Beginning phytoplankton density

2) End phytoplankton density

3) Filtering rate - No. algal cells/ml/clam/time

EXPERIMENT 1F: 96-hr acute bioassay and measurement of uptake, accumulation and depuration in Bay shrimp (*Crangon franciscorum*).

Objectives:

1. To determine the 96 hour LC_{50}
2. To determine levels and rates of accumulation and depuration of water-soluble fraction - monoaromatics (WSF-MA).
3. To determine the physiological responses of juvenile, adults, male and female and berried females to lethal doses of WSF.

Procedure: Shrimp will be exposed for 96 hours to one of four concentrations of WSF. In addition, shrimp will be subsampled to determine tissue concentrations and accumulation rates. In 96-hour post observation periods the shrimp will be observed for delayed mortalities and subsampled for depuration of WSF.

1. Set up WSF flow-through system and two control tanks.
   a. Divide each tank in half with large mesh zooplankton netting.
   b. Add seawater dilution lines to each test tank.
2. Stabilize solubilizer output of WSF.
   a. Adjust head tank manifold and dilution line flows to obtain tank concentrations of 0.5, 0.75, 1.0, 1.25 ppm of WSF-MA.
   b. Flow rates to test tanks and controls should be 0.7 l/min to 1.0 l/min.
   c. Stabilize system for 24 hours
3. Begin exposure by adding shrimp to tanks.
   a. Place into one-half of each of the 6 tanks 10 juveniles, 10 males, 10 females, 10 females with eggs.
   b. Place in the other half of each tank 4 shrimp for tissue analysis of WSF accumulation rates.

c. Observe and sample at 0, 4, 8, 12, 20, 24, 44, 48, 68, 72, 92, 96 hours.

d. Observe behavior - swimming, bottom movement, molting, cannabolism.

e. Take water samples for GC analysis from solubilizer and the 6 tanks.

f. Take physical parameters of all tanks - flow rate, temperature, salinity, D.O., ammonia.

g. Record number dead at each observation time.

h. Tissue analysis on all dead shrimp and subsample of the 2nd group of shrimp for accumulation levels.

4. End exposure

a. High flow rate to clear tank, then adjust flows back to original rates.

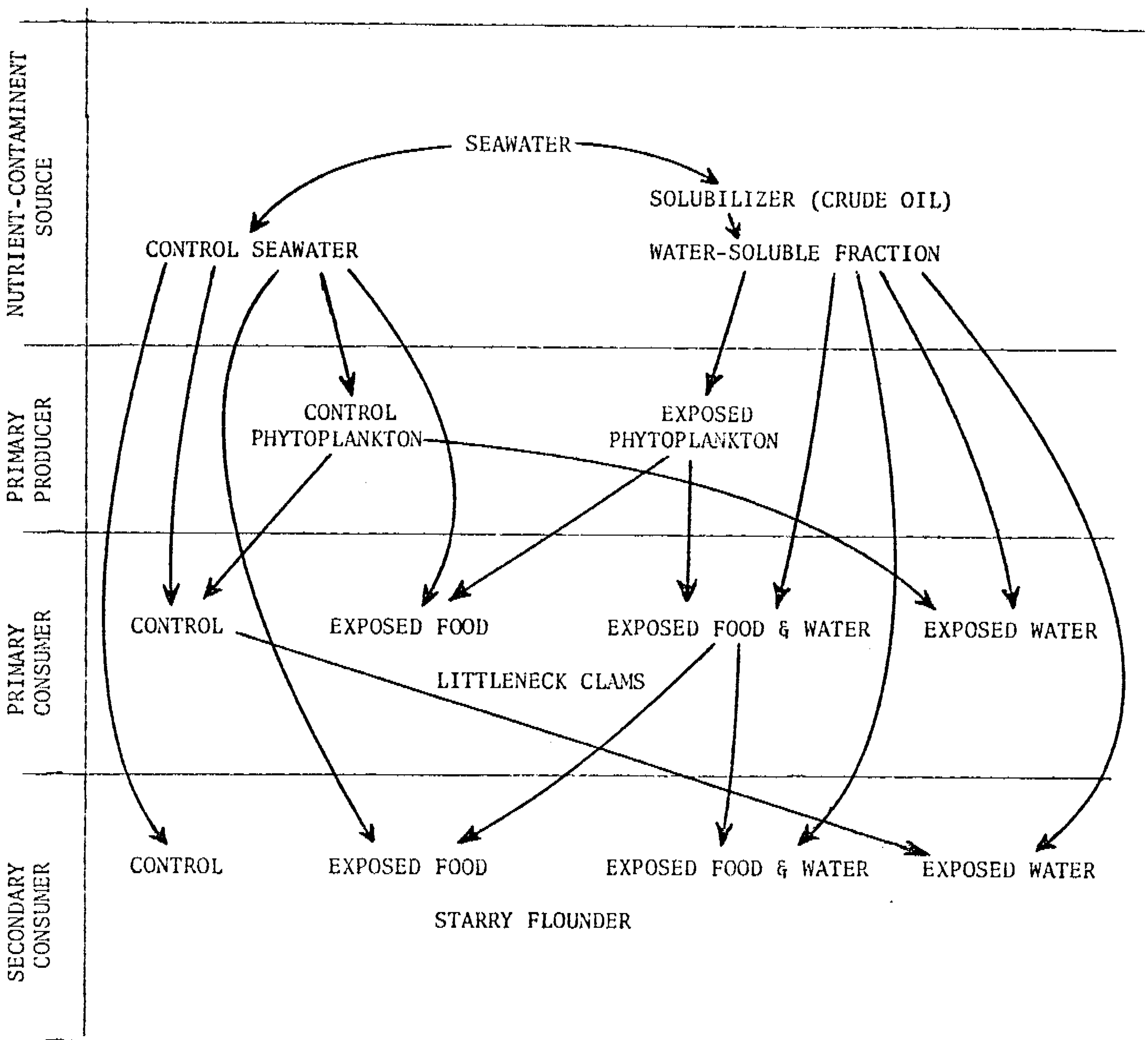
b. Allow shrimp to depurate for 96 hours; observe LC_{50} group for latent mortality.

c. Continue to subsample 2nd group for depuration rates.

EXPERIMENTAL FOOD CHAIN EXPERIMENTS:

The following three sets of experiments proceed according to the flow diagram shown in Figure 1. In all experiments the concentration of WSF in the water column will be 100 ppb. The water temperature will be 14 C, the photoperiod will be on a 12-hour cycle, and the salinity will be 30 ppt.

Figure 1. Flow diagram of food chain experiments presently underway.



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EXPERIMENT 2A: Culture of *Dunaliella* in the presence of 100 ppb of the water-soluble fraction (WSF) of Cook Inlet crude oil.

Objectives:

1. To determine the effect of low-level exposure to WSF on the growth rate of *Dunaliella*.

2. To provide an "oil-contaminated" food source for littleneck clams in food chain experiments.

Methods:

1. Innoculate a nutrient medium with a continuous source of water-soluble petroleum hydrocarbons via aeration systems (or by regular replacement of a fraction of the medium).

2. Add a known number of cells of *Dunnaliella* and incubate the medium at room temperature under a 12-hour photoperiod.

3. Determine concentration of cells in medium daily by counting with a Coulter counter.

4. When concentration reaches 10^6 cells/ml, harvest culture and feed to clams.

5. Compare growth rates to control cultures.

EXPERIMENT 2B: Uptake, retention, and effects of chronic exposures to low levels of the water-soluble fraction (WSF) of Cook Inlet crude oil to littleneck clams.

Objectives:

1. To determine the rate of uptake and depuration of water-soluble components of crude oil from food items and from the water column and to compare and contrast these pathways.

2. To determine which components are retained longest in tissues and whether metabolites accrue to any measurable degree.

3. To record any physiological, behavioral, or morphological changes in clams that can be attributed to their exposure to the WSF.

