Environmental Assessment of the Alaskan Continental Shelf

Quarterly Reports of Principal Investigators for July - September 1978

Volume I

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VOLUME I

CONTENTS

RECEPTORS (BIOTA)

Marine Mammals

Contents

QUARTERLY REPORT

Contract: #03-5-022-56
Research Unit: #194
Task Order: #8
Reporting Period: 7/1/78-9/30/78
Number of Pages: 4

MORBIDITY AND MORTALITY OF MARINE MAMMALS

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1 October 1978

I. TASK OBJECTIVES THIS QUARTER

A. To conduct field work in Kodiak, LCI, Bering and Beaufort study areas.

B. To begin processing of materials collected this quarter.

II. FIELD AND LABORATORY ACTIVITIES

A. Field Trip Schedule

1. 1-31 July (Kelly) Otter Island (Pribilofs) survey of beached mammals.

2. 7-19 July (Dieterich, O'Connor) Alaska Peninsula beached mammal survey, via Supercub aircraft.

3. 14-18 August (Dieterich, Murray) LCI beached mammal survey, via *Surveyor* 78B Leg I.

4. 15-26 August (Shults) Necropsy of collected specimens, Beaufort Sea, via CGC *Northwind*.

5. 28 August-12 September (Shults) Necropsy of collected specimens, Kodiak, via *Surveyor* 78B Leg II.

B. Laboratory and Other Activities

Collected materials were shipped to Fairbanks or forwarded to other appropriate laboratories for analysis. Analytical procedures are underway.

The P.I. participated in the Alaska Science Conference, 15-17 August, and presented a progress report on the results to date.

C. Methods

All beached mammal surveys were via helicopter or small, fixed-wing aircraft at elevations ranging from 100 to 150 feet and air speeds of 30 to 50 knots. Necropsies of beached carcasses and collected specimens were by standard methods, described previously.

III. RESULTS

A total of 103 collected specimens were necropsied this quarter, as follows:

Steller sea lion, *Eumetopias jubatus*	19
Pacific harbor seal, *Phoca vitulina richardsi*	81
Ringed seal, *Phoca hispida*	3

These had been taken primarily for the purposes of other OCSEAP projects (R.U. #229, 230, 232, 243) and were made available to this project on a cooperative basis.

About 2,000 km of beaches were surveyed for dead and moribund marine mammals in the southern Bering, Lower Cook, and Kodiak study areas. The number and kinds of carcasses found were comparable to findings in previous years. Actual numbers have not yet been tabulated.

Necropsies were performed on at least 18 of the carcasses that were still sufficiently intact to lend themselves to this procedure. They were as follows:

Belukha, *Delphinapterus leucas*	3
Steller sea lion, *Eumetopias jubatus*	3
Harbor seal, *Phoca vitulina richardsi*	8
Sea otter, *Enhydra lutris*	4

IV. PRELIMINARY INTERPRETATION OF RESULTS

No interpretation feasible at this time, due to incomplete analysis of materials collected.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

None

VI. MILESTONE CHART

Two activities planned for this quarter, and shown on earlier milestone charts, were cancelled, due to changes in scheduling which conflicted with other personnel commitments. These were the "Kodiak collection and necropsy (Pitcher charter)" in July and the "St. Lawrence Island stranding survey (charter)" in August. However, two other activities not shown in the previous schedule, were added: "Otter Island stranding survey (charter)" which was done in connection with other studies, funded largely by other sources, and "Beaufort Sea collection and necropsy (CGC *Northwind*)" funded through the OCSEAP Arctic Project Office.

MILESTONE CHART

RU #: 194 PI: Francis H. Fay

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

MAJOR MILESTONES	1977 O	N	D	1978 J	F	M	A	M	J	J	A	S	O	N	D
NEGOA collections and necropsies (SURVEYOR)	▲														
NGOA/PWS collections and necropsies (RESOLUTION)		▲													
C. St. Elias sea lion study (charter)							▲								
LCI-KODIAK collections and necropsies (SURVEYOR-IV)							▲								
Bering Sea collection and necropsy (SURVEYOR-V)								▲							
Bering Sea collection and necropsy (SURVEYOR-VI)									▲						
Bristol Bay stranding survey (UH1H)								▲							
Cook Inlet interview survey of strandings									▲						
Tugidak Island stranding survey									▲						
GOA collections and necropsy (SURVEYOR-VII)										▲					
Bristol Bay stranding survey (charter)										▲					
Otter Island stranding survey (charter)										▲					
LCI stranding survey (SURVEYOR/helo)											▲				
Beaufort Sea collection and necropsy (USC Northwind)											▲				
Kodiak collection and necropsy (SURVEYOR)												▲			

△ Planned completion date ▲ Actual completion date

QUARTERLY REPORT

Contract #03-5-002-69
Research Unit #229
Reporting Period 1 July
thru 30 September 1978

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

Field activities dominated much of the fourth quarter. Two cruises aboard the NOAA ship Surveyor and one cruise aboard the A.D.F.&G. vessel Pandalus resulted in the collection of 88 harbor seals (Table 1).

A total of 21 aerial radio tracking surveys were flown to collect data on the movements of individual harbor seals (Table 2). During these surveys, 12 animals were located at hauling areas other than those at which they had been captured.

Field camps were manned at three locations in the Gulf of Alaska for at least a portion of the quarter. Trend count areas were established at hauling areas in each of the three lease areas; Kodiak - Tugidak Island, LCI - Elizabeth Island and NEGOA - Channel Island. A series of counts of seals using these hauling areas was obtained during the molting period.

Laboratory activities were confined to processing female reproductive tracts. Ovarian sections and uterine sections were examined for evidence of reproductive activity from 28 seals.

Table 1. Numbers, dates and general locations of collected harbor seals, June-September 1978.

Area	Date	Numbers of Seals
Montague Is.	20 June	1
Nuka Bay	21 June	6
Kamishak Bay	22-23 June	19
Puale Bay	24 June	5
Shumigan Is.	26 June	5
Sanak Is.	27-28 June	11
Southern Kodiak	1-2 July	7
Northern Kodiak	29-30 July	7
Kodiak	27 Aug. - 9 Sept.	24
Puale Bay	2 Sept.	3
TOTAL		88

Table 2. Harbor seal radio tracking surveys, June-September 1978.

Area	Date	Results
N.E. Kodiak	19 June	One located
E. Alaska Pen.	24 June	Negative
Semidi Is.	29 June	Negative
Chirikof Is.	30 June	One located
S. Kodiak, Trinity Is.	1 July	Two located
S. Kodiak	2 July	One located
N.E. Kodiak	3 July	Negative
E. Kodiak	24 July	Two located
N. Kodiak	26 July	Negative
E. Kodiak	27 July	Negative
Ugak Is.	29 July	Negative
N.E. Kodiak	26 Aug.	Negative
S.E. Kodiak	27 Aug.	Negative
S.W. Kodiak	28 Aug.	Two located
W. Kodiak	1 Sept.	Negative
E. Alaska Pen.	2 Sept.	Negative
N. Kodiak	4 Sept.	Negative
N.E. Kodiak	6 Sept.	One located
Semidi Is.	8 Sept.	Negative
Chirikof Is.	8 Sept.	Negative
S. Kodiak, Trinity Is.	9 Sept.	Two located

Quarterly Report

Contract #03-5-022-53
Research Unit #230
Reporting Period: 1 July-30 September 1978
Number of Pages:

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

Principal Investigators:

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

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

30 September 1978

I. Task Objectives

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

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

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

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

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

6. Acquisition of additional information on seasonal migrations.

II. Field and Laboratory Activities

Effort this quarter was devoted primarily to laboratory processing of specimen material collected during the spring field season. Male reproductive tracts were analyzed. Claws and teeth were processed to determine seal ages.

Field work consisted of a village collection at Wainwright in which specimens from 6 bearded seals and 33 ringed seals were obtained. Project personnel participated in a Beaufort Sea icebreaker cruise aboard the USCGC NORTHWIND during which three ringed seals were collected. In addition, a person was sent to Point Lay in early August to investigate a report of a large number of belukhas in the nearby lagoon.

Data management occupied a substantial amount of time. Newly processed specimen data were coded, keypunched and prepared for submission to NODC. In mid-September we obtained a data microprocessor and began work on software for data entry and analysis.

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

Table 1. Field and laboratory activities, 1 July-30 September 1978.

Activity	Dates	Personnel
Specimen collections:		
Wainwright	1-12 August	D. Strickland
Beaufort Sea-NORTHWIND	15-22 August	K. Frost
Point Lay belukha observation	1-5 August	G. Seaman
Planning meeting for Beaufort Sea winter studies	31 July-1 August	K. Frost, J. Burns
Laboratory processing of specimen material	continuous	J. Burns, P. Field, R. Lynn, D. Strickland, R. Tremaine, G. Seaman
Data management	intermittent	K. Frost
Data microprocessor hookup, data analysis		L. Lowry, L. Miller

Methods

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

Data Collected

Table 2 summarizes the results of collection efforts during this quarter, as well as those of spring quarter collections not previously reported.

Table 2. Seal specimens obtained during the period 1 July-30 September 1978.

Location	*Phoca (Pusa) hispida*	*Erignathus barbatus*
Gambell	9	48
Savoonga	33	44
Diomede	25	10
Wales	34	29
Elephant Point	3	-
Wainwright	33	6
NORTHWIND	3	-

III. and IV. Results and Preliminary Interpretation

A detailed presentation and discussion of results was provided in our 1978 Annual Report. Further results and discussion of data will be presented upon completion of additional laboratory work and data analysis.

V. Problems Encountered/Recommended Changes

None.

VI. Estimate of Funds Expended

As of 31 August we have expended the following amounts during FY 78:

Salaries and benefits	$ 78,200
Travel and per diem	13,900
Contractual services	9,000
Commodities	3,600
Equipment	9,100
Total Expenditures	$113,800

Quarterly Report

Contract #03-5-022-53
Research Unit #232
Report Period: 1 July-30 September 1978
Number of Pages:

Trophic Relationships Among Ice Inhabiting Phocid Seals

Principal Investigators:

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

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

30 September 1978

I. Task Objectives

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

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

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

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

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

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

II. Field and Laboratory Activities

During this quarter extensive effort was directed to laboratory processing of specimen material. All seal stomachs obtained during the spring/summer field season were processed. These included collections from Shishmaref, Gambell, Savoonga, Diomede, Nome, Wales, Point Hope and

Wainwright, and totaled about 264 stomachs with food. Processing of specimen material from belukha whales was begun.

Limited field work was undertaken. A village collection was made at Wainwright in August. Project personnel participated in the Beaufort Sea NORTHWIND cruise.

Data management occurred on a continuous basis. All data generated by extensive lab work were coded, catalogued and submitted for keypunching. Additional 1976 and 1977 data were submitted to Michael Crane at AEIDC for submission to NODC. In mid-September the long awaited data microprocessor arrived. Extensive time is currently being devoted to getting this system operational and to writing software for data entry and analysis.

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

Table 1. Field and laboratory activities, 1 July-30 September 1978.

Activity	Dates	Personnel
Specimen collections:		
Wainwright	1-12 August	D. Strickland
Beaufort Sea-NORTHWIND cruise	15-22 August	K. Frost
Beaufort Sea winter work planning meeting	31 July-1 August	K. Frost, J. Burns
Data management	continuous	K. Frost
Data microprocessor hookup/ software preparation	15-30 September	L. Lowry, L. Miller
Laboratory processing of specimen material	continuous	L. Lowry, K. Frost, R. Tremaine, D. Strickland, G. Seaman

Methods

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

Data Collected or Analyzed

Table 2 summarizes the numbers of stomachs analyzed since 1 July 1978. Only stomachs containing food are tabulated.

Table 2. Seal stomachs analyzed during the period 1 July-30 September 1978. Only stomachs containing food are shown.

Location	Phoca hispida	Phoca largha	Erignathus barbatus
Southeastern Bering Sea			
Hooper Bay	3	2	2
Northern Bering Sea			
Gambell	6	5	39
Savoonga	3	7	14
Wales	20	8	12
Diomede	3	-	2
Chukchi Sea			
Shishmaref	57	10	16
Wainwright	42	2	5
Elephant Point	3	-	-
Beaufort Sea			
NORTHWIND	3		
Total	140	34	90

III. and IV. Results and Discussion

A detailed presentation and discussion of results was provided in the 1978 Annual Report. Further results and discussion of results will be presented in the 1979 Annual Report.

V. Problems Encountered/Recommended Changes

None.

VI. Estimate of Funds Expended

As of 31 August we have expended the following amounts during FY 78:

Salaries and benefits	$82,000
Travel and per diem	6,600
Contractual services	12,100
Commodities	5,900
Equipment	400
Total Expenditures	$107,000

QUARTERLY REPORT

Contract #03-5-022-69
Research Unit #243
Reporting Period-July 1 - Sept. 30
Number of Pages - 7

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

October 25, 1978

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. Field Activities

1. Cruise aboard ADF&G vessel "Pandalus"

a. July 26 through August 2

2. Cruise aboard NOAA vessel "Surveyor"

b. August 25 through September 10

B. Scientific Parties

1. July 26 through August 2

   a. Donald Calkins A.D.F.&G.

      Principal Investigator

   b. Kenneth Pitcher, A.D.F.&G.

      Co-principal Investigator

   c. Paul Smith, A.D.F.&G.

      Collector

2. August 25 through September 10

   a. Donald Calkins A.D.F.&G.

      Principal Investigator

   b. Kenneth Pitcher, A.D.F.&.G.

      Principal Investigator

   c. Karl Schneider, A.D.F.&G.

      Observer and collecting crew

   d. Dennis McAllister, A.D.F.&G.

      Collecting crew

   e. Paul Smith, A.D.F.&G.

      Collecting crew, OCS observer

   f. Larry Schults, University of Alaska

      Parsitology and pathology

C. Methods

1. See annual report

D. Sample localities

1. July 26 through August 2

   a. Kodiak

2. August 25 through September 10

a. Southern Kodiak

b. Chirikof I.

c. Semidi Is.

d. Puale Bay

e. Afognak I.

f. Marmot I.

g. Two Headed I.

III. Results

A. A total of 15 sealions were collected on the two cruises.

B. Branded Sea Lion Sightings

A summary of sightings of branded sea lions is presented in Table 1. Animals were marked with an X on Sugarloaf Island. Left shoulder brands were used in 1975 and right shoulder brands in 1976. For Marmot Island, a left shoulder O was used in 1975 and a right shoulder T in 1976.

Table 1. Branded sea lions sighted during SURVEYOR cruise RP-4-SU-78B, Leg II, August 25 - September 10, 1978.

Location	Brand	Number Sighted
Chirikof I.	X Left	1
	O Right	1
Sugarloaf I.	Unident. Left	8
	Unident. Right	2
	X Right	6
	X Left	1
	X Right	1

Latax Rocks	X Right	4
	Unident. Right	1
	Unident. Left	4
	T Right	4
	X Left	1
Marmot I.	T Right	16
	O Left	2
	Unident. Right	5
	X Left	1
	X Right	6
Chowiet I.	X Right	1

C. Sea Otter Survey - Trinity Islands

Approximately 10,000 km^2 of potential sea otter habitat lies around the southwestern end of Kodiak Island, the Trinity Islands and Chirikof Island. Portions of the area are within proposed oil and gas lease tracts. A small number of sea otters has been known to exist in this area since the 1950's. It is believed that their numbers have been increasing since then, but the distribution and size of the population remained unknown.

This survey was designed to delineate the distribution of the population and to establish at least the order of magnitude of abundance.

Sea otters had been sighted regularly around Chirikof Island and around the Trinity Islands, particularly south of Tugidak Island. The Chirikof Island area had been surveyed on Leg VII of Cruise RP-4-SU-78A. Attempts to survey the area around the Trinity Islands on that same cruise were thwarted by unsatisfactory weather conditions.

The Trinity Island survey was accomplished on 26 August 1978. North-south tracklines spaced 5 minutes of longitude apart were flown with the Bell 206 at an altitude of 200 feet. All sea otters sighted within 0.1 nautical miles of either side of the helicopter were counted. A total of 264 nautical miles of trackline were flown providing a sample of 52.82 square nautical miles. This was about 7.14 percent of the area sampled.

A total of 13 sea otters were seen inside the transects. If expanded to the entire area sampled, this yields an estimate of 182 sea otters. There are probably two to three times this number since survey conditions were marginal, a significant portion of the population is under water at any given moment and not all potential sea otter habitat was sampled. While the data are not adequate to make a precise population estimate it appears that several hundred sea otters occupy the area and that densities are still quite low. Table 2 illustrates the location of sea otter sightings.

Table 2. Locations of sea otters sighted on 8/26/78 systematic strip transect survey of Trinity Islands.

Group Size	GNS Position Latitude	GNS Position Longitude	Corrected Position* Latitude	Corrected Position* Longitude	Distance From Shore	Approx. Depth
1	56°30.8'	153°59.3'	56°30.3'	154°01.3'	50 yd	<5 fm
1	56°27.5'	154°00.0'	56°27.0'	154°02.0'	2.8 nm	20 fm
1	56°26.6'	154°10.0'	56°26.1'	154°12.0'	3.5 nm	20 fm
2	56°24.9'	154°29.7'	56°24.4'	154°31.7'	5.3 nm	15 fm
1	56°25.9'	154°29.6'	56°25.4'	154°31.6	4.2 nm	12 fm
1	56°28.4'	154°35.0'	56°27.9'	154°37.0'	0.5 nm	<5 fm
♀w/pup	56°23.9'	154°40.1'	56°23.4'	154°42.1'	1.0 nm	<10 fm
1	56°23.0'	154°40.0'	56°22.5'	154°42.0'	1.6 nm	<10 fm
1	56°23.8'	154°49.2'	56°23.3'	154°51.2'	2.7 nm	10 fm
1	56°23.8'	154°49.2'	56°23.3'	154°51.2'	2.7 nm	10 fm
♀w/pup	56°23.8'	154°50.3'	56°23.3'	154°52.3'	3.2 nm	10 fm
1	56°19.9'	154°54.8'	56°19.4'	154°56.8'	7.5 nm	12 fm
1	56°21.0'	154°54.8'	56°20.5'	154°56.8'	6.9 nm	12 fm

* Positions corrected on basis of GNS reading at known landmarks.
Correction Factors: Latitude = -0.5' Longitude = +2.0'

IV. Preliminary interpretation of results

A. Sea otter survey

The survey verified previous impressions of the distribution of the population. The majority of sea otters inhabit shallow waters south of the Trinity Islands with the greatest concentration south of Tugidak Island. None were seen north of the Trinity Islands on the survey but very small numbers have been seen there on previous occasions.

The survey fulfilled its objectives even though conditions were not good. It demonstrated that the population is well established but remains well below its potential size. The limited distribution and small size of the population make it highly vulnerable to oil spills.

B. Branded and collected sea lions--no preliminary interpretation available at this time.

V. Problems encountered

A. None

VI. Estimate of funds expended:

A. Funds expended during this quarter:

1.	Salaries and benefits	$32,000
2.	Collecting trips & surveys	12,000
3.	Commodities (lab supplies, photo supplies, etc.)	2,000
4.	Travel and per diem	4,000

Quarterly Report

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

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

Principal Investigators:

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

Assisted by: Brenden Kelley and Kathryn J. Frost

31 October 1978

I. Task Objectives

The specific project objectives are:

1) To determine the extent and distribution of regularly occurring, ice-dominated marine mammal habitats in the Bering, Chukchi and Beaufort Seas;
2) To describe and delineate those habitats;
3) To determine the physical environmental factors that produce those habitats;
4) To determine the distribution and densities of the various marine mammal species in the different ice habitats; and
5) To determine how the dynamic changes in quality, quantity and distribution of sea ice relate to major biological events in the lives of marine mammals (e.g. birth, nurture of young, mating, molt and migrations).

II. Field and Laboratory Activities

Field activities for this project ended in August. Kathryn Frost, in conjunction with her work on project RU 232, participated in the August cruise of the icebreaker NORTHWIND in the Beaufort Sea. She recorded information on the abundance of marine mammals in relation to different ice types and obtained data required for verification of NOAA satellite imagery.

Starting in September, Mr. Brenden Kelley began the tasks of analyzing all available NOAA satellite imagery which show the extent and characteristics of ice in selected areas of the Bering, Chukchi and Beaufort Seas. As an initial step in this process, imagery for the years 1974-1976 were reanalyzed to determine the applicability of previous findings to this study.

In the previous study, 20 widely scattered stations including all proposed OCS lease sites north of the Alaska Peninsula were selected. Imagery showing ice at each station was examined. Two kinds of information were coded: 1) quality of the images on a scale of 1-4, and 2) the characteristics of ice on a scale of 1-15. This scale was used to record characteristics ranging from open water to solid, landfast ice.

This effort was made to determine the accuracy and applicability of the existing data base for purposes of our project. Imagery for 1977 and 1978, not previously analyzed, will be examined in a similar manner. Additional information including extent of ice cover and movements (as determined from sequential images) are recorded.

Statistical programs to analyze these data are currently being developed. These will provide a summary of the frequency of specific ice conditions at each station, over a period of time. Another program will allow us to analyze changes in ice conditions at the 20 stations for purposes of correlating the occurrence of changes between and among the stations, and with changes in prevailing seasonal winds (expressed as vector mean winds).

III. Results

None are available for reporting at this time.

IV. Problems Encountered.

None

V. Estimate of funds expended during this quarter

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

RECEPTORS (BIOTA)

Marine Birds

Contents

QUARTERLY REPORT

Contract #03-5-022-69
Research Unit #3
Reporting Period - July 1, 1978
September 30, 1978

Pages 5

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

Paul D. Arneson

Alaska Department of Fish and Game

30 September 1978

I. Task Objectives - Kamishak Bay

A. To determine species composition and abundance of marine birds on colonies.

B. To determine as many aspects as possible of the breeding biology of marine birds on the colonies.

C. To determine whenever possible the food habits of nesting marine birds and their young.

D. To determine changes in abundance of breeding populations of marine birds on colonies visited in 1976.

E. To make other incidental observations of habitat use, forage areas, migration areas and abundance of non-colonial marine birds.

II. Field Activities

A. Field Trip Schedule: During July and August 1978, an Avon rubber raft was used to conduct pelagic and shoreline bird surveys in Kamishak Bay.

B. Scientific Party: Observers for the surveys were Paul Arneson and James Butcher, Alaska Department of Fish and Game, Anchorage, Alaska.

C. Methods: The coastline of Kamishak Bay was surveyed from a distance of 50 to 150 meters in a rubber raft. Bird observations were recorded along the route, and whenever a breeding colony was located, attempts were made to count all nests and active burrows when access to a colony was possible. Breeding biology information was recorded whenever possible. Pelagic transects were conducted to determine bird distribution and abundance in nearshore waters. Some birds were collected to determine food habits of summering birds in Kamishak. Type III sea watches were conducted in the Cottonwood/Iliamna Bay area and beached bird surveys were conducted on three beaches.

D. Sample localities: See Figure 1.

E. Data Collected: The total trackline for shoreline surveys included 364 km of beach, and 255 km of pelagic transects were conducted. Thirty-six colonies were documented and 26 sea watches were conducted. Five beached bird surveys were completed.

III. Results and Preliminary Interpretation

Data from summer bird surveys has been sent to the keypuncher, but as yet no analysis has been attempted. That information will be included in the final report scheduled for completion in FY79. Only general observations will be given in this report.

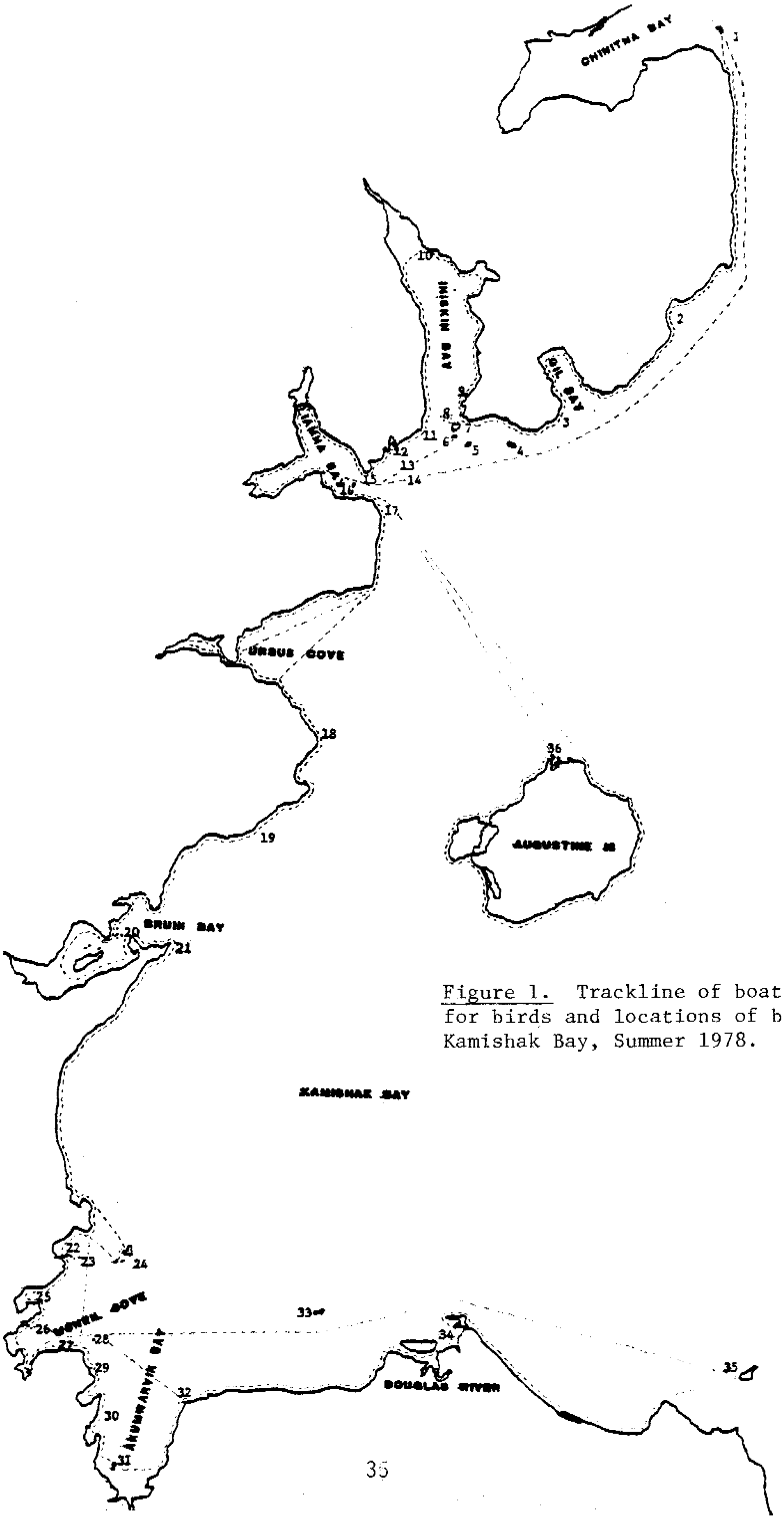

Figure 1. Trackline of boat surveys for birds and locations of bird colonies, Kamishak Bay, Summer 1978.

Seabirds were not abundant anywhere in Kamishak Bay. Glaucous-winged Gulls and Tufted Puffin comprised the bulk of the seabird population (Table 1). Only two breeding Common Murre colonies were found and Black-legged Kittiwakes did not nest in Kamishak Bay in 1978.

Seaducks comprised the largest percentage of avian biomass summering in Kamishak Bay, and the most abundant species were Surf and White-winged Scoters. A flock of 3800 scoters was sighted near Pomeroy Island in late June, and flocks of several hundred or more were seen in shallow water of bays throughout the summer. These birds appeared to be feeding largely on small clams and mussels on intertidal or shallow subtidal areas.

Glaucous-winged Gulls also frequently fed on intertidal mudflats and were found breeding throughout Kamishak. Other gull species were only locally abundant. Feeding flocks of Black-legged Kittiwakes were found in the Chinitna Point vicinity and in McNeil Cove. Elsewhere they were uncommon. Several hundreds of non-breeding Mew Gulls roosted on intertidal areas near the mouth of the Douglas River and "Kamishak" Islands but were not found in abundance anywhere else.

Tufted Puffins frequently rafted near colony sites but were seldom observed in bays or along exposed coastline on nearhsore waters. They apparently flew out into the inlet for feeding. Horned Puffins, however, frequently were found in bays and in nearshore waters both roosting and feeding. They were found in abundance only at Burr Point on Augustine Island.

All colonies visited in 1976 were revisited in 1978, and several marked differences were noted in species composition and abundance. For example, in 1976 on Iniskin Island four Double-crested and 26 Pelagic Cormorant nests were found. This year we found 49 Double-crested nests and only one Pelagic nest. On a cliff near Rocky Cove in 1976 we recorded 21 Double-crested, 42 Pelagic and 15 Red-faced Cormorant nests. This year there were 13, 24 and 0, respectively. On some cliffs where cormorants nested in 1976 there were none in 1978.

Several changes were also noted in Glaucous-winged Gull breeding populations. Nests increased from 92 to 196 and decreased from 82 to 35 between 1976 and 1978 on Vert and Daisy Islands, respectively. Other colonies contained almost identical numbers of breeding gulls. Little change was noted in Tufted Puffin populations, and the most notable additional information was the discovery of an estimated 500 Common Murres at Contact Point which were not noted in 1976 and the disappearance of 750 Black-legged Kittiwakes in Amakdedulia Cove which were replaced in 1978 by 122 Double-crested Cormorant nests.

The only species for which production data was obtainable in 1978 was for Glaucous-winged Gulls, and production was low in all areas. Several storms during the peak of hatching in late June and early

Table 1. Estimated seabird populations on colonies in Kamishak Bay, Summer 1978.

Colony	DCCo	PeCo	RFCo	BlOy	GWGu	CoMu	PiGu	HoPu	TuPu	Total
Gull Is.				4	600		20	80	750	1454
Dry Bay					30					30
Oil Reef	15	25			15		10	6	15	86
Pomeroy Is.				6	140		12	10	500	668
Iniskin Is.	100	15		4	900	2	8	8	1000	2037
Vert Is.				2	500		4		125	631
Scott Is.				4			15	15		34
Mushroom Islets				4	75				90	169
Toadstools									50	50
"Twin Rocks"					125					125
Entrance Rock				6	20					26
Knoll Head	35	100		2	12		10	10	6	175
Daisy Is.				2	70					72
Knoll Head Lagoon				6	150		6	40	15	217
North Head		30		6	20		10	15		81
White Gull Is.		8		4	350		4	12	300	678
South Head	25	10			5		15	30		85
Rocky Cove vicinity	35	75			25		15	50	6	206
Fortification Bluff					125		12			137
Bruin Bay Islands				20	300		40	75	25	460
Contact Point	250	200	60		200	500	24	12	6	1252
Amakdedulia Cove	300						6			306
Amakdedulia Islands				4	125					129
Nordyke Islands				8	500				600	1108
Akjemguiga Cove					80		4			84
North McNeil Cove					80					80
McNeil Cove	110				75		41	9		235
McNeil Islet						2000				2000
"Mushroom Rock"	35				80				6	121
Pinkidulia Peninsula	10				75					85
Akumwarvik Bay					30		2			32
"Akumwarvik Head"					100		15			115
"Kamishak Islands"					300		14		200	514
Douglas River-Islands	100				200	1	4	4		309
Shaw Is.				28	500		10	50	1500	2088
Burr Pt.-Augustine Is.				10	100		15	425	375	925
TOTAL	1015	463	60	120	5907	2503	316	851	5569	

July may have contributed substantially to the loss. The southern part of Kamishak Bay seemed to experience poorer production than northern portions. On Nordyke Island 319 adults were counted but only six nests containg eggs and three chicks were found. Nearly 500 adult gulls were counted on Shaw Island, but only one chick and two nests with one egg each were found. Scrapes were relatively abundant on both islands, but few eggs were being laid and fewer chicks being hatched.

Another source of loss in gull production in some areas was brown bear predation. A total loss occurred on several small islands in Bruin Bay, and a brown bear visited White Gull Island in both 1976 and 1978. This summer, besides destroying all accessible Glaucous-winged Gull nests and chicks, it dug up 80 percent of the Tufted Puffin burrows leaving only those that were inaccessible.

Few birds were found on beached bird surveys although evidence of the February wreck of Common Murres was found in most areas. Dead murres were still found in the upper drift line and were frequently found on promontories where they had been carried by scavengers. One was found 260 meters up Augustine volcano.

Surprising to me was the lack of certain bird species in Kamishak Bay. For example, we sighted no terns during the entire field season. While we were in southern Kamishak an injured Aleutain Tern did wash ashore at Cottonwood Bay accompanied by two flying adults, but we found no other evidence of terns in those waters. Only one Sooty Shearwater was sighted during the summer and small numbers of Fork-tailed Storm-Petrels were reported for Cottonwood Bay during a severe storm.

In summary, the greatest use of Kamishak Bay in summer is by non-breeding and molting scoters. Seabird colonies are relatively small with little species diversity. Bird densities, in general, appeared to be lower than many other areas in Alaskan waters.

V. Problems Encountered

No major problems were encountered in this report period.

VI. Estimate of Funds Expended

Salaries	$12,640
Travel/per diem	270
Contractual Services	1,290
Commodities	110
Equipment	-0-
Total	$14,310

14th Quarterly Report

Contract No. 03-5-022-72
Research Unit 083
Reporting Period 1 July 1978 - 30 September 1978

Reproductive Ecology of Pribilof Island Seabirds

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Irvine, California 92717

1 October 1978

I ABSTRACT

During the 14th quarter, our major activity has been the field work on St. Paul and St. George Islands, and participation in several cruises in the vicinity of the Pribilof Islands. In the studies of reproductive biology, our most important finding was the documentation of reproductive failure in the Red-legged Kittiwake, particularly on St. Paul, while finding other species, including the Black-legged Kittiwake to be enjoying "normal" or near normal levels of success. Shipboard cruises filled data gaps, but led to no unexpected results during July and August. The results of food sampling have yet to be analyzed.

II TASK OBJECTIVES

1) Conduct studies of phenology, reproductive success, growth rates and food habits of seabirds nesting on St. Paul and St. George Islands.

2) Participate in two cruises on the Discoverer, in August and late September.

3) Participate in PROBES cruises in July.

In addition, we took advantage of the opportunity to cooperate with Dr. Barney Easterday in his study of the incidence of avian influenza, *Salmonella* and *Pasturella* in St. Paul Island seabird populations.

III RESEARCH ACTIVITIES

A. Field Studies

1) On St. George Island, Squibb was present from early May until late September. He was joined by Pitts for the period of heaviest work load from mid June - late August.

2) On St. Paul Island, Rodstrom was present from early May through late September, as was Naughton except when away participating in cruises. Braun was present mid June - mid September, Hunt late June - late August and Roelke early July - late August.

3) Participation by Naughton on PROBES cruises occurred during the first half of July.

4) The Discoverer was staffed by Naughton and Hunt during August and by Rodstrom, Naughton and Squibb in September. Glenn Ford of Dr. John Weins' group aided on the August Cruise.

Laboratory

1) Over the summer Burgeson worked on food samples from previous years, updating indentifications.

2) Data Management tasks were performed by Bush, including coding of cruise results and cleaning up past data submissions as error checks were performed.

B. Scientific Party

George L. Hunt, Jr.	Associate Professor, U.C.I., P.I.
Barbara Braun	Graduate Student, Research Assistant, U.C.I., St. Paul colony work, field data management.
Barbara Burgeson	Administrative Assistant I, U.C.I., administrative chores, food sample work-up.
Grace Bush	Coder, U.C.I., data management.
Maura Naughton	Laboratory Assistant II, U.C.I., in charge of at-sea surveys, help with St. Paul colony work.
Mary Pitts	Laboratory Assistant I, U.C.I., Graduate student, U. Wisconsin; help in colony work, St. George island.
William Rodstrom	Laboratory Assistant II, U.C.I., in charge colony work, St. Paul Island; help with at-sea surveys.
Melody Roelke	Laboratory Assistant I, U.C.I., Veterinary student, Washington State University, Pullman; aid with colony work, St. Paul; cost-shared help with Easterday avian disease study.
Ron Squibb	Laboratory Assistant II, U.C.I., in charge colony work , St. George Island; and help on at-sea surveys.

C. Methods

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

D. Sample Locations/Tracklines

Field work was conducted on St. Paul and St. George Islands in the Bering Sea (St. George Basin lease area).

Approximate tracklines for the August cruise on the Discoverer is appended. Tracklines are not yet available for the PROBES cruises or for the September Discoverer cruise.

E. Data Collected

1) At-Sea Surveys:

PROBES Legs II - V - approximately	800 segments
Discoverer - August	292 segments
	99 XBT
	18 CTD
	26 IKMT
Discoverer - September	306 segments
	124 XBT
	22 CTD
	54 Nutrients
	11 IKMT

2) Food Samples Collected -

St. George - 158

St. Paul - not yet complete - estimate 150, species not yet available.

3) Reproductive Ecology and Growth Rates -

The final sample sizes from the islands are not yet available.

F. Data Analysed -

Little data analysis was conducted during this quarter.

IV,V RESULTS AND PRELIMINARY INTERPRETATION

Although we have yet to begin analysis of our 1978 data, limited results are available.

1) The most noteworthy of our 1978 findings is the apparent near complete failure of Red-legged Kittiwake reproduction on St. Paul and, to a lesser extent, on St. George Islands. Since the Black-legged kittiwake did not show an equivalent reproductive failure, it is reasonable to rule out weather as the prime cause. A drop in the availability of Myctophid fish is more likely the answer. Red-legs specialize on these fish, while Black-legs and other species of Pribilof Island seabirds rarely take Myctophids.

2) During the IKMT tows we found Myctophids near the surface at night at and beyond the continental slope, but not over shelf waters. This distribution fits well with our knowledge of where Red-legged kittiwakes forage. Additionally Amphipods of the genus Parathemisto seemed most abundant in areas known in the past, and found in August, to be important murre foraging areas. Parathemisto are important in the diets of Murres.

3) In August, a modest number of murres with chicks were seen at sea. Most of these were seen in known or suspected prime foraging areas.

4) The XBT and CTD casts revealed the presence of fronts around the islands, with a single-layer system in shallow water and a two-layer system in deeper water. The relationship between bird distributions and these fronts will require further analysis.

5) Preliminary screening for Salmonella and Pasturella revealed no certain positive cultures. Final analysis for bacterial infection or viral infections will be done in Dr. B. Easterday's laboratory at the University of Wisconsin. This work with Dr. Easterday was in large part supported by an N.S.F. grant to Dr. Easterday.

6) With the aid of Dr. Glenn Ford and Dennis Heineman of Dr. John Weins' group, we obtained data for trade-off times (length of absence from the nest) of Thick-billed murres. They also obtained data on flight speeds. Their data will all be used in their modeling efforts.

7) With the exception of the Red-legged Kittiwakes, 1978 looked, in general, very similar to other years. But, in 1978, several Black-legged Kittiwakes on St. Paul managed to raise two young. Until final data are available on reproductive success and growth rates, it would be premature to conjecture whether this was a particularly good year for Black-legged Kittiwakes.

VI AUXILIARY MATERIAL

None.

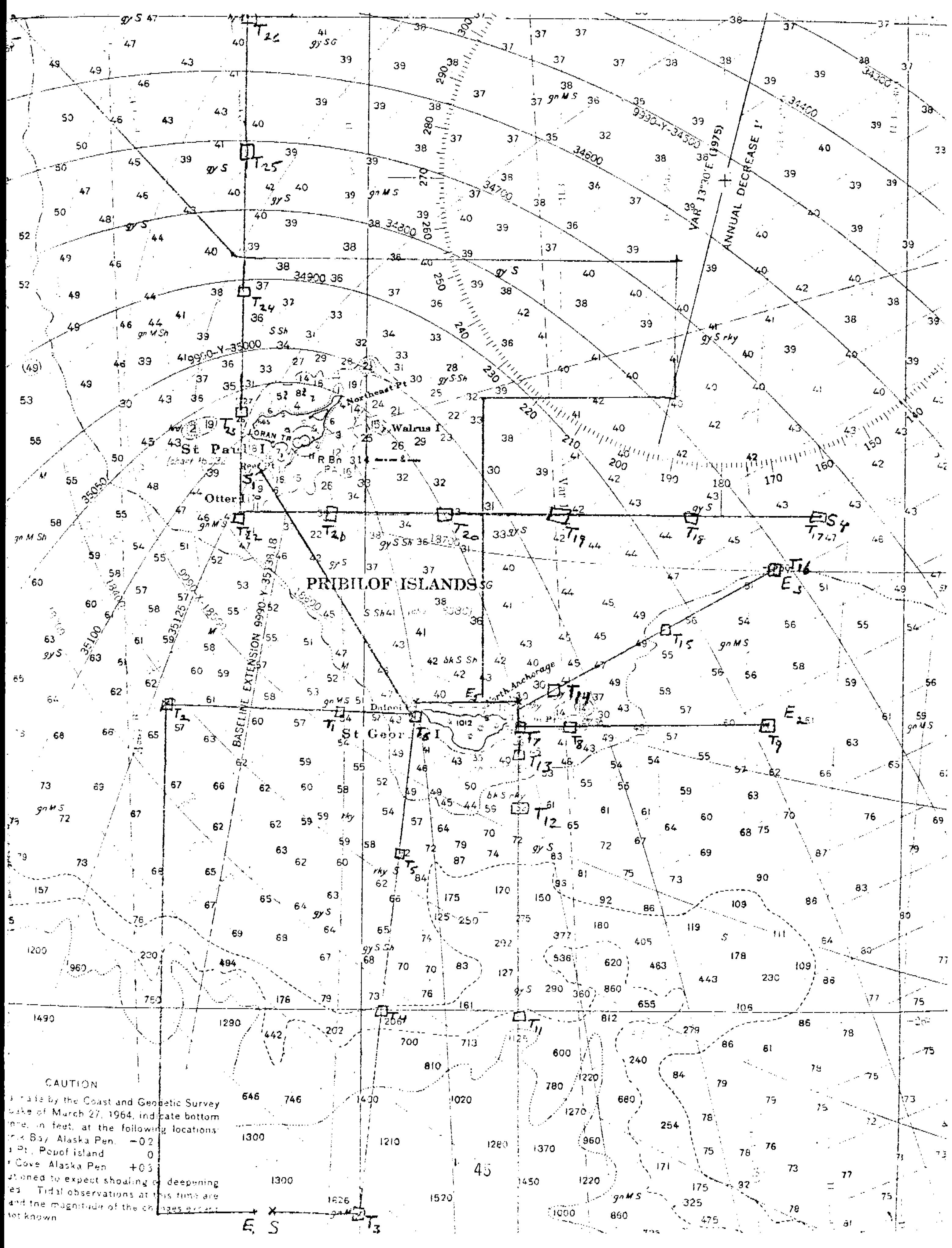
VII PROBLEMS ENCOUNTERED

No serious problems were encountered.

VIII ESTIMATE OF FUNDS EXPENDED (Direct Costs)

	Total Appropriated 1975 - 1978	Total Expended 1975 - 31 Aug 78	Balance as of 31 August 1978
Salaries	109,714	104,985	4,729
Employee Benefits	16,028	13,057	2,971
Supplies	20,499	19,953	546
Equipment	16,147	8,790	7,357
Travel	37,966	28,537	9,429
Other	7,538	3,068	4,470
Total	207,892	178,390	29,502

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


PRIBILOF ISLANDS
St Paul I
St Geor I
Walrus I
Northeast Pt
Otter I
North Anchorage
LORAN TR
R Bn 314
BASELINE EXTENSION 9990-Y-35138.18
9990-Y-34500
9990-Y-35000
9990-X-18200
VAR 13°30'E (1975)
ANNUAL DECREASE 1'
CAUTION
by the Coast and Geodetic Survey
quake of March 27, 1964, indicate bottom
in feet, at the following locations:
Bay, Alaska Pen. −0.2
Pt., Popof island 0
Cove, Alaska Pen. +0.3
cautioned to expect shoaling or deepening
Tidal observations at this time are
and the magnitude of the changes exact
not known
E S
T3

QUARTERLY REPORT

Contract No. 03-5-022-68

Research Unit No. 108

Reporting Period: 1 July-30 September 1978

SIMULATION MODELING OF MARINE BIRD POPULATION ENERGETICS, FOOD CONSUMPTION, AND SENSITIVITY TO PERTURBATION

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Glenn Ford

Dennis Heinemann

Carol Fieber

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Submitted 15 October 1978

INTRODUCTION

In order to model the role of the seabird community of the Pribilof Islands in the Bering Sea ecosystem, we must first be able to describe the temporal and spatial distribution of its energetic requirements. The knowledge of how much energy is extracted from a given area at a given time is basic to an assessment of the impact of the seabirds on their environment. It is also the information that must be used to predict what effects a perturbation of that environment will have on the population dynamics of the seabird community. Our research has thus proceeded in three steps: (1) determination of the spatial distribution of energetic demands, (2) determination of the temporal distribution of energetic demands, and (3) prediction of perturbation effects on the seabirds and temporal and spatial allocation of their energetic requirements. Our first report (March, 1978) dealt with the spatial partitioning of energetic demands based on transect data collected by George Hunt and his colleagues. This report will deal primarily with the temporal partitioning of energetic requirements based on colony data from St. Paul and St. George Islands, also collected by George Hunt.

METHODS

Our basic tool for estimating time-energy demands was a computer model of avian community energetic requirements, BIRD II, developed by John Wiens and George Innis. This model requires as input a large number of species- and population-specific variables in order to perform a detailed simulation of the changing energy demands of each species through the course of an annual cycle. The internal structure and assumptions on which this model is based may be found in Innis et al. (1974), Innis and Wiens (1977), and Wiens and Innis (1973). Because the input variables are specific to a given population, whenever possible we estimated them from data collected on the Pribilof Islands, resorting to literature values only when these data were insufficient. Although many of the variables vary between year and island, the data base was not extensive enough to permit partitioning by either year or island. Average values were calculated for all variables for which data from more than one year-island were available. Since most of our input values were calculated from raw data, we will give a brief description of the method used in the calculation of each general category of variable. Computer mnemonics are given in parentheses for all variables referred to in the text for comparison with Table 1.

Phenological parameters

Values were specified that describe the onset and end of immigration and the onset and end of emigration of adults (TS, TI, TD, and TJ), and the initiation and termination of egg laying (DOI, DCI). The timings of immigration and departure were estimated using counts of the number of birds of a given species found on reference ledges and nests. Data from all reference areas for a given species, year, and island were combined to form a plot of the percent of the maximum number of birds present through time. A flat-top curve was fitted by eye to these plots and the inflection points of the curve used to describe the phenology of arrival and departure. The time of initiation of nesting was assumed to coincide with the time of the end of immigration. Initiation and termination of egg laying was taken directly from the annual reports of Hunt's group (Hunt 1976, 1977). Juveniles were assumed to depart at the same time as adults (TDJ, TEJ). The period of incubation (PI) and the length of the nestling period (PN) were calculated directly from data for marked nests and averaged for each species.

Population size parameters

Total population size estimates (PBD) were taken from the censuses of Hickey (1976). Populations of both St. Paul and St. George were combined since we are currently interested in overall community energy demands. The proportion of the population that is breeding females (PPBF) is also a necessary input; however, there were no appropriate data available to estimate this parameter. We are certain that the true value lies between 0.25 and 0.45, and chose 0.35 as our most reasonable approximation. The effect of this uncertainty on model results will be discussed later.

Body size parameters

Body weights of hatchlings, fledglings, and adults (HMW, FW, and AMW) were available for most species from Hunt's data. We resorted to literature values for Fulmars and Tufted Puffins, but no data were available for hatching and fledging weights of Crested or Least auklets. Since Crested Auklets are similar in body size and configuration to Parakeet Auklets, we assumed that their fledging and hatching weights were the same. The ratio of adult body weight to hatching and fledging weights of Parakeet Auklets were also assumed to apply to Least Auklets. In addition to body weights, it was also necessary to estimate the logistic constant of the nestling growth equation (Ricklefs 1968) for each species (AKW). Basically this entails fitting a logistic curve to the

Table 1. Input variables: abbreviations, descriptions, units, and values. Where the value of a variable is constant for all species the value is given below, otherwise it is given on the following page. Except where noted by footnote all data are from Hunt (1976,1977,1978).

Abbr.	Description	Units	Value
NSP	Number of species	Dimensionless	11
DEF	$(\text{Digestive efficiency})^{-1}$	"	1.33
TC	Lower limit to thermoneutral zone	Degrees C	0
BOTT	Min. activity elevation of metabolism	Dimensionless	.10
SPHZ	Time that BOTT is attained	Julian date	15
TTOP	Max. activity elevation of metabolism	Dimensionless	.25
TLA	Deviation from 12-hr photoperiod	Hours	see text
TSTRT	Time of start of run	Julian date	120
PS	Population size at TSTRT	Birds	0
TS	Time of first arrival	Julian date	"
TIN	Time of initiation of nesting	"	"
PBD	Population size at TIN	Birds	"
PPBF	Fraction of PBD that are breeding ♀♀	Dimensionless	see text
DOI	Time of completion of first clutch	Julian date	Variable
DCI	Time of completion of last clutch	"	"
CS	Mean clutch size	Eggs	"
PI	Length of incubation period	Days	"
HMW	Mean body weight of hatchlings	Grams	"
HS	Hatching success	Dimensionless	"
PN	Length of nesting period	Days	"
AK	Logistic growth curve constant	Dimensionless	"
FW	Mean body weight of fledglings	Grams	"
FS	Fledging success	Dimensionless	"
AMW	Mean body weight of adults	Grams	"
TD	Time of first departure	Julian date	"
TE	Time of last departure	"	"
PE	Population size at TEND	Birds	0
TEND	Time of end of run	Julian date	263

Table 1 (cont.). Input variables.

	SPECIES										
Abbr.	NF	RFC	BLK	RLK	CM	TBM	TP	HP	PA	CA	LA
TS	143	119	146	156	146	128	141	142	120	120	120
TIN	186	140	169	171	169	165	168	169	151	151	151
PBD[1]	707	75	1030	2222	2290	16100	70	324	1840	3400	2730
DOI	186	140	169	171	169	165	168	169	151	151	151
DCI	200[2]	157	185	180	183	179	190[2]	190	163	163[2]	163[2]
CS	1	3.01	1.41	1	1	1	1	1	1[3]	1	1
PI	49[4]	30	29	32	31	36	45[5]	40[5]	36[6]	31[7]	34[7]
HMW	75	41.6	48.3	46.1	86.9	82.7	61.9[8]	63.1	50.0	87[2]	15[2]
HS	.84	.46	.75	.85	.33	.66	.76[2]	.76	.76[2]	.76[2]	.76[2]
PN	50[4]	54	43	37	20	21	55[5]	40[7]	35	31[7]	30
AK	.140[4]	.206	.183	.188	.358	.355	.183[6]	.243	.327	.286	.292[7]
FW	1000[4]	1912	442	395	188	177	560[8]	394	283	283[2]	50[2]
FS	.90	.85	.63	.82	.66	.84	.68[2]	.68	.68[2]	.68[2]	.68[2]
AMW	800[4]	1844	444	383	968	1098	811	567	290	288	89
TD	257	264	238	238	231	224	264	264	212	212	205
TE	264	264	259	261	243	292	264	264	232	229	229

[1]PBD is displayed in hundreds; Hickey (1977)
[2]Estimated
[3]Springer (1977)
[4]Hatch (1977)
[5]Leschner (1977)
[6]Manual (1977)
[7]Searing (1977)
[8]Wehle (1977)

weight-time growth pattern of a nestling. Since the only data available for most of the species were in the form of average weight gain per day, we derived a method for estimating the logistic constant from average daily weight gain that gives good correspondence with literature values, providing that the assumed logistic growth form is correct.

Reproductive parameters

Estimation of population energy demands requires knowledge of the number of eggs and nestlings present through time. Specified model inputs for this purpose are clutch size, hatching success, and fledging success (CS, HS, FS). Input values were the weighted average of these parameters for all years and islands. Values for 1975 and 1976 were for the most part available in Hunt's annual reports (Hunt 1976, 1977); values for 1977 were worked up from Hunt's raw data.

Energetic varialbes

Although the existence metabolism of many species of birds has been studied under caged conditions, free-living birds have a substantially higher existence metabolism due to the costs of their greater activity. This added cost varies as a function of time of year; it is highest during the breeding season due to the demands of courtship and repoduction, and lowest during the nonbreeding season. BIRD II assumes that this cost varies as a sine curve, with its low point (BOTT) occurring on a specified date (SPHZ). Its high point (TTOP) occurs during the peak of the breeding season. The value of TTOP for passerines is generally agreed by avian physiologists to be on the order of 0.25 of the caged existence metabolisms. It is as yet unclear whether seabirds experience a higher or lower elevation of metabolism during the breeding season; plausible arguments can be made for either case. Seabirds do not engage in singing, display, or appreicable intraspecific aggression as do passerives. On the other hand, their foraging activities require long distance flights to foraging areas and return flights heavily loaded with food for nestlings. It is likely that these variables are in part compensatory and that the ture value for seabirds also lies in the neighborhood of 0.25. We therefore used 0.25 as our best estimate, but bracketed it for sensitivity analysis by making model runs using 0.15 and 0.25 as alternative values for TTOP.

Avian metabolism is also known to vary as a function of photoperiod and temperature above the thermoneutral zone. Since sea surface temperatures in the Bering Sea during the period from May to August seldom fall below 4.5^{o}C, the lower critical zone of Murres (Johnson and West 1975) (Fig. 1) we set both lower critical temperature (TC) and ambient temperatures (TEMPC) to the same values. The effect of photoperiod on avian metabolism has been considered for temperate species (Kendeigh et al 1978) but little is known of its effect on species in higher latitudes. The equations of Kendeigh (Kendeigh et all 1978) assume a linear relationship between photoperiod and metabolism that may not be valid at higher latitudes. To correct for this, we used three different values for daylength as model inputs, bracketing the true deviation from a 12 h day of 3 h (TLA) by $\pm$ 3 h for the sensitivity analyses.

An additional energetic variable, digestive efficiency (DEF), is also a model input. For a wide variety of avian species and food types, this variable is very close to 70%. Recent data on Sooty Shearwaters (Lynne Krasnow, personal communication) suggest that birds feeding on fish and squid may hav a digestive efficiency as high as 80%. We chose an intermediate value of 15% as an approximation for

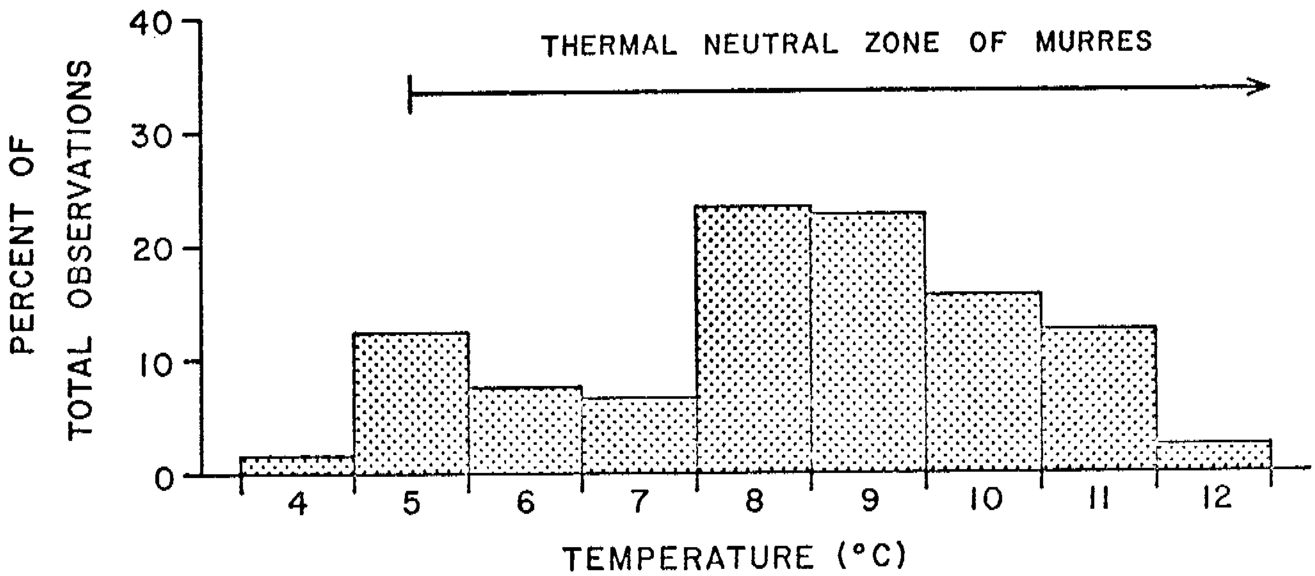

Fig. 1. Relation of recorded sea surface temperatures during May-August in the Bering Sea to the lower portion of the thermal neutral zone of murres (Johnson and West 1975).

this variable.

RESULTS AND DISCUSSION

The energetic demands of the Pribilof Island seabird community begin to increase rapidly in early May with the arrival of the murre population (Fig. 2). Thick-billed and Commom murres account for about 80% of the community energy intake during the period from May through August. Immigration of murres is completed in early June, but energy demands continue to increase due to the cost of egg production until the last week of June. Community energy demands remain at a plateau of about 7×10^8 kcal day^{-1} until late July-early August. Demand increases during this period due to the increased requirements of nestlings. With the onset of the departure of murres and auklets in early August, energy demands be begin to decline rapidly. By the end of August and the termination of the simulation, demand remains at a slightly higher level than at the beginning of the run due to the continued presence of breeding fulmars and kittiwakes.

The total community energy demand for the entire breeding season, i.e. the integral of Fig. 2, is 6.49×10^{10} kcal. Assuming an average energetic content of approximately 1.2 kcal/g wet weight of prey items (Wiens and Scott 1975), this corresponds to 53,600 metric tons of food consumed during the 4-month breeding season by all bird species. Nearly 80% of the food consumption, 42,700 metric tons (23,200 g per adult) is taken by murres alone. Of the remaining 20%, kittiwakes account for 8% and auklets 7%.

Because both murres and auklets confine their foraging activities to a region less than 40 km from their home island, these energy demands are spatially quite concentrated (Fig. 3) The most intense demands occur in the region between 10 and 20 km from St. George where birds

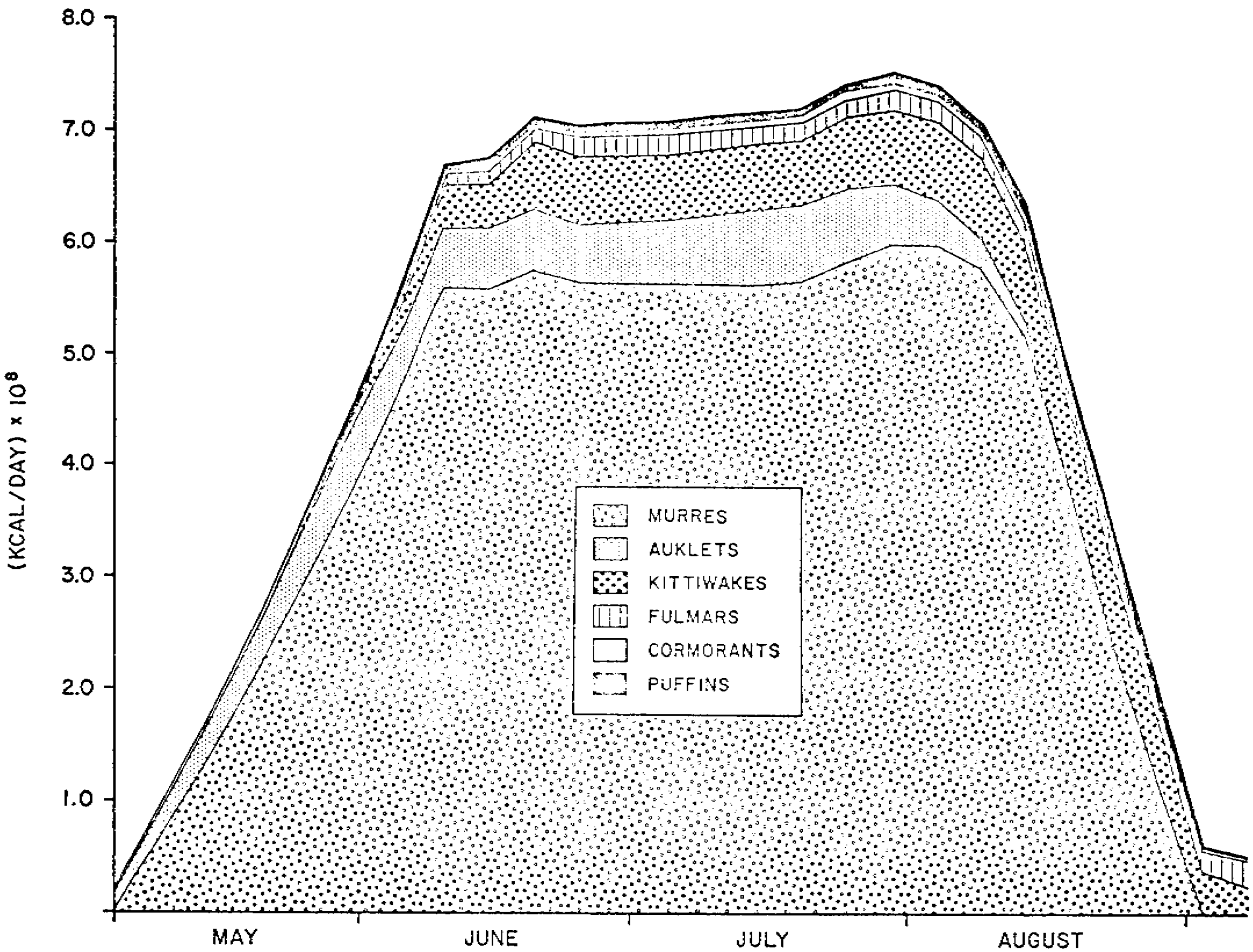

Fig. 2. Temporal course of total population energy demands of the major seabird species breeding in the Pribilof Islands during May-August.

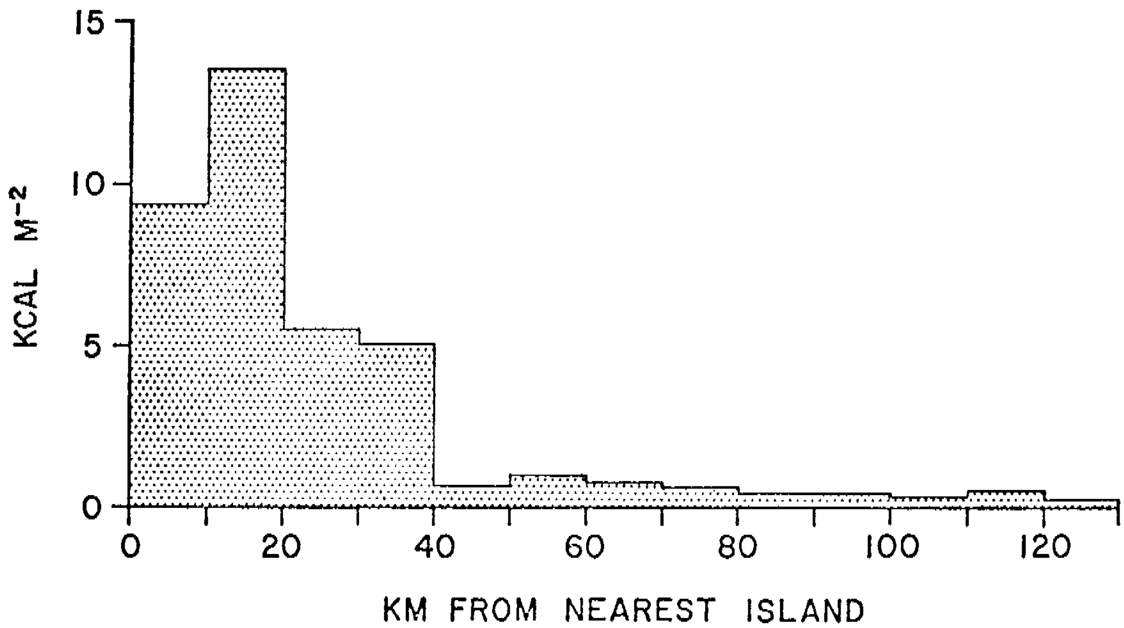

Fig. 3. Distribution of seabird energy demands with increasing distance from the breeding colony (St. George or St. Paul).

remove approximately 13.6 kcal m^{-2} during the course of the breeding season. The impact of the Pribilof Island seabird community drops off sharply beyond 40 km from either island. At 50 to 60 km distance, they remove only 1.7 g m^{-2} and the impact drops off steadily with increasing distance.

Sensitivity Analysis

In order to carry out the simulation, it was necessary to specifiy as inputs three important parameters: the proportion of the population that is breeding females (PPBF) and two parameters used for describing the annual photoperiodic effect on existence metabolism (TLA, TTOP). Model runs were made for three different values of each of these parameters - an upper limit, our best estimate, and a lower limit. The percent deviation in total community energy demand resulting from perturbation of each variable from our best estimate provides and index of the sensitivity of the model to our uncertainty (Table 2). Maximum and minimum pertubations of PPBF and TLA result in less than $\pm$ 5% variation, which is quite reasonable for our purpose. Variation in TTOP, however, could result in as much as 9% and one of our current priorities is improving our estimates for this variable.

Table 2.

Percent variation in total community energy demands resulting from perturbing variables to upper and lower limits of their reasonalbe ranges.

Variable	Upper limit	Lower limit
PPBF	3.5%	-3.3%
TLA	4.5%	-1.5%
TTOP	8.9%	-5.9%

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QUARTERLY REPORT

Contract No. 03-5-022-84
Research Unit #172
Reporting Period: 1 July - 30 Sept 1978
Number of Pages: 10

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: October 1, 1978

I. Task Objectives

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

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

II. Field Activities

A. Field work continued at 3 sites

1. Prudhoe Bay, through 10 September
2. Barrow, through 30 August
3. Kotzebue Sound, through 7 September

B. Scientific Party

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

Research assistants: Carolyn S. Connors, UC-BML

Katherine Hirsch, UC-Davis

Craig Hohenberger, UC-BML

Douglas Woodby, UC-Davis

C. Methods

We censused all previously established marked transects at each site once every 5 days, recording all species by age and sex whenever possible. Habitats on all transects were characterized to obtain foraging habitat data. At Prudhoe Bay and Barrow we sampled zooplankton densities at shoreline sites every 10 days. In Kotzebue Sound we sampled benthic invertebrates and collected birds for stomach analysis in situations of heavy shorebird use in littoral areas.

D. Sample Localities. See Section A.

E. Data Collected

1. Approximately 800 transect censuses were completed during this period. Approximately 60 birds were collected and 100 plankton or benthic samples were obtained.
2. Data analysis has not begun during this period.
3. Not applicable.

III. Only data pertaining to the most common species using shoreline transects on the ARCO West Dock and on the adjacent mainland have been partially analyzed. The seasonal changes in densities of several species in these two habitat categories are compared in figures 1 through 6.

IV. Preliminary Interpretation of Results Concerning ARCO West Dock

1. In general: Except for gulls and loons, bird use of the dock shoreline was very low until August when densities suddenly increased, with very sharp peaks for some species.
2. Zooplankton foragers (especially phalaropes) were more common on dock transects than on adjacent mainland shore transects. Phalarope foraging was almost all within 10 m of shore, usually on the wind protected shore. This is the same pattern as observed on natural spits (Pt. Barrow).
3. Very transitory but heavy use by the 2 phalarope species and by Glaucous Gulls (15-25 Aug) corresponds to the period of an extremely sudden appearance of very high densities of copepods and arctic cod along West Dock. This increase in prey densities was very local and of short duration. Copepod densities varied on opposite sides of the dock and at different positions along the dock.
4. Other patterns of seasonal habitat use were shown by other species. Arctic and Red-throated Loons also foraged very close to shore, were somewhat more common along the dock than on adjacent mainland shores, but remained at fairly constant densities over a long season.
5. Ruddy Turnstones foraged along both dock and mainland shores over a fairly long period.

6. Dunlins, utilizing both zooplankton and benthic infauna, were more common along the natural shoreline transects, but densities fluctuated quickly. Moderate numbers of Dunlins also occurred on West Dock during non-census observations.

7. The ARCO Dock, as an artificial gravel spit, seems to be favored as a foraging area by several species. This may, however, result in attracting birds to the region of highest industrial activity and therefore greatest potential environmental hazard.

V. Problems Encountered

None

VI. Estimate of Funds Expended

For 1978, funds expended through August 31, 1978 totaled approximately $55,215 of the allocation of $65,652.

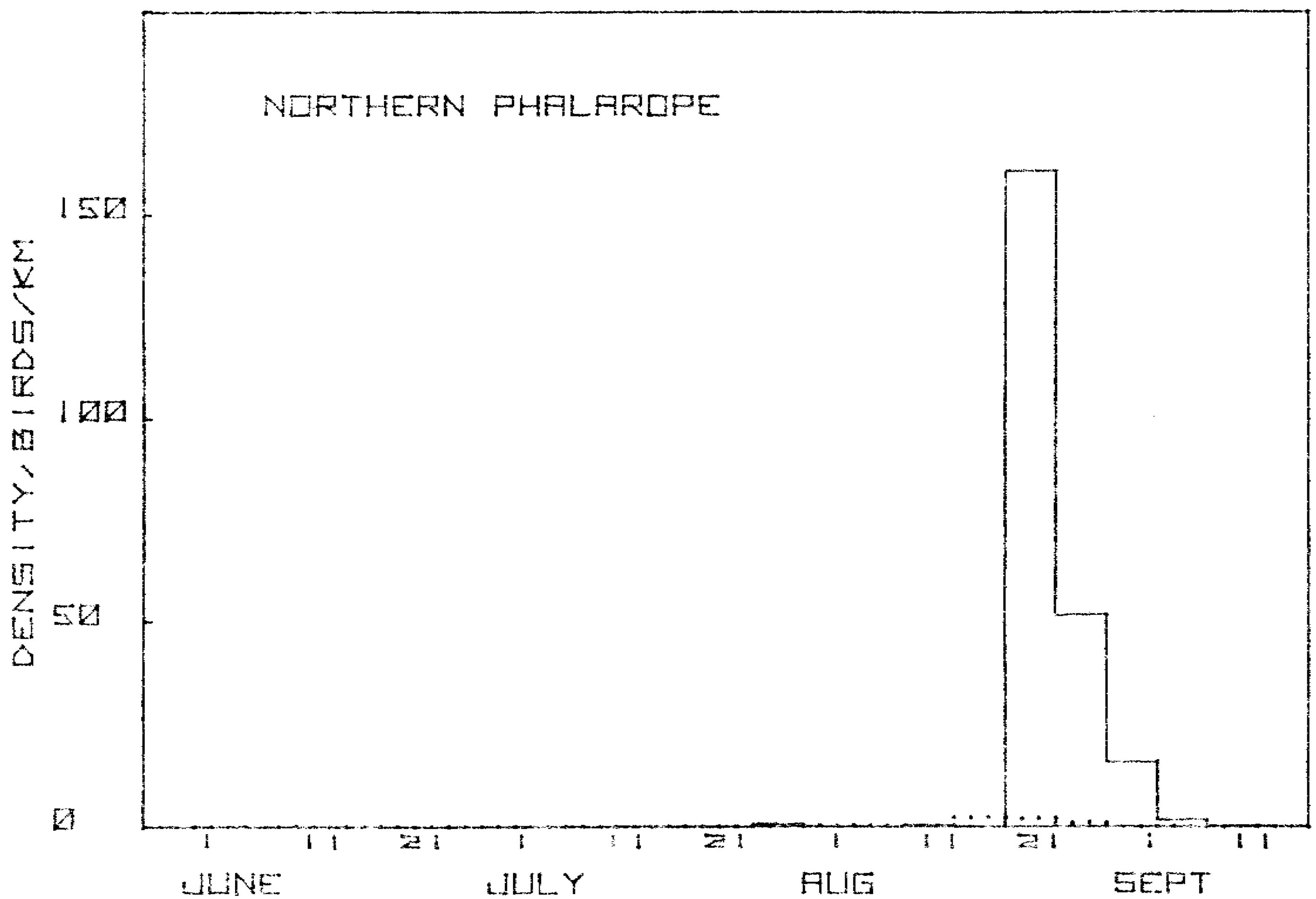

Figure 1. Density of Northern Phalaropes along shores of Arco Dock (solid line) and on adjacent mainland shores (dotted line), 1978.

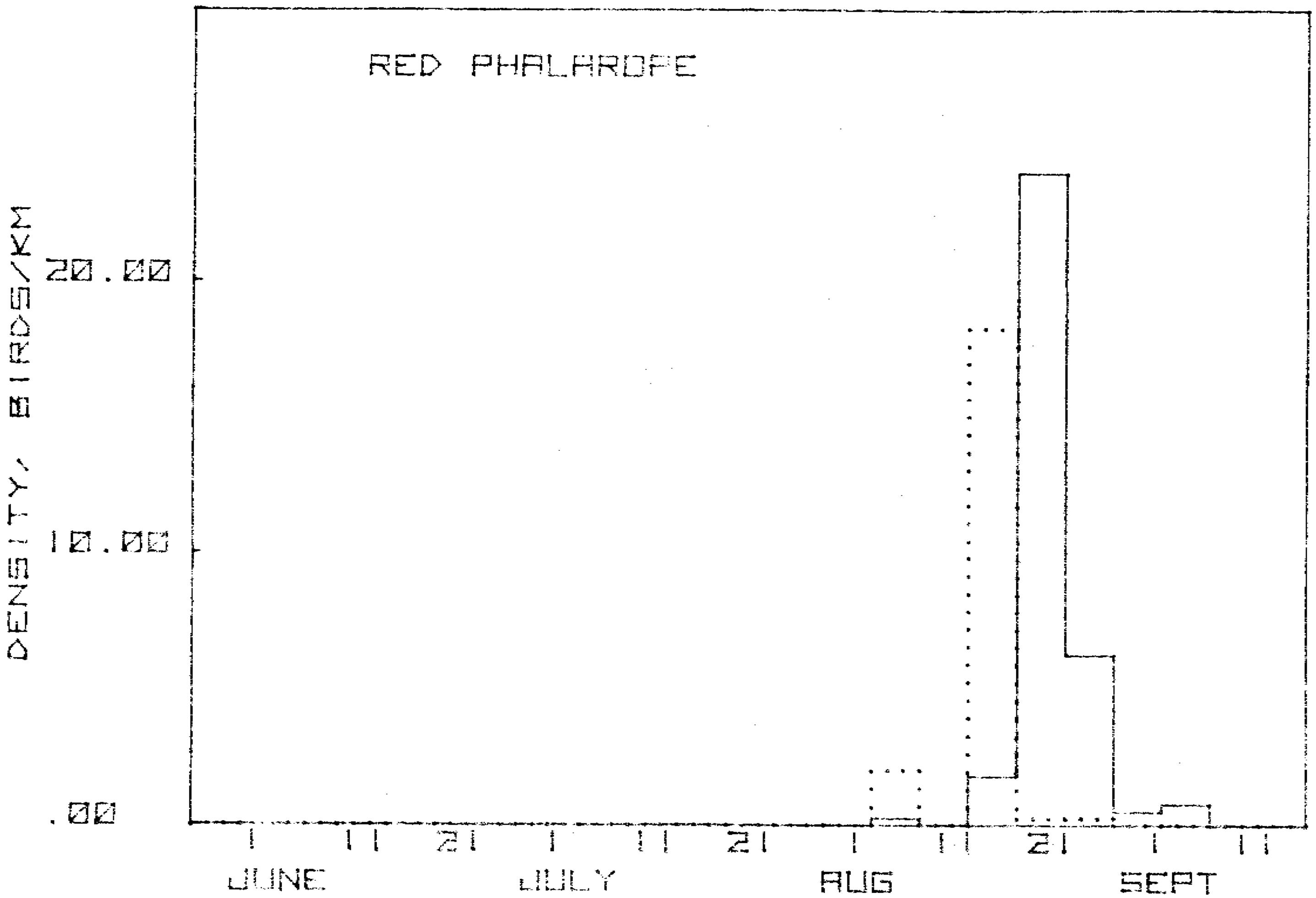

Figure 2. Density of Red Phalaropes along shores of Arco Dock (solid line) and on adjacent mainland shores (dotted line), 1978.

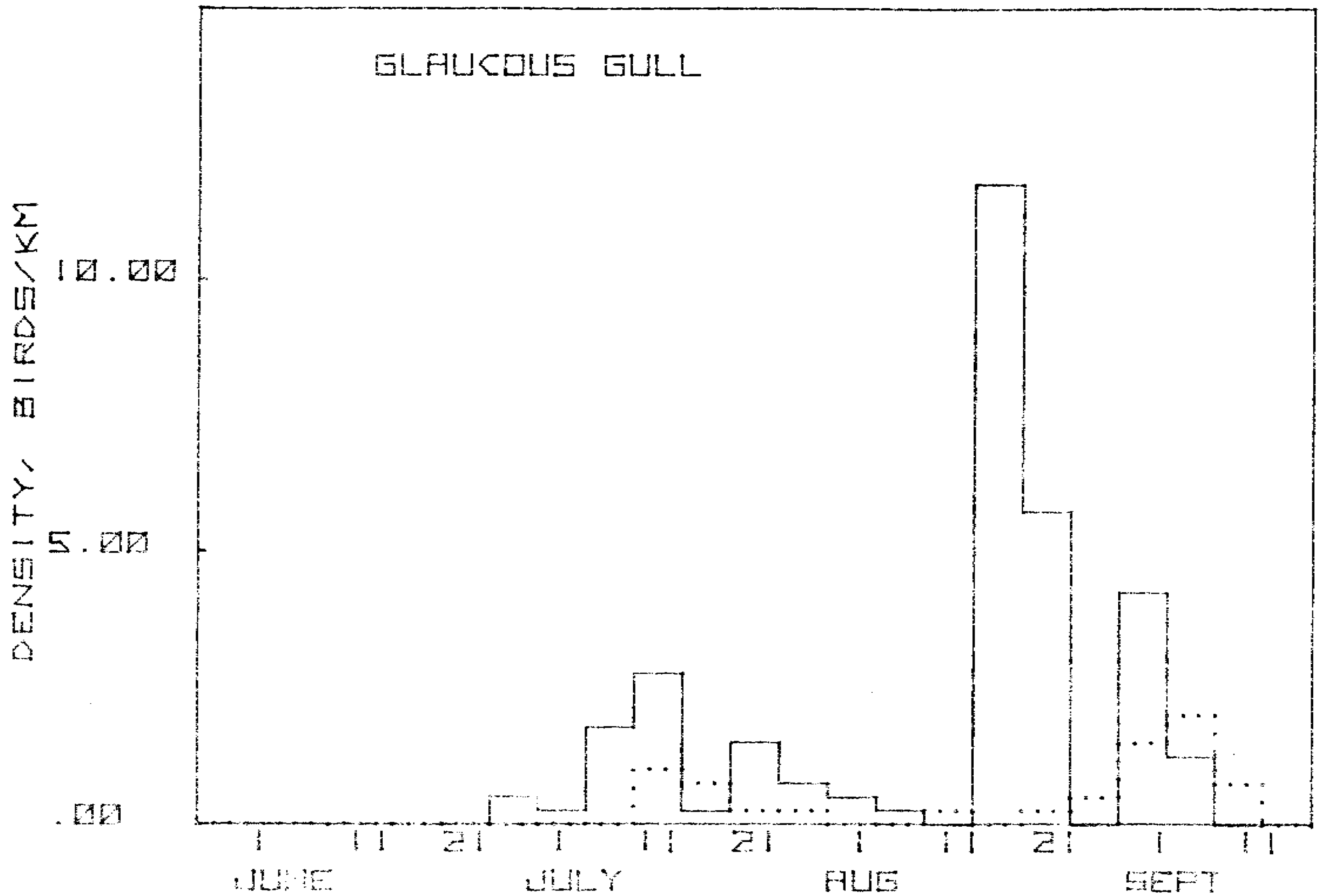

Figure 3. Density of Glaucous Gulls along shores of Arco Dock (solid line) and on adjacent mainland shores (dotted line), 1978.