4. To provide an adequate food source for starry flounder as the next step in the food chain.

Methods:

1. Groups of 60 littleneck clams will be placed in each of 4, 30 gallon aquaria after all have been weighed, measured, and marked for identification. Two of these tanks will receive a continuous inflow of water with 100 ppb of the WSF of Cook Inlet crude oil. The other tanks will receive filtered seawater.

2. At least 1000 littleneck clams will be placed in a 400-gallon holding tank receiving a continuous inflow of 100 ppb WSF and 1000 clams in a 400-gallon tank receiving filtered seawater.

3. All clams will be fed daily a ration of Dunaliella (1 liter/ 20 gallons) in cultured concentrations of at least 1 X 10^6 cells/ml. One 30-gallon tank receiving WSF and one receiving filtered seawater will receive daily rations of Dunaliella raised in 100 ppb WSF. The remaining 30-gallon tanks will receive Dunaliella grown in filtered seawater. Clams in the 400-gallon holding tank receiving WSF will be fed daily rations of WSF-exposed Dunaliella while the control tank will be fed control Dunaliella.

4. All clams in 30-gallon tanks will be weighed and measured weekly. A subsample of 6 clams will be taken each week from each tank for chemical analysis.

5. Clams in the holding tanks (400 gallon) will be used to feed flounder. Exposed clams will be fed to flounder only after a minimum exposure period of 1 week (2 weeks if adequate numbers of clams are obtained).

6. After 8 weeks, exposure to oil will cease and all tanks will receive only filtered seawater and control Dunaliella. Subsampling, weighing, and measuring will continue for 2 weeks.

EXPERIMENT 2C: Uptake, retention, and effects of chronic exposure to low levels of the water-soluble fraction (WSF) of Cook Inlet crude oil to starry flounder.

Objectives:

1. To determine the rate of uptake and depuration of water-soluble components of crude oil from food items and from the water column.

2. To contrast the relative effectiveness of food and water pathways of uptake.

3. To determine which components are retained longest in tissues and whether metabolites accrue to any measurable degree.

4. To record any physiological, behavioral, or morphological changes in flounder that can be attributed to their exposure to the WSF.

Methods:

1. Groups of 30 sub-adult and adult starry flounder will be placed in each of 4, 600-gallon holding tanks. Two of these tanks will receive continuous inflow of water with 100 ppb of the WSF of Cook Inlet crude oil. The other two tanks will receive filtered seawater.

2. Flounder will be fed daily a ration of littleneck clams (without shells) equivalent to 3-4% of their wet body weight. Two tanks (one with exposed water and one with control) will receive oil-contaminated clams; the other tanks will receive control clams.

3. All flounder will be weighed, measured, and marked prior to the start of the experiment and all will be weighed and measured weekly following the start of experimentation.

4. Three flounder from each tank will be removed each week for chemical analysis of tissues. Analyses will be made of muscle, liver, gall bladder, gonads, and gills for each fish. Other tissues such as brain will be pooled for all three fish for analysis (in order to obtain enough sample for analysis).

5. Exposure will continue for 8 weeks to be followed by a 2-week depuration period. During this time all tanks will receive filtered seawater and control clams as food. Subsamples will continue each week.

6. Water samples will be taken daily and analyzed by gas chromatography. Tissue samples will be analyzed by gas chromatography and mass spectrometry.

IV. Results

The only results that have been analyzed during the quarter are part of an acute bioassay of WSF on Bay shrimp (*Crangon*). Less than 5% of shrimp exposed to 0.6 ppm WSF, died in 96 hours; less than 10% died after a 96-hour exposure to 1.5 ppm WSF. Shrimp exposed to 1.5 ppm exhibited loss of equilibrium and abnormal swimming.

Attempts to measure concentrations of WSF in shrimp tissue were unsuccessful. Samples contained too high a concentration of lipid materials; extracts of shrimp tissue ruined our gas chromatography column.

The remainder of the experiments are ongoing and manpower restrictions prevented completing any preliminary analyses of data for this report.

V. Preliminary Interpretation of Results

Concentrations of up to 1.5 ppm of the water-soluble fraction (measured as total monocyclic aromatics) of Cook Inlet crude oil for 96 hours were not lethal to Bay shrimp (*Crangon franciscorum*). Concentrations of 1.5 ppm did, however, cause loss of equilibrium and abnormal swimming in the shrimp. Ripe females hatched eggs in exposed and control tanks.

The remainder of experiments begun during the quarter are in progress and preliminary interpretations have not been made. No results of tissues sent out for analysis have been received to date.

VI. Problems Encountered/Recommended Changes

Samples sent to the National Analytical Laboratory in April 1977 have not been analyzed to date. As a result, it is virtually impossible to accurately estimate the exposure necessary to produce equilibrium concentrations of petroleum hydrocarbons in tissues of clam or flounder (or to positively identify compounds that are taken up or metabolized). As such, long-term exposures that were begun this quarter rely on some somewhat arbitrary estimates about the length of time one trophic level should be exposed before it is fed to a higher level.

In order to shorten the analysis time, two members of the project were sent to the National Analytical Laboratory during the quarter to learn techniques for preparation of water and tissue samples for gas chromatography (capillary column) and mass spectrometry. Such training should speed outside analyses but will probably slow progress on experiments somewhat because of the lengthy processes involved.

A request was made for additional funding above that recommended for FY78 to purchase a small mass spectrometer. Such a unit would allow in-house analyses of tissue samples, rapid turnaround, and low cost per analysis.

Some problems have been encountered in obtaining starry flounder outside of San Francisco Bay. If these problems continue, flounder may be taken from inside the Bay and animals will be held in the laboratory until no petroleum hydrocarbons (if present) can be detected in any tissues.

It may not be possible to obtain enough littleneck clams (*Protothaca*) to feed 120 flounder a daily ration equivalent to 4% of their wet body weight (see Methods Section). If such is the case, Japanese littleneck clams (*Tapes*) may be substituted after a 1- to 2-week holding (clean-out) period.

VII. Estimate of Funds Expended

During the quarter, a subcontract was arranged with the National Analytical Laboratory, Seattle, for analysis of water and tissue samples (see letter of Yocom to McLeod in Section VIII). The remaining unobligated budget for FY77 is approximately $7000 which will be spent primarily on supplies and materials and computer costs.

VIII. Attachments

RESEARCH TO DETERMINE THE ACCUMULATION OF ORGANIC CONSTITUENTS AND HEAVY METALS FROM PETROLEUM-IMPACTED SEDIMENTS BY MARINE DETRITIVORES OF THE ALASKAN OUTER CONTINENTAL SHELF

R.U. 454

FOURTH QUARTERLY REPORT

to

Outer Continental Shelf Environmental Assessment Program
Bering Sea-Gulf of Alaska Project Office
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by

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RESEARCH TO DETERMINE THE ACCUMULATION OF ORGANIC CONSTITUENTS AND HEAVY METALS FROM PETROLEUM-IMPACTED SEDIMENTS BY MARINE DETRITIVORES OF THE ALASKAN OUTER CONTINENTAL SHELF

FOURTH QUARTERLY REPORT

to the

National Oceanic & Atmospheric Administration
Boulder, Colorado

July 1, 1977

During the fourth quarter of the NOAA/BLM project, several major experiments, originally described in our annual report, have been brought to a conclusion. Those studies dealt with the following topics:

1. Influence of feeding type on bioavailability of petroleum hydrocarbons from sediment

2. Uptake of ^{14}C-labeled aromatic hydrocarbons by *Macoma inquinata* in short-term experiments

3. Uptake of ^{14}C-aromatic hydrocarbons by *Macoma inquinata* in long-term experiments

and will be described below.

INFLUENCE OF FEEDING TYPE ON BIOAVAILABILITY OF PETROLEUM HYDROCARBONS FROM SEDIMENT

Benthic organisms are represented by species which exhibit diverse feeding modes. When considering the problem of uptake of material from sediment, it is reasonable to presume that organisms which feed directly on sediment or detritus would have a greater opportunity for accumulation from sediment than species which do not. We tested this hypothesis by exposing filter-feeding, detritus-feeding, and sediment-ingesting species to oil-contaminated sediment in a field experiment, then analyzing the organisms for tissue hydrocarbon concentrations. The clams *Protothaca staminea* and *Macoma inquinata* and sipunculid *Phascolosoma agassizii* were chosen as test species representative of the respective feeding modes listed above.

Details of experimental procedures have been described in our annual report. The results are presented in Table 1.

Concentrations of total petroleum hydrocarbons (IR) in exposure sediment were 887.4 ppm initially, then declined to 443.8 and 420.6 ppm at 40 and 60 da, respectively. The decreases can probably be attributed to microbial- and photo-oxidation of hydrocarbons as well as their release to the surrounding seawater. Although our exposure concentrations were relatively high, even higher levels have been reported after actual oil spills.

Accumulation of petroleum hydrocarbons was considerably higher in the deposit-feeders *Macoma inquinata* and *Phascolosoma agassizii* than in the filter-feeder *Protothaca staminea* (table 1), indicating that deposit-feeding benthic animals are more likely to take up such compounds from contaminated sediment than are filter-feeders. At the 40 da sampling interval (Table 1), hydrocarbon levels in *Protothaca staminea* were below our detection limits, while those in *M. inquinata* and *Phascolosoma agassizii* ranged between 2 to 6 ppm combined aliphatics and di-, tri-aromatics. Relative contributions of the 3 fractions were similar for both species. Aliphatics averaged 1.1 ppm, and total aromatics averaged 3.0 ppm. The diaromatics consisted of the alkylated forms, particularly the di- and tri-methylnaphthalenes. Naphthalene was not detected. At 60 da (Table 1), hydrocarbon concentrations in tissue were considerably higher than those at 40 da, primarily due to increases in levels of tri-aromatics in *Phascolosoma agassizii* and both trimethylnaphthalenes and tri-aromatics in *M. inquinata*. The apparent increase in uptake between 40 and 60 da is difficult to explain; however, we have observed a similar phenomenon with benzo(a)-pyrene uptake from sediment by *M. inquinata*. At the 60 da sampling, *Protothaca staminea* also contained petroleum hydrocarbons, approximately 1.9 ppm combined aliphatics and total aromatics (Table 1). Transfer of exposed *M. inquinata* and *Protothaca staminea* to clean seawater for 1 week resulted in significant depuration of both saturate and aromatic hydrocarbons from clam tissue (Table 1). Approximate half-times (assuming exponential decrease) for depuration of saturates were 2.3 and 3.5 da for *M. inquinata* and *Protothaca staminea*, respectively, for the 2 species.

For comparative purposes, we exposed *Protothaca staminea*, the filter-feeder, to 0.02 and 0.03 ppm Prudhoe Bay crude oil dispersed in seawater for 60 da in a continuous-flow bioassay system. The results indicated that tissue hydrocarbon levels were considerably higher than those in the exposure seawater and were consistent with previous reports on the uptake of petroleum hydrocarbons from seawater by marine bivalves. Approximately 11 ppm aliphatic and total aromatic hydrocarbons were present in clam tissue. Over 90% were aromatic hydrocarbons, predominantly tri-aromatics and lesser amounts of the di- and tri-methylnaphthalenes, a pattern similar to that described above for animals exposed to oil-contaminated sediment.

It is evident from our study that the feeding type of benthic organisms is an important factor in the bioavailability of aliphatic, diaromatic, and tri-aromatic petroleum hydrocarbons from marine sediments. Deposit-feeders accumulate hydrocarbons from oil-contaminated sediments more readily than filter-feeders. However, the extent of accumulation was relatively low compared to initial sediment hydrocarbon concentrations. Since concentrations in tissue of both *Phascolosoma agassizii* and *Macoma inquinata* increased during the 60 da

Table 1. Petroleum hydrocarbon concentrations in *Phascolosoma agassizii, Macoma inquinata,* and *Protothaca staminea* exposed to oil contaminated sediment. Samples[1] were obtained after 40 and 60 da exposure and after transfer of 60 da exposed animals to clean seawater for 7 da.

SPECIES	TREATMENT	HYDROCARBON CONCENTRATIONS (ppm wet weight)						
		C_{12}-C_{28}[2]	Naphthalene	Methylnaphthalene	Dimethylnaphthalene	Trimethylnaphthalenes	Triaromatics	Total Aromatics (<4 rings)
P. agassizzi	Control	<0.10	<0.005	<0.005	<0.01	<0.01	<0.05	<0.08
M. inquinata	Control	<0.10	<0.005	<0.005	<0.01	<0.01	<0.05	<0.08
P. staminea	Control	0.01	<0.005	<0.005	<0.01	<0.01	0.13[3]	0.13
P. agassizii	40 da exp.	1.90	<0.005	0.23	0.60	0.95	2.25	4.03
		0.73	<0.005	0.01	0.15	0.44	0.77	1.36
M. inquinata	40 da exp.	0.69	<0.005	0.06	0.89	0.90	1.90	3.75
P. staminea	40 da exp.	<0.10	<0.005	<0.005	<0.01	<0.01	<0.05	<0.08
P. agassizzi	60 da exp.	1.48	0.01	0.06	0.18	0.73	7.04	8.01
M. inquinata	60 da exp.	0.54	0.02	0.27	2.39	10.28	24.49	37.45
		3.62	0.02	0.26	1.96	9.95	21.95	34.14
P. staminea	60 da exp.	0.10	<0.005	0.02	0.16	0.54	1.07	1.79
M. inquinata	60 da exp;	0.35	<0.005	0.03	0.96	4.62	5.40	11.01
	7 da dep.	0.15	<0.005	0.02	0.20	0.55	1.93	2.71
P. staminea	60 da exp;	0.03	<0.005	<0.005	<0.01	0.07	--	--
	7 da dep.	0.02	<0.005	<0.005	0.01	0.05	0.13	0.19

[1] Each sample consisted of 2 to 4 pooled individuals; clams were shucked prior to extraction.
[2] C_{12}-C_{28} saturates include pristane and phytane, hydrocarbons of recent biological origin.
[3] This value may represent biogenic hydrocarbons or petroleum hydrocarbons of unknown origin; on the other hand, it is probable that compounds in this fraction in oil-exposed organisms represent petroleum triaromatics from our experiment.

experiment, the long-term implications for bioaccumulation cannot be adequately defined at the present time. In a study using oiled sediment similar to that reported here, concentrations in sediment of docosane, naphthalene, and phenanthrene exhibited exponential decreases with approximate half-times of 40 da. Our IR analyses also indicated a decrease of petroleum hydrocarbons with exposure time. Thus, it would appear that animals in our experiment were accumulating aliphatic, diaromatic, and triaromatic hydrocarbons during a period which coincided with release of these compounds from sediment.

UPTAKE OF ^{14}C-LABELED AROMATIC HYDROCARBONS BY *MACOMA INQUINATA* IN SHORT-TERM EXPERIMENTS

Our efforts consisted of short-term (1 week) experiments to survey the relative uptake of various aromatic hydrocarbons from oil-contaminated sediments. The objective was to screen several compounds in an attempt to identify those which may have greater significance with respect to bioavailability from marine sediments. We selected *Macoma inquinata* as a test species, since preliminary observations indicated that this clam is an active detritus-feeder. The test compounds were 2-methylnaphthalene, phenanthrene, chrysene, dimethylbenzanthracene, and benzo(a)pyrene.

Clams were collected from intertidal regions of Sequim Bay, Washington, and held at the Marine Research Laboratory of Battelle-Northwest, Sequim, Washington. Holding tanks contained raw, flowing seawater of about 10°C and 30 ‰ and sediment obtained from the vicinity of the clams' natural habitat.