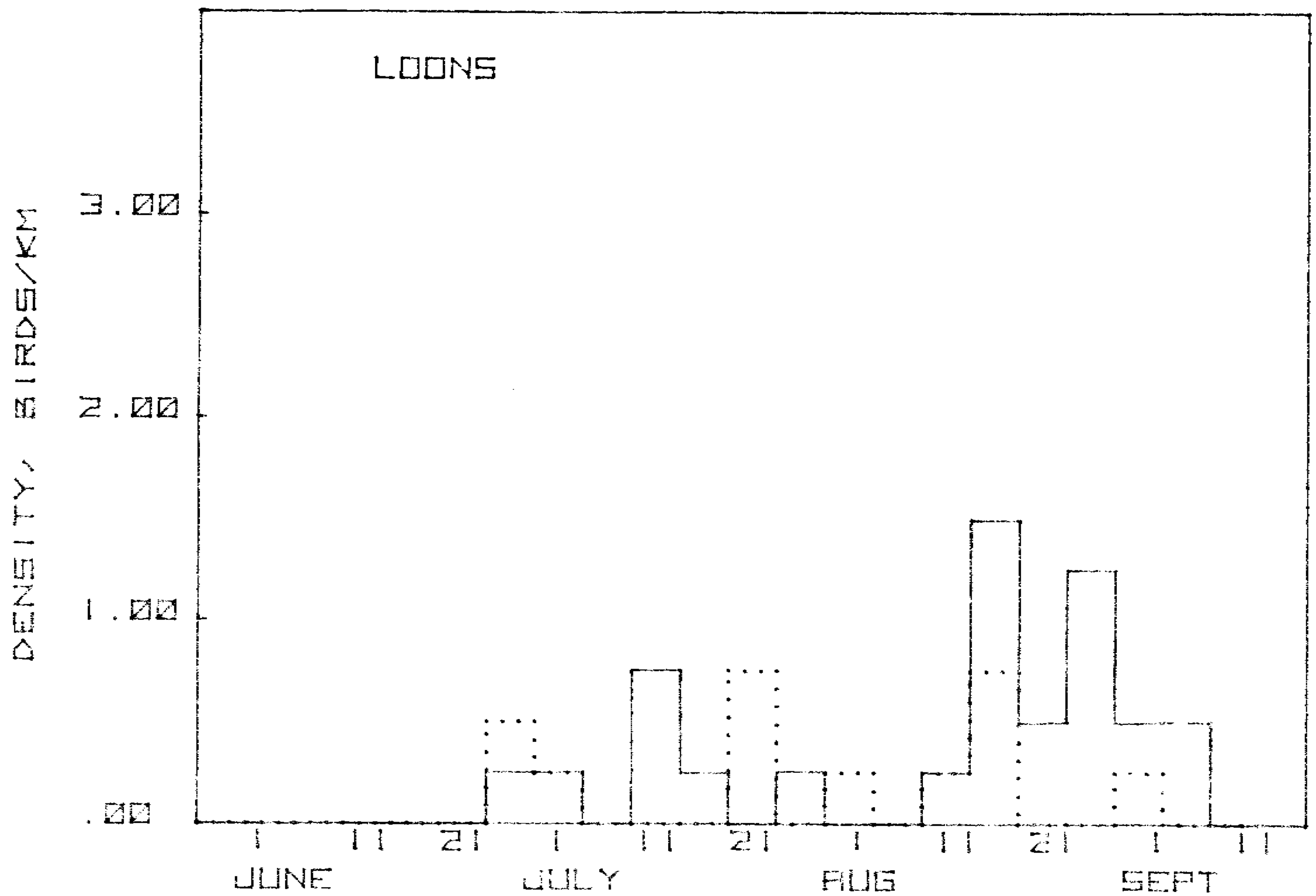

Figure 4. Density of Arctic and Red-throated Loons along shores of Arco Dock (solid line) and on adjacent mainland shores (dotted line), 1978.

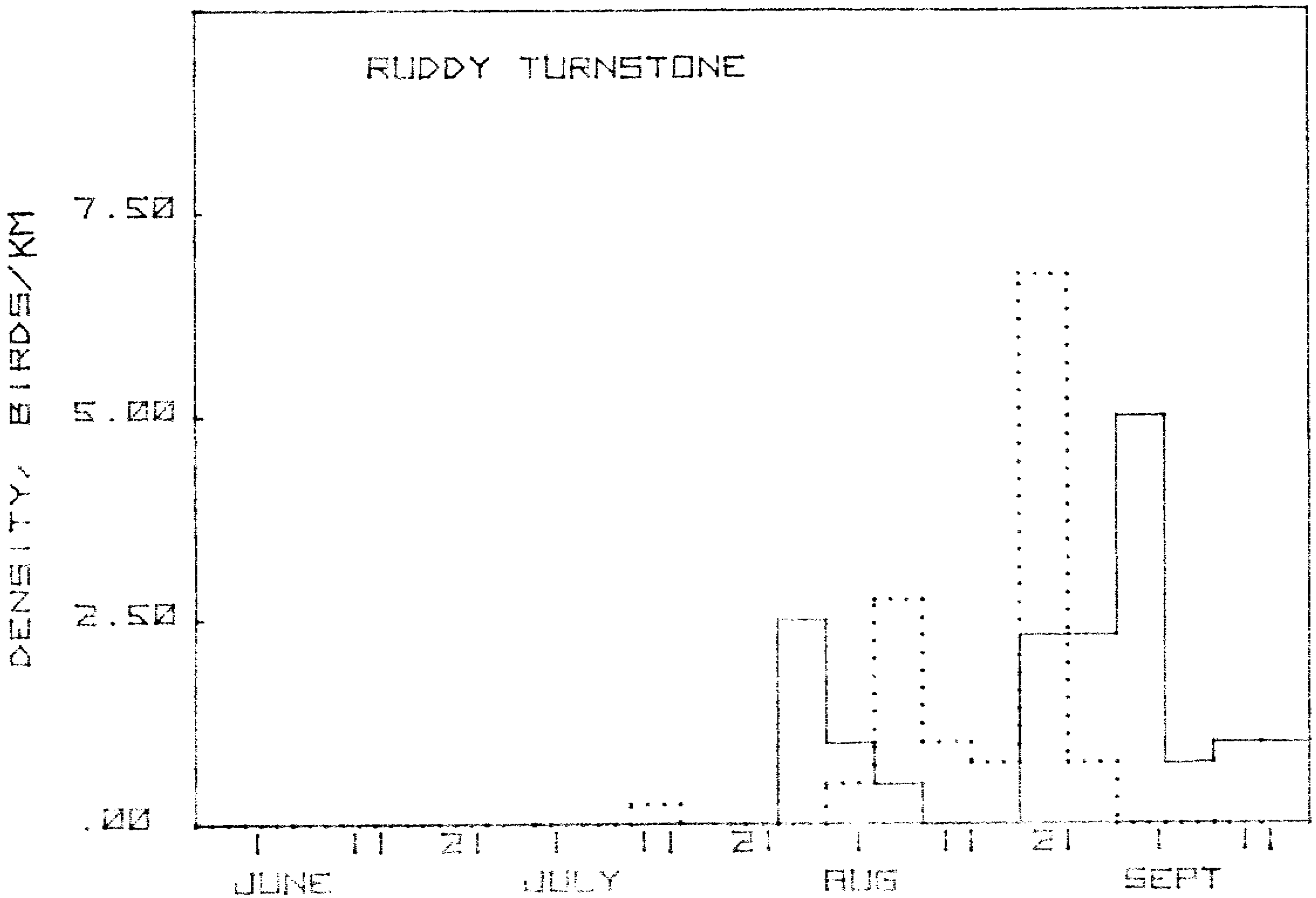

Figure 5. Density of Ruddy Turnstones along shores of Arco Dock (solid line) and on adjacent mainland shores (dotted line), 1978.

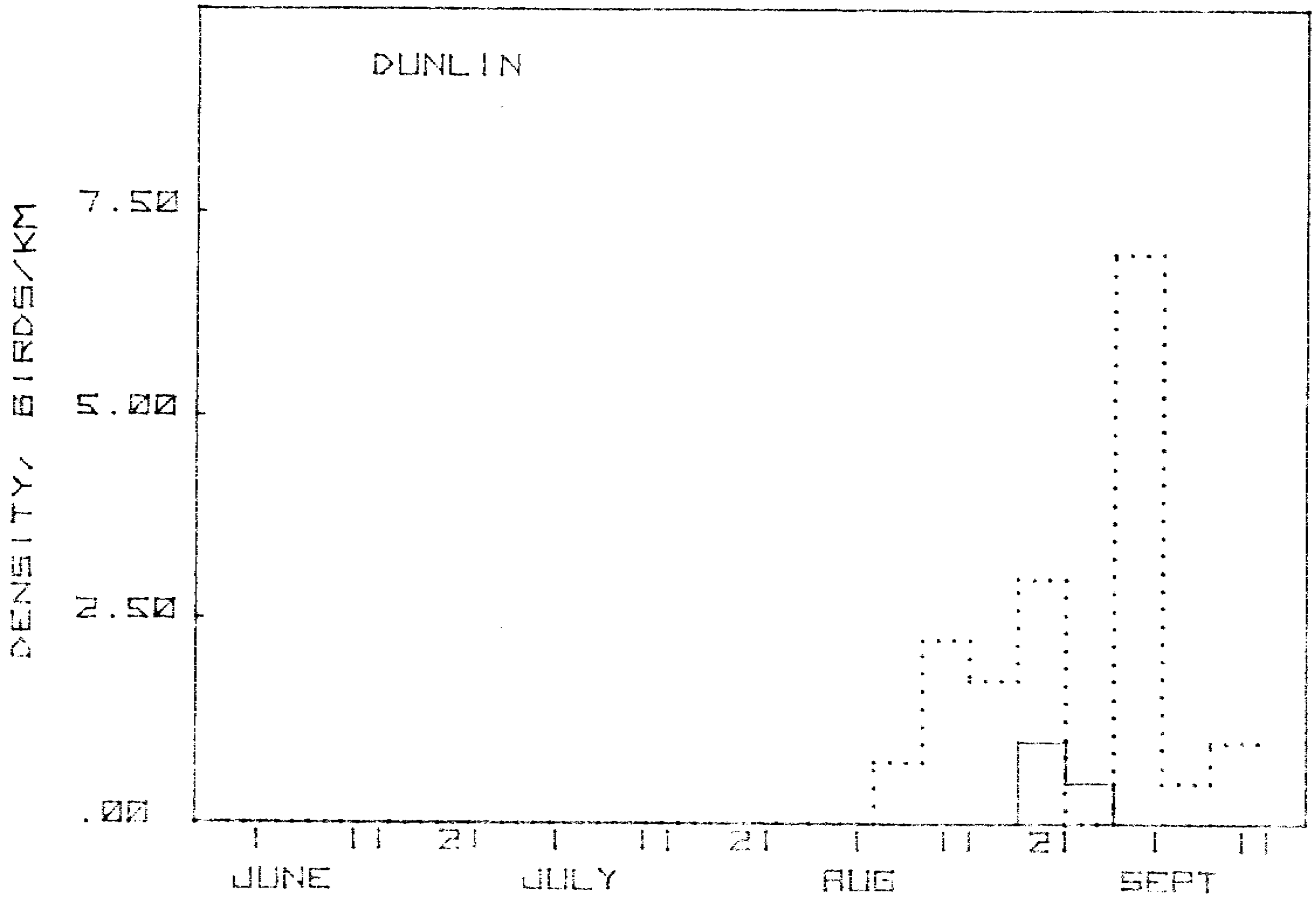

Figure 6. Density of Dunlins along shores of Arey Dock (solid line) and on adjacent mainland shores (dotted line), 1978.

Quarterly Report

Contract #: 03-7-022-35140
Research Unit: 196
Report Period: 1 July-
30 September 1978
Number of Pages: 2

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

George J. Divoky
Principal Investigator

Assisted by:

Maggi Ford
A. Edward Good
Thomas Scharffenberger
Douglas A. Woodby

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

1 October 1978

I. Task Objectives

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

II. Field Activities

A. Ship and field trip schedule

Dates	Location	Personnel
1 July - 12 September	Cooper Island	Divoky, Ford, Good, Scharffenberger
1-30 August	Inshore Beaufort Alumiak and Natchik	Divoky, Good
25 August - 15 September	Offshore Beaufort USCGG Northwind	Divoky, Good, Scharffenberger

III. Results

Excellent weather, early ice breakup and the lack of major fox predation helped to make the field season on Cooper Island an extremely productive one. Birds banded as chicks in 1975 and 1976 were found breeding in 1978 providing information on recruitment rates. The early breakup of shorefast ice allowed the observation of breeding birds and migrants in ice conditions unlike those found in past years.

Shipboard observations were hindered by fog and ice, which prevented the completion of a grid north of the coast between the Colville River and Camden Bay. Only spotty information was obtained on pelagic and nearshore densities. This problem was compounded by the early termination of the icebreaker cruise.

IV. Preliminary interpretation of results

None

V. Problems encountered

None

VI. Estimate of funds expended

Expenditure estimates not available at this time.

Research Unit #237
Reporting Period: 1 July -
1 October

Quarterly Report

ECOLOGY OF SEABIRDS IN THE BERING STRAIT REGION

William H. Drury

College of the Atlantic
Bar Harbor, Maine

QUARTERLY REPORT

RESEARCH UNIT # 237
Contract No. 03-6-022-35208

Reporting Period 1 July,1978 to 1 October, 1978

Title: Ecology of Seabirds in the Bering Strait Region

Principle Investigator: William H. Drury
Affiliation College of the Atlantic
Bar Harbor, Maine 04609

Date Submitted: 28 October, 1978

I Abstract

This report is in abstract form. See Sections IV Results and V Preliminary Interpretation of results.

II Objectives

1) To provide estimates of nesting success of the principle species of marine birds;

2) To establish and describe sample areas which may be used in subsequent years for monitoring the populations at Bluff Cliffs;

3) To determine the amount and kinds of foods used by the principle species, and to describe the daily foraging patterns; when possible to determine the relationships of food selected to food available;

4) To describe the chronology and phenology of events during the breeding season, including changes in populations and their habitat distribution, from occupation of the nest sites in spring to departure in the fall;

5) To provide comparison of current data with recent historical data;

III Field Activities

A. Field Schedule

1) Fixed transects were taken over the Northern Bering Sea and Norton Sound in July and August. The aircraft used was Cessna 336.

2) Searches were made for the distribution of feeding seabirds in the Hope Basin in July and August. The aircraft used was a Cessna 336.

3) Counts were made of the age classes of Glaucous Gulls along the beaches between Wainwright and Unalakleet in July, coincident with these operations.

4) An excursion of the NARL vessel Natchik was made from Barrow to Wainwright in late July, but the cruise was terminated (see below, VII).

5) A visit to Little Diomede Island by Diomede Islanders' skin boats was prevented by bad weather. The Diomeders did not come to Wales for about three weeks. The purpose of the trip was to repeat observations made in 1977.

6) Detailed studies of breeding biology were carried out at 14 study sites and repeated visits were made to seven other sites at the seabird cliffs at Bluff. Censuses were made of the entire cliffs at Bluff and Sledge Island.

7) Aerial estimates were made of the seabird populations of the cliffs at Bluff Cliffs, Sledge Island, King Island, Saint Lawrence Island (Savoonga, Cambel and Southwest Capes), Little Diomede, Fairway Rock, Cape Thompson and Cape Lisburne.

B. Scientific party

William H. Drury, College of the Atlantic	P.I.
Mary Drury	Field Assistant
J. Brand French, Univ. of Wisconsin	Field Assistant

Cathy Ramsdell	College of the Atlantic	Field Assistant
David M. Rand	Harvard College	Field Assistant
Alan Watson	White Mountain School	Field Assistant
E. Murphy	Univ. of Alaska	Consultant

C. Methods

1) Fixed transects flown at 120 ft., 120 knots; birds counted in a 30° arc.

2) Surveys of the beaches flown at 100 feet, 120 knots.

3) Visits to study sites at three-day intervals (more frequently during laying or hatching) to record the breeding phenology and success of Common Murres and Black-legged Kittiwakes. Contents and activities at mapped nests are recorded.

4) Counts of all species on the cliffs

5) Collections were made of food dropped on ledges, brought in by parents. A sample of 50 adults carrying food to the cliffs was taken.

D. Sample locations

Locations are recorded in previous annual reports. Transect lines are shown on the map.

E. Data collected

1) 650 five-minute periods of counts were spread along about 6500 miles of transects .

2) About 1500 miles of beach were surveyed.

3) 580 nesting sites of Black-legged Kittiwakes were studied; 127 mapped areas, including on average 4 pairs each, of Common Murres were studied.

4) Seven censuses were made of the Bluff Cliffs. Five areas were identified and counted as sample locations for detailed comparisons in the future. Five 24-hour counts were made to observe the daily changes in numbers of birds at the cliffs.

IV Results

1) Seabird feeding areas during the breeding season

a) Murres and kittiwakes were found to gather at the mouth of the Golovnin Lagoon and within 20 miles of the Bluff Cliffs.

b) Moderate concentrations of feeding seabirds were observed from about 20 miles East of King Island to about 50 miles Southeast of King Island.

Extensive, important feeding concentrations were observed West of King Island extending at least as far as the international boundary. These concentrations extend Southwest to the West end of Saint Lawrence Island and at least as far as 35 miles Southwest of the Southwest Capes on St. Lawrence Is.

c) A heavy concentration of feeding seabirds occurs in the Bering Strait.

d) Feeding seabirds were observed to gather along the edge of the deeper water Southwest and West of Cape Thompson.

Feeding seabirds were observed in large numbers in shallow water within a few miles of shore to the Northeast of Cape Lisburne.

2) About 1,000 Glaucous Gulls were aged and counted between Wainwright and Unalakleet. Of these 18% were subadults. Chicks had not yet fledged when the survey was made in late July.

3) Censuses of seabirds at Bluff Cliffs and Sledge Island gave results similar to those of 1975, 1976, and 1977, except that an unusually large count was made during one trip to Sledge Island and a maximum count was made in early June at Bluff Cliffs. These high counts may be associated with favorable conditions for reproduction.

Aerial estimates were made of the Bluff Cliffs, Sledge Island, King Island and Little Diomede Island. We compared these aerial estimates to previous counts made from the surface. This comparison provides a correction factor to apply to the aerial estimates we made of the seabird cliffs at

Saint Lawrence Island, Cape Thompson and Cape Lisburne. We can also compare our aerial estimates with the surface counts of Springer and Roseneau.

4) Our studies of breeding biology showed an exceptionally high reproductive success among Common Murres and Black-legged Kittiwakes at Bluff.

5) Observations on food showed again that Sand Launce in the major food of Black-legged Kittiwakes. Common Murres feed heavily on Sand Launce, but bring Pricklebacks back to their chicks on the cliffs.

V Preliminary Interpretation of Results

1) The data collected in the course of overwater transects confirmed our previous ideas about the distribution of feeding concentrations of seabirds in the Northern Bering Sea and Norton Sound. Our observations are also consistant with those of Schwartz in the Hope Basin, off Cape Thompson, in the early 1960s and the observations of Roseneau and Springer at Cape Thompson and Cape Lisburne in the 1970s.

We believe that we have a good picture of the location of the important feeding concentrations of seabirds in the Northern Bering Sea, Bering Strait and Southern Chukchi Sea. Unfortunately we do not have data from West of the International Date Line.

2) Common Murres and Black-legged Kittiwakes had unusually successful reproductive season at Bluff Cliffs in 1978. The kittiwakes produced about 4/5 of a young one per nest which is twice as well as they did in the next best year, 1975, and 40 times as well as they did in the poorest year, 1976.

Reproductive performance among kittiwakes was so high that differences in performance among different parts of the cliff were not evident. During 1975 conspicuous differences were found, while during 1976 and 1977 reproduction was so poor that differences were masked.

3) Counts of the age classes of Glaucous Gulls along 1500 miles of coastline in Northwest Alaska suggest that Glaucous Gulls may be in or entering a period of rapid growth of their population. Such growth, a familiar secondary effect of economic development, has unfortunate implications for other seabird populations. For example, a single pair of Glaucous Gulls nesting on top of a rock stack will exclude five hundred or more pairs of Common Murres from the preferred nesting habitat.

VII Problems Encountered

In July 1977 we arranged a lease of a fishing vessel out of Kodiak in order to make studies of the food of seabirds in the Northern Bering Sea, Norton Sound and the Bering Strait. Unfortunately, the lease was cancelled by the fishermen when they found other ways of making more money.

We subsequently arranged to lease Natchik out of NARL, Barrow. This vessel left Barrow in late July and we flew D. Roseneau to Wainwright to join the vessel. Two members of an LGL fisheries group were on board during the trip from Barrow to Wainwright and Roseneau joined them on the return trip to Barrow for repairs and refitting. We recieved negative reports from W. Griffiths and D. Roseneau about the condition and operation of the vessel, and as a result decided that Natchik was suitable for operations out of Barrow in sheltered waters where repair facilities are available. We decided not to use her for the long trip to Nome and for extended work many tens of miles off shore in a region lacking shelter from the weather and lacking any repair facilities. The reports we have recieved about the Natchik's operations later in the summer support this decision.

As a result of these two circumstsnces we were unable to carry out our studies of the reproductive success of seabirds at King Island and Little Diomede. We also reduced our studies on the food of seabirds to taking about fifty specimens at Bluff Cliffs for examination of stomach contents.

In the meantime we have reconsidered our plans to make studies of the fisheries resources in relation to the diets of seabirds. We have, furthermore compared the fisheries data available from the Northern Bering Sea(Wolotira, 1978) with our observations on seabirds. It is doubtful that contemporary fisheries technology will allow us to take the samples needed to sample the resources which the seabirds are using, at least from the benthic or demersal stocks. We think that the most productive next step would be based on study of the feeding behavior of birds, on samples of stomachs of feeding birds, and on surface samples. We believe that instead of a larger vessel, a small, fast craft (large sized whaler or Aquasport 22.5) would be best. Such a small boat would allow sampling fish and invertebrates near the surface and measuring temperatures and salinities. Its greatly increased mobility and low logistics and personnel requirements are in its favor.

We can explain these conclusions in greater detail and develop~~e~~ the plans further if that seems desireable.

QUARTERLY REPORT

Contract: 01-5-022-2538
Research Unit: RU 337
Reporting Period: July 1, 1978 to
September 30, 1978

SEASONAL DISTRIBUTION AND ABUNDANCE OF MARINE BIRDS IN ALASKAN WATERS

Calvin Lensink
PRINCIPAL INVESTIGATOR

Patrick Gould
PROJECT LEADER

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

October 1, 1978

RU 337
QUARTERLY REPORT
JULY - SEPTEMBER 1978

I. ABSTRACT OF QUARTERS ACCOMPLISHMENTS

Data processing and the initial stages of writing the first draft of the final 337 report occupied this entire quarter. Keypunching and digital data verification was begun and partially completed for 1978 cruises in the Kodiak area. Writing was begun on some introductory sections of the final report. The first two final data tapes were received from Dr. Hal Peterson.

II. TASK OBJECTIVES

The overall objective of RU 337 in 1978 is the analysis of shipboard and aerial survey data and the preparation of a final report. Specific tasks for this quarter included: 1) processing of data from limited cruises conducted under RU 341 in the Kodiak integrated project, 2) review of pertinent literature, and 3) preparation of introductory sections of the final report.

III. FIELD OR LABORATORY ACTIVITIES

No field or laboratory programs were conducted although some support was given to shipboard surveys conducted under RU 341 in the integrated Kodiak studies.

IV. RESULTS

None of the tasks were completed during this work period but major headway was made in all areas.

V. PRELIMINARY INTERPRETATION OF RESULTS

This section is not applicable to this quarters work.

VI. AUXILIARY MATERIAL

There was no auxiliary material for this quarters work.

VII. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

No new or specific problems were encountered during this quarter. The length of time needed by Dr. Hal Peterson to complete the editing, verification and format conversion of RU 337 digital data remains the central problem with respect to beginning data analysis and to establishing a date for the completion of the final report.

QUARTERLY REPORT

Contract: 01-5-022-2538
Research Unit: 341
Reporting Period: July 1, 1978 to
September 30, 1978

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

Principal Investigator

Calvin Lensink

Study Leaders

Gerald Sanger
Patrick Gould
Robert Gill
Robert Jones

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

November 1, 1978

QUARTERLY REPORT

RU 341
JULY - SEPTEMBER 1978

I. ABSTRACT OR HIGHLIGHTS OF QUARTERS ACCOMPLISHMENTS

Breeding biology studies were completed at Chisik Island, Middleton Island, Sitkalidak Straits and Chiniak Bay. These studies produced a wealth of new data and the field personnel returned with new insights into the relationship between seabird breeding and food availability. Field efforts associated with the Integrated Kodiak Food Web Studies were completed. Data were collected on the feeding habits of selected seabird species and on the distribution and abundance of all seabirds occurring in Kodiak bays and over the nearby continental shelf. Laboratory personnel devoted an increasing amount of their time to data management. Data from all of the 3,405 stomach samples assessed to date have been keypunched and now await computer analysis. An analysis of Marbled Murrelet stomach contents data was completed and showed a dramatic shift in diet from summer to winter.

II. TASK OBJECTIVES

A. Colony Studies

The colony work was directed toward obtaining baseline data on the breeding biology of important seabird species. The most important data collected included: colony size, breeding chronology, clutch size, productivity, growth rates, food habits, and habitat use. The major species studied at each camp were: Black-legged Kittiwake (all colonies), Tufted Puffin (Chiniak and Sitkalidak), Horned Puffin (Chisik), Pelagic Cormorant (Middleton Island and Chiniak), Glaucous-winged Gull (all colonies). Other species investigated under lower priority status included: Mew Gull, Arctic Tern, Aleutian Tern, Common Murre, Pigeon Guillemot, Common Eider, Rhinoceros Auklet and Black Oystercatcher.

B. Feeding Ecology and Trophic Relationships

Feeding ecology studies were both lab and field oriented. The field work centered on the collection of selected seabird species and their stomach contents in conjunction with plankton and fisheries research being conducted in the same area and time frames. Key species being studied were Sooty Shearwater, Tufted Puffin, Black-legged Kittiwake, Common Murre and Pigeon Guillemot. Distribution and abundance data on all seabirds in the study area were gathered by standard USFWS transect techniques. Movement of Tufted Puffins and Black-legged Kittiwakes to and from colony areas was studied by 48-hour seawatches at Outer Right Cape. Laboratory work involved data processing and stomach content analysis.

III. FIELD AND LABORATORY ACTIVITIES

A. Ship or Field Trip Schedule

The ship and field trip schedule is presented in Table 1.

B. Scientific Party

The scientific parties are listed in Table 1.

C. Methods

Field and laboratory methods used during this quarter were the same as for the previous quarter. In general, colony work is conducted by establishing study plots and marking individual nests and birds. Basic data on each aspect of the birds' breeding biology is checked at least every five days and frequently every two days depending on the specific requirements of each species and each chronological event. Feeding ecology studies included, in order of descending priority: intensive collections of birds in Izhut Bay and Kiliuda Bay for feeding habits data; observing and documenting foraging behavior and areas; and, conducting transect counts to determine distribution and abundance in relation to distribution and abundance of prey. Seawatches from Outer Right Cape, Kodiak Island, monitored the movements of birds through a spotting scope over a 48-hour period. Laboratory methods involved sorting, measuring and classifying stomach contents and the digitizing of all derived data.

D. Sample Location/Ship or Aircraft Tracklines

The location of the seawatches is indicated on Figure 1. The location of colony studies is indicated on Figure 2. Collecting work aboard the R/V Commando was concentrated in Izhut and Kiliuda Bays, Kodiak Island, but transect counts were taken over most bay and continental shelf areas of east and south Kodiak Island.

E. Data Collected or Analyzed

1. Number and types of Samples/Observations

A preliminary listing of data and sample sizes obtained during the 1978 colony studies is presented in Table 2. Fish and Wildlife Service personnel participated in cruises 7B through 10 of the R/V Commando as part of the Integrated Kodiak Food Web Study. A total of 63 Sooty Shearwaters, 30 Tufted Puffins, 43 Black-legged Kittiwakes, 25 Common Murres, 22 Marbled Murrelets and 18 Pigeon Guillemots were collected in Izhut Bay and northern Sitkalidak Strait. One hundred and thirty three transects for distribution and abundance data were completed aboard the R/V Commando and 109 were obtained aboard the NOAA ship Miller Freeman. Four 48-hour seawatch studies were conducted at Outer Right Cape, Kodiak Island.

2. Sorting and analysis of data from the 1978 field season has not yet been completed although a few preliminary products are available. USFWS personnel on the Alaska Information Management Systems (AIMS) program have been working on computer programs to translate feeding data from two older formats to the final format. After frustrating delays that continued for nearly a year and a half, the final computer format for feeding studies of marine birds (NODC Record Type 031) was approved by NODC and NOAA in August. AIMS is also working on quality control checking programs for our data, and we anticipate being able to begin computer analysis of our feeding data in the near future.

3. Miles of Trackline

This information has not yet been derived for the 1978 field season.

IV. RESULTS

A. Colony Studies

Only a general summary of the results of colony studies for the major marine bird species is appropriate at this point in time.

1. The 1978 breeding chronology for all species appears to be similar to that found in previous years. The new studies on Middleton Island indicate that local populations begin breeding at a significantly earlier date and that the breeding season there is spread over a longer period of time.

2. The 1978 breeding success for all species except Black-legged Kittiwake appears to be similar to that found in previous years.

3. Black-legged Kittiwake breeding success was very poor throughout the Gulf of Alaska with the exception of one colony in Chiniak Bay (see Table 3).

B. Feeding Ecology

One of our laboratory personnel (Valerie Hironaka) has calculated the Index of Relative Importance (IRI) for the prey of Marbled Murrelets in the Kodiak area and in Kachemak Bay, Lower Cook Inlet. The IRI (Pinkas _et al._, 1971) is defined as: IRI = % frequency of occurrence X (% numbers + % volume). The resulting number provides a means of evaluating the relationship of various food items. For Marbled Murrelets in the Kodiak area the IRI reflects a dramatic shift in diet from summer to winter. In summer, the 59 birds sampled were exclusively piscivorous, eating juvenile Caplin and Sandlance. They ate predominantly Capelin in May, and predominantly Sandlance by mid-August. A trace of juvenile Walleye Pollock also occurred in their diet. However, in winter no fish occurred in the diet of the 38 murrelets sampled. Their diet was then dominated by the mysids _Acanthomysis_ and _Neomysis_. In Kachemak Bay in winter, the diet of 20 Marbled Murrelets was dominated by _Thysanoessa_ euphausiids and juvenile Capelin, and contained some unidentiable mysids.

V. PRELIMINARY INTERPRETATION OF RESULTS

An interpretation of results other than those presented in the Results section of this report is not possible at this point in time.

VI. AUXILIARY MATERIAL

We have no auxiliary material to present with this report.

VII. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

No new problems have been encountered during this quarter nor do we have any recommended changes at this point.

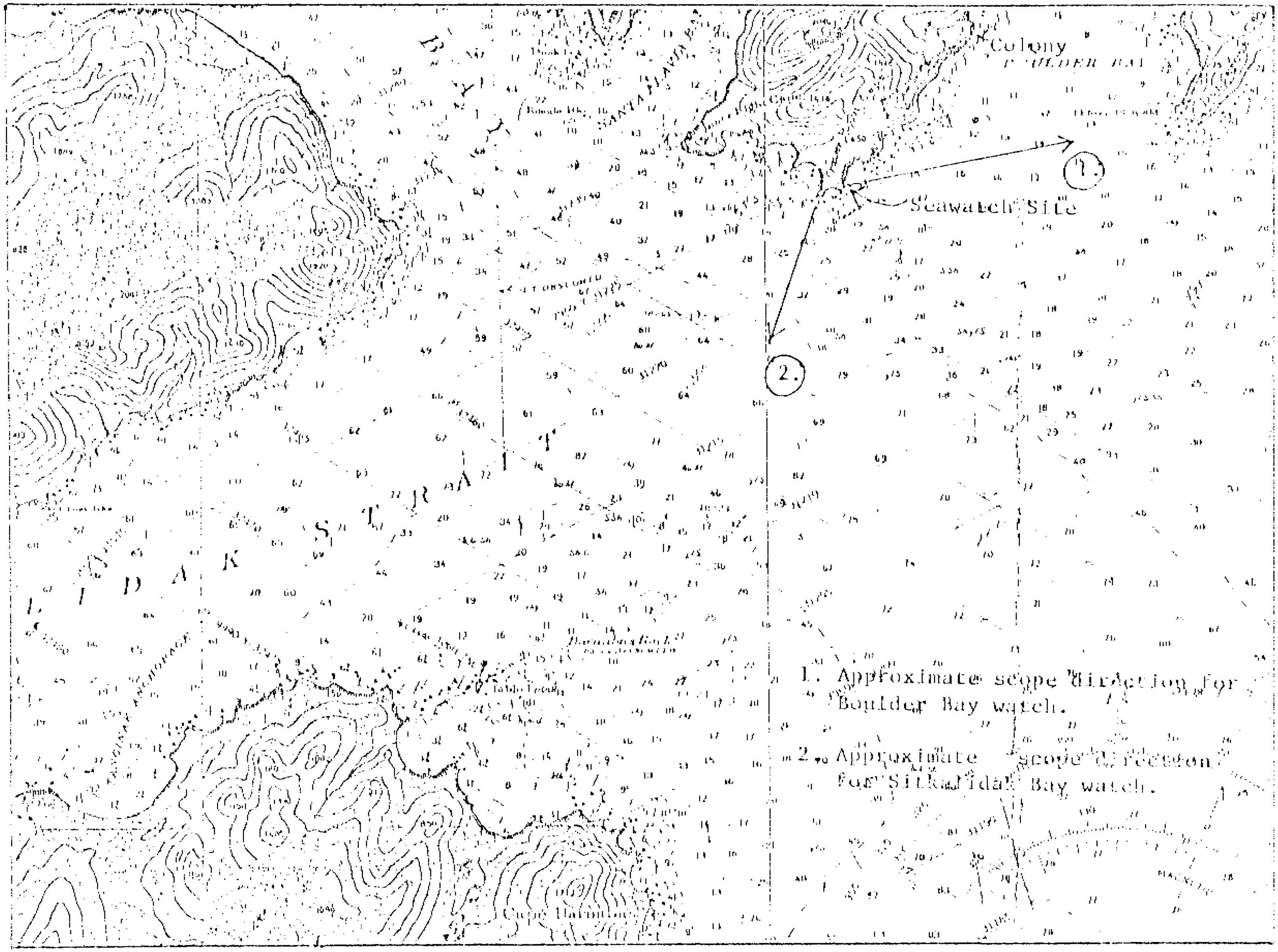

Figure 1.--Location of special seawatch project at Outer Right Cape, Sitkalidak Strait, to monitor foraging and other activity cycles of Black-legged Kittiwakes and Tufted Puffins.

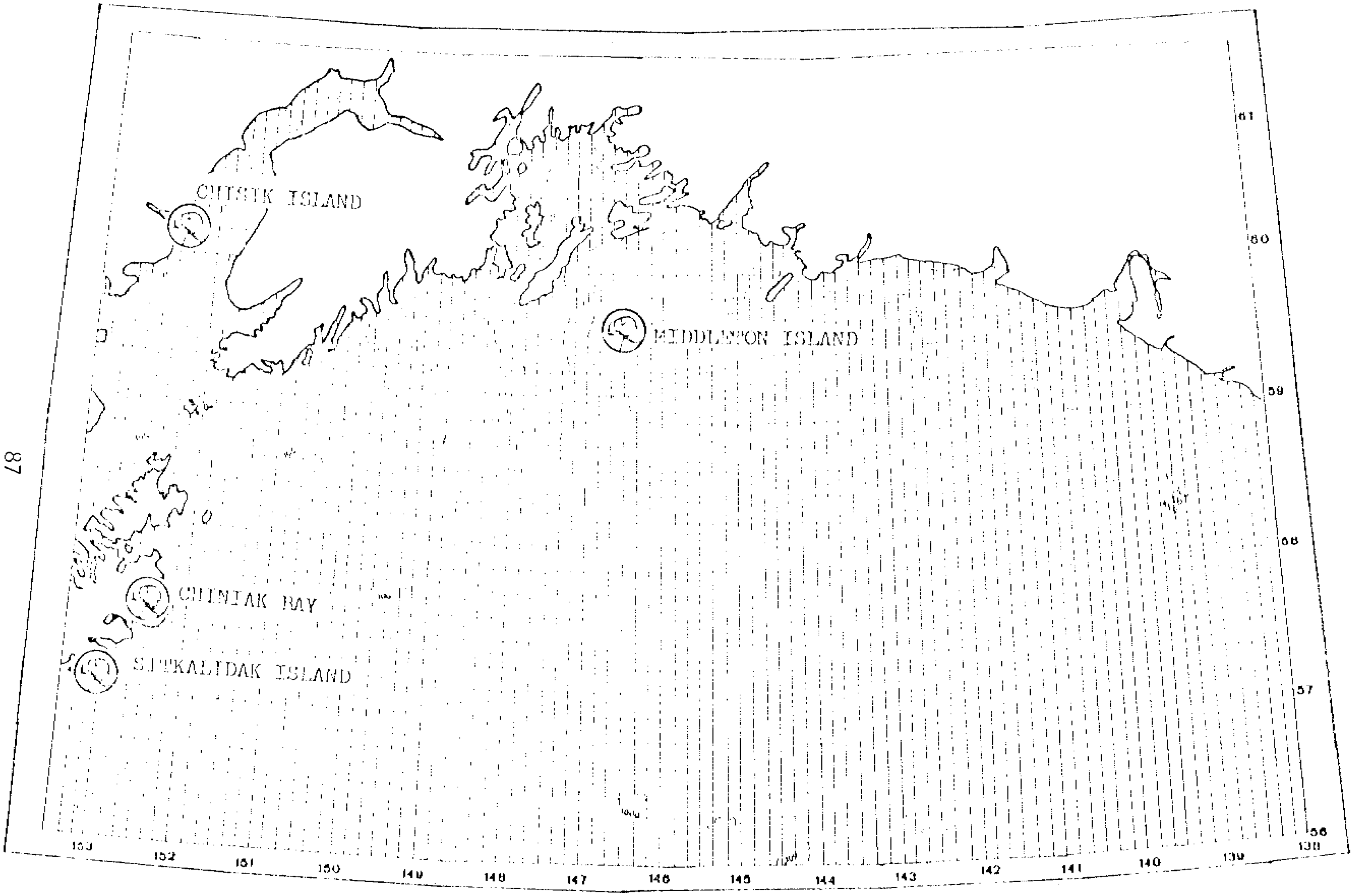

Figure 2. Locations of the four field camps established for colony studies in 1978.

Table 1. Ship and Field Trip Schedules and Scientific Party.

FIELD OPERATION	BEGIN DATE	END DATE	PLATFORM	USFWS PERSONNEL
Colony Study FW8009	78-05-08	78-09-07	Sitkalidak Island	Patricia Baird (work leader) Martha Hatch (field assistant)
Colony Study FW8010	78-05-15	78-09-04	Chisik Island	Robert Jones (work co-leader) Margaret Petersen (work co-leader)
Colony Study FW8013	78-05-15	78-09-04	Chiniak Bay	David Nysewander (work leader) Bruce Barbour (field assistant)
Colony Study FW8021	78-04-28	78-08-18	Middleton Island	Scott Hatch (work leader) Tom Pearson (field assistant)
Feeding Ecology FW8017	78-07-11	78-07-31	R/V Commando	Lynne Krasnow (work leader) David Wiswar (field assistant)
Feeding Ecology FW8018	78-07-31	78-08-13	R/V Commando	Douglas Forsell (work leader) Claudia Voss (field assistant)
Feeding Ecology FW8019	78-08-14	78-08-30	R/V Commando	Lynne Krasnow (work leader) Kenton Wohl (field assistant)
Seawatch FW8017	78-07-15	78-07-18	Outer Right Cape	Lynne Krasnow (work leader) David Wiswar (field assistant)
Seawatch FW8017	78-07-28	78-07-30	Outer Right Cape	Lynne Krasnow (work leader) David Wiswar (field assistant)
Seawatch FW8018	78-08-08	78-08-10	Outer Right Cape	Douglas Forsell (work leader) Claudia Voss (field assistant)

Table 1. Ship and Field Trip Schedules and Scientific Party (cont'd.)

FIELD OPERATION	BEGIN DATE	END DATE	PLATFORM	USFWS PERSONNEL
Seawatch FW8019	78-08-25	78-08-27	Outer Right Cape	Douglas Forsell (work leader) Patricia Baird (field assistant)
Shipboard Survey FW8016	78-06-20	78-07-07	NOAA Ship Miller Freeman	Juan Guzman (work leader) Univ. of Calgary, Canada
Foraging Ecology FW8023	78-08-04	78-08-04	Small Boat	Robert Jones (work leader) Gerry Sanger (field assistant)
Foraging Ecology FW8027	78-08-03	78-08-03	Small boat	Robert Jones (work leader)
Foraging Ecology FW8028	78-09-04	78-09-04	Small boat	Robert Jones (work leader)

Table 2. Data Collected During 1978 Colony Studies.

Black-legged Kittiwake

Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitkalidak Straits
Population Census	X[2]	X	X	X
Chronology[1]	180 nests	155 nests	61 nests	121 nests
Productivity[1]	180 nests	147 nests	171 nests	121 nests
Growth[1]	30 chicks	2 chicks	53 chicks	24 chicks
Food Samples[1]	45	5	0[2]	35
Habitat Use	+[2]	+	+	X

Tufted Puffin

Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitkalidak Straits
Population Census	X	0	0	X
Chronology[1]	40 nests	0	46 nests	103 nests
Productivity[1]	0	0	46 nests	103 nests
Growth[1]	10 chicks	0	37 chicks	16 chicks
Food Samples[1]	16	0	0	27
Habitat Use	+	0	+	X

Table 2. Data Collected During 1978 Colony Studies (cont'd.)

Glaucous-Winged Gull

Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitkalidak Straits
Population Census	+	+	X	X
Chronology[1]	67 nests	+	38 nests	117 nests
Productivity[1]	67 nests	0	35 nests	117 nests
Growth[1]	0	0	0	30 chicks
Habitat Use	+	+	+	X
Food Samples[1]	0	0	0	61

Horned Puffin

Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitkalidak Straits
Population Census	0	+	0	+
Chronology[1]	0	30 nests	0	+
Productivity[1]	0	30 nests	0	+
Growth[1]	0	30 chicks	0	0
Food Samples[1]	0	1	0	0
Habitat	0	+	0	+

Table 2. Data Collected During 1978 Colony Studies (cont'd.)

Common Murres				
Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitkalidak Straits
Population Census	X	X	0	0
Chronology[1]	399 chicks	10 chicks	0	0
Productivity[1]	0	0	0	0
Growth[1]	Fledging condition	0	0	0
Food Samples	0	0	0	0
Habitat Use	+	+	0	0

Pelagic Cormorant				
Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitakalidak Straits
Population Census	X	0	X	X
Chronology[1]	60 nests	0	28 nests	+
Productivity[1]	100 nests	0	135 nests	+
Growth[1]	0	0	0	0
Food Samples	5	0	0	0
Habitat Use	+	0	+	+

Table 2. Data Collected During 1978 Colony Studies (cont'd.)

Rhinoceros Auklet

Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitkalidak Straits
Population Census	+	0	+	0
Chronology[1]	30 nests	0	0	0
Productivity[1]	0	0	0	0
Growth[1]	0	0	0	0
Food Samples	72	0	0	0
Habitat Use	+	0	+	0

Red-faced Cormorant

Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitkalidak Straits
Population Census	X	0	X	+
Chronology[1]	0	0	+	+
Productivity[1]	0	0	40 nests	+
Growth[1]	0	0	0	0
Food Samples	0	0	0	0
Habitat Use	+	0	+	+

Table 2. Data Collected During 1978 Colony Studies (cont'd.)

Mew Gull

Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitkalidak Straits
Population Census	0	0	X	+
Chronology[1]	0	0	40 nests	+
Productivity[1]	0	0	40 nests	0
Growth[1]	0	0	0	0
Food Samples	0	0	0	0
Habitat Use	0	0	+	0

Common Eider

Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitkalidak Straits
Population Census	0	+	+	0
Chronology[1]	0	+	20 nests	0
Productivity[1]	0	+	20 nests	0
Growth[1]	0	0	0	0
Food Samples	0	0	0	0
Habitat Use	0	+	+	0

Table 2. Data Collected During 1978 Colony Studies (cont'd.)

Arctic Tern

Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitkalidak Straits
Population Census	0	0	X	X
Chronology[1]	0	0	108 nests	51 nests
Productivity[1]	0	0	63 nests	51 nests
Growth[1]	0	0	0	56 chicks
Food Samples	0	0	0	10
Habitat Use	0	0	+	X

Aleutian Tern

Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitkalidak Straits
Population Census	0	0	X	X
Chronology[1]	0	0	106 nests	53 nests
Productivity[1]	0	0	13 nests	53 nests
Growth[1]	0	0	0	30 chicks
Food Samples	0	0	0	12
Habitat Use	0	0	+	X

Table 2. Data Collected During 1978 Colony Studies (cont'd.)

Black Oystercatcher

Data Type	Middleton Island	Chisik Island	Chiniak Bay	Sitkalidak Straits
Population Census	X	+	X	+
Chronology[1]	0	1 nest	14 nests	+
Productivity[1]	0	+	14 nests	0
Growth[1]	0	0	0	0
Food Samples	0	0	0	0
Habitat Use	+	+	+	0

[1]Sample sizes given in this table are only close approximations. Exact values will not be available until the data has been sorted and analyzed.

[2]X = Samples Taken
+ = General Observations Taken
0 = No Data

Table 3. Breeding Success of Black-legged Kittiwakes in the Gulf of Alaska in 1978.

Breeding Parameter	Colonies			
	Chiniak	Sitkalidak	Middleton	Chisik
Number of Nests Built	259	121	180	155
% Nests Built Containing Eggs	0.66	0.54	0.81	0.75
Mean Clutch Size	1.72	1.15	1.94	1.56
% Nests with Eggs Hatching 1 or More Egg	77.2	43.0	70.3	25.5
% Chicks Hatched Per Egg Laid	0.72	0.49	0.63	0.13
% Chicks Fledged Per Chick Hatched	0.93	0.52	0.14	0.09
Number of Chicks Fledged Per Nest Containing Eggs	1.16	0.31	0.17	0.02
Number of Chicks Fledged Per Nest Built	0.77	0.17	0.15	0.01

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

Quarterly Report

30 September 1978

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

Principal Investigators

Alan M. Springer
David G. Roseneau

Renewable Resources Consulting Services, Ltd.
3670 Geraghty, Suite F
Fairbanks, Alaska 99701

Summary of Second Quarter Operations

The majority of our field work occurred during the second quarter. A one day visit was made to Cape Thompson on 4 July. Cape Lisburne was visited from 5 July to 13 July and a field party of two returned to Cape Lisburne on 22 July and remained there until 22 August. A second party of 2 people worked at Cape Thompson from 12 August to 24 August. A final one day visit was made to Cape Thompson on 17 September.

In cooperation with Bill Drury and the Arctic Project Office, we flew aerial transects on 25-29 July and 18-19 August. The flights were made in a Cessna 336 chartered from Don Olson in Golovin. We intended to use the aerial transects to establish areas where seabirds were feeding and the flights were planned to coincide with arrival of the vessel Natchik out of Barrow. Marine sampling of the waters within which birds were found feeding was planned as well as sampling in areas not being utilized by seabirds in an attempt to determine both physical and biological characteristics of waters which appear to be relatively highly productive. Unfortunately the Natchik ran aground at Wainwright and the remainder of that cruise had to be scratched. None the less, the aerial transects proved valuable in determining areas of important feeding habitat for seabirds at the two colonies. We were able to refine our estimates of murre and kittiwake feeding areas which we had made from observations of the directions bird took when flying to and from the colonies. We have not yet completed our analysis of the data obtained during those flights, however, it appears that murres at Cape Lisburne may feed as far as 125 km to the northeast of the colony and murres at Cape Thompson may feed an equal distance to the south and southeast of that colony.

Almost without exception the breeding season this summer was earlier than in 1977 and, in the case of murres at least, was earlier than in any other year for which we have data. The first seagoing of murres at Cape Thompson was observed on 13 August, the next earliest date being 18 August in 1960.

We did not count murres at Cape Thompson but limited counts at Cape Lisburne suggested no major change in the population between 1977 and 1978. The number of kittiwakes at Cape Thompson, Cape Lisburne and Cape Lewis, however, did change appreciable between the two years. At both Cape Thompson and Cape Lisburne kittiwake populations may have been as much as 13-15 per cent higher than last year while at Cape Lewis the population may have been at least 35 per cent higher than in 1977. Productivity of kittiwakes at these colonies was also higher than in 1977, a greater number of breeding pairs had on an average larger clutches and larger broods of young.

These observations indicated that some factor or a combination of factors were particularly favorable for seabird nesting this summer. Spring came unusually early and the ice went out nearly a month earlier than in 1977. The resulting open water, therefore, provided an enlarged feeding area near the cliffs during the early phases of the breeding cycle and probably helped promote the success of the effort. The food base upon which murres and kittiwakes depend also seemed to be larger than in 1977. Sand Launce appeared to be abundant throughout the summer at least from early July on, as did cod and invertebrates, principally decapods and amphipods.

This summer we also saw a relatively large number of "unusual" birds at Cape Lisburne. We saw at least 6 individual murres in winter plumage, at least two individual kittiwakes in a plumage which was neither adult nor juvenile but was characterized by a grey hood just above the nape, and a guillemot in winter plumage. We also observed at least two kittiwakes with grey hoods at Cape Thompson. We had not seen any birds similar to those in previous years either at Cape Thompson or Cape Lisburne, however, Swartz reported murres in winter plumage at Cape Thompson in 1960. We believe that the factors which resulted in the early and productive season may also have been responsible for the presence of these atypical birds.

Estimate of Funds Expended

Total Budget:	$112,423.00
Expenses through 31 August 1978:	109,154.57
Balance:	$3,268.43

QUARTERLY REPORT

Contract No. - 03-78-B01-31

Research Unit No. - 467

Reporting Period - 1 July - 30 September 1978

Number of Pages - 7

Project Director	Joe C. Truett, Ph.D. LGL Limited - U.S., Inc. 103-A Pleasant Street BRYAN, Texas U.S.A. 77801
PI, Invertebrates	William B. Griffiths, M.Sc. LGL Limited 10110 - 124 Street EDMONTON, Alberta T5N 1P6
PI, Aquatic Ecology	Peter C. Craig, Ph.D. LGL Limited 53 Howard Avenue NANAIMO, British Columbia V9R 3P9
PI, Avian Ecology	Stephen R. Johnson, Ph.D. LGL Limited 10110 - 124 Street EDMONTON, Alberta T5N 1P6

BEAUFORT SEA BARRIER ISLAND-LAGOON ECOLOGICAL PROCESS STUDIES

I. Highlights

Field research, which commenced in June of last quarter from the Milne Point field camp at Simpson Lagoon, continued until the last week of this quarter. Field research efforts included sampling in nearshore habitats for fish and benthic invertebrates, measuring physical characteristics of the water at these sampling sites, surveying island and mainland habitats for nesting birds, and surveying coastal waters for waterfowl in the vicinity of Simpson Lagoon and east to Demarcation Point.

II. Task Objectives

This program was originated to design and carry out a series of integrated ecological process studies in a barrier island-lagoon ecosystem on Alaska's Beaufort Sea coast. The program's broad objectives are to:

(1) Identify and analyze the importance of selected ecosystem components and processes contributing importantly to the structure and productivity of nearshore ecosystems.

(2) Evaluate the feasibility of detecting and quantifying temporal change in those ecosystem components and processes identified as important.

(3) Identify mechanisms by which those components and processes could be tested for their sensitivity to man-caused change, and, therefore, for their utility in predicting and analyzing impacts of OCS petroleum development.

This program is being implemented in conjunction with the research efforts of OCSEAP Research Units No. 526, 527, 529, 530, and 531, (nutrient dynamics, oceanography, geomorphology, and sedimentology). It is the responsibility of LGL Limited to conduct studies in aquatic ecology and ornithology, to administer the integration of the above Research Units into the entire barrier island-lagoon program, and to synthesize information from all related research disciplines to make a final assessment of petroleum development impact on the nearshore ecological processes of the Beaufort Sea.

Ecosystem modeling during the course of the program functions to create a common base for communication among PI's, program managers, and NOAA and BLM coordinators. Each stage of computer simulation of the geophysical and biological processes in the barrier island-lagoon system represents the current level of understanding. In successive interdisciplinary workshops investigators critically examine each research effort in light of data gaps revealed through in-depth workshop discussions and through evaluations of key processes represented by the model.

Specific task objectives of RU 467 are as follows:

(1) To clarify the food web and energy flow processes (to include all trophic levels from the ultimate food base to the key bird and fish species) which support important vertebrates in the barrier island-lagoon system.

(2) To assess food sources and feeding dependencies of fishes and invertebrates in lagoon and nearshore marine waters.

(3) To document movements and residency behavior of fish and invertebrates in the lagoon habitat.

(4) To characterize the manner in which selected bird species utilize the barrier island-lagoon system for feeding, resting, nesting and/or molting.

(5) To describe the feeding and habitat dependencies of the bird and fish species studied as these dependencies may be disrupted by OCS-related development.

(6) To evaluate the importance of microhabitat features (which may potentially be altered by petroleum development activities) to the breeding and feeding activities of birds and fish.

(7) To determine locations and mechanisms of over-wintering (as opposed to annual recolonization) by fish and invertebrates.

(8) To evaluate feeding dependencies and habitat use by arctic foxes as these relate to other elements of the biological community.

(9) To document the dependencies of biotic communities on coastal dynamics, geochemical processes, and nearshore circulation patterns through active coordination with Research Units No. 526, 527, 529, 530, and 531.

III. Activities

A. Field Work, Laboratory Analyses, Workshops

The following types of research activities were performed during this quarter:

(1) Samples of invertebrates were taken by several methods at stations near the mainland, on landward and seaward sides of the barrier island chain, in mid-lagoon, and in lagoon entrances between islands. Gill nets, fyke nets, beach seines, and purse seines were used for sampling fish in waters in and near the lagoon. Temperature and salinity were routinely measured as these invertebrate and fish samples were being taken. Samples of water were also taken periodically at these stations for subsequent nutrient analysis by Don Schell of RU 527.

(2) Invertebrate samples taken were examined to determine their general composition, then preserved for more thorough analysis at a later date. Appropriate samples of all fish caught were measured, otoliths of some were excised for subsequent aging of the fish, and stomachs of some were removed and preserved for later analysis.

(3) Rectangular plots established on the barrier islands and on the nearshore mainland were searched for nesting birds so that bird nesting densities by habitat type could be estimated. Daily watches were made during a portion of the quarter for birds moving through or into the area to help evaluate the extent to which migrating and feeding birds used the lagoon and adjacent land areas. Aerial surveys were conducted in the Simpson Lagoon and Harrison Bay areas and eastward to Demarcation Point to determine the distribution and density of waterfowl (primarily oldsquaw) by habitat type and location along the coast.

(4) Detailed laboratory analyses of samples of invertebrates and of fish and bird stomachs commenced in August. These analyses included species identifications, composition by biomass, and life history interpretations.

B. Scientific Party

The scientists involved in this program and their roles and affiliations are listed below.

Name	Affiliation	Project Role
Joe Truett, Ph.D.	LGL Limited - U.S., Inc.*	Project Director
Peter Craig, Ph.D.	LGL Limited **	PI, Aquatic Ecology (fish)
William Griffiths, M.Sc.	LGL Limited ***	Aquatic Ecology (invertebrates)

B. Scientific Party (cont'd)

Name	Affiliation	Project Role
Lewis Haldorson, Ph.D.	LGL Limited - U.S., Inc.*	Aquatic Ecology (fish and invertebrates)
Howard McElderry, B.S.	LGL Limited - U.S., Inc.*	Aquatic Ecology (fish and invertebrates)
Stephen Johnson, Ph.D.	LGL Limited ***	PI, Avian Ecology
Robert Dillinger, B.S.	LGL Limited ***	Laboratory Analysis (invertebrates)

* 103-A Pleasant Street, Bryan, Texas 77801

** 53 Howard Avenue, Nanaimo, British Columbia V9R 3P9

*** 10110 - 124 Street, Edmonton, Alberta T5N 1P6

C. Methods

General methods used for the several areas of research this quarter are presented below:

Research Activity	Methods
Collecting epibenthic invertebrates	Drop nets, air lifts, hand nets, otter trawl, epibenthic trawl, baited traps
Sampling epibenthos in lagoon entrances between islands	Drift nets
Collecting fish	Gill nets, fyke nets, beach seine, purse seine
Measuring water temperature and salinity profiles	Hydro-lab
Collecting water samples for nutrient analysis	Messenger-activated water sampling bottle; freezing of samples for storage
Laboratory analyses of invertebrates and fish and bird stomach samples	Included in analyses are species identifications, percent composition by biomass, and size classes of selected species (for life history determinations).

C. Methods (cont'd)

Research Activity	Methods
Estimating nesting bird densities	Searches of permanent rectangular plots
Evaluating local bird movement and habitat use	Standardized watches with binoculars and telescope; opportunistic observations
Surveys of waterfowl distribution and abundance	Aerial survey by fixed-wing aircraft

D. Sample Localities

All fish and invertebrate samples were collected in or near Simpson Lagoon. Bird surveys were made in nearshore waters in the vicinity of Simpson Lagoon and Harrison Bay as well as eastward to the Canadian border. Bird surveys were also made on the barrier islands and on the nearshore mainland.

E. Data Analyzed

Data collected in 1978 have not been analyzed to date; commencement of analysis is expected to occur next quarter.

IV. Results

Results from the sampling program this quarter are preliminary and should at this point be viewed as unsubstantiated by critical analysis. Important hypotheses proposed as a consequence of the sampling efforts performed, and which will be tested as data are analyzed, include the following:

(1) The lagoon appears to be an overwintering area for amphipods (mainly *Onisimus* sp.), bivalves, polychaetes and isopods but not for mysids.

The area was recolonized by mysids in early summer, first along open water leads near the mainland and island shores and then the central portions of the lagoon as the ice cover disintegrated.

Seasonal amphipod and mysid abundance and biomass showed similar patterns to those reported in 1977 except that the number of mysids in the system this year declined rapidly after mid-August; this was not evident in 1977.

(2) Generally, anadromous fish species collected in 1978 and their patterns of movements were similar to those found in 1977. The one major exception to this was a run of pink salmon (*Oncorhynchus garbuscha*) which moved through the system in early August.

The marine fish species collected were similar to those reported in 1977. The main difference was the drastic increase in the number of arctic cod (*Boreogadus saida*) moving through the system. This large run started in mid-August and continued into September.

(3) Nesting densities of most birds, as well as diversity of bird species, appeared to be higher on the mainland tundra adjacent to the lagoon than they were on the tundra-covered islands. Exceptions to this trend were the high densities of glaucous gulls found on a few of the islands bordering Simpson Lagoon. (Glaucous gulls were not found nesting on the mainland study plots.)

(4) Aerial and shoreline surveys conducted during 1978 indicated that, similar to 1977, oldsquaws and red and northern phalaropes were the key species present in the study area. Surveys of shoreline transects, which were conducted once during each 5-day period, indicated that the densities of phalaropes in the study area were lower than during 1977. Aerial surveys, conducted once during each 10-day period, covered a more extensive area of coastline during 1978, compared with 1977. Although Simpson Lagoon (and adjoining Gwydyr Bay) remained as an important area for large numbers of oldsquaws during 1978, areas farther east, especially Foggy Island Bay and Jago and Beaufort Lagoons also supported large numbers of this species.

(5) It appears that bivalves (clams) comprised a larger proportion of oldsquaw diets than was the case in 1977; however, mysids and amphipods remained the primary source of food for oldsquaws in Simpson Lagoon. Indications are that copepods remained the major taxon consumed by phalaropes in 1978.

(6) The density of lemmings in the study area remained exceedingly low for the second consecutive year. Possibly related to this feature, no foxes were recorded on any of the Jones Islands during 1978, and the number of nesting common eiders, arctic terns and glaucous gulls recorded on the barrier islands greatly increased during 1978 compared with 1977, when at least one fox was present on each island of the Jones Islands chain.

V. Preliminary Interpretation of Results

Interpretation of the results of this quarter's research in more detail than is given in IV above is not presented at this time.

VI. Auxiliary Material

None submitted.

VII. Problems Encountered/Recommended Changes

No major problems have been encountered. There are no recommended major changes in research objectives.

VIII. An estimated 60% of 1978 project funds has been expended.

RECEPTORS (BIOTA)

Marine Fish

Contents

553	Rabin, D. Rogers, D.	Univ. of Wash. Seattle, WA	Seasonal Composition and Food Web Relationships of Marine Organisms in the Nearshore Zone of Kodiak Island-Including Ichthyoplankton, Meroplankton, Forage Fishes, Marine Birds and Marine Mammals. Part A: A Report on the Ichthyoplankton Component of the Study	239

QUARTERLY REPORT

Contract: 03-5-022-56
Research Unit: #5
Task Order: #15
Reporting Period: 7/01/78-9/30/78
Number of Pages: 24

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

Principal Investigator
Dr. Howard M. Feder

with

Joan Forshaug, Karl Haflinger, Max Hoberg, Stephen C. Jewett,
Kris McCumby, Grant Matheke, Randy Rice, John Rose,
A. J. Paul, Judy McDonald, Phyllis Shoemaker.

Institute of Marine Science
University of Alaska
Fairbanks, Alaska

September 1978

TABLE OF CONTENTS

KODIAK SHELF

I. TASK OBJECTIVES

A. Preliminary observations of biological interrelationships, specifically crab and shrimp trophic interrelationships, between selected segments of the benthic biota.

B. A qualitative and quantitative inventory of dominant epibenthic species within and near identified oil-lease sites.

C. A description of spatial distribution patterns of selected species within and near identified oil-lease sites.

II. FIELD AND LABORATORY ACTIVITIES

A. Trawl cruise 19 June-9 July 1978 *via* the NOAA Ship *Miller Freeman*.

1. Scientific party - Stephen C. Jewett and William Kopplin, Institute of Marine Science (IMS), responsible for collection of all benthic invertebrate data and feeding data.

2. Methods - Samples were obtained *via* a 400-mesh otter trawl and a 36 X 91 cm pipe dredge.

3. Sample locality - Continental Shelf north, east and south of Kodiak Island.

4. Data Collection - Tows were made at 16 stations and a pipe dredge was taken at 13 stations. Miscellaneous invertebrates were recorded at all stations. Stomachs were examined from 190 Pacific cod (*Gadus macrocephalus*), 189 yellow Irish lords (*Hemilepidotus jordani*), 72 great sculpins (*Myoxocephalus polyacanthocephalus*), 156 flathead sole (*Hippoglossoides elassodon*), 94 rock sole (*Lepidopsetta bilineata*), 31 sablefish (*Anaplopoma fimbria*), 20 Atka mackerel (*Pleurogrammus monopterigius*), and 18 arrowtooth flounders (*Atheresthes stomias*). A total of 191 king crabs, 167 snow crabs, and approximately 1000 pink shrimps were collected for stomach analysis.

B. Trawl cruise 9-21 July 1978 *via* M/V *Yankee Clipper* and R/V *Commando*.

1. Scientific party - Max K. Hoberg, IMS, responsible for collection of all benthic invertebrate data.

2. Methods - Samples were obtained *via* a 20 foot try-net on the *Yankee Clipper* and *via* a 400-mesh otter trawl on the *Commando*.

3. Sample locality - Izhut and Kiliuda bays of Kodiak Island.

4. Data Collection - Izhut Bay: 17 tows were made from the *Yankee Clipper* as well as four tows from the *Commando*. In addition to obtaining invertebrate catch data from each tow, 158 snow crabs (*Chionoecetes bairdi*), 18 king crabs (*Paralithodes camtschatica*), and two quarts of pink shimps (*Pandalus borealis*) were taken for stomach analysis.
Kiliuda Bay: Seven tows were made from the *Yankee Clipper* as well as three tows from the *Commando*. A total of 222 snow crabs, 72 king crabs, and one quart of pink shrimps were collected for stomach analysis.

C. Trawl cruise 8-23 August 1978 *via* the M/V *Yankee Clipper* and the R/V *Commando*.

1. Scientific party - John R. Rose, IMS, responsible for collection of all benthic invertebrate data.

2. Methods - Samples were obtained *via* a 20 foot try-net on the *Yankee Clipper* and *via* a 400-mesh otter trawl on the *Commando*.

3. Sample locality - Izhut and Kiliuda bays of Kodiak Island.

4. Data collection - Izhut Bay: A total of 14 tows were made from the *Yankee Clipper* as well as three tows from the *Commando*. In addition to obtaining invertebrate catch data, 31 snow crabs, 20 dungeness crabs (*Cancer magister*), one king crab, and 300 pink shrimps were collected for stomach analysis. Fourteen large sunflower sea stars (*Pycnopodia helianthoides*) were examined in the field for food contents.
Kiliuda Bay: Seven tows were made from the *Yankee Clipper* as well as three tows from the *Commando*. Forty-four king crabs and 61

snow crabs stomachs were taken for analysis; 20 Pacific cod and 20 walleye pollock (*Theragra chalcogramma*) stomachs were examined for contents in the field.

D. Laboratory activity: Invertebrates taken by trawl from the 7-15 May, 7-22 June, 19 June-9 July, 9-21 July, and 8-23 August cruises have been verified. Stomachs of king crabs and snow crabs were also examined. Pink shrimps were stored for examination in FY 1978-79.

III. RESULTS

1. All trawl data are in process of organization for key punching.

2. To date, the following stomachs have been collected and examined: king crabs 653 collected - 250 examined; snow crabs 1216-307; dungeness crabs 37-0; pink shimps ≈ 200-0; yellow Irish lord 228-228; great sculpin 94-94; Pacific cod 234-234; flathead sole 156-156; rock sole 117-117; arrowtooth flounder 18-18; sablefish 31-31; Atka mackerel 20-20; walleye pollock 20-20; and the sunflower sea star 163-163.

IV. PRELIMINARY INTERPRETATION OF RESULTS

Data collected during the past quarter will aid in fulfilling the task objectives.

The food of king and snow crabs appears to be dominated by polychaete worms, snails, and clams. A quantitative interpretation of most of the results will be available once all crab and shrimp feeding data have been analyzed.

Food of all fishes and the sunflower sea star were examined in the field by the frequency of occurrence method. Dominating foods within each species were: Yellow Irish lord - polychaetes, snow crabs, hermit crabs, and pea crabs; great sculpin - pink shrimps, snow crabs, and unidentified fishes; Pacific cod - snow crabs and pink shrimps; flathead sole - pink shrimps; rock sole - polychaetes, protobranch clams (*Yoldia* spp.), and brittle stars; arrowtooth flounders - walleye pollock; sablefish and Atka mackerel - sand lance; walleye pollock - pink shrimps; and the sunflower sea star - snails (*Oenopota* sp. and *Solariella* sp.), and the clam *Nuculana fossa*.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

Biological sampling by IMS on Leg IV of the NOAA Ship *Miller Freeman* (19 June–9 July) was conducted on a "not-to-interfere basis". As a result, two biologist spent 21 days collecting data from only 16 stations; eight of which were sampled in the last four days. Furthermore, the ships overtime funds for the fishing crew were nearly exhausted, and consequently, trawling from 19 June to 1 July was limited to only 8 hours per day.

Another problem on Leg IV centered around the gear. The trawl drum was being repaired in Seattle. The lack of this piece of gear also reduced the time available for trawling. Only two 400-mesh otter trawls were available for trawling — both of which were badly worn and constantly needed repair. These problems, in addition to those outlined in the previous Quarterly Report (June 1978), have made biological sampling on the Kodiak shelf, as required by RU 5, less than adequate.

It is suggested that collection of data on a "not-to-interfere basis" or "piggy-back operation" be thoroughly examined, by way of meetings with all concerned parties, in future planning. Care must be taken to see that the objectives established by each participating research group are met.

BERING SEA AND GULF OF ALASKA

I. TASK OBJECTIVES

A. Inventory and census of dominant species

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

C. Provide comparisons of dominant species distribution with physical, chemical and geological factors as appropriate.

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

II. FIELD AND LABORATORY ACTIVITIES

A. Grab Program

1. No cruises were scheduled for the Bering Sea this quarter.

2. A cruise to Port Etches, Zaikof and Rocky Bays, adjacent to Hinchinbrook Entrance to Prince William Sound, was accomplished in Northeast Gulf of Alaska (NEGOA) on the M/V *Searcher* 27 July-8 August 1978.

   a. Scientific party - Howard M. Feder and Max Hoberg, IMS.

   b. Methods - samples were obtained *via* van Veen grab; samples were washed by standard methodology (see past Annual and Quarterly OCSEAP reports by Howard M. Feder).

3. Final organization of the NEGOA Final Grab Report occupied much of this quarter.

B. Trawl Program

1. No cruises were scheduled for the Bering Sea this quarter.

2. A cruise to Port Etches, Zaikof and Rocky Bays was accomplished in NEGOA on the M/V *Searcher* 27 July-8 August 1978.

   a. Scientific party - Howard M. Feder and Max Hoberg, IMS.

b. Methods - samples were obtained *via* a small otter trawl (try-net).

3. Organization of the NEGOA Final Trawl Report occupied much of this quarter.

III. RESULTS

Grab and Trawl Programs

1. The final Bering Sea Trawl Report was submitted to OCSEAP at the beginning of this quarter.

2. The Final NEGOA Grab Report is now in final draft form. Drafting is essentially complete.

3. The Final NEGOA Trawl Report was submitted to OCSEAP at the end of this quarter.

4. The Bering Sea Final Report on the infauna is in the final stages of completion.

5. A thesis tentatively entitled "A Numerical Analysis of the Distribution of the Benthic Infauna of the Southeastern Bering Sea Shelf" is in the final stages of completion. This thesis will be submitted as part of the Bering Sea Final Infauna (Grab - Pipe Dredge - Clam Dredge) Report.

6. A total of 14 try-net tows were made in Port Etches, 11 tows in Zaikof Bay and seven tows in Rocky Bay. Six grab stations were occupied in Port Etches; time did not permit grab stations in Zaikof and Rocky Bays.

IV. PRELIMINARY INTERPRETATION OF RESULTS

General interpretations of grab and trawl data are included in the 1976, 1977, and 1978 Annual Reports, the NEGOA, Norton Sound-Chukchi Sea and Bering Sea Final Reports, and in Institute of Marine Science Technical Report R76-8 submitted by H. Feder and his research group. Additional comments on Grab and Pipe-dredge data and food relationships will be included in the appropriate Final Reports.

V. PROBLEMS ENCOUNTERED

No direct problems.

With the exception of the food data collected from Port Etches, Zaikof Bay and Rocky Bay - three areas adjacent to Hinchinbrook Entrance, Prince William Sound - we have essentially no invertebrate food data from the northeast Gulf of Alaska (NEGOA), and Bering Sea food data is spotty. I would strongly suggest that further data on food habits of invertebrates and fishes in these regions be collected in the near future if oil-related activities are initiated in either area.

Any cruises accomplished in the future offshore in NEGOA or outside of Hinchinbrook Entrance should be planned on vessels designed to operate with safety in these unpredictable waters. NOAA vessels and selected, large commercial fishing boats are appropriate.

LOWER COOK INLET

I. TASK OBJECTIVES

A. Inventory and census of dominant species.

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

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

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

II. FIELD AND LABORATORY ACTIVITIES

A. Field Activities

1. Two cruises, 12 July to 22 July (NOAA Ship *Miller Freeman*) and 13 August to 22 August (NOAA Ship *Surveyor*) have been completed. The following goals and activities were completed:

   a. Distribution and abundance data were collected from several established stations. A major nursery area for snow crab identified on previous cruises was reoccupied.

   b. Summer feeding data for snow crabs, king crabs, dungeness crabs, hermit crabs, pink shrimps, humpy shrimps, crangonid shrimps, and miscellaneous fishes were collected to compliment existing winter and spring data.

   c. Qualitative and quantitative benthic samples were collected from areas with major concentrations of snow crab. Prey abundance will be related to snow crab food preferences.

   d. Qualitative and quantitative benthic samples were collected in areas with major concentrations of clams.

e. Sediment samples were collected for Dr. Arnold Bouma of the Geologic survey, Menlo Park, California and for organic carbon and nitrogen analysis in Fairbanks.

f. Grab and trawl samples were collected from PMEL sediment trap stations and OSU Microbiology stations enabling integration with these studies. Species composition and abundance were recorded. Stomachs of common invertebrates were collected for analysis of prey species, sediment content and bacteria content.

g. Live clams and shrimps were collected for radioactive tracer experiments (see below).

h. Sediment samples and shrimp-gut contents were collected for preliminary work designed to assess bacterial biomass.

2. Surveys of shallow water macroinvertebrates were conducted during the summer of 1978 in Kachemak Bay/Lower Cook Inlet (Rick Rosenthal, Alaska Coastal Research, Subcontract). Subtidal investigations were carried out:

a. Along the broad shelf off Bluff Point and Anchor Point;

b. At the rocky entrance to Jakolof Bay;

c. Within the extensive kelp bed off Seldovia Point and,

d. On the soft bottom at the head of Sadie Cove.

Direct observations were made at each of these station while scuba diving from -2.0 m to about -18.0 m below the sea surface. Numerical information, e.g., frequency of occurrence, density, percent coverage etc., on the dominant or key species of macroinvertebrates living in each of these general study sites was collected from randomly placed transect lines and 1/4 m^2 quadrats. Samples of the macroinvertebrate population were also obtained for size distribution, aging and growth analysis. Other specimens were collected in order to delineate dietary trends and food habits.

B. Laboratory Activities

Data on the following subjects have been collected:

1. Detailed stomach analysis (species present, KOH and HCl digestible fractions of snow crabs, king crabs, dungeness crabs, hermit crabs, pink shrimps, humpy shrimps, and crangonid shrimps are underway.

2. Analysis of sediment content of stomachs of the above organisms was initiated.

3. Post-larval king crabs and juvenile dungeness crabs were collected by divers for detailed stomach analysis.

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

5. Dry tissue weights are being determined for organisms from grab samples to determine the relative importance of the major groups of infauna to standing stock.

6. Techniques to study the sediment-detrital system, utilizing radioactive (^{14}C) bacteria, are currently being explored. Live pink shrimps, coonstripe shrimps, crangonid shrimps, hermit crabs, and clams (*Macoma* spp.) are being utilized in these experiments. The objective of the research is to determine if these organisms have the ability to assimilate bacterial carbon.

7. A graduate thesis concerning the feeding biology of the sand shrimp, *Crangon dalli*, an important forage species for many benthic predators, has been initiated. This study will include:

    a. A detailed microscopic evaluation of the gut contents of the shrimp collected on Lower Cook Inlet cruises in 1978.

    b. Caustic alkali (KOH) and Hydrochloric Acid digestion of shrimp gut contents to determine the fraction of sediment and digestible organic content present.

    c. Radioactive tracer experiments to examine the importance of bacteria in the diet of *Crangon* (see 5 above).

d. Assessment of environmental parameters at selected stations where the shrimp is present.

7. Preliminary experiments designed to estimate bacterial biomass are in progress. Several methods are being assessed.

III. RESULTS

A. The 1978 field program is completed and collected specimens are now being examined in the laboratory. Data for the November 1977 and March 1978 cruises are now available for analysis, and are presently being evaluated for species compositon, KOH and HCl digestible fractions and sediment content. Examination of collections from cruises of May, June, July, and August 1978 are in progress.

B. An intensive effort has been made to examine the feeding habits of a variety of shrimps; this effort is being accomplished in parallel with the studies noted above that are primarily concerned with quantitative estimates of stomach contents.

1. A total of 557 specimens of shrimps of the Families Pandalidae (*Pandalus borealis, Pandalus goniurus, Pandalus danae, Pandalus hypsinotus*), Crangonidae (*Crangon dalli, Crangon communis, Crangon franciscorum, Sclerocrangon boreas*) and Hyppotytidae (*Lebbeus groenlandica*) from eleven stations from cruises of March, June, and July were examined. The shrimp were weighed, measured, and their stomach contents analyzed.

2. A list of the prey found in the stomachs of the above shrimp species has been compiled. The frequency of occurrence of the prey species contained in the stomachs was noted (see Table I for preliminary data). When possible, the quantity of the prey species in a stomach was determined.

C. Dry weights of aged clams (see Annual Report for 1978 by H. Feder for age data) are completed. Carbon analysis is in progress. Species examined were: *Spisula polynyma, Nuculana fossa, Tellina nuculoides, Glycymeris subobsoleta, Macoma calcarea, Nucula tenuis.* Productivity calculations for these species will be initiated when carbon values are determined.

TABLE I

ROUGH ESTIMATES OF THE FREQUENCY OF OCCURRENCE OF ITEMS IN SHRIMP STOMACHS FROM COOK INLET

Stations are those of Feder (see OCSEAP Annual Reports) or Lawrence (see OCSEAP Annual Reports)

Crangon dalli 50 specimens
C.I. St. 62B 11 June 78

- Diatoms - few
- Foraminifera - few
- Polychaeta - Common
- Bivalvia - few
- Crustacea - abundant
- Sediment - abundant

C. dalli 50 specimens
C.I. PMEL 1 14 July 78

- Diatoms - abundant
- Foraminifera - few
- Hydrozoa - few
- Nematoda - few
- Polychaeta - abundant
- Gastropoda - few
- Bivalvia - few
- Crustacea - common
- Holothuria - few
- Teleost - few
- Sediment - abundant

C. dalli 80 specimens
C.I. St. 53 Tr. 1 18 July 78

- Diatoms - common
- Foraminifera - few
- Nematoda - few
- Polychaeta - abundant
- Bivalvia - few
- Crustacea - few
- Sediment - common

C. dalli 27 specimens
C.I. St. 5 27 March 78

- Diatoms - few
- Foraminifera - few
- Polychaeta - common
- Bivalvia - few
- Crustacea - abundant
- Sediment - common

Sclerocrangon boreas 34 specimens
C.I. St. E 1 28 March 78

- Diatoms - common
- Foraminifera - few
- Polychaeta - common
- Polyplacophora - few
- Bivalvia - common
- Crustacea - common
- Sediment - abundant

S. boreas 16 specimens
C.I. St. 56A 29 March 78

- Diatoms - few
- Foraminifera - few
- Polychaeta - abundant
- Crustacea - common
- Polyplacophora - few
- Bivalvia - few

Crangon communis 20 specimens
C.I. St. 5 27 March 78

- Polychaeta - few
- Crustacea - few
- Sediment - common

Crangon franciscorum 8 specimens

- Crustacea - common

Lebbeus groenlandica 25 specimens
C.I. St. 56A 29 March 78

- Diatoms - few
- Foraminifera - few
- Porifera - common
- Polychaeta - few
- Gastropoda - few
- Crustacea - abundant
- Sediment - common

TABLE I

CONTINUED

Pandalus hypsinotus 20 specimens
C.I. St. 56A 29 March 78

- Diatoms - few
- Hydrozoa - few
- Polychaeta - abundant
- Bivalvia - common
- Crustacea - abundant
- Sediment - abundant

P. hypsinotus 32 specimens
C.I. St. 27 31 March 78

- Diatoms - few
- Foraminifera - few
- Polychaeta - common
- Bivalvia - few
- Crustacea - common
- Teleost - few
- Sediment - common

Pandalus goniurus 50 specimens
C.I. St. N2 28 March 78

- Foraminifera - few
- Bivalvia - few
- Crustacea - few
- Holothuroidea - few
- Sediment - common

P. goniurus 48 specimens
C.I. St. 37 31 March 1978

- Diatoms - few
- Foraminifera - few
- Polychaeta - few
- Bivalvia - few
- Crustacea - common
- Teleost - few
- Sediment - abundant

P. goniurus 30 specimens
C.I. St. 62A 30 March 78

- Diatoms - few
- Foraminifera - few
- Polychaeta - common
- Gastropoda - few
- Bivalvia - common
- Sediment - abundant

Pandalus danae 27 specimens
C.I. St. 56A 29 March 78

- Diatoms - few
- Foraminifera - few
- Porifera - few
- Hydrozoa - few
- Polychaeta - common
- Crustacea - common
- Sediment - abundant

Pandalus borealis 19 specimens
L.C.I. PMEL 7 13 July 78

- Diatoms - few
- Foraminifera - few
- Porifera - few
- Polychaeta - common
- Bivalvia - common
- Crustacea - abundant
- Teleost - few
- Sediment - abundant

P. borealis 21 species
C.I. St. 5 27 March 78

- Diatoms - few
- Foraminifera - few
- Polychaeta - common
- Bivalvia - few
- Crustacea - abundant
- Sediment - common

D. Release of larvae of pink shrimps, snow crabs, and king crabs in tanks at the Seward Marine Laboratory has made it possible to complete a series of experiments on food density and larval responses to these densities. These types of experiments had not been accomplished prior to this study, and should contribute to the understanding of the lower Cook Inlet system and its potential "response" to oil contamination. A report on these experiments is completed, and will appear in the Annual Report for 1978-79.

E. A rather modest effort has resulted in a general comprehension of methodologies needed to assay the bacterial biomass of sediments. Techniques examined to date are: assessment of viable counts in sediments, gram stain characteristics of sediment bacteria (necessary technique when indirect biomass assessment methods are used); and Muramic Acid assay-this is an indirect determination of biomass by assaying for Muramic Acid. The muramic acid assay methods of King and White (1977) and Casagrande and Park (1978) are being examined presently.

F. Radiotracer experimental data are currently being analyzed, and are not available at this time.

G. Preliminary diving studies in Kachemak Bay have resulted in the following:

1. Samples of subtidal populations of the horse mussel (*Modiolus modiolus*) were obtained from different geographical areas in Kachemak Bay. Size frequency data has been generated from these collections, and large numbers of individual *Modiolus* were preserved and shipped to the University of Alaska, Seward Marine Station, for preliminary examination of the growth rings in the shell. Average age of the mussels will be reported if feasible. Preliminary observations show that the *Modiolus modiolus* population in Kachemak Bay is strongly bimodal.

2. Dungeness crabs (*Cancer magister*) were captured by divers during daylight hours in the shallow waters of Sadie Cove. Attempts were made to capture different size (age) crabs engaged in various

modes of activity, i.e., walking, feeding, mating, and burrowing. These samples of the dungeness crab population in Sadie Cove were also transported to the Seward Marine Station for future examination of food items by University personnel.

3. Juvenile tanner crab (*Chionoecetes bairdi*) were obtained for food habit studies. Specimens were captured on the west side of Cook Inlet and from within the confines of Kachemak Bay. Most of the crabs have been preserved for future processing.