Detrital material which settles out of our flowing seawater system was collected and filtered onto No. 42 Whatman filter paper. Fifteen grams were weighed and suspended in approximately 30 ml seawater. Ten μCi of the appropriate ^{14}C-labeled hydrocarbon and 0.033 ml Prudhoe Bay Crude oil dissolved together in 1 ml ethyl ether were added to the suspended detritus, mixed thoroughly by shaking, then filtered onto No. 42 Whatman filter paper. The contaminated detritus was used in exposures. Stock solutions of ^{14}C-hydrocarbons were tested for radioisotope purity by thin-layer chromatography and auto-radiography. Measurements by infrared spectrophotometry (IR) indicated approximately 2,000 μg/g total hydrocarbons in the detritus.

Since oil-contaminated sediments can release hydrocarbons to the surrounding water, it was necessary to consider the possibility of uptake of solubilized, as well as sediment-bound, hydrocarbons. Therefore, some clams were placed on the bottom of exposure aquaria containing the contaminated detritus, while others were placed in a nylon-mesh (Nitex) basket suspended in the water column above the detritus. The first group fed directly on the detritus, and the latter served as a control for uptake from the water. Seven-day exposures were conducted in all-glass aquaria containing detritus and 3 ℓ of 0.45μ filtered seawater. At the end of exposure, some individuals from the bottom and suspended basket were removed for immediate extraction, while the remainder were transferred to clean seawater for a 24-h gut purging period.

Net uptake from sediment, i.e., the amount of hydrocarbon ingested and present in clam tissue at the end of the exposure period, can be calculated as follows:

Net uptake = Concentration in clams on bottom - concentration due to seawater uptake - concentration in gut contents + concentration lost from tissue during gut purging.

If uptake is primarily due to absorption of solubilized hydrocarbons, then the value for actual uptake would be essentially zero or negative.

Seawater samples were taken prior to the addition of clams and at 1, 2, 4, and 7 days. Detritus was sampled initially and at 7 days. All samples were analyzed by liquid scintillation spectrometry and corrected for quench. Additional experimental details are described in our annual report.

The results are summarized in Table 2. There was no measurable uptake of the diaromatic 2-methylnaphthalene from sediment. Uptake from seawater could account for the entire amount of this substance in clam tissue. Higher molecular weight compounds possessed an uptake component associated with net uptake from sediment. Comparison of net uptake from sediment to uptake from seawater indicated that both sources contributed similar amounts to the tissue burden of polyaromatic hydrocarbons. Magnification factors indicated that hydrocarbons in sediment were not as readily accumulated by clams as hydrocarbons in seawater. Sediment magnification factors were typically less than 0.1, while seawater magnification factors ranged from 3.2 to 420. Furthermore, seawater magnification factors exhibited a correlation with molecular weight of the aromatic compound, increasing with increasing size of compound. Such a correlation is undoubtedly related to the lipid vs water solubilities of the compounds. Thus, larger molecular weight compounds which are more lipophilic would tend to have a greater affinity for animal tissues than smaller compounds. Sediment magnification factors did not exhibit such a trend.

UPTAKE OF ^{14}C-AROMATIC HYDROCARBONS BY *MACOMA INQUINATA* IN A LONG-TERM EXPERIMENT

We examined long-term uptake of phenanthrene, chrysene, and benzo(a)pyrene from sediment by *Macoma inquinata*. Since short-term experiments, already described, indicated a low level of accumulation of these compounds by *M. inquinata*, it was necessary to determine if prolonged exposure would also produce similar results.

Clams were collected in the intertidal region of Sequim Bay and held in the laboratory in flowing seawater of approximately 10°C and 30 °/₀₀. Exposures were conducted in compartmentalized sediment trays already described. Each compartment was filled with 3 kg clean sand and placed in holding tanks with flowing seawater and a simulated diurnal tidal flux. Cement blocks held the trays at a level that prevented "high tide" from overflowing the upper edges

TABLE 2. Uptake of ^{14}C-polyaromatic hydrocarbons from sediment by *Macoma inquinata*. Clams were exposed to sediment containing 2000 ppm crude oil spiked with 10 μC of the hydrocarbon indicated in the table.

Parameter	2-Methyl-Naphthalene	Phenanthrene	Chrysene	Dimethyl-Benzanthracene	Benzo(a)pyrene
Net Uptake From Sediment[1] *(ug/g)*	0	0.096	0.308	0.297	0.059
Uptake From Seawater *(ug/g)*	0.048	0.038	0.297	0.856	0.037
Sediment Magnification Factor[2]	0	0.056	0.029	0.039	0.057
Seawater Magnification Factor[3]	3.2	5.89	105	295	420

[1] Calculated As Indicated In Text (Annual Report).

[2] Sediment Magnification Factor = Net Uptake/Geometric Mean Concentration In Sediment.

[3] Seawater Magnification Factor = Uptake From Seawater/Geometric Mean Concentration In Seawater.

of the sediment trays. "Low tide" completely drained seawater from the trays through fiberglass mesh bottoms. Therefore, the only water flux in the exposure trays occurred through the tray bottoms as the trays drained and filled. Twenty clams were placed in each compartment. Six exposure and one control trays were prepared.

Contaminated detritus was prepared as described for short-term experiments. At "high tide," approximately 25 g of suspended detritus was added to each compartment and allowed to settle on the surface of the sand containing clams. Clams and sediment were sampled at 3, 7, 14, 28, and 42 days of exposure. Each sampling period entailed removal of all clams and one sediment core from a compartment. Half the clams and the sediment core were extracted and analyzed immediately. The remaining clams were transferred to clean seawater for 24 h to allow purging of gut contents, then analyzed.

During the course of exposure, the detritus which had settled onto the surface of the sand penetrated into interstitial spaces as a result of the tidal fluxes. Since it was impossible to separate detritus from sand at sampling intervals after day 3, counts for core samples were used as a measure of hydrocarbon content. For purposes of comparison, initial counts for detritus were corrected to account for the total sediment load (= detritus + sand), assuming uniform distribution of the detritus in sand. These values could then be directly compared to values for core samples.

For phenanthrene and chrysene, ^{14}C-radioactivity was also separated into parent compound and metabolite fractions using a procedure described by Roubal *et al.*, of NOAA, Seattle.

Concentrations of radioactivity in sediment are described in Figure 1. Initial concentrations were similar ($\sim 1.0 \times 10^4$ dpm/g) for phenanthrene, chrysene, and benzo(a)pyrene and exhibited an apparent two-component exponential decrease with time. Phenanthrene, the smallest compound, decreased at a faster rate than chrysene or benzo(a)pyrene. Final sediment ^{14}C concentrations were 2 orders of magnitude less than initial levels with phenanthrene and approximately 1 order of magnitude less with chrysene and benzo(a)pyrene. In all 3 cases, loss rates were relatively rapid.

Behavior of ^{14}C-radioactivity in tissue of exposed clams were different for the 3 compounds and apparently related to relative solubilities (Figure 2). With all 3 compounds, exposed clams took up an initial high dose measured at either 2 or 3 days of exposure. This initial uptake was probably associated with the high levels in the initial exposure detritus on the sand surface and active filtration of this highly contaminated material. With time, however, the detritus percolated into the underlying sand substrate as described earlier. Tissue concentrations of ^{14}C-phenanthrene radioactivity steadily declined with subsequent exposure indicating an initial high uptake followed by depuration. Tissue ^{14}C-chrysene concentrations increased up to day 14, then began to decline after that time. ^{14}C-benzo(a)pyrene in tissue, however, continued to increase throughout the duration of the experiment (42 da in this case). These observed differences are probably associated with the relative solubilities of the 3 compounds in water and lipids. For example, net uptake as presented in Figure 2

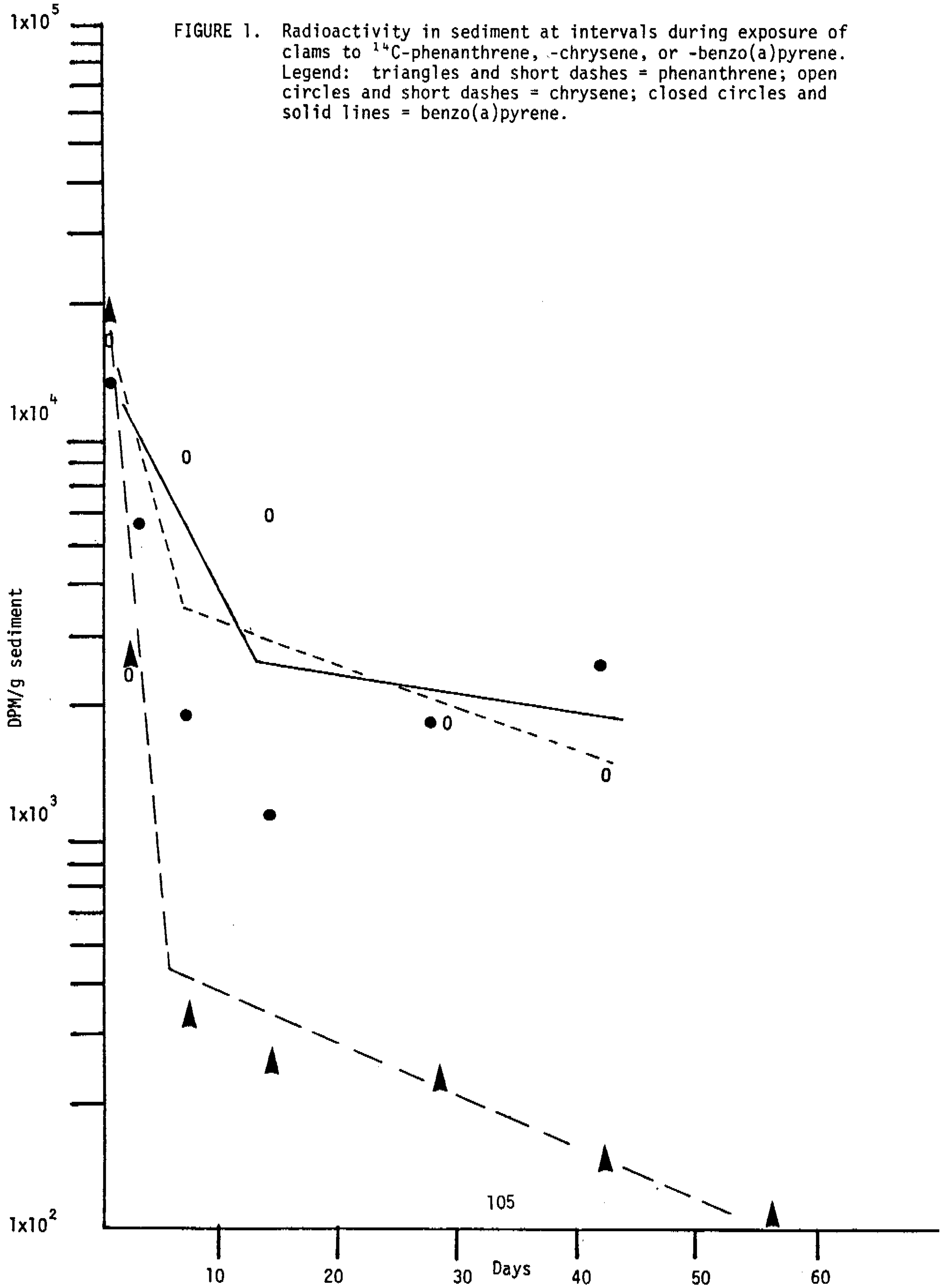

FIGURE 1. Radioactivity in sediment at intervals during exposure of clams to ^{14}C-phenanthrene, -chrysene, or -benzo(a)pyrene. Legend: triangles and short dashes = phenanthrene; open circles and short dashes = chrysene; closed circles and solid lines = benzo(a)pyrene.

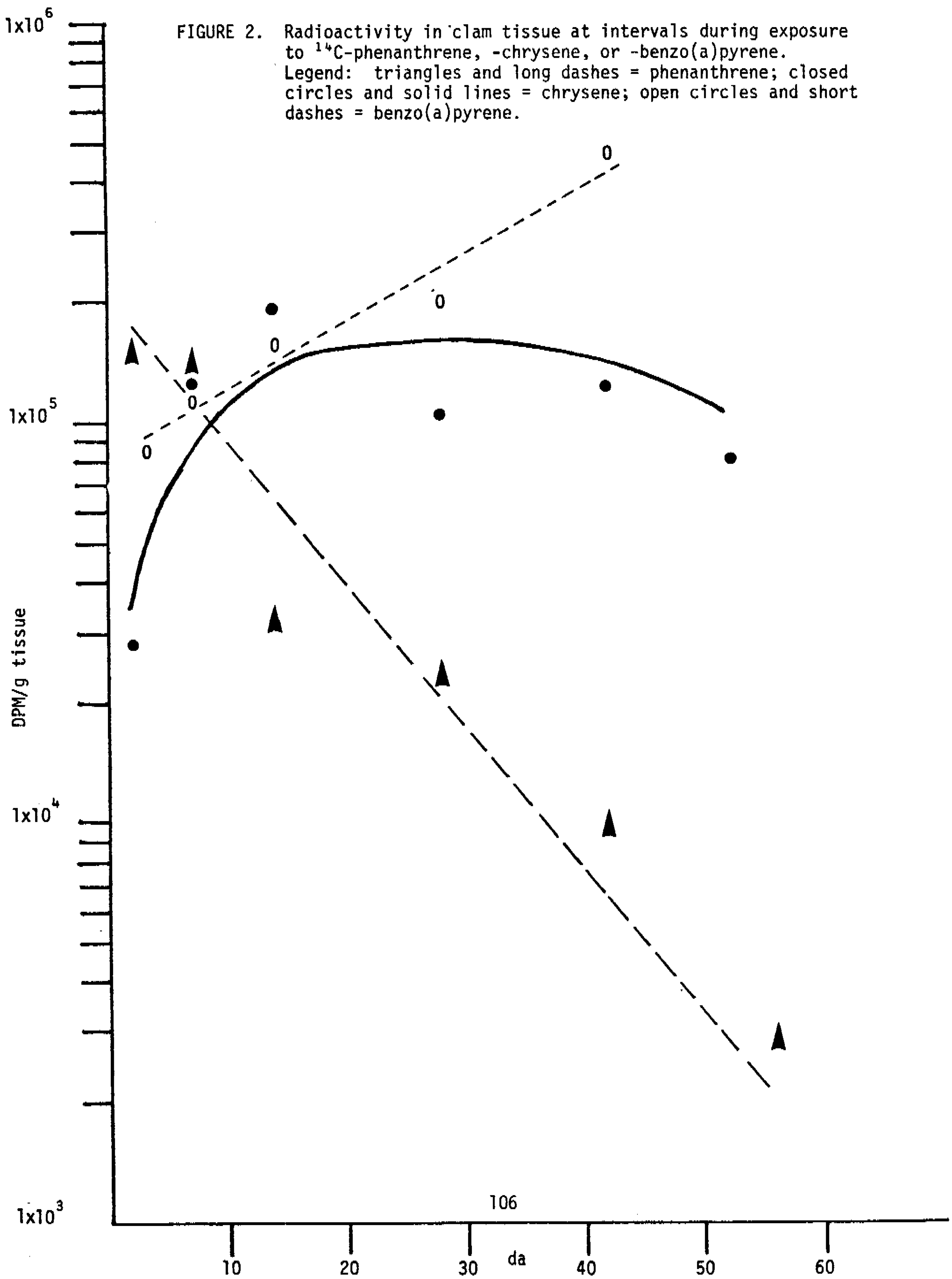

FIGURE 2. Radioactivity in clam tissue at intervals during exposure to ^{14}C-phenanthrene, -chrysene, or -benzo(a)pyrene. Legend: triangles and long dashes = phenanthrene; closed circles and solid lines = chrysene; open circles and short dashes = benzo(a)pyrene.

can be described as follows:

$$\text{net uptake} = \text{influx} - \text{efflux}.$$

Therefore, net uptake is positive when influx exceeds efflux and negative when efflux exceeds influx. The kinetics of benzo(a)pyrene radioactivity uptake is clearly representative of the former case, while phenanthrene kinetics is representative of the latter. Chrysene possessed a positive net uptake during the early stages of the exposure when tissue concentrations began to decrease. Since benzo(a)pyrene was the most lipophilic compound of the 3, phenanthrene the most hydrophilic, and chrysene intermediate; it appears that the relative affinities of the 3 compounds for clam tissue, probably the lipid pool, was associated with the behavior of these compounds in our experimental system.