4. The shallow water assemblage of macroinvertebrates inhabiting the rocky shelf off Bluff Point/Anchor Point has been examined for community structure, estimation of relative abundance and trophic interaction between the conspicuous species. Shallow water random transect stations and 1/4 m^2 quadrats revealed some of the important members of the community to be: *Flustrella gigantea* (bryozoan); *Fusitriton oregonensis* (gastropod); *Strongylocentrotus* spp. (sea urchin); *Evasterias troschelli* (sea star); *Tonicella* spp. (chiton); *Cucumaria* spp. (sea cucumber); *Cancer oregonensis* (crab); *Neptunea* spp. (gastropod); *Balanus nubilus* (Barnacle); *Microporina borealis* (bryozoan); *Ritterella* ? spp. (ascidian) and *Modiolus modiolus* (mussel).

5. It appears from subtidal observations of this season that there has been a decline in the abundance of the horse mussel (*Modiolus modiolus*) off Bluff Point since studies in Kachemak Bay began in 1974 (Rosenthal and Lees, unpub. OCSEAP data). Densities of up to 57 mussels/m^2 were recorded for *Modiolus* in 1975-1976; however the average density at Bluff Point for the current year was probably closer to 15 individuals/m^2. During August (1978) we observed windrows of freshly killed *Modiolus* shells along the 10 fathom contour. Predation could possibly account for this dramatic decrease in the *Modiolus* population; however, more dives and samples will be needed to delineate the extent of reduction of the subtidal population.

IV. PRELIMINARY INTERPRETATION OF RESULTS

General interpretations of all initial data are included in the 1978 Lower Cook Inlet Annual Report. Additional comments on the work in progress, field studies and laboratory experiments will be included in subsequent Quarterly Reports and in the Annual Report for the 1978-1979 research period.

Gut content analyses of shrimps of lower Cook Inlet indicate that they are benthic feeders and that they are opportunistic in selection of prey. Bacterial biomass data, should it become available in the next research period, and ^{14}C assimilation experiments will help in the evaluation of potential importance of bacteria to these shrimps.

Of the 285 crangonid shrimps analyzed, from Cook Inlet, the major prey items appear to be polychaetous annelids and crustacean remains. Benthic and pelagic diatoms were common in stomachs. Protobranch clams (*Nucula, Nuculana, Yoldia*) made up the majority of the bivalves in stomachs, and often were almost intact (i.e., valves undamaged). Sediment was common in stomach contents (Table I).

Within the 247 pandalid shrimp stomachs analyzed, the major prey items were also polychaetes and crustacean remains. Protobranch clams commonly occurred in the stomachs. Some diatoms were present; however, they were not as common as in crangonid stomachs. Sediment was often found in stomach contents (Table I).

Of the 25 hippolytid shrimps examined, the dominant prey items were crustaceans, mainly small brachyuran crabs. Bivalves were not found in stomachs. Diatoms and polychaetes were less numerous in stomachs than they were in pandalids and crangonids. Porifera (sponge) spicules and hydrozoan (hydroid) fragments were commonly found. Sediment was often present in the stomachs (Table I).

The presence of deposit-feeding polychaetous annelids (Spionidae; Maldanidae; Ampharetidae; Terebellidae) and protobranch clams (*Nuculana* sp.; *Yoldia* sp.; *Nucula tenuis*) in the stomachs of pandalid and crangonid shrimps demonstrates the important indirect trophic relationship between sediment, with its associated organic carbon sources, and the two shrimp groups. A further relationship is the known importance of many of the shrimp species investigated as a food resource for bottom-feeding fishes and some crab species (see various Annual and Final Reports by Howard M. Feder and research group). The latter relationship further expands the importance of the interaction between sediment-deposit feeders-shrimps (and crabs)- and demersal fishes (Table I).

It has become increasingly apparent that bacteria play an important role in the carbon cycles of ecosystems and specifically in detrital food chains in the ocean (Fenchel and Jørgensen, 1977). A variety of aquatic invertebrates have been shown to utilize bacteria for their nutritional needs (Rieper, 1978). The distribution of certain deposit-feeding invertebrates has been related to bacterial numbers in the sediments (Dale, 1974).

There are many methodological problems associated with studying the numbers, biomass, and activity of sediment bacteria in nature, and the resolution of these problems is mandatory to understand sediment systems. A variety of methods, both direct and indirect, for determining bacterial biomass are currently being assessed. Much literature now exists on methodologies useful for measurement of bacterial biomass (see attached selected bibliography). Many of the methods have been adapted from those used in the water column. However, the nature of the sediment and the association of the bacteria with the sediment complicates the methodology. To date, no completely satisfactory method exists. It is assumed that a combination of methods will ultimately be used to characterize the sediment environment.

We examined several methods to measure biomass. Colony forming units were determined by plating on Zobell's 2216E Marine Agar, and were used as a gross estimate of biomass and also to supply colonies from various stations for gram stains. The gram stains were used to characterize the population for application in the indirect biomass assays. The muramic acid assay was chosen because of its specifity for prokaryotes and because it can be used on gut contents of detrital feeding animals with a minimal amount of interference from other substances (Moriarty, 1976; Moriarty, 1977).

Several authors (Moss, Diaz, Lambert, 1971; Casagrande and Park, 1978; Casagrande and Park, 1977) have suggested that gas-liquid chromatography can be used for the quantitative analysis of muramic acid. The technique has been applied to analysis of muramic acid in bog soil in the Okefenokee swamp by

Casagrande and Park (1978). This would suggest that a similar technique could be applicable in the analysis of marine-sediment. The procedure described by Casagrande and Park (1977 and 1978) consists of 3 main steps: (1) extraction of the soil by HCl; (2) derivation of the muramic acid by a silyation reaction to make a compound more easily volatilizable; and (3) analysis by gas-liquid chromatography. By use of a standard response curve to know amounts of muramic acid, quantification of unknown samples should be possible. The amount of muramic acid in a particular sample can then be used as an indicator of bacterial carbon/total C in that sample. It is planned to accomplish preliminary stages only of this analytical procedure during the balance of the present research period. It should be stressed that only very preliminary assessment of relevant techniques will be possible within the financial and time constraints of the present Research Unit (R.U. 5).

Not only are bacterial numbers important, but, the activity and, thus, turnover of the population is also important. Although there are some problems with measuring activity by using artificial substrates, nevertheless, if used with caution, this can be another means of describing bacterial populations (see Morita and Griffiths OCSEAP Reports for Methods and data for Cook Inlet).

Understanding the relative importance of sediment bacteria in specific areas and relating this importance to invertebrate distribution and the bacterial component in gut contents of detrital feeders should give a better understanding of detrital food chains in lower Cook Inlet.

V. PROBLEMS ENCOUNTERED

Basically the research program is going very well with very adequate ship time available during the past fiscal year. Both the NOAA Ships, *Surveyor* and *Miller Freeman*, proved to be excellent vessels in Cook Inlet to complete the field studies listed in our objectives (see 1978 proposal to NOAA). The laboratory and deck space on the *Miller Freeman* have been especially valuable to us, and have enabled us to expand all programs satisfactorily.

The one problem not anticipated on the NOAA Ship *Miller Freeman* concerns the expected availability of the ship's full trawling capability (based on our past cruises on this vessel) and the presence on shipboard of all facilities essential to process trawl material (again, based on our many past experiences on cruises with this vessel). We have been somewhat hampered in some areas by not being able to use a large trawl (always assumed to be ship's equipment), and instead had to use a very small try-net not designed to use on a large vessel. Thus, we have seldom been able to collect large samples of adult and juvenile snow and king crabs as planned.

The total absence of previous summer distribution data for snow and king crabs in relation to established stations also hampered the collection of these animals. The inability of the *Miller Freeman* and the *Surveyor* to enter shallow water bays precluded sampling in these areas.

As always on shipboard, it was difficult to maintain living benthic organisms for return to the Seward Marine Station. This problem was compounded when a "Touch and Go" for the NOAA in Seward could not be arranged initially. Fortunately, it was ultimately possible for a few brief port calls on occasion, and it was animals from these stopovers that were used in laboratory experiments. It is recommended that "Touch and Go" port calls be considered essential to projects requiring living material for OCSEAP experimental work.

As expected, evolving methodologies have delayed the output of data from important aspects of the experimental program, i.e. bacterial biomass analyses of sediment and stomach contents, and ^{14}C assimilation experiments with shrimps and clams. The very poorly funded and, thus, necessarily brief bacterial program carried on by this project will only result in suggestive procedures for the future. It is highly recommended that this very important aspect of the sediment system, the sediment-bacteria association (an association undoubtedly vulnerable to oil impact), be treated intensively in a Research Unit in the near future.

Milestones

It is intended to maintain a relatively consistent schedule of submission of Final Reports. Some of the report submission dates have been altered from that suggested in past Quarterly Reports. This is primarily related to the subdivision of the northeast Gulf of Alaska (NEGOA) and Bering Sea Reports into Grab-Pipe Dredge Trawl Reports. The completed and tentative completion dates for Final Report Submissions are as follows:

1. Kodiak (Alitak and Ugak Bays) - Completed and submitted
2. Norton Sound-Chukchi Sea - Completed and submitted
3. Cook Inlet (Report of First Two Years of Study) - Completed and submitted with the 1978 OCSEAP Annual Report
4. Bering Sea Trawl Report - Completed and submitted
5. NEGOA Trawl Report - Completed and Submitted
6. NEGOA Grab Report - October 1978
7. Bering Sea Grab and Pipe Dredge Report - November 1978

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QUARTERLY REPORT

NOAA-OCSEAP
Contract No. 03-5-022-68
Research Unit #6
Reporting Period: 1 July - 30 September 1978

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

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September, 1978

Andrew G. Carey, Jr.
Principal Investigator

I. Abstract

Laboratory research this quarter has included additional grab sample processing and the identification of large benthic macro-infauna (> 0.5 mm in size). Food web synthesis and invertebrate stomach analyses continue. A large amount of WEBSEC-71 polychaete data have been analyzed and the basic distributional data transmitted on magnetic tape to NODC. RU #6 participated in the 1978 USCGC NORTHWIND cruise; grab, trawl, box-core and epibenthic sled samples were taken for continued analysis of the Beaufort Sea food web and of the ecology of dominant prey organisms.

II. Task Objectives

A. General nature and scope of the study.

The ecological studies of the shelf benthos include functional, process-oriented research that is built on a strong base of descriptive work on ecological patterns and their relationship to the environment. Seasonal changes in the numerical abundance and biomass of the large macro-infauna (> 1.0 mm) are defined at stations across the continental shelf. The benthic food web and its relationship to bird, fish and mammalian predators are under investigation.

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

B. Specific Objectives

The major emphasis of the ongoing research (FY-78) is the delineation of the benthic food web and description of the coastal benthos. Efforts to characterize the composition of the Beaufort Sea fauna to the species level are continuing since this is a critical step toward understanding the dynamics of the benthic ecosystem.

1) <u>Objective 1 - Beaufort Sea benthic food web analysis</u>

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

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

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

2) Objective 2 - Beaufort Sea coastal benthos

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

3) Objective 3 - Benthic macro-infaunal ecology

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

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

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

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

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

III. Field and Laboratory Activities

A. Field activities - OCS 8.

1) Ship Schedule

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

2) Field Scientific Party (OSU Benthos)

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

3) Field Methods

a) Benthic macro-infauna (> 0.05 mm) were sampled by 0.1 m^2 Smith-McIntyre bottom grab at selected stations. Five to ten quantitative samples were obtained at each station to provide adequate estimates of quantitative variability and a sufficient number of species for description of the community composition. Several shallow stations were occupied from a hovering U.S. Coast Guard helicopter. The samples were washed on shipboard with 0.42 mm aperture screens to retain the macrofauna. The samples were temporarily preserved in 10% neutralized formalin and shipped back to Oregon for laboratory analysis. Subsamples for sedimentological analyses were taken from each grab and were stored deep-frozen.

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

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

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

4) Sample localities

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

B. Laboratory Activities

1. Laboratory personnel

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

Responsibilities: coordination, evaluation, analysis, and reporting

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

Responsibilities: data management [NB: Gish resigned from the position on 9 March 1978. Mr. Keniston was hired as a part-time temporary replacement until additional funds are awarded for FY-79 (?)].

c. Paul Montagna — Research Assistant

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

d. R. Eugene Ruff — Research Assistant

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

e. Paul Scott — Research Assistant

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

2. Laboratory Methods

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

3. Data Analyzed

a. Numerical density of macro-infauna.

Faunal densities for 21 grabs from PPB-25 and PPB-55 collection on OCS-4 (August 1976) are listed in Tables 4 through 8.

b. Biomass of macro-infauan.

Wet-preserved weights for 21 grabs from PPB-25 and PPB-55 collected on OCS-4 are summarized in Tables 9 through 13.

c. Systematics.

(1) Polychaete Species Identification

Species identification of polychaetous annelids collected on OCS-5 (August 1976) from the R/V ALUMIAK in water depths of 5 to 25 meters has continued throughout the quarter. A total of 42 species from 14 families have been examined and identified by R.E. Ruff. A summarization of polychaete families and species encountered is found on Table 14. Identifications will be verified with the cooperation of Dr. Kristian Fauchald of the University of Southern California.

(2) Pelecypod Mollusc Species Identifications

Pelecypod molluscs from OCS-1, OCS-2, and OCS-5 have been identified to species by P.H. Scott. This material includes 40 species from 18 families for a total of 2571 specimens examined. The bivalve species data, stations of occurrence and number of specimens encountered is listed on Table 15. All species have been verified by Dr. Frank Bernard of the Fisheries Research Board of Canada (Nanaimo, B.C.).

(3) Harpacticoid Copepod Species Identification

All harpacticoid copepods from the large macro-infaunal fraction (> 1.0 mm in size) from cruises OCS-1 through OCS-7 have been identified by P.A. Montagna. Table 16 summarizes the data for 41 harpacticoid species from 10 families which were collected on the OCS and WEBSEC-71 cruises. Identifications have been verified by Dr. Bruce Coull at the University of South Carolina.

4. Milestone Chart and Data Submission Schedule

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

   b. Explanation of schedule changes

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

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

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

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

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

IV. Preliminary Interpretation of Results.

As further accumulation of data is needed for some of the proposed objectives, an interpretation of results is premature at this time.

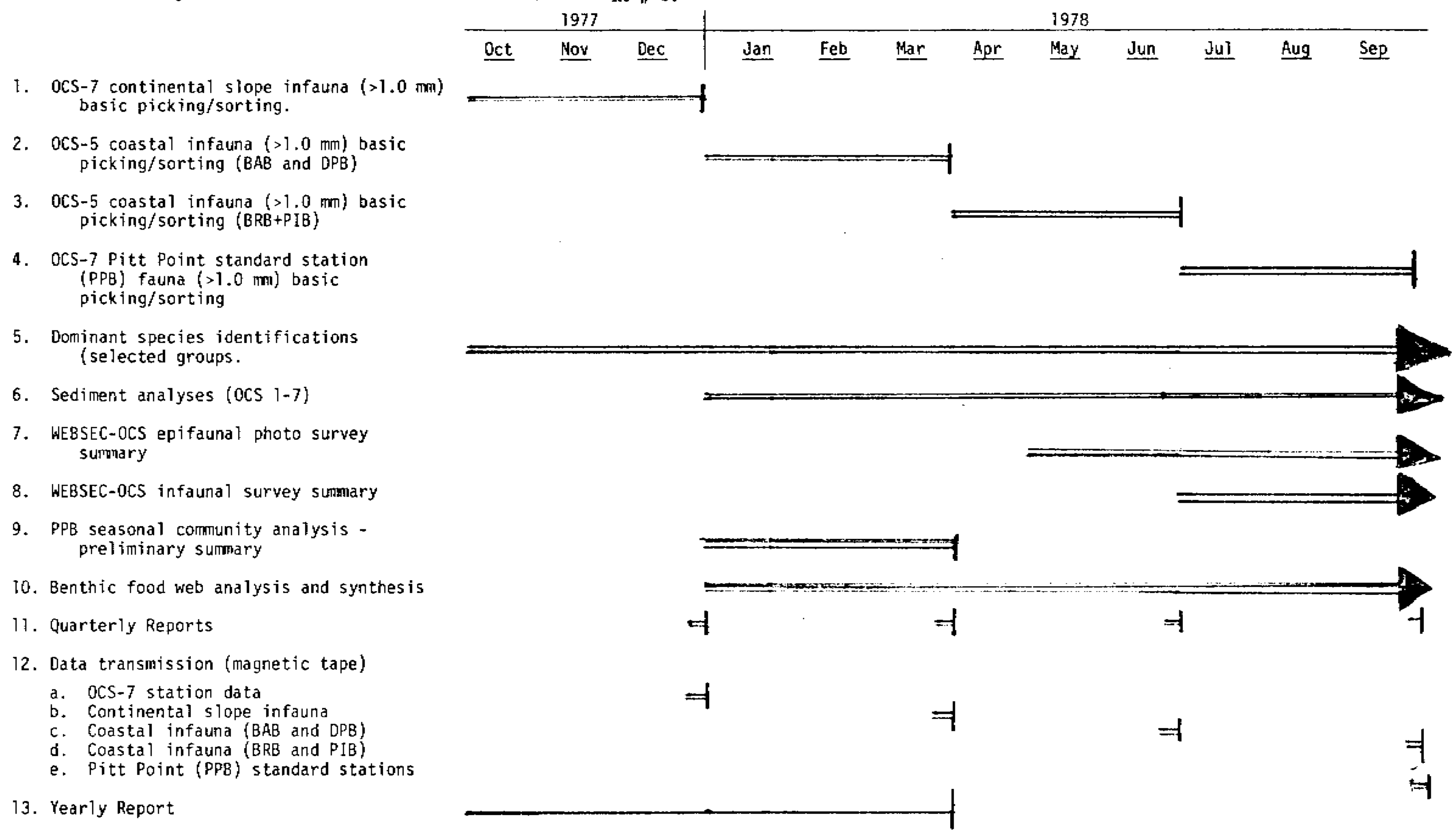
V. Problems Encountered and Recommended Changes.

The analysis of the small macro-infauna (0.5-1.0 mm in size) and the life histories of dominant species at the PPB seasonal stations have not been undertaken owing to lack of personnel and funding.

Figure 1

MILESTONE CHART and DATA SUBMISSION SCHEDULE

1977-78 Laboratory Schedule - Contract No. 03-5-022-68, **RU # 6.**



NOTE: OCS-5 = 1976 R/V ALUMIAK coastal cruise; OCS-7 = 1977 USCGC GLACIER summer cruise; WEBSEC = Western Beaufort Sea Ecological Cruise - USCG 1970-73; PPB = Pitt Point Benthos transect line; BAB = Barter Island Benthos transect line; DPB = Demarcation Point Benthos transect line; BRB = Barrow Benthos transect line; PIB = Pongok Island Benthos transect line.

KEY:
= accomplished
= continuing effort
= milestone extended
= future milestone to be extended

VI. Estimate of Funds Expended (1/30/78).

	Budget	Spent	Spent This Quarter
Salaries & Wages	$166,965	$156,815*	$16,570
Materials & Services	31,235	33,420	6,664
Travel	13,350	14,243	1,627
Equipment	47,617	47,431	-------
Payroll Assessment	26,291	24,078	2,768
Overhead	85,367	76,163	9,393
TOTAL	$370,825	$352,150	$37,022

*The surplus funds in Salaries and Wages have accumulated owing to the departure of James Gish, the Programmer - Data Analyst, from the job. Because of the short period of guaranteed funds, it was impossible to hire a full-time replacement to fill the position until the end of the FY-78 contract year. The plan is to hire a full-time person for FY-79 and to utilize some of these excess funds for that purpose. A portion of them will probably also be used to balance the overspent budget categories, Materials/Services and Travel.

Table 1 . List of benthic stations on the OCS 1978 USCGC NORTHWIND summer cruise.

Station	Position		Smith-McIntyre Grab Samples
1	71°11.13'N	150°13.55'W	5
4	70°20.18'N	146°04.8'W	5
5	70°36.3'N	148°19.6'W	5
19	70°13.2'N	143°19.7'W	5
21	71°01'N	142°23'W	5
PPB-25	71°10.1'N	152°47'W	10
PPB-40	71°16.5'N	152°37'W	10
PPB-55	71°18.9'N	152°48.5'W	5
PPB-70	71°20'N	152°39'W	5
PPB-100	71°21.7'N	152°41.4'W	5
NIB-15	70°28'N	147°36'W	2
NIB-25	70°29.6'N	147°34.6'W	5
		TOTAL	67

Table 2. List of (proposed) seasonal benthic stations occupied by helicopter on the OCS 1978 USCGC NORTHWIND summer cruise.

Station	Position		Depth	Smith-McIntyre Grab Samples
S1	70°20.0'N	147°28.5'W	7m	7
S2	70°12.8'N	146°39.0'W	5.5m	5
S3	70°14.4'N	146°36.5'W	7m	5
S4	70°09.8'N	146°05'W	3m	5
S5	70°12'N	146°02'W	6.5m	5
EB-1	70°24'N	147°30'W	3m	3
			TOTAL	30

Table 3. Tentative list of epibenthic otter trawl stations on the OCS 1978 USCGC NORTHWIND summer cruise.

Station	Position		Depth	Samples
DPB-50	70°06.5'N	142°04.1'W	42	1
DPB-1000	70°39.7'N	141°12.0'W	768-914	1
DPB-250	70°25.9'N	141°28.1'W	290	1
DPB-250	70°25.5'N	141°44.5'W	150-310	1
			TOTAL	4

Table 4: Animal densities for PPB-25 (OCS-4) collected on 20 August 1976.

Phylum	Class	Order	Grab Number 1281	1282	1283	1284	1285	Total per m^2	% of fauna
Protozoa		Foraminiferida	--	--	+	--	--	+	
Nematoda			5	--	3	--	1	18	2.9
Priapulida			1	--	--	--	1	4	0.6
Arthropoda:	Crustacea:	Decapoda	2	1	--	1	--	8	1.3
		Amphipoda	2	14	6	2	3	54	8.6
		Cirripedia	--	--	--	--	--	--	--
		Isopoda	1	4	--	2	6	26	4.1
		Tanaidacea	1	--	3	1	1	12	1.9
		Cumacea	1	--	5	--	3	18	2.9
		Calanoida	3	3	--	--	--	12	1.9
Mollusca:	Pelecypoda		55	24	33	40	69	442	70.2
	Gastropoda		4	4	1	1	6	32	5.1
Chordata:	Pisces		1	--	--	--	--	2	0.3
TOTAL			76	50	51	48	90	628	100.0

Table 5: Animal densities for PPB-25 (OCS-4) collected on 1 September 1976.

Phylum	Class	Order	Grab Number 1359	Total per m^2	% of fauna
Protozoa		Foraminiferida	+	+	+
Nematoda			3	6	7.1
Arthropoda:	Crustacea	Amphipoda	5	10	11.9
		Isopoda	3	6	7.1
		Tanaidacea	1	2	2.4
		Calanoida	1	2	2.4
Mollusca:	Pelecypoda		26	52	61.9
	Gastropoda		3	6	7.1
TOTAL			42	84	100.0

Table 6 : Animal densities for PPB-55 (OCS-4) collected on 1 August 1976

Phylum	Class	Order	Grab Number 1331	1333	1334	1337	1338	Total per m^2	% of fauna
Protozoa		Foraminiferida	+	+	+	+	+	+	+
Cnidaria:	Anthozoa		--	+	--	--	--	+	+
Nematoda			188	85	79	56	191	1198	35.3
Nemertinea			6	3	2	1	11	46	1.4
Sipuncula			2	5	6	1	3	34	1.0
Echiura			1	2	2	--	8	26	0.8
Arthropoda:	Crustacea:	Decapoda	--	--	--	1	1	4	0.1
		Amphipoda	46	58	57	32	62	510	15.0
		Cirripedia	33	6	5	1	45	180	5.3
		Harpacticoida	4	11	11	3	20	98	2.9
		Isopoda	--	--	1	5	--	12	0.4
		Ostracoda	57	40	39	23	66	450	13.3
		Tanaidacea	20	29	14	8	23	188	5.5
		Cumacea	27	35	29	22	36	298	8.8
		Calanoida	3	1	--	--	--	8	0.1
Nonbenthic		Mysidacea	--	--	1	--	--	2	0.1
	Arachnida:	Acarina	--	1	--	--	--	2	0.1
	Pycnogonida		--	--	--	1	--	2	0.1
Mollusca:	Pelecypoda		17	13	12	22	20	168	4.9
	Gastropoda		3	11	17	10	12	106	3.1
	Aplacophora			1	--	--	--	2	0.1
Brachiopoda			--	1	--	--	--	2	0.1
Echinodermata:	Ophiuroidea		3	1	9	6	9	56	1.6
Chordata:	Ascidiacea		--	--	--	--	1	2	0.1
TOTAL			410	303	284	192	508	3394	100.0

Table 7 : Animal densities for PPB-55 (OCS-4) collected on 31 August 1976.

Phylum	Class	Order	Grab Number 1339	1342	1343	1345	1346	Total per m^2	% of fauna
Protozoa		Foraminiferida	+	+	+	+	+	+	+
Cnidaria:	Anthozoa		--	--	--	--	2	4	0.1
Nematoda			92	78	150	154	87	1122	34.2
Nemertinea			5	2	--	--	--	14	0.4
Platyhelminthes:	Turbellaria		--	--	--	1	--	2	0.1
Sipuncula			1	4	--	2	1	16	0.5
Echiura			1	--	--	--	--	2	0.1
Arthropoda:	Crustacea:	Decapoda	2	3	--	4	3	24	0.7
		Amphipoda	66	50	68	68	82	668	20.4
		Cirripedia	--	--	1	--	2	6	0.2
		Harpacticoida	3	8	4	4	2	42	1.3
		Isopoda	2	--	1	--	9	24	0.7
		Ostracoda	27	51	57	41	42	436	13.3
		Tanaidacea	15	10	9	26	14	148	4.5
		Cumacea	31	29	32	32	38	324	9.9
	Copepoda:	(Calanoida)	1	1	--	1	12	30	0.9
		(parasitic)	--	2	--	--	--	4	0.1
	Pycnogonida		--	--	1	--	--	2	0.1
Mollusca:	Pelecypoda		11	31	50	32	21	290	8.8
	Gastropoda		10	7	3	8	5	66	2.0
	Polyplacophora		--	--	--	--	4	8	0.2
Brachiopoda			--	--	1	--	--	2	0.1
Echinodermata:	Ophiuroidea		2	4	2	3	7	36	1.1
	Holothuroidea		--	1	--	--	--	2	0.1
Chordata:	Ascidiacea		1	1	1	1	3	14	0.4
TOTAL			270	282	380	377	332	3282	100.0

Table 8 : Animal densities for PPB-55 (OCS-4) collected on 31 August 1976.

Phylum	Class	Order	Grab Number 1347	1348	1349	1350	1351	Total per m^2	% of fauna
Protozoa		Foraminifera	+	+	+	+	+	+	+
Cnidaria:	Anthozoa		--	--	--	4	--	8	0.1
Nematoda			104	207	54	255	59	1358	29.0
Nemertinea			--	2	--	9	2	26	0.6
Sipuncula			1	1	1	5	3	22	0.5
Echiura			--	--	--	7	--	14	0.3
Priapulida			--	1	--	--	--	2	0.0
Arthropoda:	Crustacea:	Decapoda	2	1	--	1	--	8	0.0
		Amphipoda	56	94	59	117	26	704	15.0
		Cirripedia	1	12	1	78	--	184	3.9
		Harpacticoida	4	11	1	24	--	80	1.7
		Isopoda	--	2	3	6	1	24	0.5
		Ostracoda	41	224	37	312	35	1298	27.7
		Tanaidacea	28	34	8	32	7	218	4.7
		Cumacea	27	59	24	34	20	328	7.0
		Copepoda (parasite)	--	--	1	--	--	2	0.0
		Calanoida	1	1	--	--	1	6	0.1
Mollusca:	Pelecypoda		15	29	16	41	19	240	5.1
	Gastropoda		12	17	7	4	12	104	2.2
Brachiopoda			--	1	--	--	--	2	0.0
Echinodermata:	Ophiuroidea		2	7	6	7	5	54	1.2
Chordata:	Ascidiacea		--	--	1	--	1	4	0.1
	Pisces		1	--	--	--	--	2	0.0
TOTAL			295	703	219	936	191	4688	100.0

Table 9: Biomass, preserved wet weight in grams per 0.1 m^2 from PPB-25 (OCS-4) collected on 20 August 1976.

Group	Grab Number 1281	1282	1283	1284	1285	Total weight per m^2	% of biomass
Anthozoa	-	-	-	-	-		
Sipuncula	-	-	-	-	-		
Annelida	.72	1.71	.37	1.41	1.59	11.60	31.6
Arthropoda	.10	.42	.16	.21	.21	2.20	6.0
Mollusca	3.20	1.31	.83	.93	3.10	18.74	51.0
Echinodermata	-	-	-	-	-		
Misc.	1.52	-	.08	-	.50	4.20	11.4
TOTAL	5.54	3.44	1.44	2.55	5.40	36.74	100.0

- = absent

Table 10: Biomass preserved wet weight in grams per 0.1 m^2 from PPB-25 (OCS-4) collected on 1 September 1976.

Group	Grab Number 1359	Total weight per m^2	% of biomass
Anthozoa	-		
Sipuncula	-		
Annelida	1.96	3.92	60.3
Arthropoda	.70	1.40	21.5
Mollusca	.58	1.16	17.8
Echinodermata	.01	.02	0.3
Misc.	-		
TOTAL	3.25	6.50	100.0

- = absent

Table 11: Biomass preserved wet weight in grams per 0.1 m^2 from PPB-55 (OCS-4) collected on 31 August 1976.

Group	Grab Number 1331	1333	1334	1337	1338	Total weight per m^2	% of biomass
Anthozoa	-	.04	-	-	-	.08	.1
Sipuncula	-	.45	.09*	.02	.12	1.36	1.9
Annelida	4.51	4.11	4.87	4.95	3.31	43.50	59.4
Arthropoda	.63	1.65	1.00	1.15	.34	9.54	13.0
Mollusca	.42	1.11	.79	1.90	2.45	13.34	18.2
Echinodermata	.07	.06	.48	1.00	.16	3.54	4.8
Misc.	.14	.08	.12	.09	.48	1.82	2.5
TOTAL	5.77	7.50	7.35	9.11	6.86	73.18	100.0

- = absent
* = one large Sipuncula weighed 12.17 g.

Table 12: Biomass preserved wet weight in grams per 0.1 m^2 from PPB-55 (OCS-4) collected on 31 August 1976.

Group	Grab Number 1339	1342	1343	1345	1346	Total weight per m^2	% of biomass
Anthozoa	-	-	-	-	.09	.18	0.2
Sipuncula	.09	.04	-	.04	.02	.38	0.4
Annelida	2.14	3.12	1.49	3.04	2.45	24.48	27.9
Arthropoda	1.74	.98	.82	3.62	.60	15.52	17.7
Mollusca	4.23	1.05	2.77	2.73	7.05	35.66	40.7
Echinodermata	.15	.11	.15	.03	.40	1.68	1.9
Misc.	.20	.04	.04	.94	3.68	9.80	11.2
TOTAL	8.55	5.34	5.27	10.40	14.29	87.70	100.0

- = absent

Table 13: Biomass preserved wet weight in grams per 0.1 m^2 from PPB-55 (OCS-4) collected on 31 August 1976.

Group	Grab Number 1347	1348	1349	1350	1351	Total weight per m^2	% of biomass
Anthozoa	--	--	+	.62	--	1.24	2.0
Sipuncula	.02	--	--	.14	.02	.36	0.6
Annelida	2.44	3.50	2.46	2.41	3.30	28.22	46.6
Arthropoda	.73	1.17	2.53	1.80*	1.18	14.82	24.4
Mollusca	.35	.57	.54	1.12	3.79	12.74	21.0
Echinodermata	.03	.03	.58	.04	.04	1.44	2.4
Misc.	.41	.27	.07	.11	.04	1.80	3.0
TOTAL	3.98	5.54	6.18	6.24	8.37	60.62	100.0

- = absent
+ = present, not weighable
* = one crab weighed 12.95 g.

Table 14. Species data for polychaetous annelids from OCS-5 (August 1976).

Family: Species	Stations of Occurrence	Total Specimens
AMPHARETIDAE		
Ampharete acutifrons	BRB-5, BRB-10, BRB-25, PPB-5, PPB-10, PIB-15, NIB-5, NIB-10, NIB-15, BAB-5, BAB-10, BAB-15, BAB-20	83
Ampharete arctica	PPB-10	1
Ampharete vega	BRB-5, BRB-10, PPB-5, PIB-5, PIB-10, NIB-5, NIB-10, NIB-15, BAB-5, BAB-10, BAB-15	1024
Amphicteis sundevalli	PIB-15, NIB-10, BAB-25	19
Lysippe labiata	PIB-15, NIB-15, BAB-15, BAB-20	13
Neosabellides sp?	BRB-5, BRB-10, BRB-20, BRB-25	12
Sabellides borealis	PIB-15, NIB-10	4
ARENICOLIDAE		
Arenicola glacialis	PPB-5, BAB-5	2
FLABELLIGERIDAE		
Brada incrustata	BAB-15	1
Brada villosa	BRB-5, BRB-10, BRB-15, BRB-20, PPB-10, PIB-15, NIB-5, NIB-10, NIB-15, BAB-10 BAB-15, BAB-20, BAB-25	305
Diplocirrus hirsutus	NIB-15	1
Diplocirrus longosetosus	NIB-15, BAB-20	3
Flabelligera affinis	BRB-20	1
NEPHTYIDAE		
Aglaophamus malmgreni	PPB-20	1
Micronephthys minuta	BRB-5, BRB-10, BRB-15, BRB-20, BRB-25, PPB-5, PPB-10, PPB-15, PPB-20, PIB-5, PIB-10, PIB-15, NIB-15, BAB-10, BAB-15, BAB-20, BAB-25	586
Nephtys ciliata	BRB-15, BRB-20, BRB-25, PPB-10, PPB-15, PIB-10, PIB-15, NIB-10, NIB-15, BAB 15, BAB-20, BAB-25	36

NEPHTYIDAE (con't)

Nephtys discors	BRB-10, BRB-25	4
Nephtys incisa	BRB-10, BAB-25	2
Nephtys longosetosa	BRB-5, BRB-10, BRB-20, PPB-10, PIB-15, NIB-10, BAB-10, BAB-15, BAB-20	134

OPHELIIDAE

Ophelina acuminata	PPB-15, PPB-20, NIB-15	3
Ophelina cylindricaudata	PIB-15, NIB-10, NIB-15, BAB-15, BAB-20, BAB-25	76
Ophelina groenlandica	BRB-10, BAB-15, BAB-20	7
Travisia sp.	PPB-5, NIB-10	3

ORBINIIDAE

Scoloplos acutus	BRB-10, BRB-15, BRB-20, BRB-25, PPB-10, PIB-15, NIB-15, BAB-15, BAB-20, BAB-25	78
Scoloplos armiger	BRB-5, BRB-10, PPB-5, PPB-10, PIB-5, PIB-15, NIB-10, NIB-15, BAB-5, BAB-10, BAB-20	383

PECTINARIIDAE

Cistenides hyperborea	BRB-5, BRB-10, BRB-15, BRB-20, BRB-25, PPB-20, BAB-15, BAB-20	1764

PHYLLODOCIDAE

Anaitides groenlandica	BRB-5, BRB-10, BRB-15, BRB-20, BRB-25, PPB-20, PIB-15, NIB-10, NIB-15, BAB-5 BAB-10, BAB-15, BAB-20, BAB-25	86
Eteone flava	BRB-25	1
Eteone longa	BRB-5, BRB-10, BRB-15, BRB-20, BRB-25, PPB-5, PPB-10, PPB-15, PPB-20, PIB-5, PIB-10, PIB-15, NIB-5, NIB-10, NIB-15, BAB-5, BAB-10, BAB-15, BAB-20, BAB-25	233
Eteone spetsbergensis	BAB-15	2
Mysta barbata	BRB-5	1

HESIONIDAE

Bonuania sp?	BRB-5, BRB-10, BRB-25, PIB-15, NIB-5, NIB-10, NIB-15, BAB-15, BAB-20 --------	147
Nereimyra aphroditoides	BRB-5, BRB-25, PPB-15, PPB-20, PIB-5, PIB-15, NIB-5, NIB-10, NIB-15, BAB-5, BAB-10, BAB-15, BAB-20, BAB-25 --------	253

SCALIBREGMIDAE

Scalibregma inflatum	BRB-10, PPB-10, PIB-10, PIB-15, NIB-5, NIB-10, NIB-15, BAB-10, BAB-15, BAB-20 --------------------------------	83

SIGALIONIDAE

Pholoe minuta	BRB-10, BRB-15, BRB-20, BRB-25, PPB-5, PPB-20, PIB-15, NIB-15, BAB-15, BAB-20, BAB-25 --------------------------------	116

STERNASPIDAE

Sternaspis scutata	BRB-20, BRB-25, PPB-10, PPB-20, PIB-10, PIB-15, BAB-20 ------------------------	44

TEREBELLIDAE

Artacama proboscidea	PPB-10, PPB-20, BAB-20 ------------------	6
Lanassa venusta	PIB-15 ----------------------------------	1
Proclea graffii	PPB-5, PPB-10, NIB-15, BAB-10, BAB-20 ---	6
Laphania boecki	NIB-15 ----------------------------------	4
Polycirrus medusa	BRB-10, PPB-5, NIB-5, NIB-10, BAB-10 ----	13
Terebellidae n.g., n.sp.	PPB-5, PPB-10, PPB-20, PIB-5, PIB-10, NIB-5, NIB-10, BAB-5, BAB-10 ----------	47

TRICHOBRANCHIDAE

Terebellides stroemi	BRB-10, BRB-15, PPB-5, PPB-10, PIB-5, PIB-10, PIB-15, NIB-5, NIB-10, NIB-15, BAB-5, BAB-10, BAB-15, BAB-20, BAB-25 -	292

Table 15. Species data for pelecypod molluscs from OCS-1 (October 1975), OCS-2 (March 1976) and OCS-5 (August 1976). * denotes presence of shells only

Family: Species	Stations of Occurrence	Total Specimens
Nuculidae		
Nucula bellotii	BRB-25, PPB-25, PPB-55, PPB-100, PIB-10, PIB-15, BAB-20, BAB-25	133
Nuculanidae		
Nuculana minuta	PPB-55, PPB-70, PPB-100	12
Nuculana pernula	PPB-25, PPB-40, PPB-55, PPB-70, PPB-100, PIB-15, BAB-20	25
Nuculana radiata	BAB-20	1
Portlandia arctica	PPB-25, PIB-10, PIB-15, BAB-5, BAB-10, BAB-15, BAB-20, BAB-25	401
Portlandia frigida	PPB-25, PPB-40, PPB-55, PPB-70, PPB-100, BAB-25	111
Portlandia lenticula	PPB-25, BAB-20, BAB-25	6
Yoldia hyperborea	PPB-40, PPB-100	2
Yoldia myalis	BRB-10, BRB-25, PPB-55	9
Yoldia scissurata	BRB-20	*
Arcidae		
Bathyarea glacialis	PPB-100	*
Mytilidae		
Crenella decussata	BAB-20	2
Dacrydium vitreum	PPB-55, PPB-70, PPB-100	6
Musculas discors	PPB-55	2
Musculus niger	PPB-25, PPB-70	11
Pectinidae		
Cyclopecten greenlandicus	PPB-25, PPB-55, PPB-70, PPB-100, PIB-10, PIB-15, BAB-15, BAB-20, BAB-25	101
Thyasiridae		
Axinopsida orbiculata	BRB-10, BRB-20, BRB-25, PPB-100, PIB-10, BAB-5, BAB-10, BAB-15, BAB-20, BAB-25	660
Thyasira gouldii	PPB-25, PPB-40, PPB-55, PPB-100	41
Thyasira equalis	PPB-40	1
Montacutidae		
Montacuta dawsoni	BRB-5, BRB-10, PIB-10, BAB-10, BAB-15	37
Mysella planata	BRB-10, PPB-100	9
Mysella tumida	PPB-100	8
Carditidae		
Cyclocardia crebricostata	PPB-55, PPB-100	7

Family: Species	Stations of Occurrence	Total Specimens
Astartidae		
Astarte crenata	PPB-55	1
Astarte esquimalti	PPB-55	22
Astarte borealis	PPB-40, PPB-100, PIB-10, PIB-15	*
Astarte montagui	PPB-55, PPB-70, PPB-100, PIB-15	318
Cardiidae		
Clinocardium ciliatum	PPB-55, PPB-70	9
Serripes greenlandicus	BRB-5, BRB-10, BRB-15, PPB-55	54
Tellinidae		
Macoma calcarea	BRB-10, BRB-15, BRB-20, BRB-25, PPB-25, PPB-55, PIB-10, PIB-15, BAB-5, BAB-10, BAB-15, BAB-20, BAB-25	225
Macoma moesta	PIB-15	1
Veneridae		
Liocyma fluctuosa	BRB-5, BRB-10, PPB-25, PPB-55, PPB-70, PPB-100, PIB-10, PIB-15, BAB-5, BAB-10, BAB-15	252
Liocyma viridis	BRB-25	*
Myidae		
Mya pseudoarenaria	BRB-10, BRB-20, BRB-25, PIB-15	18
Hiatellidae		
Cyrtodaria kurriana	BAB-5	5
Hiatella arctica	BRB-10, BRB-25, PPB-55, PPB-70, PPB-100	10
Pandoridae		
Pandora glacialis	PPB-25, PPB-55, PPB-70, PIB-10, PIB-15 BAB-15, BAB-20	36
Lyonsiidae		
Lyonsia arenosa	PPB-25, PPB-55, PPB-70, PPB-100, PIB-10 PIB-15, BAB-15	25
Periplomatidae		
Periploma aleutica	PPB-25, PPB-100	2
Thraciidae		
Thracia devexa	PPB-40, PPB-70, PIB-15, BAB-20	8

Table 16. Species data for harpacticoid copepods from cruises OCS-1 through OCS-7 and WEBSEC-71.

Family: Species	Stations of Occurrence	Total Specimens
Ameiridae		
Proameira dubia	PPB-100	1
Sarsameira elongata	PPB-70	1
Sarsameira sp.	PPB-55	1
Cerviniidae		
Cervinia langi	WBS-2, WBS-6, WBS-10, WBS-11, WBS-18, WBS-20, WBS-29, WBS-37, NIB-40, PPB-70, PPB-100, AW-34, AW-35, AW-36, AW-40	110
Cervinia sp. A	AW-29, AW-32	3
Cervinia sp. B	WBS-43, AW-58	6
Cerviniopsis smirnovi	AW-10, AW-58	3
Pseudocervinia magna	WBS-1, WBS-2, WBS-8, WBS-11, WBS-15, WBS-16, WBS-18, WBS-19, WBS-20, WBS-22, WBS-23, WBS-28, WBS-29, WBS-35, WBS-36, WBS-37, WBS-40, PPB-25, PPB-55, PPB-70, PPB-100, NIB-55, NIB-40, AW-37	215
Stratiopontes sp.	AW-40	1
Cletodidae		
Argestes mollis	WBS-20, WBS-22, WBS-28, WBS-29, PPB-55, AW-34, AW-35, AW-40, AW-54, AW-58	21
Eurycletodes arcticus	PPB-5, PPB-55, PPB-100	5
Eurycletodes serratus	PPB-55	1
Mesocletodes brevifurca	AW-10	1
Mesocletodes katherinae	AW-40	1
Mesocletodes monensis	NIB-40	1
Paranannopus echinipes	WBS-19, WBS-20, WBS-22, WBS-29, WBS-36, WBS-37, WBS-40, PPB-55, PPB-100, BAB-20, AW-37	113
Diosaccidae		
Amphiascus propingvus	WBS-22	1
Paramphiscella fulvofusciata	WBS-21, WBS-23	2
Paramphiascopsis giesbrechti	WBS-2, WBS-12, WBS-20, WBS-22, WBS-29, PPB-25, PPB-40, PPB-55, PPB-70, PPB-100, AW-37, AW-39	60
Pseudomesochra longifurcata	PPB-55	1
Stenhelia nuwukensis	PPB-5, PPB-10, PIB-10, BAB-20, BAB-15, AW-37	809
Stenhelia proxima	PPB-5, BAB-20	5
Stenhelia sp. B	PPB-5	21
Stenhelia sp. C	PPB-5	14
Stenhelia sp. E	BAB-20	3
Typhlampiascus lamellifer	WBS-19, WBS-41, PPB-40, PPB-55, PPB-70, PPB-100	16

Family: Species	Stations of Occurrence	Total Specimens
Ectinomidae		
Bradya confluens	WBS-6, WBS-20, AW-35, AW-40, AW-58	12
Bradya typica	WBS-19, WBS-20, WBS-23, WBS-24, WBS-37, PPB-40, PPB-55, PPB-70, PPB-100, PPB-5, NIB-15, PIB-5, BAB-20, BAB-15, AW-37	71
Halectinosoma neglectum	PPB-55, PPB-100, PPB-5, BRB-10, BAB-20	23
Halectinosoma sp.	WBS-2, WBS-9, WBS-20, WBS-28, WBS-37, PPB-40, PPB-55, PPB-70, PPB-100, PPB-5, BAB-20, AW-37	32
Harpacticidae		
Harpacticus superflexus	WBS-1, WBS-2, WBS-6, WBS-8, WBS-9, WBS-10, WBS-15, WBS-16, WBS-18, WBS-19, WBS-20, WBS-21, WBS-22, WBS-23, WBS-24, WBS-28, WBS-29, WBS-30, WBS-34, WBS-37, WBS-38, WBS-39, WBS-40, PPB-25, PPB-40, PPB-55, PPB-70, PPB-100, PPB-5, PPB-10, NIB-5, NIB-15, NIB-10, BRB-10, BRB-5, BAB-20, BAB-15, BAB-10, AW-34, AW-35, AW-36, AW-37, AW-39, AW-40, AW-54, AW-58	879
Zaus sp.	PPB-55	2
Laophontidae		
Echinolaophonte brevispinosus	PPB-55	1
Tachidudae		
Danielssenia fusiformis	PPB-100	4
Thompsonala hyaenae	PPB-5	7
Thalestridae		
Parathalestris jacksoni	PPB-100, BRB-5	2
Pseudotachindius sp.	AW-35, AW-36, AW-58	60
Thalestris frigida	WBS-9, PPB-55, PPB-100, PPB-5, BRB-10, BRB-5, PIB-10, BAB-20, BAB-15	34
Genus A	AW-35, AW-58	6
Tisbidae		
Tisbe sp.	PPB-55, PPB-100, BAB-20, AW-39	31
Zosime sp.	PPB-55, BAB-20	2

WBS = WEBSEC-71

PPB = Pitt Point Benthic

AW = Arctic West Summer 77 (OCS-7)

QUARTERLY REPORT

Contract No.
Research Unit: #78
Reporting Period: July 1-September 30, 1978
Number of Pages: 3

BASELINE/RECONNAISSANCE CHARACTERIZATION LITTORAL BIOTA, GULF OF ALASKA AND BERING SEA

by

Charles E. O'Clair
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

October 1, 1978

I. Abstract

During this quarter we completed the analysis and tabulation of data from quantitative samples previously collected in the Pribilof Islands and on the Alaska Peninsula. A report on the results of our studies at these sites is partially written. The analysis of data collected in the Bering Sea and Norton Sound is in progress. Magnetic tapes containing data from five cruises in the Eastern Gulf of Alaska, Bering Sea, and Kodiak Island area have been submitted to NODC.

II. Objectives

Our objectives are to describe the distribution and abundance patterns of benthic plants and invertebrates in communities in the intertidal zone at representative sites along the coast of Alaska and to compare the patterns within and between sites in order to identify key factors controlling the structure of the communities.

III. No field studies were conducted. Laboratory activities included graphical and numerical analyses of species composition and relative biomass and abundances of plants and invertebrates at representative sites on the Alaska Peninsula and in the Bering Sea and Norton Sound.

IV. A processed report on the results of our studies in the vicinity of Kodiak Island is complete and was submitted in August to the Juneau Project Office of OCSEAP. Separate "basin reports" of the results of our studies in the Bering Sea and Norton Sound are partially written and will be submitted in the first quarter of Fiscal Year 1979. Magnetic tapes containing the remainder of the data (four cruises to the Eastern Gulf of Alaska and the Bering Sea) collected in 1975 and the data from one cruise (to Kodiak Island) in 1976 were submitted to NODC. Four 1976 cruises remain to be key punched and sent to NODC. The University of Alaska Sorting Center completed processing our intertidal samples and a summary report was received from George Mueller, Director of the Center.

V. Auxiliary Material

Papers in print.

Calvin, N.I. and R.J. Ellis. 1978. Quantitative and qualitative observations on _Laminaria dentigera_ and other subtidal kelps of southern Kodiak Island, Alaska. Marine Biology _47_:331-336.

Zimmerman, S.T., J.L. Hanson, J.T. Fujioka, N.I. Calvin, J.A. Gharrett, and J.S. MacKinnon. 1978. Intertidal biota and subtidal kelp communities of the Kodiak Island area. Northwest and Alaska Fisheries Center Auke Bay Laboratory, Auke Bay, Alaska. 192 p.

V. Problems Encountered

C.E. O'Clair, the Project Leader and the only person still funded by OCSEAP on RU #78 was unemployed from July 13 to September 22 because the Civil Service Commission in Washington, D.C. had misplaced two sets of employment application and update forms which were required for his continued federal employment. Consequently the completion schedules for the reports on St. George Basin, Bering Sea, and Norton Sound have been delayed.

VII. Estimate of FY 1978 funds expended through September 30, 1978.

Salaries	$44.4K
Travel	2.9
Contracts (Computer Services)	6.9
GSA Printing	0.7
Equipment and Supplies	1.9
Other Direct and Indirect Costs	18.2
TOTAL	$75.0K

Contract 03-5-022-81
Research Unit 356
July 1 to September 30, 1978
17 pages

QUARTERLY REPORT

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

A. C. Broad

September 30, 1978

I. Task Objectives: Task objectives of the quarter were those set forth in our proposal for Fiscal 1978. The specific approaches followed were:

A. Sample littoral biota at selected shore stations in the Colville delta, Prudhoe Bay, and on Flaxman Island to determine population structure and contribute to studies of annual and seasonal variability and population dynamics in the littoral zone (proposal objectives 1, 2, 3, and 5).

B. Sample benthic and epibenthic biota in water deeper than 2 meters for studies of population structure, variability and dynamics (objectives 1, 2, 3, and 9).

C. Continue studies of food and feeding of the principal coastal invertebrate species of the Beaufort Sea through analyses of gut contents and through experimental work on assimilation (objective 4).

D. Continue studies of ecology and trophic relationships in Arctic salt marshes and effects of chemical and physical perturbations on the marshes and marsh biota (objectives 1 and 7).

E. Collect fish from the Beaufort Sea lease zone for benzopyrene hydroxylase determinations (objective 8).

F. Initiate studies of the flora and fauna of the Stefansson Sound Boulder Patch by on-site diving and sampling (objectives 1, 10, 11, 12, 13, 14).

G. Continue laboratory analysis of material collected during the 1977 field season (objectives 1, 2, 3, and 5).

II. Field or Laboratory Activities:

A. Ship or Field trip schedule

1. Shore and littoral stations in the Colville delta, in Prudhoe Bay and on Flaxman Island (see table 1) were sampled by the party of Harris and Kannestrom between July 6 and August 26.

2. Broad and Smith participated in the cruise of the RV ALUMIAK (see table 2) between August 3 and August 30.

3. A party of Schneider, Koch, Childers and Pounds worked on gut analyses and feeding experiments at NARL, Barrow, from June 21 to September 15.

Table 1: Shore stations sampled by RU356 during 1978.

Station	North Latitude	West Longitude	Dates Sampled
J2D	70 26.3	150 22.0	7/15, 7/29, 8/20
J2E	70 26.3	150 21.8	7/15, 7/29, 8/20
J2F	70 26.3	150 21.6	7/15, 7/29, 8/20
J2G	70 28.7	150 24.5	7/17, 7/30, 8/19
J2H	70 29.0	150 25.5	7/17, 7/30, 8/19
J2I	70 29.2	150 26.0	7/17, 7/30, 8/19
E59	70 10.9	145 59.0	7/21, 8/7, 8/25
F05	70 12.0	146 05.0	7/20, 8/8, 8/24
H12	70 20.7	148 12.3	7/10, 7/25, 8/18
H28	10 18.5	148 28.8	7/8, 7/24, 8/15
H32	70 22.6	148 32.6	7/11, 7/28, 8/14

Table 2: Stations sampled from RV ALUMIAK during 1978. P = plankton tow; E = epibenthic dredge tow; T = trawl sample. Stations marked * are within the boulder patch area.

Station	North Latitude	West Longitude	Depth (m)	No. Grabs	Other Samples	Remarks
J2C	70 35.5	150 25.0	10	4	--	
J1A	70 33.1	150 14.0	5	4	PET	Laminaria
JØB	70 30.9	150 01.9	3	4	PET	
I3G	70 34.5	149 30.0	10	4	T	Laminaria with holdfasts
I3H	70 33.8	149 30.0	5	4	--	
H4A	70 25.5	148 43.3	5	4	--	
H3G	70 25.7	148 32.4	5	4	PET	
H3H	70 32.4	148 32.4	10	4	PET	
HØB*	70 24.3	148 06.6	5	4	PET	Laminaria with holdfasts
G5A*	70 29.8	147 53.0	7	4	PE	Productive grabs Ophiuroid
G4A*	70 21.2	147 46.5	6	4	PET	Laminaria, Red Algae
G3C*	70 16.0	147 38.0	5	4	PET	Peat in grabs, Laminaria with holdfasts
GØA	70 14.0	147 06.0	6	4	PE	3-5 Astarte/Grab very productive grabs
F5A	70 10.7	146 52.5	3	4	PE	
FØE	70 11.2	146 05.7	3	4	PET	Many molgula
F1A	70 10.1	146 14.3	3	4	PE	
F2A	70 12.4	146 27.8	4	4	PE	
F4B	70 12.1	146 41.4	5	4	PET	
GØB	70 12.6	147 00.0	5	4	PET	
GØC	70 15.5	147 00.0	5	4	PE	
G2A	70 17.5	147 20.0	5	4	PET	

4. Mason and Kiera began studies of Marsh Ecology and grazing by black brant on May 15. This study, which was interrupted during mid-summer, was ended on September 10.

5. Dunton, Plesha, Smith and Olson did field work in Alaska and particularly in Stefansson Sound from July 11 to August 24 (see table 3).

6. The laboratory in Bellingham was in operation during the entire quarter but functioned mornings only during July and August.

B. Scientific Party (all of Western Washington University)

1. A. C. Broad, Principal Investigator
2. Helmut Koch, Laboratory Supervisor
3. David E. Schneider, Associate Investigator
4. David T. Mason, Associate Investigator
5. Martin Harris, Field Team Leader
6. Ken Dunton, Assistant Investigator
7. Gary Smith, Field Assistant, Diver
8. John Olson, Field Assistant, Diver
9. Paul Plesha, Field Assistant, Diver
10. Harold Kannestrom, Field Assistant
11. Scott Smith, Field Assistant
12. Mark Childers, Field Assistant
13. Wendy Pounds, Field Assistant
14. Eileen Kiera, Field Assistant
15. James Hanes, Laboratory Assistant Supervisor, part time
16. Dawn Christman, Laboratory Helper, part time
17. John Zehr, Laboratory Helper, part time
18. Janice Chiavario, Laboratory Helper, part time
19. Alexander Benedict, Computer Programmer, part time
20. Don C. Williams, Associate Investigator (August only)

C. Methods

1. Littoral stations were sampled at depths up to 2 or 2.5 meters with an Ekman or Ponar grab, epibenthic dredge and plankton net. Each site was sampled three times during the summer. Methods were those we have used since 1975.

2. Benthic biota in deeper water was sampled from RV ALUMIAK with a $0.1m^2$ Smith-McIntyre grab and with an epibenthic dredge. The methods were employed in 1976 and have been reported previously. Trawling for epibenthos using either a 6 ft. otter trawl of 2 inch mesh or a 10 ft. beam trawl of ½ inch mesh (cod end only) was done in 1978. These are reported in more detail in the cruise report to the Arctic Project Office.

3. Methods employed in analyzing gut contents of littoral invertebrates and experiments designed to test hypotheses of feeding and assimilation are dealt with separately below (see appendix 1).

Table 3: Summary of dive sites in Stefansson Sound during the 1978 field season.

Dive Site	Latitude	Longitude	Kelp Transect	Occurrence of Kelp	Comments
DS-1	70 20.5	147 34.8	X	X	
DS-2	70 20.8	147 44.5			
DS-3	70 20.4	147 38.0	X	X	
DS-4	70 21.0	147 36.6			
DS-5	70 21.4	147 39.3			
DS-6	70 21.8	147 39.8			
DS-7	70 22.4	147 40.8			
DS-8	70 23.1	147 41.8		X	
DS-9	70 20.4	147 35.6		X	
DS-10	70 20.2	147 35.3		X	
DS-11	70 19.5	147 34.5	X	X	Winter site Pinger deployed
DS-12	70 20.8	147 36.2		X	Pinger deployed
DS-13	70 21.0	147 34.3			
DS-14	70 21.2	147 42.7			
DS-15	70 20.8	147 40.3			
DS-16	70 20.6	147 39.0			

4. Methods employed in the investigations of Marsh Ecology were those used in 1977 and reported earlier.

5. For exploration of the Boulder Patch in Stefansson Sound, the following methods were employed.

   a. Dive Strategy: Divers followed a plan drawn up by the Team Leader which delegated tasks and outlined procedures for the day at hand. Underwater sampling was done in teams of two with the alternate diver acting as standby. An underwater communication system enabled divers to be in constant communication with the surface and with each other. This system was used in coordinating underwater sampling efforts, relaying data to a surface tape recorder, and as a diver safety aid. Divers made two dives a day, each dive averaging 45 minutes. A rest period was usually taken between dives.

   b. Sampling Strategy: Three dive sites, DS-1, DS-3, and DS-11 were sampled intensively in this program. These dive sites were found by spot diving at 800 or 1500m intervals along a magnetic course. Prior to sampling at each site a 50m transect line, buoyed and anchored at each end, was set on the bottom. The transect line provided a reference point from which divers could work underwater. Tasks assigned to the dive team for a sampling day included, (1) estimation of algal and rock cover at every square meter along the transect line, (2) .05 and .25m^2 quadrat photography, (3) close-up photography, (4) overall community photography and (5) collection of fauna and flora. Divers were also required to make independent observations on depth, visibility, currents, approximate rock and algal cover, sediment characteristics, predominant algal and invertebrate species, and other distinguishing community characteristics. From shipboard salinity and temperature measurements were taken at the surface, 2m, 4m, and at 6m using an SCT meter. Meteorological data were also recorded and our exact position calculated using a sextant to measure angles between known surface points. At completion of diving the transect was retrieved and a buoy anchored on location. The buoy provided a reference marker for the dive site and was used as a pivot point on which subsequent transect lines of known degree bearings were set. DS-1 and DS-3 were sampled over a three-day period and DS-11 was sampled only once (the other time spent on winter experiments).

   c. Several dive sites were merely inspected (not sampled) in this study as they were part of a four mile transect which was undertaken to determine the extent of the boulder patch. It was on this transect that a large and dense algal community at DS-11 was discovered. At these sites (DS-4, DS-5, DS-6, DS-7, DS-8, DS-9 and

and DS-10) a quick spot dive of 5-15 minute duration was made. The diver noted depth, visibility, currents, approximate rock and algal cover, sediment characteristics and biota.

6. Methods of laboratory analyses were those we have used since 1975.

D. Sample Localities and E. Data Collected

1. Shore stations sampled in 1978 are given in table 1.
2. Stations sampled from RV ALUMIAK are given in table 2.
3. The marsh sites studies were in the mouth of the Putuligayak River at Prudhoe Bay and at Arctic Circle Landing Strip near Kotzebue. These study sites are those at which studies were begun in 1977. Black brant were studied in the Colville Delta and at Prudhoe Bay.
4. Sites in Stefansson Sound at which diving operations were conducted are given in table 3.

F. Milestone Chart: No update required.

III. Results and IV. Preliminary interpretations.

Results of shore or benthic sampling are premature at this time. Those benthic stations within or near the Boulder Patch were noted to be richer than other stations sampled which may reflect higher production in this area.

A preliminary paper on bioassay has been submitted by D. T. Mason (see Arctic Project Bulletin 21) and will be followed by a more definitive report.

Some preliminary interpretations of feeding experiments are presented in attached appendix 1.

The Boulder Patch in Stefansson Sound supports a kelp community comprised largely of brown algae (Laminariaceae), several species of red algae (bladed, filamentous and encrusting), and an abundance of invertebrate life dominated by sponges and cnidarians. The boulder patch is by no means contiguous. Instead it appears that a number of patches at DS-11 covers at least 400 square meters and is characterized by a dense cobble bed interspersed with boulders. The area is rich in animal and plant life. Kelp plants (*Laminaria* sp.) one meter long are not uncommon and dominate the community. Other boulder patches are far smaller and less spectacular in comparison, but all the patches studied seem to possess distinct differences in floral or faunal assemblages. We believe that these patches or vegetated "islands" might be a result of the age of the patch but are unsure of other factors that might be involved.

The notion that these kelp communities appear as islands is further supported by their occurrence on undersea shelves which rise 1 to 2 feet above the sea bottom. Using a recording fathometer we observed simultaneous decreases in depth with slight elongation of return signals. Reimnitz (RU-205) has reported similar responses on a Simrad depth recorder when traversing boulder patches. The composition of sediments in the boulder patches varied greatly, from hard compacted silt (DS-3) to course granular materials (DS-11) to sand (DS-8).

It is our belief that the boulder patches in Stefansson Sound support a kelp community which in itself is unique to the Beaufort Sea. Many of the attached algae found in this community have been previously found only as drift and some along with several invertebrates are suspected to be new to the Beaufort Sea. The ecological importance of this community to fish and marine mammals, its resilience to disturbance created by offshore development, and its role in a detrital based food web (due to relatively high biomasses per m^2) are yet to be determined.

V. Problems encountered: Except for mechanical hydraulic problems on RV ALUMIAK dealt with in the cruise report, there were no problems encountered during the quarter.

VI. Estimate of funds expended: To be submitted later.

Appendix 1

Trophic Relationship of the Arctic Shallow Water Marine Ecosystem

by

D. E. Schneider and H. Koch

with the assistance of

M. Childers and W. Pounds

The continuation of our study of the trophic relationships of the shallow water animals of the Beaufort Sea during the summer of 1978 employed two major approaches. First, we again collected data on the composition of gut contents and fecal pellets of freshly collected specimens. Secondly, we conducted a series of experiments to assess the ability of selected species to derive nutrition from the vascular plant detritus that originates by erosion of terrestrial peat deposits. Only a brief outline of the studies completed will be presented in this Quarterly Report. A detailed report of these experiments will appear in the 1978 Annual Report following complete analysis of the data.

Composition of Gut Contents and Fecal Pellets

The following uniform procedure was used for all of the observations on the composition of fecal pellets and gut contents. A single pellet was thoroughly teased apart on a microscope slide and covered with a cover slip. Four complete, non-overlapping traverses of the slide were made at 400X magnification and all identifiable structures were counted. Following this, the entire slide was examined at 100X to note structures not seen in the traverses.

A total of 165 pellets and guts were examined with this technique. Table 4 presents the number of fecal pellets and guts examined for each of the 19 species studied and indicates the principal structures found. From the degree of overlap of general food categories it is evident that there is little trophic specialization in this ecosystem. The high proportion of species ingesting diatoms (95%) and peat (68%), along with the presence of fine mineral grains in most of the species studied, suggests that deposit feeding may be important in many of these animals. The proportion of species ingesting crustaceans (53%) and polychaetes (32%) is lower, however most of these must be considered omnivorous since diatoms and peat

Table 4

Fecal Pellet and Gut Analysis

FP = fecal pellet
F = fecal material
G = gut

Species	Structure Sampled		No. Structures Sampled	Principal food items
Amphipods				
Gammarus setosus	FP		24	Diatoms, peat and crustaceans
Onisimus litoralis	FP	G	17	Crustaceans, diatoms (many not digested
Apherusa glacialis	FP	G	19	Diatoms, dinoflagellates, peat, crustaceans
Gammaracanthus loricata	FP		3	Crustaceans, peat
Atylus carinatus	FP		3	Diatoms, peat, crustaceans
Acanthostephia behringensis		G	2	Diatoms, crustaceans, peat
Caprellids	FP		5	Diatoms, polychaetes, peat
Isopods				
Saduria entomon	FP	G	15	Diatoms, polychaetes, peat
Saduria sabini	F		1	Diatoms, peat
Mysid				
Mysis relicta	FP		34	Peat, diatoms, crustaceans
Decapod				
Pagurus trigonicheirus	FP	G	2	Diatoms, crustaceans

Table 1 (continued)

Species	Structure Sampled	Number Structures Sampled	Principal food items
Chironomidi			
Dyscamptocladius sp.	G	1	Diatoms, peat
Polychaetes			
Terebellides stroemi	F G	12	Diatoms, peat
Scolecolepides arctius	F	3	Diatoms, polychaetes, peat
Haploscoloplos elongatus	F	1	Peat, polychaetes, diatoms
Pectinaria granulata	G	2	Diatoms
Harmothoe imbricata	FP	1	Diatoms, crustaceans
Priapulid			
Priapulus caudatus	FP	1	Diatoms, polychaetes, peat
Fish			
Myoxocephalus quadricornis	FP G	19	Polychaetes, crustaceans, diatoms

are frequently major components of their diet. Of the species studies, only Onisimus litoralis is predominantly a carnivore.

Egestion Rate Experiments

In a number of our experiments we have used the egestion rate or rate of fecal pellet production as an index of the feeding activity on different classes of food. In animals that produce discreet fecal pellets, the quantitative collection of these is more reliable than attempting to estimate the amount of food actually ingested. Described below are the experiments in which this technique was used.

Gut Clearance Times

In an attempt to provide information on the length of time food was held in the gut, several experiments were set up to measure gut clearance times. Two experiments were set up using freshly collected Gammarus setosus. The animals were placed in millipore filtered seawater in compartmented plastic boxes and the fecal pellet production was monitored at frequent intervals. Experiment no. 1 ran for 34 hours and had 30 replicates. Experiment no. 2 ran for 9.5 hours with 24 replicates. A similar experiment was set up using Onisimus litoralis. This experiment was run for 56.5 hours with 24 replicates. Information from these experiments was used in the design of future experiments where it was important to know how long to hold animals before presenting them with an experimental food.

Sediment Feeding Experiments

The ability of Gammarus setosus to ingest fine silty sediments was examined in several experiments. Twenty-four starved Gammarus were placed in silt-laden water in individual compartments of a plastic box and their fecal pellet production was monitored in which certain particle sizes were removed from the silty water by sieving through a graded series of nitex screens and Nuclepore filters. Fecal pellet production was monitored over an 11 hour period. Twelve replicates of this experiment were run.

Peat Particle Size Feeding Experiment

The ability of Gammarus setosus to ingest different particle sizes derived from peat was investigated by the following experiment. Peat was fractioned into the following size series by passing it through nitex screens: $> 1050\ \mu$; $425 < X < 1050\ \mu$; $202 < X < 425\ \mu$; $102 < X < 202\ \mu$; $63 < X\ 102\ \mu$; and $< 63\ \mu$. Eight replicate samples of each size fraction were offered to Gammarus setosus for a 10.5 hour period and fecal pellet production was monitored. In addition the organic content of the peat size fractions and the fecal pellets produced was measured by the weight loss on ignition in a muffle furnace.

Egestion Rate with > 1.168 mm Peat Particles

Twenty-four Gammarus setosus were fed peat particles > 1.168 mm for a period of 24 hours. The rate of production of fecal pellets was monitored at hourly intervals for the first 12 hours and again at 24 hours. Only data on the number of pellets produced was collected and no dry weights of pellets were determined.

Combined Sediment and > 1.168 mm Peat Feeding Experiment

A combination of silty water and peat particles > 1.168 mm was offered to 24 Gammarus setosus)for 24 hours. Fecal pellet production was monitored at hourly intervals for the first 12 hours and again at 24 hours. The organic content of 10 samples of these fecal pellets was determined for comparison to freshly produced pellets from recently collected animals.

Gravimetric Assimilation Experiments

Experiments were performed on several common species of shallow water animals to determine their ability to assimilate material from several different types of food. In these experiments the initial dry weight and organic content of the food presented to each animal was estimated. After a period of feeding, the remaining food and the fecal pellets were quantitatively recovered and the dry weights and organic contents were determined. From this information it is possible to calculate the amount ingested and compare it to the amount of feces produced. A gravimetric assimilation efficiency can then be calculated using the relationship

$$U^1 = \left(\frac{I-N}{I}\right) X\ 100$$

where U^1 is the percentage of assimilation, I is the quantity ingested, and N is the quantity excreted as feces. Assimilation efficiencies of this type can be calculated for total (inorganic and organic) assimilation, for organic matter, and for ash. In view of the difficulty in quantitatively collecting food and feces without some error, Conover (1966) has derived an equation from the above relationship that does not necessitate quantitative collection of food and feces. Assimilation efficiences derived from Connover's equation will be used as a somewhat independent estimate of assimilation efficiency:

$$U^1 = \left[\frac{(F^1-E^1)}{(1-E')(F')}\right] X\ 100$$

where U^1 is the percentage of assimilation, and F^1 and E^1 are the ash-free dry weight: dry weight ratios for ingested food and feces respectively. As the data analysis for these experiments is not yet complete, the assimilation efficiences will not be reported in this Quarterly Report. A brief description of the experiments performed follows:

Gammarus Coarse Peat Experiments

Peat collected from a submerged location on the shore of Elson Lagoon was sieved to yield a fraction of particle sizes > 1.168 mm. Known quantities of this fraction were presented to Gammarus setosus for a period of 10 or 24 hours. The animals were then moved to fresh containers and allowed an additional 12 or 24 hours for gut clearance. Uneaten food and fecal pellets were collected for gravimetric and organic content analysis as described in the introduction to this section. Three spearate experiments of this type with 19, 10, and 12 replicates were run.

Gammarus Fine Peat Experiments

Two experiments were performed with Gammarus setosus using fine particulate fractions sieved from peat collected at a submerged location on the shore of Elson Lagoon. The first experiment used a particle size $< 63\ \mu$ and had 10 replicates. The second experiment used a particle size $63 < X < 102\,\mu$ with 12 replicates. The procedures were similar to those described above.

Gammarus Eroding Tundra Experiments

A major question is whether peat that has freshly eroded into the marine ecosystem can be utilized as a food source by Gammarus setosus. In an attempt to provide an answer to this question, two experiments were set up to examine the assimilation of peat derived from an eroding tundra bank. The material collected had not yet entered the marine system so two different procedures were used in each experiment. The first experiment was conducted on eroding tundra peat that had been soaked in millipore filtered sea water for 12 hours. This procedure was employed to soften the peat and allow clumps to be broken up without exposing the material to marine microbes. The peat was then sieved and the fraction > 1.168 mm was used for the experiment. The second experiment was conducted using a > 1.168 mm fraction that had been soaked in raw unfiltered sea water for one week. The procedures were as described for the previous assimilation experiments. In both experiments 12 replicates were run.

Gammarus Dried Tundra Grass Experiment

An experiment was conducted to determine whether freshly dried tundra grass can be utiized as a food source by Gammarus setosus. Presumably during erosion of tundra, some fresh material of this sort will be washed into the marine system. Fresh tundra grass (leaves only) were collected and dried at room temperature in the laboratory before being presented to Gammarus. The procedure was essentially as described for the other gravimetric assimilation experiments and 12 replicates were run.

Onisimus Coarse Peat Experiment

A parallel experiment to the Gammarus coarse peat experiment was set up using Onisimus litoralis. No fecal pellets were produced over a 72 hour period in any of the 10 replicates set up.

Mysis Fine Peat Experiments

Mysis relicta has been observed frequenting areas where peat deposits are prevalent and peat was shown to be the major fecal pellet component. Two experiments were set up to determine the assimilation efficienty for < 63 μ particle size fraction sieved from peat collected from a submerged location on the Elson Lagoon shore. Both experiments were conducted using the same basic procedure outlined for the other assimilation experiments. Ten replicates were run in the first experiment and 12 were run in the second.

Gammarus Laminaria Experiment

It is not uncommon to find either broken pieces or small whole plants of the kelp Laminaria drifting in shallow water inhabited by Gammarus setosus. Feeding experiments in 1977 indicated that Gammarus would ingest this material. As a result, we set up an experiment to determine the assimilation efficiency of Gammarus feeding upon Laminaria. The procedure paralleled that used for the peat assimilation experiments and 10 replicates were run.

Organic Content Determinations

Several sets of data were collected on the organic content of peat derived from different sources. In all cases the peat was sieved through a graded series of nitex screens to give the following particle sizes: >1 mm; 425 μ < X < 1 mm; 202 μ < X < 425 μ; 102 μ < X < 202 μ; 63 μ < X < 102 μ; and < 63 μ. Peat for these determinations was derived from: 1) eroding tundra not yet washed by sea water; 2) a clump of tundra sod on the beach that had been washed intermittently by sea water; and 3) peat from a submerged location in Elson Lagoon. In addition, the organic content of three species of amphipods (Apherusa glacialis, Onisimus litoralis, and Gammarus setosus) was determined.

ATP and Nitrogen Content of Food and Fecal Pellets

Several experiments were set up to analyze the ATP content of food and fecal pellets. ATP content has been used as a measure of microbial biomass in ecological studies (Holm-Hansen and Booth, 1966; Lopez et al., 1977) and it was hoped that these analyses would yield some information on the utilization of microbial populations associated with peat. Some technical difficulties were encountered in these experiments and at present the data are inconclusive. Further experimentation is planned using this technique.

Some preliminary work was done on the determination of the nitrogen content of food and fecal pellets by the Kjeldahl method. Technical difficulties were encountered, perhaps attributable to the small sample sizes available and further work will have to be done before these determinations can be made.

General Conclusions

As the data from the above experiments have not yet undergone complete analysis, only some tentative, rather general conclusions will be presented here. A detailed discussion of these experiments will appear in the Final Report.

Both the fecal pellet analysis and the sediment feeding experiment indicate that *Gammarus setosus* actively ingests small particles down to $< 62\ \mu$ but probably does not ingest particles $< 8\ \mu$ in diameter. The implication of these observations is that this species, at least under some conditions, acts as a deposit feeder ingesting organic rich surface sediments. In addition, this species is apparently capable of ingesting a wide range of peat particle sizes from > 1 mm to $< 63\mu$.

The gravimetric assimilation experiments suggest that *Gammarus setosus* can assimilate a surprisingly high proportion of the organic matter in a coarse fraction of peat that had been immersed in sea water for some time. Assimilation efficiencies calculated according to Conover's (1966) equation averaged around 65 to 75% for all three experiments. Assimilation efficiencies were negative for the five fractions from sea water soaked peat. This low assimilation may be the result of prior utilization of the more easily assimilated carbon in the peat as it was being broken down to a small particle size. Analysis of the organic content of different peat particle sizes supports this view in that the percent of organic matter is lowest in the smallest particle sizes. Microscopic examination of the five peat fractions also suggests that they may include a large proportion of material derived from the breakdown of fecal pellets.

A comparison of the assimilation efficiencies for dried tundra grass, eroding tundra peat, and peat that had been submerged in sea water suggests that the peat may require a period of conditioning in sea water before it can be efficiently assimilated by *Gammarus setosus*. Assimilation efficiencies were low or even slightly negative for eroding tundra peat even after presoaking in raw sea water for a week, yet the assimilation was high for peat actually collected from a saltwater covered location. Assimilation of dried tundra grass was high, probably the result of a high proportion of relatively easily digested organic matter in this fresh material.

The ability of *Gammarus setosus* to assimilate the kelp, *Laminaria* is high. Considering that drifting or attached macro algae may seasonally abundant in some localities, *Laminaria* may be an important supplementary food source for *Gammarus*.

Mysis relicta showed a low but positive assimilation of $< 63\mu$ peat. This appears to be a higher assimilation for this material than that shown by *Gammarus*, but further analysis of the data and further experimentation are needed before this can be fully evaluated.

Literature Cited

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Contract: 03-5-022-81
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July 1 to September 30, 1978
1 page

QUARTERLY REPORT

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

ADDENDUM

November 6, 1978

VI. Estimate of funds expended (as of September 30, 1978)

	Amount Budgeted	Amount Spent	Amount Remaining
Salary, P.I.	$ 41,506	$ 44,034	$ -2,528
Salaries, Associates	66,623	80,979	-14,356
Salaries, Other	126,972	134,878	- 7,906
Fringe	30,579	32,033	- 1,454
Travel & Freight	39,025	39,544	- 519
P.I. Logistics	92,451	37,045	55,406
Supplies & Contract Services	7,500	18,584	-11,084
Equipment	17,265	19,220	- 1,955
Computer costs	7,800	5,441	2,359
Overhead	102,103	90,327	11,776
Totals	$531,824	$502,085	$29,739

NOTE--Addendum to fiscal 1978 contract/work statement authorized expenditure of P.I. logistics funds originally allocated for Chukchi Sea support for Beaufort Boulder Patch Investigations.

QUARTERLY REPORT

Contract #: 03-78-B01-6
Research Unit #: 359
Reporting Period: 1 Jul - 30 Sep 1978
Number of Pages: 15

Beaufort Sea Plankton Studies

Rita A. Horner

1 October 1978

I. Abstract - Highlights

This quarter was spent preparing for and going on the USCGC *Northwind* cruise in the Beaufort Sea. Processing of the 1977 data was completed.

II. Task Objectives

The objectives of this study are to assess the density distribution and environmental requirements of zooplankton and ichthyoplankton collected in the Beaufort Sea and to measure phytoplankton activity.

III. Field or Laboratory Activities

A. Ship schedule

1. 15 Aug to 15 Sep 1978; cruise length shortened from 10 Aug to 25 Sep due to ship scheduling and equipment problems
2. USCGC *Northwind*

B. Scientific party

1. Rita A. Horner, Principal Investigator
2. Thomas Kaperak, Assistant Oceanographer

C. Acknowledgements

We thank Captain R. R. Garrett, the officers and men of *Northwind* for their outstanding support during the cruise. We particularly thank Ens. Rich Gaudiosi, MSTC Bruce Carnell, and MST 1 Tony Creamer for their help in making our work go more smoothly. Special thanks go to LTJG Dennis Sobeck and the deck force for the many hours they spent supporting our project.

D. Methods

Phytoplankton samples were collected with 5-ℓ Niskin bottles. Subsamples of the water were taken for salinity, standing stock, primary productivity, and plant pigment determinations. Standing stock samples were preserved with 5-10 ml of 4% formalin buffered with sodium acetate. Primary productivity measurements were made in 60 ml reagent bottles. Two light and one dark bottle were used for each depth. Two ml of $NaH^{14}CO_3$ solution were added to each bottle, aluminum foil was wrapped around the dark bottle, and the samples were incubated in a laboratory sink under a bank of cool white fluorescent lights. Light levels were measured at the beginning and end of the incubation period with a Gossen Super Pilot photographic light meter. Low temperature was maintained by running seawater and was monitored throughout the incubation period. Following a 3 to 4 hr incubation period, the samples were filtered onto 25 mm HA (0.45 μm) Millipore filters, rinsed with 5 ml filtered seawater and 5 ml 0.01 N HCl, and placed in liquid scintillation vials.

Water for plant pigment determinations was filtered through 47 mm HA (0.45 μm) Millipore filters. A few drops of a saturated $MgCO_3$ solution were added near the end of the filtration and the filter was rinsed with filtered seawater. The filters were folded into quarters, placed in glassine envelopes, and frozen.

Salinity was determined on board using a Beckman Industrial Instruments Model RS-7A portable induction salinometer. "Copenhagen" water was used as the standard. Temperatures, measured with deep sea reversing thermometers, were corrected using calibration factors provided by the Coast Guard and following the procedure outlined in the U.S. Naval Oceanographic Office Publ. 607 (1968). Water transparency was measured with a Secchi disc.

Zooplankton samples were collected with bongo nets having mesh sizes of 333 and 500 μm, mouth openings of 60 cm, and areas of 0.2827 m^2. A TSK Model 313 flowmeter (InterOcean Systems, Inc.) was mounted in the mouth of each net. A 45 kg rectangular weight was attached to the net frame. Tows were double oblique with the net lowered at *ca.* 40-50 m/min to a depth *ca.* 10 m from the bottom at shallow stations or to 200 m at deep stations, soaked for 30 sec, and retrieved at *ca.* 20 m/min.

The samples were concentrated by gently swirling in a net collection cup to remove excess water. The samples were poured into jars and preserved with 37% formalin and saturated sodium acetate solution. The amount of formalin and buffer depended on the jar size. A label containing collection data was put in the jar, seawater added if necessary to fill the jar, and the jar was capped for storage.

E. Sample locations

Sample locations are given in Table 1 and Fig. 1.

F. Data collected

Parameter	Number Collected	Number Analyzed
Temperature	241	241
Salinity	242	242
Primary productivity	241	In progress
Plant Pigments	241	0
Standing stock		
Phytoplankton	241	0
Zooplankton (bongo nets)	34	0
Water transparency		
Secchi disc	28	-
Quantum meter	9	0

Table 1. Summary of station locations, hydrography, and ice cover, USCGC *Northwind*, 15 Aug to 15 Sep 1978.