Separation of ^{14}C-radioactivity for phenanthrene and chrysene into parent and metabolite fractions indicated a difference in the behavior of these compounds in both sediment and clam tissue. For example, the fraction of phenanthrene radioactivity present as parent compound in sediment decreased at a faster rate than that for chrysene (Table 3), indicating that phenanthrene was a less stable compound in our exposure system. Furthermore, the fraction of phenanthrene radioactivity in clam tissue associated with parent compound decreased from 97.1 to 44.5 % of the total radioactivity over the 56 da exposure period. For chrysene, almost all the radioactivity in clam tissue was still associated with the parent compound at the end of exposure.

It is obvious that degradation of phenanthrene in sediment occurred at a faster rate than for chrysene, and that the relative contributions of metabolites of phenanthrene increased with time in clam tissue. Chrysene metabolites in tissue were negligible. Microbes and photo-chemical oxidation as well as loss to the seawater were probably responsible for the turnover of these compounds in sediment. At the present time, there is no evidence to suggest that marine bivalves possess enzymatic systems which can degrade aromatic hydrocarbons. Therefore, phenanthrene metabolites present in clam tissue may have originated in the sediment and were subsequently taken up by clams.

Table 3. Percent of total radioactivity present as parent compound

Compound	Time (days)	Sediment	Tissue
Phenanthrene	0	98.4	-
	2	83.5	97.1
	7	36.6	87.1
	14	35.3	80.6
	28	17.4	60.2
	42	27.2	51.2
	56	17.7	44.5
Chrysene	0	90.4	-
	2	94.7	98.4
	7	78.1	96.2
	14	63.0	95.8
	28	72.0	93.9
	43	67.4	94.7
	52	24.6	95.8

QUARTERLY REPORT

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30 June 1977

BEAUFORT SEA BARRIER ISLAND - LAGOON

ECOLOGICAL PROCESS STUDIES

I. Introduction and Objectives

This program commenced in May 1976. Its general objective was 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 study was to be designed 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 change in those ecosystem components and processes identified as important, and (3) identify mechanisms by which those components and processes could be tested for their sensitivity to man-caused change and, therefore, for their utility in predicting and analyzing impacts of OCS development. This is the first submittal to be published as a quarterly report by the OCSEAP Program and for that reason it contains a brief synopsis of activities carried out during the course of the entire year since the program's inception.

Since the study was structured as a 2-phase effort — a research planning phase (Phase I) followed by an implementation phase (Phase II) — the Phase I effort was necessarily almost complete before the specific objectives of Phase II were finalized. During the course of the research planning efforts of Phase I, the program design progressed temporally from the most general approach to the most particular in a step-wise fashion and successive editions of the research plan resulting from this planning included increasing amounts of detail. The basic planning was to initially describe in as much detail as possible the hypothetical ecosystem interactions and then by simulation and sensitivity analysis to determine which ecological elements would most likely be affected by OCS development. Throughout the planning process, the primary design emphasis was to create a program which was (1) interdisciplinary to the maximum extent and (2) mission-oriented (e.g., which focused on critical ecosystem processes likely to be impacted by OCS development.

The use of modelling during the course of interdisciplinary workshops functioned to create a common base for communication among PI's, project managers, and NOAA and BLM coordinators. Computer simulation models that generally represented the current level of understanding of the key ecological processes operating in the study area were prepared and refined during the course of the planning program. At each successive workshop, investigators critically examined each task statement in light of new insights gained through interdisciplinary workshop discussions and through evaluations of key processes as depicted by simulation models.

During the last research planning workshop (April 1977), investigators finalized research goals and field tasks and coordinated logistics planning with other investigators for the field season of 1977.

II. Activities

A. Activity Schedule

Significant events in the Beaufort Sea Barrier Island - Lagoon Program from May 1976 to July 1977 are as follows:

Date	Event or Data Product
May 1976	Reconnaissance flight made along the Alaskan Beaufort coast to inspect potential study areas.
8 July 1976	Progress Report to OCSEAP - "Background Information For the Beaufort Sea Barrier Island - Lagoon Ecosystem Studies", 32 pp.
29 - 30 July 1976	Barrier Island - Lagoon Ecosystem Planning Workshop (Edmonton, Alberta).
6 September 1976	First Draft Research Plan to OCSEAP - "Beaufort Sea Barrier Island - Lagoon Ecological Process Studies."
12 October 1976	Second Draft Research Plan to OCSEAP - "Beaufort Sea Barrier Island - Lagoon Ecological Process Studies." 143 pp. + appendices.
2 - 4 December 1976	First Barrier Island - Lagoon Ecosystem Integration and Modelling Workshop (Vancouver, British Columbia)
17 January 1977	Third Draft Research Plan to OCSEAP - "Beaufort Sea Barrier Island - Lagoon Ecological Process Studies." 160 pp.
6 - 8 April 1977	Second Barrier Island - Lagoon Ecosystem Integration and Modelling Workshop (Vancouver, British Columbia)
15 May 1977	LGL ornithologists began bird migration studies at Oliktok DEW station, Simpson Lagoon.
14 June 1977	LGL Aquatic ecologists and ornithologists moved to camp on Pingok Island.

B. Scientific Party

The scientists involved in the Beaufort Sea Barrier Island - Lagoon program, their roles, and their affiliations are listed below.

Name	Affiliation	Project Role
Alan Birdsall	LGL Limited*	General Management
Joe Truett	LGL Limited**	Project Director. Mammals
Tom Wetmore	LGL Limited*	Data Management
Carl J. Walters Ray Hilborn Sandra Buckingham Randall Peterman	Institute of Animal Resource Ecology Univ. of British Columbia Vancouver, British Columbia	Systems Analysis & Modelling. Nutrient Dynamics
J. Brian Matthews [1]	Geophysical Institute University of Alaska	Physical Oceanography (storm surge and current modelling)
John C. H. Mungall [1]	Dept. of Oceanography Texas A & M University College Station, Texas	Physical Oceanography (current modelling)
A. S. Naidu [1] (PI, Sedimentology)	Institute of Marine Science University of Alaska Fairbanks, Alaska 99701	Sedimentology (origin and dynamics of barrier island system)
P. Jan Cannon [1] (PI, Geomorphology)	Solid-Earth Science Program University of Alaska Fairbanks, Alaska 99701	Geomorphology (origin and dynamics of barrier islands; dynamics of shoreline erosion)
Peter Craig (PI, Aquatic Ecology)	LGL Limited***	Aquatic Ecology (ecology of fishes; nutrient dynamics)
William Griffiths	LGL Limited****	Aquatic Ecology (ecology of fishes and benthos)
Lewis Haldorman	LGL Limited**	Aquatic Ecology
Stephen Johnson (PI, Ornithology)	LGL Limited*	Ornithology

Name	Affiliation	Project Role
Gary Searing	LGL Limited*	Ornithology
W. John Richardson	LGL Limited****	Ornithology (bird migration analysis)

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[1] These investigators are funded separately for Phase II of the Program.