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Sonic Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/₀₀
01	17 Aug	71°11'	150°14'	8	45	∿ 1	005	-0.01*	24.16
							015	2.55*	30.19
							025	1.95*	31.16
							035	2.39	31.55
							045	1.57†	32.08
03	18 Aug	70°58.5'	149°17'	7	41	4-5	003	-0.27	15.93
							010	-1.03	29.11
							015	-0.45	29.88
							020	-0.71*	30.73
							025	2.80	31.52
							030	2.40	31.68
							035	2.17	31.68
04	19 Aug	70°19.8'	146°05'	5	33	1	000	-0.36	28.86
							005	-0.42	29.30
							010	---	31.82
							015	-1.16	32.15
							020	-1.64	32.17
							025	-1.64	32.22
05	21 Aug	70°36.2'	148°20.2'	5	22	3-4	000	-0.08	22.36
							003	-0.20	26.20
							006	-0.84	31.31
							009	-1.52	32.06
							012	-1.45*	32.09
							015	-1.52	32.10
							020	-1.53	32.08

* Temperature based on only one thermometer
-- All thermometers on the water bottle failed to work
† Temperature values questionable

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Sonic Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/∘∘
06	22 Aug	70°55'	148°11'	5	40	∿ 5	000	0.56*	9.46
							005	-1.13	28.38
							010	-1.42	29.80
							015	-1.39	30.12
							020	-0.17*	31.05
							025	-0.64	31.32
							030	-0.64*	31.60
							035	0.18	31.87
07	23 Aug	70°05.9'	149°54'	8	24	0	000	0.56	24.90
							005	0.49	25.16
							010	0.79	27.93
							015	3.46	29.97
							020	2.12	30.58
08	23 Aug	71°03.6'	150°52.9'	9	23	0	000	0.89	25.33
							005	0.92	25.65
							010	3.34	28.87
							015	3.60	29.69
							020	3.54	29.77
09	24 Aug	71°11.1'	151°51.3'	10	29	0	000	1.77*	25.76
							005	1.84	26.31
							010	1.73	28.73
							015	4.81	29.30
							020	3.51	29.93

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Sonic Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/∘∘
10	24 Aug	71°05'	152°51'	7	23	0	000	1.76*	25.46
							005	2.22	27.94
							010	2.68	30.24
							015	2.33	31.09
							020	2.38	31.13
11	24 Aug	71°19.8'	152°47.7'	10	55	0	000	1.96*	26.02
							005	1.75	26.06
							010	5.12	28.64
							015	4.91	29.23
							020	3.91*	29.72
							030	2.12	31.26
							040	2.07*	31.34
							050	1.27	31.52
12	24 Aug	71°21.6'	152°41.1'	10	99		000	2.88*	26.11
							005	3.31	26.83
							010	4.59	28.90
							015	5.74	29.19
							020	5.88	29.22
							030	5.44	29.65
							045	2.07*	31.21
							060	0.72	31.60
							075	-1.03	31.88
							090	-1.24	32.47

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Sonic Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/∘∘
13	26 Aug	71°33.5'	150°27.0'	10	1050	2	000	0.08*	23.40
							005	0.21	24.14
							010	0.30	27.54
							015	0.62	28.80
							020	0.87	30.61
							030	-0.45	31.13
							045	-1.01*	31.72
							060	-1.43	31.98
							075	-1.20*	32.16
							100	-1.16	32.41
							125	-1.30	32.67
							150	-1.12*	32.98
							175	-0.96	33.62
							200	-0.30	34.09
							1800	-0.36	34.52
14	28 Aug	70°36'	147°38.7'	7	27	∿ 4	000	-0.69*	21.29
							003	-0.79	27.81
							006	-1.20	29.92
							009	-1.26	30.55
							012	-1.43	31.76
							015	-1.44	31.81
							018	-1.48	31.84
16	29 Aug	70°29'	147°23'	7	27	∿ 4	000	-0.33*	21.11
							003	-0.80	26.37
							006	-1.10	29.88
							009	-1.15	34.37
							012	-1.45	31.75
							015	-1.36*	31.79
							018	-1.46*	31.79
							021	-1.49	31.80

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Sonic Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/∘∘
17	30 Aug	70°21.9'	146°51.7'	7	21		000	-0.15	22.47
							003	-0.73	26.01
							006	-0.94*	29.05
							009	-1.28	30.60
							012	-1.38†	31.45
							015	-0.99*	31.66
							018	-1.16	31.63
18	31 Aug	70°34'	145°51.7'	5	20	1-2	000	0.44	23.65
							003	-0.20	27.14
							006	-0.63*	29.37
							009	-0.99†	30.73
							012	-0.87*	31.74
							015	-1.37†	31.75
							018	-1.04	31.75
19	01 Sep	70°12.7'	143°22.6'	11	25	0	000	2.63	26.28
							003	-0.12	30.10
							006	-0.54*	30.59
							009	-0.42	31.06
							012	-0.90†	31.62
							015	-0.41	32.05
							018	-1.21	32.07
20	02 Sep	69°58.5'	142°15'	5	18	0	000	4.07	28.51
							003	1.97†	30.09
							006	1.88	31.00
							009	0.43†	31.02
							012	0.32	31.05
							015	0.28	31.08

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Sonic Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/oo
21	03 Sep	70°57.8'	142°20.8'		1848	0	000	-1.38	27.69
							005	-1.29	30.27
							010	-1.19	30.26
							015	-1.12	30.88
							020	-1.28	31.12
							025	-1.33	31.32
							030	-1.33	31.59
							045	-1.53	31.83
							2400[§]	-0.39	35.01
22	05 Sep	69°45'	141°17.5'	10	18	0	000	3.44	29.42
							003	2.12	30.96
							006	1.79	31.30
							009	0.93	31.79
							012	0.12	31.85
							015	0.10[*]	31.85
23	06 Sep	70°28.0'	143°33.0'		42	0	000	4.36	25.60
							005	3.34	28.03
							010	0.13	30.22
							015	-1.03	31.41
							020	-1.28[*]	31.87
							025	-1.24[*]	32.26
							030	-1.45[*]	32.32
							035	-1.61	32.34

[§] Ship drifted to where water depth was 2560 m

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Sonic Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/₀₀
24	06 Sep	70°28.6'	143°42.3'	15	62	0	000	4.18*	26.25
							005	3.02*	30.33
							010	1.75	31.08
							015	-1.11	31.34
							020	-1.26*	31.52
							030	-1.48	31.81
							045	-1.56	32.11
							055	-1.33	32.42
25	07 Sep	70°15.1'	143°40.0'		31		000	2.93*	27.35
							003	2.18	27.94
							006	-0.18	30.43
							009	-0.54	31.27
							012	-1.14*	31.85
							015	-1.43*	32.21
							020	-1.47	32.23
							025	-1.51	32.23
26	08 Sep	70°07.7'	144°48.4'		18	0	000	2.33	25.13
							003	1.13	26.36
							006	0.23	28.09
							009	-0.37	30.32
							012	-1.24*	31.63
							015	-1.33	31.82

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Sonic Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/oo
27	08 Sep	70°17.8'	146°30.8'	8	22	∿ 6	000	-1.01	26.08
							003	-0.97	27.40
							006	-0.92	28.93
							009	-1.12	30.03
							012	-1.27	30.39
							015	-1.38*	31.28
							018	-1.40	31.32
28	09 Sep	70°28.0'	147°25.7'	8	24	2	000	-0.24*	15.93
							003	-0.77	25.60
							006	-1.01	28.30
							009	-1.06*	29.44
							012	-0.74*	29.84
							015	-0.65	30.37
							018	-1.16*	30.82
							021	-1.09	30.85
29	09 Sep	71°01'	147°56.5'	10	53	2-3	000	-0.05	24.40
							005	0.21	27.28
							010	4.88	29.16
							015	4.86	29.80
							020	4.22	30.19
							025	4.48	30.58
							030	2.63*	30.83
							045	0.42	31.54

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Sonic Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/∘∘
30	10 Sep	70°44.9'	148°34'		25	2-3	000	0.12	10.35
							003	-0.89	25.92
							006	-0.98	28.33
							009	-1.17	29.65
							012	-0.91*	29.93
							015	1.89*	31.16
							018	1.28*	31.39
							021	1.11*	31.39
31	11 Sep	70°35.5'	148°00.0'	10	22	3-4	000	-0.49	16.94
							003	-0.68*	27.98
							006	0.02	30.35
							009	0.07	30.58
							012	-0.41	31.20
							015	-0.27*	31.42
							018	-0.84	31.49
32	12 Sep	70°46.6'	149°30.4'	5	22	6-7	000	-0.55	10.48
							003	-0.82	28.54
							006	-0.82	29.61
							009	-0.56	30.31
							012	0.45†	31.00
							015	0.26†	31.10
							018	0.79†	31.10

Table 1. (continued)

Sta	Date (1978) (GMT)	Latitude (N)	Longitude (W)	Secchi Depth (m)	Sonic Depth (m)	Ice Cover (oktas)	Sample Depth (m)	Temp (°C)	S°/..
33	13 Sep	71°12.6'	149°38.4'	7	67	0-1	000	1.44	27.26
							005	1.43*	27.26
							010	1.54	27.35
							015	1.72	27.50
							020	2.59‡	30.48
							030	1.68*	31.61
							045	1.27*	31.47
							060	1.08*	31.64
34	13 Sep	70°52'	150°16'	8	27	< 1	000	-0.63	25.66
							003	-0.59	26.17
							006	-0.17	28.58
							009	0.41	29.60
							012	2.29†	30.51
							017	1.66‡	30.53
							022	1.66‡	30.53
35	14 Sep	71°01'	150°25'	7	22	1-2	000	-0.98	26.57
							003	-0.92*	27.35
							006	-0.95*	27.39
							009	-0.53	28.11
							012	2.37	29.98
							015	3.62*	30.17
							018	3.59	30.18
							021	3.58*	30.17

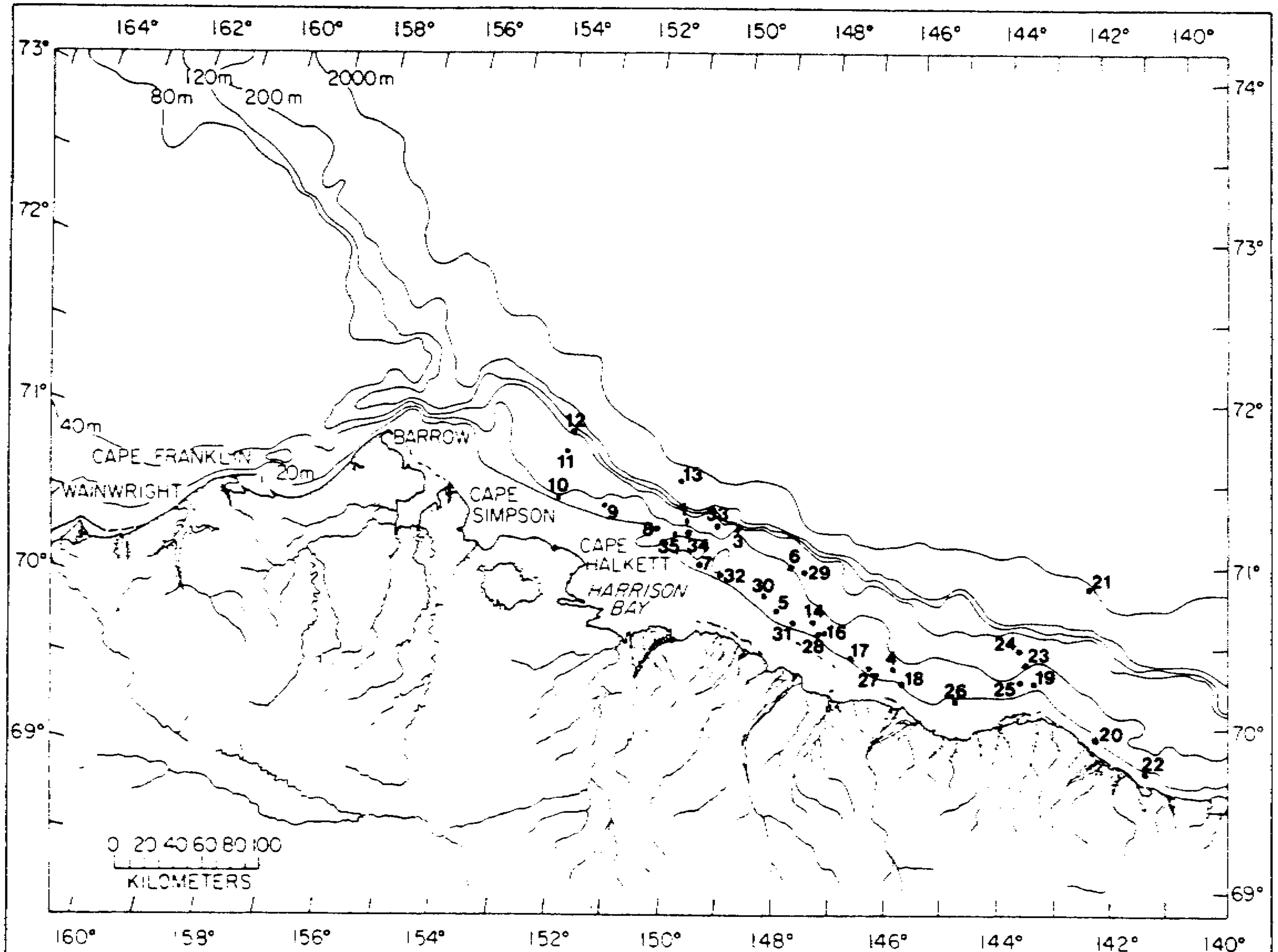

Fig. 1. Study area and station locations, USCGC *Northwind*, 15 Aug to 15 Sep 1978.

IV. Results

Table 1 lists results from temperature and salinity samples. No other samples have been analyzed yet.

V. Preliminary Interpretation of Results

It is too early for any interpretation of results.

VI. Auxiliary Materials - Literature Cited

U.S. Naval Oceanographic Office. 1968. Instruction Manual for Obtaining Oceanographic Data. Publ. 607, Third ed. U.S. Government Printing Office, Washington, D.C.

VII. Problems

Few problems were encountered during the cruise and they were easily solved by scientists or ship's personnel. The major problem was that the cruise was cut short due to ship scheduling and the breakdown of a ship's service generator. The later, along with relatively heavy ice concentrations in the lease area, prevented our doing the bird transects and sampling that were originally scheduled.

VIII. Estimate of Funds Expended

It is estimated that 100% of the funds have been expended.

IX. Correction

The English umbrella net used during the 1977 cruise has been erroneously reported to have a mesh size of 216 μm. The actual mesh size of this net was 571 μm.

X. Milestone Chart

The milestone chart is given on page 15.

O - Planned Completion Date

X - Actual Completion Date

RU # 359 PI: Rita A. Horner

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

MAJOR MILESTONES	O	N (1977)	D	J	F	M	A (1978)	M	J	J	A	S	O	N	D
Reports: Quarterly	X			X						X			O		
Annual							X								
Sample Analysis: Plant pigments	O					X	X	X							
Primary Productivity	O	O			X	X									
Zooplankton									O X						
Phytoplankton									O X						
Data Processing: Plant pigments			O						X	X					
Primary productivity				O		X			X	X					
Zooplankton									O X	O X					
Phytoplankton									O X	O X					
Data Submission: All data submitted													O		
FY 78 Field Effort											X	X			

Contract # 03-5-022-69

Research Unit 512

Reporting Period July 1, 1978 -
September 30, 1978

Quarterly Report

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

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

September 30, 1978

I. Highlights of Quarter's Accomplishments

From the first of July through the end of September a field crew was in the OCSEAP established Cottonwood camp and conducting sampling operations for nearshore fish. A total of 253 net hauls were completed during the quarter (through mid-September) for a total of 416 net hauls to date. Food habits analyses have been conducted during the quarter on fish captured. A total of 317 fish stomachs were examined this quarter for a total of 733 to date.

The Kamishak Bay area is important to juvenile tanner crab in spring (probably during autumn and winter also) herring spawning and larval growth during summer and juvenile halibut during summer.

II. Task Objectives

1. Determine the feeding habits of principal life stages of dominant pelagic and demersal fish and provide an initial description of their role in the food web.
2. Describe the distribution and relative abundance of pelagic and demersal fish and their seasonal changes.
3. Identify areas of unusual abundance or of apparent importance to fish, especially commercially important species.

III. Field Activities

A. Field Schedule

A 17' skiff and a 21' skiff have been used continuously during the quarter. The M/V HUMDINGER has been used as it has been available and as weather permits. The HUMDINGER is an OCSEAP chartered vessel.

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

1. James Blackburn - Principal Investigator
2. Jay Field - Crew Leader
3. Robert Sanderlin - crew member/crew chief
4. Daniel Locke - crew member
5. Jim Sicina - crew member
6. Harry Dodge - crew member
7. Claudia Mauro - crew member
8. Karen Anderson - Food habits analysis

C. Methods

1. Sampling Methods:

   a. Beach seine - require skiff.

   b. Trammel net - require skiff.

   c. Gill net - require skiff.

   d. Surface tow net - require chartered vessel & skiff.

   e. Try net (20' bottom trawl) - require chartered vessel.

2. Fish Collections:

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

3. Food Habits Analysis

   The data sheets and samples are sent to the Kodiak lab where the catches are tallied by species within each cruise (one half month). The following priority list is used to select fish for analysis until all the available analysis time for a cruise has been expended (Table 1).

D. Sample Locations

Figure 1 depicts locations sampled.

E. Data Collected.

Table 2 lists the number of samples collected by gear type and cruise. Table 3 lists the number of fish stomachs analysed for food content by species and time period. An additional 100 sandlance and 99 longfin smelt stomachs have been examined from collection in 1976. Thus, a total of 733 stomachs have been examined to date.

IV. Results

Although data analysis has not yet been conducted, several observations seem worthy of note.

The summer temperatures were comparatively high in the nearshore zone and even for some distance offshore in Kamishak Bay. Temperatures observed at 21 stations in the first half of August (which is a random sample of about half

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

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

those taken during this time period) ranged from 11.4°C to 17.0°C with a mean of 13.9°C. A profile of temperature by depth was taken at two stations offshore on August 15 and the results are presented in Table 4. There is a distinct stratification, however, it is clear that the relatively warm water extended for some distance offshore and was several meters thick.

The second observation is that nearshore zone of Kamishak Bay seems to be a relatively poor area for some species, however, it is used extensively by several commercially important species. The kelp bed community usually consisting of several greenling species is represented in Kamishak by one species,

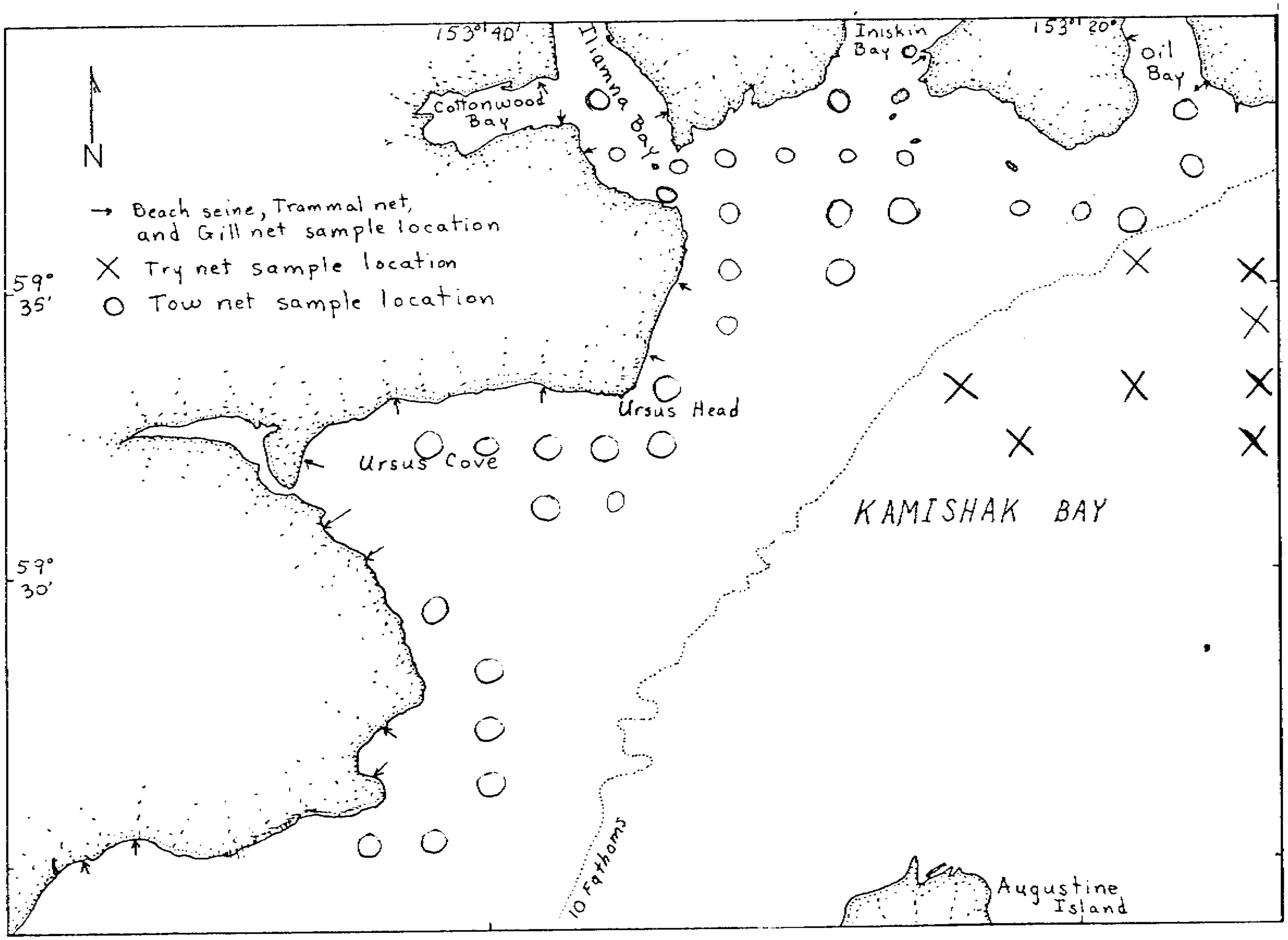

Figure 1. Locations sampled in Kamishak Bay during July, August and September 1978 by gear type.

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

Date	Gear Type				
	Beach Seine	Tow Net	Gill Net	Trammel Net	Try Net
April 10-30[1]	10	0	0	0	1
May 1-15	6	0	0	1	0
16-31	32	4	2	7	1
June 1-15	16	17	3	6	5
16-30	32	12	0	3	5
July 1-15	20	20	3	2	0
16-31	24	13	4	1	4
August 1-15	31	20	1	6	11
16-31	21	20	1	5	9
Sept. 1-15 (partial)	33	0	2	2	0
Total	225	106	16	33	36

[1]All April samples were in Kachemak Bay and all since have been in Kamishak Bay.

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

SPECIES	NUMBER BY TIME PERIOD			
	April 10-May 15	May 16-31	June 1-15	June 16-31
Sandlance	9	25	25	16
Herring		24	3	25
Dolly	1	24	25	25
Chum	25	25	17	25
Chinook				
Red salmon			1	15
Coho				1
Pink	35		3	15
Whitespot Greenling - Juv	4	3	13	11
Whitespot - Adult			2	
Masked Greenling - Juv				
Masked - Adult				
Capelin		10		
Eulachon				
Longfin smelt		15	10	
Great sculpin	13	20	8	
Yellowfin sole		9	10	
Starry flounder		11		
Rock sole	1	9		
Staghorn sculpin	3	5		
Pollock		10		
Pacific cod				
Sand sole		1		
Surf smelt		1		
Bering cisco				1
TOTAL	91	192	117	134

whitespotted greenling, and occasionally a masked greenling. In addition, there seem to be relatively few sculpin species present.

Table 4. Temperature profiles for two sample locations on August 15, 1978.

	Location	
	59° 33' 15" N 153° 12' 00" W	59° 32' 15" N 153° 09' 00" W
Depth, m	Temperature C	Temperature C
0.5	12.2	13.0
1	11.9	12.9
3	12.0	12.4
5	11.8	12.1
10	11.5	12.0
14	11.5	11.4

The abundance of fish in the rocky / kelpy type of habitat is reflected in the consistently low catches of the trammel nets in comparision with those in Kodiak. The general absence of kelp beds may contribute to this low population abundance and low species richness.

The sandlance, which is quite abundant in many marine areas of Cook Inlet and Kodiak and an important link in the food web, appears to be in low abundance in the Kamishak Bay area. Results of work in 1976 suggested that sandlance were in low abundance in Kamishak Bay and showed a lower growth rate for them in Kamishak Bay and the northerly portions of the inlet.

The larvae of herring were captured virtually everywhere in Kamishak Bay. The Kamishak Bay area is undoubtedly important to the reproduction of local herring stocks. The try net catches consistently yielded fairly good catches of juvenile halibut and Kamishak Bay apparently is important to this commercial species. The abundance of tanner crab during the summer quarter was lower than earlier as this species resides in deeper water during summers.

V. Preliminary Interpretation of Results.

The Kamishak Bay area is undoubtedly important to several commercial species, specifically juvenile tanner crab in spring (and probably during autumn and winter), herring spawning and larval growth during summer, and juvenile halibut during summer.

The environmental conditions seem to be severe and may effect the abundance of the fish fauna and its species richness.

VII. Estimate of funds expended: $150,262.99

Research Unit # 542
Reporting Period: June 1 -
September 28, 1978

Quarterly Report

SHALLOW WATER FISH COMMUNITIES IN THE NORTHEASTERN GULF OF ALASKA: HABITAT EVALUATION, TEMPORAL AND SPATIAL DISTRIBUTION, RELATIVE ABUNDANCE AND TROPHIC INTERACTIONS

Richard J. Rosenthal

Alaska Coastal Research
Homer, Alaska

Richard J. Rosenthal
Box 937
Homer, Alaska 99603

September 29, 1978

Alaska Coastal Research

U.S. Department of Commerce
NOAA, Environmental Research Laboratories
Gulf of Alaska Project Office
P.O. Box 1808
Juneau, Alaska 99802

Attention: Laurie Jarvela
NEGOA Lease Area Coordinator

Progress Report
Shallow Water Fish Communities in the Northeastern Gulf of Alaska: Habitat Evaluation, Temporal and Spatial Distribution, Relative Abundance and Trophic Interactions

The late summer sampling program under the proposed research project for 1978-79 was initiated on August 26, 1978 and concluded on September 15, 1978. During this time period a total of 35 dives were made in the subtidal waters of Hinchinbrook Entrance and Montague Strait. Equinoctial storms which were accompanied by gale force winds and heavy seas prevented any further field activities on the outer coast. However, prior to our departure from the NEGOA region we were able to accumulate some pertinent information on the ecology of the fishes of the Gulf of Alaska. Significant highlights and observations obtained during the summer field activities are described below.

A) Emplacement of Fixed Transects

Fixed transects were established at four different locations in the NEGOA region: 1) Constantine Harbor, 2) Schooner Rock, 3) Zaikof Point and 4) Danger Island. Fourteen transects comprised of sectioned lines and galvanized stakes were placed in the shallow water adjacent to the shoreline. In all, the fixed lines totaled 470 meters in length, and were usually placed in comparable depths and microhabitats.

B) Estimates of Fish Density and Vertical Distribution

To date, 2,790 square meters of sea floor have been examined for fish density and vertical distribution along 39 randomly placed transects. Another 2,310 square meters of underwater terrain was examined within the fixed transect bands. This sampling array enables us to compare the fixed transects with randomly placed ones to determine if the data is comparable or should be treated separately. Most of the counts were replicated with the passage of time to account for differences in tidal height and direction, time of day and activity patterns of the fish. Underwater visibility was generally good, greater than 10.0 m during late summer, making the counts of the censused fish more accurate than those obtained when visibility is restricted due to planktonic blooms and, or low light penetration.

C) Habitat Utilization

Patterns of habitat utilization in the shallow water fish communities of the Gulf of Alaska are being studied in relation to a few key parameters which seemingly effect spatial distributions and contribute to resource partitioning in the nearshore zone. _In situ_ observations suggest that these distributions are effected by (1) the position or depth of the water column, (2) type of bottom topography, (3) vegetation structure or zone and (4) degree of exposure in relation to ocean swell and net water flow. Corresponding shifts in the useage of these nearshore habitats are expected with seasonal changes in fish density and distribution.

The water column has been arbitrarily divided into three different strata or levels: 1) 0 m or the bottom, 2) 0.5 m to 2.0 m and 3) that portion of the water column above 2.0 m.

Bottom topography or the type of inorganic substratum present in these locations seems to be another contributory factor. Major categories include silty clays, sand, gravel, cobbles, boulders and rock pavement. Rock walls, pinnacles, and outcrops are other important features of the submarine landscape. In many cases the underlying bottom is heterogeneous or comprised of different substrates such as sand and rock.

Five major vegetative zones are recognized as characteristic features of the biota in these locations. The shallow sublittoral zone was typically dominated by benthic marine plants. The vegetative band was multi-layered or composed of a number of separate canopies. Major zones include the algal turf, low statured reds, understory or laminarian kelps, sea grass meadows and floating beds of bull kelp.

The activity of the fish at the time of encounter or observation was also recorded by the underwater observer. Some of the major activity patterns included feeding, swimming, chasing, nest guarding, hiding and resting.

D) <u>Foraging Habits and Size Composition</u>

Samples of fish populations inhabiting the nearshore zone have been taken for trophic analysis and size composition. Specimens have been captured by hand net, spear, hook and line and variable mesh gillnets. To date, a total of 245 fishes, comprised of 24 species, have been collected for size distribution and dietary information. All specimens are measured, weighed, sexed, and the stomach contents examined for possible food items. The diets of some fishes such as the kelp greenling, china rockfish and alaskan ronquil are beginning to follow definable pathways and routes in the food chain. However, with a number of other species many more samples are needed to accurrately describe their food habits.

E) Species Composition/Range Extensions

The shallow water fish communities of the NEGOA region are represented by at least 50 species which are typical of these four locations. Other species are no doubt present, however the inventory does not include those species that are difficult to identify or collect underwater because of their small size or cryptic nature. More species will undoubtedly be added to the list as each of the study sites comes under closer scrutiny with the passage of time.

It is worth noting that 8/50, or 16 percent of the fishes identified to date were previously unreported in these waters, and as such represent northern range extensions in the Gulf of Alaska. For example, the longfin sculpin *Jordania zonope* was only reported to range as far north as Barkley Sound on the west coast of Vancouver Island. *Jordania* not only occurs in the NEGOA region, but is one of the more commonly encountered species in the boulder field habitat below about 18.0 m off the southeast end of Danger Island. This seems to be the case with most of the range extensions - as most are not casual or infrequent visitors to these waters, but are conspicuous members of the shallow water ichthyofauna of the northeastern Gulf of Alaska.

Participants In The Summer Field Work

Mr. Richard J. Rosenthal
Senior Marine Biologist
ALASKA COASTAL RESEARCH

Dr. Ronald Shimek
Assistant Professor of Biology
UNIVERSTTY OF ALASKA

Dr. D. Craig Barilotti
Research Associate
CALIFORNIA STATE UNIVERSITY

Dr. Rimon C. Fay
Director of Research
PACIFIC BIO-MARINE LABORATORIES

Mr. Thomas M. Rosenthal
Diver/Biologist
CONSULTANT

QUARTERLY REPORT

Contract No:	R7120825
Research Unit No:	RU 551A and 551B
Reporting Period:	July 1-September 30, 1978
Number of Pages:	7

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

Co-Principal Investigators

Jean R. Dunn and Felix Favorite
National Marine Fisheries Service
Northwest and Alaska Fisheries Center
Seattle, Washington
September 1978

PI QUARTERLY PROGRESS REPORT RU 551A

Reporting Period: July 1-September 30, 1978

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

I. Highlights of Quarter's Accomplishments

Third quarterly cruise (4MF78) conducted in waters contiguous to Kodiak Island from June 19 to July 9, 1978. A total of 113 biological stations was occupied, including 88 grid stations, 2 diel stations, and one supplementary station. A total of 505 plankton samples was collected. CTD measurements totaled 106 and 800 sea-bed drifters were released.

Ichthyo- and zooplankton samples from the second cruise, conducted in spring 1978 (4DI78) were received from the sorting contractor. Identification of ichthyoplankton from this cruise is nearing completion.

II. Objectives

To determine the seasonal composition, distribution, and apparent abundance of marine organisms in waters contiguous to Kodiak Island with emphasis on ichthyoplankton, meroplankton, and holoplankton.

III. Field or Laboratory Activities

A. Field Activities

1. Ship schedules:

   June 19-July 9, 1978, cruise 4MF78 aboard FRS *Miller Freeman*.

2. Field party:

Name	Affiliation	Role
Kenneth Waldron	NWAFC	Chief Scientist
Langdon Quetin	NWAFC	Biologist
Kevin Bailey	NWAFC	Biologist
Kristin Stahl	NWAFC	Biologist
Lynn Gmeiner	NWAFC	Biological Technician
Jay Clark	Univ. Wash.	Biological Technician

3. Methods

   At each grid station a CTD probe was made to near bottom or, in deep water, to 1500 m. A neuston tow was made for 10 minutes to sample ichthyoneuston, followed by a double-oblique Bongo tow from near bottom to the surface. At selected stations a Tucker Trawl was used to sample to discrete strata and, at other stations, micronekton was sampled using a 6-foot Isaacs-Kidd midwater trawl.

Two stations were sampled over a 24 hour period using a neuston net and a Tucker Trawl to assess diel variation in catches. Sea-bed drifters were released at 16 locations.

4. Sample collection localities:

The station plan is illustrated in Figure 1.

5. Data collected and analyzed:

(a) Number of samples collected

111 neuston samples
178 Bongo samples (89 each 0.505 and 0.333 mm mesh)
176 Tucker Trawl samples
40 Isaacs-Kidd Midwater Trawl samples

A total of 106 CTD measurements was taken and 800 sea-bed drifters were released.

(b) Number and types of analyses

Ichthyoplankton from this cruise have been received from the sorting contractor. Zooplankton samples are due in Seattle on October 9.

B. Laboratory Activities

1. Scientific group:

Name	Affiliation	Role
Jean Dunn	NWAFC	Co-principal Investigator (half-time)
Dr. Arthur W. Kendall	NWAFC	Fishery Research Biologist (half-time)
Kevin Bailey	NWAFC	Fishery Biologist (half-time)
Beverly Vinter	NWAFC	Ichthyoplankton specialist
Donald Fisk	NWAFC	Physical Science Technician
Langdon Quetin	NWAFC	Biologist (half-time)

2. Methods:

Fish eggs and larvae were identified by microscopic examination using standard procedures of larval fish taxonomy. Fish eggs and larvae were measured by means of a calibrated ocular micrometer.

Aliquots of zooplankton from the 0.333 mm mesh Bongo net were identified by the sorting contractor to phylum, class, or order as appropriate except for euphausiids which were identified to species. Euphausiids from the Tucker Trawl and IKMT were also identified by the sorting contractor. Copepods are being identified by Dr. Bruce Wing, Auke Bay Fisheries Laboratory, NMFS, for this RU. Crab and shrimp larvae are being identified by John Bowerman, Kodiak Laboratory, NMFS, under RU-551.

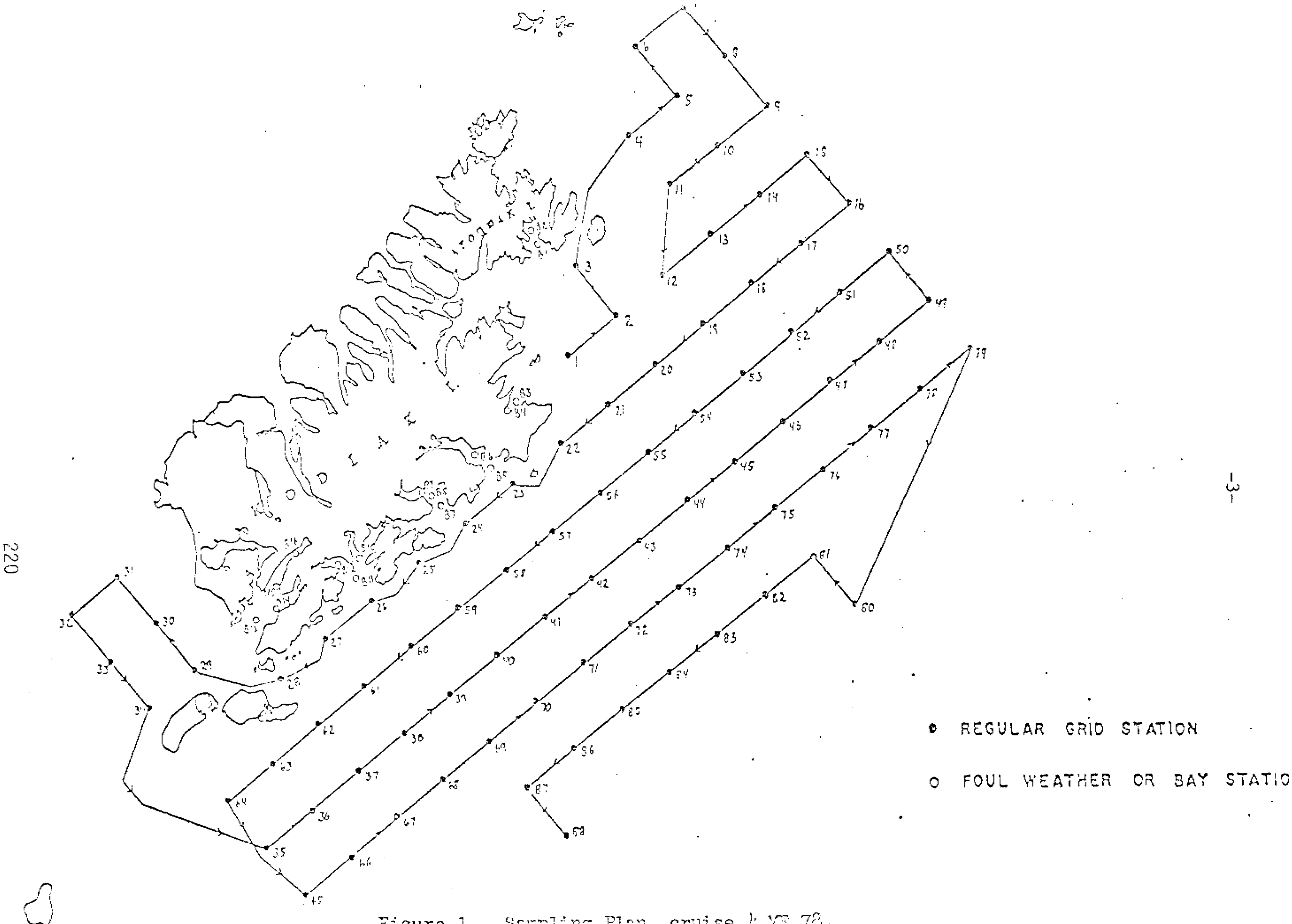

Figure 1.--Sampling Plan, cruise 4 MF 78.

3. Sample collection localities:

Samples presently being analyzed were collected during the spring 1978 cruise (4DI78). The cruise track is shown in Figure 2.

4. Data analyzed:

a. Number of samples examined:

To date, fish eggs and larvae from cruise 4DI78 have been identified from the following samples:

Type of sample	No. Identified	No. Collected
Neuston	99	112
Bongo (0.505 mm mesh)	85	85
Tucker Trawl	139	139
IKMT	0	56
Total	323	392

Zooplankton have been sorted from aliquots from 85 Bongo (0.333 mm mesh) samples, aliquots of euphausiids and crab and shrimp from 139 Tucker Trawl samples, and aliquots of euphausiids from 56 IKMT samples.

IV. Results

A major emphasis in the laboratory this quarter was directed toward getting our data in machine readable form for inhouse analysis and submission to OCSEAP in the proper NODC format. To this end the field and laboratory data from the fall cruise of last year have been entered and corrected, and programs are being written to convert them to NODC format. Routines have been established so that data from subsequent cruises should flow smoothly from collection through processing and reporting.

The composition of the ichthyoplankton from the fall 1977 cruise was reported in the June 1978 quarterly report. Here we briefly summarize the zooplankton composition for that cruise.

Cruise 4MF77 yielded some interesting zooplankton patterns. As expected, the abundance of copepods was an order of magnitude greater than any other zooplankton group, averaging 7×10^4 animals/1000 m^3. Amphipods, euphausiid larvae and juveniles, larvaceans, chaetognaths, gastropods, and cnidarians occurred at all but 2 or 3 stations. Groups absent from more than 50% of the stations (number of positive stations indicated in parentheses) were mysids (4), cladocerans (20), isopods (17), shrimp (3), cumaceans (6), cirripedia nauplii (20), pteropods (0), ctenophores (13), and echinoderm larvae (8).

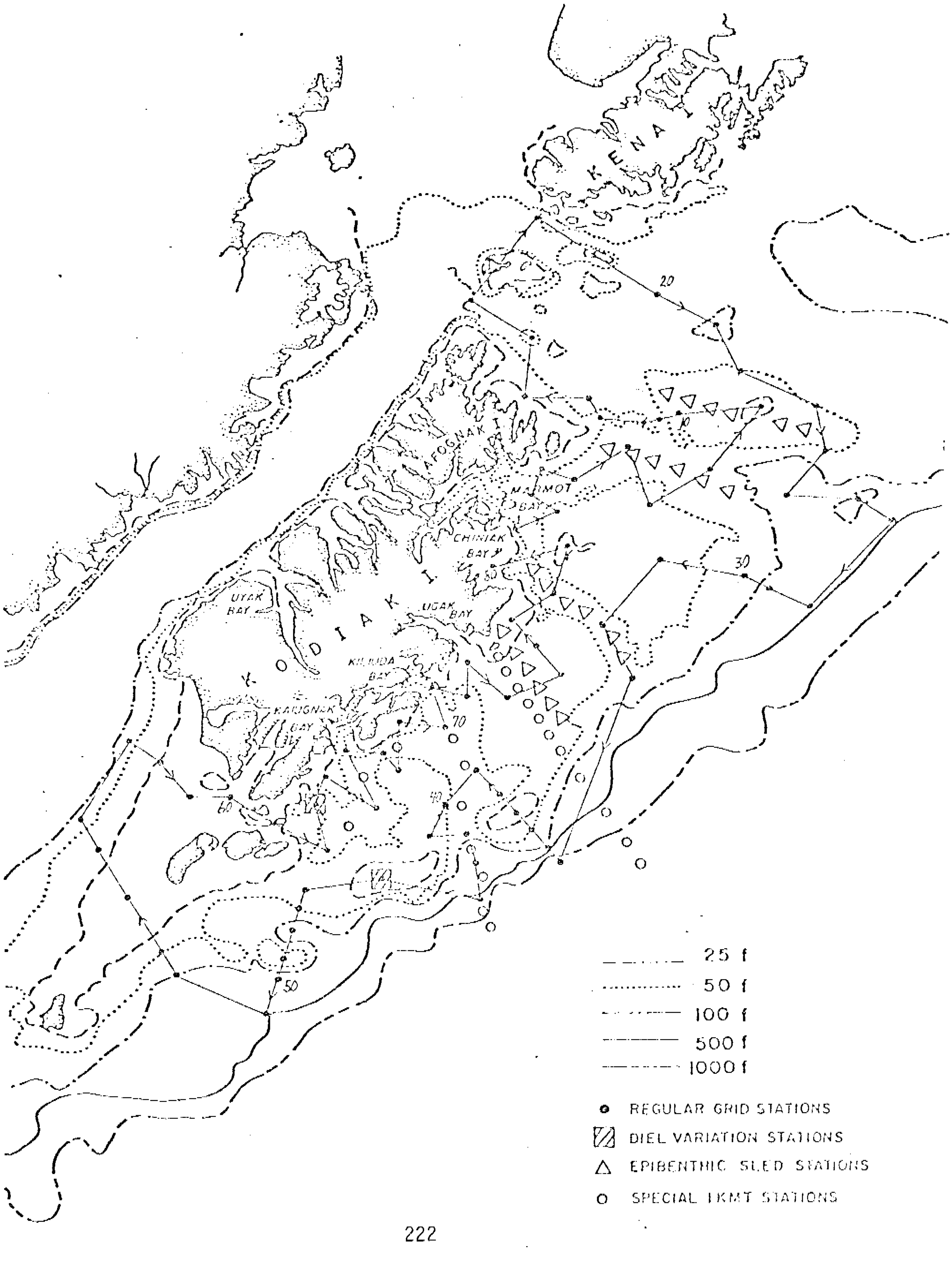

Figure 2.--Sampling plan, cruise 4-DI-78.

Echinoderm larvae were not very abundant and occurred at only seven stations. Crab larvae were found in low abundance and only at two stations. Euphausiid larvae and juveniles were very abundant (relative to other groups except copepods) and occurred at all stations. *Thysanoessa inermis* was numerically the most abundant euphausiid. Other species of less importance were *Thysanoessa longipes*, *Thysanoessa raschii*, and *Tessarabrachion oculatus*.

V. Preliminary Interpretation of Results

None

VI. Auxiliary Material

None

VII. Problems Encountered and Recommended Changes

None

VIII. Estimate of Funds Expended

Approximately $35.0K was expended this quarter, not including sorting costs.

MILESTONE CHART

| - Start

△ - Planned Completion Date

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

RU # 551 PI: Dunn and Favorite.

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

MILESTONES /Activities	1977 O	N	D	J	F	M	1978 A	M	J	J	A	S	O	N	D	J	F	1979 M	A	M	J
Quarterly report										▲											
Ichthyoplankton data analysis (4MF77)									|					△							
Zooplankton data analysis (4MF77)										|				△						
Ichthyoplankton identified (4DI78)										|			△							
Receive sorted zooplankton (4DI78)										▲											
Miller Freeman cruise 4-MF-78										|	▲									
Quarterly report													▲								
Ichthyoplankton data analysis (4DI-78)															|		△				
Zooplankton data analysis (4DI78)															|			△			
Wecoma cruise														|	△						
Ichthyoplankton identified (4MF78)														|				△			
Sorted zooplankton received (4MF78)													△								
Quarterly report															△						
Second OCSEAP cruise FY 79																		|	△		

Contract No. : R7120825
Research Unit : 551B
Reporting Period: July 1-Sep 30,1978
Number of pages: 3

QUARTERLY PROGRESS REPORT

June 15 to August 15, 1978

I Abstract

During the reported quarter, all remaining nearshore plankton sampling was completed. Over 500 samples were collected and shipped to a contracted sorting center for partial sorting into major taxa such as: Euphausiids, Chaetognaths, Copepods, decapod shrimp and crab, and fish eggs and larvae. The decapod crustacea portion of these subsamples have started to arrive at the Kodiak Facility and are being further sorted and analyzed for species composition and life stage development.

II Objectives

The objectives of R.U. 551B are to determine the seasonal composition, distribution, relative abundance and life stage development of commercially and ecologically important species of larval crabs and shrimps in four bay systems on the eastern coast of Kodiak Island.

III Field or Laboratory Activities

A. Ship or field trip schedule
Field operations were performed in conjunction with R.U. 553 aboard the chartered University of Washington R/V COMMANDO. Specific cruise dates were as follows:

Cruise	Date
VI	6/13 - 6/27
VII	6/28 - 7/20
VIII	7/21 - 7/31
IX	8/1 - 8/14
X	8/15 - 8/21

B. Scientific Party

Field operations were handled jointly by personnel from R.U. 553

party
and 551B. The scientific/for both R.U.'s includes:

Mr. D. Rabin, FRI, Biologist
Mr. K. Semmens, FRI, Technician
Mr. B. Birmingham, FRI, Biologist
Mr. J. Bowerman, NMFS, Biologist

C. Methods

Zooplankton was sampled bi-weekly at stations located in the central and outer areas of Izhut, Kalsin, Kiliuda and Kaiugnak Bays (Fig. 1). Stations were sampled once every two weeks with a surface neuston sampler, bongo arrayed plankton nets, opening-closing Tucker trawl and an epibenthic plankton sled. Diel sampling was conducted at one location each in Izhut and Kiliuda Bays. Samples were preserved in buffered formalin solution and stored until shipment to the contracted sorting center. Following sorting of a 500 organisms aliquot into major taxa at the sorting center, the unsorted portion of each sample and decapod crustacea portion from the aliquot were to be shipped to the Kodiak Facility for more detailed sorts and analyses.

D. Sample Collection Localities

Samples were obtained from five stations each in the Izhut-Marmot, Kalsin-Chiniak, Kiliuda and Kiaugnak Bay systems. (See Table).

E. Data Collected and/or Analyzed

1. During this quarter 541 plankton samples were collected and shipped to the sorting center. Numbers of samples by gear type are:

   140 surface neuston
   130 bongo arrayed plankton net
   120 open-closing Tucker trawl
   21 epibenthic plankton sled

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

2. The decapod crustacea portion of 47 sample aliquots have been received from the contractor. Additionally, 56 bulk samples (i.e., that portion of the original sample remaining after removal of the 500 organism aliquot) have also been returned to the project investigators. The decapod shrimp and crab larvae aliquot subsamples have been further sorted to the lowest taxanomic classification possible and these data are being prepared for computer analysis.

   The decapod crustacea portion of 95 presorted bongo and Tucker trawl samples have been received from R.U. 551A, the offshore plankton survey, but only preliminary examinations of these samples have been completed.

IV Results

All aliquot subsamples received from the nearshore plankton survey have been sorted and several species of Pandalid shrimps, and Brachyuran and Lithodid crabs have been identified and counted. Detailed analysis awaits the arrival of all remaining aliquot subsamples and their sorting.

Initial examination of surface neuston samples, prior to their shipment to the contractor, has indicated the presence of large numbers of Tanner crab megalops in the surface layers of the water at several sampling stations. Additionally, sorts of the aliquot subsamples have located several sidestripe shrimp (Pandalopsis dispar) in the Stage II of development which are substantially larger than that size reported in the literature.

V Preliminary Interpretation of Results

Nothing to report at this time.

VI Problems Encountered and Recommended Changes

Very low numbers of important Pandalid and Lithodid larval forms have been found in those aliquot subsamples examined to date. Pink shrimp (Pandalus borealis) larvae have occasionally been found in relatively large numbers (up to 41 individuals) but only one or two organisms of several other important Pandalid species were present.

Our contract for the presort into major taxanomic categories required examination of a 500 organisms aliquot regardless of plankton density in the sample. Unfortunately, in many instances, other forms such as barnacle larvae or copepods occur in extremely high amounts in the water column and consequently in the plankton samples. When this situation occurs, these abundant forms represent nearly all individuals in the aliquot, thereby masking detailed species composition and abundance information for our species of interest.

Greater amounts of decapod larvae need to be examined to achieve the objectives of our project (See Section II). This will be accomplished by splitting each bulk sample until our subsample contains approximately 500 Pandalid shrimp. A split containing such an amount of Pandalids will assure sufficient numbers of other decapods of interest. The resulting subsample will then be sorted, decapod larvae identified to the lowest taxonomic classification and enumerated.

Delay in the analysis of the samples has resulted from an extended time lag for the following: 1) getting the samples to Seattle for shipment to the contracted sorter; 2) receipt of the shrimp/crab portions of the aliquot following its shipment from Texas to Seattle. Samples expected to be received in May were not received until late July. All aliquot subsamples from the nearshore survey received to date, have been examined and we are awaiting further shipments. Bulk samples are currently being sorted into larval crab and shrimp forms.

Contract # 03-5-022-69

Research Unit 552

Reporting Period: July 1, 1978 -
September 30, 1978

Quarterly Report

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

James E. Blackburn

Peter B. Jackson

Alaska Department of Fish & Game

P.O. Box 686

Kodiak, Alaska 99615

September 30, 1978

I. Abstract of Quarter's Accomplishments

The activities of R.U. 552 during the July - September 1978 quarter consist of conducting the Kodiak nearshore fish survey. This survey effort in FY 78 consisted of five successive monthly assessments of nearshore fish stocks in four bay systems which collectively represent the east side of Kodiak Island. Approximately one week per month was spent in each bay system. Surveys were conducted from a large (60 ft.) chartered fishing vessel and utilized a wide variety of fishing gear types to insure fishing effort in all habitat types. Surveys were organized and conducted by R.U. 552 which had primary responsibility for obtaining information on the spatial and temporal distribution of fish. Activities of R.U. 552 were closely integrated with those of R.U. 553 which had the primary responsibility of obtaining data on feeding habits of nearshore fish species. Also integrated into this fish assessment study are field activities of R.U. 5 (IMS) and 332 (NMFS).

Survey effort was initiated on April 1 and has continued uninterrupted through August 31, 1978. Sampling has been conducted according to schedule throughout this reporting period. A total of 880 units of effort have been expended.

An observer was placed aboard the R/V MILLER FREEMAN during June 18 thru July 7, 1978 and 16 otter trawl hauls were completed on the Kodiak shelf.

II. Task Objectives

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

III. Field or Laboratory Activities

A. Ship or Field trip schedule. Tables 1 and 2.

The ship schedules are contained in Tables 1 and 2. The M/V YANKEE CLIPPER was a chartered vessel used for the continuous sampling indicated in Table 1. No aircraft were utilized. The R/V COMMANDO was a chartered vessel and a cruise was made aboard the R/V MILLER FREEMAN, a NOAA vessel during 18 June through 7 July, 1978.

B. Scientific Party.

Peter B. Jackson, Principal Investigator.	A.D.F.& G.
James E. Blackburn, Principal Investigator.	A.D.F.& G.
Mark Buckley, Fishery Biologist.	A.D.F.& G.
Leslie J. Watson, Fishery Biologist.	A.D.F.& G.
Toni Harsh, Fish & Game Technician.	A.D.F.& G.
Steven Quinnell, Fishery Biologist.	Fishery Research Institute
Michael Gross, Fishery Biologist.	Fishery Research Institute
Max Hoberg, Fishery Biologist.	Institute of Marine Science
John Rose, Fishery Biologist.	Institute of Marine Science
Bill Gronlin, Fish Pathologist.	N.M.F.S.
Jolly Hibbitts, Fish Pathologist.	N.M.F.S.

C. Methods.

1. Data were obtained during 5 - one month surveys (April-August) conducted from the chartered research vessel YANKEE CLIPPER.

2. Four study areas were surveyed monthly as follows:

   a. Izhut Bay - inside of a line between Pillar Cape and Peril Cape.

   b. Kalsin Bay - inside of a line between Broad Point and Isthmus Point.

   c. Kiliuda Bay - inside of a line between Pivot Point and Shearwater Point.

   d. Kaiugnak Bay - inside of a line between Cape Kiavak and Cape Kasiak.

3. Surveys utilized the charter vessel for primary logistical support as well as for certain fishing operations (i.e. try net and tow net operations).

4. Nearshore fishing operations required the full time use of one 14-16 foot light skiff equipped with a 25 h.p. outboard engine. Tow net operations required use of a 17-20 foot skiff equipped with a 70 h.p. engine.

5. Each study area was separated in to regions which were sampled as systematically as possible. The following suite of gear types, selected on the basis of their combined ability to catch fish species throughout the nearshore zone, were used:

   a. Beach seine: 155' - tapered from wings to 12' at center, ¼" mesh throughout.

   b. Variable mesh gill nets: ¼" - 2½" mesh - floating and sinking.

   c. Trammel net: 150' x 6' (3 panel).

   d. Tow net: 10' x 20' x 43'.

   e. 20' Standard try net with 15" x 30 " trawl doors.

   f. Midwater trawl - utilize 10' x 20' tow net as described above.

   g. Standard 400 mesh Eastern Otter Trawl (fished from M/V COMMANDO).

6. Studies were conducted by four scientific personnel (two from FRI and two from ADF&G) in addition to a two person vessel crew. Personnel from R.U. 5 and 332 were periodically on the vessel and obtained their samples incidentally to primary fishing operations. The only exception to this is that one try net tow per day is made in deep (50-70 fathoms) water specifically for IMS personnel to insure they obtain an adequate sample of king crab.

7. The four person scientific crew were divided into 2 two person crews; one handled beach seines, trammel nets, gill nets and tow nets from the open skiff and the other remained on board the seine vessel to handle the tow net, try net and mid-water trawl. In most cases these tow crews were able to operate simultaneously.

8. Catch processing (i.e. species identification, enumeration, subsampling, measuring, weighing, foregut removal) was done immediately following fishing operations.

9. Sampling was accomplished aboard the M/V COMMANDO in both Izhut and Kiliuda Bay study areas during one day each month in each area from April through August 1978.

10. All trawling is done at depths from 30 to 50 fathoms. A total of three hauls were completed each month. Exact trawl locations were identified during the April 1978 survey and remained consistant.

11. The cooperative survey biologist completed one cruise on board the NOAA vessel MILLER FREEMAN during June 13 through July 7, 1978. A total of sixteen hauls were completed.

D. Sample locations/ship or aircraft tracklines (Figures 1 and 2). Figure 1 depicts the four bays sampled. Figure 2 depicts the station locations sampled by the cooperative survey.

E. Data collected. (Table 1).

A total of 880 hauls of all gear types were completed by the nearshore fish survey during the entire summer (Table 1).

A total of 16 hauls were completed by the cooperative survey.

IV. Results:

Data collections have been completed and coded data has been nearly all proofed for keypunching.

V. Estimate of funds expended: $159,847.35

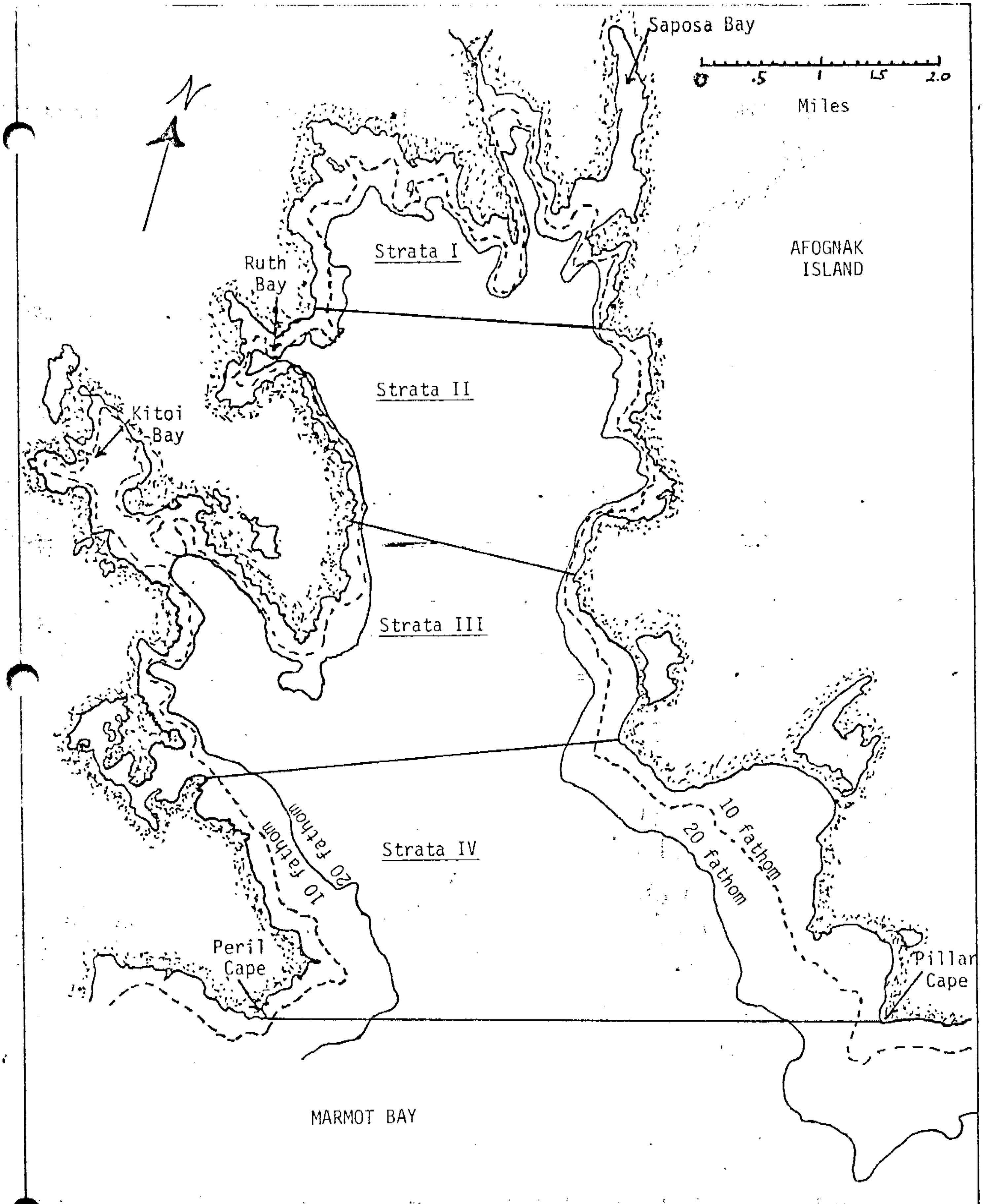

Figure 1A - Izhut Bay sampling region with ~~10 fathom~~ (18.29 M) and 20 fathom (36.58 M) contours and sampling strata as utilized by R.U. 552 & 553 on Kodiak Nearshore Fish Assessment Study, 1978.

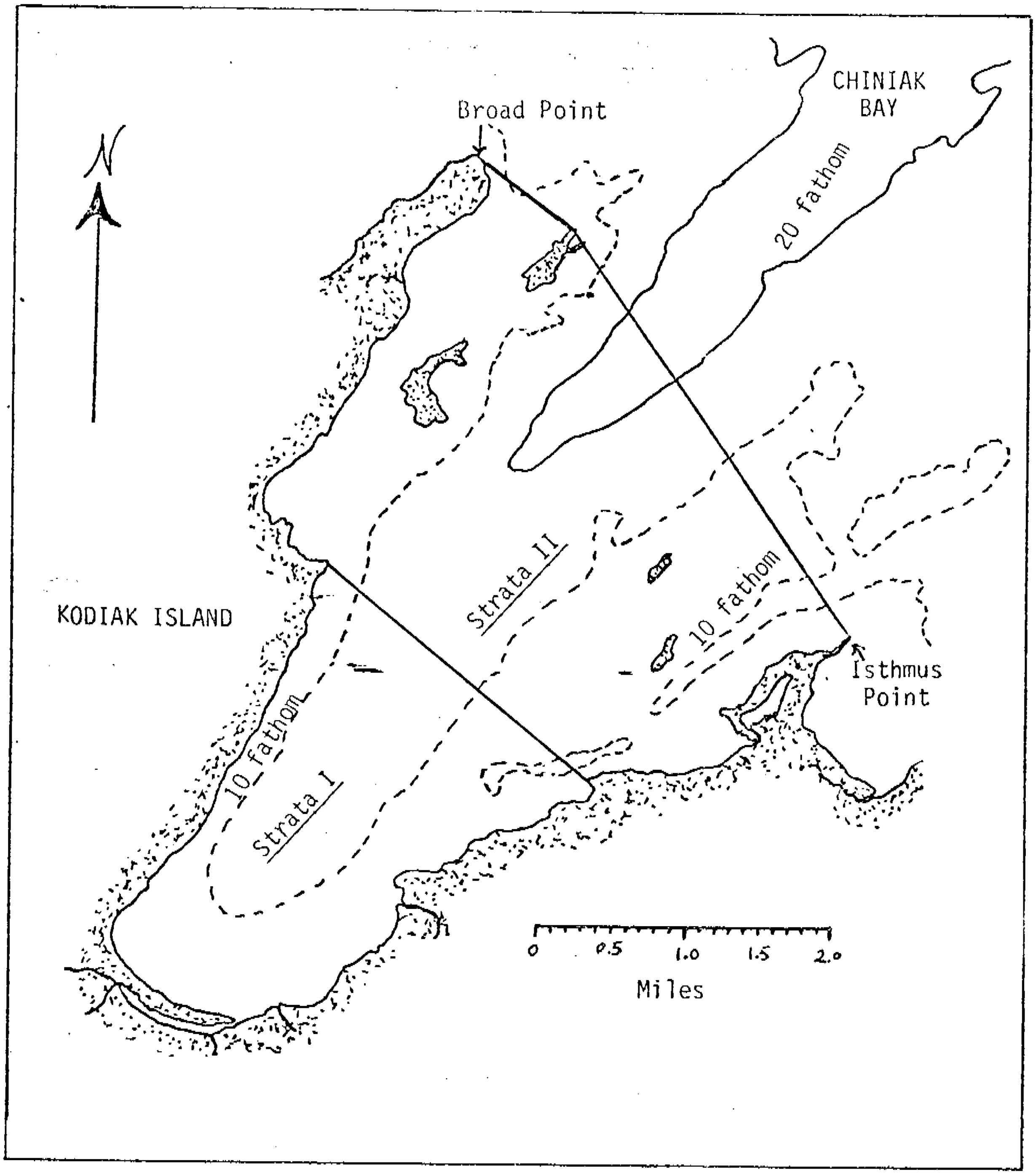

Figure 1B - Kalsin Bay sampling region with 10 fathom (18.29M) and 20 fathom (36.58M) contours and sampling strata as utilized by R.U.552 and 553 on Kodiak Nearshore Fish Assessment Study, 1978.

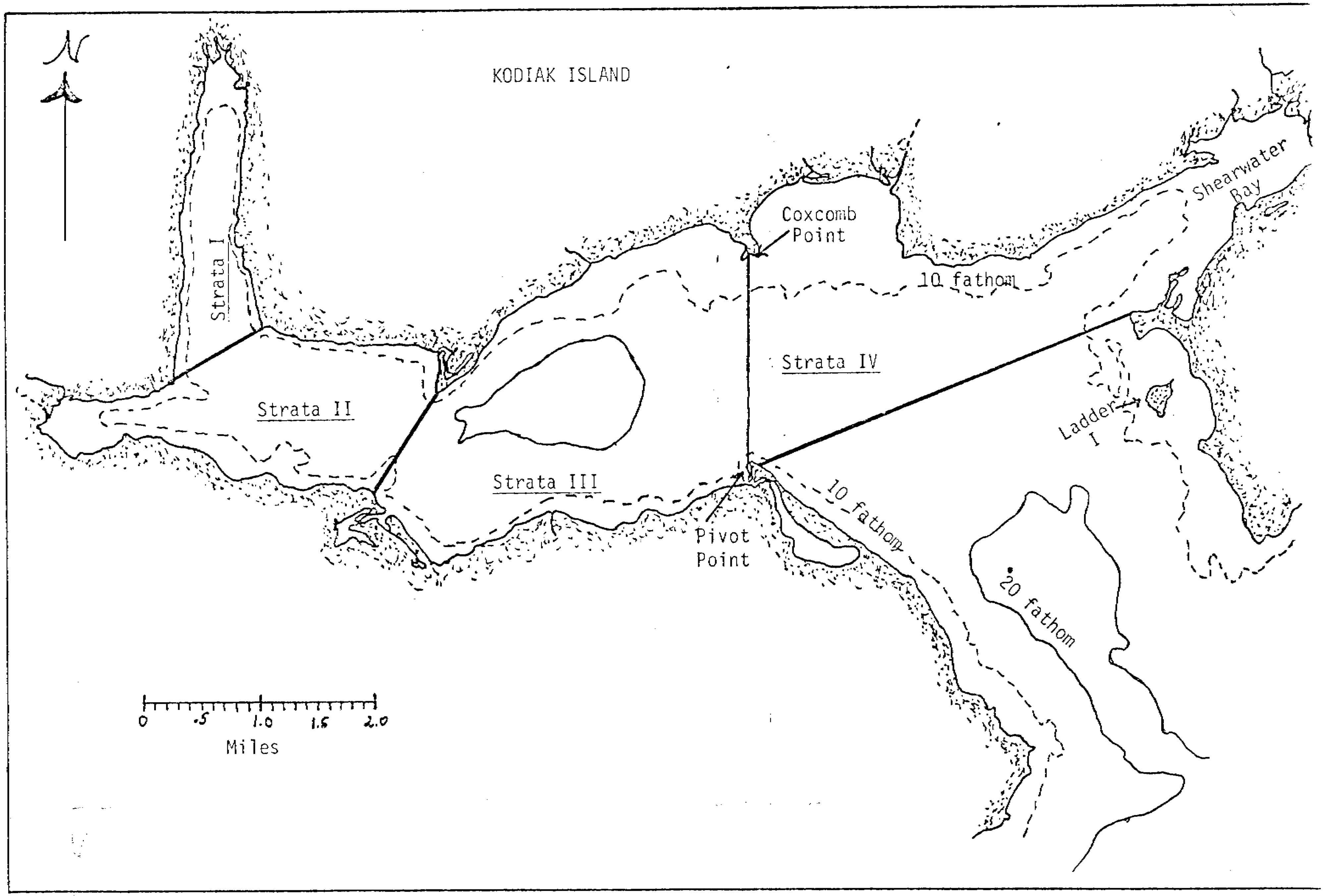

Figure 1C - Kiliuda Bay sampling region with 10 fathom (18.29M) and 20 fathom (36.58M) contours and sampling strata as utilized by R.U.552 and 553 on Kodiak Island Nearshore Fish Assessment Study, 1978.

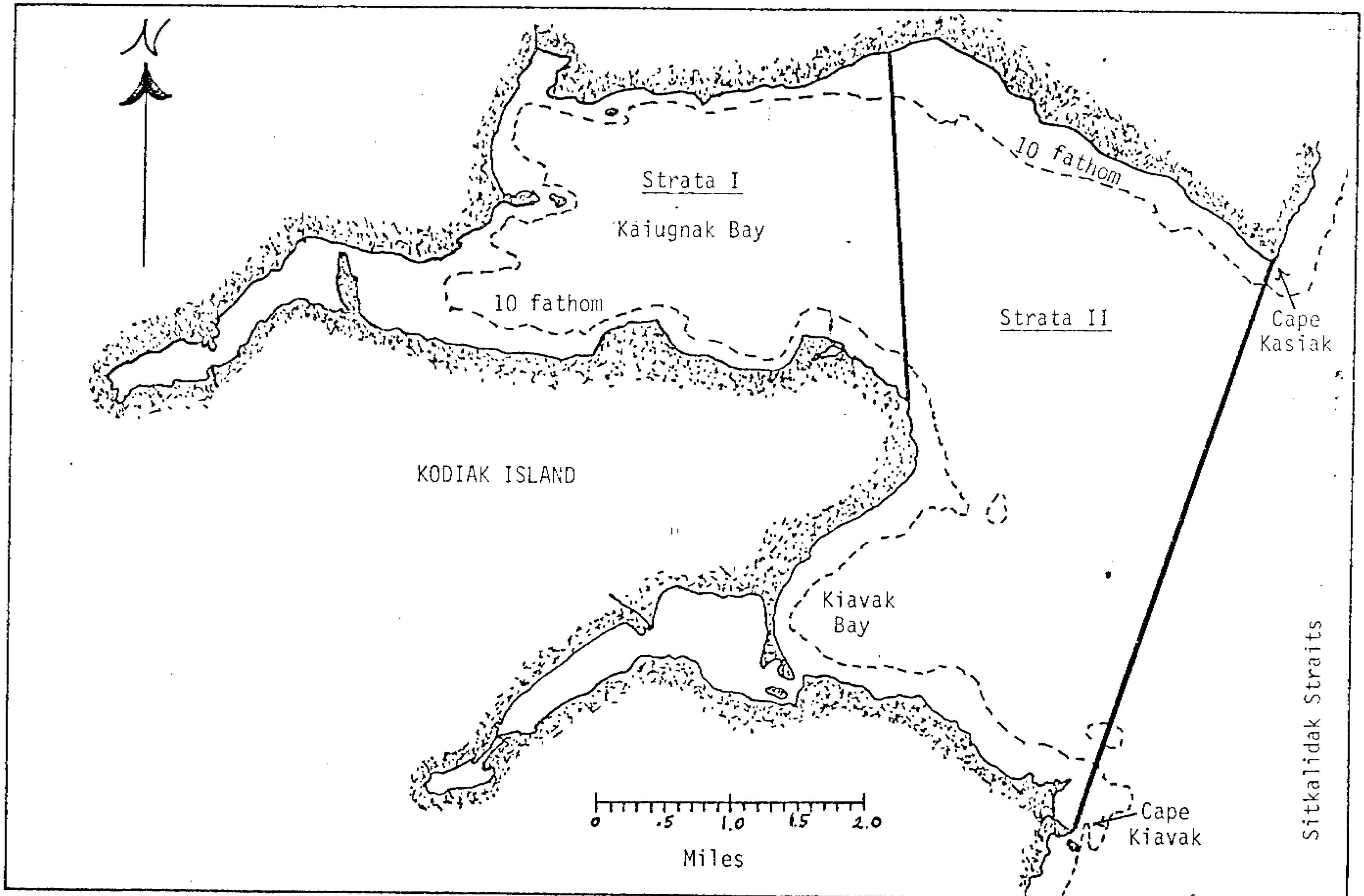

Figure 1D - Kaiugnak Bay sampling region with 10 fathom (18.29M) and 20 fathom (36.58M) contours and sampling strata as utilized by R.U. 552 & 553 on Kodiak Nearshore Fish Assessment Study, 1978.

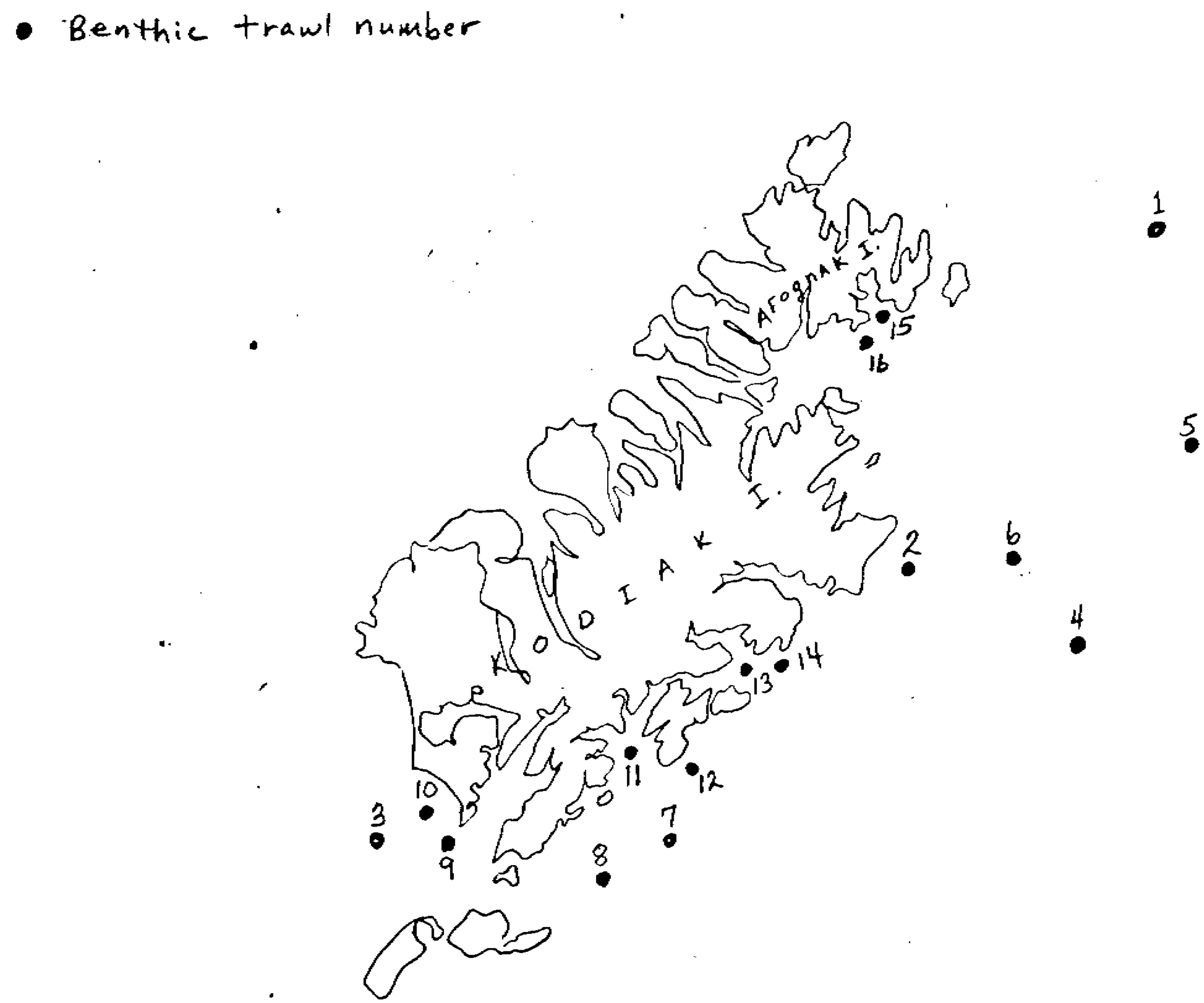

Figure 2. Stations sampled from R/V MILLER FREEMAN, June 18 through July 7, 1978.

Table 1 . Number of hauls by gear, area and cruise. Also inclusive dates of each survey cruise, FY 78, RU 552.

Bay	Date	Gear Type						
		Beach Seine	Trammel Net	Gill Net	Try Net	Tow Net	Midwater Trawl	Otter Trawl
Kalsin	April 1-8	10	3	0	11	0	0	-
	May 1-7	12	5	5	9	11	0	-
	June 2-6	12	4	4	7	3	4	-
	July 1-7	9	4	5	7	0	5	-
	Aug. 1-7	13	4	4	7	6	4	-
Izhut	April 9-15	18	5	0	13	8	0	3[1]
	May 10-15	16	6	7	15	0	4	3
	June 8-15	17	5	5	15	10	2	4
	July 8-15	19	7	5	14	13	2	3
	Aug. 8-15	21	7	6	14	16	4	3
Kiliuda	April 17-22	24	4	7	5	12	4	4[2]
	May 17-22	21	7	8	6	7	4	3
	June 17-22	24	6	7	6	2	4	3
	July 17-22	22	6	8	6	17	4	3
	Aug. 17-22	22	6	9	6	16	4	3
Kaiugnak	April 23-30	4	2	1	2	0	2	-
	May 23-31	12	4	5	2	0	0	-
	June 23-30	11	4	5	2	0	2	-
	July 23-31	12	4	5	2	8	2	-
	Aug. 23-30	11	4	5	2	8	2	-

[1]Date was March 31.

[2]Date was April 5-15.

Table 2. Dates of otter trawling aboard R/V COMMANDO, FY 78, RU 552.

Cruise Date	Izhut Bay	Kiliuda Bay
April	March 31	April 15
May	May 11	May 24
June	June 12, 13	June 22
July	July 12	July 19
August	August 10	August 22

QUARTERLY REPORT

Contract No.: 03-5-022-67
Research Unit: 553
Reporting Period: 1 July - 30 September 1978

Seasonal Composition and Food Web Relationships of Marine Organisms in the Nearshore Zone of Kodiak Island - Including Ichthyoplankton, Meroplankton, Forage Fishes, Marine Birds and Marine Mammals. Part A: A Report on the Ichthyoplankton Component of the Study

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

Approved:

Submitted: 29 September 1978

R. L. Burgner, Director

I. ABSTRACT

Spring and summer collections of zooplankton have been completed. All samples have been sent to a sorting center, of which approximately 65% have been processed. Fish larvae have been identified in samples collected from March through June.

II. TASK OBJECTIVES

1. Determine spring and summer composition, inter-bay distribution, and relative abundance of planktonic stages of fishes, shrimp, and crab.
2. Determine seasonal development and succession of selected commercially and ecologically important fish and invertebrate species.
3. Determine general relationships between seasonal changes in oceanographic conditions and the timing of occurrence and distribution of selected species or species assemblages.

III. FIELD OR LABORATORY ACTIVITIES

A. Ten two-week cruises were conducted aboard the R/V Commando from March 27 to August 25, 1978. Members of the scientific crew included Biff Birmingham, Warner Lew, Kenneth Semmens, Doug Rabin, and Kathryn Garrison.

During each cruise, five stations were sampled per bay area with both the neuston and bongo nets. Bottom substrates permitted epibenthic sled tows at two stations per bay area (Table 1, Figs. 1A and 1B).

Our diel (day-night) sampling was conducted once at mid-day and once at night. Five-minute horizontal tows were made at discrete depths--specifically, -10, -30, 50, -70, and -90 meters. In addition

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

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

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

**Stations added 5/78.

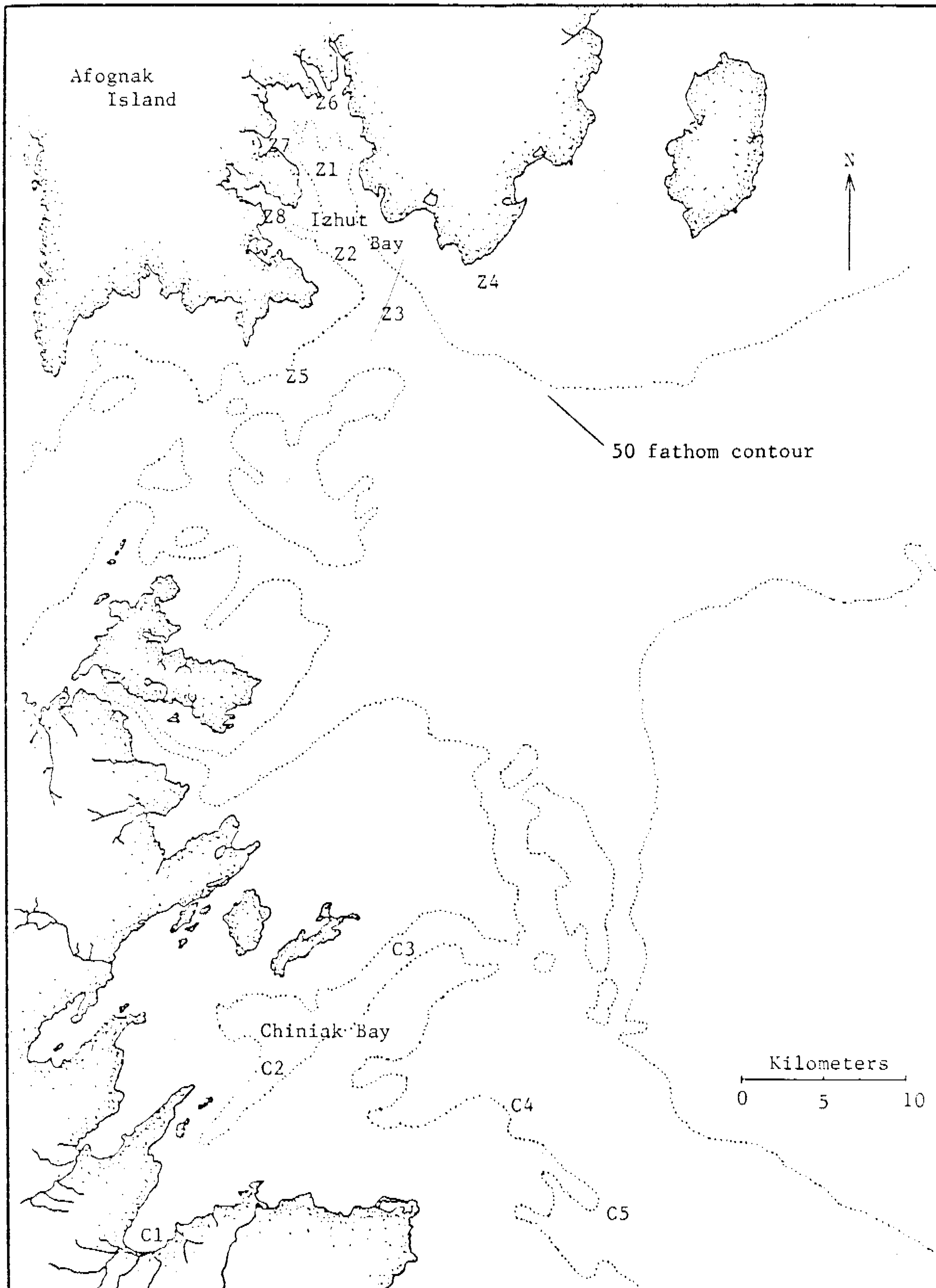

Fig. 1A. Station locations for Kodiak Island nearshore zooplankton research, 1978.

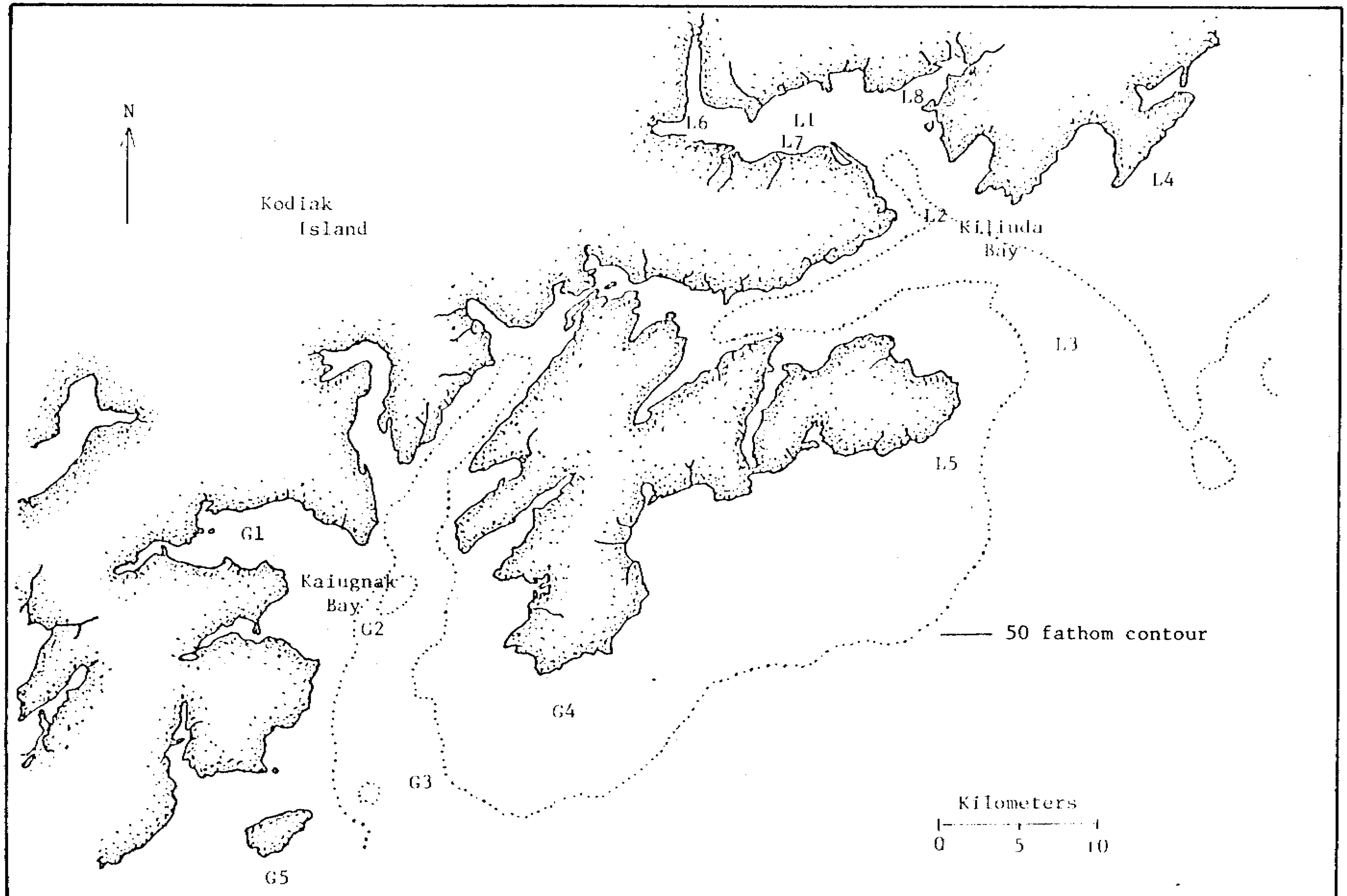

Fig. 1B. Station locations for Kodiak Island nearshore zooplankton research, 1978.

to these samples, double oblique Tucker trawls were taken to -90 m with 505μ and 3 mm mesh nets. Concurrent surface tows with the neuston sampler were also made.

Beginning May 12 sampling sites were added to the nearshore stations in Izhut and Kiliuda bays where surface and/or bottom trawl samples were taken by ADF&G. The additional sampling included three stations per bay, and at each station neuston and double oblique bongo samples were taken.

Samples from cruises I-X have been sent to a commercial sorting center for zooplankton separation.

B. Fish eggs and larvae collected during cruises I-VI were returned from the sorting center and are currently being identified, counted, and stored in a buffered formalin solution for future reference. Some species could not be identified and were therefore given a generic name, i.e., *Hemilepidotus* sp. When larvae could not be positively identified at the generic level they were typed, i.e., *Artedius* type, or given a family name, i.e., Bathymasteridae.

Data from the earlier cruises are currently being prepared for keypunching.

IV. RESULTS

A total of 1067 plankton samples was taken between March and August 1978 (Table 2). Fish larvae and eggs from the first six cruises have been sorted, enumerated, and returned to FRI (Table 2).

Fish larvae from cruises I-V have been identified or typed. These larvae represent 15 families and 30 genera (Table 3).

Laboratory findings indicate that the following:

1) Larval stages of pricklebacks (Stichaeidae) and sand lance (Ammodytidae)

Table 2. Cruise dates, number of samples collected, and total number of fish eggs and larvae sorted, by gear type, from March through September, 1978, from Kodiak Island nearshore zooplankton research

Cruise	Date	Total Number of Samples						Number of Fish Larvae					Number of Eggs				
		N	B (333)	B (505)	T (505)	T (3 mm)	Sled	N	B (505)	T (505)	T (3 mm)	S	N	B (505)	T (505)	T (3 mm)	S
1	3/27-4/9	21	20	20	12	2	3	863	861	782	2	1	805	194	228	0	0
2	4/10-4/20	22	20	20	24	4	8	478	912	1585	4	10	843	364	434	0	16
3	4/21-5/2	22	20	20	24	4	8	835	1517	3714	7	27	363	677	150	0	164
4	5/3-5/30	28	26	26	24	4	8	497*	821*	2673	26	43	1065*	673*	1184	0	237
5	5/31-6/13	28	26	26	24	4	8	271*	866*	2217	21	20	375*	894*	1486	0	53
6	6/14-6/27	28	26	26	24	4	5	197*	2268*	9927	77	153	10,992*	2495*	1644	0	19
7	6/28-7/20	28	26	26	24	4	4										
8	7/21-7/31	28	26	26	24	4	4										
9	8/1-8/14	28	26	26	24	4	4			Samples to be sorted							
10	8/15-8/25	28	26	26	24	4	4										
	Σ	261	242	242	228	38	56										

* excludes larvae from 6 unsorted samples

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

Table 3. Fish larvae identified in the Kodiak Nearshore Zooplankton Survey in samples taken from March through June, 1978.

Agonidae

4 types

Ammodytidae

Ammodytes hexapterus

Bathymasteridae (4 possible species)

Cottidae

Artedius type
Blepsias sp.
Dasycottus setiger
Gymnocanthus sp.
Hemilepidotus sp.
Icelinus sp.
Myoxocephalus sp.
Nautichthys sp.
Psychrolutes type
Radulinus asprellus
Rhamphocottus richardsoni
Triglops sp.
Cottid type B (Myoxocephalus sp.?)
Cottid type I (Icelus sp?)

Cryptoacanthodidae

Lyconectes sp.

Cyclopteridae

4 types

Gadidae

Gadus macrocephalus
Microgadus proximus
Theragra chalcogramma

Hexagrammidae

Hexagrammos stelleri

Osmeridae

Mallotus villosus

Pholidae (3 possible species)

Pleuronectidae

Hippoglossoides elassodon
Hippoglossus stenolepis
Lepidopsetta bilineata

Ptilichthyidae

Ptilichthys goodei

Salmonidae

Oncorhynchus gorbuscha (juveniles)

Stichaeidae

Anoplarchus sp.
Chirolophus sp.
Lumpenus sagitta
Lumpenus/Lumpenella type

Zoarcidae

Lycodes brevipes

remained relatively abundant from March through June.

2) Although many adult and juvenile flatfish species were caught in the Kodiak survey area (RU # 486) we have found larvae of only three species *Lepidopsetta bilineata*, *Hippoglossus stenolepis*, and *Hippoglossoides elassodon*. Only larvae of *Lepidopsetta bilineata*, the rock sole, have been found in relative abundance.

3) Similarly, several species of adult greenlings occur in Kodiak waters, but we have found only white spotted greenling, *Hexagrammos stelleri*, larvae. The majority of these were caught in neuston samples.

V. PRELIMINARY INTERPRETATION OF RESULTS: None at this time

VI. PROBLEMS ENCOUNTERED AND RECOMMENDED CHANGES

None to report at this time.

MICROBIOLOGY

Contents

QUARTERLY REPORT

Contract # 03-5-022-85
Research Unit 29
Period 7/1 - 9/30

Assessment of Potential Interactions of Microorganisms and Pollutants Resulting from Petroleum Development

Submitted by: Ronald M. Atlas
Principal Investigator
Department of Biology
University of Louisville
Louisville, Kentucky 40208

October 1, 1978

I. Task Objectives

A. To characterize marine microbiological communities in sufficient detail to establish a baseline description of microbiological community characteristics on a seasonal basis.

B. To determine the role of microorganisms in the biodegradation of petroleum hydrocarbons.

II. Field and Laboratory Activities

A. Field Activities

1. Cook Inlet. No samples were collected during this period.

2. Beaufort Sea. Samples were recovered from the Plexiglas trays containing oil-sediment. Recovered samples had been incubating for 4 and 8 months.

Samples were collected during a cruise of the icebreaker Northwind between August 25 and September 25. A total of 36 surface water and 29 surface sediment samples were collected. Most samples were collected within the 10 fathom curve. Samples were processed aboard ship for direct counts, total viable counts, most probable numbers of hydrocarbon utilizers, hydrocarbon biodegradation potentials and denitrification potentials. Analyses of these samples have not yet been accomplished.

B. Laboratory Activities

1. Cook Inlet. Computer cluster and feature frequency analyses were performed for numerical taxonomy on 869 isolates from samples collected in Cook Inlet during November 1977. The analyses were run in 3 groups:

   Group 1: isolates from marine agar (heterotrophs) and marine oil agar (oil tolerant heterotrophs).

   Group 2: isolates from oil agar (presumed oil utilizers) and Bushnell-Haas agar (presumed low nutrient bacteria).

   Group 3: isolates from marine agar.

   Laboratory tests were completed on 579 isolates from samples collected in Cook Inlet during April-May 1978. The laboratory test procedures have been previously reported. The data is presently being punched on computer cards and will be transmitted to NIH shortly.

   Enumeration of microorganisms, hydrocarbon biodegradation potentials and denitrification potentials on samples collected during April-May 1978 have been completed and the data has been sent to NIH.

2. Beaufort Sea. Gas liquid chromatographic analyses were completed on approximately 450 solvent extracts from the oil in sediment - Plexiglas tray experiment.

III. Results

Cook Inlet

The cluster analyses showed that heterotrophic bacterial populations in Cook Inlet are very diverse and are generally characteristized by a large number of small clusters (Table 1). Some water samples had fewer and larger clusters indicating lower bacterial diversities. The addition of Cook Inlet crude oil did not appear to be a great stress to the heterotrophic bacterial population. Similar numbers and sizes of clusters were found on media with and without oil added (Table 2), indicating that the presence of oil had not greatly reduced bacterial diversity. The abilities to grow at low nutrient concentrations and on hydrocarbons as sole source of carbon were restricted in the bacterial populations examined. One cluster represented 44% of the strains isolated from low nutrient agar or oil agar (Table 3).

Beaufort Sea

The gas liquid chromatographic analyses showed changes in the composition of the solvent recovered material from the oiled sediment exposed in Elson Lagoon. The oil-sediment was sequentially extracted with diethyl ether, benzene (more polar to recover aromatics) and methylene chloride (to recover polynuclear aromatics and more polar compounds). Some characteristics of the solvent recovered material are shown in Tables 4 and 5. The data presented for each exposure time represents the mean of analyses of up to 20 replicate samples. Compounds found in 1 sample and no others were considered to be part of background noise and were not included in these tables. There was a clear decrease in the relative proportion of compounds recovered in the polar methylene chloride fraction during 28 days of exposure. There was also a clear change in the proportion of compounds extracted in the ether and benzene fractions after 7 days exposure. The large increase in the number of compounds detected in the ether fraction at 14 and 21 days could be due to the accumulation of oil degradation products. The decrease in the proportion of benzene extractable material could be due to the accumulation of such degradation products in the ether fraction and/or to the loss of aromatic compounds from the sediment. Changes in the relative proportions of compounds recovered in each of the fractions could also be due to changes in the binding of compounds to sediment. The pristane/heptadecane ratios (Table 6) did not indicate biodegradative changes in the recovered oil. It is possible in these sediments that heptadecane is not preferentially degraded over pristane in which case this ratio would not change even with extensive biodegradation.

IV. Interpretation of Results

See Section III.

V. Problems Encountered

The Hewlett Packard 5992 GC-MS unit has not functioned properly since its installation in January. Some analyses were accomplished with the unit but sensitivity was several orders of magnitude below specifications. The unit was also subject to a number of malfunctions and was constantly being serviced by a HP field engineer. The unit has been returned to the factory as its performance was unsatisfactory for this work, and we are awaiting its replacement. This instrument failure has delayed analyses of the solvent recovered material from the Elson Lagoon oil-sediment experiment. Until such analyses can be accomplished we can not identify possible degradation products nor hydrocarbons in the oil.

Recent changes in the objectives of work to be performed in FY 79 have caused a delay in obtaining a contract by October 1 for a continuation of work. An interim agreement has allowed work to temporarily continue.

VI. Estimate of Funds

All funds allocated for work during FY 78 have been used.

TABLE 1 Heterotrophic bacteria which were initially isolated on marine agar.

Cluster #	# of Strains	# of Strains From: Sediment	Water
1	3	3	-
2	21	9	12
3	2	-	2
4	2	-	2
5	5	1	4
6	5	2	3
7	2	2	-
8	2	-	2
9	2	-	2
10	43	-	43
11	14	-	14
12	2	-	2
13	3	-	3
14	2	1	1
15	5	-	5
16	7	-	7
17	9	-	9
18	2	-	2
19	2	1	1
20	2	2	-
21	2	2	-
22	2	-	2
23	3	-	3
24	5	5	-
25	3	3	-
26	5	5	-
27	2	2	-
28	2	2	-
29	2	2	-
30	3	3	-
31	2	2	-
32	2	-	2
33	2	2	-

TABLE 2 Cluster analyses for bacterial populations which were initially isolated on marine agar (MA), and marine agar supplemented with Cook Inlet crude oil (MO) plates.

Cluster #	# of Strains	# of Strains From: Sediment	Water	MA	MO
1	2	2	-	-	2
2	2	2	-	-	2
3	2	2	-	2	-
4	2	2	-	-	2
5	2	2	-	2	-
6	2	2	-	2	-
7	2	2	-	-	2
8	2	2	-	2	-
9	2	2	-	-	2
10	6	6	-	-	6
11	6	6	-	6	-
12	4	4	-	-	4
13	2	2	-	-	2
14	2	2	-	2	-
15	8	8	-	7	1
16	2	2	-	-	2
17	8	-	8	8	-
18	3	-	3	3	-
19	2	-	2	2	-
20	13	-	13	7	6
21	2	2	-	1	1
22	2	-	2	1	1
23	3	1	2	2	1
24	10	1	9	8	2
25	12	11	1	3	9
26	2	1	1	1	1
27	2	-	2	2	-
28	21	1	20	14	7
29	2	-	2	2	-
30	16	3	13	3	13
31	9	-	9	9	-
32	2	-	2	2	-
33	2	2	-	-	2
34	4	-	4	-	4
35	21	-	21	21	-
36	5	-	5	-	5
37	2	-	2	-	2

TABLE 3 Cluster analyses for bacterial populations which were initially isolated on Bushnell-Haas agar (BA), and Bushnell-Haas agar supplemented with Cook Inlet crude oil (OA) plates.

		# of Strains From:			
Cluster #	# of Strains	Sediment	Water	BA	OA
1	118	45	73	43	75
2	13	4	9	8	5
3	4	1	3	-	4
4	4	1	3	1	3
5	2	1	1	2	-
6	6	3	3	-	6
7	4	-	4	4	-
8	5	-	5	-	5
9	2	-	2	-	2
10	3	2	1	-	3
11	3	-	3	3	-
12	2	2	-	-	2
13	4	-	4	-	4
14	4	4	-	-	4
15	3	2	1	3	-
16	2	2	-	2	-
17	13	2	11	12	1
18	8	-	8	5	3
19	4	2	2	-	4
20	2	2	-	-	2
21	46	20	26	21	25
22	3	2	1	2	1
23	11	-	11	11	-

TABLE 4 Proportions of solvent recovered material from oil-sediment experiment.

Exposure Time (Days)	Fraction		
	Ether (%)	Benzene (%)	Methylene Chloride (%)
2	41.2	36.8	22.0
7	42.6	44.9	12.5
14	81.8	7.5	10.7
21	81.2	12.8	6.0
28	77.3	21.8	0.9

TABLE 5 Number of peaks detected in each solvent fraction.

Exposure Time (Days)	Fraction Ether	Benzene	Methylene Chloride
2	44	32	22
7	30	25	4
14	81	17	7
21	108	23	11
28	45	15	1

TABLE 6 Pristane/Heptadecane ratios in oil recovered from oil-sediment experiment.

Exposure Time (Days)	Pristane/C_{17}
2	0.68
7	0.79
14	0.75
21	0.74
28	0.75

Quarterly Report

RU 190
Task Numbers A-27; B-9
Contract # 03-5-022-68
Report Period 1 June, to
30 September, 1978

Number of pages: 10

Study of Microbial Activity and Crude Oil-Microbial Interactions In the Waters and Sediments of Cook Inlet and the Beaufort Sea

SUBMITTED BY:

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I. Task Objectives

A. Cook Inlet

1. To continue studies of relative microbial activity and respiration (mineralization) ratios of natural microbial populations found in water and sediment samples. The samples will be taken in such a way as to characterize these measurements both geographically and temporally. These studies will fill some of the data gaps which still exist from past studies in this region. Areas which are shown to have particularly high activity should be those in which crude oil will be degraded at higher rates. These areas probably support the highest overall biological activity and as such may be the areas which will be most affected by the presence of crude oil. These data may also be used in the future to estimate the degree of perturbation caused by chronic crude oil input.

Characterization of water masses using microbial measurements might also be useful in following movement of water masses within the Inlet.

2. To evaluate the extent of nitrogen fixation in the sediments and gut contents of animals found in this region and to determine what, if any, effect crude oil might have on this process. Significant impact on function of any process in the nitrogen cycle could have a profound effect on all trophic levels in the Cook Inlet.

3. To provide nutrient data on all water and sediment samples taken by both microbiological groups. These data are important in evaluating other data collected by us, especially data on N_2 fixation and denitrificiation.

B. Beaufort Sea

1. To obtain information concerning the effects of added crude oil on the natural microflora of the sediments. These studies will include crude oil effects on microbial function as measured by uptake and respiration characteristics using several labeled compounds. They will also include the study of nitrogen fixation and the effects of crude oil on this process.

2. To continue collecting data on relative microbial activity and respiration percentages in this region during the August-September, 1978 North Wind cruise in this region. Nitrogen fixation rates will also be estimated on sediment samples collected at the same time.

3. To provide nutrient data on all water and sediment samples collected by both Dr. Atlas and ourselves.

4. To estimate the effects of crude oil on natural microbial populations which undergo osmotic stress during freezing and thawing.

C. General

1. To coordinate our sampling efforts and experimentation with that of Dr. Atlas and his associates at the University of Louisville. This will minimize duplication of effort and maximize the usefulness of the resulting data.

2. To continue our laboratory studies at Oregon State Unversity on the effects of crude oil on nitrogen fixation and microbial activity in marine sediments.

II. Field and Laboratory Activities

A. Field trip schedule

In August, Mr. McNamara and Ms. Steven conducted a series of experiments on the sediment trays removed from Elson Lagoon, Barrow, AK. We also participated in the Beaufort Sea cruise aboard the Coast Guard icebreaker North Wind from 25 August to 15 September, 1978.

B. Scientific party

All of the personnel involved in this project are in the Department of Microbiology, Oregon State University.

C. Personnel

Dr. Robert Griffiths, Co-Principal Investigator
Dr. Richard Y. Morita, Co-Principal Investigator
Mr. Thomas McNamara, Technicial (Research Assistant, Unclassified)
Ms. Sue Steven " " " "

D. Methods

The methods used in our field work are essentially the same as those reported in our last quarterly and annual reports.

III. Results

The nutrient analyses have been completed on a large number of samples. These results include the TOC (total organic carbon) and TON (total organic nitrogen) values observed in sediment samples collected in Barrow, AK during the January, 1978 field trip (Table 1). Complete analyses have also been completed on the sediment samples collected during the October, 1976 and November, 1977 Lower Cook Inlet cruises (Tables 2 and 3). TOC and TON measurements were also made on sediment samples collected during the April, 1977 Lower Cook Inlet cruise (Table 4). In addition, inorganic nutrient measurements were made on all water and sediment samples collected during the April, 1978 Lower Cook Inlet cruise (Table 5).

During this reporting period, we have continued our assessment of the best procedures for quantitatively extracting the adenylate pools from marine sediments. Analysis has continued on the crude oil degradation samples using gas chromatography. Pilot studies have also been initiated on the growth of marine protozoa under laboratory conditions. We are also evaluating the potential usefulness of measuring dehydrogenase activity in marine sediments as a means of better characterizing microbial populations.

Data have been submitted to NIH in the proper format to be included in that data base. The 1977 Beaufort Sea summer cruise data were placed into file number, 100307. The April, 1977 Lower Cook Inlet cruise data were placed into file number 100254; the November, 1977 and April, 1978 cruise data were placed into file numbers 100259 and 100307 respectively.

VI. Preliminary interpretation of results

None at this time.

V. Problems encountered

In April, 1978, we submitted a supplemental fund request to purchase equipment that we would need to conduct studies on the detrital food web in the sediments of Cook Inlet. This request was made at that time to insure that we would have this equipment in our hands in sufficient time to work out the techniques required to conduct these studies. If this request was granted within a matter of a few weeks, we would have received the equipment sometime in July, 1978. We finally received these funds on 9/12/78 which means that we will not have the equipment in our hands until sometime in November, 1978. The delay in granting these funds has set back our preparation a minimum of three months.

Table 1. The total organic nitrogen (TON) and total organic carbon (TOC) in sediment samples collected during the January field study period in Barrow, AK. The units used are mg/g. dry weight.

Sample #	TOC	TON
BB402	17.7	1.9
BB403	38.8	2.2
BB404	26.5	2.1
BB405	32.9	1.8
BB406	29.0	1.6
BB407	25.7	2.0
BB408	25.7	1.9
BB409	28.4	1.9
BB410	29.6	2.0

Table 2. Inorganic nutrient and TOC and TON concentrations in sediment samples colelcted during the October, 1976 Lower Cook Inlet cruise. The inorganic nutrient concentrations are reported in μM and the TOC and TON values are reported in units of mg/g. dry weight sediment. The inorganic nutrient data was measured on interstitial water only.

Sample #	NH_3	NO_2	NO_3	TAN	PO_4	TOC	TON
GB301	371			474		4.4	0.5
GB304	245	24.7	4.4	2060	85	4.4	0.4
GB308	18	3.0	32.7	45		4.1	0.4
GB311	245	58.3	9.7	619	56	9.1	0.6
GB312	3	0.8	6.7	2087		0.9	0.2
GB313	121	3.9	14.3	540	14	10.2	1.0
GB318	295	27.2	29.2	606	117	10.7	1.3
GB319	105			760	13	2.0	0.4
GB320	249	17.5	44.7	566	41	7.6	0.5

Table 3. Measurements made on sediment samples collected during the November 1977 Lower Cook Inlet cruise. The same units as those given in Table 2 were used.

Sample #	NH_3	NO_3	NO_3	TAN	PO_4	TOC	TON
GB501	124	12.9	17.8	533	95	5.9	1.0
GB502	63			624	51	11.3	1.5
GB506	119	1.7	15.4	521	18	27.8	2.3
GB507	73			455	8	6.8	0.6
GB508				1450		8.0	0.8
GB509	71	1.1	16.0	345	19	11.4	1.2
GB510	34	13.9	15.8	235	33	10.9	0.9
GB511	52	1.1	16.0	250	20	15.2	1.9
GB512	289	16.3	10.0	127	6	10.4	1.2
GB513	56			259	19	11.1	1.0
GB514	79	8.9	20.8	290	31	10.3	2.0
GB515	130	2.4	52.0	220	48	12.0	1.3
GB516	213	17.0	low	108	13		
GB518	102			588	54	6.5	0.7
GB519	92			434	24	4.2	0.4
GB520	78	2.8	14.3	411	39	8.1	0.9
GB523	122	9.3	low	483	23	5.5	0.8
GB524	206	22.6	6.7	484	85	8.7	1.5
GB525	93	1.2	19.4	520	23	6.1	0.6
GB526	62	2.4	32.7	370	46		
GB527	103	5.7	0.9	186	12	9.8	1.3
GB528						6.8	0.9
GB529		13.3	12.6	123			
GB532	275			337	25	6.9	1.0
GB538	124	5.0	5.0	789	32	13.4	1.5
GB549	87	2.4	3.0	251	14	6.1	0.8
GB554	79	1.2	19.3	451	31	5.0	0.4
GB557	54	3.6	16.9	301	30	3.2	1.1
GB558	114	3.9	4.4	215	31	13.8	1.3

Table 4. Concentrations of TOC and TON in sediment samples taken during the April, 1977 Lower Cook Inlet cruise. All values are reported as mg/g dry weight of sediment.

Sample #	TOC	TON
GB401	1.9	0.3
GB410	5.6	0.5
GB420	12.2	0.8
GB421	16.8	1.2
GB425	12.6	1.2
GB430	6.6	0.5
GB431	12.8	1.1
GB432	4.7	0.4
GB434	3.7	0.4
GB437	12.9	0.8
GB440	6.6	0.7
GB442	12.3	0.6
GB444	8.5	0.9
GB445	5.1	0.7

Table 5. Inorganic nutrient data observed in samples taken in the Cook Inlet during the April, 1978 cruise. All concentrations in μM.

A. Water samples

Sample #	NH_3	NO_2	NO_3	PO_4
GW601	2.58	0.23	5.4	1.00
GW602	1.66	0.71	17.1	1.83
GW603	0.78	0.39	5.9	1.02
GW604	2.38	0.26	12.8	1.48
GW605	2.13	0.64	14.9	1.60
GW606	1.36	0.36	13.5	1.50
GW607	1.22	0.46	12.0	1.34
GW608	1.13	0.26	1.7	0.70
GW609	2.38	0.24	15.0	1.49
GW610	1.38	0.49	15.7	1.54
GW611	1.23	0.42	15.6	1.67
GW612	0.98	0.27	9.3	1.24
GW613	1.30	0.26	14.7	1.60
GW614	1.95	0.20	15.4	1.62
GW615	1.27	0.19	15.3	1.57
GW616	1.43	0.16	3.1	0.78
GW617	1.25	0.13	9.4	1.28
GW618	1.50	0.17	6.3	1.09
GW619	1.37	0.25	14.8	1.29
GW620	1.59	0.34	12.8	1.52
GW621	1.19	0.34	15.6	1.48
GW623	1.45	0.29	11.9	1.41
GW624	1.17	0.20	15.1	1.54
GW625	2.19	0.32	16.3	1.59
GW626	1.60	0.38	15.1	1.54
GW627	1.66	0.26	14.3	1.45
GW629	1.70	0.22	15.6	1.61
GW630	1.42	0.17	15.2	1.59
GW631	2.52	0.42	16.2	1.76
GW632	1.66	0.42	16.0	1.65
GW633	0.99	0.28	14.0	0.86
GW635	1.42	0.40	15.8	1.70
GW637	1.28	0.19	15.4	1.59
GW638	2.51	0.41	15.4	1.62
GW639	1.60	0.50	15.9	1.70
GW640	1.73	0.29	16.4	1.75
GW641	1.52	0.22	14.8	1.66
GW642	2.13	0.21	13.7	1.61
GW643	1.97	0.48	14.2	1.62
GW645	1.68	0.23	11.4	1.40
GW646	1.70	0.33	0.2	1.65
GW647	2.01	0.31	12.3	1.48

Table 5 (cont'd)

Sample #	NH_3	NO_2	NO_3	PO_4
GW650	1.92	0.29	9.5	0.57
GW652	1.63	0.19	12.3	0.32
GW655	2.74	0.76	14.3	1.73
GW656	2.35	0.60	13.4	1.49
GW657	2.52	0.47	13.5	1.48
GW658	1.83	0.53	11.6	1.43
GW659	1.46	0.06	0.9	0.89
GW660	2.13	0.50	3.8	0.91
GW661	1.44	0.34	4.0	0.35
GW662	1.88	0.17	9.5	1.20
GW663	1.49	0.14	3.5	0.85
GW664	1.27	0.24	0.6	0.87
GW665	0.61	0.47	4.0	0.80
GW666	1.08	0.11	0.9	0.56
GW667	2.31	0.36	4.4	0.91
GW668	1.86	0.17	3.0	0.50
GW669	1,70	0.10	0.3	0.56
GW670	1.08	0.14	15.2	1.42
GW671	0.80	0.17	16.2	1.45
GW672	0.78	0.22	15.4	1.50
GW673	1.22	3.39	15.0	1.42
GW674	1.36	0.20	15.3	1.43
GW675	1.13	0.19	13.6	1.39
GW676	1.17	0.14	13.9	1.42
GW677	1.32	0.16	13.6	1.43
GW678	1.20	0.16	14.0	1.42
GW679	2.43	0.23	13.6	1.34
GW680	0.95	0.18	13.6	1.39
GW681	1.02	0.17	12.3	1.39
GW682	0.85	0.23	14.1	1.42
GW683	1.03	0.24	12.6	1.40

B. Sediment samples (interstial water)

					TAN
GB601	171	13.0	7.1	38.6	190
GB602	141	2.3	2.0	13.0	94
GB603	47	1.4	1.3	9.6	66
GB604	56	1.1	2.3	5.2	109
GB605	115	1.4	2.6	9.1	130
GB606	139	0.9		15.4	133
GB607	111	1.1	2.1	8.7	93
GB608	186	5.7		25.9	170
GB609	100	10.0	5.4	9.5	89
GB610	80	2.8	13.8	6.1	85
GB611	101	0.8	3.0	9.5	124
GB612	53	1.1	2.3	13.8	48

Table 5 (cont'd)

Sample #	NH_3	NO_2	NO_3	PO_4	TAN
GB613	113	1.1	2.9	9.4	139
GB614	184	0.2	2.0	44.7	77
GB616	109	3.0	2.1	9.1	66
GB625	120	0.6	9.8	7.9	142
GB627	78	1.2	42.6	8.7	43
GB628	117	1.2	34.4	6.8	109
GB629	125	2.1	40.3	13.0	169
GB630	106	1.4	2.9	0.0	99
GB631	246	7.6	15.5	29.6	137
GB632	85	0.9	23.9	5.5	141
GB633	111	1.3	16.7	7.5	173
GB636	57	2.3		12.4	85
GB649	227	1.0	1.7	17.5	
GB650	265	1.7	1.9	9.0	241
GB652	273	16.1		62.4	61
GB654	93	5.3	4.7	8.0	81
GB660	136	18.7	25.3	17.4	196
GB669	628	1.4	1.1		
GB677	37	0.3	72.7	6.7	130

The following page was inadvertently omitted from the April-June Quarterly Report of RU 190.

two Elson Lagoon oiled sediment studies suggest that the exposure of sediments to crude oil may not act to decrease the effect of crude oil when the sediments are exposed to fresh crude oil during a short term substrate uptake study.

D. Nitrogen fixation

1. Rates of nitrogen fixation were once again measured in sediment samples collected in Elson Lagoon and in the Cook Inlet during April, 1978 (Table 10). The rates observed in the Elson Lagoon sediment samples were higher than those observed in the Cook Inlet area (mean values of 1.3 and 0.4 ng nitrogen/g dry wt/h respectively). The mean value observed in the Elson Lagoon samples was also higher than that observed in the Beaufort Sea sediment samples collected during the summer, 1977 Glacier cruise (the mean value was 0.06 ng/g/h). Unfortunately these two studies are not directly comparable for two reasons: (1) the samples were collected in different geographical areas (one set taken from one site in Elson Lagoon and the other set was taken from offshore locations, (2) the nitrogen fixation assay was performed on location in the Elson Lagoon study but the other set was analyzed at our OSU laboratory after a minimum of 4 weeks sample storage time.

2. The pattern of nitrogen fixation in the sediments of Cook Inlet and the Shelikof Strait as observed during the April cruise (Fig. 7) were similar to those observed during the April and November, 1977 cruises in the same area (also see Tables 18, 19, and 20 of the annual report). The highest values observed were again in the Kachemak Bay area and in the Shelikof Strait.

3. In both the Elson Lagoon and the Cook Inlet studies, we also measured the effects of crude oil on nitrogen fixation rates (Table 10). As we have observed in the past, there was no significant difference between the rates observed in the oiled and non-oiled sediments. This was also the case in sediment samples that were treated with sucrose. We have made these comparisons in a number of field studies to date using both samples returned to our laboratory at OSU for analysis and studies in which these analyses have been conducted in the field. In none of these studies have we observed a consistant negative effect of crude oil on nitrogen fixation rates. Knowles and Eishart (1977, Environ. Pollut. 13: 133-149) reported that they were unable to see any effects of Normal Wells crude oil on nitrogen fixation rates in sediment samples taken from the Beaufort Sea and Eskimo Lakes, Northwest Territories, Canada. Taken as a whole, these data suggest that there is probably no short term effect of crude oil on nitrogen fixation rates in Arctic and Subarctic marine sediments. It will not be known what the longer term effects might be until total nitrogen budget information becomes available from oiled sediment experiments.

E. Laboratory studies

We are currently analyzing some of the data that we have been accumulating on rates of crude oil biodegradation. One such study involved measuring the effects of incubation temperature

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
U.S. Department of the Interior
Bureau of Land Management

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ABSTRACT

Personnel of RU 332 participated in field activities in the Kodiak Island near-shore studies, in cooperation with the Alaska Department of Fish and Game (ADFG) (RU 552). Either a fish pathologist or an invertebrate pathologist from RU 332 were on the RV YANKEE CLIPPER and the RV COMMANDO from May 31 to June 15, and August 1 to 30, 1978. Pathological conditions detected in fish from Kalsin, Izhut and Kayugnak Bays, included skin tumors (epidermal papillomas) of rock sole (Lepidopsetta bilineata) and skin tumors of flathead sole (Hippoglossoides elassodon). Too few flatfish were captured in Kailiuda Bay to make determinations of disease frequency. Invertebrates from Kalsin and Izhut Bays were found to have fungal infections as well as several types of parasitic infections.

OBJECTIVES

Determine the frequency, geographical distribution, and pathological characteristics of diseases of marine fish and macroinvertebrates in the Bering and Beaufort Seas, and the Gulf of Alaska.

FIELD OR LABORATORY ACTIVITIES

SHIP OR FIELD TRIP SCHEDULE

Dates: August 1 to 30, 1978
Vessel: RV YANKEE CLIPPER
(Chartered by ADFG, RU 552, with OCSEAP support)

Dates: August 10 and 22, 1978
Vessel: RV COMMANDO
(Chartered by ADFG with OCSEAP support)

SCIENTIFIC PARTY

Name	Role
Bruce B. McCain, PhD	P.I., Coordinates and participates in field and laboratory activities;histopathological and microbiological analyses.
Harold O. Hodgins, PhD	P.I., supervises NMFS investigations.
Albert K. Sparks, PhD	P.I., supervises the collection and histopathological analyses of invertebrates
William D. Gronlund, MS	P.I., participates in field activities, data processing, and analyses of biological data
Jolly Hibbits, MS	Invertebrate pathologis; assistant to Dr. Sparks.
Mark S. Myers	Performs histopathological analyses of tissue specimens and participates in field activities and data processing

Warren E. Ames — Fishery biologist, participates in field activities

METHODS

Fish and invertebrates were sorted according to species, and the total sample or subsamples were examined for externally visible pathological conditions and, when feasible, for readily recognizable internal disorders. The following information was recorded for each haul in the Species Catch Record: haul number, date, number of animals examined by species, sex, type of pathological condition observed, and number of animals with each type of condition for each species and each sex. Animals with abnormal conditions were processed immediately. Each abnormal animal was assigned a specimen number and the following information was recorded on the Individual Data Sheet: species, sex, size, method of age determination (fish only), condition, and body location and size of the condition(s). Photographs were taken of representative and unusual conditions. Tissue samples were preserved in appropriate fixatives.

In addition to observations on invertebrates for gross evidence of disease, a number of animals were necropsied and representative tissues fixed for subsequent sectioning, staining, and microscopic observation. Routinely, portions of the following organs were fixed: epidermis, gill, heart, esophagus, cardiac and pyloric stomach, midgut, hepatopancreas, anterior and posterior caecum, testis and vas deferences or ovary, heart, hemopoetic tissue, bladder, antennal gland, mandibular organ, brain, thoracic ganglion, and eyestalk.

SAMPLE COLLECTION LOCALITIES

Four bays near Kodiak Island were sampled: Kalsin, Izhut, Kayugnak, and Kailiuda Bays. Invertebrate samples were not collected in Kayugnak and Kailiuda Bays.

DATA COLLECTED AND/OR ANALYZED

(1) Number and types of samples: Approximately 10,000 fish and 2,860 invertebrates representing over 40 species of fish and 50 species of invertebrates were examined; 147 fish and 175 invertebrates had pathological conditions.

(2) Number and type of analyses: Approximately 120 and 1,300 tissue specimens from fish and invertebrates, respectively, were collected and preserved from 36 fish and 67 invertebrates for light microscopy. The tissues from 36 fish and 20 invertebrates have so far been examined microscopically.

RESULTS

Compilation of the data presently available shows that the frequencies of rock sole with skin tumors found in Kalsin and Izhut Bays, 13.8 (27/195) and 5.8 (84/1457)%, respectively, in August 1978, were very similar to those detected in these bays in May 1978, 11.5 (22/192) and 4.9 (28/574)%. The frequencies of skin-tumor-bearing flathead sole were somewhat different in

Kalsin and Izhut Bays sampled in May [9.1 (2/22) and 1.1 (1/93)%] and August [5.4 (13/243) and 12.5 (7/56)%].

Invertebrates with major pathological conditions found in Kalsin and Izhut Bays, respectively, during August and their frequencies of occurrence were as follows: "black mat" syndrome, a fungal infection, of snow crabs (Chionoecetes bairdi), 3.0 (1/33) and 8.7 (39/401)%; rhizocephalans infections of hermit crabs (Pagurus alaskensis), 5.5 (6/109) and 5.2 (7/135)%; and infections of the eggs of the rock shrimp (Crangon dalli) by fungi of the Langenidium spp., 13.1 (112/858) and 6.3 (7/111)%.

Kayugnak and Kailiuda Bays were also sampled in May and August, 1978. Only 1 tumor-bearing flatfish (a rock sole) was observed in Kailiuda Bay during both months; but, since only 44 rock sole and no flathead sole were captured, a frequency determination is probably not meaningful. In Kayugnak Bay, the frequencies of skin tumors in rock sole and flathead sole were 4.3 (7/163) and 3.0 (8/263)%, respectively, in August and 9.6 (28/292) and 0 (0/16)% in May.

Histopathological examination of tissue specimens from flatfish has demonstrated the most early form of the skin tumors of rock sole and flathead appears before or during the first year of life. Epidermal cysts of rock sole, which were found in Kalsin, Izhut, and Kayagnak Bays in May, were found to be subcutaneous, intramuscular metacercaria of digenetic trematodes bordered by a capsule of fibrotic host response tissue. The "black mat" syndrome, which has been previously assumed to be confined to the carapace of snow crabs and, therefore, harmless, was found to involve penetration of the carapace by fungal hyphae and invasion of the underlying epithelium, internal organs, and the eyestalk.

PRELIMINARY INTERPRETATION OF RESULTS

Minimal geographical variation of the frequencies of tumor-bearing rock sole and flathead sole, of "black mat" syndrome of snow crab, and of Lagendium spp.-caused diseases of rock shrimp were observed between areas where sufficient numbers of individuals were examined. Also, with regard to fish diseases, very little seasonal variation was observed between May and August.

The earliest form of skin tumors found on pleuronectids in the northeastern Pacific Ocean are known as angeoepithelial nodules (AEN). Along the West Coast of the U.S., these tumors are first observed on flatfish during their first year (Wellings et al. 1976). The histopathological and age data reported here confirms that rock sole in Alaskan waters develop AENs at around 1 yr and that the pathogenesis of this condition in Alaskan flatfish is probably similar to that observed elsewhere.

Although previous reports of "black mat" syndrome of snow crab have tentatively identified the etiological agent as a fungus, they have not considered this condition to adversely affect the host (Van Hyning and Scarborough 1973 and Hodgins et al. 1977). Our microscopic examination of infected tanner crab has demonstrated that the fungal hyphae are not confined to the exoskeleton, but can invade other areas of the crab critical for survival, such as the eyestalk and esophagus. Thus, "black mat" syndrome may be indicative of a systemic disease, and the pathogenic fungus, or fungi, causing this syndrome may prove to have an important effect on snow crab populations.

AUXILIARY MATERIAL

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ORAL PRESENTATIONS - None

PROBLEMS ENCOUNTERED AND RECOMMENDED CHANGES - None

ESTIMATE OF FUNDS EXPENDED - 47.6 K

QUARTERLY REPORT

Contract: #03-5-022-56
Research Unit: #427
Task Order: #1
Reporting Period: 7/1/78-9/30/78
Number of Pages: 3

ICE EDGE ECOSYSTEM
BERING SEA

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September 1978

I. TASK OBJECTIVES

To study the dynamics of the phytoplankton and zooplankton populations at the edge of the retreating ice pack in the Bering Sea in order to assess the significance of the ice-related production to the Bering Sea ecosystem, to estimate its importance in comparison with summer production on the shelf, to clarify the mode of transfer of organic matter between phytoplankton and zooplankton and to evaluate the sensitivity of the system to perturbation due to resource development activities.

II. FIELD ACTIVITIES

None

Laboratory Activities

None

Major Activities during the Past Quarter

Phytoplankton ....

The principal activity during the past quarter has involved continuing work on the analysis of the phytoplankton data from all the cruises during the three years study, using cluster analysis techniques. Some additional identification work is still in progress, but the basic counts are all completed, and the 1975 and 1977 cluster analysis is almost completed. In addition, with the assistance of Dr. Joe Niebauer, we are looking in detail at the time sequence of ice edge bloom distribution and activity in relation to physical oceanographic regimes, both on a macro and local scale. This work is also involving considerable computer plotting. Dr. Charles Geist has taken all the material on the phytoplankton model prepared by Dr. Katherine Green and has been evaluating the potential for continued work on this.

Zooplankton and Micronekton

Sample analysis was completed on material collected in Norton Sound and the southern Chukchi Sea, June and July of 1977. Standing stock as dry weight/ m^2 and species abundance for 1-m net tows and 2-m NIO samples are available for synthesis and inclusion in the final report of the project.

Dr. Charles Geist developed an R-mode cluster analysis for samples of net plankton collected over the southern shelf and open ocean of the southeastern Bering Sea. Seven groups were discerned of which two were related very closely to water mass characteristics in the region. The cold shelf region shallower than 100 m was consistantly dominated by two small copepods of the genus *Pseudocalanus* and *Acartca*, while the more oceanic water mass intruding the outer shelf, supported the typical North Pacific grazing community dominated by *Metridia*, *Calanus*, and *Eucalanus*. While the results in themselves are not particularly noteworthy, when viewed in relation to organic matter transfer processes as investigated this past spring by PROBES (NSF; Polar Programs), difference in the constituency of the shelf and ocean zooplankton communities are probably very important in regard to the coupling of organic matter to a pelagic food web. In this respect the shelf waters appear "leaky", while grazing is tightly coupled in the oceanic environment.

Contract No. 01-6-022-15670
Report Period: 5/1/78-9/30/78
RU-481

Quarterly Report

A Survey of Cetaceans of Prince William Sound and Adjacent Vivinity

Principal Investigator:

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October 1978

I. Abstract:

During these final two quarters of the active contract period data reduction and analysis formed the bulk of the activity. Additionally, the outline for the final report (due 12/31/78) was developed.

II. Task Objectives:

1. Determine seasonal distribution and abundance of principal cetacean species utilizing Prince William Sound and adjacent areas in the Northern Gulf of Alaska.
2. Determine major foraging areas and critical habitats for principal species.

III. Field Activities:

A. Field Schedule

1. Data reduction and analysis throughout the period. No actual field work performed per instructions from OCSEAP Juneau.

B. Scientific Party

Data Analysis: John D. Hall

IV. Results:

A Numonics Graphics Computer and NOAA charts were utilized to determine the habitat of Dall porpoise, *Phocoenoides dalli*, in the study area. An ERTS MSS Band 5 satellite image of Prince William Sound was utilized along with the Graphics Computer to determine harbor porpoise habitat in the study area. Sightings of this small porpoise have been limited to the turbid water area near Hinchenbrook Entrance, and the ERTS image of this area clearly delimits the turbid outflow of the Copper River.

A refined analysis of Dall and harbor porpoise aerial survey data has begun, but valid results are not expected before 12/78.

The PI, at Fish and Wildlife Service expense, attended (in Logan, Utah 5/78) a symposium dealing with the development of models for estimating the population dynamics of large mammals.

A 10/11 telephone call from the Fish and Wildlife Service office in Anchorage indicated the possibility of missing equipment purchased for this project and stored in the FWS, Anchorage warehouse from 10/77 until the present. Additional details of the equipment problem will be transmitted to the Juneau OCSEAP office as they become available.

The PI was notified in September 1978 by the Juneau project office that RU-481 final data submission to EDS, Washington, D.C. was complete and accepted by EDS for entry into their storage bank.

QUARTERLY REPORT

Contract # 3-5-022-56
Research Unit 537
Task Order 32
Reporting Period 7/1/78 - 10/1/78
Number of pages:

NUTRIENT DYNAMICS IN NEARSHORE UNDER-ICE WATERS OF THE ALASKAN BEAUFORT SEA

Dr. Donald M. Schell

Institute of Water Resources (note change)
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I. TASK OBJECTIVES

The overall objectives of this research unit are to investigate the trophic system dynamics of the primary producers in the nearshore waters of the Beaufort Sea and to relate the observed nutrient regimes with the *in situ* primary production and secondary production arising from the input of terrestrially derived carbon, nitrogen and phosphorus. Specific objectives addressed during the past quarter have been directed toward surveying nutrient concentrations in the Simpson Lagoon area, and measuring uptake and regeneration rates of nitrogen and phosphorus in the water column. The individual tasks undertaken can be summarized as follows:

(1) Water samples were collected from the water column at several stations in Simpson Lagoon and immediately seaward by helicopter (while ice-covered), and by small boat during open water.

(2) Samples of peat materials were collected from eroding shoreline bluffs for carbon, nitrogen, and phosphorus analysis. These samples will be used for (a) C-14 dating and $^{12}C/^{13}C$ isotope ratio determinations.

(3) N-15 ammonia and N-15 nitrate were used for uptake and regeneration experiments with water samples taken from Simpson Lagoon.

(4) P-32 phosphate was utilized to determine turnover time of inorganic phosphate and the partitioning of phosphorus in the various biological and abiotic pools in sediments and the water column.

(5) Specimens of marine fauna from Simpson Lagoon were collected for $^{12}C/^{14}C$ and $^{12}C/^{13}C$ isotopic analyses. These data will be utilized in determining the pathways of carbon movement in the nearshore trophic system.

(6) Primary production measurements were made on water column samples from Simpson Lagoon to obtain additional data on phytoplankton productivity during the ice-free period.

II. FIELD ACTIVITIES

Water sampling for spatial and temporal distribution of salinity and nutrient concentrations has been conducted throughout the summer season and is continuing. Samples were collected during June by helicopter and with the appearance of open water, by small boat.

During the period 7-12 August, an intensive experimental program was undertaken at the Milne Point field station on water column samples from Simpson Lagoon. Isotopic tracer studies were performed and samples of peat collected from along the shorelines, and from the lagoon bottom. Weather conditions were marginal for small boat operation. The lagoon water column appeared well mixed with a large suspended sediment load.

III. LABORATORY ACTIVITIES

All acquired samples have been returned to the Institute of Water Resources where they have either been processed appropriately or are awaiting analysis. A status description for each sample set follows:

(1) C-14 dating and $^{12}C/^{13}C$ isotopic abundance samples: Have been fully processed and sent out for analysis. Data turnaround is estimated at 6 to 9 weeks.

(2) ^{32}P and ^{14}C isotope tracer samples: All samples have been counted by liquid scintillation techniques and the data is being processed.

(3) ^{15}N-ammonia and nitrate uptake and regeneration experiments: Awaiting mass spectrometric analysis.

(4) Nutrient chemistry: Samples are frozen and will be analyzed in the near future.

(5) Salinity determinations: All samples have been run and their data processed.

(6) Chlorophyll samples: Frozen, awaiting purchase of analytical equipment.

IV. PROBLEMS ENCOUNTERED

No serious problems obstructed data collection except that ice conditions somewhat limited the spatial coverage of water sampling during the breakup period. This was anticipated, however, and sampling dates were chosen to allow the maximum possible flexibility in station selection.

EFFECTS

Contents

Quarterly Progress Report
Research Unit #71
July-September, 1978

The Effects of Oil on Temperature Regulation in Sea Otters

Gerald Kooyman
Daniel Costa
Physiological Research Lab
Scripps Institution of Oceanography
La Jolla, California 92093

Date:

I. Highlights of the July-September Quarter 1978.

During this Quarter we carried out a preliminary expedition to Prince William Sound, Alaska. The primary goals of this trip were to: locate a suitable study area; test our capture equipment; capture several sea otters, restrain them and attach self-releasing floating collars with mock depth-recorder and radio-transmitters. In addition to meeting the above goals, we carried out a partial census of the sea otter population in Prince William Sound, Alaska.

At Scripps work has continued on the development of the depth of dive recorders. In addition, a second system has been designed which will record 4,000 dives by logging each dive to one of eight depth categories (essentially a histogram plot). The sea otter pup born on June 1 died from lack of proper grooming by the mother. During September we conducted our last oiling experiment on Shannon and made arrangements to transfer the animals to Sea World upon completion of the project.

LL. Task Objectives:

1. Energy requirements of normal sea otters at various water temperatures.
2. Energy requirements of sea otters after oiling.
3. Appropriate procedures for rehabilitating oiled sea otters.
4. At sea behavior and energetics of sea otters.

These objectives will provide a data base from which the assessment of any kind of oil contamination, or other activity which may alter the nature of the otter's food sources can be derived. In addition, relative to oil contamination the difficulties and costs of rehabilitating the oiled otters can be estimated.

III. Laboratory Activities:

A. Scientific Party

1. Dr. Gerald Kooyman-Principal Investigator
2. Daniel Costa-Associate Investigator
3. Randall Davis-Assist. in data analysis and experimental runs
4. Michael Bergey has left the Project
5. Rick Price 50% time-Animal Caretaker
6. Jim Herpolsheimer-Animal Caretaker
7. Debbie Zmarsly-Research Assistant assists in data analysis
8. John Gregory-NOAA-NMFS paid helper-assists in metabolic runs and data analysis
9. Michael Delarm-NOAA-NMFS paid helper-assists in metabolic runs and data analysis.

B. Methods:

The sampling procedures will be the same as those recently used for fur seals and used previously in metabolic rates in penguins (Kooyman, G. L., R. L. Gentry, W. P. Bergman and H. T. Hammel, 1976, Comp. Biochem. Physiol. 54A: 75-80).

The thermal neutral zone will be determined in four sea otters conditioned to "rest" in the metabolic test chamber. The principle variable measured in these tests is oxygen consumed, and body and skin temperature. The control thermal neutral zone will be compared to otters after oiling and after cleaning. Furthermore, the continuous sampling ability of our method will permit us to determine the average whole body heat conductance for a 5 to 6 hr. run. This will include the important activity (mainly grooming) periods. The changes in whole body conductance during exposure to various water temperatures before and after oiling will indicate the metabolic costs of oil on the fur. These same sampling proceudres will be repeated after the oiled animals have been anesthetized and cleaned.

IV. Results:

Additional metabolic runs have been made on the three remaining sea otters. We have measured the increased energy produced from the catabolism of food and (specific dynamic action) have found it to raise the basal metabolic approximately 20%. During September we conducted our final oiling on Shannon and obtained the following results. (Table 1)

Table 1

Condition	ml O_2/kg-min	Percent Above Control
Control	19.0	-----
Initial oiling	25.6	35.0%
1 day post-oiling	31.0	63.4%
6 day post-oiling	37.6	98.2%
Washed 8 days post-oil	35.4	86.6%
3 days post-wash	33.1	74.5%
8 days post-wash	33.2	74.5%

During the field expedition we captured four sea otters and attached radio-collars to two of them. We found an excellent study area at the West end of Hinchinbrook Island and sea otters, were easily captured. The radio collared sea otters were followed until the corrasable link allowed the collar to fall off. The radio-collars were recovered three and four days after deployment. The population survey results can be found in a previously submitted report.

QUARTERLY REPORT

Contract No.
Research Unit #72
Report Period - July 1 to September 30, 1978
Number of Pages - 9

ACUTE AND CHRONIC TOXICITY, UPTAKE AND DEPURATION, AND SUBLETHAL METABOLIC RESPONSE OF ALASKAN MARINE ORGANISMS TO PETROLEUM HYDROCARBONS

by

Stanley D. Rice
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Sid Korn

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September 1978

TASK OBJECTIVES AND PROGRESS[1/]

A. Toxic components and synergism of toxic components: These studies have examined the contribution of individual toxic components of petroleum hydrocarbons to determine which compounds are primarily responsible for most of the observed toxicity.

1. Compare the toxicity of water-soluble fractions (WSF's) of crude oil with synthetically produced WSF's. Exposures are flow-through, analyses by GC, and test animals are pink salmon fry and shrimp (*Eualus*).

Progress: Two bioassays with pink salmon were completed. Fish were exposed to Cook Inlet WSF and a synthetic solution containing benzene, toluene, ortho- and para-xylene, naphthalene, methyl naphthalene and dimethyl naphthalene in the same proportions as they appear in the WSF. The detailed GC analyses of the WSF's have not been completed, but it appears that the toxicity of the synthetic solution was slightly less than the WSF indicating that these compounds make up the most of the observed toxicity, but there are additional components that contribute to acute oil toxicity. The results with fish need further GC analyses and statistical analyses. This study will be repeated with *Eualus* this fall.

2. Synergistic effects of toluene and naphthalene: Several studies with fish and shrimp larvae strongly suggest that toluene and naphthalene have different mechanisms of toxicity, indicating that the toxicants probably have synergistic effects. If the

1/ Primary objectives and secondary objectives are underlined.

toxicities are synergistic, this would help explain why simplistic experiments with single compounds have under-estimated the toxicities of WSF's.

Secondary Objectives:

a. Determine if toluene and naphthalene have synergistic toxicities to pink salmon fry and *Eualus* shrimp under flow-through conditions.

Progress: Tests were completed last quarter. Statistical analyses and manuscript preparation is in progress. Synergistic toxicity was indicated.

b. Determine if toluene and naphthalene have synergistic effects on uptake and/or depuration in pink salmon fry and *Eualus* shrimp;

Progress: This study requires constant and stable dosing. R&D for flow-through isotope exposures took longer than expected. Experiments have been rescheduled for the fall.

B. Larval Studies

1. Determine the sensitivity of eggs and larvae from several noncommercial species: barnacles, mussels, snails, starfish, and sea urchins. Static exposures will be used and will include tests with WSF's, toluene, and naphthalene.

naphthalene.

Progress: Eggs and veligers from 3 species (2 nudibranchs, and 1 snail) were tested with toluene, naphthalene, and Cook Inlet WSF. The eggs were quite resistant, while veligers were more sensitive to the toxicants. Results after 90 minutes were similar to 24 h exposures, indicating that larvae take up toxicans quickly and are readily affected, even by brief exposures. The veligers from both species were more sensitive than the bipinnaria larval stage of starfish tested last quarter. Additional tests with mussel and barnacle larvae will be done in fall 1979, provided spawning can be induced in the laboratory, or wild spawners can be obtained.

2. Determine the uptake and retention of hydrocarbons into new and old eggs carried by Eualus shrimp. Exposures will be WSF's and isotopes, and analyses by GC and liquid scintillation.

Progress: Exposures and GC analyses have been completed. Uptake in the eggs was slow, and retention was lengthy. The data have not yet been analyzed.

C. Sensitivity increase of salmonid smolts in sea water. Through bioassays, we have found that the sensitivity of sea water-adapted pink and sockeye salmon, and Dolly Varden, is greater than sensitivity in fresh water in exposures to WSF's, toluene, and naphthalene. First attempts at explaining this phenomenon through uptake and excretion experiments did not completely answer the question.

1. Determine the uptake of isotopes into tissues of fresh water- and sea water-adapted salmonid smolts Although whole body uptake was essentially the same, the uptake into different tissues may be different.

Progress: Uptake between freshwater and sea water smolts was tested in two ways: via water and via oral administration of known quantities. No difference in uptake was found in liver and brains of smolts exposed in fresh- or sea-water. Oral uptake did show some differences. More isotope and more percent metabolites was found in the brain and muscle of sea water-adapted animals.

2. Determine the osmotic and ionic composition of blood in fresh water and sea water-adapted smolts exposed to toluene and naphthalene. Dr. W. Stickle, Louisiana State University, is co-investigator for this experiment, which should give data relevant to osmotic and ionic regulating interferece by the toxicants.

Progress: Bioassays of smolts were conducted in 0, 10, 20, and 30 °/oo salinity water with both toluene and naphalene. Sensitivity increased with salinity and remained at the greater level of sensitivity for over 42 days (smolts were fed and grew in sea water, but maintained a relatively high level of sensitivity). Little change was noted in blood ion concentrations at sublethal exposures. Only at the higher concentrations were changes measured.

Several invertebrate species were acclimated to salinities lower than 30 °/oo. Sensitivity to toluene and naphthalene did not change at the different salinities. Blood ion changed between salinities, since invertebrates are not regulators, but exposure to lethal concentrations did not affect the blood ion concentrations significantly.

D. Long-term exposures: Long-term exposures have recently been possible because of improvements in flow-through exposure techniques. Most previous flow-through tests have been crude attempts, without verification of stable concentrations during exposure. We will conduct long-term exposures and compare the result with species we have previously tested in short-term exposures.

1. Determine the effects of flow-through toluene and naphthalene exposures on growth and survival of pink salmon fry exposed at different temperatures. Tests will be 40 days long, with samples of fish taken at 1-day intervals to measure effects on growth. Tests will be replicated at three temperatures to determine the influence of temperature on toxicity in long-term exposures.

Progress: This study was cancelled after two attempts. The first attempt was terminated after 6 days when the main sea water pump to the lab failed and our sea water low-water alarm also failed, causing a massive fish kill, including about 1/3 of the stock of experimental fish. The second attempt was terminated after 8 days when a power outage combined with a failure of our emergency generator caused fish mortalities in the experiment and most of the remaining stock of pink salmon. We then had to cancel the study due to lack of fish.

2. Determine the survival of two tolerant and two sensitive species to flow-through exposures of toluene and naphthalene.

Progress: Study was completed last quarter with six species. There are toxicity differences between static and flow-through tests, especially with the tolerant species. Manuscript preparation is in progress.

E. Test the effect of intermittent air exposures on the sensitivity of intertidal species to toluene, naphthalene, and WSF. Exposure to air during and after exposure to toxicants may cause an additional stress on intertidal animals and result in decreased survival.

1. Determine the sensitivity and uptake-depuration by the intertidal shore crab *Hemigrapsus nudis* to toluene and naphthalene exposures, with and without intermittent exposure to air.

Progress: Bioassays with shore crab to toluene and naphthalene are scheduled for fall 1978. Preliminary bioassays and uptake without air exposures have been completed.

F. Dispersant testing: Literature review and R&D on methods of analysis and exposure will be probed to prepare for expanded testing in FY 79. Emphasis on this project was reduced considerably from original plans, when OCSEAP decided part way through the contract year not to fund dispersant studies in FY 78.

Progress: Literature review has been completed. Stocks of several dispersants have been obtained and preliminary tests with fish and shrimp are scheduled for fall 1978.

G. Manuscripts: Progress: Manuscripts describing FY 1977 research projects will be completed. The manuscript "Sensitivity of Alaskan Marine Organisms to Cook Inlet Oil and No. 2 Fuel Oil" has been accepted for presentation and publication at the spring 1979 Oil Spill Conference, Los Angeles, California.

H. Additional Projects

1. Effects of temperature on toxicity and uptake-depuration of aromatic hydrocarbons to animals with varying potential to metabolize aromatic hydrocarbons. Continuous-flow bioassays and uptake studies will be run at two temperatures on animals with differing abilities to metabolize aromatic components. Pink salmon eggs, snails, shirmp, and pink salmon juvenile will be tested with toluene and naphthalene.

Progress: Pink salmon and shrimp bioassays were completed last spring. The additional sensitivity tests and uptake tests are logical needed extensions of previous experiments. Pink salmon juveniles and snail temperature uptake studies have been completed. The shrimp uptake tests and snail bioassays are scheduled for fall 1978.

Thus far, pink salmon are more sensitive to low temperatures and shrimp are more sensitive at higher temperatures. Uptake-depuration by fish was not significantly affected by exposure at different temperatures. In contrast, snails accumulate and depurate aromatics faster at higher temperatures. Shrimp tests are in progress.

2. Effects of sublethal exposures to oil components on the tolerance of pink salmon and shrimp. Pink salmon and shrimp will be exposed to varying sublethal concentrations and lengths of exposure to toluene, naphthalene, and crude oil WSF. After exposure to sublethal concentrations, standard continuous-flow bioassays will be used to determine changes in tolerance levels between controls and exposed animals. We expect animals with a high metabolizing potential to adapt to the toxicants as they mobilize metabolic pathways to detoxify oil components.

Progress: Tests with pink salmon juveniles were completed this quarter. Data analyses is in progress, but preliminary results with pink salmon show increased tolerance after pre-exposure to toluene, naphthalene, and WSF. Shrimp will be tested in fall 1978.

INTERPRETATION OF RESULTS

Interpretation of results will occur in reviewed manuscripts.

PROBLEMS ENCOUNTERED

Unforeseen failures in sea water pumps, generators, alarms etc. caused cancellation of one major study when most of the pink salmon to be used in the tests, died.

Manuscript preparation is behind schedule due to the demands of running laboratory experiments during the spring and summer. Emphasis in fall 1979 will be on manuscript preparation.

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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Submitted as a Quarterly Report
for Contract #R7120819
Research Unit #73
OUTER CONTINENTAL SHELF ENERGY ASSESSMENT PROGRAM
Sponsored by
U.S. Department of the Interior
Bureau of Land Management

July 1 to September 30, 1978

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ABSTRACT

The responses of marine organisms to environmental contaminants are reflected in numerous changes that are detectable at population and organismic levels, as well as at cellular and molecular levels. The general scope of this study is to evaluate effects caused by behavioral, physiological, pathological, morphological, and chemical changes in subarctic and arctic marine animals exposed to petroleum hydrocarbons and trace metals.

Behavior

Juvenile English sole (Parophrys vetulus) were released on uncontaminated sediment in a double chambered "choice" apparatus. In eight avoidance tests the number of fish on uncontaminated and Prudhoe Bay crude oil (PBCO)-contaminated sediment (8,000 ppm) after 22 hr was not significantly different from controls. In addition, fish on oil-contaminated sediment exhibited burying activity and feeding responses identical to fish on uncontaminated sediment.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-contaminated Sediment

Starry flounder (Platichthys stellatus) have been exposed to sediment contaminated with 0.5% (v/v) PBCO for over two months. During this period, 32% (16/50) of the oil-exposed and 30% (15/50) of the control fish died. The cause(s) of death has not been established. Both groups fed actively and by two months had increased in average weight by 35%. Reversible hematological differences between the two groups were observed. Another major difference between the two groups has been the development of hemorrhagic lesions on the lower jaw of 26% of the control group and 5% of the oil-exposed group.

Effect of Petroleum Hydrocarbons on Host Defense Mechanisms and Disease Resistance

Adult starry flounder exposed for 2 and 6 weeks to sediment containing 1,800 ppm PBCO showed no demonstrable alteration to infection with pathogenic bacteria.

Morphology

In addition to involvement in several other OCSEAP-related projects, efforts this quarter were directed toward preparation of manuscripts on two major areas of research conducted in the past year: (1) eye changes related to petroleum exposure, and (2) the morphology of eggs from both pelagic and demersal marine fish. The egg studies were also presented at an AAAS symposium in Fairbanks, Alaska.

In addition, we have completed a manuscript in collaboration with Dr. M. Mix, Oregon State University, and Dr. A. Sparks, NWAFC, on a putative neoplastic disorder of Mytilus edulis from a high benz(a)pyrene area of Yaquina Bay, Oregon.

Chemistry

Metabolism of Hydrocarbons in Demersal Fish

1,2-Dihydro-1,2-dihydroxynaphthalene constituted one-third of the total extracted metabolites in liver of naphthalene-exposed starry flounder and rock sole (Lepidopsetta bilineata) at 24 hr. Biliary metabolites were primarily (>90%) conjugates. From 24 to 168 hr, a significant ($P<0.05$) decrease in the proportion of the dihydrodiol derivative and a concomitant increase in the proportion of conjugates--specifically, sulfate/glucoside fraction--were observed with liver. No significant change occurred in the spectrum of biliary metabolites with time. The composition of metabolites in skin of both species was qualitatively similar to that in liver; however, the proportion of the dihydrodiol was greater in skin than in liver at 24 hr.

Biotransformation of Petroleum Hydrocarbons

Work was continued on the food-chain transfer of 2,6-dimethylnaphthalene (2,6-DMN) from seawater to the seaweed Fucus distichus, and then to the sea urchin, Strongylcentrotus droebachiensis, feeding on these treated plants. In this phase of the work, data were collected on the levels of accumulated 2,6-DMN and its total metabolites in tissues of urchins.

OBJECTIVES

This multidisciplinary study has a series of objectives designed to evaluate the effects of petroleum on marine organisms. The specific objectives of work performed during the current quarterly period of July 1, 1978 to September 30, 1978, are as follows:

Behavior

To determine if flatfish avoid Prudhoe Bay crude oil-contaminated sediment.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-contaminated Sediment

To define the uptake and disposition of petroleum hydrocarbons by flatfish exposed to crude-oil-contaminated sediments and to characterize possible pathological effects resulting from long-term exposure.

Effect of Petroleum Hydrocarbons on Host Defense Mechanisms and Disease Resistance

To determine if exposure to oil-contaminated sediment alters disease resistance in selected species of flatfish.

Morphology

To prepare manuscripts for publication on lens and larval fish studies.

Metabolism of Hydrocarbons in Demersal Fish

To define the metabolism and disposition of dietary naphthalene in starry flounder and rock sole.

Biotransformation of Petroleum Hydrocarbons

(1) To determine levels of accumulation of 2,6-DMN and its total metabolites in the digestive tract and gonads of urchins feeding on treated Fucus, and (2) to follow the losses in accumulated levels when urchins were removed from the source of 2,6-DMN.

FIELD OR LABORATORY ACTIVITIES

SHIP OR FIELD TRIP SCHEDULE - N/A

SCIENTIFIC PARTY

The following persons affiliated with the Environmental Conservation Division of the Northwest and Alaska Fisheries Center participated in the planning, development, and performance of experiments presented in this report.

Name	Role
D. Malins, PhD, DSc	Principal investigator; hydrocarbon metabolism
E. Gruger, Jr., PhD	Principal investigator; coordinator of chemical analyses and reports to OCSEAP
H. Hodgins, PhD	Principal investigator; physiological and pathological studies
N. Karrick	Principal investigator; chemical investigations
D. Weber	Principal investigator; behavioral studies
W. Roubal, PhD	Research chemist; hydrocarbon metabolism
D. Federighi	Chemist; assistant to Dr. Roubal
U. Varanasi, PhD	Research chemist; metal/hydrocarbon studies
D. Gmur	Chemist; assistant to Dr. Varanasi
W. Reichert, PhD	Research chemist; metal/hydrocarbon studies
F. Johnson	Fishery biologist; part-time behavioral studies
J. Parker	NOAA Corps Officer; assistant in pathology studies

T. Scherman	Physical science technician; part-time assistant in pathology and behavioral studies
B. McCain, PhD	Microbiologist; effects of petroleum in sediments on flatfish, coinvestigator with Dr. Hodgins
W. Gronlund	Fishery research biologist; assistant in pathology and behavior studies
K. Pierce	Fishery biologist; part-time assistant to Dr. McCain
L. Rhodes	Biological aide; part-time assistant to Dr. McCain
M. Schiewe	Fishery research biologist; disease resistance studies
P. Scordelis	Fishery biologist; part-time assistant to Mr. Schiewe
J. Hawkes, PhD	Fishery research biologist; electron microscopy
C. Stehr	Technician; assistant to Dr. Hawkes

METHODS

Behavior

Groups of 20 English sole (0-1 age class, 45 to 120 mm length) were introduced on the uncontaminated side of a choice test apparatus, and the number on both the uncontaminated and oil-contaminated sides determined 22 hr later. The test apparatus consisted of a 55 cm by 150 cm box with 20 cm standpipes at each end. In the box were two identical 3400 cm^2 trays each filled with 15 l of sediment to a depth of 3.5 cm. The sediment in one tray was mixed with PBCO to give 2.5% (v/v) and allowed to rinse for 22 hr before initiating the test. Control tests were run with uncontaminated sediments on both sides. A diffusion pipe running the width of the box, and located between trays, provided seawater at 12 l/min. Dye studies and hydrocarbon analysis of water samples above the sediment indicate negligible mixing of water columns between sides of the test apparatus.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-contaminated Sediment

Starry flounder are being exposed to oil-contaminated sediments in flow-through seawater aquaria containing a 5 cm layer of sediment alone or sediment containing 0.5% PBCO. Each aquarium contains 50 fish, 25 marked with cold branding and 25 unmarked. Sediment, above-sediment water, and interstitial water were collected at the time fish were placed on the sediment (0-time), at 2 weeks, and at 1 and 2 months. These samples were analyzed for total extractable petroleum hydrocarbons (TEPH) and in some cases for aromatic hydrocarbons by gas chromatography (GC). At the same intervals, four unbranded control and four unbranded oil-exposed fish were sacrificed and tissue samples were taken and subjected to histology, hematology, electron microscopy and analyses for aromatic hydrocarbons by GC; in addition, all fish were weighed and measured for length. The fish with cold branded markings were used to monitor length/weight changes in individuals.

Effect of Petroleum Hydrocarbons on Host Defense Mechanisms and Disease Resistance

Disease resistance of adult starry flounder maintained on sediment initially containing 1,800 ppm PBCO or control sediment was compared after exposure of 2 and 6 weeks. Test and control fish were challenged with varying concentrations of the marine fish pathogen, *Vibrio anguillarum*, and LD_{50} values were determined.

Chemistry

Metabolism of Hydrocarbons in Demersal Fish

Starry flounder and rock sole were force-fed 56 μCi of ^{3}H-naphthalene as described in previous quarterly report (OCSEAP March-June 1978).

The metabolites were isolated from liver, skin, and bile of the exposed fish as follows: The samples (≈200 mg each) were homogenized in 3 ml of methanol. The homogenate was filtered and the filtrate was collected in a flask kept in ice. The residue was extracted twice with 8 ml aliquots of a mixture of boiling methylene chloride:2-propanol:water (75:25:2, v:v:v) and twice with 8 ml of boiling ethanol:diethyl ether (50:50, v:v). The combined extracts were concentrated at 4°C, under a stream of nitrogen, to minimize any loss of volatile components. Individual classes of metabolites were separated by thin-layer chromatography (Varanasi et al. 1978).

Biotransformation of Petroleum Hydrocarbons

Analyses for 2,6-DMN and its metabolites in urchins were performed using radiochemical tracer techniques and tissue extracts and digests prepared from tissues, as reported earlier for fish tissue (Roubal et al. 1977).

SAMPLE COLLECTION LOCALITIES

Behavior

Juvenile English sole were collected in Puget Sound on the west side of Whidby Island with a 10 m beach seine. Sediments were from a beach near Sequim, Washington, known to have low levels of hydrocarbon contamination.

Pathology

Starry flounder were collected from the mouth of the Columbia River, and sediment from the same site as described in the Behavior section.

Chemistry

Metabolism of Hydrocarbons in Demersal Fish

Sexually immature starry flounder and rock sole (82 ± 30 g) were captured by trawling or beach seining from the mouth of the Columbia River and

Point Pully, Washington, respectively. The fish were acclimated to experimental temperature (12° ± 1°C) in flowing seawater (28 ‰) for a period of two weeks prior to treatment.

Biotransformation of Petroleum Hydrocarbons

The sea urchins used in this portion of the study were collected from Puget Sound.

DATA COLLECTED AND/OR ANALYZED

Behavior

Sediment, interstitial water, and above-sediment water were taken before each of the eight avoidance tests and are being analyzed for total extractable petroleum hydrocarbons (TEPH) and for aromatic hydrocarbons by gas chromatography (GC). In addition, four control tests were conducted.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-contaminated Sediment

(1) Number and types of samples: Tissue samples for histology (260); blood for hematology (29); sediment for hydrocarbon analyses (10); interstitial water samples for hydrocarbon analyses (10); tissues for hydrocarbon analyses (28).

(2) Number and type of analyses: Microscopic examination of histological specimens (202); hematology (hematocrit, hemoglobin, total blood cell count, differential white cell count) (206); sediment and water samples for TEPH analyses (6); tissues for hydrocarbon analyses (0).

Effects of Petroleum Hydrocarbons on Host Defense Mechanisms and Disease Resistance

(1) Number and types of samples: Starry flounder for disease resistance tests (120); sediment samples for hydrocarbon analyses (6); tissue samples for hydrocarbon analyses (12).

(2) Number and type of analyses: Hydrocarbon analyses of sediment (4); LD_{50} determinations (4)--five fish per group and four groups per determination

Chemistry

Biotransformation of Petroleum Hydrocarbons

(1) Number and types of samples: Samples of 2,6-DMN-exposed sea urchin digestive tracts and gonads, in separate tests, were analyzed for 2,6-DMN and its total metabolites (expressed as naphthol).

(2) Number and types of analyses: The digestive tracts and gonads (three urchins per data point) were analyzed for 2,6-DMN and its total metabolites at 5, 24, 48, 72, and 96 hr from the onset of feeding on treated Fucus, which had been exposed to 2,6-DMN for 96 hr, for a total of 30 analyses (See previous report for exposure details). In addition, digestive

tracts and gonads (three urchins per data point) were assayed at 10, 24, 48, 74, and 100 hr after treated urchins had been transferred to Fucus-free clean seawater, for a total of 30 analyses.

RESULTS

Behavior

No significant differences (P=0.05) were observed between counts of juvenile English sole on oil-contaminated sediment after 22 hr, and counts of fish on uncontaminated sediment. In two separate series of tests performed sequentially at 24 hr intervals using the same oiled-sediment mixture (TEPH remained constant at 8,000 μg/g) for 3 days, an initial slightly higher number of fish in the control side was followed by equal distributions in both chambers at 2 and 3 days.

Feeding response was used as a measure of performance of the fish after 22 hr in the test apparatus. Fish on either the uncontaminated or oil-contaminated side responded to food equally well, both in ability to locate the food source, and in food consumption. Also, no length-related differences in the behavior of test or control fish were observed.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-contaminated Sediment

After 2 mo exposure to oil-contaminated sediment (containing initial levels of TEPH of approximately 2,000 μg/g), the main differences between the control and oil-exposed starry flounder, were a higher frequency of skin lesions on the lower jaw of control fish, and hematological changes. Hemorrhagic lesions were first observed on the lower jaws of 26% of the controls and 5% of the test fish at 2 mo. The cause of these lesions is not known, although abrasion from the sides of the aquaria are suspected. One hematological change consisted of an increase in hematocrit from an initial (0-time) average of 19.7% to 29.3 and 22.4% at 2 weeks for the controls and oil-exposed, respectively, with the values being significantly higher ($P<0.02$) in the controls. At 1 and 2 mo, the hematocrits in both groups had returned to approximately the initial values. The second hematological change involved an increase in the number of white blood cells in both groups from an initial average of 9.4×10^4 cells/mm^3 to 19.2×10^4 cells/mm^3 for the controls and 13.4×10^4 cells/mm^3 for the test fish at 1 mo; again, the average value for the controls was significantly higher ($P<0.05$).

The other parameters for which the control and oil-exposed fish were tested and found not to differ significantly were the following: (1) although the controls had lost 2% and the test fish lost 5% of their average body weight at 2 weeks, by 2 mo both groups had increased their average weight by 35%; (2) 32 and 30% of the test and control fish, respectively, died of unknown causes by 2 months; and (3) the livers in both groups when examined histologically changed from normal at 2 weeks to abnormal by 1 mo. These changes consisted primarily of extensive hepatocellular glycogen accumulation.

Effect of Petroleum Hydrocarbons on Host Defense Mechanisms and Disease Resistance

Tests in which starry flounder were exposed for 2 and 6 weeks to sediment containing 1,800 ppm PBCO showed that essentially no alteration occurred in disease resistance. LD_{50} values computed from mortality data following the 2-week oil exposure followed by challenge with Vibrio anguillarum were 1.1×10^7 and 5.6×10^7 organisms for oil-exposed and control fish, respectively. After the 6 week exposure, LD_{50} values were 1.2×10^7 and 6.0×10^7 organisms for these same respective groups.

Morphology

Experimental data were obtained during this and previous quarters concerning petroleum-induced eye changes in trout and the structure of eggs from marine fish. Impairment of vision as a result of cataract formation occurred in laboratory experiments with trout exposed to high levels of petroleum (1 g/kg) in their diet. The progression of changes in the lens, which lead to opacity, parallel cataract formation in trout exposed to thioacetamide (Sallmann 1966) and in numerous species of mammals exposed to a wide range of toxic assaults (Kinoshita 1974). The initial effect, common to each case, including the fish studied in our laboratory, is osmotic swelling of the lens fiber cells. Eventually, the membranes of the fiber cells are damaged and major changes in the morphology of the internal regions of these cells are apparent. Lenticular opacity occurs at some point during degradation of the lens proteins when the degree of alteration in normal α- and β-crystallin has altered the refractive index of the lens.