C. Methods

The research planning portion of the program commenced in May 1976 with a brief reconnaissance flight made by investigators along the Alaskan Beaufort Sea coast to inspect potential study areas. The Simpson Lagoon - Jones Island complex was subsequently chosen as the area most suitable for investigation on the basis of its typicalness, the extent of its historical exposure to man's activities, the availability of existing scientific data about the area, and the nearness of the area to logistics support relative to these aspects of other Beaufort Sea barrier island - lagoon complexes.

A progress report characterizing the Simpson Lagoon - Jones Island area and surrounding ecosystems was submitted to OCSEAP on 8 July 1976. This report served as a background document for investigators during the course of initial research planning efforts.

In late July 1976, representatives from NOAA-OCSEAP and LGL Limited, plus several consulting scientists (including a systems modeller), convened in Edmonton, Alberta for a combined interdisciplinary research planning workshop. During the course of this workshop a preliminary conceptual model of the ecosystem to be studied was created with inputs from ecologists, physical process scientists, and systems modellers. The purpose of the model at this stage was to assist in ordering current knowledge so that critical system processes would become more evident to the workshop group and so conspicuous data gaps could be identified.

Following the July workshop, a draft study plan with disciplinary task statements was developed. This plan was submitted to NOAA-OCSEAP in early September and was subsequently distributed by OCSEAP to selected in-house staff members and other arctic scientists for review. In response to review comments received, the original draft plan was revised by LGL Limited and resubmitted to OCSEAP as a second draft plan on 12 October 1976.

The first general meeting of project Principal Investigators (PI's) was combined with the first extensive modelling workshop and was held in Vancouver, British Columbia in early December 1976. At that time a preliminary computer model of the system was constructed, interdisciplinary research needs were clarified, and PI's took initial steps toward integrating their proposed field research efforts. Proposed research found to be irrelevant to program objectives was eliminated, and methods whereby investigators could promote interdisciplinary cooperation to increase the efficiency of field efforts were discussed. As a consequence of that workshop and its modelling exercise, the second draft research plan was subsequently revised and submitted as the third draft research plan on 17 January 1977.

Project investigators and coordinators attended the second major modelling and program integration workshop in Vancouver, 6 - 8 April 1977. The main objectives and eventual accomplishments of this final workshop of the planning portion of the study were three:

(1) To critique and refine the preliminary model constructed during the last workshop (December 1976). A more realistic and relevant simulation of the barrier island - lagoon ecosystem was made possible by more detailed and recent information gathered by PI's since the last workshop.

(2) To evaluate and revise proposed field research. Each PI's field research proposal was critically evaluated by disciplinary subgroups as well as by the entire complement of attendees. Critieria by which each proposal was evaluated were, (a) its relevance to needs of other disciplines of the program, (b) the relevance of its objectives to general program objectives, and (c) the convenience with which field research efforts could be coordinated with those of other disciplines.

(3) To develop a detailed plan for coordination of timing, logistics support, and sampling among the various disciplines during field research in the 1977 field season. Such requirements as base camp and field support needs by each PI were discussed. Samples to be collected by one investigator for use by another were identified. Time scheduling for data transfer among disciplines was discussed.

Field work began in mid-May. At that time Stephen Johnson began observations of spring migration of birds near the study area. For this purpose the Oliktok DEW station radar was used in a manner similar to that reported by Flock (1973); data collected are to be analyzed as by Richardson et al. (1975). This effort enables a relatively complete analysis to be made of the major spring bird migrations near this point on the Beaufort Sea coast by combining the bird-detection capabilities of the DEW line radar with simultaneous visual observations of migrating birds.

In early June, W. John Richardson arrived at Oliktok to complete the radar study and Johnson moved across Simpson Lagoon to Pingok Island to begin observations of bird migration near the island and use of the island by migrating birds. At this time, Gary Searing, who will assist Johnson in performing the bird study throughout the summer, also arrived at the Pingok Island camp. Richardson left the field in mid-June after the major portion of the spring bird migration had ended; Johnson and Searing remained on Pingok Island.

Two aquatic biologists, William Griffiths and Lewis Haldorman and a technician, Victor Roxburgh, arrived at the Pingok Island camp in mid-June to begin collecting data for the aquatic ecology portion of the program.

D. Sample Localities

Fig. 1. depicts the location of the Oliktok DEW station used during bird migration studies and shows the Simpson Lagoon - Jones Islands area within which the Barrier Island - Lagoon Program is to be carried out.

III. Results

Information resulting from the field program to date is preliminary in that no data have been analyzed. However, descriptions by field personnel of bird migration, physical phenomena associated with spring breakup, general use of the lagoon - barrier island area by vertebrates, and potential impacts of development in the area are of interest.

A. Bird Migration

Bird migration between mid-May and mid-June in the Jones Islands - Simpson Lagoon area generally resembled migration patterns in the vicinity of Komakuk DEW Station, Yukon Territory, as reported by Richardson et al. (1975). The majority of migrants observed were moving eastward, and large numbers of birds passed both over coastal areas (shoreline, lagoon, barrier island chain, and offshore of the islands) and inland.