Major differences in the structure of salmonid and flatfish eggs were demonstrated, which may be important in their ability to survive petroleum exposure. The flatfish chorion has a simple internal pore as well as lamellar structure, whereas the salmon egg has a thick multilamellar membrane with a highly complex pore structure. In salmon the ratio of chorion thickness to egg diameter is 8%, compared to 2% in the flounder. Damage to the egg surface or transport of toxic material through the chorion to the developing embryo are important considerations in evaluating the effects of petroleum on embryogenesis of teleosts. These data were the subject of manuscripts being prepared for journal publication.

Chemistry

Metabolism of Hydrocarbons in Demersal Fish

The bile from both rock sole and starry flounder contained primarily glucuronic acid derivatives at 24 and 168 hr after feeding of naphthalene. Small amounts of the mercapturic acid derivatives were also detected. No statistically significant changes were observed in the spectrum of biliary metabolites with time.

In livers of both rock sole and starry flounder, 1,2-dihydro-1,2-dihydroxynaphthalene was the major metabolite (38.7 and 39.5%, respectively) at 24 hr after feeding of the naphthalene. Considerable proportions of conjugates (e.g., naphthyl glucuronic acid, naphthyl mercapturic acid, and naphthyl sulfate/glucoside) were also present in the livers. Although profiles of metabolites in liver and skin were qualitatively similar, 1,2-

dihydro-1,2-dihydroxynaphthalene was present in larger proportions in skin than in liver of rock sole; skin of starry flounder contained 44.7% of total metabolites as the diol. From 24 to 168 hr after naphthalene feeding, the proportion of the dihydrodiol derivative decreased and that of the conjugates increased in the livers of both starry flounder and rock sole.

Biotransformation of Petroleum Hydrocarbons

Concentrations of radioactively-labeled 2,6-DMN in urchins feeding on treated Fucus rose abruptly from a zero level, at the onset of feeding, to 1.2 ± 0.16 and 0.26 ± 0.02 ng/g in the digestive tract and gonads, respectively, in 24 hr. Concentrations of total metabolites (expressed as naphthol) of 2,6-DMN were 0.41 ± 0.01 and 0.12 ± 0.02 ng/g in the digestive tract and gonads, respectively. All concentrations are based on dry weight.

After 96 hr of feeding on treated Fucus, the concentrations of 2,6-DMN in the digestive tract were 1.44 ± 0.05 and 0.77 ± 0.05 ng/g in the gonads. At the same time, total metabolites were 1.35 ± 0.21 and 0.18 ± 0.04 ng/g in the digestive tract and gonads, respectively.

Urchins, which were transferred to Fucus-free clean seawater, had tissue levels for 2,6-DMN in digestive tract and gonads of 0.09 ± 0.02 and 0.21 ± 0.04 ng/g, respectively, after 100 hr, while at the same time total metabolites were 0.80 ± 0.1 and 0.09 ± 0.02 ng/g in the digestive tract and gonads, respectively.

During the latter stages of feeding (45-96 hr), when the concentrations of 2,6-DMN and its metabolites appeared to approach a limit in the urchins, the radioactivity associated with the total of 2,6-DMN and its metabolites (ng/g dry weight tissue) was approximately 2/3 of that associated with 2,6-DMN in Fucus. In addition, the proportions of 2,6-DMN to its metabolites in the urchins was approximately 2.6:1.0 (wt/wt).

PRELIMINARY INTERPRETATION OF RESULTS

Behavior

Observations on flatfish activity in the choice apparatus, both under control and test conditions, indicated that juvenile English sole remain buried in the sediment 60 to 85% of the time. Prolonged contact with hydrocarbons in the sediment at concentrations of 700 to 400 ppm has been observed to cause both physiological and pathological abnormalities in English sole (McCain et al. 1978). In the behavioral tests reported here, though the TEPH in the sediments are over one magnitude greater than that shown to have adverse effects, the fish did not avoid oil-contaminated sediment. Also, the fish buried and fed readily in the presence of oil. These results suggest that in future experiments concerning chronic exposure of flatfish to oil-contaminated sediment, higher concentrations of oil in the sediment should be tested to determine if physiological and pathological consequences can be more severe than previously reported.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-contaminated Sediment

During 2 months exposure to sediments containing over 2,000 μg/g TEPH, the test starry flounder responded in much the same way as did controls. The principal adverse effects, including mortalities and skin lesions, observed so far may have been caused by the experimental conditions.

Effect of Petroleum Hydrocarbons on Host Defense Mechanisms and Disease Resistance

Tests completed to date provide no evidence that exposure to PBCO for durations up to 6 weeks alter bacterial disease resistance in adult flatfish. Future efforts will be directed toward assessing disease resistance in juvenile life stages of selected flatfish species.

Morphology

We conclude that, although the relationship of petroleum to cataractogenesis in trout is evident under restricted conditions, definition of the process in terms of the biochemical mechanisms are not yet known, other than that a petroleum-related compound, naphthalene, or its metabolites do accumulate in lens tissue. The physiological-morphological changes in lenses from petroleum-exposed fish begin with hydration and distortion and proceed to protein coagulation, loss of fiber cell integrity and opacity. The ability of visually impaired fish to survive normal environmental stresses is a topic of speculation.

Chemistry

Metabolism of Hydrocarbons in Demersal Fish

Our results show that the pattern of metabolites accumulated in skin were qualitatively similar to that in the liver of the same fish. However, in both species of flatfish studied, the proportion of non-conjugates, specifically 1,2-dihydro-1,2-dihydroxynaphthalene, was higher in the skin compared to that in the liver. If the presence of metabolic products in skin was primarily due to the transport of these compounds from the liver, then certain selection seems to take place in the types of metabolites that are deposited in skin. Whether other tissues especially those for human consumption (e.g., muscle), also preferentially accumulated non-conjugates (e.g., the dihydrodiol derivative) was not ascertained in these studies and remains an important question to be answered, especially in the case of known carcinogenic hydrocarbons.

Moreover, our findings show that the types of metabolites accumulated in the liver were dependent on the time elapsed after the administration of naphthalene. With time, there was an increase in the proportion of conjugates--specifically sulfate/glucoside fraction--and a decrease in the proportion of 1,2-dihydro-1,2-dihydroxynaphthalene. Burke et al. (1977) reported that the pattern of metabolites changed from a higher proportion of organic-soluble metabolites to a higher proportion of aqueous-soluble metabolites from 10 to 30 min after the addition of benzo(a)pyrene in rat hepatocytes. Because certain dihydrodiols of PAH are precursors of diol epoxides, which are implicated in covalent binding with cellular DNA (Levin et al. 1976), decreased proportion of the diol may imply increased detoxification of the hydrocarbon.

Biotransformation of Petroleum Hydrocarbons

It was established that a dialkylated naphthalene is efficiently transferred to sea urchins from water via a marine plant. Moreover, once exposure to 2,6-DMN was curtailed, accumulations of 2,6-DMN and its metabolites persisted for 100 hr. Thus, the potential exists whereby metabolites and their short-lived precursors (which arise in urchins as a consequence of their incorporating 2,6-DMN, but whose nature has yet to be established) may interact with tissue sites in urchins. Whether or not such interactions are deleterious or not has yet to be established. In mammalian systems, certain metabolites of a variety of polynuclear hydrocarbons are able to induce cancer and other abnormalities (Arcos and Argus 1974).

AUXILIARY MATERIAL

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ESTIMATE OF FUNDS EXPENDED

Funds expended for the Fiscal Year ending September 30, 1978 - 360.0 K

QUARTERLY REPORT

Contract No:	R7120810
Research Unit No:	RU-77
Reporting Period:	July 1-September 30, 1978
Number of Pages:	1 + NWAFC Prog. Doc. No. 6 (110 p.)

NUMERICAL ECOSYSTEM MODEL FOR THE EASTERN BERING SEA

Co-Principal Investigators

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National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest and Alaska Fisheries Center
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September 1978

QUARTERLY PROGRESS REPORT

Reporting Period: July 1-September 30, 1978

I. Highlights of Quarter's Accomplishments

The Program Documentation of the extended model (DYNUMES III) is completed and attached. We have had no response from OCSEAP offices to our previous requests (see quarterly reports submitted in December, March, and June) for biological data for the Bering Sea, obtained by other OCSEAP projects, nor estimates of the nature, magnitude, and effects on individual organisms of possible oil exploration/exploitation leaks, spills, or disasters. If this contract is renewed, we are prepared to simulate ecosystem responses.

II. Task Objectives

(same as in previous quarterly report)

III. Field and Laboratory Activities

(same as in previous quarterly report)

IV. Results

(see I above)

V. Preliminary Interpretation of Results

(see I above)

VI. Auxiliary Material

N.A.

VII. Problems Encountered/Recommended Changes

Access to data.

VIII. Estimate of Funds Expended

$50K

Program Documentation

No. 6

DYNAMIC NUMERICAL MARINE ECOSYSTEM MODEL (DYNUMES III) FOR EVALUATION OF FISHERY RESOURCES

by

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Resource Ecology Task
Resource Ecology and Fisheries Management Division

August 1978

Northwest and Alaska Fisheries Center
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CONTENTS

1. ORGANIZATION OF THE PROGRAM

The objectives, principles, and basic formulas of DYNUMES III are described by Laevastu and Favorite 1978. This report describes the computer code of the model.

A diagnostic (analytical) phase is a necessary first step in the setup and initiation of an ecosystem model program for any region. Therefore, it was considered desirable to present a program documentation which includes the diagnostic stage (i.e. tuning of inputs). In the prognostic phase the tuning parts of the program are bypassed.

The program uses an equal-area grid with subregions (Figure 1). All species/ecological groups and auxiliary data, such as sea-land-subregion tables and depths, are digitized in this grid.

The main (or control) program handles the inputs and timekeeping and calls other computational subroutines. Various time-step end (month-end) bookkeeping, such as writing on discs and outputs, are also done in the main program. The preparations for computations of fish species/ecological group biomasses are done in five subroutines, arranged by ecological groupings (pelagic, demersal, etc.). These subroutines call other computational subroutines (migration, growth, feeding, etc.).

2. DESCRIPTION OF THE SUBROUTINES

2.1 Main program (AKODIA).

The lists of disc storage locations of various fields are given as comments at the beginning of the program. The random access discs are opened and zeroed and various inputs are read from the cards. The quantitative distribution of marine mammals and birds is created in the program utilizing specified subregions. The input and tuning of the fish species/ecological groups biomasses are done by subregions as well as by direct reading from cards for some species. The space and time variable fishing intensity coefficients for some species are created by statistical subareas (Figure 2).

The computation subroutines are called once a month. At the end of each month the actual month consumptions are transferred to the disc locations for previous month consumption, and fractions of biomasses consumed are computed and printed out.

2.2 Marine mammals and birds subroutine (BIRMAM).

The consumption of various species/ecological groups by marine mammals and birds are computed in this subroutine. The subroutine arranges also output of this consumption. The food composition of the individual species is constant in space and time but can be changed directly within the code, if so desired.

2.3 Fish and crustacean subroutines (DEMFIS, SEMDEM, ROCKFI, PELFIS and CRUSTA).

The species/ecological groups are divided between five subroutines using ecological regimes as criteria for division. Each subroutine contains the computations of several species. The manipulation of each species is similar with respect to the order of computational subroutines called.

After reading the previous month biomass from the disc, the migration timing is tested and migration speed creation subroutines (e.g. PLASRA) are called. The migrating fraction of the biomass is separated in subroutine RANPOR and the main migration computation subroutine RANNAK is called. The resulting effects of migrations are printed (optional).

Before calling the subroutine for migrations caused by temperatures outside the optimum range or food abundance being low (subroutine CYLTOT), a subroutine for interpolation of food composition tables must be called (subroutine TOJAGS). A smoothing (diffusion) subroutine SILITA is applied after the migration subroutine.

Various growth, mortality, and food coefficients are introduced before calling the growth computation subroutine ASVNTS. For the computation of food-availability dependent grazing, a relatively large number of fields (arrays) must be read into the core from the discs. These reading-writing arrangements for feeding computations are done within the subroutine PORTOS, where the actual feeding subroutine TOIFOO is also called.

Corrections to growth due to starvation effects are computed in subroutine CROCOR, which computes also a slight spawning mortality in the months of peak spawning. Finally, the fishery is computed using one of the fishery subroutines (PUGIMO or CASTAT) and the resulting monthly distribution of the species is printed.

2.4 Benthos subroutine (BENTOS).

Subroutine BENTOS computes the growth, consumption, and feeding of predatory benthos, infauna, and epifauna. No seasonal migrations are computed for these benthos components. The same growth and feeding subroutines are called as in the fish subroutines, except the coefficients used in these subroutines are different, corresponding to the biological behavior of benthos.

2.5 Plankton subroutine (PLANKT).

Subroutine PLANKT simulates the standing stocks of phyto- and zooplankton, based on subregional coefficients which are derived from empirical observations. Furthermore, the percentage of zooplankton consumption is computed in this subroutine. The simulated zooplankton standing stock and its fractional consumption are the only outputs from this subroutine which are used further in the program (in food consumption subroutine).

2.6 Growth subroutine (ASVNTS).

The biomass balance (growth, consumption, mortalities) is computed in this subroutine. The growth coefficient is a harmonic function of time. Furthermore, the growth coefficient is made also a function of temperature.

2.7 Feeding subroutines (TOJAGS, PORTOS, TOIFOO).

Subroutine TOJAGS extracts the food composition of the given species from the food composition table and interpolates between seasonal tables, if necessary. The food items are also arranged into decreasing order of importance for the given species.

Subroutine PORTOS reads from discs the arrays necessary for feeding computations, calls the feeding subroutine TOIFOO and writes the resultant arrays on the discs.

The feeding, food substitution, and starvation are computed in subroutine TOIFOO. Subroutine TOIFOO treats five food items in one call; thus, it must be called several times, depending on the number of food items specified for the individual species.

2.8 Migration subroutines (PALSRA, CRUSRA, PIRPAN, RANNAK AND RANPOR).

Migration speed, direction and timing varies from species to species and from region to region. Therefore, only a few examples of the migration speed simulation are given in the appended program (6).

Migration speed components (u and v) for flatfish are created in subroutine PALSRA as function of month and depth. The speed components for migrations of crustaceans are created in subroutine CRUSRA, considering the nature (e.g. depth) of different subregions. Some migrations speeds are created directly in species subroutines.

Subroutine PIRPAN adjusts migration speeds near the coast (setting of coastal boundary conditions). The migrating fraction of the stock is separated in subroutine RANPOR, using a prescribed migrating fraction and depth as criteria.

The migrations proper are computed in subroutine RANNAK. This subroutine requires a specific stability criterion and consequently uses a smaller time step than one month. Subroutine SILITA (smoothing, diffusion subroutine) is called several times in subroutine RANNAK.

2.9 Migrations caused by environmental anomalies and shortage of food subroutine (CYLTOT).

Subroutine CYLTOT computes the partial migrations of the species in areas where the temperature is below and/or above the specified optimum temperature limits, or where the availability of the three most important food items for the species is too low. The temperature and food availability conditions and gradients at the surrounding grid points are checked and a specified part of the biomass is moved in the direction of more favorable environmental and feeding conditions. Two passes are usually made through the field (array) for each item checked at each time step.

2.10 Subroutine for growth correction due to starvation and for spawning mortality computation (GROCOR).

The biomass growth is changed in this subroutine at those grid points where partial starvation occurs. The lowering of the growth is proportional to the degree of food shortage. A small spawning mortality is also computed in this subroutine in the months of peak spawning.

2.11 Fishery subroutines (PUGIMO and CASTAT).

Two different subroutines are available for the computation of the fishery. If a general fishing mortality coefficient is specified, subroutine PUGIMO is used. If the space and time variable fishing coefficient is used, subroutine CASTAT is called. Both subroutines compute also the total catch per month.

2.12 <u>Smoothing, diffusion and boundary subroutines (SILITA and BOUSET)</u>.

Subroutine SILITA is a smoothing subroutine which simulates diffusion. The degree of smoothing is specified with a variable smoothing coefficient. Subroutine BOUSET set boundaries ("in-out flat gradient boundaries") and is called either in or after those subroutines where boundary values cannot be computed due to neighboring-grid considerations (i.e. the use of $n \pm 1$ and $m \pm 1$ gridpoints).

2.13 Output subroutine (PRIAFP)

The program contains one printing subroutine PRIAFP which prints the fields (arrays) so that these can be examined in two space dimensions with a geographic overlay. All plotting subroutines are external to the program (see forthcoming program documentation for GRIDS).

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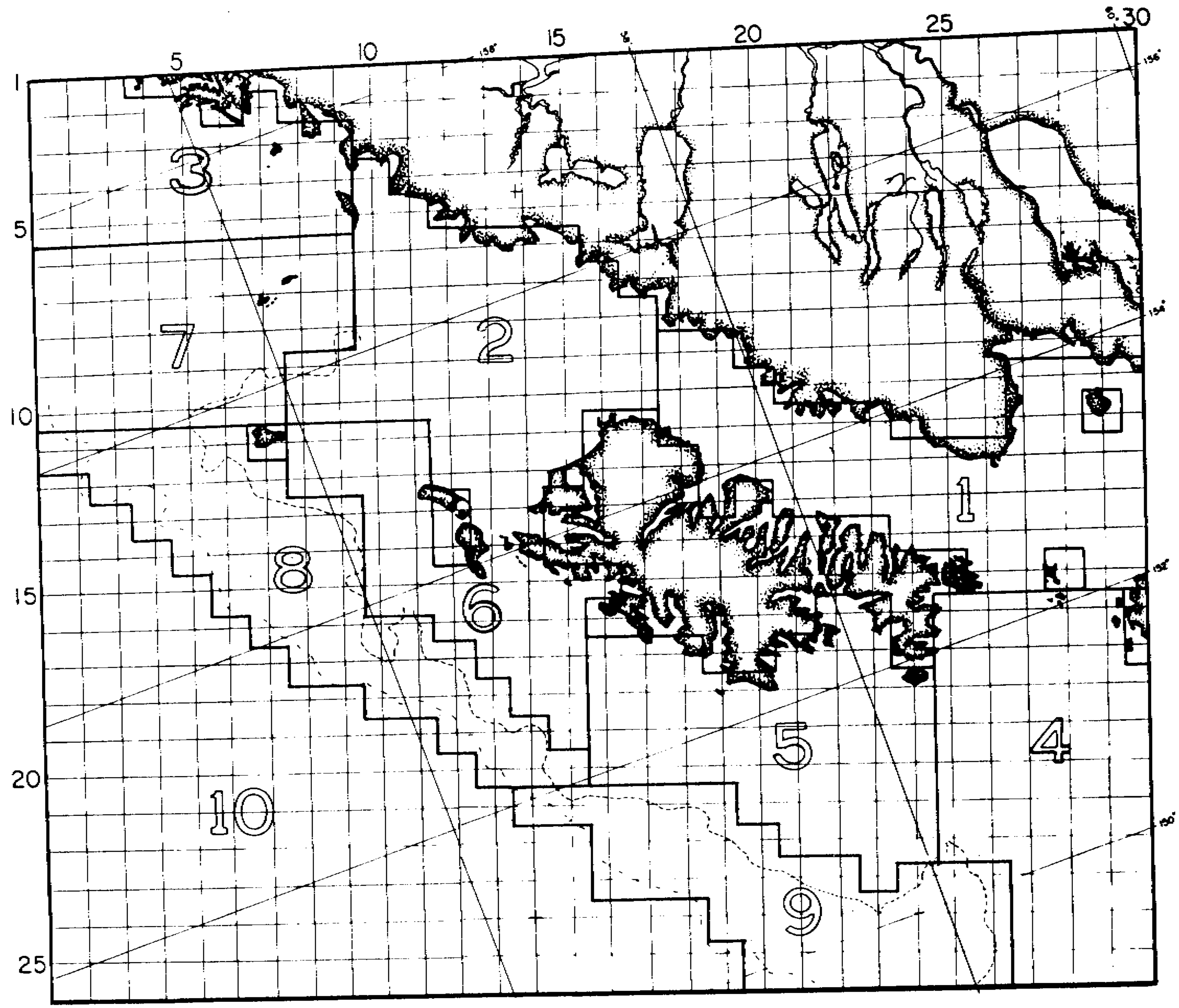

Figure 1.--Computational grid with subregions for Kodiak area.

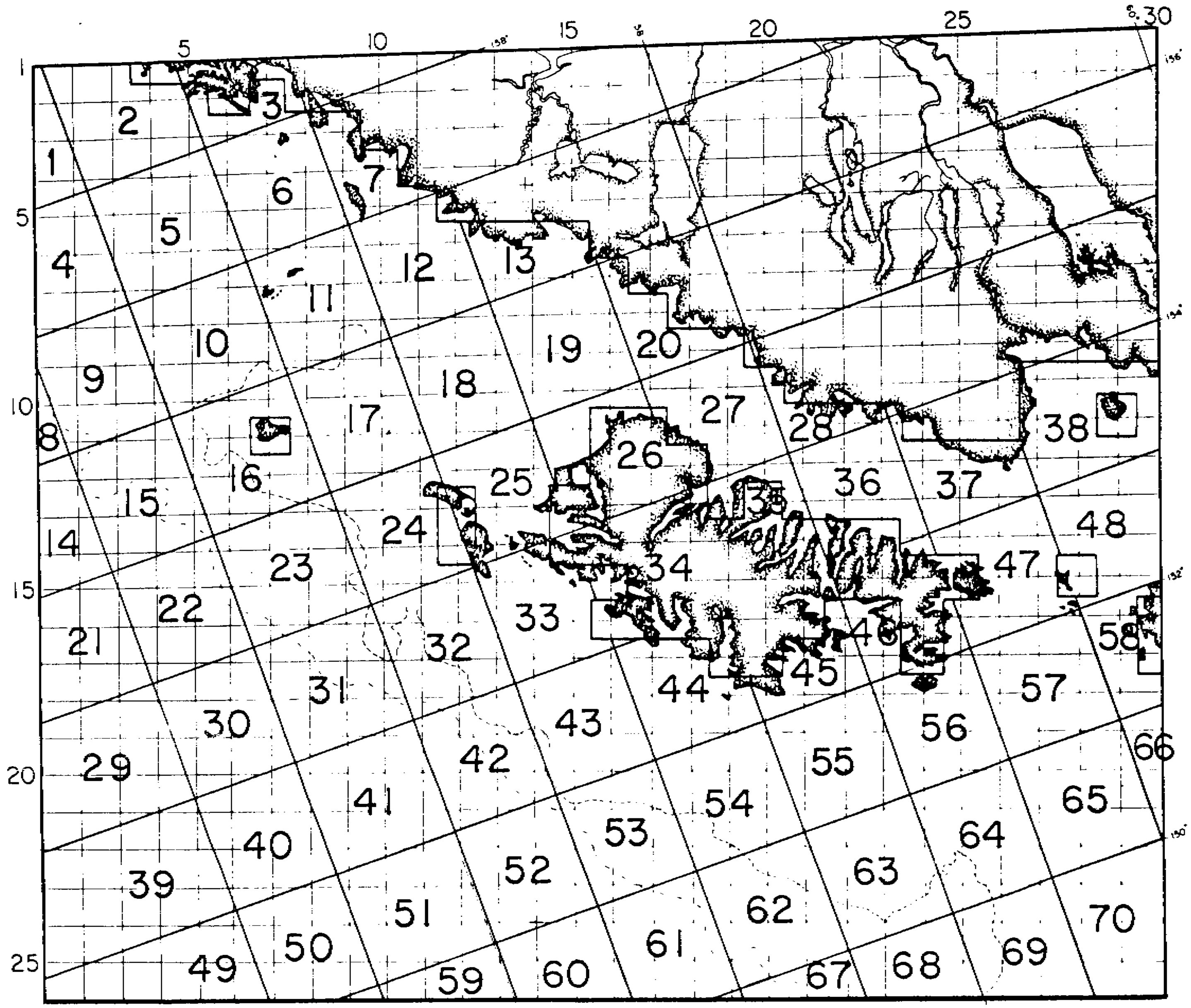

Figure 2.--Statistical subareas for Kodiak area.

4. PROGRAM INPUTS

4.1. Principal input arrays

The principal input arrays are read and/or created in the main program. Most of these arrays are stored on discs and the storage locations are shown on the storage table in the beginning of the main program. (AW) signifies the use of any operational array for the input below:

ISL	- 1) Sea-land table and subregion table. 2) Catch statistics areas.
SD	- Depth.
B1 (B2)	- Food composition tables (annual or seasonal).
(AW)	- Surface and bottom temperature (monthly).
(AW)	- Distribution of marine mammals and marine birds (by single species or groups of species) (monthly). This input can be created (programmed) in the main program, whereby use is made of subregions (statements 180 to 520), or the distributions are digitized and read from cards.
(AW)	- Distribution of fish, crustaceans, and benthos (by species and/or ecological groups). Initial (preferably January) distribution is required. These distributions are created in the main program, utilizing subregions (statements 530 to 800) or digitized and read from cards (e.g. Pacific ocean perch, statement 816).
(AW)	- Fishing intensity (effort) coefficients, digitized from charts or created in main program (e.g. statements 819 to 886). (for species where the fishing effort coefficient is not given by area distribution, a fishing mortality coefficient is used).

4.2. Input factors and coefficients

These factors and coefficients are input in different subroutines, where examples of plausible values are given in enclosed program. Most of the factors and coefficients are different for different species/ecological groups.

ALP	- 1) Phase speed of main harmonic component (30 deg./month). 2) Smooth factor (in SILITA)
ALPP	- Phase speed of second harmonic component (usually 60 deg./month).
AUS	- Austausch (diffusion) coefficient.
A1 to A5	- Criterion for food take from given food item, based on consumption of this food item in previous month (different for different ecological groups).
B1 to B5	- Fraction of food requirement for given food item which will be taken from the biomass of this item (based on criterion in A1 to A5).
C1 to C5	- Fraction of food requirement which could not be satisfied and is added into "starvation bin" (array). C1 to C5 are complimentary fractions to B1 to B5.
D1 to D5	- Criterion for "starvation bin" fraction to be satisfied from food item under consideration.
DD	- Deepest depth of migration.
DL	- Grid size.
FIM	- Fishing mortality coefficient.
ME	- Array size (in rows).
NE	- Array size (in columns).
PKAP	- Phase lag of primary phytoplankton maximum (degrees) (Introduced with data statement for each subregion).

PYZM - Approximately the annual range of primary phytoplankton maximum (first harmonic constant). (Introduced with data statement for each subregion.)

PYZMM - Approximately the annual range of secondary phytoplankton maximum (second harmonic constant) (in data statement).

PYZO - Annual mean phytoplankton standing crop (in data statement).

RP - Fraction of the population migrating in different depth zones.

RAD - Conversion factor, from degrees to radians.

SL (SV) - Mortality coefficient (from old age and diseases).

SS - Shallowest depth of migration (to or from).

TA (TOA) - Food coefficient for growth (ratio-growth/food).

TJ (TOJ) - Food coeffcient for maintenance (percent body weight daily).

TS (TKA, TBS) - Monthly growth coefficient (annual mean).

TK (PL, TUK) - Phase lag of maximum growth (degrees).

TY (AA, TBY) - Annual range of growth coefficient change

TD - Time step (in RANNAK).

TSL (TSSL) - Spawning mortality coefficient.

TMAX (TMX) - Upper limit for optimum temperature range.

TMIN (TMI) - Lower limit for optimum temperature range.

UR (UP) - U component of migration speed.

VR (VP) - V component of migration speed

WBB TO WTW - Mean weights of marine birds and mammals (see list of symbols and abbreviations).

ZKAP - Phase lag of primary zooplankton maximum (degrees) (in data statement, by subregions).

ZKAS - Phase lag of secondary plankton maximum (degrees) (in data statement by subregions).

ZOM - Range of zooplankton primary change (first harmonic constant) (in data statement).

ZOMS - Range of zooplankton secondary change (second harmonic constant (in data statement).

ZOO - Annual mean zooplankton standing stock (in data statement).

5. SYMBOLS AND ABBREVIATIONS

AA	- Range of annual change of growth coefficient.
AA1 (N,M)	- Operational array (species).
AA2 (N,M)	- Food requirement (kg/km^2).
AB	- Area
AG	- Coefficient.
ALP	- Phase speed (main component); also smoothing factor (α).
ALPP	- Phase speed, secondary component.
AMA, AQR, ARR	- Area in 1000 km^2.
AR	- Area in 1000 km^2.
AS	- Area, coefficient.
AST	- Intermediate.
AUS	- Austausch coefficient.
A1, A2, A3, A4, A5	- Coefficients (defined in program).
BAB (N,M), BB2 (N,M)	- Operational arrays.
BET $(1-\alpha)/4$	- Smoothing coefficient.
B1 (N,M), B2 (N,M)	- Food composition table.

B1	
B2	
B3	- Coefficients (defined in program).
B4	
B5	
CO	- Intermediate.
COVR	- Lack of food (storage, carry-over).
C1	
C2	
C3	- Coefficients (defined in program) (also intermediate arrays).
C4	
C5	
C6 to C25	- Intermediates (arrays).
DD	- Deepest depth of migration.
DL	- Grid size.
DLJ	- Index.
D1 to D5	- Coefficients (defined in program) (D1 (N,M) also operational array.
EAT	- Intermediates (in food consumption computation).
EATS	
E1 (N,M)	- Temperature.
E2 (N,M)	- Consumption (previous month).
E3 (N,M)	- Food requirements (kg/km^2).
E4 (N,M)	- Growth (kg/km^2).

FC 1 FC 2 FC 3 FC 4 FC 5	- Percentage of food item in diet (from food composition table).
FIM	- Fishing mortality coefficient.
FIMC (N,M)	- Fishing intensity (effort) coefficient.
FLD (N,M)	- Operational array (species).
FK FK1 FK2 FK3 FK4 FK5	- Percentage of given food item in diet.
FOT (I)	- Percentage of food item in diet.
FO1 FO2 FO3 FO4	- Food consumed per month (mammals).
GKAP	- Phase lag of maximum growth.
GROS	- Corrected growth coefficient.
H1 (N,M)	- Operational array.
H2 (N,M)	- Starvation array.
H3 (N,M)	- Food consumption (requirement) array.
H4 (N,M)	- Operational array

I	- Index.
II	- Counter, index.
INI	- Index.
IN1 (I)	- Arrays for random access mass storage.
IN2 (I)	
ISL (N,M)	- Sea-land and subregion table.
IZP	
IZ1	
IZ2	
J	- Indices.
JF	
JJ	
JSF	
K	- Month.
KAK	
KBK	- Indices, counters.
KCK	
KDK	
KFB	
KFK, KNK	- Number of food items.
KOB	
KIK	
KPK	
KM	- Indices.
KRK	
KRCK	
KRI	
KS	
KSK	

KTK KUK KWI LA LL LM M	- Indices.
ME MEH	- Indices, size of array.
MM	- Index.
MS (I)	- Array (unused).
MUM M1 to M9	- Indices.
N NAM	- Indices.
NE NEH	- Indices, array size.
NF NFM	- Indices.
NS (I)	- Array (unused).
NSM NU	- Indices.
NUK (I)	- Identifier (food item number).
PL	- Phase lag of maximum growth.
PKAP (I)	- Phase lag of phytoplankton maximum (deg.).

PKP	- Intermediate.
PYZM (I)	- Range of main phytoplankton maximum change.
PYZMM (I)	- Range of secondary phytoplankton maximum change.
PYZO (I)	- Annual mean phytoplankton standing crop.
P1 (N,M) to P6 (N,M)	- Operational arrays.
RP	- Migrating fraction.
RAD	- Conversion factor (from deg. to rad.).
R1 (N,M) to R5(N,M)	- Food item consumption arrays.
SD (N,M)	- Depth.
SI (N,M)	- Operational array.
SL	- Mortality coefficient.
SOCY (N,M)	- Operational array.
SOSY (N,M)	- Operational array (species).
SS	- Shallowest depth of migration.
SU SUT SUM SU1	- Summation
SUS	- Adjusted mortality coefficient.
SV	- Mortality coefficient; also intermediate (advection rate in V direction).
SUTAB	- Biomass sum.

S1 (N,M) to S6 (N,M) S8 (N,M)	- Operational arrays
TA	- Food coefficient for growth (ratio-growth/food).
TBS	- Growth coefficient, annual mean.
TBY	- Annual range of growth coefficient change.
TD	- Time step.
TJ	- Food coefficient for maintenance (percent body weight daily).
TK	- Phase lag for maximum growth.
TKA	- Annual mean growth coefficient.
TKG	- Harmonically adjusted growth coefficient.
TKP	- Adjusted growth coefficient.
TMAX TMX	- Maximum temperature for given species.
TMIN TMI	- Minimum temperature for given species.
TOA	- Food coefficient for growth.
TOB	- Adjusted food coefficient for growth.
TOJ	- Food coefficient for maintenance
TOS	- Adjusted food coefficient for maintenance.
TS	- Annual mean growth coefficient.
TSL TSSL	- Spawning mortality coefficient.
TUK	- Phase lag for maximum growth
TV (N,M)	- Temperature.

TY	- Range of annual growth change.
T1 (N,M) to T6 (N,M)	- Operational arrays.
UP (N,M) UR (N,M)	- Migration speed, U component.
US	- Summation.
U1	- Intermediate.
VP (N,M) VR (N,M)	- Migration speed, V component.
VALE VALO VARI VAUP	- Intermediates.
VALIP (N,M)	- Operational array.
VAP	- Index
VMAK	- Temperature (max.,min.) (also food abundance index).
V1 (N,M) V2 (N,M) V3 (N,M)	- Operational arrays.
WBB	- Fish eating birds, weight.
WBO	- Other marine birds, weight.
WBW	- Baleen whales, weight.
WFS	- Fur seals, weight.
WOP	- Other pinnipeds, weight.

WPD	- Porpoises/dolphins, weight.
WSL	- Sea lions, weight.
WSW	- Sperm whales, weight.
WTW	- Toothed whales, weight.
X2 (N,M) to X6 (N,M)	- Fraction of food items consumed in previous month.
ZKAP (I)	- Phase lag of zooplankton maximum (deg.).
ZKP	- Phase lag of zooplankton maximum (rad.).
ZKAS (I)	- Phase lag of secondary plankton maximum (deg.).
ZKPP	- Phase lag of secondary plankton maximum (rad.).
ZOM (I)	- Range of zooplankton main annual change.
ZOMS (I)	- Range of zooplankton secondary annual change
ZOO (I)	- Annual mean zooplankton standing stock.
Z1 (N,M)	- Operational array (species).

6. THE PROGRAM IN FORTRAN

```
      PROGRAM AKODIA      73/73   OPT=1                              FTN 4.6+460        07/31

      PROGRAM AKODIA (TAPE1,TAPE2,INPUT,OUTPUT,PUNCH)
      DIMENSION ISL(26,30),SD(26,30),UR(26,30),VR(26,30),SUTAB(30,12),   002
     1B1(30,30),B2(30,30),FOT(30),NUK(30),NS(50),
     2MS(50),S1(26,30),S2(26,30),S3(26,30),S4(26,30),S5(26,30),S6(26,30)
     3,P1(26,30),P2(26,30),P3(26,30),P4(26,30),P5(26,30),P6(26,30)
     4,T1(26,30),T2(26,30),T3(26,30),T4(26,30),T5(26,30),T6(26,30)
      COMMON ISL,SD,UR,VR,SUTAB,                                         002
     1B1,B2,FOT,NUK,NS,MS,
     2S1,S2,S3,S4,S5,S6,P1,P2,P3,P4,P5,P6,T1,T2,T3,T4,T5,T6,
     3K,LL,IZP,IZ1,IZ2,NE,ME,NU
     5,IN1(201),IN2(201)                                                 000
C******************************** DISC 1 ***************************
C                         JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
C     FUR SEAL              1   2   3   4   5   6   7   8   9  10  11  12
C     SEA LION             13  14  15  16  17  18  19  20  21  22  23  24
C     BALEEN WHALES        25  26  27  28  29  30  31  32  33  34  35  36
C     TOOTHED WHALES       37  38  39  40  41  42  43  44  45  46  47  48
C     BIRDS,FISH EAT.      49  50  51  52  53  54  55  56  57  58  59  60
C     BIRDS,OTHERS         61  62  63  64  65  66  67  68  69  70  71  72
C     SURFACE TEMP.        73  74  75  76  77  78  79  80  81  82  83  84
C     BOTTOM TEMP.         85  86  87  88  89  90  91  92  93  94  95  96
C     CURRENTS             97  98  99 100 101 102 103 104 105 106 107 108
C     FOOD COMP.       109         110         111         112
C     OTHER PINNEPEDS     113 114 115 116 117 118 119 120 121 122 123 124
C     SPERM WHALES        125 126 127 128 129 130 131 132 133 134 135 136
C     PORPOISE,DOLPHIN    137 138 139 140 141 142 143 144 145 146 147 148
C     CATCH STAT. AREA    149                                            001
C     SEA-LAND TABLE      150                                            001
C     POP CATCH COEFF.    151 152 153 154 155 156 157 158 159 160 161 162 001
C******************************** DISC 2 ***************************
C    *   SPECIES     *FOOD** BIOMASS  ** CONSUMPTION*       *STAR/* ZCONS*000
C    *     OR        *RANK**INPUT*COMP** PREV*ACTUAL*GROWTH *ATION* PREV.*000
C    *SPECIES GROUP* NR **      *      **MONTH*MONTH**       *      * MONTH*000
C*******************************************************************
C SPECIES        GR 1      1      1      2      3      4      5      6      7
C UNDER          GR 2      2      8      9     10     11     12     13     14
C SPECIAL        GR 3      3     15     16     17     18     19     20     21
C STUDY          GR 4      4     22     23     24     25     26     27     28
C TURBOT,HALIBUT           5     29     30     31     32     33     34     35
C FLATHEAD SOLE            6     36     37     38     39     40     41     42
C ROCK,YELLOWFIN SOLE      7     43     44     45     46     47     48     49
C DOVER,REX SOLE           8     50     51     52     53     54     55     56
C PAC. OCEAN PERCH         9     57     58     59     60     61     62     63
C SEBASTOLOBUS            10     64     65     66     67     68     69     70
C COTTIDS, OTHERS         11     71     72     73     74     75     76     77
C POLLOCK                 12     78     79     80     81     82     83     84
C COD                     13     85     86     87     88     89     90     91
C HERRING                 14     92     93     94     95     96     97     98
C SMELTS, OTHERS          15     99    100    101    102    103    104    105
C ATKA MACKEREL           16    106    107    108    109    110    111    112
C SALMON                  17    113    114    115    116    117    118    119
C SQUIDS                  18    120    121    122    123    124    125    126
C KING CRAB               19    127    128    129    130    131    132    133
C TANNER CRAB             20    134    135    136    137    138    139    140
C PANDALID SHRIMP         21    141    142    143    144    145    146    147
C PRED. BENTHOS           22    148    149    150    151    152    153    154
C INFAUNA                 23    155    156    157    158    159    160    161
```

Storage locations on discs

PROGRAM AKODIA 73/73 OPT=1 FTN 4.6+460 07/3

```
      C EPIFAUNA                24    162   163   164   165   166   167   168
      C COPEPODS                25    169   170   171   172   173   174   175
      C EUPHAUSIDS              26    176   177   178   179   180   181   182
      C PHYTOPLANKTON           27    183   184   185   186   187   188   189
      C ICHTHYPLANKTON          28    190   191   192   193   194   195   196
      C     UR, VR - MIGRATION SPEED COMP., KM/DAY
      C     SD  - DEPTH, METERS
      C     TSD - CODED SEDIMENT TYPE
            DO 9 N=1,26
            DO 9 M=1,30
            T1(N,M)=0.
          9 CONTINUE
            DO 230 N=1,30
            DO 230 M= 1,30
            B1(N,M)=0.
        230 CONTINUE
            CALL OPENMS (1,IN1,201,0)
            DO 10 M=1,108
            CALL WRITMS (1,T1,780,M,0)
         10 CONTINUE
            DO 11 M=109,112
            CALL WRITMS (1,B1,900,M,0)
         11 CONTINUE
            DO 12 M=113,200
            CALL WRITMS (1,T1,780,M,0)
         12 CONTINUE
            CALL OPENMS (2,IN2,201,0)
            DO 13 M=1,200
            CALL WRITMS (2,T1,780,M,0)
         13 CONTINUE
         14 FORMAT(24I3)
         15 FORMAT (12I5)
         16 FORMAT(12F6.0)
      C     SET PRINTING INDICES
            IZ1=1
            IZ2=1
      C     READING GENERAL INPUTS
            READ 14,NE,ME,NU
            PRINT 17,NE,ME,NU
         17 FORMAT(7X,12I8)
            READ 15,((ISL(N,M),M=1,30),N=1,26)
            IF(IZ1)20,20,180
         18 PRINT 19
            DO 33 N=1,26
            DO 33 M=1,30
         33 T1(N,M)=ISL(N,M)
            CALL PRIAFP (T1,1)
         19 FORMAT (5X,14HSEA-LAND TABLE//)
        180 CALL WRITMS (1,ISL,780,150,1)
            READ 15,((ISL(N,M),M=1,30),N=1,26)
            IF(IZ1)185,185,181
        181 PRINT 182
        182 FORMAT(5X,21HCATCH STATISTIC AREAS//)
            DO 183 N=1,NE
            DO 183 M=1,ME
        183 T1(N,M)=ISL(N,M)
            CALL PRIAFP(T1,0)
```

Opening of disc storage

Input and printing of sea-land and subregions table and other catch statistics areas table.

```
      195 CALL WRITMS (1,ISL,780,149,1)
          CALL READMS (1,ISL,780,150)
       20 READ 16,((SD(N,M),M=1,30),N=1,26)
          DO 21 N=1,26
          DO 21 M=1,30                              Input of depths
          SD(N,M)=SD(N,M)*1.8288
       21 CONTINUE
    C     TSD - TYPE OF BOTTOM WILL BE DIGITIZED LATER
    C     FOOD COMPOSITION TABLES
    C**********
    C     NO TWO NUMBERS ON ONE LINE CAN BE
    C     OF SAME MAGNITUDE] RANK THEM ] E.G. 10.02
    C**********
          MUM=109
       22 READ 23,((B1(N,M),M=1,30),N=1,30)  Input of food
       23 FORMAT (15F5.2)                      composition table
          CALL WRITMS (1,B1,900,MUM,1)
    C     MUM=MUM+1
          IF(IZ1)28,28,228
      228 PRINT 24,(N,N=1,15)
       24 FORMAT (5X,16HFOOD COMPOSITION//7X,15I7)
          PRINT 25,(N,(B1(N,M),M=1,15),N=1,30)
       25 FORMAT(//I5,15F7.2)
          B1(12,11)=5.06   $ B1(13,13)=9.01   $ B1(11,20)=10.01
          B1(11,22)=18.00  $ B1(11,24)=19.00  $ B1(12,21)=5.05
          B1(12,26)=30.00  $ B1(13,18)=5.05   $ B1(13,20)=10.00
          B1(13,24)=12.02  $ B1(13,26)=6.03   $ B1(22,21)=1.00
          B1(22,24)=25.00  $ B1(22,27)=46.00
          PRINT 26,(N,N=16,30)
       26 FORMAT (7X,15I7)
          PRINT 25,(N,(B1(N,M),M=16,30),N=1,30)
          PRINT 229
      229 FORMAT(5X,15HDEPTH IN METERS)
          CALL PRIAFP(SD,1)
    C  27 IF(MUM-112)22,22,28
    C     INITIALLY SFC TEMP=10 DEG C AND BOTTOM TEMP=4.5 DEG C
    C     JAN, FEBR, MAR, SFC TEMP SAME AS BOTTOM
       28 DO 30 N=1,NE
          DO 30 M=1,ME                     Input of surface and bottom
          IF(ISL(N,M))30,30,29              temperatures (preliminary)
       29 T1(N,M)=10.
          T2(N,M)=4.5
       30 CONTINUE
          DO 31 M=76,84
          CALL WRITMS (1,T1,780,M,1)
       31 CONTINUE
          DO 8 M=73,75
          CALL WRITMS (1,T2,780,M,1)
        8 CONTINUE
          DO 32 M=85,96
          CALL WRITMS (1,T2,780,M,1)
       32 CONTINUE
    C     INITIAL INPUT OF PINNIPEDS, WHALES AND BIRDS
    C     DIVISION WITH AR GIVES KG/SQKM
          AR=18.5*18.5
          WFS=55./AR                       Weight and area factors for
          WSL=250./AR                      birds and mammals.
```

```
      WOP=65./AR
      WBW=40000./AR
      WTW=10000./AR
      WSW=30000./AR
      WPD=100./AR
      WBB=0.35/AR
      WBO=0.65/AR
      KAK=1
   34 IF(KAK-3)35,35,36
   36 IF(KAK-5)37,37,38
   38 IF(KAK-8)39,39,40
   40 IF(KAK-10)37,37,35
C     S1-FUR SEAL   S2- SEA LION      S3-OTHER PINNIPEDS
C     S4-BALEEN WHALES     S5-TOOTHED WHALES   S6- SPERM WHALES
C     P1-PORPOISES, DOLPHINS P2-FISH EATING BIRDS P3-OTHER BIRDS
   35 DO 41 N=1,NE
      DO 41 M=1,ME
      IF(ISL(N,M))41,41,44
   44 IF(ISL(N,M)-2)45,46,47
   45 S1(N,M)=40000./52.*WFS
      S2(N,M)=3200./52.*WSL
      S3(N,M)=3000./52.*WOP
      S4(N,M)=0.
      S5(N,M)=25./52.*WTW
      S6(N,M)=0.
      P1(N,M)=30./52.*WPD
      P2(N,M)=6.*AR*WBB
      P3(N,M)=4.*AR*WBO
      GO TO 41
   46 S1(N,M)=33000./55.*WFS
      S2(N,M)=2800./55.*WSL
      S3(N,M)=3500./55.*WOP
      S4(N,M)=0.
      S5(N,M)=21./55.*WTW
      S6(N,M)=0.
      P1(N,M)=40./55.*WPD
      P2(N,M)=6.*AR*WBB
      P3(N,M)=5.*AR*WBO
      GO TO 41
   47 IF(ISL(N,M)-4)48,49,50
   48 S1(N,M)=12000./36.*WFS
      S2(N,M)=1300./36.*WSL
      S3(N,M)=2000./36.*WOP
      S4(N,M)=0.
      S5(N,M)=9./36.*WTW
      S6(N,M)=0.
      P1(N,M)=35./36.*WPD
      P2(N,M)=5.*AR*WBB
      P3(N,M)=3.*AR*WBO
      GO TO 41
   49 S1(N,M)=10000./56.*WFS
      S2(N,M)=1600./56.*WSL
      S3(N,M)=800./56.*WOP
      S4(N,M)=0.
      S5(N,M)=60./56.*WTW
      S6(N,M)=0.
      P1(N,M)=40./56.*WPD
```

Creation of birds and mammals biomass distributions

```
      P2(N,M)=7.*AR*WBB
      P3(N,M)=5.*AR*WBO
      GO TO 41
   50 IF(ISL(N,M)-6)51,52,53
   51 S1(N,M)=25000./45.*WFS
      S2(N,M)=3000./45.*WSL
      S3(N,M)=1900./45.*WOP
      S4(N,M)=0.
      S5(N,M)=80./45.*WTW
      S6(N,M)=0.
      P1(N,M)=40./45.*WPD
      P2(N,M)=9.*AR*WBB
      P3(N,M)=8.*AR*WBO
      GO TO 41
   52 S1(N,M)=10000./29.*WFS
      S2(N,M)=2200./29.*WSL
      S3(N,M)=2000./29.*WOP
      S4(N,M)=0.
      S5(N,M)=50./29.*WTW
      S6(N,M)=0.
      P1(N,M)=20./29.*WPD
      P2(N,M)=8.*AR*WBB
      P3(N,M)=5.*AR*WBO
      GO TO 41
   53 IF(ISL(N,M)-8)54,55,56
   54 S1(N,M)=10000./41.*WFS
      S2(N,M)=2200./41.*WSL
      S3(N,M)=400./41.*WOP
      S4(N,M)=0.
      S5(N,M)=45./41.*WTW
      S6(N,M)=0.
      P1(N,M)=20./41.*WPD
      P2(N,M)=7.*AR*WBB
      P3(N,M)=4.*AR*WBO
      GO TO 41
   55 S1(N,M)=500./46.*WFS
      S2(N,M)=100./46.*WSL
      S3(N,M)=200./46.*WOP
      S4(N,M)=0.
      S5(N,M)=8./46.*WTW
      S6(N,M)=0.
      P1(N,M)=5./46.*WPD
      P2(N,M)=2.*AR*WBB
      P3(N,M)=3.*AR*WBO
      GO TO 41
   56 IF(ISL(N,M)-10)57,58,41
   57 S1(N,M)=300./43.*WFS
      S2(N,M)=100./43.*WSL
      S3(N,M)=200./43.*WOP
      S4(N,M)=0.
      S5(N,M)=8./43.*WTW
      S6(N,M)=0.
      P1(N,M)=5./43.*WPD
      P2(N,M)=4.*AR*WBB
      P3(N,M)=5.*AR*WBO
      GO TO 41
   58 S1(N,M)=500./158.*WFS
```

```
      S2(N,M)=200./158.*WSL
      S3(N,M)=100./158.*WOP
      S4(N,M)=0.
      S5(N,M)=13./158.*WTW
      S6(N,M)=0.
      P1(N,M)=15./158.*WPD
      P2(N,M)=2.*AR*WBB
      P3(N,M)=1.*AR*WBO
   41 CONTINUE
      GO TO 5
   37 DO 42 N=1,NE
      DO 42 M=1,MF
      IF(ISL(N,M))42,42,59
   59 IF(ISL(N,M)-2)60,61,62
   60 S1(N,M)=25000./52.*WFS
      S2(N,M)=2900./52.*WSL
      S3(N,M)=3000./52.*WBW
      S3(N,M)=3000./52.*WOP
      S4(N,M)=0.2/52.*WBW
      S5(N,M)=25./52.*WTW
      S6(N,M)=0.1/52.*WSW
      P1(N,M)=30./52.*WPD
      P2(N,M)=12.*AR*WBB
      P3(N,M)=16.*AR*WBO
      GO TO 42
   61 S1(N,M)=20000./55.*WFS
      S2(N,M)=2600./55.*WSL
      S3(N,M)=3500./55.*WOP
      S4(N,M)=0.2/55.*WBW
      S5(N,M)=15./55.*WTW
      S6(N,M)=0.2/55.*WSW
      P1(N,M)=40./55.*WPD
      P2(N,M)=10.*AR*WBB
      P3(N,M)=15.*AR*WBO
      GO TO 42
   62 IF(ISL(N,M)-4)63,64,65
   63 S1(N,M)=9000./36.*WFS
      S2(N,M)=1200./36.*WSL
      S3(N,M)=2000./36.*WOP
      S4(N,M)=0.1/36.*WBW
      S5(N,M)=7./36.*WTW
      S6(N,M)=0.1/36.*WSW
      P1(N,M)=35./36.*WPD
      P2(N,M)=12.*AR*WBB
      P3(N,M)=19.*AR*WBO
      GO TO 42
   64 S1(N,M)=11000./56.*WFS
      S2(N,M)=1800./56.*WSL
      S3(N,M)=800./56.*WOP
      S4(N,M)=5./56.*WBW
      S5(N,M)=95./56.*WTW
      S6(N,M)=2./56.*WSW
      P1(N,M)=40./56.*WPD
      P2(N,M)=9.*AR*WBB
      P3(N,M)=6.*AR*WBO
      GO TO 42
   65 IF(ISL(N,M)-6)66,67,68
```

```
      66 S1(N,M)=22000./45.*WFS
         S2(N,M)=3600./45.*WSL
         S3(N,M)=1900./45.*WOP
         S4(N,M)=9./45.*WBW
         S5(N,M)=110./45.*WTW
         S6(N,M)=4./45.*WSW
         P1(N,M)=40./45.*WPD
         P2(N,M)=11.*AR*WBB
         P3(N,M)=15.*AR*WBO
         GO TO 42
      67 S1(N,M)=14000./29.*WFS
         S2(N,M)=2800./29.*WSL
         S3(N,M)=2000./29.*WOP
         S4(N,M)=6.5/29.*WBW
         S5(N,M)=80./29.*WTW
         S6(N,M)=3./29.*WSW
         P1(N,M)=20./29.*WPD
         P2(N,M)=13.*AR*WBB
         P3(N,M)=15.*AR*WBO
         GO TO 42
      68 IF(ISL(N,M)-8)69,70,71
      69 S1(N,M)=14000./41.*WFS
         S2(N,M)=2800./41.*WSL
         S3(N,M)=400./41.*WOP
         S4(N,M)=5./41.*WBW
         S5(N,M)=70./41.*WTW
         S6(N,M)=5./41.*WSW
         P1(N,M)=20./41.*WPD
         P2(N,M)=9.*AR*WBB
         P3(N,M)=10.*AR*WBO
         GO TO 42
      70 S1(N,M)=10000./46.*WFS
         S2(N,M)=2200./46.*WSL
         S3(N,M)=200./46.*WOP
         S4(N,M)=2.5/46.*WBW
         S5(N,M)=6./46.*WTW
         S6(N,M)=8./46.*WSW
         P1(N,M)=5./46.*WPD
         P2(N,M)=4.*AR*WBB
         P3(N,M)=4.*AR*WBO
         GO TO 42
      71 IF(ISL(N,M)-10)72,73,42
      72 S1(N,M)=300./43.*WFS
         S2(N,M)=300./43.*WSL
         S3(N,M)=200./43.*WOP
         S4(N,M)=6.5/43.*WBW
         S5(N,M)=9./43.*WTW
         S6(N,M)=8./43.*WSW
         P1(N,M)=5./43.*WPD
         P2(N,M)=4.*AR*WBB
         P3(N,M)=4.*AR*WBO
         GO TO 42
      73 S1(N,M)=500./158.*WFS
         S2(N,M)=200./158.*WSL
         S3(N,M)=100./158.*WOP
         S4(N,M)=7./158.*WBW
         S5(N,M)=15./158.*WTW
```

```
      S6(N,M)=30./158.*WSW
      P1(N,M)=15./158.*WPD
      P2(N,M)=3.*AR*WBB
      P3(N,M)=3.*AR*WBD
   42 CONTINUE
      GO TO 5
   39 DO 43 N=1,NE
      DO 43 M=1,ME
      IF(ISL(N,M))43,43,74
   74 IF(ISL(N,M)-2)75,76,77
   75 S1(N,M)=4000./52.*WFS
      S2(N,M)=600./52.*WSL
      S3(N,M)=3000./52.*WOP
      S4(N,M)=1./52.*WBW
      S5(N,M)=40./52.*WTW
      S6(N,M)=0.1/52.*WSW
      P1(N,M)=30./52.*WPD
      P2(N,M)=14.*AR*WBB
      P3(N,M)=11.*AR*WBD
      GO TO 43
   76 S1(N,M)=4000./55.*WFS
      S2(N,M)=500./55.*WSL
      S3(N,M)=3500./55.*WOP
      S4(N,M)=1./55.*WBW
      S5(N,M)=21./55.*WTW
      S6(N,M)=0.2/55.*WSW
      P1(N,M)=40./55.*WPD
      P2(N,M)=13.*AR*WBB
      P3(N,M)=10.*AR*WBD
      GO TO 43
   77 IF(ISL(N,M)-4)78,79,80
   78 S1(N,M)=2000./36.*WFS
      S2(N,M)=300./36.*WSL
      S3(N,M)=2000./36.*WOP
      S4(N,M)=0.5/36.*WBW
      S5(N,M)=9./36.*WTW
      S6(N,M)=0.1/36.*WSW
      P1(N,M)=35./36.*WPD
      P2(N,M)=15.*AR*WBB
      P3(N,M)=12.*AR*WBD
      GO TO 43
   79 S1(N,M)=2000./56.*WFS
      S2(N,M)=300./56.*WSL
      S3(N,M)=600./56.*WOP
      S4(N,M)=3.5/56.*WBW
      S5(N,M)=170./56.*WTW
      S6(N,M)=6./56.*WSW
      P1(N,M)=40./56.*WPD
      P2(N,M)=9.*AR*WBB
      P3(N,M)=8.*AR*WBD
      GO TO 43
   80 IF(ISL(N,M)-6)81,82,83
   81 S1(N,M)=2000./45.*WFS
      S2(N,M)=500./45.*WSL
      S3(N,M)=1900./45.*WOP
      S4(N,M)=3./45.*WBW
      S5(N,M)=150./45.*WTW
```

```
      S6(N,M)=14./45.*WSW
      P1(N,M)=40./45.*WPD
      P2(N,M)=20.*AR*WBB
      P3(N,M)=10.*AR*WBD
      GO TO 43
   82 S1(N,M)=4000./29.*WFS
      S2(N,M)=500./29.*WSL
      S3(N,M)=2000./29.*WOP
      S4(N,M)=2./29.*WBW
      S5(N,M)=140./29.*WTW
      S6(N,M)=12./29.*WSW
      P1(N,M)=20./29.*WPD
      P2(N,M)=12.*AR*WBB
      P3(N,M)=12.*AR*WBD
      GO TO 43
   83 IF(ISL(N,M)-6)84,85,86
   84 S1(N,M)=3500./41.*WFS
      S2(N,M)=500./41.*WSL
      S3(N,M)=400./41.*WOP
      S4(N,M)=1./41.*WBW
      S5(N,M)=125./41.*WTW
      S6(N,M)=13./41.*WSW
      P1(N,M)=20./41.*WPD
      P2(N,M)=10.*AR*WBB
      P3(N,M)=10.*AR*WBD
      GO TO 43
   85 S1(N,M)=200./46.*WFS
      S2(N,M)=100./46.*WSL
      S3(N,M)=200./46.*WOP
      S4(N,M)=2./46.*WBW
      S5(N,M)=12./46.*WTW
      S6(N,M)=15./46.*WSW
      P1(N,M)=5./46.*WPD
      P2(N,M)=3.*AR*WBB
      P3(N,M)=3.*AR*WBD
      GO TO 43
   86 IF(ISL(N,M)-10)87,88,43
   87 S1(N,M)=200./43.*WFS
      S2(N,M)=100./43.*WSL
      S3(N,M)=200./43.*WOP
      S4(N,M)=3./43.*WBW
      S5(N,M)=15./43.*WTW
      S6(N,M)=15./43.*WSW
      P1(N,M)=5./43.*WPD
      P2(N,M)=4.*AR*WBB
      P3(N,M)=4.*AR*WBD
      GO TO 43
   88 S1(N,M)=300./158.*WFS
      S2(N,M)=200./158.*WSL
      S3(N,M)=100./158.*WOP
      S4(N,M)=5./158.*WBW
      S5(N,M)=25./158.*WTW
      S6(N,M)=80./158.*WSW
      P1(N,M)=15./158.*WPD
      P2(N,M)=2.*AR*WBB
      P3(N,M)=2.*AR*WBD
   43 CONTINUE
```

```
    5 M1=0+KAK  $ M2=12+KAK  $ M3=112+KAK
      M4=24+KAK $  M5=36+KAK  $  M6=124+KAK
      M7=136+KAK $ M8=48+KAK  $  M9=60+KAK
      CALL WRITMS (1,S1,780,M1,1)
      CALL WRITMS (1,S2,780,M2,1)
      CALL WRITMS (1,S3,780,M3,1)
      CALL WRITMS (1,S4,780,M4,1)
      CALL WRITMS (1,S5,780,M5,1)
      CALL WRITMS (1,S6,780,M6,1)
      CALL WRITMS (1,P1,780,M7,1)
      CALL WRITMS (1,P2,780,M8,1)
      CALL WRITMS (1,P3,780,M9,1)
      KAK=KAK+1
      IF(KAK-12)24,34,89
   89 CONTINUE
C     ABOVE MAMMALS HAVE BEEN SIMULATED IN 3 SEASONS
C     MONTHS 1,2,3,11,12 - WINTER
C     MONTHS 4,5,9,10 - SPRING AND AUTUMN
C     MONTHS 6,7,8 - SUMMER
C     BIOMASSES ARE CONVERTED TO KG/KM2
C*************************************************************************
C     THE FOLLOWING SECTION INPUTS PRELIMINARY
C     BIOMASSES BY SUBREGIONS KG/KM2
      DO 90 N=1,NE
      DO 90 M=1,ME
      IF(ISL(N,M))90,90,91
   91 IF(ISL(N,M)-2)92,93,94
   92 S1(N,M)=5400.
      S2(N,M)=7700.
      S3(N,M)=900.
      S4(N,M)=1000.
      S5(N,M)=600.
      S6(N,M)=4300.
      P1(N,M)=2000.
      P4(N,M)=3200.
      GO TO 90
   93 S1(N,M)=5900.
      S2(N,M)=8300.
      S3(N,M)=800.
      S4(N,M)=1200.
      S5(N,M)=600.
      S6(N,M)=4300.
      P1(N,M)=2000.
      P4(N,M)=3200.
      GO TO 90
   94 IF(ISL(N,M)-4)95,96,97
   95 S1(N,M)=6500.
      S2(N,M)=9000.
      S3(N,M)=1200.
      S4(N,M)=1500.
      S5(N,M)=600.
      S6(N,M)=4000.
      P1(N,M)=2500.
      P4(N,M)=3200.
      GO TO 90
   96 S1(N,M)=3100.
      S2(N,M)=12000.
```

Creation of fish species and ecological groups initial distributions (the arrays corresponding to different species/ecological groups can be recognized from disc location indicators, statements 650 and ff and disc location table)

```
      S3(N,M)=1500.
      S4(N,M)=3200.
      S5(N,M)=900.
      S6(N,M)=5600.
      P1(N,M)=3000.
      P4(N,M)=2900.
      GO TO 90
   97 IF(ISL(N,M)-6)98,99,100
   98 S1(N,M)=2800.
      S2(N,M)=11000.
      S3(N,M)=1500.
      S4(N,M)=3200.
      S5(N,M)=700.
      S6(N,M)=5200.
      P1(N,M)=3500.
      P4(N,M)=2900.
      GO TO 90
   99 S1(N,M)=2300.
      S2(N,M)=10000.
      S3(N,M)=1800.
      S4(N,M)=2600.
      S5(N,M)=700.
      S6(N,M)=5500.
      P1(N,M)=3500.
      P4(N,M)=2600.
      GO TO 90
  100 IF(ISL(N,M)-8)101,102,103
  101 S1(N,M)=2000.
      S2(N,M)=9500.
      S3(N,M)=1800.
      S4(N,M)=2900.
      S5(N,M)=600.
      S6(N,M)=6000.
      P1(N,M)=3500.
      P4(N,M)=2600.
      GO TO 90
  102 S1(N,M)=1500.
      S2(N,M)=8700.
      S3(N,M)=1200.
      S4(N,M)=3500.
      S5(N,M)=500.
      S6(N,M)=7000.
      P1(N,M)=2000.
      P4(N,M)=2000.
      GO TO 90
  103 IF(ISL(N,M)-10)104,105,90
  104 S1(N,M)=1600.
      S2(N,M)=8400.
      S3(N,M)=1200.
      S4(N,M)=3500.
      S5(N,M)=500.
      S6(N,M)=7000.
      P1(N,M)=2000.
      P4(N,M)=2000.
      GO TO 90
  105 S1(N,M)=900.
      S2(N,M)=4000.
```

```
                S3(N,M)=1000.
                S4(N,M)=2500.
                S5(N,M)=300.
                S6(N,M)=2500.
                P1(N,M)=1500.
                P4(N,M)=800.
             90 CONTINUE
          C***  TUNING OF INPUTS /DO 336 N=1,NE $ DO336 M=1,ME                 000
                S3(N,M)=S3(N,M)*2.45
                S4(N,M)=S4(N,M)*1.65     Tuning of biomasses
                P4(N,M)=P4(N,M)*4.5      before writing on
                S2(N,M)=S2(N,M)*2.2      disc
                P1(N,M)=P1(N,M)*1.5
            336 CONTINUE                                                        000
                CALL WRITMS (2,S1,730,92,1)
                CALL WRITMS (2,S2,730,99,1)
                CALL WRITMS (2,S3,730,106,1)
                CALL WRITMS (2,S4,730,120,1)
                CALL WRITMS (2,S5,730,113,1)
                CALL WRITMS (2,S6,780,78,1)
                CALL WRITMS (2,P1,780,85,1)
                CALL WRITMS (2,P4,730,71,1)
                DO 106 N=1,NE
                DO 106 M=1,ME
                IF(ISL(N,M))106,106,107
            107 IF(ISL(N,M)-2)108,109,110
            108 S1(N,M)=1200.
                S2(N,M)=1000.
                S3(N,M)=1400.
                S4(N,M)=2000.
                S5(N,M)=30000.
                S6(N,M)=10000.
                P1(N,M)=20000.
                P2(N,M)=600.
                GO TO 106
            109 S1(N,M)=1200.
                S2(N,M)=1000.
                S3(N,M)=1400.
                S4(N,M)=2000.
                S5(N,M)=30000.
                S6(N,M)=10000.
                P1(N,M)=20000.
                P2(N,M)=600.
                GO TO 106
            110 IF(ISL(N,M)-4)111,112,113
            111 S1(N,M)=1200.
                S2(N,M)=1000.
                S3(N,M)=1400.
                S4(N,M)=2000.
                S5(N,M)=30000.
                S6(N,M)=10000.
                P1(N,M)=20000.
                P2(N,M)=600.
                GO TO 106
            112 S1(N,M)=1800.
                S2(N,M)=1000.
                S3(N,M)=2000.
```

35


```
      S4(N,M)=1600.
      S5(N,M)=15000.
      S6(N,M)=8000.
      P1(N,M)=25000.
      P2(N,M)=1200.
      GO TO 106
  113 IF(ISL(N,M)-6)114,115,116
  114 S1(N,M)=1800.
      S2(N,M)=1000.
      S3(N,M)=2000.
      S4(N,M)=1600.
      S5(N,M)=15000.
      S6(N,M)=8000.
      P1(N,M)=25000.
      P2(N,M)=1500.
      GO TO 106
  115 S1(N,M)=1800.
      S2(N,M)=500.
      S3(N,M)=2000.
      S4(N,M)=1600.
      S5(N,M)=15000.
      S6(N,M)=5000.
      P1(N,M)=25000.
      P2(N,M)=1400.
      GO TO 106
  116 IF(ISL(N,M)-8)117,118,119
  117 S1(N,M)=1800.
      S2(N,M)=800.
      S3(N,M)=2000.
      S4(N,M)=1600.
      S5(N,M)=15000.
      S6(N,M)=8000.
      P1(N,M)=25000.
      P2(N,M)=1100.
      GO TO 106
  118 S1(N,M)=1000.
      S2(N,M)=500.
      S3(N,M)=800.
      S4(N,M)=800.
      S5(N,M)=8000.
      S6(N,M)=4000.
      P1(N,M)=10000.
      P2(N,M)=1000.
      GO TO 106
  119 IF(ISL(N,M)-10)120,121,106
  120 S1(N,M)=1000.
      S2(N,M)=500.
      S3(N,M)=600.
      S4(N,M)=800.
      S5(N,M)=8000.
      S6(N,M)=4000.
      P1(N,M)=10000.
      P2(N,M)=1000.
      GO TO 106
  121 S1(N,M)=300.
      S2(N,M)=200.
      S3(N,M)=200.
```

```
      S4(N,M)=200.
      S5(N,M)=3000.
      S6(N,M)=1000.
      P1(N,M)=2000.
      P2(N,M)=400.
  106 CONTINUE
C*********
C  TUNING OF INPUTS
C  HALIPUT S1, TANNER CRAB P4, SHRIMP P2
      DO 331 N=1,NE   $ DO331 M=1,ME
      S1(N,M)=S1(N,M)*0.9
      P2(N,M)=P2(N,M)*15.0
      S2(N,M)=S2(N,M)*1.55
      S5(N,M)=S5(N,M)*0.63
      S6(N,M)=S6(N,M)*3.8
      S3(N,M)=S3(N,M)*1.35
      P1(N,M)=P1(N,M)*1.4
      S4(N,M)=S4(N,M)*1.15
  331 CONTINUE
      CALL WRITMS (2,S1,730,29,1)
      CALL WRITMS (2,S2,730,36,1)
      CALL WRITMS (2,S3,730,43,1)
      CALL WRITMS (2,S4,730,50,1)
      CALL WRITMS (2,S5,730,148,1)
      CALL WRITMS (2,S6,730,155,1)
      CALL WRITMS (2,P1,730,162,1)
      CALL WRITMS (2,P2,730,141,1)
C     PRESET ACTUAL MONTH CONSUMPTION,STARVATION, FRACTION
C     CONSUMED TO ZERO
      DO 231 N=1,NE
      DO 231 M=1,ME
      S1(N,M)=0.
      S2(N,M)=0.10
  231 CONTINUE
      DO 232 N=1,27
      NAM=N*7-3
      NSM=N*7-1
      NEM=N*7
      CALL WRITMS (2,S1,730,NAM,1)
      CALL WRITMS (2,S1,730,NSM,1)
      CALL WRITMS (2,S2,730,NEM,1)
  232 CONTINUE
C     PACIFIC OCEAN PERCH INPUT
      READ 196,((P2(N,M),M=1,30),N=1,26)
C     TANNER CRAB INPUT
      READ 196,((P3(N,M),M=1,30),N=1,26)
C     KING CRAB INPUT
      READ 196,((P4(N,M),M=1,30),N=1,26)
C     SEBASTOLOBUS AND SABLEFISH INPUT
      READ 196,((P5(N,M),M=1,30),N=1,26)
  196 FORMAT(15F5.0)
      AR=18.5*18.5
      DO 187 N=1,NE
      DO 187 M=1,ME
      IF(ISL(N,M))188,189,189
  188 P2(N,M)=0.
      P3(N,M)=0.   $  P4(N,M)=0.   $  P5(N,M)=0.
```

Tuning of biomasses before ~~writing on discs~~

Input of Pacific ocean perch with digitized data ~~on cards~~

```
      GO TO 187
  189 IF(P2(N,M))190,190,191
  190 P2(N,M)=3.
  191 P2(N,M)=(P2(N,M)/AR)*1000.
      P3(N,M)=(P3(N,M)/AR)*1000.
      P4(N,M)=(P4(N,M)/AR)*1000.
      P5(N,M)=(P5(N,M)/AR)*1000.
  192 P2(N,M)=P2(N,M)*1.08
      P3(N,M)=P3(N,M)*7.5
      P4(N,M)=P4(N,M)*3.9
      P5(N,M)=P5(N,M)*3.3
      IF(SD(N,M)-300.)332,332,334
  332 IF(P2(N,M)-150.)333,333,187
  333 P2(N,M)=P2(N,M)+165.
      GO TO 187
  334 IF(P2(N,M)-85.)335,187,187
  335 P2(N,M)=85.
  187 CONTINUE
C     STATEMENT 192 IN DO LOOP IS FOR BIOMASS TUNING
      CALL WRITMS (2,P3,780,134,1)
      CALL WRITMS (2,P4,780,127,1)
      CALL WRITMS (2,P5,780,64,1)
      CALL WRITMS (2,P2,780,57,1)
C     CREATION OF FISHING EFFORT COEFFICIENT
C     FOR PACIFIC OCEAN PERCH IN JUNE
      CALL READMS (1,ISL,780,149)
      DO 337 N=1,NE $ DO 337 M=1,ME
      IF(ISL(N,M))302,302,303
  302 P2(N,M)=0.
      GO TO 301
  303 IF(ISL(N,M)-9)302,304,305
  304 P2(N,M)=0.0045
      GO TO 301
  305 IF(ISL(N,M)-10)301,306,307
  306 P2(N,M)=0.0010
      GO TO 301
  307 IF(ISL(N,M)-15)302,308,309
  308 P2(N,M)=0.0115
      GO TO 301
  309 IF(ISL(N,M)-16)301,310,311
  310 P2(N,M)=0.0035
      GO TO 301
  311 IF(ISL(N,M)-23)302,312,313
  312 P2(N,M)=0.0055
      GO TO 301
  313 IF(ISL(N,M)-24)301,314,315
  314 P2(N,M)=0.0010
      GO TO 310
  315 IF(ISL(N,M)-31)302,316,317
  316 P2(N,M)=0.0140
      GO TO 310
  317 IF(ISL(N,M)-32)301,318,319
  318 P2(N,M)=0.0075
      GO TO 301
  319 IF(ISL(N,M)-33)301,320,321
  320 P2(N,M)=0.0005
      GO TO 301
```

```
  321 IF(ISL(N,M)-42)302,322,323
  322 P2(N,M)=0.0020
      GO TO 301
  323 IF(ISL(N,M)-43)301,324,325
  324 P2(N,M)=0.0025
      GO TO 301
  325 IF(ISL(N,M)-54)302,326,327
  326 P2(N,M)=0.0005
      GO TO 301
  327 IF(ISL(N,M)-62)302,328,329
  328 P2(N,M)=0.0025
      GO TO 301
  329 IF(ISL(N,M)-63)301,330,302
  330 P2(N,M)=0.0095
  301 P2(N,M)=P2(N,M)*2.0
  337 CONTINUE
C     STATEMENT 301 IS FOR TUNING
      CALL WRITMS (1,P2,780,156,1)
      CALL READMS (1,ISL,780,150)
C     PRESET PREVIOUS MONTH CONSUMPTION TO 10PCT. OF STAND. STOCK
      KRI=1
    2 CALL READMS (2,S5,780,KRI)
      DO 1 N=1,NE
      DO 1 M=1,ME
      S6(N,M)=S5(N,M)*0.10
    1 CONTINUE
      KWI=KRI+2
      CALL WRITMS (2,S6,780,KWI,1)
      KRI=KRI+7
      IF(183-KRI)3,2,2
C     SET YEAR COUNT AND PRINT OUT INDEX
    3 LL=1  $ K=1
      IZP=1
C     ZERO SUMMATION
  251 DO 252 N=1,30
      DO 252 M=1,12
      SUTAB(N,M)=0.
  252 CONTINUE
C     CALL COMPUTATION SUBROUTINE
C     BASIC TIME STEP 1 MONTH
  122 CALL BIRMAM
      CALL PLANKT
      CALL DEMFIS
      CALL SEMDEM
      CALL ROCKFI
      CALL PELFIS
      CALL CRUSTA
      CALL BENTOS
C     SUMMARY OF MONTHLY CONSUMPTION AND TRANSFER TO PREVIOUS MONTH
      DO 123 N=1,ME
      DO 123 M=1,MF
      P1(N,M)=0.
  123 CONTINUE
      SUM=0.
      KRK=1
      CALL READMS (2,S1,780,32)
      CALL READMS (2,S2,780,30)
```

```
      GO TO 150
  124 CALL WRITMS (2,S1,780,31,1)
      CALL WRITMS (2,P1,780,32,1)
      CALL WRITMS (2,S3,780,35,1)
      CALL READMS (2,S1,780,39)
      CALL READMS (2,S2,780,37)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  125 CALL WRITMS (2,S1,780,38,1)
      CALL WRITMS (2,P1,780,39,1)
      CALL WRITMS (2,S3,780,42,1)
      CALL READMS (2,S1,780,46)
      CALL READMS (2,S2,780,44)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  126 CALL WRITMS (2,S1,780,45,1)
      CALL WRITMS (2,P1,780,46,1)
      CALL WRITMS (2,S3,780,49,1)
      CALL READMS (2,S1,780,53)
      CALL READMS (2,S2,780,51)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  127 CALL WRITMS (2,S1,780,52,1)
      CALL WRITMS (2,P1,780,53,1)
      CALL WRITMS (2,S3,780,56,1)
      CALL READMS (2,S1,780,60)
      CALL READMS (2,S2,780,58)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  128 CALL WRITMS (2,S1,780,59,1)
      CALL WRITMS (2,P1,780,60,1)
      CALL WRITMS (2,S3,780,63,1)
      CALL READMS (2,S1,780,67)
      CALL READMS (2,S2,780,65)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  129 CALL WRITMS (2,S1,780,66,1)
      CALL WRITMS (2,P1,780,67,1)
      CALL WRITMS (2,S3,780,70,1)
      CALL READMS (2,S1,780,74)
      CALL READMS (2,S2,780,72)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  130 CALL WRITMS (2,S1,780,73,1)
      CALL WRITMS (2,P1,780,74,1)
      CALL WRITMS (2,S3,780,77,1)
      CALL READMS (2,S1,780,81)
      CALL READMS (2,S2,780,79)
      SUM=0.
      KRK=KRK+1
      GO TO 150
```

```
  131 CALL WRITMS (2,S1,780,80,1)
      CALL WRITMS (2,R1,780,81,1)
      CALL WRITMS (2,S3,780,84,1)
      CALL READMS (2,S1,780,88)
      CALL READMS (2,S2,780,86)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  132 CALL WRITMS (2,S1,780,87,1)
      CALL WRITMS (2,R1,780,88,1)
      CALL WRITMS (2,S3,780,91,1)
      CALL READMS (2,S1,780,95)
      CALL READMS (2,S2,780,93)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  133 CALL WRITMS (2,S1,780,94,1)
      CALL WRITMS (2,R1,780,95,1)
      CALL WRITMS (2,S3,780,98,1)
      CALL READMS (2,S1,780,102)
      CALL READMS (2,S2,780,100)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  134 CALL WRITMS (2,S1,780,101,1)
      CALL WRITMS (2,R1,780,102,1)
      CALL WRITMS (2,S3,780,105,1)
      CALL READMS (2,S1,780,109)
      CALL READMS (2,S2,780,107)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  135 CALL WRITMS (2,S1,780,108,1)
      CALL WRITMS (2,R1,780,109,1)
      CALL WRITMS (2,S3,780,112,1)
      CALL READMS (2,S1,780,116)
      CALL READMS (2,S2,780,114)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  136 CALL WRITMS (2,S1,780,115,1)
      CALL WRITMS (2,R1,780,116,1)
      CALL WRITMS (2,S3,780,119,1)
      CALL READMS (2,S1,780,123)
      CALL READMS (2,S2,780,121)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  137 CALL WRITMS (2,S1,780,122,1)
      CALL WRITMS (2,R1,780,123,1)
      CALL WRITMS (2,S3,780,126,1)
      CALL READMS (2,S1,780,130)
      CALL READMS (2,S2,780,128)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  138 CALL WRITMS (2,S1,780,129,1)
```

```
      CALL WRITMS (2,P1,780,130,1)
      CALL WRITMS (2,S3,780,133,1)
      CALL READMS (2,S1,780,137)
      CALL READMS (2,S2,780,135)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  139 CALL WRITMS (2,S1,780,136,1)
      CALL WRITMS (2,P1,780,137,1)
      CALL WRITMS (2,S3,780,140,1)
      CALL READMS (2,S1,780,144)
      CALL READMS (2,S2,780,142)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  140 CALL WRITMS (2,S1,780,143,1)
      CALL WRITMS (2,P1,780,144,1)
      CALL WRITMS (2,S3,780,147,1)
      CALL READMS (2,S1,780,151)
      CALL READMS (2,S2,780,149)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  141 CALL WRITMS (2,S1,780,150,1)
      CALL WRITMS (2,P1,780,151,1)
      CALL WRITMS (2,S3,780,154,1)
      CALL READMS (2,S1,780,158)
      CALL READMS (2,S2,780,156)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  142 CALL WRITMS (2,S1,780,157,1)
      CALL WRITMS (2,P1,780,158,1)
      CALL WRITMS (2,S3,780,161,1)
      CALL READMS (2,S1,780,165)
      CALL READMS (2,S2,780,163)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  143 CALL WRITMS (2,S1,780,164,1)
      CALL WRITMS (2,P1,780,165,1)
      CALL WRITMS (2,S3,780,168,1)
      CALL READMS (2,S1,780,172)
      CALL READMS (2,S2,780,170)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  144 CALL WRITMS (2,S1,780,171,1)
      CALL WRITMS (2,P1,780,172,1)
      CALL WRITMS (2,S3,780,175,1)
      CALL READMS (2,S1,780,179)
      CALL READMS (2,S2,780,177)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  145 CALL WRITMS (2,S1,780,178,1)
      CALL WRITMS (2,P1,780,179,1)
```

```
      CALL WRITMS (2,S3,780,182,1)
      CALL READMS (2,S1,780,184)
      CALL READMS (2,S2,780,184)
      SUM=0.
      KRK=KRK+1
      GO TO 150
  146 CALL WRITMS (2,S1,780,185,1)
      CALL WRITMS (2,P1,780,186,1)
      CALL WRITMS (2,S3,780,189,1)
      GO TO 147
  150 AR=18.5*16.5                                                  002
      AQR=AR/1000.                                                  002
      DO 151 N=1,NE                                                 002
      DO 151 M=1,ME
      SUM=SUM+S1(N,M)*AQR                                           002
      IF(S2(N,M)-0.01)6,6,7                                         000
    6 S3(N,M)=0.                                                    000
      S4(N,M)=0.                          Summation                 000
      GO TO 151                                                     000
    7 S3(N,M)=S1(N,M)/S2(N,M)                                       000
      S4(N,M)=S3(N,M)*100.                                          000
  151 CONTINUE
      GO TO (152,153,154,155,156,157,158,159,160,161,162,163,164,165,
     1166,167,168,169,170,171,172,173,174),KRK
  152 PRINT 201,K,SUM
  201 FORMAT(///5X,19HTURBOT, HALIBUT, M=,I3,17HCONSUMPTION, TONS,F8.0/)
  206 IF(IZP)204,204,202
  202 IF(K-2)204,4,204                                              000
    4 CALL PRIAFP (S1,0)                                            000
      PRINT 203,K
  203 FORMAT(///5X,38HPERCENT OF STANDING STOCK CONSUMED, M=,I3/)
      CALL PRIAFP(S4,1)                                             000
  204 GO TO (124,125,126,127,128,129,130,131,132,133,134,135,136,137,
     1138,139,140,141,142,143,144,145,146),KRK
  153 PRINT 205,K,SUM
  205 FORMAT(///5X,19HFLATHEAD SOLE    M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  154 PRINT 207,K,SUM
  207 FORMAT(///5X,19HROCK + YELLOWF.S.M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  155 PRINT 208,K,SUM
  208 FORMAT(///5X,19HDOVER + REX SOLE,M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  156 PRINT 209,K,SUM
  209 FORMAT(///5X,19HPAC. OC. PERCH    M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  157 PRINT 210,K,SUM
  210 FORMAT(///5X,19HSEBASTOLOBUS SP. M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  158 PRINT 211,K,SUM
  211 FORMAT(///5X,19HCOTTIDS, OTHERS  M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  159 PRINT 212,K,SUM
  212 FORMAT(///5X,19HPOLLOCK          M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  160 PRINT 213,K,SUM
  213 FORMAT(///5X,19HCOD              M=,I3,17HCONSUMPTION, TONS,F8.0/)
```