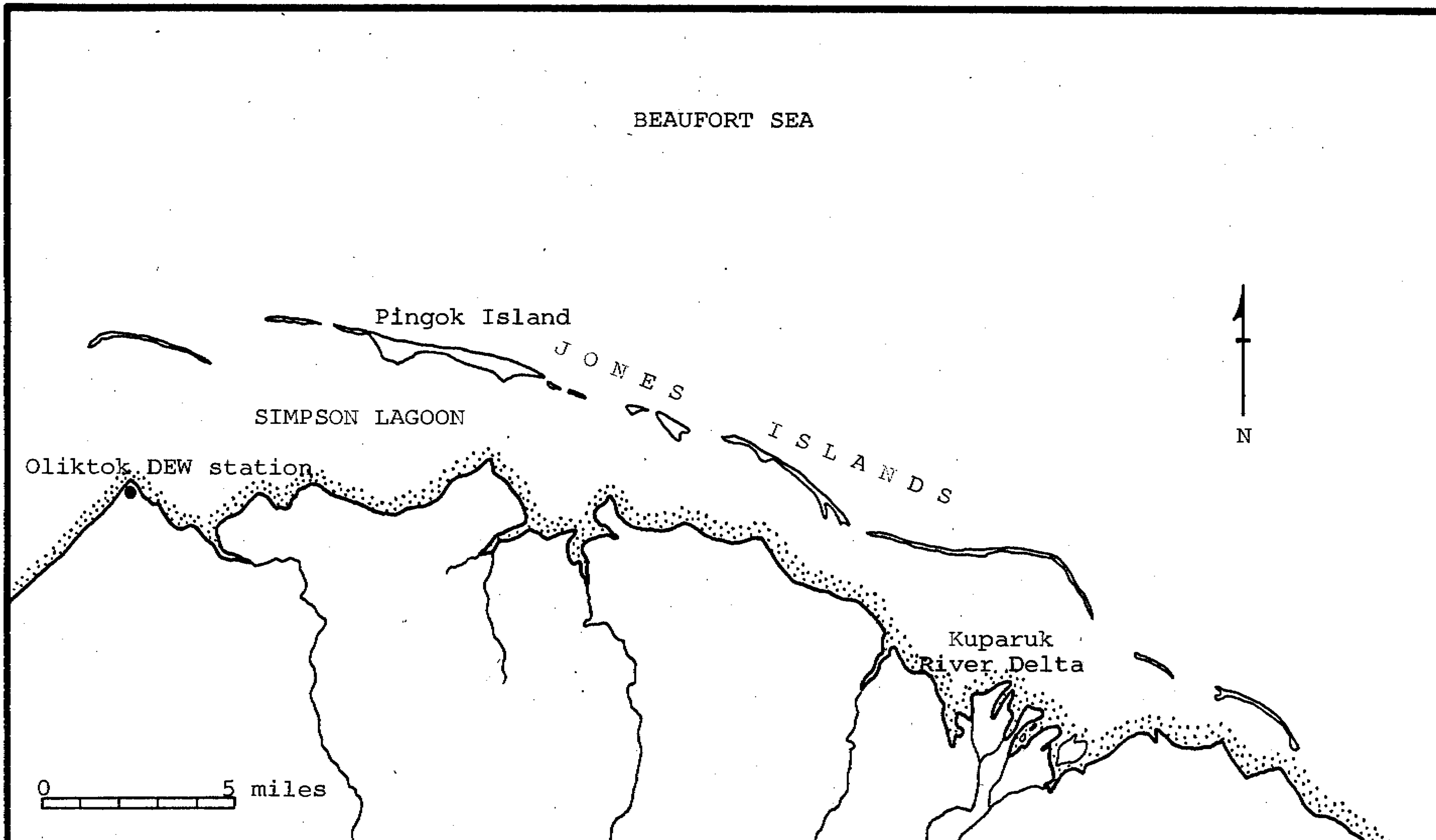

Figure 1. Location map of the Simpson Lagoon - Jones Islands study area. The base camp is located on Pingok Island.

However, there are some basic disparities in numbers of individuals of particular species observed between this site and at Komakuk in 1975, e.g., Black Brant (*Branta nigricans*). Observers suspected that many migrants were passing undetected far inland over the coastal plain, which is much wider here than at Komakuk.

Neither the barrier island chain nor the lagoon appeared to be particularly effective as keys to bird movement. That is, the mass of east-west migration was spread over a broad front, extending well offshore and for an undetermined distance inland.

Strong tail winds appeared to stimulate migration; greater numbers of birds were observed moving eastward with westerly winds, and vice versa. The peak of migration appeared to occur during the first week in June.

The general composition of migratory flocks was about as expected. Commonly seen species were Common Eider (*Somateria mollissima*), King Eider (*S. spectabilis*), Oldsquaw (*Clangula hyemalis*), Black Brant, Parasitic Jaeger (*Stercorarius parasiticus*), Glaucus Gull (*Larus hyperboreus*), Pintail (*Anas acuta*), Arctic Loon (*Gavia arctica*), and White-fronted Goose (*Anser albifrons*).

Shorebirds in general were not observed migrating coastwise in large numbers. They simply "appeared" almost overnight during early June; such arrival is characteristic of these birds (Bailey 1948: 31).

B. Spring Breakup

The over-ice flooding of freshwater streams and associated phenomena in the area provided an opportunity for biologists at Oliktok and on Pingok Island to observe critical processes which are potentially very important to area ecosystems.

All of the over-ice flood waters in Simpson Lagoon apparently came from the Kuparuk, the Sakonowyak, and Ugnuravik Rivers and smaller tundra streams immediately adjacent to the lagoon. Floodwaters from the Colville River overflow remained several km to the south and west of Oliktok Point and did not extend into Simpson Lagoon. It is possible that a very minor input of Colville water to Simpson Lagoon could have taken place beneath the ice on the east end of the lagoon, since the flood waters eventually flowed through holes in the ice.

Flood waters from these streams were heavily silt- and detritus-laden, as is normal for spring peak flow of arctic rivers, and at their height (about 9 June) appeared about a meter deep over many areas of the lagoon ice. Water and detritus flowed across Simpson Lagoon and a large amount left the lagoon system oceanward through passes between islands such as Thetis and Spy, and Spy and Pingok. As these overflow waters passed the island chain, they appeared to begin flowing through the ice in holes created by ice ridging and possibly by ringed seals (Pusa hispida).

By 12 June, water depth over the lagoon ice had receded to about 10-20 cm in depth, and large pieces of tundra mat and other detrital material lay on the ice surface of the lagoon.

C. Bird Activity Relative To Breakup

Birds began using flooded lagoons soon after breakup began. Jan Cannon reported seeing from the air large flocks of water birds on over-ice flood pools near the mouth of the Colville River in early June. Steve Johnson observed King Eiders, Oldsquaws, and Glaucous Gulls feeding in shallow over-ice water a few days following the peak flow; inspection of the feeding sites revealed an abundance of amphipods among the pieces of surface debris. Presumably these invertebrates migrated from beneath the ice during the flood period and then became available to birds as the waters receded.

D. Vertebrate Use of Islands

Bird use of the barrier islands during spring migration appeared to be important for neither resting, feeding, nor migration orientation. However, by 20 June, several species were found nesting on Pingok in appreciable numbers (Table 1).

Other vertebrates on Pingok include several caribou (Rangifer tarandus) and three Arctic foxes (Alopex lagopus) seen, and signs of lemmings and Arctic ground squirrels (Citellus undulatus) encountered. Several ringed seals and one polar bear (Ursus maritimus) were seen on the ice between Pingok and Spy Island.

E. Potential Impacts of OCS - Related Activity

Many ice roads created by petroleum exploration crews during the winter were encountered. During the construction of these roadways across the lagoon and nearshore ice, the snow cover had been pushed aside, thereby creating a berm and exposing an 8'-10' strip of ice.

Table 1. Occurrence and abundance of nesting birds on Pingok and nearby islands in early June

Species	Evidence of Nesting	Abundance
Lapland Longspur (*Calcarius lapponicus*)	nests with eggs found	common
Baird's Sandpiper (*Calidris bairdii*)	nests with eggs found	common
Dunlin (*Calidris alpina*)	nests with eggs found	common
Snow Bunting (*Plectrophenax nivalis*)	nests with eggs found	common locally
Oldsquaw (*Clangula hyemalis*)	nest with eggs found	one nest on beach
Willow Ptarmigan (*Lagopus lagopus*)	nest with eggs found	one nest; several territorial males
Glaucous Gull (*Larus hyperboreus*)	seen nesting	several seen
Parasitic Jaeger (*Stercorarius parasiticus*)	birds with nesting territories	at least two on Pingok
Ruddy Turnstone (*Arenaria interpres*)	nests found	uncommon
Semipalmated Sandpiper (*Calidris pusillus*)	probable territory establishment	common
Sabine's Gull (*Xema sabini*)	one pair seen consistently	uncommon
Golden Plover (*Pluvialis dominica*)	male on territory	one seen
Arctic Loon (*Gavia arctica*)	territory on lake on Pingok	at least one pair
White-fronted Goose (*Anser albifrons*)	one pair seen consistently	at least one pair
Pintail (*Anas acuta*)	nesting behavior probable	common

Two potential indirect results of this activity could result: First, the snow berms created by the road construction appeared to block and redirect the flow of river floodwater, causing it and its detritus load to be channeled toward the paths of least resistance. The distribution of sediment load deposition on the ice, therefore, depended to a great extent upon the spatial arrangement and height of ice-road berms. This in turn may markedly affect detritus transfer patterns to nearshore benthic environments during breakup of the nearshore ice cover.

Second, it is likely that removal of the insulating layer of snow above the ice promotes a greater depth of freezing beneath the roadways. The resulting increase in ice thickness may significantly affect under-ice transport of water and nutrients and the movement of organisms in the shallow lagoon system.

IV. Preliminary Interpretation of Results

Adequate data for significant interpretations other than those discussed above are not yet available.

V. Problems Encountered

No major difficulties have been encountered. The program has proceeded on schedule and accomplishments have, if anything, exceeded expectations.

VI. Estimate of Funds Expended

Phase I and Phase II of this program are being funded under the same contract; Phase II funding has been provided as a contract modification to the original Phase I contract. To date, approximately 25% of the total contract amount (Phase I & Phase II) has been expended.

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