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      GO TO 206
  161 PRINT 214,K,SUM
  214 FORMAT(///5X,19HHERRING          M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  162 PRINT 215,K,SUM
  215 FORMAT(///5X,19HSMELTS, OTHERS   M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  163 PRINT 216,K,SUM
  216 FORMAT(///5X,19HATKA MACKEREL    M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  164 PRINT 217,K,SUM
  217 FORMAT(///5X,19HSALMON           M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  165 PRINT 218,K,SUM
  218 FORMAT(///5X,19HSQUIDS           M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  166 PRINT 219,K,SUM
  219 FORMAT(///5X,19HKING CRAB        M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  167 PRINT 220,K,SUM
  220 FORMAT(///5X,19HTANNER CRAB      M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  168 PRINT 221,K,SUM
  221 FORMAT(///5X,19HSHRIMP           M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  169 PRINT 222,K,SUM
  222 FORMAT(///5X,19HPREDAT. BENTHOS  M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  170 PRINT 223,K,SUM
  223 FORMAT(///5X,19HINFAUNA          M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  171 PRINT 224,K,SUM
  224 FORMAT(///5X,19HEPIFAUNA         M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  172 PRINT 225,K,SUM
  225 FORMAT(///5X,19HCOPEPODS         M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  173 PRINT 226,K,SUM
  226 FORMAT(///5X,19HEUPHAUSIDS       M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  174 PRINT 227,K,SUM
  227 FORMAT(///5X,19HPHYTOPLANKTON    M=,I3,17HCONSUMPTION, TONS,F8.0/)
      GO TO 206
  147 K=K+1
C     IF(K-12)122,122,175                                           000
      IF(K-6)122,122,177      Augmentation of month and             000
  175 LL=LL+1                 year count and return to
      IF(LL-2)176,176,177     computation
  176 K=1
      GO TO 251                                                     002
  177 PRINT 253,(N,N=1,12)                                          002
  253 FORMAT(5X,34HMONTHLY STANDING STOCKS, 1000 TONS//9X,12I8)     002
      PRINT 254,(N,(SUTAB(N,M),M=1,12),N=1,30)                      002
  254 FORMAT(//I7,12F8.1)                                           002
      STOP                                                          002
      END                                                           002
```

```
      SUBROUTINE BIRMAM
      DIMENSION ISL(26,30),SD(26,30),UR(26,30),VR(26,30),SUTAB(30,12),      0023
     1B1(30,30),B2(30,30),FOT(30),NUK(30),NS(50),
     2MS(50),S1(26,30),S2(26,30),S3(26,30),S4(26,30),S5(26,30),S6(26,30)
     3,P1(26,30),P2(26,30),P3(26,30),P4(26,30),P5(26,30),P6(26,30)
     4,T1(26,30),T2(26,30),T3(26,30),T4(26,30),T5(26,30),T6(26,30)
      COMMON ISL,SD,UR,VR,SUTAB,                                             0023
     1B1,B2,FOT,NUK,NS,MS,
     2S1,S2,S3,S4,S5,S6,P1,P2,P3,P4,P5,P6,T1,T2,T3,T4,T5,T6,
     3K,LL,IZ0,IZ1,IZ2,NE,ME,NU
     5,IN1(201),IN2(201)                                                     0002
      COMMON /B/C1(3),C2(3),C3(3),C4(3),C5(3),C6(3),C7(3),C8(3),C9(3),
     1C10(3),C11(3),C12(3),C13(3),C14(3),C15(3),C16(3),C17(3),C18(3),
     2C19(3),C20(3),C21(3),C22(3),C23(3),C24(3),C25(3)
C     PINNIPEDS
C     FOOD CONSUMPTION 6% BW DAILY
      AR=13.5*12.5                                                           0025
      AMA=AR/1000.                                                           0026
      KFK=K
      KSK=12+K
      KPK=112+K
      CALL READMS (1,P1,780,KFK)
      CALL READMS (1,P2,780,KSK)
      CALL READMS (1,P3,780,KPK)
      CALL READMS(2,S1,780,95)
      CALL READMS (2,S2,780,102)
      CALL READMS (2,S3,780,109)
      CALL READMS (2,S4,780,123)     Consumption arrays
      CALL READMS (2,S5,780,116)
      CALL READMS (2,S6,780,151)
      CALL READMS (2,T1,780,130)
      CALL READMS (2,T2,780,137)
      CALL READMS (2,T3,780,81)
      DO 1 I=1,3
      C1(I)=C2(I)=C3(I)=C4(I)=C5(I)=0.
      C6(I)=C7(I)=C8(I)=C9(I)=C10(I)=0.
      C11(I)=C12(I)=C13(I)=C14(I)=C15(I)=0.
      C16(I)=C17(I)=C18(I)=C19(I)=C20(I)=0.
      C21(I)=C22(I)=C23(I)=C24(I)=C25(I)=0.
    1 CONTINUE
      DO 5 N=1,NE                    Food consumption by
      DO 5 M=1,ME                    pinnipeds
      FO1=P1(N,M)*1.8
      FO2=P2(N,M)*1.8
      FO3=P3(N,M)*1.8
      CO=0.12*FO1+0.05*FO2+0.05*FO3
      S1(N,M)=S1(N,M)+CO
      C3(1)=C3(1)+CO*AMA
      CO=0.08*FO1+0.05*FO2+0.10*FO3
      S2(N,M)=S2(N,M)+CO
      C4(1)=C4(1)+CO*AMA
      CO=0.03*FO1+0.15*FO2+0.02*FO3
      S3(N,M)=S3(N,M)+CO
      C5(1)=C5(1)+CO*AMA
      CO=0.10*FO1+0.05*FO2+0.05*FO3
      S4(N,M)=S4(N,M)+CO
      C7(1)=C7(1)+CO*AMA
```

```
      C0=0.015*F01+0.02*F02+0.02*F03
      S5(N,M)=S5(N,M)+C0
      C6(1)=C6(1)+C0*AMA
      C0=0.17*F03
      S6(N,M)=S6(N,M)+C0
      C9(1)=C9(1)+C0*AMA
      C0=0.02*F03
      T1(N,M)=T1(N,M)+C0
      C12(1)=C12(1)+C0*AMA
      C0=0.02*F03
      T2(N,M)=T2(N,M)+C0
      C13(1)=C13(1)+C0*AMA
      C0=0.32*F01+0.40*F02+0.20*F03
      T3(N,M)=T3(N,M)+C0
      C15(1)=C15(1)+C0*AMA
    5 CONTINUE
      CALL WRITMS (2,S1,780,95,1)
      CALL WRITMS (2,S2,780,102,1)
      CALL WRITMS (2,S3,780,109,1)
      CALL WRITMS (2,S4,780,123,1)
      CALL WRITMS (2,S5,780,116,1)
      CALL WRITMS (2,S6,780,151,1)
      CALL WRITMS (2,T1,780,130,1)
      CALL WRITMS (2,T2,780,137,1)
      CALL WRITMS (2,T3,780,81,1)
      CALL READMS (2,S1,780,88)
      CALL READMS (2,S2,780,60)
      CALL READMS (2,S3,780,67)
      CALL READMS (2,S4,780,74)
      CALL READMS (2,S5,780,32)
      CALL READMS (2,S6,780,39)
      CALL READMS (2,T1,780,46)
      CALL READMS (2,T2,780,53)
      DO 6 N=1,NE
      DO 6 M=1,ME
      F01=P1(N,M)*1.8
      F02=P2(N,M)*1.8
      F03=P3(N,M)*1.8
      C0=0.10*F01+0.10*F02+0.05*F03
      S1(N,M)=S1(N,M)+C0
      C16(1)=C16(1)+C0*AMA
      C0=0.10*F01+0.08*F02+0.05*F03
      S2(N,M)=S2(N,M)+C0
      C17(1)=C17(1)+C0*AMA
      C0=0.03*F01+0.02*F02+0.02*F03
      S3(N,M)=S3(N,M)+C0
      C18(1)=C18(1)+C0*AMA
      C0=0.035*F01+0.03*F02+0.15*F03
      S4(N,M)=S4(N,M)+C0
      C19(1)=C19(1)+C0*AMA
      C0=0.005*F01+0.05*F02+0.03*F03
      S5(N,M)=S5(N,M)+C0
      C20(1)=C20(1)+C0*AMA
      C0=0.005*F01+0.03*F03
      S6(N,M)=S6(N,M)+C0
      C21(1)=C21(1)+C0*AMA
      C0=0.005*F01+0.02*F03
```

```
      T1(N,M)=T1(N,M)+CO
      C22(1)=C22(1)+CO*AMA
      CO=0.005*FO1+0.03*FO3
      C23(1)=C23(1)+CO*AMA
      T2(N,M)=T2(N,M)+CO
    6 CONTINUE
      CALL WRITMS (2,S1,780,88,1)
      CALL WRITMS (2,S2,780,60,1)
      CALL WRITMS (2,S3,780,67,1)
      CALL WRITMS (2,S4,780,74,1)
      CALL WRITMS (2,S5,780,32,1)
      CALL WRITMS (2,S6,780,39,1)
      CALL WRITMS (2,T1,780,46,1)
      CALL WRITMS (2,T2,780,53,1)
C     WHALES, DOLPHINS, AND PORPOISES
C     CONSUMPTION 5% BW DAILY
      KBK=24+K
      KTK=36+K
      KSK=124+K
      KDK=136+K
      CALL READMS (1,P1,780,KBK)
      CALL READMS (1,P2,780,KTK)
      CALL READMS (1,P3,780,KSK)
      CALL READMS (1,P4,780,KDK)
      CALL READMS (2,S1,780,172)
      CALL READMS (2,S2,780,179)
      CALL READMS (2,S3,780,95)
      CALL READMS (2,S4,780,102)
      CALL READMS (2,S5,780,109)
      CALL READMS (2,S6,780,116)
      CALL READMS (2,T1,780,123)
      CALL READMS(2,T2,780,81)
      DO 11 N=1,NE
      DO 11 M=1,ME
      FO1=P1(N,M)*1.5
      FO2=P2(N,M)*1.5
      FO3=P3(N,M)*1.5
      FO4=P4(N,M)*1.5
      CO=0.08*FO1
      S1(N,M)=S1(N,M)+CO
      C1(2)=C1(2)+CO/1000.
      CO=0.75*FO1
      S2(N,M)=S2(N,M)+CO
      C2(2)=C2(2)+CO*AMA
      CO=0.02*FO1+0.07*FO2+0.03*FO3+0.12*FO4
      S3(N,M)=S3(N,M)+CO
      C3(2)=C3(2)+CO*AMA
      CO=C.02*FO1+0.12*FO2+0.05*FO3+0.18*FO4
      S4(N,M)=S4(N,M)+CO
      C4(2)=C4(2)+CO*AMA
      CO=0.01*FO1+0.06*FO2+0.01*FO3+0.05*FO4
      S5(N,M)=S5(N,M)+CO
      C5(2)=C5(2)+CO*AMA
      CO=0.04*FO2+0.02*FO3+0.04*FO4
      S6(N,M)=S6(N,M)+CO
      C6(2)=C6(2)+CO*AMA
      CO=0.07*FO1+0.05*FO2+0.73*FO3+0.20*FO4
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      T1(N,M)=T1(N,M)+C0
      C7(2)=C7(2)+C0*AMA
      C0=0.02*F01+0.22*F02+0.10*F03+0.20*F04
      T2(N,M)=T2(N,M)+C0
      C15(2)=C15(2)+C0*AMA
   11 CONTINUE
      CALL WRITMS (2,S1,730,172,1)
      CALL WRITMS (2,S2,730,179,1)
      CALL WRITMS (2,S3,730,95,1)
      CALL WRITMS (2,S4,730,102,1)
      CALL WRITMS (2,S5,730,109,1)
      CALL WRITMS (2,S6,730,116,1)
      CALL WRITMS (2,T1,730,123,1)
      CALL WRITMS (2,T2,730,81,1)
      CALL READMS (2,S1,730,88)
      CALL READMS (2,S2,730,60)
      CALL READMS (2,S3,730,67)
      CALL READMS (2,S4,730,74)
      CALL READMS (2,S5,730,32)
      CALL READMS (2,S6,730,39)
      CALL READMS (2,T1,730,46)
      CALL READMS (2,T2,730,53)
      DO 12 N=1,NE
      DO 12 M=1,ME
      F01=P1(N,M)*1.5
      F02=P2(N,M)*1.5
      F03=P3(N,M)*1.5
      F04=P4(N,M)*1.5
      C0=0.01*F01+0.09*F02+0.02*F03+0.10*F04
      S1(N,M)=S1(N,M)+C0
      C16(2)=C16(2)+C0*AMA
      C0=0.01*F01+0.08*F02+0.02*F03+0.10*F04
      S2(N,M)=S2(N,M)+C0
      C17(2)=C17(2)+C0*AMA
      C0=0.01*F01+0.04*F02+0.01*F03+0.01*F04
      S3(N,M)=S3(N,M)+C0
      C18(2)=C18(2)+C0*AMA
      C0=0.03*F02+0.01*F03
      S4(N,M)=S4(N,M)+C0
      C19(2)=C19(2)+C0*AMA
      C0=0.08*F02
      S5(N,M)=S5(N,M)+C0
      C20(2)=C20(2)+C0*AMA
      C0=0.06*F02
      S6(N,M)=S6(N,M)+C0
      C21(2)=C21(2)+C0*AMA
      C0=0.03*F02
      T1(N,M)=T1(N,M)+C0
      C22(2)=C22(2)+C0*AMA
      C0=0.03*F02
      T2(N,M)=T2(N,M)+C0
      C23(2)=C23(2)+C0*AMA
   12 CONTINUE
      CALL WRITMS (2,S1,730,88,1)
      CALL WRITMS (2,S2,730,60,1)
      CALL WRITMS (2,S3,730,67,1)
      CALL WRITMS (2,S4,730,74,1)
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```
      CALL WRITMS (2,S5,780,32,1)
      CALL WRITMS (2,S6,780,39,1)
      CALL WRITMS (2,T1,780,46,1)
      CALL WRITMS (2,T2,780,53,1)
C     MARINE BIRDS
C     CONSUMPTION 18% BW DAILY
      KFB=43+K
      KOB=60+K
      CALL READMS (1,P1,780,KFB)
      CALL READMS (1,P2,780,KOB)
      CALL READMS (2,S1,780,172)
      CALL READMS (2,S2,780,179)
      CALL READMS (2,S3,780,95)
      CALL READMS (2,S4,780,102)
      CALL READMS (2,S5,780,109)
      CALL READMS (2,S6,780,116)
      CALL READMS (2,T1,780,123)
      CALL READMS (2,T2,780,151)
      DO 14 N=1,NE
      DO 14 M=1,ME
      FO1=P1(N,M)*5.4
      FO2=P2(N,M)*5.4
      CO=0.03*FO2
      S1(N,M)=S1(N,M)+CO
      C1(3)=C1(3)+CO*AMA
      CO=0.09*FO1+0.47*FO2
      S2(N,M)=S2(N,M)+CO
      C2(3)=C2(3)+CO*AMA
      CO=0.15*FO1+0.04*FO2
      S3(N,M)=S3(N,M)+CO
      C3(3)=C3(3)+CO*AMA
      CO=0.20*FO1+0.08*FO2
      S4(N,M)=S4(N,M)+CO
      C4(3)=C4(3)+CO*AMA
      CO=0.07*FO1+0.02*FO2
      S5(N,M)=S5(N,M)+CO
      C5(3)=C5(3)+CO*AMA
      CO=0.008*FO1+0.003*FO2
      S6(N,M)=S6(N,M)+CO
      C6(3)=C6(3)+CO*AMA
      CO=0.10*FO1+0.05*FO2
      T1(N,M)=T1(N,M)+CO
      C7(3)=C7(3)+CO*AMA
      CO=0.05*FO1+0.10*FO2
      T2(N,M)=T2(N,M)+CO
      C8(3)=C8(3)+CO*AMA
   14 CONTINUE
      CALL WRITMS (2,S1,780,172,1)
      CALL WRITMS (2,S2,780,179,1)
      CALL WRITMS (2,S3,780,95,1)
      CALL WRITMS (2,S4,780,102,1)
      CALL WRITMS (2,S5,780,109,1)
      CALL WRITMS (2,S6,780,116,1)
      CALL WRITMS (2,T1,780,123,1)
      CALL WRITMS (2,T2,780,151,1)
      CALL READMS (2,S1,780,158)
      CALL READMS (2,S2,780,165)
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      CALL READMS (2,S3,780,130)
      CALL READMS (2,S4,780,137)
      CALL READMS (2,S5,780,144)
      CALL READMS (2,S6,780,81)
      CALL READMS (2,T1,780,88)
      CALL READMS (2,T2,780,60)
      DO 15 N=1,NF
      DO 15 M=1,MF
      FO1=P1(N,M)*5.4
      FO2=P2(N,M)*5.4
      CO=0.01*FO1+0.03*FO2
      S1(N,M)=S1(N,M)+CO
      C10(3)=C10(3)+CO*AMA
      CO=0.05*FO1+0.03*FO2
      S2(N,M)=S2(N,M)+CO
      C11(3)=C11(3)+CO*AMA
      CO=0.01*FO1
      S3(N,M)=S3(N,M)+CO
      C12(3)=C12(3)+CO*AMA
      CO=0.01*FO1
      S4(N,M)=S4(N,M)+CO
      C13(3)=C13(3)+CO*AMA
      CO=0.03*FO1+0.03*FO2
      S5(N,M)=S5(N,M)+CO
      C14(3)=C14(3)+CO*AMA
      CO=0.09*FO1+0.02*FO2
      S6(N,M)=S6(N,M)+CO
      C15(3)=C15(3)+CO*AMA
      CO=0.03*FO1+0.015*FO2
      T1(N,M)=T1(N,M)+CO
      C16(3)=C16(3)+CO*AMA
      CO=0.02*FO1+0.005*FO2
      T2(N,M)=T2(N,M)+CO
      C17(3)=C17(3)+CO*AMA
   15 CONTINUE
      CALL WRITMS (2,S1,780,158,1)
      CALL WRITMS (2,S2,780,165,1)
      CALL WRITMS (2,S3,780,130,1)
      CALL WRITMS (2,S4,780,137,1)
      CALL WRITMS (2,S5,780,144,1)
      CALL WRITMS (2,S6,780,81,1)
      CALL WRITMS (2,T1,780,88,1)
      CALL WRITMS (2,T2,780,60,1)
      CALL READMS (2,S1,780,67)
      CALL READMS (2,S2,780,74)
      CALL READMS (2,S3,780,32)
      CALL READMS (2,S4,780,39)
      CALL READMS (2,S5,780,46)
      CALL READMS (2,S6,780,53)
      DO 16 N=1,NF
      DO 16 M=1,MF
      FO1=P1(N,M)*5.4
      FO2=P2(N,M)*5.4
      CO=0.01*FO1+0.005*FO2
      S1(N,M)=S1(N,M)+CO
      C18(3)=C18(3)+CO*AMA
      CO=0.053*FO1+0.002*FO2
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```
      S2(N,M)=S2(N,M)+CO
      C19(3)=C19(3)+CO*AMA
      CO=0.01*F01
      S3(N,M)=S3(N,M)+CO
      C20(3)=C20(3)+CO*AMA
      CO=0.01*F01
      S4(N,M)=S4(N,M)+CO
      C21(3)=C21(3)+CO*AMA
      CO=0.01*F01
      S5(N,M)=S5(N,M)+CO
      C22(3)=C22(3)+CO*AMA
      CO=0.01*F01
      S6(N,M)=S6(N,M)+CO
      C23(3)=C23(3)+CO*AMA
   16 CONTINUE
      CALL WRITMS (2,S1,780,67,1)
      CALL WRITMS (2,S2,780,74,1)
      CALL WRITMS (2,S3,780,32,1)
      CALL WRITMS (2,S4,780,39,1)
      CALL WRITMS (2,S5,780,46,1)
      CALL WRITMS (2,S6,780,53,1)
      PRINT 20,K
   20 FORMAT(///5X,36HCONSUMPTION BY MAMMALS AND BIRDS, M=,I3,5X,
     17HIN TONS//)
      PRINT 21
   21 FORMAT(/5X,22HCONSUMED SPECIES       ,10X,9HCONSUMERS,//)
      PRINT 22
   22 FORMAT(//33X,9HPINNIPEDS,9X,6HWHALES,10X,5HBIRDS,///)
      PRINT 23,C1(1),C1(2),C1(3)
   23 FORMAT(/6X,9HCOPEPODS,20X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 24,C2(1),C2(2),C2(3)
   24 FORMAT(/6X,10HEUPHAUSIDS,19X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 25,C3(1),C3(2),C3(3)
   25 FORMAT(/6X,7HHERRING,21X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 26,C4(1),C4(2),C4(3)
   26 FORMAT(/6X,16HSMELTS A. OTHERS,12X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 27,C5(1),C5(2),C5(3)
   27 FORMAT(/6X,13HATKA MACKEREL,15X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 28,C6(1),C6(2),C6(3)
   28 FORMAT(/6X,6HSALMON,22X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 29,C7(1),C7(2),C7(3)
   29 FORMAT(/6X,5HSQUID,23X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 30,C9(1),C9(2),C9(3)
   30 FORMAT(/6X,17HPREDATORY BENTHOS,11X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 31,C10(1),C10(2),C10(3)
   31 FORMAT(/6X,7HINFAUNA,21X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 32,C11(1),C11(2),C11(3)
   32 FORMAT(/6X,8HEPIFAUNA,20X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 33,C12(1),C12(2),C12(3)
   33 FORMAT(/6X,9HKING CRAB,19X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 34,C13(1),C13(2),C13(3)
   34 FORMAT(/6X,11HTANNER CRAB,17X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 35,C14(1),C14(2),C14(3)
   35 FORMAT(/6X,6HSHRIMP,22X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 36,C15(1),C15(2),C15(3)
   36 FORMAT(/6X,7HPOLLOCK,21X,F8.2,7X,F8.2,7X,F8.2//)
      PRINT 37,C16(1),C16(2),C16(3)
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51

SUBROUTINE BIRMAM 73/73 OPT=1 FTN 4.6+460 07/

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 37 FORMAT(/6X,3HCOD,25X,F8.2,7X,F8.2,7X,F8.2//)
    PRINT 38,C17(1),C17(2),C17(3)
 38 FORMAT(/6X,19HPACIFIC OCEAN PERCH,9X,F8.2,7X,F8.2,7X,F8.2//)
    PRINT 39,C18(1),C18(2),C18(3)
 39 FORMAT(/6X,12HSEBASTOLOBUS,16X,F8.2,7X,F8.2,7X,F8.2//)
    PRINT 40,C19(1),C19(2),C19(3)
 40 FORMAT(/6X,17HCOTTIDS A. OTHERS,11X,F8.2,7X,F8.2,7X,F8.2//)
    PRINT 41,C20(1),C20(2),C20(3)
 41 FORMAT(/6X,15HTURBOT, HALIBUT,13X,F8.2,7X,F8.2,7X,F8.2//)
    PRINT 42,C21(1),C21(2),C21(3)
 42 FORMAT(/6X,13HFLATHEAD SOLE,15X,F8.2,7X,F8.2,7X,F8.2//)
    PRINT 43,C22(1),C22(2),C22(3)
 43 FORMAT(/6X,22HROCK A. YELLOWFIN SOLE,6X,F8.2,7X,F8.2,7X,F8.2//)
    PRINT 44,C23(1),C23(2),C23(3)
 44 FORMAT(/6X,17HDOVER A. REX SOLE,11X,F8.2,7X,F8.2,7X,F8.2//)
    RETURN
    END
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SUBROUTINE DEMFIS      73/73    OPT=1                               FTN 4.6+460        07/1

      SUBROUTINE DEMFIS
      DIMENSION ISL(26,30),SD(26,30),UR(26,30),VR(26,30),SUTAB(30,12),
     1B1(30,30),B2(30,30),FOT(30),NUK(30),NS(50),
     2MS(50),S1(26,30),S2(26,30),S3(26,30),S4(26,30),S5(26,30),S6(26,30)
     3,P1(26,30),P2(26,30),P3(26,30),P4(26,30),P5(26,30),P6(26,30)
     4,T1(26,30),T2(26,30),T3(26,30),T4(26,30),T5(26,30),T6(26,30)
      COMMON ISL,SD,UR,VR,SUTAB,
     1B1,B2,FOT,NUK,NS,MS,
     2S1,S2,S3,S4,S5,S6,P1,P2,P3,P4,P5,P6,T1,T2,T3,T4,T5,T6,
     3K,LL,IZ2,IZ1,IZZ,NE,ME,NU
     5,IN1(201),IN2(201)
      INTEGER DLJ
C     THIS SUBROUTINE COMPUTES TURBOT-HALIBUT-5, FLATHEAD SOLE-6,
C     ROCK AND YELLOWFIN SOLE-7, DOVER AND REX SOLE-8
C     MIGRATIONS
C     SPECIES MIGRATES ONLY IN MAY-JUNE (INTO SHALLOWER WATER) AND
C     OCT. NOV. (INTO DEEPER WATER)
C     IF DEPTH<20M NO MIGRATIONS
C     40% OF BIOMASSS MIGRATES BETWEEN DEPTHS OF 20 TO 200M DEPTH
C     15% OF BIOMASSS MIGRATES BETWEEN 200-400M
C     IF DEPTH>400M - NO MIGRATION
C     V DIRECTION DOMINATES; U=% OF V
C     NEAR COAST LAND (SHALLOW WATER) MIGRATION IS PARALLEL TO COAST
C*******
C     TURBOT-HALIBUT
      IF(LL-1)1,1,3
    1 IF(K-1)2,2,3
    2 CALL READMS (2,S1,780,29)
      GO TO 4
    3 CALL READMS (2,S1,780,30)
C     TESTING FOR MONTH  ——  for migration computation
    4 IF(5-K)5,9,112
    5 IF(6-K)6,8,112
    6 IF(10-K)7,9,112
    7 IF(11-K)112,9,112
    8 KE=1
      SS=50.  $ DD=500.
      CALL PLASRA (ISL,UR,VR,SD,SS,DD,NE,ME,KE)    Calling of
      GO TO 12                                     migration speed
    9 KE=2                                         creation sub-
      SS=50.  $ DD=600.                            routines
      CALL PLASRA (ISL,UR,VR,SD,SS,DD,NE,ME,KE)
   12 RP=0.30
      SS=50.  $ DD=600.                            Portioning of
      CALL PANPOR (ISL,SD,S1,S2,S3,RP,SS,DD,NE,ME) migrating population
   11 CONTINUE
C     CALL MIGRATION SUBROUTINE
      CALL RANNAK (S2,P1,ISL,UR,VR,NE,ME)
C     S2 - SPECIES (PORTION WHICH MIGRATED)
C     P1 - SPECIES UPON EXIT
C     ISL-SEA-LAND TABLE
C     UR,VR - U AND V SPEEDS OF MIGRATION, KM/DAY
C*************************
C     ADDING NONMIGRATING PORTION
      NEH=NE-1  $ MEH=ME-1
      DO 114 N=2,NEH
      DO 114 M=2,MEH
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      SUBROUTINE DEMEIS      73/73    OPT=1                                FTN 4.6+460          07/3
          P1(N,M)=P1(N,M)+S3(N,M)
      114 CONTINUE
C         SETTING OF BOUNDARIES
          CALL BOUSET (P1,NE,ME)
C         OUTPUT OF THE MIGRATION RESULTS
          DO 101 N=1,NE
          DO 101 M=1,ME
          S1(N,M)=P1(N,M)-S1(N,M)
      101 CONTINUE
          PRINT 102,K
      102 FORMAT(5X,26HMIGR. OF HALIBUT-TURBOT M=,I3//)
          CALL PRIAFP (S1,1)
          GO TO 111
      112 DO 113 N=1,NE               Transfer of biomass if
          DO 113 M=1,ME               no migration is computed
          P1(N,M)=S1(N,M)
      113 CONTINUE
C*****************************
C         MIGRATIONS CAUSED BY FOOD SCARCITY AND BY ENVIRONMENT
C         READING MONTHLY SEC OR BOTTOM TEMP.
      111 MM=72+K
          CALL READMS (1,T1,780,MM)
C         MM DISC LOCATION OF TEMPERATURE FIELD
C         READING 3 MAJOR FOOD ITEM PERCENTAGE CONSUMPTION INTO T2 T3 T4
C         IF THEIR ORDER CHANGES SEASONALLY CALL INTERPOL SUPR.
          J=5
          KS=1 $ KEK=0
          CALL TOJAGS (B1,B2,FOT,NUK,J,K,KS,KEK)
          NF=NUK(1)*7
          CALL READMS (2,T2,780,NF)
          NF=NUK(2)*7
          CALL READMS (2,T3,780,NF)
          NF=NUK(3)*7
          CALL READMS (2,T4,780,NF)
C         NF - FIELD LOCATION ON DISC OF MAIN FOOD ITEM
C         TMAX, TMIN - TEMP. MAX AND MIN (TOLERANCES)
          TMAX=10. $ TMIN=2.                                                        000
          CALL CYLIOT(P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
C         SMOOTHING (DIFFUSION)
          ALP=0.82
          CALL SILITA (P1,ISL,NE,ME,ALP)
C         CALL GROWTH AND MORTALITY SUBROUTINE
C         P1- SPECIES, T1- TEMP., T2- CONS. PREVIOUS MONTH
C         T3- FOOD CONSUMPTION, KG/KM2
C         T4- GROWTH, KG/KM2
C         TA- FOOD COEFFICIENT FOR GROWTH IN FORM OF RATIO
C         TJ- FOOD COEFFICIENT FOR MAINTENANCE,PERCENT OF BODY WEIGHT DAILY
C         TS- GROWTH COEFFICIENT (ANNUAL MEAN)
C         TY- HALF MAGNITUDE OF ANNUAL CHANGE OF TS
C         TK- PHASE LAG OF MAX. GROWTH, DEG.
C         SL- NATURAL MORTALITY COEFFICIENT          Setting of parameters
C         K- MONTH                                   for growth subroutines
          JF=(J*7)-4
          CALL READMS (2,T2,780,JF)
          TA=1.25 $ TJ=0.009 $ TS=0.079 $ TY=0.0092
          TK=125. $ SL=0.0025
          CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME) Growth
                                                                 subroutine
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SUBROUTINE DEMFIS 73/73 OPT=1 FTN 4.6+460 07/31

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      C     WRITE T4 (GROWTH) INTO A DISC LOCATION TO BE USED IN MAIN
      C     PROGRAMME FOR SOURCE - SINK COMPUTATION (GROWTH - CONSUMPTION)
            DLJ=J*7-2
            CALL WRITMS (2,T4,780,DLJ,1)
      C*********************************
      C     CALL FOOD SUBROUTINE
      C     P1- SPECIES, T2- STARVATION
      C     T3- FOOD CONSUMPTION (FROM PREVIOUS SUBR.)
      C     INI- INDEX NUMBER OF ITEMS SPECIFIED
      C     COVR- CARRY OVER-LACK OF FOOD FROM PREVIOUS TOIFOO CALL
      C     THERE MUST BE 5 FOOD ITEMS IN EVERY CALL
            INI=1 $ COVR=0.
      C     T2 IS DERIVED IN TOIFOO
      C     OBTAIN THE ORDER AND PERCENTAGE OF FOOD ITEMS FROM IDJAGS SUBR.
      C     S1 TO S5 FOOD ITEM CONSUMPTION FIELDS
      C     P2 TO P6 PERCENT OF FOOD CONSUMED PREVIOUS MONTH
  110       JJ=1 $ INI=1 $ COVR=0.                       Feeding subroutine
            CALL PORIDS (JJ,INI,COVR,KEK,J)              calls TOIFOO
      C     GROWTH CORRECTION SUBROUTINE (DUE TO STARVATION)
      C     AND SPAWNING MORTALITY SUBROUTINE
      C     KSK - MONTH OF SPAWNING ( SPECIFY )
      C     TSL - SPAWNING MORTALITY (SPECIFY)
            KSK=1                       <----  Month of spawning
            IF(KSK-K)104,105,104
  104       TSL=0.
            GO TO 106
  105       TSL=0.003                   <----  Spawning mortality
  106       CALL GROCOR(P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
      C     P1- SPECIES,  T2- STARVATION
      C     COMPUTE FISHERY
            FIM=0.003                   <----  Fishing mortality
            CALL PUGIMD (P1,S1,SU,SUM,FIM,NE,ME)      coefficient
            CALL WRITMS (2,P1,780,30,1)
      C     OUTPUTS
            PRINT 121,K,SU,SUM
  121       FORMAT(///5X,19HTURBOT, HALIBUT, M=,I3,10H  FISHERY,,F8.0,10H TONS
           1TOTAL,F8.0,10H 1000 TONS//)
            CALL PRIAFP (P1,0)              Output of monthly distribution
            SUTAB(5,K)=SUM
      C**********
      C     FLATHEAD SOLE
      C     SAME MIGRATION SPEED FOR ALL FLATFISHES
  150       IF(LL-1)151,151,153
  151       IF(K-1)152,152,153
  152       CALL READMS (2,S1,780,36)   Reading initial or previous
            GO TO 154                     month biomass
  153       CALL READMS (2,S1,780,37)
  154       IF(5-K)155,158,170          Testing for month of
  155       IF(6-K)156,158,170          onshore-offshore migration
  156       IF(10-K)157,159,170
  157       IF(11-K)170,159,170
  158       KE=1
            SS=50.  $ DD=600.
            CALL PLASRA (TSL,UP,VR,SD,SS,DD,NE,ME,KE)
            GO TO 161                              Calling migration
  159       KE=2                                   speed creation
            SS=50.  $ DD=600.                      subroutines
```

55

```
      SUBROUTINE DEMEIS        73/73    OPT=1                                  FTN 4.6+460        07/3

          CALL PLASRA (TSL,UR,VR,SD,SS,DD,NE,ME,KE)
      161 RP=0.30
          SS=50.   $ DD=600.
          CALL RANPOR (ISL,SD,S1,S2,S3,RP,SS,DD,NE,ME)   Subroutine for
      162 CONTINUE                                        separation of migrating portion
          CALL RANNAK (S2,PL,ISL,UR,VR,NE,ME)   Migration subroutine
          DO 163 N=1,NE        Adding of nonmigrating portion to migrating
          DO 163 M=1,ME
          P1(N,M)=P1(N,M)+S3(N,M)    portion
      163 CONTINUE
          CALL BOUSFT (P1,NE,ME)    Setting of boundaries
C         OUTPUT OF MIGRATION RESULTS
          DO 164 N=1,NE
          DO 164 M=1,ME
          S1(N,M)=P1(N,M)-S1(N,M)
      164 CONTINUE
          PRINT 165,K                   Output of migration results
      165 FORMAT(//5X,44HINCR.-DECR. OF FLATHEAD SOLE DUE TO MIGR., M=,I3//)
          CALL PRTAFP (S1,1)
          GO TO 167
      170 DO 166 N=1,NE        Transfer of biomass into proper array if
          DO 166 M=1,ME        no migration occurred.
          P1(N,M)=S1(N,M)
      166 CONTINUE
C         TEMP IS STILL IN T1
      167 J=6
          KS=1   $ KFK=0
          CALL IOJAGS (B1,B2,FOT,NUK,J,K,KS,KFK)
          NE=NUK(1)*7                                Sorting and reading of
          CALL READMS (2,T2,780,NE)                  food composition from
          NE=NUK(2)*7
          CALL READMS (2,T3,780,NE)                  food table
          NE=NUK(3)*7
          CALL READMS (2,T4,780,NE)               Migration due to temperature
          TMAX=7.   $   TMIN=2.                   and high/low food avail-
          CALL CYLTOT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)    ability
          ALP=0.82
          CALL SILIJA (P1,TSL,NE,ME,ALP)   Smoothing (diffusion)
          JE=(J*7)-4
          CALL READMS (2,T2,780,JE)
          TA=1.25  $ TJ=0.008  $ TS=0.080   Input parameters for
          TY=0.013  $TK=175.  $ SL=0.003    growth subroutine
          CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)   Growth
          DLJ=J*7-2                                                 subroutine
          CALL WRITMS (2,T4,780,DLJ,1)
          JJ=1 $ INI=1 $ COVR=0.
          CALL PORTOS (JJ,INI,COVR,KFK,J)   Feeding subroutine                001
C         KSK - MONTH OF SPAWNING
          KSK=3                          Month of spawning                    001
          IF(KSK-K)171,172,171
      171 TSL=0.
          GO TO 173
      172 TSL=0.004                      Spawning mortality coefficient       001
      173 CALL GROCOR (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)   Growth correction
C         CALL FISHING MORTALITY COMP SUBROUTINE         subroutine
          FIM=0.0015     Fishing mortality coefficient                       001
          CALL PUGIMP (P1,S1,SU,SUM,FIM,NE,ME)   Fishing subroutine
```

```
JRRCUTINE DEMFLS      73/73   OPI=1                                         FTN 4.6+460          07/3
```

```
      CALL WRITMS (2,P1,780,37,1)
C     OUTPUTS
      PRINT 174,K,SU,SUM
  174 FORMAT(///5X,17HFLATHEAD SOLE, M=,I3,10H  FISHERY,,F8.0,12H TONS,
     1TOTAL,F8.0,10H 1000 TONS//)
      CALL PRIAFP (P1,0)
      SUTAB(6,K)=SUM                                                    002
```

Output of monthly biomass ~~distribution~~

```
C **  **  **  **  **
C     ROCK AND YELLOWFIN SOLE
  250 IF(LL-1)251,251,253
  251 IF(K-1)252,252,253
  252 CALL READMS (2,S1,780,43)
      GO TO 254
  253 CALL READMS (2,S1,780,44)
```

Note: all species/ecological groups ~~follow above order of computations with~~ few exceptions (e.g. Pacific ocean perch in ROCKFI)

```
C     SAME MIGRATION TIME AND SPEED FOR ALL FLATFISH IN INITIAL PROGRAM
  254 IF(5-K)255,259,270
  255 IF(6-K)256,259,270
  256 IF(10-K)257,259,270
  257 IF(11-K)270,259,270
  258 KE=1                                                              001
      SS=50.  $ DD=600.                                                 001
      CALL PLASRA (ISL,UR,VR,SD,SS,DD,NE,ME,KE)                         001
      GO TO 261                                                         001
  259 KE=2                                                              001
      SS=50.  $ DD=600.                                                 001
      CALL PLASRA (ISL,UR,VR,SD,SS,DD,NE,ME,KE)                         001
  261 RP=0.30                                                           001
      SS=50.  $ DD=600.                                                 001
      CALL RANPOR(ISL,SD,S1,S2,S3,RP,SS,DD,NE,ME)                       001
  262 CONTINUE                                                          001
      CALL RANNAK (S2,P1,ISL,UR,VR,NE,ME)
      DO 263 N=1,NE
      DO 263 M=1,ME
      P1(N,M)=P1(N,M)+S3(N,M)
  263 CONTINUE
      CALL ROJSET (P1,NE,ME)
C     OUTPUT OF MIGRATION RESULTS
      DO 264 N=1,NE
      DO 264 M=1,ME
      S1(N,M)=P1(N,M)-S1(N,M)
  264 CONTINUE
      PRINT 265,K
  265 FORMAT(//5X,49HINCR.-DECR. OF ROCK AND YELLOWFIN DUE TO MIGR.,M=,I
     13//)
      CALL PRIAFP (S1,1)
      GO TO 267
  270 DO 266 N=1,NE
      DO 266 M=1,ME
      P1(N,M)=S1(N,M)
  266 CONTINUE
C     TEMP IS IN T1, IF NOT READ
  267 J=7
      KS=1  $ KFK=0
      CALL TOJAGS (31,92,FOT,NUK,J,K,KS,KFK)
      NE=NUK(1)*7
      CALL READMS (2,T2,780,NE)
      NE=NUK(2)*7
```

57


```
      CALL READMS (2,T3,780,NF)
      ME=NUK(3)*7
      CALL READMS (2,T4,780,NF)
      TMAX=10.  $ TMIN=2.
      CALL CYLTCT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
      ALP=0.82
      CALL SILITA (P1,TSL,NE,ME,ALP)
      JF=(J*7)-6
      CALL READMS (2,T2,780,JF)
      TA=1.3  $  TJ=0.006
      TS=0.085  $ TY=0.015
      TK=175.  $  SL=0.0062
      CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
      DLJ=J*7-2
      CALL WRITMS (2,T4,780,DLJ,1)
      JJ=1  $ INI=1  $ COVR=0.
      CALL PORTGS (JJ,INI,COVR,KFK,J)
C     KSK=MONTH OF MAIN SPAWNING
      KSK=5
      IF(KSK-K)271,272,271
  271 TSL=0.
      GO TO 273
  272 TSL=0.005
  273 CALL GROCOR (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
C     FISHING MORTALITY
      FIM=0.0005
      CALL PUGIMO (P1,S1,SU,SUM,FIM,NE,ME)
      CALL WRITMS (2,P1,780,44,1)
C     OUTPUTS
      PRINT 274,K,SU,SUM
  274 FORMAT(///5X,22HROCK AND YELLOWFIN, M=,I3,10H  FISHERY,,F8.0,6H  T
     1ONS,F8.0,10H 1000 TONS//)
      CALL PRTAFP (P1,0)
      SUTAB(7,K)=SUM
C  **   **   **   **
C     DOVER AND REX SOLE
C     SAME MIGRATION SPEED FOR ALL FLATFISHES
  350 IF(LL-1)351,351,353
  351 IF(K-1)352,352,353
  352 CALL READMS (2,S1,780,50)
      GO TO 354
  353 CALL READMS (2,S1,780,51)
  354 IF(5-K)355,358,370
  355 IF(6-K)356,358,370
  356 IF(10-K)357,359,370
  357 IF(11-K)370,359,370
  358 KE=1
      SS=50.  $ DD=600.
      CALL PLASRA (ISL,UR,VR,SD,SS,DD,NE,ME,KE)
      GO TO 361
  359 KE=2
      SS=50.  $ DD=600.
      CALL PLASRA (ISL,UR,VR,SD,SS,DD,NE,ME,KE)
  361 RP=0.30
      SS=50.  $ DD=600.
      CALL RANDOR (ISL,SD,S1,S2,S3,RP,SS,DD,NE,ME)
  362 CONTINUE
```

```
      CALL RANNAK (S2,P1,ISL,UP,VP,NE,ME)
      DO 363 N=1,NE
      DO 363 M=1,ME
      P1(N,M)=P1(N,M)+S3(N,M)
  363 CONTINUE
      CALL BOUSET (P1,NE,ME)
C     OUTPUT OF MIGRATION RESULTS
      DO 364 N=1,NE
      DO 364 M=1,ME
      S1(N,M)=P1(N,M)-S1(N,M)
  364 CONTINUE
      PRINT 365,K
  365 FORMAT(//5X,44HINCR.-DECR. OF DOVER AND REX DUE TO MIGR.,M=,I3//)
      CALL PRIAFP (S1,1)
      GO TO 367
  370 DO 366 N=1,NE
      DO 366 M=1,ME
      P1(N,M)=S1(N,M)
  366 CONTINUE
C     TEMP IS STILL IN T1
  367 J=8
      KS=1 $ KFK=0
      CALL TCJAGS (B1,B2,FOT,NUK,J,K,KS,KFK)
      NF=NUK(1)*7
      CALL READMS (2,T2,730,NF)
      NF=NUK(2)*7
      CALL READMS (2,T3,780,NF)
      NF=NUK(3)*7
      CALL READMS (2,T4,780,NF)
      TMAX=10. $ TMIN=3.                                                  0011
      CALL CYLFOT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
      ALP=0.82
      CALL SILITA (P1,ISL,NE,ME,ALP)
      JF=(J*7)-4                                                          0011
      CALL READMS (2,T2,780,JF)                                           0011
      TA=1.2 $ TJ=0.007 $ TS=0.078                                        0011
      TY=0.012 $ TK=175. $ SL=0.0022                                      0011
      CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
      DLJ=J*7-2
      CALL WRITMS (2,T4,780,DLJ,1)
      JJ=1 $ INI=1 $ COVR=0.
      CALL POSTOS (JJ,INI,COVR,KFK,J)                                     0011
C     KSK - MONTH OF SPAWNING
      KSK=1                                                               0012
      IF(KSK-K)371,372,371
  371 TSL=0.
      GO TO 373
  372 TSL=0.0035                                                          0012
  373 CALL GROCOR (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
C     CALL FISHING MORTALITY COMP SUBROUTINE
      FIM=0.00045                                                         0012
      CALL PUGIMO (P1,S1,SU,SUM,FIM,NE,ME)
      CALL WRITMS (2,P1,790,51,1)
C     OUTPUTS
      PRINT 374,K,SU,SUM
  374 FORMAT(///5X,17HDOVER AND REX, M=,I3,10H  FISHERY,,F9.0,12H TONS
     1TOTAL,F9.0,10H 1000 TONS//)
```

59

SUBROUTINE DEMFIS 73/73 OPT=1 FTN 4.6+460 07/3

```
C0        CALL PRTAFP (PI,O)
          SUTAB(3,K)=SUM                                             002
          RETURN
          END
```

```
      SUBROUTINE SEMDEM
      DIMENSION ISL(26,30),SD(26,30),UR(26,30),VR(26,30),SUTAB(30,12),   0023
     131(30,30),B2(30,30),FOT(30),NUK(30),NS(50),
     2MS(50),S1(26,30),S2(26,30),S3(26,30),S4(26,30),S5(26,30),S6(26,30)
     3,P1(26,30),P2(26,30),P3(26,30),P4(26,30),P5(26,30),P6(26,30)
     4,T1(26,30),T2(26,30),T3(26,30),T4(26,30),T5(26,30),T6(26,30)
      COMMON ISL,SD,UR,VR,SUTAB,                                          0023
     1B1,B2,FOT,NUK,NS,MS,
     2S1,S2,S3,S4,S5,S6,P1,P2,P3,P4,P5,P6,T1,T2,T3,T4,T5,T6,
     3K,LL,IZP,IZ1,IZ2,NE,ME,NU
     5,IN1(201),IN2(201)                                                  0002
      INTEGER OLJ
C     POLLOCK
C     COD
C     NO MIGRATION IN INITIAL PROGRAMME
C     MIGRATION BYPASSED
C ** ** ** ** **
C     POLLOCK
   50 IF(LL-1)51,51,53
   51 IF(K-1)52,52,53
   52 CALL READMS (2,S1,780,78)
      GO TO 70                                                            0035
   53 CALL READMS (2,S1,780,79)
      GO TO 70
C*****                                                                   0013
C  MIGRATION TIMING, SPEED, AND DIRECTION                                0013
C  CREATION TO BE ADDED HERE                                             0013
C*****                                                                   0013
      CALL RANNAK (S2,P1,ISL,UR,VR,NE,ME)
      DO 63 N=1,NE
      DO 63 M=1,ME
      P1(N,M)=P1(N,M)+S3(N,M)
   63 CONTINUE
      CALL BOUSET (P1,NE,ME)
C     OUTPUT OF MIGRATION RESULTS
      DO 64 N=1,NE
      DO 64 M=1,ME
      S1(N,M)=P1(N,M)-S1(N,M)
   64 CONTINUE
      PRINT 65,K
   65 FORMAT(//5X,49HINCR.-DECR. OF POLLOCK              DUE TO MIGR.,M=,I
     13//)
      CALL PRIAFP (S1,1)
      GO TO 67
   70 DO 66 N=1,NE
      DO 66 M=1,ME
      P1(N,M)=S1(N,M)
   66 CONTINUE
C     TEMP IS IN T1,IF NOT,READ
      MM=72+K
      CALL READMS (1,T1,780,MM)                                           001
   67 J=12
      KS=1   $ KFK=0
      CALL TOJAGS (B1,B2,FOT,NUK,J,K,KS,KFK)
      NF=NUK(1)*7
      CALL READMS (2,T2,780,NF)
      NF=NUK(2)*7
```

```
      CALL READMS (2,T3,780,NE)
      NE=NUK(3)*7
      CALL READMS (2,T4,780,NE)
      TMAX=8. $ TMIN=2.
      CALL CYLTOT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
      ALP=0.82
      CALL SILITA (P1,ISL,NE,ME,ALP)
      JF=(J*7)-4
      CALL READMS (2,T2,780,JF)
      TA=1.25  $ TJ=0.009  $ TS=0.095
      TY=0.02  $ TK=175.   $ SL=0.0028
      CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
      DLJ=J*7-2
      CALL WRITMS (2,T4,780,DLJ,1)
      JJ=1  $ INI=1  $ COVR=0.
      CALL PORTOS (JJ,INI,COVR,KFK,J)
C     TRIFOD CALLED IN PORTOS
C     KSK= MONTH OF MAIN SPAWNING
      KSK=3
      IF(KSK-K)71,72,71
   71 TSL=0.
      GO TO 73
   72 TSL=0.003
   73 CALL GROCOF (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
C     FISHING MORTALITY
      FIM=0.0045
      CALL PUGIMP (P1,S1,SU,SUM,FIM,NE,ME)
      CALL WRITMS (2,P1,780,79,1)
C     OUTPUTS
      PRINT 74,K,SU,SUM
   74 FORMAT(///5X,22HPOLLOCK              , M=,I3,10H FISHERY,,F8.0,6H  T
     1ONS,F8.0,10H1000 TONS//)
      CALL PRIAFP (P1,0)
      SUTAB(12,K)=SUM
C  ** ** ** ** **
C     COD
C     MIGRATION BYPASSED
  150 IF(LL-1)151,151,153
  151 IF(K-1)152,152,153
  152 CALL READMS (2,S1,780,85)
      GO TO 170
  153 CALL READMS (2,S1,780,86)
      GO TO 170
C*****
C     MIGRATION TIMING, SPEED, AND DIRECTION
C     CREATION TO BE ADDED HERE
C*****
      CALL RANNAK (S2,P1,ISL,UR,VR,NE,ME)
      DO 163 N=1,NE
      DO 163 M=1,ME
      P1(N,M)=P1(N,M)+S3(N,M)
  163 CONTINUE
      CALL BOUSET (P1,NE,ME)
C     OUTPUT OF MIGRATION RESULTS
      DO 164 N=1,NE
      DO 164 M=1,ME
      S1(N,M)=P1(N,M)-S1(N,M)
```

```
      164 CONTINUE
          PRINT 165,K
      165 FORMAT(//5X,49HINCR.-DECR. OF COD                    DUE TO MIGR.,M=,I
         13//)
          CALL PRIAFP (S1,1)
          GO TO 167
      170 DO 166 N=1,NE
          DO 166 M=1,ME
          P1(N,M)=S1(N,M)
      166 CONTINUE
C         TEMP IS IN T1, IF NOT, READ
      167 J=13
          KS=1    $ KFK=0
          CALL TOJAGS (B1,32,FCT,NUK,J,K,KS,KFK)
          NF=NUK(1)*7
          CALL READMS (2,T2,780,NF)
          NF=NUK(2)*7
          CALL READMS (2,T3,780,NF)
          NF=NUK(3)*7
          CALL READMS (2,T4,780,NF)
          TMAX=10.   $   TMIN=5.
          CALL CYLTOT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
          ALP=0.62
          CALL STLITA (P1,ISL,NE,ME,ALP)
          JF=(J*7)-4
          CALL READMS (2,T2,780,JF)
          TA=1.25    $   TJ=0.009   $   TS=0.095
          TY=0.02    $   TK=175.    $   SL=0.0035
          CALL ASVNTS(P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
          DLJ=J*7-2
          CALL WRITMS (2,T4,780,DLJ,1)
          JJ=1    $ INI=1    $ COVR=0.
          CALL PORTOS (JJ,INI,COVR,KFK,J)
C         KSK-MONTH OF MAIN SPAWNING
          KSK=2
          IF(KSK-K)171,172,171
      171 TSL=0.
          GO TO 173
      172 TSL=0.005
      173 CALL GROCOK (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
C         FISHING MORTALITY
          FIM=0.00085
          CALL PUGIMO (P1,S1,SU,SUM,FIM,NE,ME)
          CALL WRITMS (2,P1,780,96,1)
C         OUTPUTS
          PRINT 174,K,SU,SUM
      174 FORMAT(///5X,22HCOD                 , M=,I3,10H  FISHERY,,F8.0,6H  T
         1ONS,F8.0,10H 1000 TONS//)
          CALL PRIAFP (P1,0)
          SUTAB(13,K)=SUM
          RETURN
          END
```

```
      SUBROUTINE ROCKFI
      DIMENSION ISL(26,30),SD(26,30),UR(26,30),VR(26,30),SUTAB(30,12),
     1B1(30,30),B2(30,30),FOT(30),NUK(30),NS(50),
     2MS(50),S1(26,30),S2(26,30),S3(26,30),S4(26,30),S5(26,30),S6(26,30)
     3,P1(26,30),P2(26,30),P3(26,30),P4(26,30),P5(26,30),P6(26,30)
     4,T1(26,30),T2(26,30),T3(26,30),T4(26,30),T5(26,30),T6(26,30)
      COMMON ISL,SD,UR,VR,SUTAB,
     1B1,B2,FOT,NUK,NS,MS,
     2S1,S2,S3,S4,S5,S6,P1,P2,P3,P4,P5,P6,T1,T2,T3,T4,T5,T6,
     3K,LL,IZP,IZ1,IZ2,NE,ME,NU
     5,IN1(201),IN2(201)
      INTEGER DLJ
C     PACIFIC OCEAN PERCH
C     SEBASTOLOBUS
C     COTTIDS AND OTHERS
C     ALL INPUTS ARE PRELIMINARY ESTIMATES
C     SAME UNTUNED MIGRATION SPEED USED
C ** ** ** **
C     PACIFIC OCEAN PERCH
      IF(LL-1)1,1,3
    1 IF(K-1)2,2,3
    2 CALL READMS (2,S1,730,57)          Creation of migration
      GO TO 4                            speeds
    3 CALL READMS (2,S1,730,58)
    4 IF(5-K)5,8,70
    5 IF(7-K)6,8,8
    6 IF(10-K)9,9,70
    8 DO 10 N=1,NE
      DO 10 M=1,ME
      IF(ISL(N,M)-2)10,11,12
   11 UR(N,M)=0.45
      VR(N,M)=0.16
      GO TO 10
   12 IF(ISL(N,M)-4)10,13,14
   13 UR(N,M)=0.3
      VR(N,M)=0.
      GO TO 10
   14 IF(ISL(N,M)-6)15,16,17
   15 UR(N,M)=0.5
      VR(N,M)=0.
      GO TO 10
   16 UR(N,M)=0.65
      VR(N,M)=0.65
      GO TO 10
   17 IF(ISL(N,M)-8)18,19,20
   18 UR(N,M)=0.45
      VR(N,M)=0.18
      GO TO 10
   19 UR(N,M)=0.65
      VR(N,M)=0.65
      GO TO 10
   20 IF(ISL(N,M)-10)21,22,10
   21 UR(N,M)=0.5
      VR(N,M)=0.
      GO TO 10
   22 UR(N,M)=0.32
      VR(N,M)=0.
```

```
   10 CONTINUE
      GO TO 62
    9 DO 23 N=1,NE
      DO 23 M=1,ME
      IF(ISL(N,M)-2)23,24,25
   24 UR(N,M)=-0.45
      VR(N,M)=-0.18
      GO TO 23
   25 IF(ISL(N,M)-4)23,26,27
   26 UR(N,M)=-0.3
      VR(N,M)=0.
      GO TO 23
   27 IF(ISL(N,M)-6)28,29,30
   28 UR(N,M)=-0.5
      VR(N,M)=0.
      GO TO 23
   29 UR(N,M)=-0.65
      VR(N,M)=-0.65
      GO TO 23
   30 IF(ISL(N,M)-8)31,32,33
   31 UR(N,M)=-0.45
      VR(N,M)=-0.18
      GO TO 23
   32 UR(N,M)=-0.65
      VR(N,M)=-0.65
      GO TO 23
   33 IF(ISL(N,M)-10)34,35,23
   34 UR(N,M)=-0.5
      VR(N,M)=0.
      GO TO 23
   35 UR(N,M)=-0.32
      VR(N,M)=0.
   23 CONTINUE                                  Setting of migration speed
   62 CALL BIRBAN (ISL,UR,VR,NE,ME)             boundary values.
      RF=0.30                                          Separation of
      SS=60. $ DD=900.                                 migrating portion
      CALL RANPGR (ISL,SD,S1,S2,S3,RF,SS,DD,NE,ME)  of population
      CALL RANNAK (S2,P1,ISL,UR,VR,NE,ME) Migration subroutine
      DO 63 N=1,NE
      DO 63 M=1,ME
      P1(N,M)=P1(N,M)+S2(N,M)       Setting of boundaries
   63 CONTINUE
      CALL BOUSET (P1,NE,ME)
C     OUTPUT OF MIGRATION RESULTS
      DO 64 N=1,NE
      DO 64 M=1,ME
      S1(N,M)=P1(N,M)-S1(N,M)
   64 CONTINUE
      PRINT 65,K
   65 FORMAT(//5X,49HINCR.-DECR. OF PACIFIC OCEAN PER. DUE TO MIGR.,M=,I
     13//)
      CALL PRIMAP (S1,1)
      GO TO 67
   70 DO 66 N=1,NE
      DO 66 M=1,ME                 Transfer of biomass if no migration
      P1(N,M)=S1(N,M)              occurred
   66 CONTINUE
```

65

SUBROUTINE ROCKFI 73/73 OPT=1 FTN 4.6+460 07/3

```
      C     TEMP IS IN T1, IF NOT READ
         67 MM=72+K
            CALL READMS (1,T1,780,MM)
            J=9
            KS=1  $ KFK=0                                     Extraction and sorting
            CALL TOJAGS (B1,B2,EDT,NUK,J,K,KS,KFK)            of food composition
            NF=NUK(1)*7
            CALL READMS (2,T2,780,NF)
            NF=NUK(2)*7
            CALL READMS (2,T3,780,NF)
            NF=NUK(3)*7
            CALL READMS (2,T4,780,NF)
            TMAX=7.  $  TMIN=4.                               Migrations due to
            CALL CYLIDI (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)  temperature & food
            ALP=0.82                                          abundance
            CALL SILITA (P1,ISL,NE,ME,ALP)   Smoothing (diffusion)
            JF=(J*7)-4
            CALL READMS (2,T2,780,JF)
            TA=1.3  $  TJ=0.009  $  TS=0.08    Setting growth and food
            TY=0.015 $  TK=175.  $  SL=0.0028  requirement parameters
            CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)  Growth sub-
            DLJ=J*7-2                                                routine
            CALL WRITMS (2,T4,780,DLJ,1)
            JJ=1  $ INI=1  $ COVR=0.
            CALL PORTUS (JJ,INI,COVR,KFK,J)   Feeding subroutine
      C     KSK-MONTH OF MAIN SPAWNING
            KSK=5                             Month of spawning
            IF(KSK-K)71,72,71
         71 TSL=0.
            GO TO 73
         72 TSL=0.0035                        Spawning mortality
         73 CALL GROCOR (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)  Growth correction
      C     FISHING MORTALITY
            IF(K-6)296,297,296
        297 KCK=150                                          Fishing subroutine (with
            CALL CASTAT (P1,S1,SU,SUM,J,K,NE,ME,KCK)  fishing intensity)
            PRINT 299,K
        299 FORMAT(///5X,33HPAC. OC. PERCH,FISHERY KG/KM2, M=,I3//)
            CALL PRIAFP(S1,0)                 Output of fishery
            GO TO 298
        296 FIM=0.0105
            CALL FUGINO (P1,S1,SU,SUM,FIM,NE,ME)  Fishing subroutine
            IF(K-1)298,298,310
        310 CALL READMS (2,P2,780,58)
            DO 280 N=1,NE                     Computation of source-sink
            DO 280 M=1,ME                     of biomass
            P3(N,M)=P2(N,M)-P1(N,M)
        280 CONTINUE
            PRINT 281,K
        281 FORMAT(///5X,31HPAC. OC. PERCH, SOURCE-SINK, M=,I3//)
            CALL PRIAFP(P3,0)
        298 CALL WRITMS (2,P1,780,58,1)
      C     OUTPUTS
            PRINT 74,K,SU,SUM
         74 FORMAT(///5X,22HPAC. OCEAN PERCH  , M=,I3,10H  FISHERY,,F8.0,6H  T
           1ONS,F8.0,10H 1000 TONS//)   Monthly biomass output
            CALL PRIAFP (P1,0)
```

```
      SUMTAB(9,K)=SUM                                            0037
C **  **  **  **  **
C     SEBASTOLOBUS AND SABLEFISH
      IF(LL-1)101,101,103
  101 IF(K-1)102,102,103
  102 CALL READMS (2,S1,730,64)
      GO TO 104
  103 CALL READMS (2,S1,730,65)
      GO TO 170                                                  0014
C****                                                            0014
C MIGRATION BYPASSED - NEW MIGRATION SPEED REQUIRED              0014
C****                                                            0015
  104 IF(5-K)105,108,170
  105 IF(7-K)106,108,108
  106 IF(10-K)109,109,170
  108 DO 110 N=1,NE
      DO 110 M=1,ME
      IF(ISL(N,M)-2)110,111,112
  111 UR(N,M)=0.45
      VR(N,M)=0.15
      GO TO 110
  112 IF(ISL(N,M)-4)110,113,114
  113 UR(N,M)=0.3
      VR(N,M)=0.
      GO TO 110
  114 IF(ISL(N,M)-6)115,116,117
  115 UR(N,M)=0.5
      VR(N,M)=0.
      GO TO 110
  116 UR(N,M)=0.65
      VR(N,M)=0.65
      GO TO 110
  117 IF(ISL(N,M)-8)118,119,120
  118 UR(N,M)=0.45
      VR(N,M)=0.18
      GO TO 110
  119 UR(N,M)=0.65
      VR(N,M)=0.65
      GO TO 110
  120 IF(ISL(N,M)-10)121,122,110
  121 UR(N,M)=0.5
      VR(N,M)=0.
      GO TO 110
  122 UR(N,M)=0.32
      VR(N,M)=0.
  110 CONTINUE
      GO TO 162
  109 DO 123 N=1,NE
      DO 123 M=1,ME
      IF(ISL(N,M)-2)123,124,125
  124 UR(N,M)=-0.45
      VR(N,M)=-0.18
      GO TO 123
  125 IF(ISL(N,M)-4)123,126,127
  126 UR(N,M)=-0.3
      VR(N,M)=0.
      GO TO 123
```

```
      127 IF(ISL(N,M)-6)128,129,130
      128 UR(N,M)=-0.5
          VR(N,M)=0.
          GO TO 123
      129 UR(N,M)=-0.65
          VR(N,M)=-0.65
          GO TO 123
      130 IF(ISL(N,M)-8)131,132,133
      131 UR(N,M)=-0.45
          VR(N,M)=-0.18
          GO TO 123
      132 UR(N,M)=-0.65
          VR(N,M)=-0.65
          GO TO 123
      133 IF(ISL(N,M)-10)134,135,123
      134 UR(N,M)=-0.5
          VR(N,M)=0.
          GO TO 123
      135 UR(N,M)=-0.32
          VR(N,M)=0.
      123 CONTINUE
      162 CALL PIPRAN (ISL,UR,VR,NE,ME)                                  001
          PP=0.20                                                       001
          SS=100.  $ DD=1000.                                           001
          CALL RANPOR (ISL,SO,S1,S2,S3,PP,SS,DD,NE,ME)                  001
          CALL RANNAK (S2,P1,ISL,UR,VR,NE,ME)
          DO 163 N=1,NE
          DO 163 M=1,ME
          P1(N,M)=P1(N,M)+S3(N,M)
      163 CONTINUE
          CALL POUSET (P1,NE,ME)
C         OUTPUT OF MIGRATION RESULTS
          DO 164 N=1,NE
          DO 164 M=1,ME
          S1(N,M)=P1(N,M)-S1(N,M)
      164 CONTINUE
          PRINT 165,K
      165 FORMAT(//5X,49HINCR.-DECR. OF SEBASTOL AND SABLE DUE TO MIGR.,M=,I
         13//)
          CALL PRIAER (S1,1)
          GO TO 167
      170 DO 166 N=1,NE
          DO 166 M=1,ME
          P1(N,M)=S1(N,M)
      166 CONTINUE
C         TEMP IS IN T1,IF NOT, READ
      167 J=10
          KS=1  $ KFK=0
          CALL TOJAGS (B1,B2,FOT,NUK,J,K,KS,KFK)
          NF=NUK(1)*7
          CALL READMS (2,T2,780,NF)
          NF=NUK(2)*7
          CALL READMS (2,T3,780,NF)
          NF=NUK(3)*7
          CALL READMS (2,T4,780,NF)
          TMAX=9.  $ TMIN=3.                                            001
          CALL CYLTOT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
```

SUBROUTINE ROCKET 73/73 OPT=1 FTN 4.6+460 07/3

```
      ALP=0.82
      CALL SILITA (P1,ISL,NE,ME,ALP)
      JF=(J*7)-4
      CALL READMS (2,T2,780,JF)
      TA=1.25  $  TJ=0.0095  $  TS=0.085
      TY=0.015  $ TK=175.  $  SL=0.0025
      CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
      DLJ=J*7-2
      CALL WRITMS (2,T4,780,DLJ,1)
      JJ=1  $ INT=1  $ COVR=0.
      CALL PORTDS (JJ,INT,COVR,KEK,J)
C     KSK= MONTH OF MAIN SPAWNING
      KSK=2
      IF(KSK-K)171,172,171
  171 TSL=0.
      GO TO 173
  172 TSL=0.004
  173 CALL GSDLCR (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
C     FISHING MORTALITY
      FIM=0.0026
      CALL PUGIMC (P1,S1,SU,SUM,FIM,NE,ME)
      CALL WRITMS (2,P1,780,65,1)
C     OUTPUTS
      PRINT 174,K,SU,SUM
  174 FORMAT(///5X,22HSEBAST.AND SABLEF.,  M=,I3,10H  FISHERY,,F8.0,6H  T
     1ONS,F8.0,10H 1000 TONS//)
      CALL PRIAFP (P1,0)
      SUTAB(10,K)=SUM
C **  **  **  ***
C     COTTIDS AND OTHERS
      IF(LL-1)201,201,203
  201 IF(K-1)202,202,203
  202 CALL READMS (2,S1,780,71)
      GO TO 270
  203 CALL READMS (2,S1,780,72)
C**MIGRATION BYPASSED
  270 DO 266 N=1,NE
      DO 266 M=1,ME
      P1(N,M)=S1(N,M)
  266 CONTINUE
C     TEMP IS IN T1,IF NOT, READ
  267 J=11
      KS=1   $ KEK=0.
      CALL TOJACS (B1,B2,EOT,NUK,J,K,KS,KEK)
      NE=NUK(1)*7
      CALL READMS (2,T2,780,NE)
      NE=NUK(2)*7
      CALL READMS (2,T3,780,NE)
      NE=NUK(3)*7
      CALL READMS (2,T4,780,NE)
      TMAX=12.  $ TMIN=2.
      CALL CYLTOT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
      ALP=0.82
      CALL SILITA (P1,ISL,NE,ME,ALP)
      JF=(J*7)-4
      CALL READMS (2,T2,780,JF)
      TA=1.25  $ TJ=0.01
```

```
SUBROUTINE ROCKEI        73/73    OPT=1                                      FTN 4.6+460        07/1

                     TS=0.085   $ TY=0.015
                     TK=175.    $ SL=0.003
                     CALL ASVNTS (P1,T1,T2,T3,T4,TA,TU,TS,TY,TK,SL,K,NE,ME)
                     DLJ=J*7-2
                     CALL WRITMS (2,T4,720,DLJ,1)
                     JJ=1   $ INI=1   $ COVR=0.
                     CALL PORTIO (JJ,INI,COVR,KFK,J)                                          001
               C     KSK= MONTH OF MAIN SPAWNING
                     KSK=5
                     IF(KSK-K)271,272,271
                 271 TSL=0.
                     GO TO 273
                 272 TSL=0.005
                 273 CALL GROCCK (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
               C     FISHING MORTALITY
                     FIM=0.001
                     CALL PUGIMC (P1,S1,SU,SUM,FIM,NE,ME)
                     CALL WRITMS (2,P1,720,72,1)
               C     OUTPUTS
                     PRINT 274,K,SU,SUM
                 274 FORMAT(///5X,22HCOTTIDS AND OTHERS, M=,I3,10H  FISHERY,,F5.0,6H  T
                    1ONS,F5.0,10H 1000 TONS//)
                     CALL PRIAFP (P1,0)
                     SUTAB(11,K)=SUM                                                          003
                     RETURN
                     END
```

```
                   SUBROUTINE PELEIS
                   DIMENSION ISL(26,30),SD(26,30),UR(26,30),VR(26,30),SUTAB(30,12),  002
                  1B1(30,30),B2(30,30),FOT(30),NUK(30),NS(50),
                  2MS(50),S1(26,30),S2(26,30),S3(26,30),S4(26,30),S5(26,30),S6(26,30)
                  3,P1(26,30),P2(26,30),P3(26,30),P4(26,30),P5(26,30),P6(26,30)
                  4,T1(26,30),T2(26,30),T3(26,30),T4(26,30),T5(26,30),T6(26,30)
                   COMMON ISL,SD,UR,VR,SUTAB,                                            002
                  1B1,B2,FOT,NUK,NS,MS,
                  2S1,S2,S3,S4,S5,S6,P1,P2,P3,P4,P5,P6,T1,T2,T3,T4,T5,T6,
                  3K,LL,IZP,IZ1,IZ2,NE,ME,NU
                  5,IN1(201),IN2(201)                                                    C00
                   INTEGER DLJ
             C     HERRING
             C     SMELT AND OTHERS
             C     ATKA MACKEREL
             C     SALMON
             C     SQUIDS
             C     MIGRATION GIVEN TO ATKA MACKEREL ONLY (PRELIMINARY)
             C **  **  **  **  **
             C     HERRING
                50 IF(LL-1)51,51,53
                51 IF(K-1)52,52,53
                52 CALL READMS (2,S1,780,92)
                   GO TO 70                                                              003
                53 CALL READMS (2,S1,780,93)
                   GO TO 70
             C****                                                                       001
             C MIGRATION TIMING, SPEED, AND DIRECTION                                    001
             C TO BE CREATED                                                             001
             C****                                                                       001
                   CALL RANNAK (S2,P1,ISL,UR,VR,NE,ME)
                   DO 63 N=1,NE
                   DO 63 M=1,ME
                   P1(N,M)=P1(N,M)+S3(N,M)
                63 CONTINUE
                   CALL ROUSET (P1,NE,ME)
             C     OUTPUT OF MIGRATION RESULTS
                   DO 64 N=1,NE
                   DO 64 M=1,ME
                   S1(N,M)=P1(N,M)-S1(N,M)
                64 CONTINUE
                   PRINT 65,K
                65 FORMAT(//5X,49HINCR.-DECR. OF HERRING            DUE TO MIGR.,M=,I
                  13//)
                   CALL PRIAFF (S1,1)
                   GO TO 67
                70 DO 66 N=1,NE
                   DO 66 M=1,ME
                   P1(N,M)=S1(N,M)
                66 CONTINUE
             C     TEMP IS IN T1, IF NOT, READ
                   MM=72+K
                   CALL READMS (1,T1,780,MM)
                67 J=14
                   KS=1 $ KEK=0
                   CALL TOJAGS (B1,B2,FOT,NUK,J,K,KS,KEK)
                   NF=NUK(1)*7
```

```
      CALL READMS (2,T2,780,NF)
      NF=NUK(2)*7
      CALL READMS (2,T3,780,NF)
      NF=NUK(3)*7
      CALL READMS (2,T4,780,NF)
      TMAX=10. $ TMIN=0.5
      CALL CYLTCT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,TSL)
      ALP=0.82
      CALL SILITA (P1,TSL,NE,ME,ALP)
      JF=(J*7)-4
      CALL READMS (2,T2,780,JF)
      TA=1.25 $ TJ=0.01
      TS=0.10 $ TY=0.025
      TK=175. $ SL=0.0025
      CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
      DLJ=J*7-2
      CALL WRITMS (2,T4,780,DLJ,1)
      JJ=1 $ INI=1 $ COVR=0.
      CALL PORTCS (JJ,INI,COVR,KFK,J)
C     KSK- MONTH OF MAIN SPAWNING
      KSK=5
      IF(KSK-K)71,72,71
   71 TSL=0.
      GO TO 73
   72 TSL=0.003
   73 CALL GROCDF (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
C     FISHING MORTALITY
      FIM=0.0001
      CALL FUCINE (P1,S1,SU,SUM,FIM,NF,ME)
      CALL WRITMS (2,P1,780,93,1)
C     OUTPUTS
      PRINT 74,K,SU,SUM
   74 FORMAT(///5X,22HHERRING                 , M=,I3,10H   FISHERY,,F3.0,6H   T
     1ONS,F8.0,10H 1000 TONS//)
      CALL PRTAFP (P1,0)
      SUTAB(14,K)=SUM
C **   **   **   **   **
C     SMELT AND OTHERS
  150 IF(LL-1)151,151,153
  151 IF(K-1)152,152,153
  152 CALL READMS (2,S1,780,99)
      GO TO 170
  153 CALL READMS (2,S1,780,100)
      GO TO 170
C****
C MIGRATION TIMING, SPEED, AND DIRECTION
C TO BE CREATED
C****
      CALL RANNAK (S2,P1,TSL,UR,VR,NF,ME)
      DO 163 N=1,NE
      DO 163 M=1,ME
      P1(N,M)=P1(N,M)+S2(N,M)
  163 CONTINUE
      CALL BOUSET (P1,NE,ME)
C     OUTPUT OF MIGRATION RESULTS
      DO 164 N=1,NE
      DO 164 M=1,ME
```

```
                S1(N,M)=P1(N,M)-S1(N,M)
            164 CONTINUE
                PRINT 165,K
            165 FORMAT(//5X,49HINCR.-DECR. OF SMELT AND OTHERS    DUE TO MIGR.,M=,I
               13//)
                CALL PRIAER (S1,1)
                GO TO 167
            170 DO 166 N=1,NE
                DO 166 M=1,ME
                P1(N,M)=S1(N,M)
            166 CONTINUE
          C     TEMP IS IN T1,IF NOT,READ
            167 J=15
                KS=1  $ KFK=0
                CALL TOJAGS (P1,P2,FOT,NUK,J,K,KS,KFK)
                NF=NUK(1)*7
                CALL READMS (2,T2,780,NF)
                NF=NUK(2)*7
                CALL READMS (2,T3,780,NF)
                NF=NUK(3)*7
                CALL READMS (2,T4,780,NF)
                TMAX=12.  $ TMIN=2.
                CALL CYLTOT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
                ALP=0.22
                CALL SILITA (P1,ISL,NE,ME,ALP)                                0019
                JF=(J*7)-4                                                    0019
                CALL READMS (2,T2,780,JF)                                     00207
                TA=1.25  $  TJ=0.01
                TS=0.10  $ TY=0.025
                TK=175. $ SL=0.0035                                           0020
                CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
                DLJ=J*7-2
                CALL WRITMS (2,T4,780,DLJ,1)
                JJ=1   $ INI=1  $ COVR=0.                                     0020
                CALL PORTOS (JJ,INI,COVR,KFK,J)
          C     KSK- MONTH OF MAIN SPAWNING
                KSK=5
                IF(KSK-K)171,172,171
            171 TSL=0.
                GO TO 173
            172 TSL=0.005
            173 CALL GROCOR (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
          C     FISHING MORTALITY
                FIM=0.0001                                                    002
                CALL RUCIFO (P1,F1,SU,SUM,FIM,NE,ME)
                CALL WRITMS (2,F1,780,100,1)
          C     OUTPUTS
                PRINT 174,K,SU,SUM
            174 FORMAT(///5X,22HSMELT AND OTHERS  , M=,I3,10H  FISHERY,,F9.0,6H  T
               1ONS,F9.0,10H 1000 TONS//)
                CALL PRIAFF (P1,0)
                SUTAB(15,K)=SUM                                               003
          C **  **   **   **   **
          C     ATKA MACKEREL
            250 IF(LL-1)251,251,253
            251 IF(K-1)252,252,253
            252 CALL READMS (2,S1,780,106)
```

```
      GO TO 254
  253 CALL READMS (2,S1,790,107)
C     PRELIMINARY MIGRATION
  254 IF(5-K)255,258,270
  255 IF(6-K)256,258,270
  256 IF(10-K)257,259,270
  257 IF(11-K)270,259,270
  258 DO 260 N=1,NE
      DO 260 M=1,ME
      VR(N,M)=1.0
      UR(N,M)=1.0
  260 CONTINUE
      GO TO 262
  259 DO 261 N=1,NE
      DO 261 M=1,ME
      VR(N,M)=-1.0
      UR(N,M)=-1.0
  261 CONTINUE
  262 CALL PIPPAN (ISL,UR,VR,NE,ME)
      PP=0.4
      SS=50.   $ DD=2000.
      CALL RANPOK (ISL,SD,S1,S2,S3,PP,SS,DD,NE,ME)
      CALL RANNAK (S2,P1,ISL,UR,VR,NE,ME)
      DO 263 N=1,NE
      DO 263 M=1,ME
      P1(N,M)=P1(N,M)+S3(N,M)
  263 CONTINUE
      CALL ROUSET (P1,NE,ME)
C     OUTPUT OF MIGRATION RESULTS
      DO 264 N=1,NE
      DO 264 M=1,ME
      S1(N,M)=P1(N,M)-S1(N,M)
  264 CONTINUE
      PRINT 265,K
  265 FORMAT(//5X,49HINCR.-DECR. OF ATKA MACKEREL       DUE TO MIGR.,M=,I
     13//)
      CALL PRIAPP (S1,1)
      GO TO 267
  270 DO 266 N=1,NE
      DO 266 M=1,ME
      P1(N,M)=S1(N,M)
  266 CONTINUE
C     TEMP IS IN T1,T2 NOT, READ
  267 J=16
      KS=1   $ KFK=0
      CALL TOJAGS (E1,P2,FOT,NUK,J,K,KS,KFK)
      NF=NUK(1)*7
      CALL READMS (2,T2,790,NF)
      NF=NUK(2)*7
      CALL READMS (2,T3,790,NF)
      NF=NUK(3)*7
      CALL READMS (2,T4,790,NF)
      TMAX=12.   $  TMIN=4.
      CALL CYLTOT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
      ALP=0.82
      CALL SILITA (P1,ISL,NE,ME,ALP)
      JF=(J*7)-4
```

```
      CALL READMS (2,T2,780,JF)
      TA=1.25 $ TJ=0.01 $ TS=0.10
      TY=0.02 $ TK=175. $ SL=0.0035
      CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
      DLJ=J*7-2
      CALL WRITMS (2,T4,780,DLJ,1)
      JJ=1 $ INI=1 $ COVP=0.
      CALL PORTOS (JJ,INI,COVP,KEK,J)
C     KSK-MONTH OF MAIN SPAWNING
      KSK=7
      IF(KSK-K)271,272,271
  271 TSL=0.
      GO TO 273
  272 TSL=0.003
  273 CALL GROCER (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
C     FISHING MORTALITY
      FIM=0.006
      CALL PUGIMO (P1,S1,SU,SUM,FIM,NE,ME)
      CALL WRITMS (2,P1,780,107,1)
C     OUTPUTS
      PRINT 274,K,SU,SUM
  274 FORMAT(///5X,22HATKA MACKEREL      , M=,I3,10H  FISHERY,,F8.0,6H  T
     1ONS,F6.3,10H 1000 TONS//)
      CALL PRIAFP (P1,0)
      SLTAB(16,K)=SUM
C **  **  **  **  **
C     SALMON
  350 IF(LL-1)351,351,353
  351 IF(K-1)352,352,353
  352 CALL READMS (2,S1,780,113)
      GO TO 354
  353 CALL READMS (2,S1,780,114)
C     VERY PRELIMINARY NO MIGRATION
  354 GO TO 370
  370 DO 366 N=1,NE
      DO 366 M=1,ME
      P1(N,M)=S1(N,M)
  366 CONTINUE
C     TEMP IS IN T1, IF NOT, READ
  367 J=17
      KS=1 $ KEK=0
      CALL TOJACS (B1,B2,HOT,NUK,J,K,KS,KEK)
      NF=NUK(1)*7
      CALL READMS (2,T2,780,NF)
      NF=NUK(2)*7
      CALL READMS (2,T3,780,NF)
      NF=NUK(3)*7
      CALL READMS (2,T4,780,NF)
      TMAX=12. $ TMIN=2.
      CALL CYLTOT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,TSL)
      ALP=0.82
      CALL SILDIA (P1,TSL,NE,ME,ALP)
      JF=(J*7)-4
      CALL READMS (2,T2,780,JF)
      TA=1.25 $ TJ=0.015
      TS=0.10 $ TY=0.025
      TK=175. $ SL=0.002
```

75


```
      CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
      DIJ=J*7-2
      CALL WRITMS (2,T4,780,DIJ,1)
      JJ=1  $ INI=1  $ COVR=0.
      CALL PERTES (JJ,INI,COVR,KFK,J)
  371 TSL=0.
  373 CALL GROCER (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
C     FISHING MORTALITY
      FIM=0.05
      CALL PUSING (P1,S1,SU,SUM,FIM,NE,ME)
      CALL WRITMS (2,P1,780,114,1)
C     OUTPUTS
      PRINT 374,K,SU,SUM
  374 FORMAT(///5Y,22HSALMON          , M=,I3,10H  FISHERY,,F8.0,6H  T
     1ONS,F8.0,10H 1000 TONS//)
      CALL PRIAFP (P1,0)
      SUTAB(17,K)=SUM
C **   **   **   **   **
C     SQUIDS
  450 IF(LL-1)451,451,453
  451 IF(K-1)452,452,453
  452 CALL READMS (2,S1,780,120)
      GO TO 470
  453 CALL READMS (2,S1,780,121)
      GO TO 470
C     NO MIGRATION
  454 IF(5-K)455,458,470
  455 IF(6-K)456,458,470
  456 IF(10-K)457,459,470
  457 IF(11-K)470,459,470
  458 DO 460 N=1,NE
      DO 460 M=1,ME
      VR(N,M)=1.0
      UR(N,M)=1.0
  460 CONTINUE
      GO TO 462
  459 DO 461 N=1,NE
      DO 461 M=1,ME
      VR(N,M)=-1.0
      UR(N,M)=-1.0
  461 CONTINUE
  462 CALL PIRPAN (ISL,UR,VR,NE,ME)
      RP=0.2
      SS=100.  $ DD=2000.
      CALL RANPOR (ISL,S0,S1,S2,S3,RP,SS,DD,NE,ME)
      CALL RANNAK (S2,P1,TSL,UR,VR,NE,ME)
      DO 463 N=1,NE
      DO 463 M=1,ME
      P1(N,M)=P1(N,M)+S3(N,M)
  463 CONTINUE
      CALL BOUSET (P1,NE,ME)
C     OUTPUT OF MIGRATION RESULTS
      DO 464 N=1,NE
      DO 464 M=1,ME
      S1(N,M)=P1(N,M)-S1(N,M)
  464 CONTINUE
      PRINT 465,K
```

```
      465 FORMAT(//5X,49HINCR.-DECR. OF SQUIDS                    DUE TO MIGR.,M=,I
         13//)
          CALL PRIAFP (S1,1)
          GO TO 467
      470 DO 466 N=1,NE
          DO 466 M=1,ME
          P1(N,M)=S1(N,M)
      466 CONTINUE
C         TEMP IS IN T1, IF NOT, READ
      467 J=18
          KS=1   $ KEK=0
          CALL TCJAGS (B1,B2,CCT,NUK,J,K,KS,KEK)
          NE=NUK(1)*7
          CALL READMS (2,T2,780,NE)
          NE=NUK(2)*7
          CALL READMS (2,T3,780,NE)
          NE=NUK(3)*7
          CALL READMS (2,T4,780,NE)
          TMAX=12.  $  TMIN=4.
          CALL CYLTCI (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
          ALP=0.82
          CALL STLITA (P1,ISL,NE,ME,ALP)
          JE=(J*7)-4
          CALL READMS (2,T2,780,JE)
          TA=1.3   $ TJ=0.0135
          TS=0.15  $ TY=0.025
          TK=175.  $  SL=0.006
          CALL ASVNTS (P1,T1,T2,T3,T4,TA,TU,TS,TY,TK,SL,K,NE,ME)
          DLJ=J*7-2
          CALL WRITMS (2,T4,780,DLJ,1)
          JJ=1   $ INI=1 $ COVR=0.
          CALL PORTCS (JJ,INI,COVR,KEK,J)
C         KSK- MONTH OF MAIN SPAWNING
          KSK=8
          IF(KSK-K)471,472,471
      471 TSL=0.
          GO TO 473
      472 TSL=0.005
      473 CALL GRUCOR (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
C         FISHING MORTALITY
          FIM=0.0001
          CALL PUGINC (P1,S1,SU,SUM,FIM,NE,ME)
          CALL WRITMS (2,P1,780,121,1)
C         OUTPUTS
          PRINT 474,K,SU,SUM
      474 FORMAT(///5X,22HSQUIDS                 , M=,I3,10H  FISHERY,,F8.0,6H  T
         1ONS,F8.0,10H 1000 TONS//)
          CALL PRIAFP (P1,0)
          SUTAB(18,K)=SUM
          RETURN
          END
```

SUBROUTINE CRUSTA 73/73 OPT=1 FTN 4.6+460 07/3

```
      SUBROUTINE CRUSTA
      DIMENSION ISL(26,30),SD(26,30),UR(26,30),VR(26,30),SUTAB(30,12),
     1B1(30,30),B2(30,30),FOT(30),NUK(30),NS(50),
     2MS(50),S1(26,30),S2(26,30),S3(26,30),S4(26,30),S5(26,30),S6(26,30)
     3,P1(26,30),P2(26,30),P3(26,30),P4(26,30),P5(26,30),P6(26,30)
     4,T1(26,30),T2(26,30),T3(26,30),T4(26,30),T5(26,30),T6(26,30)
      COMMON ISL,SD,UR,VR,SUTAB,
     1B1,B2,FOT,NUK,NS,MS,
     2S1,S2,S3,S4,S5,S6,P1,P2,P3,P4,P5,P6,T1,T2,T3,T4,T5,T6,
     3K,LL,IZP,IZ1,IZ2,NE,ME,NU
     5,IN1(201),IN2(201)
      INTEGER DLJ
C     KING CRAB
C     TANNER CRAB
C     PANDALID SHRIMP
C **  **  **  **  **
C     KING CRAB
   50 IF(LL-1)51,51,53
   51 IF(K-1)52,52,53
   52 CALL READMS (2,S1,780,127)
      GO TO 54
   53 CALL READMS (2,S1,780,128)
C     SAME MIGRATION TIME AND SPEED FOR ALL CRABS IN INITIAL PROGRAM
   54 IF(5-K)55,59,70
   55 IF(6-K)56,59,70
   56 IF(10-K)57,59,70
   57 IF(11-K)70,59,70
   58 KE=1
      SS=40.  $ DD=600.
      CALL CRUSRA (ISL,UR,VR,SD,SS,DD,NE,ME,KE)       Migration speed
      GO TO 61                                        creation subroutine
   59 KE=2
      SS=40.  $ DD=400.
      CALL CRUSRA (ISL,UR,VR,SD,SS,DD,NE,ME,KE)
   61 RP=0.40
      CALL RANPOR (ISL,SD,S1,S2,S3,RP,SS,DD,NE,ME)
   62 CONTINUE
      CALL RANNAK (S2,P1,ISL,UR,VR,NE,ME)
      DO 63 N=1,NE
      DO 63 M=1,ME
      P1(N,M)=P1(N,M)+S3(N,M)
   63 CONTINUE
      CALL BOUSET (P1,NE,ME)
C     OUTPUT OF MIGRATION RESULTS
      DO 64 N=1,NE
      DO 64 M=1,ME
      S1(N,M)=P1(N,M)-S1(N,M)
   64 CONTINUE
      PRINT 65,K
   65 FORMAT(//5X,49HINCR.-DECR. OF KING CRAB          DUE TO MIGR.,M=,I
     13//)
      CALL PRTAER (S1,1)
      GO TO 67
   70 DO 66 N=1,NE
      DO 66 M=1,ME
      P1(N,M)=S1(N,M)
   66 CONTINUE
```

```
      C      TEMP IS IN T1, IF NOT, READ
          67 MM=72+K
             CALL READMS (1,T1,780,MM)
             J=19
             KS=1   $ KFK=0
             CALL TOJAGS (B1,B2,EOT,NUK,J,K,KS,KFK)
             NE=NUK(1)*7
             CALL READMS (2,T2,780,NE)
             NE=NUK(2)*7
             CALL READMS (2,T3,780,NE)
             NE=NUK(3)*7
             CALL READMS (2,T4,780,NE)
             TMAX=8.   $  TMIN=2.
             CALL CYLTOT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
             ALP=0.52
             CALL SILITA (P1,ISL,NE,ME,ALP)
             JE=(J*7)-4
             CALL READMS (2,T2,780,JE)
             TA=1.2  $  TJ=0.008
             TS=0.070  $  TY=0.01
             TK=175.   $  SL=0.003
             CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
             DLJ=J*7-2
             CALL WRITMS (2,T4,780,DLJ,1)
             JJ=1   $ INT=1   $ COVR=0.
             CALL PORTES (JJ,INT,COVR,KFK,J)
      C      KSK=MONTH OF MAIN SPAWNING
             KSK=4
             IF(KSK-K)71,72,71
          71 TSL=0.
             GO TO 73
          72 TSL=0.004
          73 CALL GROCER (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
      C      FISHING MORTALITY
             FIM=0.009
             CALL PUGIMO (P1,S1,SU,SUM,FIM,NE,ME)
             CALL WRITMS (2,P1,780,128,1)
      C      OUTPUTS
             PRINT 74,K,SU,SUM
          74 FORMAT(///5X,22HKING CRAB           , M=,I5,10H  FISHERY,,F8.0,6H  T
            1ONS,F8.0,10H 1000 TONS//)
             CALL PRIAEP (P1,0)
             SUTAB(19,K)=SUM
      C **   **   **   **   **
      C      TANNER CRAB
         150 IF(LL-1)151,151,153
         151 IF(K-1)152,152,153
         152 CALL READMS (2,S1,780,134)
             GO TO 154
         153 CALL READMS (2,S1,780,135)
      C      SAME MIGRATION TIME AND SPEED FOR ALL CRABS IN INITIAL PROGRAM
         154 IF(5-K)155,159,170
         155 IF(6-K)156,158,170
         156 IF(10-K)157,159,170
         157 IF(11-K)170,159,170
         158 KE=1
             SS=40.  $ DD=600.
```

```
      CALL CRUSRA (ISL,UR,VR,SD,SS,DD,NE,ME,KF)
      GO TO 161
  159 KE=2
      SS=40. $ DD=400.
      CALL CRUSRA (ISL,UR,VR,SD,SS,DD,NE,ME,KF)
  161 RP=0.30
      CALL RANPOR (ISL,SD,S1,S2,S3,RP,SS,DD,NE,ME)
  162 CONTINUE
      CALL RANNAK (S2,P1,ISL,UR,VR,NE,ME)
      DO 163 N=1,NE
      DO 163 M=1,ME
      P1(N,M)=P1(N,M)+S3(N,M)
  163 CONTINUE
      CALL BOUSET (P1,NE,ME)
C     OUTPUT OF MIGRATION RESULTS
      DO 164 N=1,NE
      DO 164 M=1,ME
      S1(N,M)=P1(N,M)-S1(N,M)
  164 CONTINUE
      PRINT 165,K
  165 FORMAT(//5X,49HINCR.-DECR. OF TANNER CRAB          DUE TO MIGR.,M=,I
     13//)
      CALL PRIAFP (S1,1)
      GO TO 167
  170 DO 166 N=1,NE
      DO 166 M=1,ME
      P1(N,M)=S1(N,M)
  166 CONTINUE
C     TEMP IS IN T1, IF NOT, READ
  167 J=20
      KS=1  $ KFK=0
      CALL TOJAGS (P1,P2,FDT,NUK,J,K,KS,KFK)
      NF=NUK(1)*7
      CALL READMS (2,T2,780,NF)
      NF=NUK(2)*7
      CALL READMS (2,T3,780,NF)
      NF=NUK(3)*7
      CALL READMS (2,T4,780,NF)
      TMAX=8.  $  TMIN=2.
      CALL CYLTCT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
      ALP=0.82
      CALL SILITA (P1,ISL,NE,ME,ALP)
      JF=(J*7)-6
      CALL READMS (2,T2,780,JF)
      TA=1.2  $  TJ=0.008
      TS=0.075  $  TY=0.01
      TK=175.  $  SL=0.0028
      CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
      DLJ=J*7-2
      CALL WRITMS (2,T4,780,DLJ,1)
      JJ=1   $ INI=1   $ COVR=0.
      CALL PORTLS (JJ,INI,COVR,KFK,J)
C     KSK- MONTH OF MAIN SPAWNING
      KSK=5
      IF(KSK-K)171,172,171
  171 TSL=0.
      GO TO 173
```

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      172 TSL=0.003
      173 CALL GROCOR (P1,T2,T3,TS,IY,TK,TSL,K,NE,ME)
C         FISHING MORTALITY
          FIM=0.005
          CALL PUSTMO (P1,S1,SU,SUM,FIM,NE,ME)
          CALL WRITMS (2,P1,780,135,1)
C         OUTPUTS
          PRINT 174,K,SU,SUM
      174 FORMAT(///5X,22HTANNER CRAB         , M=,I3,10H  FISHERY,,F8.0,6H  T
         1ONS,F8.0,10H 1000 TONS//)
          CALL PRIAFP (P1,0)
          SUTAB(20,K)=SUM
C **      **   **   **   **
C         PANDALID SHRIMP
      250 IF(LL-1)251,251,253
      251 IF(K-1)252,252,253
      252 CALL READMS (2,S1,780,141)
          GO TO 254
      253 CALL READMS (2,S1,780,142)
C         SAME MIGRATION TIME AND SPEED FOR ALL CRABS IN INITIAL PROGRAM
C*****
C** MIGRATION BYPASSED
          GO TO 270
      254 IF(5-K)255,258,270
      255 IF(6-K)256,258,270
      256 IF(10-K)257,259,270
      257 IF(11-K)270,259,270
      258 KE=1
          SS=40.   $ DD=600.
          CALL CRUSRA (ISL,UR,VR,SD,SS,DD,NE,ME,KE)
          GO TO 261
      259 KE=2
          SS=40.   $ DD=600.
          CALL CRUSRA (ISL,UR,VR,SD,SS,DD,NE,ME,KE)
      261 RP=0.30
          CALL PANPOF (ISL,SD,S1,S2,S3,RP,SS,DD,NE,ME)
      262 CONTINUE
          CALL PANNAK (S2,P1,TSL,UP,VP,NE,ME)
          DO 263 N=1,NE
          DO 263 M=1,ME
          P1(N,M)=P1(N,M)+S3(N,M)
      263 CONTINUE
          CALL BOUSET (P1,NE,ME)
C         OUTPUT OF MIGRATION RESULTS
          DO 264 N=1,NE
          DO 264 M=1,ME
          S1(N,M)=P1(N,M)-S1(N,M)
      264 CONTINUE
          PRINT 265,K
      265 FORMAT(//5X,49HINCR.-DECR. OF PANDALID SHRIMP    DUE TO MIGR.,M=,I
         13//)
          CALL PRIAFP (S1,1)
          GO TO 267
      270 DO 266 N=1,NE
          DO 266 M=1,ME
          P1(N,M)=S1(N,M)
      266 CONTINUE
```

81


```
      C     TEMP IS IN T1, IF NOT, READ
        267 J=21
            KS=1    $ KEK=0
            CALL TRJAGS (P1,P2,FOT,NUK,J,K,KS,KEK)
            NE=NUK(1)*7
            CALL READMS (2,T2,790,NE)
            NE=NUK(2)*7
            CALL READMS (2,T3,780,NE)
            NE=NUK(3)*7
            CALL READMS (2,T4,780,NE)
            TMAX=11.   $   TMIN=3.
            CALL CYLTLT (P1,T1,T2,T3,T4,TMAX,TMIN,NE,ME,ISL)
            ALP=0.82
            CALL SILITA (P1,TSL,NE,ME,ALP)
            JE=(J*7)-4
            CALL READMS (2,T2,780,JE)
            TA=1.2   $   TJ=0.005
            TS=0.07   $   TY=0.01
            TK=175.   $   SL=0.003
            CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
            DLJ=J*7-2
            CALL WRITMS (2,T4,790,DLJ,1)
            JJ=1    $ INI=1    $ COVR=0.
            CALL POPICS (JJ,INI,COVR,KEK,J)
      C     KSK- MONTH OF MAIN SPAWNING
            KSK=3
            IF(KSK-K)271,272,271
        271 TSL=0.
            GO TO 273
        272 TSL=0.003
        273 CALL GPECCR (P1,T2,T3,TS,TY,TK,TSL,K,NE,ME)
      C     FISHING MORTALITY
            FIM=0.0038
            CALL PUGINP (P1,S1,SU,SUM,FIM,NE,ME)
            CALL WRITMS (2,P1,780,142,1)
      C     OUTPUTS
            PRINT 274,K,SU,SUM
        274 FORMAT(///5X,22HPANDALID SHRIMP   , M=,I3,10H  FISHERY,,F8.0,6H  T
           1ONS,F8.0,10H 1000 TONS//)
            CALL PRIAFP (P1,0)
            SUTAB(21,K)=SUM
            RETURN
            END
```

```
      SUBROUTINE BENTOS
      DIMENSION ISL(26,30),SD(26,30),UR(26,30),VR(26,30),SUTAB(30,12),
     1B1(30,30),B2(30,30),FOT(30),NUK(30),NS(50),
     2MS(50),S1(26,30),S2(26,30),S3(26,30),S4(26,30),S5(26,30),S6(26,30)
     3,P1(26,30),P2(26,30),P3(26,30),P4(26,30),P5(26,30),P6(26,30)
     4,T1(26,30),T2(26,30),T3(26,30),T4(26,30),T5(26,30),T6(26,30)
      COMMON ISL,SD,UR,VR,SUTAB,
     1B1,B2,FOT,NUK,NS,MS,
     2S1,S2,S3,S4,S5,S6,P1,P2,P3,P4,P5,P6,T1,T2,T3,T4,T5,T6,
     3K,LL,IZ0,IZ1,IZ2,NE,ME,NU
     5,IN1(201),IN2(201)
      INTEGER DLJ
C     P1 - PREDATORY BENTHOS
C     P2 - INFAUNA
C     P3 - EPIFAUNA
C     READING BOTTOM TEMPERATURES INTO T1
      MM=84+K
      CALL READMS (1,T1,780,MM)
      IF(LL-1)1,1,3
    1 IF(K-1)2,2,3
    2 CALL READMS (2,P1,780,148)      Reading of initial or previous
      GO TO 4                         month biomass.
    3 CALL READMS (2,P1,780,149)
    4 CALL READMS (2,T2,780,150)
C     FOOD CONSUMPTION INTO T3
C     T4-GROWTH
C     PREDATORY BENTHOS
      J=22   $ KS=1   $ KFK=0                      Sorting & extraction
      CALL TOJAGS (B1,B2,FOT,NUK,J,K,KS,KFK)       of food composition
      TA=1.2   $ TJ=0.008
      TS=0.12   $ TY=0.032     Growth & food requirements parameters
      TK=175.    $ SL=0.004                                   Growth
      CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME) subroutine
      CALL WRITMS (2,T4,780,152,1)
      JJ=1   $ INI=1    $ COVR=0.
      JJ=1   $ INI=1   $ COVR=0.
      CALL PORTOS (JJ,INI,COVR,KFK,J)  Feeding subroutine
      CALL WRITMS (2,P1,780,149,1)
      KIK=1
      GO TO 31
C     INFAUNA
   32 CALL READMS (2,T2,780,157)
      IF(LL-1)34,34,36
   34 IF(K-1)35,35,36
   35 CALL READMS (2,P1,780,155)
      GO TO 37
   36 CALL READMS (2,P1,780,156)
   37 J=23   $ KS=1   $ KFK=0
      CALL TOJAGS (B1,B2,FOT,NUK,J,K,KS,KFK)
      TA=1.2   $ TJ=0.004
      TS=0.10    $ TY=0.02
      TK=175.    $ SL=0.004
      CALL ASVNTS(P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
      CALL WRITMS (2,T4,780,159,1)
      JJ=1    $ INI=1     $ COVR=0.
      JJ=1   $ INI=1   $ COVR=0.
      CALL PORTOS (JJ,INI,COVR,KFK,J)
```

```
      CALL WRITMS (2,P1,780,156,1)
      KIK=2
      GO TO 31
C     EPIFAUNA
   33 CALL READMS (2,T2,780,164)
      IF(LL-1)38,38,40
   38 IF(K-1)39,39,40
   39 CALL READMS (2,P1,780,162)
      GO TO 41
   40 CALL READMS (2,P1,780,163)
   41 J=24   $ KS=1   $ KEK=0
      CALL TOJAGS (B1,B2,EOT,NUK,J,K,KS,KEK)
      TA=1.3   $ TJ=0.006
      TS=0.10     $ TY=0.02
      TK=175.     $ SL=0.003
      CALL ASVNTS (P1,T1,T2,T3,T4,TA,TJ,TS,TY,TK,SL,K,NE,ME)
      CALL WRITMS (2,T4,780,166,1)
      JJ=1        $ INI=1       $ COVR=0.
      CALL PORTOS (JJ,INI,COVR,KEK,J)
      CALL WRITMS (2,P1,780,163,1)
      KIK=3
C     PRINTING, SUMMATION
   31 SU1=0.
      AR=18.5*18.5
      ARR=AR/1000.
      DO 21 N=1,NE
      DO 21 M=1,ME
      IF(ISL(N,M))21,21,22
   22 S1(N,M)=P1(N,M)/1000.
      SU1=SU1+S1(N,M)*ARR
   21 CONTINUE
      GO TO (43,44,45),KIK
   43 PRINT 23,K,SU1
   23 FORMAT(///5X,30HPREDATORY BENTHOS, TON/KM2, M=,I3,11H 1000 TONS,
     1F8.0//)
      CALL PRIAEP(S1,J)
      SUTAB(22,K)=SU1
      GO TO 32
   44 PRINT 24,K,SU1
   24 FORMAT(///5X,20HINFAUNA, TON/KM2, M=,I3,11H 1000 TONS,F8.0//)
      CALL PRIAEP(S1,1)
      SUTAB(23,K)=SU1
      GO TO 33
   45 PRINT 25,K,SU1
   25 FORMAT(///5X,21HEPIFAUNA, TON/KM2, M=,I3,11H 1000 TONS, F8.0//)
      CALL PRIAEP(S1,1)
      SUTAB(24,K)=SU1
      RETURN
      END
```

```
      SUBROUTINE PLANKT
      DIMENSION ISL(26,30),SD(26,30),UR(26,30),VR(26,30),SUTAB(30,12),   002
     1B1(30,30),B2(30,30),FOT(30),NUK(30),NS(50),
     2MS(50),S1(26,30),S2(26,30),S3(26,30),S4(26,30),S5(26,30),S6(26,30)
     3,P1(26,30),P2(26,30),P3(26,30),P4(26,30),P5(26,30),P6(26,30)
     4,T1(26,30),T2(26,30),T3(26,30),T4(26,30),T5(26,30),T6(26,30)
      COMMON ISL,SD,UR,VR,SUTAB,                                         002
     1B1,B2,FOT,NUK,NS,MS,
     2S1,S2,S3,S4,S5,S6,P1,P2,P3,P4,P5,P6,T1,T2,T3,T4,T5,T6,
     3K,LL,IZP,IZ1,IZ2,NE,ME,NU
     5,IN1(201),IN2(201)                                                 000
      COMMON /PLNK/ZOO(10),ZOM(10),ZOMS(10),ZKAP(10),PYZO(10),
     1PYZM(10),PYZMM(10),PKAP(10),ZKAS(10)
      DATA ZOO/420.,420.,420.,420.,420.,420.,420.,360.,360.,330./,
     1ZOM/80.,80.,80.,80.,80.,80.,80.,75.,75.,70./,
     2ZOMS/55.,55.,55.,55.,55.,55.,55.,45.,45.,35./,
     3ZKAP/188.,188.,188.,188.,188.,188.,188.,195.,195.,205./,
     4PYZO/1850.,1850.,1850.,1850.,1850.,1850.,1850.,1700.,1700.,1400./,
     5PYZM/600.,600.,600.,600.,600.,600.,600.,700.,700.,650./,
     6PYZMM/180.,180.,180.,180.,180.,180.,180.,120.,120.,100./,
     7PKAP/180.,180.,180.,180.,180.,180.,180.,185.,185.,190./,
     8ZKAS/275.,275.,275.,275.,275.,275.,275.,285.,285.,295./
C     UNITS IN MG/M3
C     RADFA - CONVERSION FACTOR FROM DEGRESS TO RADIANS
C     PKAP   ZKAP- PHASE LAGS
C     ZOO ZOM ZOMS - ZOOPLANKTON PARAMETERS
C     PYZO PYZM PYZMM - PHYTOPLANKTON PARMETERS
C     ALP  ALPP - PHASE SPEEDS
C     ZOOPLANKTON CONSISTS OF 65 P.C. COPEPODS AND 35 P.C. EUPHAUSIDS
C     IZPL-PRINT INDICATOR
      T=K
      RADFA=0.0174533
      ALP=30.*RADFA
      ALPP=60.*RADFA
      PYP=1500.
      IZPL=1
      CALL READMS(2,S1,780,172)        Copepods, consumption
      CALL READMS(2,S2,780,179)        Euphausids, consumption
      CALL READMS(2,S3,780,186)        Phytoplankton, consumption
      DO 10 N=1,NE
      DO 10 M=1,ME
      IF(ISL(N,M))10,10,11
   11 I=ISL(N,M)                       Sum of copepods and euphausids
      S4(N,M)=S1(N,M)+S2(N,M)          (zooplankton)
      PKP=PKAP(I)*RADFA        Setting of phase lag
      ZKP=ZKAP(I)*RADFA
      ZKPP=ZKAS(I)*RADFA
      PLP=PYZO(I)*1.8          Tuning of phytoplankton standing crop
      P1(N,M)=PLP+PYZM(I)*COS(ALP*T-PKP)+PYZMM(I)*SIN(ALPP*T-ZKPP)       002
      S5(N,M)=ZOO(I)*1.8+ZOM(I)*COS(ALP*T-ZKP)+ZOMS(I)*SIN(ALPP*T-ZKPP)
C*** ADD PHYTOPLANKTON CONSUMPTION BY ZOOPLANKTON (100M DEPTH DISTR.)     002
      S3(N,M)=S5(N,M)*1.2*60.+S3(N,M)
      P2(N,M)=S3(N,M)/(P1(N,M)*60.)*100. Percent phytoplankton consumed
      S4(N,M)=S1(N,M)+S2(N,M)          Zooplankton consumption           002
      S6(N,M)=S4(N,M)/(S5(N,M)*60.)*100. Percent zooplankton consumed
   10 CONTINUE
      CALL WRITMS (2,S3,780,186,1)                                        004
```

```
      DO 31 N=1,NE                                                          00404
      DO 31 M=1,ME                                                          00405
      P3(N,M)=0.4*S5(N,M)*100.   Separation of copepods and                 00224
      P4(N,M)=0.6*S5(N,M)*100.       euphausids                             00225
      P5(N,M)=0.62*S6(N,M)/100.  Percent copepods & euphausids
      P6(N,M)=0.38*S6(N,M)/100.      consumed
      S3(N,M)=P1(N,M)*60.        Phytoplankton biomass
   31 CONTINUE                                                              0042
C     ONLY 70 PCT. ZOOPL. CONSUMPTION ACCOUNTED                             0041
      CALL WRITMS (2,P5,780,175,1)
      CALL WRITMS (2,P6,780,182,1)
      CALL WRITMS (2,P4,780,170,1)                                          0041
      CALL WRITMS (2,P3,780,177,1)
      CALL WRITMS (2,S3,780,184,1)                                          0023
      IF(IZPL)12,12,14
   14 PRINT 15,K
   15 FORMAT(///5X,29HZOOPLANKTON BIOMASS, MG/M3 M=,I3//)
      CALL PRIAFP (S5,0)
      PRINT 16,K
   16 FORMAT(///5X,26HPERCENT ZOOPL. CONSUMED M=,I3//)
      CALL PRIAFP (S6,0)
      PRINT 17,K
   17 FORMAT(///5X,31HPHYTOPLANKTON BIOMASS, MG/M3 M=,I3//)
      CALL PRIAFP (P1,0)
      PRINT 18,K
   18 FORMAT(///5X,29HPERCENT PHYTOPL. CONSUMED, M=,I3//)
      CALL PRIAFP (P2,0)
   12 RETURN
      END
```

SUBROUTINE ASVNTS 73/73 OPT=1 FTN 4.6+460 07/3

```
      SUBROUTINE ASVNTS (D1,E1,E2,E3,E4,TOA,TOJ,TKA,AA,PL,SV,K,NE,ME)
      DIMENSION D1(26,30),E1(26,30),E2(26,30),E3(26,30),E4(26,30)
C     D1-P1-SPECIES
C     E1-T1-TEMPERATURE
C     E2-T2-CONSUMPTION,PREVIOUS MONTH
C     E3-T3-FOOD CONSUMPTION (REQUIREMENT),FOR FOOD SUPP. (KG/KM2)
C     E4-T4-GROWTH (KG/KM2), FOR COMP. OF SOURCE-SINK(INCL.NAT.MORT.)
C     TOA-TA-FOOD COEFFICIENT FOR GROWTH IN FORM OF RATIO
C     TOJ-TJ-FOOD COEFFICIENT FOR MAINTENANCE PERCENT OF BW DAILY
C     TKA-TS-GROWTH COEFFICIENT (ANNUAL MEAN)
C     AA-TY-HALF MAGNITUDE OF ANNUAL CHANGE OF GROWTH
C     PL-TK-PHASE LAG OF MAXIMUM GROWTH
C     SV-SL-COEFFICIENT OF MORTALITY FROM OLD AGE AND DISEASES
C********************
C     IF TOA(TA) IS NOT GIVEN (IN FORM OF RATIO), COMPUTE WITH TJ ONLY
      RAD=0.01745329
      ALPA=30.*RAD
      GKAP=PL*RAD
```

Setting of parameters

```
      TKG=TKA+AA*COS(ALPA*K-GKAP)
      DO 60 N=1,NE
      DO 60 M=1,ME
      TKP=TKG $ TOS=TOJ $ TOB=TOA $ SUS=SV
      IF(E1(N,M)-30.)24,23,23
   23 E1(N,M)=-50.+E1(N,M)
   24 IF(E1(N,M)-4.)25,22,22
   25 TKP=TKG-TKG*ABS((E1(N,M)-4.)/7.)
      TOS=TOJ-TOJ*ABS((E1(N,M)-4.)/8.)
      SUS=SV+SV*ABS((E1(N,M)-4.)/8.)
      IF(TOA)22,22,26
   26 TOB=TOA-TOA*ABS((E1(N,M)-4.)/8.)
```

Adjustment of growth parameters, ~~including temperature effects~~

```
C     STATEMENT 22 COMPUTES GROWTH ONLY
   22 E4(N,M)=(D1(N,M)*(2.-EXP(-TKP)))*EXP(-SUS)-D1(N,M)
```

Growth comp.

```
C     NEXT STATEMENT COMPUTES BIOMASS (GROWTH-CONS.+ORIGINAL BIOMASS)
      D1(N,M)=E4(N,M)-E2(N,M)+D1(N,M)
      IF(TOA)27,27,28
   27 E3(N,M)=D1(N,M)*30.*TOS
```

Computation of monthly total food requirement

```
      GO TO 60
   28 E3(N,M)=D1(N,M)*30.*TOS+E4(N,M)*TOB
   60 CONTINUE
  100 RETURN
      END
```

```
      SUBROUTINE TOJAGS (B1,B2,FDT,NUK,J,K,KS,KFK)
      DIMENSION B1(30,30),B2(30,30),FDT(30),NUK(30)
C     FDT- PERCENTAGE OF FOOD ITEM IN DIET
C     NUK- FOOD ITEM NUMBER (1 TO 30)
C     J- SPECIES NUMBER
C     B1, B2 - SEASONAL FOOD TABLES
C     N IS SPECIES NUMBER , M IS FOOD ITEM NUMBER
C     FIELD CONTAINS FOOD COMPOSITION IN PERCENT
C     C1- JAN(1), C2- APR(4), C3- JUL(7), C4- OCT(10)
C     KFK - NUMBER OF FOOD ITEMS
C     KS - NUMBER OF SEASONAL FOOD TABLES
      DO 41 N=1,30                                            004
      NUK(N)=0                                                004
      FDT(N)=0.                                               004
   41 CONTINUE                                                004
      IF(KS-1)23,30,31
   30 CALL READMS (1,B1,900,109)
      GO TO 32
   31 GO TO (1,2,3,4,5,6,7,8,9,10,11,12),K
    1 CALL READMS (1,B1,900,109)
      GO TO 19
    2 CALL READMS (1,B1,900,109)
      CALL READMS (1,B2,900,110)
      AG=0.33                Interpolation between
      GO TO 13               seasonal food
    3 CALL READMS (1,B1,900,109)   composition tables
      CALL READMS (1,B2,900,110)
      AG=0.66
      GO TO 13
    4 CALL READMS (1,B1,900,110)
      GO TO 19
    5 CALL READMS (1,B1,900,110)
      CALL READMS (1,B2,900,111)
      AG=0.33
      GO TO 13
    6 CALL READMS (1,B1,900,110)
      CALL READMS (1,B2,900,111)
      AG=0.66
      GO TO 13
    7 CALL READMS (1,B1,900,111)
      GO TO 19
    8 CALL READMS (1,B1,900,111)
      CALL READMS (1,B2,900,112)
      AG=0.33
      GO TO 13
    9 CALL READMS (1,B1,900,111)
      CALL READMS (1,B2,900,112)
      AG=0.66
      GO TO 13
   10 CALL READMS (1,B1,900,112)
      GO TO 19
   11 CALL READMS (1,B1,900,112)
      CALL READMS (1,B2,900,109)
      AG=0.33
      GO TO 13
   12 CALL READMS (1,B1,900,112)
      CALL READMS (1,B2,900,109)
```

SUBROUTINE TOJAGS 73/73 OPT=1 FTN 4.6+460 07/3

```
      AG=0.66
   13 DO 14 N=1,30
      DO 14 M=1,30
      AST=B1(N,M)-B2(N,M)
      B1(N,M)=B1(N,M)-AG*AST
   14 CONTINUE
   30 CONTINUE
      KFK=0
   19 LM=1
   20 SUT=0.
      DO 25 N=1,30
   25 SUT=SUT+B1(J,N)
      IF(SUT)29,28,26
   26 FOT(LM)=AMAX1(B1(J,1),B1(J,2),B1(J,3),B1(J,4),B1(J,5),B1(J,6),
     2B1(J,7),B1(J,8),B1(J,9),B1(J,10),B1(J,11),B1(J,12),B1(J,13),
     3B1(J,14),B1(J,15),B1(J,16),B1(J,17),B1(J,18),B1(J,19),B1(J,20),
     4B1(J,21),B1(J,22),B1(J,23),B1(J,24),B1(J,25),B1(J,26),B1(J,27),
     5B1(J,28),B1(J,29),B1(J,30))
      DO 21 N=1,30
      IF(FOT(LM)-B1(J,N))21,22,21
   22 NUK(LM)=N
      B1(J,N)=0.
   21 CONTINUE
      KFK=KFK+1
      GO TO 27
   28 NUK(LM)=30
      GO TO 23                                                      004
   27 LM=LM+1
      IF(30-LM)23,20,20
   23 RETURN
      END
```

Sorting of food composition in order of percentual amount. NUK contains food item number and FOF contains percentual amount.

```
      SUBROUTINE PORTOS (JJ,INI,COVR,KFK,J)                                002
      DIMENSION ISL(26,30),SD(26,30),UR(26,30),VR(26,30),SUTAB(30,12),     002
     1B1(30,30),B2(30,30),FOT(30),NUK(30),NS(50),
     2MS(50),S1(26,30),S2(26,30),S3(26,30),S4(26,30),S5(26,30),S6(26,30)
     3,P1(26,30),P2(26,30),P3(26,30),P4(26,30),P5(26,30),P6(26,30)
     4,T1(26,30),T2(26,30),T3(26,30),T4(26,30),T5(26,30),T6(26,30)
      COMMON ISL,SD,UR,VR,SUTAB,                                           002
     1B1,B2,FOT,NUK,NS,MS,
     2S1,S2,S3,S4,S5,S6,P1,P2,P3,P4,P5,P6,T1,T2,T3,T4,T5,T6,
     3K,LL,IZP,IZ1,IZ2,NE,ME,NU
     5,IN1(201),IN2(201)                                                   000
C     JJ,INI - COUNTERS
C     COVR - CARRYOVER,LACK OF FOOD FROM PREVIOUS TOIFOC CALL
C     KFK - NUMBER OF FOOD ITEMS, FROM TOJAGS
C     KNK NUMBER OF FOOD ITEMS INTO TOIFOOD
      KNK=0
      COVR=0.
      KNKN=KFK
    9 DO 10 N=1,NE
      DO 10 M=1,ME
      T2(N,M)=0.
      P2(N,M)=T3(N,M)
   10 CONTINUE
   40 KBK=NUK(JJ)*7
      KAK=KBK-3
      CALL READMS (2,S1,780,KAK)
      CALL READMS (2,T5,780,KBK)
      KNK=KNK+1
      FC1=FOT(JJ)
      KFK=KFK-1
      IF(KFK)100,20,11
   11 KBK=NUK(JJ+1)*7
      KAK=KBK-3
      CALL READMS (2,S2,780,KAK)
      CALL READMS (2,T6,780,KBK)
      KNK=KNK+1
      FC2=FOT(JJ+1)
      KFK=KFK-1
      IF(KFK)100,20,12
   12 KBK=NUK(JJ+2)*7
      KAK=KBK-3
      CALL READMS (2,S3,780,KAK)
      CALL READMS (2,P4,780,KBK)
      KNK=KNK+1
      FC3=FOT(JJ+2)
      KFK=KFK-1
      IF(KFK)100,20,13
   13 KBK=NUK(JJ+3)*7
      KAK=KBK-3
      CALL READMS (2,S4,780,KAK)
      CALL READMS (2,P5,780,KBK)
      KNK=KNK+1
      FC4=FOT(JJ+3)
      KFK=KFK-1
      IF(KFK)100,20,14
   14 KBK=NUK(JJ+4)*7
      KAK=KBK-3
```

Reading of percent of food item consumed in previous month and actual month consumption for five food items

```
SUBROUTINE PORTOS      73/73    OPT=1                                FTN 4.6+460          08/04

          CALL READMS (2,S5,780,KAK)
          CALL READMS (2,P6,780,KBK)
          KNK=KNK+1
          FC5=FOT(JJ+4)                     Calling of feeding subroutine
          KFK=KFK-1                         proper.(Parameter list see TOIFOO
       20 JJ=INI*5-4                        subroutine)
       42 KNKN=KNK
       30 CALL TOIFOO(P1,T1,I2,T3,T4,S1,S2,S3,S4,S5,T5,T6,P4,P5,P6,INI,NE,   0042
         1ME,FC1,FC2,FC3,FC4,FC5,NUK,COVR,KNK)
          JJ=INI*5-4
          KAK=NUK(JJ)*7-3
          CALL WRITMS (2,S1,780,KAK,1)
          IF(KNKN-1)36,36,32
       32 KAK=NUK(JJ+1)*7-3                 Writing of actual month
          CALL WRITMS (2,S2,780,KAK,1)      consumption on disc
          IF(KNKN-2)36,36,33
       33 KAK=NUK(JJ+2)*7-3
          CALL WRITMS (2,S3,780,KAK,1)
          IF(KNKN-3)36,36,34
       34 KAK=NUK(JJ+3)*7-3
          CALL WRITMS (2,S4,780,KAK,1)
          IF(KNKN-4)36,36,35
       35 KAK=NUK(JJ+4)*7-3
          CALL WRITMS (2,S5,780,KAK,1)
       36 INI=INI+1
          IF(KFK)38,38,37
       37 KNKN=KFK
       19 JJ=INI*5-4
          GO TO 40
C         WRITING STARVATION FIELD
       38 JSF=(J*7)-1                                                          002
          CALL WRITMS (2,T2,780,JSF,1)                                         002
          DO 51 N=1,NE
          DO 51 M=1,ME                       Summation of starvation
          COVR=COVR+T2(N,M)/1000.
          T3(N,M)=P2(N,M)
       51 CONTINUE
          PRINT 52,J,COVR
       52 FORMAT(///5X,20HTOT. STARV., SPECIES,I3,5HTONS ,F8.2//)
      100 RETURN
          END
```

```
      SUBROUTINE TOIFOO (Z1,H1,H2,H3,H4,R1,R2,R3,R4,R5,X2,X3,X4,X5,X6,
     1INI,NE,ME,FK1,FK2,FK3,FK4,FK5,NUK,COVR,KNK)
      DIMENSION Z1(26,30),H1(26,30),H2(26,30),H3(26,30),H4(26,30),
     1R1(26,30),R2(26,30),R3(26,30),R4(26,30),R5(26,30),X2(26,30),
     2X3(26,30),X4(26,30),X5(26,30),X6(26,30),NUK(30)
C     Z1-P1 SPECIES
C     H1-T1 OPERATIONAL FIELD (FOR X FIELDS)
C     H2-T2 STARVATION (KG/KM2 FOOD SHORTAGE)
C     H3-T3 FOOD CONSUMPTION (REQUIREMENT) FROM ASVNTS SUBR.
C     H4-T4 OPERATIONAL FIELD (FOR R FIELDS)
C     R1-S1  //
C     R2-S2  //
C     R3-S3 FOOD ITEM CONSUMPTION FIELDS (ACTUAL MONTH)
C     R4-S4  //
C     R5-S5  //
C     X2-P2  ***
C     X3-P3  ***
C     X4-P4 FRACTION OF FOOD ITEMS CONSUMED (PREVIOUS MONTH)
C     X5-P5  ***
C     X6-P6  ***
C     INI - INDEX (SEQUENTIAL NUMBER OF SUBROUTINE CALL )
C     FK1-FC1 ////
C     FK2-FC2 ////
C     FK3-FC3 PERCENTAGE OF GIVEN FOOD ITEM IN DIET
C     FK4-FC4 ////
C     FK5-FC5 ////
C     COVR- CARRY OVER - LACK OF FOOD FROM PREVIOUS TOIFOO CALL
C     NUK- ITEM NUMBER (IDENTIFIER OF FOOD ITEM )
      IK=1
    9 II=INI*5-5+IK
C     IK- SPECIES BEING CONSUMED (5 SPECIES IN ORDER OF PREFERENCE)
   10 CONTINUE
      GO TO (21,22,23,24,25),IK
   21 DO 11 N=1,NE
      DO 11 M=1,ME                Setting fraction of food item
      H1(N,M)=X2(N,M)             consumed in previous month and
      H4(N,M)=R1(N,M)             food item consumption in actual
   11 CONTINUE                    month into operational arrays
      FK=FK1
      GO TO 20
   22 DO 12 N=1,NE
      DO 12 M=1,ME
      H1(N,M)=X3(N,M)
      H4(N,M)=R2(N,M)
   12 CONTINUE
      FK=FK2
      GO TO 20
   23 DO 13 N=1,NE
      DO 13 M=1,ME
      H1(N,M)=X4(N,M)
      H4(N,M)=R3(N,M)
   13 CONTINUE
      FK=FK3
      GO TO 20
   24 DO 14 N=1,NE
      DO 14 M=1,ME
      H1(N,M)=X5(N,M)
```

```
      H4(N,M)=R4(N,M)
   14 CONTINUE
      FK=FK4
      GO TO 20
   25 DO 15 N=1,NE
      DO 15 M=1,ME
      H1(N,M)=X6(N,M)
      H4(N,M)=R5(N,M)
   15 CONTINUE
      FK=FK5
   20 CONTINUE
C     FOOD SPECIES GROUP DETERMINATION
      IF(NUK(II)-11)50,100,2
    2 IF(NUK(II)-15)50,100,3
    3 IF(NUK(II)-17)100,50,6
    6 IF(NUK(II)-18)50,100,7
    7 IF(NUK(II)-23)50,200,4
    4 IF(NUK(II)-24)50,200,5
    5 IF(NUK(II)-27)300,300,50
C     FISH GROUP (GENERAL)
   50 A1=0.1          $ A2=0.15   $ A3=0.19   $ A4=0.22   $ A5=0.22
      B1=1.0          $ B2=0.62   $ B3=0.33   $ B4=0.20   $ B5=0.10
      C1=0.0          $ C2=0.38   $ C3=0.67   $ C4=0.80   $ C5=0.90
      D1=0.20         $ D2=0.10   $ D3=0.05   $ D4=0.02   $ D5=0.01
      GO TO 30
C     SMELTS, COTTIDS AND OTHERS
  100 A1=0.12         $ A2=0.20   $ A3=0.24   $ A4=0.28   $ A5=0.28
      B1=1.0          $ B2=0.65   $ B3=0.38   $ B4=0.20   $ B5=0.10
      C1=0.0          $ C2=0.35   $ C3=0.62   $ C4=0.80   $ C5=0.90
      D1=0.25         $ D2=0.12   $ D3=0.08   $ D4=0.03   $ D5=0.02
      GO TO 30
C     BENTHOS
  200 A1=0.15         $ A2=0.23   $ A3=0.30   $ A4=0.35   $ A5=0.35
      B1=1.0          $ B2=0.70   $ B3=0.45   $ B4=0.25   $ B5=0.10
      C1=0.0          $ C2=0.30   $ C3=0.55   $ C4=0.75   $ C5=0.90
      D1=0.30         $ D2=0.15   $ D3=0.08   $ D4=0.04   $ D5=0.02
      GO TO 30
C     PLANKTON
  300 A1=0.20         $ A2=0.30   $ A3=0.40   $ A4=0.50   $ A5=0.50
      B1=1.0          $ B2=0.78   $ B3=0.55   $ B4=0.35   $ B5=0.20
      C1=0.0          $ C2=0.22   $ C3=0.45   $ C4=0.65   $ C5=0.80
      D1=0.40         $ D2=0.20   $ D3=0.09   $ D4=0.05   $ D5=0.03
   30 DO 500 N=1,NE  $  DO 500 M=1,ME
      IF(H1(N,M)-A1)51,51,52
   51 EATS=H3(N,M)*0.01*FK
      EAT=B1*EATS
      IF(H2(N,M)-D1*EATS)53,53,54
   53 H4(N,M)=H4(N,M)+EAT+H2(N,M)
      H2(N,M)=H2(N,M)+C1*EATS
      H3(N,M)=H3(N,M)-H2(N,M)
      GO TO 500
   54 H4(N,M)=H4(N,M)+EAT+D1*EATS
      H2(N,M)=H2(N,M)-D1*EATS+C1*EATS
      H3(N,M)=H3(N,M)-D1*EATS
      GO TO 500
   52 IF(H1(N,M)-A2)55,55,56
   55 EATS=H3(N,M)*0.01*FK
```

Consumption criteria tables (see in list of input parameters for explanation)

```
      EAT=B2*EATS
      IF(H2(N,M)-D2*EATS)57,57,58
   57 H4(N,M)=H4(N,M)+EAT+H2(N,M)
      H2(N,M)=H2(N,M)+C2*EATS
      H3(N,M)=H3(N,M)-H2(N,M)
      GO TO 500
   58 H4(N,M)=H4(N,M)+EAT+D2*EATS
      H2(N,M)=H2(N,M)-D2*EATS+C2*EATS
      H3(N,M)=H3(N,M)-D2*EATS
      GO TO 500
   56 IF(H1(N,M)-A3)59,59,60
   59 EATS=H3(N,M)*0.01*FK
      EAT=B3*EATS
      IF(H2(N,M)-D3*EATS)61,61,62
   61 H4(N,M)=H4(N,M)+EAT+H2(N,M)
      H2(N,M)=H2(N,M)+C3*EATS
      H3(N,M)=H3(N,M)-H2(N,M)
      GO TO 500
   62 H4(N,M)=H4(N,M)+EAT+D3*EATS
      H2(N,M)=H2(N,M)-D3*EATS+C3*EATS
      H3(N,M)=H3(N,M)-D3*EATS
      GO TO 500
   60 IF(H1(N,M)-A4)63,63,64
   63 EATS=H3(N,M)*0.01*FK
      EAT=B4*EATS
      IF(H2(N,M)-D4*EATS)65,65,66
   65 H4(N,M)=H4(N,M)+EAT+H2(N,M)
      H2(N,M)=H2(N,M)+C4*EATS
      H3(N,M)=H3(N,M)-H2(N,M)
      GO TO 500
   66 H4(N,M)=H4(N,M)+EAT+D4*EATS
      H2(N,M)=H2(N,M)-D4*EATS+C4*EATS
      H3(N,M)=H3(N,M)-D4*EATS
      GO TO 500
   64 EATS=H3(N,M)*0.01*FK
      EAT=B5*EATS
      IF(H2(N,M)-D5*EATS)67,67,68
   67 H4(N,M)=H4(N,M)+EAT+H2(N,M)
      H2(N,M)=H2(N,M)+C5*EATS
      H3(N,M)=H3(N,M)-H2(N,M)
      GO TO 500
   68 H4(N,M)=H4(N,M)+EAT+D5*EATS
      H2(N,M)=H2(N,M)-D5*EATS+C5*EATS
      H3(N,M)=H3(N,M)-D5*EATS
  500 CONTINUE
```

Computation of individual food item consumption, substitution, and possible starvation (criteria see input parameters and criteria tables)

```
      GO TO (501,502,503,504,505),IK
  501 DO 511 N=1,NE
      DO 511 M=1,ME
      X2(N,M)=H1(N,M)
      R1(N,M)=H4(N,M)
  511 CONTINUE
      GO TO 520
  502 DO 512 N=1,NE
      DO 512 M=1,ME
      X3(N,M)=H1(N,M)
      R2(N,M)=H4(N,M)
  512 CONTINUE
```

Return of data from operational arrays to storage and transfer arrays

```
      GO TO 520
  503 DO 513 N=1,NE
      DO 513 M=1,ME
      X4(N,M)=H1(N,M)
      R3(N,M)=H4(N,M)
  513 CONTINUE
      GO TO 520
  504 DO 514 N=1,NE
      DO 514 M=1,ME
      X5(N,M)=H1(N,M)
      R4(N,M)=H4(N,M)
  514 CONTINUE
      GO TO 520
  505 DO 515 N=1,NE
      DO 515 M=1,ME
      X6(N,M)=H1(N,M)
      R5(N,M)=H4(N,M)
  515 CONTINUE
  520 IK=IK+1
      KNK=KNK-1
      IF(KNK)521,521,9
  521 RETURN
      END
```

```
SUBROUTINE PLASRA     73/73   OPT=1                                FTN 4.6+460        07/

      SUBROUTINE PLASRA (ISL,UR,VR,SD,SS,DD,NE,ME,KE)
      DIMENSION ISL(26,30),UR(26,30),VR(26,30),SD(26,30)
C     SPRING MIGRATION SPEED OF FLATFISH
C     SS SHALLOWEST DEPTH OF NO MIGRATION
C     DD DEEPEST DEPTH OF NO MIGRATION
C     KE SEASON INDICATOR, KE=1 - SPRING , KE=2 - FALL
      DO 10 N=1,NE
      DO 10 M=1,ME
      IF(ISL(N,M))10,10,11
   11 IF(SD(N,M)-SS)12,12,13
   12 UR(N,M)=0.
      VR(N,M)=0.
      GO TO 10
   13 IF(SD(N,M)-DD)14,14,12
   14 IF(KE-1)10,15,17
   15 IF(ISL(N,M)-4)10,16,16
   16 UR(N,M)=0.6
      VR(N,M)=0.6
      GO TO 10
   17 IF(ISL(N,M)-4)10,18,18
   18 UR(N,M)=-0.6
      VR(N,M)=-0.6
   10 CONTINUE
      CALL PIRRAM (ISL,UR,VR,NE,ME)
      RETURN
      END
```

Seasonal depth migration speed creation for flatfish (called in DEMFISH)

SUBROUTINE CRUSRA   73/73   OPT=1   FTN 4.6+460   07/31

```
      SUBROUTINE CRUSRA (ISL,UR,VR,SD,SS,DD,NE,ME,KE)
      DIMENSION ISL(26,30),UR(26,30),VR(26,30),SD(26,30)
C     MIGRATION SPEEDS OF CRUSTACEANS
      DO 10 N=1,NE  $ DO 10 M=1,ME
      IF(ISL(N,M))10,10,11
   11 IF(SD(N,M)-SS)12,12,13
   12 UR(N,M)=0.
      VR(N,M)=0.
      GO TO 10
   13 IF(SD(N,M)-DD)14,14,12
   14 IF(KE-1)10,15,22
   15 IF(ISL(N,M)-2)10,16,17
   16 UR(N,M)=0.7  $ VR(N,M)=0.0
      GO TO 10
   17 IF(ISL(N,M)-4)10,18,19
   18 UR(N,M)=0.0  $ VR(N,M)=0.8
      GO TO 10
   19 IF(ISL(N,M)-7)20,21,20
   20 UR(N,M)=0.6  $ VR(N,M)=0.6
      GO TO 10
   21 UR(N,M)=0.7  $ VR(N,M)=0.0
      GO TO 10
   22 IF(ISL(N,M)-2)10,23,24
   23 UR(N,M)=-0.7  $ VR(N,M)=0.0
      GO TO 10
   24 IF(ISL(N,M)-4)10,25,26
   25 UR(N,M)=0.0  $ VR(N,M)=-0.8
      GO TO 10
   26 IF(ISL(N,M)-7)27,28,27
   27 UR(N,M)=-0.6  $ VR(N,M)=-0.6
      GO TO 10
   28 UR(N,M)=-0.7  $ VR(N,M)=0.0
   10 CONTINUE
      CALL PIRPAN (ISL,UR,VR,NE,ME)
      RETURN
      END
```

Seasonal migration speed creation subroutine for ~~crustaceans (called in~~ CRUSTA)

SUBROUTINE PIRPAN 73/73 OPT=1 FTN 4.6+460 07/3

```
      SUBROUTINE PIRPAN (ISL,UR,VR,NE,ME)
      DIMENSION ISL(26,30),UR(26,30),VR(26,30)
      NEH=NE-1 $ MEH=ME-1
      DO 20 N=2,NEH
      DO 20 M=2,MEH
      IF(ISL(N,M))21,21,22
   21 UR(N,M)=0.
      VR(N,M)=0.
      GO TO 20
   22 IF(ISL(N-1,M))23,23,24
   23 IF(VR(N,M))24,24,25
   25 VR(N,M)=0.
   24 IF(ISL(N+1,M))26,26,27
   26 IF(VR(N,M))28,27,27
   28 VR(N,M)=0.
   27 IF(ISL(N,M-1))29,29,30
   29 IF(UR(N,M))31,30,30
   31 UR(N,M)=0.
   30 IF(ISL(N,M+1))32,32,20
   32 IF(UR(N,M))20,20,33
   33 UR(N,M)=0.
   20 CONTINUE
      RETURN
      END
```

Setting of migration speed boundary values for Pacific ocean perch (called in ROCKFI)

```
      SUBROUTINE PANNAK(S8,F8,ISL,UP,VP,NE,ME)
      DIMENSION S8(26,30),F8(26,30),UP(26,30),VP(26,30),ISL(26,30)
C     ISL- SEA-LAND TABLE
C     S8 - (SPECIES)
C     F8 - SPECIES UPON EXIT                   Migration subroutine
C     UP - (U-COMP)
C     VP - (V-COMP)
C     VAP- IND. FOR SPEED PRINTING
C          1-PRINT, 0-NO
      VAP=0.
      KK=1
      TD=3.
      NEH=NE-1
      MEH=ME-1
      AUS=0.5                                  Setting of parameters
      DL=18.5
      B1=DL*DL
      B2=(2.*TD*AUS)/B1
      B5=(AUS*TD)/B1
  254 SU=US=0.
      DO 260 N=2,NEH
      DO 260 M=2,MEH                           Testing of direction and
      SU=SU+S8(N,M)/1000.                      computation of migration
      IF(ISL(N,M))260,260,221                  rate
  221 IF(UP(N,M))225,225,231
  225 SH=(S8(N,M)-S8(N,M+1))/DL
      GO TO 232
  231 SH=(S8(N,M)-S8(N,M-1))/DL
  232 IF(VP(N,M))233,233,234
  233 SV=(S8(N,M)-S8(N-1,M))/DL
      GO TO 235
  234 SV=(S8(N,M)-S8(N+1,M))/DL
  235 F8(N,M)=S8(N,M)-(TD*ABS(UP(N,M))*SH)-          Migration
     2(TD*ABS(VP(N,M))*SV)
      US=US+F8(N,M)/1000.
  260 CONTINUE
      U1=SU/US
      DO 751 N=2,NEH
      DO 751 M=2,MEH                           Conservation of mass and
      F8(N,M)=F8(N,M)*U1                            0 land
      IF(F8(N,M)-0.1)716,722,722
  716 F8(N,M)=0.
  722 IF(ISL(N,M))251,251,751
  251 F8(N,M)=0.
  751 CONTINUE
      DO 10 N=1,NE
      IF(ISL(N,1))9,9,8
    9 F8(N,1)=0.
      GO TO 7                                  Transfer into computation
    8 F8(N,1)=(S8(N,1)+F8(N,2))/2.             array and setting of
    7 IF(ISL(N,ME))6,6,5                       boundaries
    6 F8(N,ME)=0.
      GO TO 10
    5 F8(N,ME)=(S8(N,ME)+F8(N,MEH))/2.
   10 CONTINUE
      DO 11 M=1,ME
      IF(ISL(1,M))4,4,3
```

```
SUBROUTINE RANNAK      73/73    OPT=1                                FTN 4.6+460        08/0

        4 FB(1,M)=0.
          GO TO 2
        3 FB(1,M)=(SB(1,M)+FB(2,M))/2.
        2 FB(NE,M)=(SB(NE,M)+FB(NEH,M))/2.
       11 CONTINUE                                                                      002
          ALP=0.86                                                                      002
          CALL SILITA (FB,ISL,NE,ME,ALP)                                                002
          DO 12 N=1,NE   $ DO 12 M=1,ME                                                 002
          SB(N,M)=FB(N,M)                                                               002
       12 CONTINUE                                                                      002
          KK=KK+1                             Testing of completion and
          IF(KK-.))254,254,255                          return                          002
      255 KK=0
      752 SU=US=0.
          IF(VAP-1)256,259,258
      259 PRINT 256,KK                                  Optional output
      256 FORMAT(1H1,5X,27HU COMP. OF MIGR. KM/DAY, M=,I3//)
          CALL PRIAFP(UP,2)
          PRINT 257,KK
      257 FORMAT(1H1,5X,27HV COMP. OF MIGR. KM/DAY, M=,I3//)
          CALL PRIAFP(VP,2)
      258 RETURN
          END
```

100

SUBROUTINE RANPOR   73/73 OPT=1   FTN 4.6+460   07/3

```
      SUBROUTINE RANPOR (ISL,SD,S1,S2,S3,RP,SS,DD,NE,ME)                    003
      DIMENSION ISL(26,30),SD(26,30),S1(26,30),S2(26,30),S3(26,30)          003
C     SEPARATION OF MIGRATING PORTION                                       003
C     S1 SPECIES, TOTAL                                                     003
C     S2 MIGRATING PART OF POPULATION                                       003
C     S3 NONMIGRATING PART OF POPULATION                                    003
C     RP MIGRATING FRACTION                                                 003
C     SS SHALLOWEST DEPTH OF NO MIGRATION                                   003
C     DD DEEPEST DEPTH OF NO MIGRATION                                      003
C*****************************************                                 003
      DO 10 N=1,NE                                                          003
      DO 10 M=1,ME                                                          003
      IF(ISL(N,M))10,10,11                                                  003
   11 IF(SD(N,M)-SS)12,12,13                                                003
   12 S2(N,M)=0.                                                            003
      S3(N,M)=S1(N,M)                                                       003
      GO TO 10                                                              003
   13 IF(SD(N,M)-DD)14,14,12                                                003
   14 S2(N,M)=S1(N,M)*RP                                                    003
      S3(N,M)=S1(N,M)-S2(N,M)                                               003
   10 CONTINUE                                                              003
      RETURN                                                                003
      END                                                                   003
```

Separation of migrating
portion of population
from nonmigrating portion

```
                    SUBROUTINE CYLTOT (SOSY,TV,V1,V2,V3,TMX,TMI,NE,ME,ISL)
                    DIMENSION SOSY(26,30),TV(26,30),V1(26,30),V2(26,30),V3(26,30),
                   2ISL(26,30),SOCY(26,30)
              C     SOSY-SPECIES
              C     SOCY-OPERATING FIELD
              C     TV- TEMPERATURE
              C     V1 TO V3 THREE MAJOR FOOD ITEMS, PERCENTAGE CONSUMED PREV. MONTH
              C     TMX, TMI/TEMP. MAX,  IN (REQUIREMENTS FOR SPECIES)
              C     ISL- SEA-LAND TABLE
                    LA=0 $ NEH=NE-1 $ MEH=ME-1
                    KTK=1
                 40 GO TO (71,72,73,74,75),KTK
                 71 DO 76 N=1,NE
                    DO 76 M=1,ME
                    SOCY(N,M)=TV(N,M)
                    IF(ISL(N,M))77,77,76
                 77 SOCY(N,M)=0.
                 76 CONTINUE
                    VMAK=TMX
                    KUK=0
                    A1=0.014 $ A2=0.020 $ A3=0.030 $ A4=0.045
                    GO TO 81
                 72 VMAK=TMI
                    KUK=1
                    A1=0.018 $ A2=0.025 $ A3=0.035 $ A4=0.060
                    GO TO 81
                 73 DO 78 N=1,NE
                    DO 78 M=1,ME
                    SOCY(N,M)=V1(N,M)
                 78 CONTINUE
                    KUK=2
                    VMAK=0.35
                    A1=0.008 $ A2=0.011 $ A3=0.018 $ A4=0.030
                    GO TO 81
                 74 DO 79 N=1,NE
                    DO 79 M=1,ME
                    SOCY(N,M)=V2(N,M)
                 79 CONTINUE
                    VMAK=0.30  $  KUK=2
                    A1=0.007 $ A2=0.010 $ A3=0.015 $ A4=0.022
                    GO TO 81
                 75 DO 80 N=1,NE
                    DO 80 M=1,ME
                    SOCY(N,M)=V3(N,M)
                 80 CONTINUE
                    VMAK=0.20  $  KUK=2
                    A1=0.005 $ A2=0.007 $ A3=0.010 $ A4=0.012
                 81 KK=1
                  1 DO 49 N=2,NEH
                    DO 49 M=2,MEH
                    IF(KUK-1)101,101,103
                101 IF(SOCY(N,M)-30.)103,102,102
                102 SOCY(N,M)=-50.+SOCY(N,M)
                103 IF(KUK-1)104,105,104
                104 IF(VMAK-SOCY(N,M))4,4,49
                  4 IF(VMAK-SOCY(N,M+1))5,6,6
                  5 LA=1
```

Setting of percentage of major food items consumed into operational array, setting of food item abundance criterion and transfer coefficient (A1 to A4)

```
      6 IF(VMAK-SOCY(N,M-1))7,8,8
      7 LA=LA+10
      8 IF(VMAK-SOCY(N-1,M))9,10,10
      9 LA=LA+100
     10 IF(VMAK-SOCY(N+1,M))15,11,11
     15 LA=LA+1000
        GO TO 11
    105 IF(SOCY(N,M)-VMAK)44,44,49
     44 IF(SOCY(N,M+1)-VMAK)45,46,46
     45 LA=1
     46 IF(SOCY(N,M-1)-VMAK)47,48,48
     47 LA=LA+10
     48 IF(SOCY(N-1,M)-VMAK)51,52,52
     51 LA=LA+100
     52 IF(SOCY(N+1,M)-VMAK)53,11,11
     53 LA=LA+1000
     11 IF(ISL(N,M+1))83,83,84
     83 LA=LA-1
     84 IF(ISL(N,M-1))85,85,86
     85 LA=LA-10
     86 IF(ISL(N-1,M))87,87,88
     87 LA=LA-100
     88 IF(ISL(N+1,M))89,89,92
     89 LA=LA-1000
     92 IF(LA-1)49,12,22
     12 AS=A4*SOSY(N,M)
        SOSY(N,M+1)=SOSY(N,M+1)+AS
        SOSY(N,M)=SOSY(N,M)-AS
        GO TO 49
     22 IF(1110-LA)23,24,25
     23 AS=A1*SOSY(N,M)
        SOSY(N-1,M)=SOSY(N-1,M)+AS
        SOSY(N+1,M)=SOSY(N+1,M)+AS
        SOSY(N,M-1)=SOSY(N,M-1)+AS
        SOSY(N,M+1)=SOSY(N,M+1)+AS
        SOSY(N,M)=SOSY(N,M)-4.*AS
        GO TO 49
     24 AS=A2*SOSY(N,M)
        SOSY(N,M+1)=SOSY(N,M-1)+AS
        SOSY(N+1,M)=SOSY(N+1,M)+AS
        SOSY(N-1,M)=SOSY(N-1,M)+AS
        SOSY(N,M)=SOSY(N,M)-3.*AS
        GO TO 49
     25 IF(1100-LA)26,27,28
     26 AS=A2*SOSY(N,M)
        SOSY(N,M-1)=SOSY(N,M+1)+AS
        SOSY(N+1,M)=SOSY(N+1,M)+AS
        SOSY(N-1,M)=SOSY(N-1,M)+AS
        SOSY(N,M)=SOSY(N,M)-3.*AS
        GO TO 49
     27 AS=A3*SOSY(N,M)
        SOSY(N,M-1)=SOSY(N-1,M)+AS
        SOSY(N,M+1)=SOSY(N+1,M)+AS
        SOSY(N,M)=SOSY(N,M)-2.*AS
        GO TO 49
     28 IF(1010-LA)29,30,31
     29 AS=A2*SOSY(N,M)
```

Testing of abundance and/or temperature at surrounding four points and indexing the directions (points) towards which no migration will take place.

Computation of partial migration due to too high or too low temperature and food abundance, using directional criterion established above

```
      SOSY(N-1,M)=SOSY(N+1,M)+AS
      SOSY(N,M-1)=SOSY(N,M-1)+AS
      SOSY(N,M+1)=SOSY(N,M+1)+AS
      SOSY(N,M)=SOSY(N,M)-3.*AS
      GO TO 49
   30 AS=A3*SOSY(N,M)
      SOSY(N,M+1)=SOSY(N,M-1)+AS
      SOSY(N-1,M)=SOSY(N+1,M)+AS
      SOSY(N,M)=SOSY(N,M)-2.*AS
      GO TO 49
   31 IF(1000-LA)32,33,34
   32 AS=A3*SOSY(N,M)
      SOSY(N,M-1)=SOSY(N,M+1)+AS
      SOSY(N-1,M)=SOSY(N+1,M)+AS
      SOSY(N,M)=SOSY(N,M)-2.*AS
      GO TO 49
   33 AS=A4*SOSY(N,M)
      SOSY(N,M+1)=SOSY(N+1,M)+AS
      SOSY(N,M)=SOSY(N,M)-AS
      GO TO 49
   34 IF(110-LA)35,36,37
   35 AS=A2*SOSY(N,M)
      SOSY(N+1,M)=SOSY(N-1,M)+AS
      SOSY(N,M-1)=SOSY(N,M-1)+AS
      SOSY(N,M+1)=SOSY(N,M+1)+AS
      SOSY(N,M)=SOSY(N,M)-3.*AS
      GO TO 49
   36 AS=A3*SOSY(N,M)
      SOSY(N+1,M)=SOSY(N-1,M)+AS
      SOSY(N,M+1)=SOSY(N,M-1)+AS
      SOSY(N,M)=SOSY(N,M)-2.*AS
      GO TO 49
   37 IF(100-LA)38,39,54
   38 AS=A3*SOSY(N,M)
      SOSY(N+1,M)=SOSY(N-1,M)+AS
      SOSY(N,M-1)=SOSY(N,M+1)+AS
      SOSY(N,M)=SOSY(N,M)-2.*AS
      GO TO 49
   39 AS=A4*SOSY(N,M)
      SOSY(N+1,M)=SOSY(N-1,M)+AS
      SOSY(N,M)=SOSY(N,M)-AS
      GO TO 49
   54 IF(10-LA)55,56,49
   55 AS=A3*SOSY(N,M)
      SOSY(N+1,M)=SOSY(N,M-1)+AS
      SOSY(N-1,M)=SOSY(N,M+1)+AS
      SOSY(N,M)=SOSY(N,M)-2.*AS
      GO TO 49
   56 AS=A4*SOSY(N,M)
      SOSY(N-1,M)=SOSY(N,M-1)+AS
      SOSY(N,M)=SOSY(N,M)-AS
   49 CONTINUE
      DO 106 N=1,NE
      SOSY(N,1)=(SOSY(N,1)+SOSY(N,2))/2.
      SOSY(N,ME)=(SOSY(N,ME)+SOSY(N,MEH))/2.
  106 CONTINUE
      DO 107 M=1,ME
```

```
      SOSY(1,M)=(SOSY(1,M)+SOSY(2,M))/2.
      SOSY(NE,M)=(SOSY(NE,M)+SOSY(NEH,M))/2.
  107 CONTINUE
      KK=KK+1
      IF(2-KK)99,99,108          Testify whether all criteria
  108 LA=0.                      have been used and return to
      GO TO 1                    computations
   99 KK=1
      LA=0
      KTK=KTK+1
      IF(6-KTK)150,150,40
  150 DO 60 N=1,NE
      DO 60 M=1,ME               0 arrays over land
      IF(ISL(N,M))61,61,60
   61 SOSY(N,M)=0.
   60 CONTINUE
  100 RETURN
      END
```

SUBROUTINE GROCOR 73/73 OPT=1 FTN 4.6+460 07/3

```
      SUBROUTINE GROCOR (AA1,BB2,AA2,TBS,TBY,TUK,TSSL,K,NE,ME)
      DIMENSION AA1(26,30),BB2(26,30),AA2(26,30)
C     AA1- SPECIES
C     BB2- STARVATION
C     AA2- FOOD REQUIREMENTS (KG/KM2)
C     TBS- GROWTH COEFFICIENT, ANNUAL MEAN
C     TBY- HALF MAGNITUDE OF ANNUAL CHANGE OF TBS
C     TUK-PHASE LAGE OF MAXIMUM GROWTH
C     TSSL- SPAWNING MORTALITY COEFFICIENT
      RAD=0.01745329
      ALPA=30.*RAD
      GKAP=TUK*RAD
      TKG=TBS+TBY*COS(ALPA*K-GKAP)
      DO 10 N=1,NE
      DO 10 M=1,ME
      IF(BB2(N,M)-0.20*AA2(N,M))11,11,12
   12 GROS=TKG-BB2(N,M)/AA2(N,M)*TKG
      AA1(N,M)=AA1(N,M)+AA1(N,M)*(2.-EXP(-GROS))
     2-AA1(N,M)*(2.-EXP(-TKG))
   11 IF(TSSL)10,10,14
   14 AA1(N,M)=AA1(N,M)*EXP(-TSSL)
   10 CONTINUE
      RETURN
      END
```

Correction of growth due to partial starvation and computation of spawning mortality

SUBROUTINE PUGIMO 73/73 OPT=1 FTN 4.6+460 07/31

```
      SUBROUTINE PUGIMO (PU,SI,SU,SUM,FIM,NE,ME)
      DIMENSION PU(26,30),SI(26,30)
      SU=SUM=0.
      AR=18.5*18.5
      DO 10 N=1,NE
      DO 10 M=1,ME
      SI(N,M)=PU(N,M)-PU(N,M)*EXP(-FIM)
      SU=SU+SI(N,M)*AR/1000.
      PU(N,M)=PU(N,M)-SI(N,M)
      SUM=SUM+PU(N,M)*AR/1000000.
      IF(PU(N,M))9,10,10
    9 PU(N,M)=0.
   10 CONTINUE
      RETURN
      END
```

Computation of catch when general fishing mortality coefficient is given

```
SUBROUTINE CASTAT      73/73    OPT=1                           FTN 4.6+460        07/3

                       SUBROUTINE CASTAT (PU,SI,SU,SUM,J,K,NF,MF,KCK)                    002
                       DIMENSION PU(26,30),SI(26,30),FIMC(26,30)                         002
              C        KCK - FIRST FISHING COEFF. LOCATION - 1                           002
                       KRCK=KCK+K                                                        002
                       CALL READMS (1,FIMC,780,KRCK)                                     002
                       SU=SUM=0.                                                         002
                       AS=18.5*18.5                                                      002
                       DO 20 N=1,NF                                                      002
                       DO 20 M=1,MF                                                      002
                       IF(PU(N,M))18,19,19                                               002
                    18 PU(N,M)=0.                                                        002
                       SI(N,M)=0.                                                        002
                       GO TO 20                                                          002
                    19 SI(N,M)=PU(N,M)-PU(N,M)*EXP(-FIMC(N,M))                           002
                       SU=SU+SI(N,M)*AS/1000.                                            002
                       PU(N,M)=PU(N,M)-SI(N,M)                                           002
                       SUM=SUM+PU(N,M)*AS/1000000.                                       002
                    20 CONTINUE                                                          002
                       RETURN                                                            002
                       END                                                               002
```

Computation of fishing when fishing intensity (effort) coefficients are given (see Pacific ocean perch in ROCKFI)

```
      SUBROUTINE SILITA (BAB,ISL,NE,ME,ALP)
      DIMENSION VALIP(26,30),BAB(26,30),ISL(26,30)
      BET=(1.-ALP)/4.
      NEH=NE-1  $ MEH=ME-1
      DO 523 N=2,NEH
      DO 523 M=2,MEH
      IF(ISL(N,M))523,523,503
  503 IF(1-N)504,507,504
  504 IF(ISL(N-1,M))507,507,505
  505 VAUP=BAB(N-1,M)
      GO TO 508
  507 VAUP=BAB(N,M)                      Smoothing (and diffusion)
  508 IF(NE-N)509,512,509                   computation
  509 IF(ISL(N+1,M))512,512,510
  510 VALO=BAB(N+1,M)
      GO TO 513
  512 VALO=BAB(N,M)
  513 IF(1-M)514,516,514
  514 IF(ISL(N,M-1))516,516,515
  515 VALE=BAB(N,M-1)
      GO TO 517
  516 VALE=BAB(N,M)
  517 IF(ME-M)518,521,518
  518 IF(ISL(N,M+1))521,521,519
  519 VARI=BAB(N,M+1)
      GO TO 522
  521 VARI=BAB(N,M)
  522 VALIP(N,M)=ALP*BAB(N,M)+BET*(VAUP+VALO+VALE+VARI)
  523 CONTINUE
      DO 550 N=1,NE
      VALIP(N,1)=BAB(N,1)
      VALIP(N,ME)=BAB(N,ME)           Setting of boundaries
  550 CONTINUE
      DO 551 M=1,ME
      VALIP(1,M)=BAB(1,M)
      VALIP(NE,M)=BAB(NE,M)
  551 CONTINUE
      DO 500 N=1,NE
      DO 500 M=1,ME
      BAB(N,M)=VALIP(N,M)
  500 CONTINUE
      RETURN
      END
```

```
SUBROUTINE BOUSET     73/73   OPT=1                        FTN 4.6+460        07/1

      SUBROUTINE BOUSET (P1,NE,ME)
      DIMENSION P1(26,30)
      DO 10 N=1,NE
      P1(N,1)=P1(N,2)
      P1(N,ME)=P1(N,ME-1)
   10 CONTINUE                Setting of boundary values
      DO 11 M=1,ME
      P1(1,M)=P1(2,M)
      P1(NE,M)=P1(NE-1,M)
   11 CONTINUE
      RETURN
      END
```

110

SUBROUTINE PRIAFP   73/73   OPT=1   FTN 4.6+460   07/31

```
                 SUBROUTINE PRIAFP (FLD,KM)
                 DIMENSION FLD(26,30)
                 NE=26 $ ME=30
                 PRINT 500,(N,N=1,15)
             500 FORMAT(////5X,15I7)
                 IF(KM-1)502,503,504
             503 PRINT 501,(N,(FLD(N,M),M=1,15),N=1,26)
             501 FORMAT(//I5,15F7.1)
                 PRINT 500,(N,N=16,30)
                 PRINT 508,(N,(FLD(N,M),M=16,30),N=1,26)
             508 FORMAT(//I5,15F7.1)
                 GO TO 506
             502 PRINT 505,(N,(FLD(N,M),M=1,15),N=1,26)
             505 FORMAT(//I5,15F7.0)
                 PRINT 500,(N,N=16,30)
                 PRINT 509,(N,(FLD(N,M),M=16,30),N=1,26)
             509 FORMAT(//I5,15F7.0)
                 GO TO 506
             504 PRINT 507,KM
             507 FORMAT(5X,22HERROR IN PRINTFLD, KM=,I3)
             506 RETURN
                 END
```

Printing of arrays (two-dimensional map print)

RU 417

Ecological Studies of Intertidal and Shallow Subtidal Habitats in Lower Cook Inlet

Prepared for

NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION

Prepared by

DAMES & MOORE

10 November 1978

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Job No. 6797-010-20

QUARTERLY REPORT

I. Task Objectives

The main purpose of the study is to describe some of the important features of the principal intertidal and nearshore assemblages in Lower Cook Inlet and Prince William Sound. Specific overall objectives are to obtain information on patterns of trophic dynamics and succession, and to develop preliminary estimates of primary and secondary production in the assemblages examined. Considerable effort is being placed in obtaining biomass and production estimates for the algal assemblages in the rocky intertidal and subtidal region on the south side of Kachemak Bay.

II. Field and Laboratory Activities

A. Ship or Field Trip Schedule

1. 10 July--Archimandritof Shoals and Mud Bay--subtidal--via Dames & Moore skiff
2. 11, 12 July--Seldovia Point--subtidal--via Dames & Moore skiff
3. 13 July--Barabara Bluffs--subtidal--via Dames & Moore skiff
4. 18 July--Gull Island--intertidal--via Dames & Moore skiff
5. 19 July--Seldovia Point--intertidal--via Dames & Moore skiff
6. 20-22 July--Cottonwood area, Kamishak Bay--intertidal--via chartered float plane
7. 31 July--Bluff Point--subtidal--via NOAA-chartered vessel, M. V. Humdinger
8. 1 August--off Troublesome Creek--subtidal--via NOAA-chartered vessel, M. V. Humdinger and Dames & Moore skiff
9. 2-5 August--Kamishak Bay--subtidal--via chartered float plane
10. 8 August--Jakolof Bay--subtidal--via Dames & Moore skiff
11. 10-16 August--Prince William Sound--subtidal--via chartered vessel, M. V. Searcher; travel to by NOAA-chartered float plane and from by commercial airlines
12. 16 August--Deep Creek--intertidal--via personal car
13. 17 August--Homer Spit--intertidal--via personal car
14. 18-19 August--Cottonwood Bay and Iniskin Beach--intertidal--via NOAA-chartered float plane--poor weather, return delayed until 21 August
15. 9 September--Jakolof Bay--subtidal--via Dames & Moore skiff
16. 15-17 September--Cottonwood area, Kamishak intertidal--via NOAA-chartered float plane

B. Scientific Party

1. Deborah Boettcher, Dames & Moore, Assistant Biologist
2. William Driskell, Dames & Moore, Assistant Biologist

3. David Erikson, Dames & Moore, Assistant Biologist
4. Dr. Jonathon Houghton, Dames & Moore, Project Marine Biologist
5. Michael Kyte, Dames & Moore, Assistant Biologist
6. Dennis Lees, Dames & Moore, Principal Investigator, Project Manager
7. Richard Rosenthal, Alaska Coastal Research, Contract Labor
8. Thomas Rosenthal, Contract Labor
9. Dr. Ronald Shimek, University of Alaska, Contract Labor

C. Methods

1. Field Sampling

a. Soft Substrates

(1) A profile of beach elevations is established.
(2) A stratified random sample design is being utilized.
(3) Ten cores 10 cm in diameter and about 30 cm long are collected randomly at each of at least three levels of the beach below mean sea level.
(4) Samples are individually bagged and labelled.
(5) When weather permits, the fresh samples are screened in seawater through a 1 mm sieve to remove the sand. The sample remaining in the screen is rebagged with its label and fixed with a 10 percent formaldehyde-seawater solution.

b. Rock Substrates

(1) A stratified sampling design is being used.
(2) Levels being occupied at Seldovia Point are about +8 ft, +2 ft, -1 ft, -20 ft, -40 ft and -60 ft elevations.
(3) Levels being occupied at Gull Island are about +12 ft, +5 ft, MLLW and -1 ft elevations.
(4) Ten-1/4 m^2 quadrats are placed randomly at each level; within each quadrat the number and/or relative cover of each plant taxon are recorded and all plants attached within the frame are removed and bagged. Additionally, the number and/or relative cover of conspicuous invertebrates and fish are recorded.
(5) Additional quadrats (from 1/16 m^2 to 25 m^2) are utilized at each level to obtain better estimates of density and cover for the plants and animals in the study area.
(6) Feeding observations are recorded.
(7) Samples of many invertebrates are collected to establish size distributions.

(8) At Jakolof Bay, 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 for verfication.

b. Rock Substrates

(1) Plant samples from each level are handled and recorded individually.
(2) Drained wet weight and length are measured for each laminarian; aggregate drained wet weights are measured for all other algae.
(3) Sizes are measured for various invertebrate species to establish size distributions.
(4) Fish and selected invertebrate species are dissected in order to examine stomach contents and develop food webs.

D. Sample Localities

1. Soft Substrates

a. Deep Creek--1-1/2 mi. south of beach access at beach park (Figure 1); transect based on very large triangular boulder at base of cliff.
b. Homer Spit--2-1/2 mi. south of Kachemak Drive, off beach access ramp on west side of spit (Figure 1).
c. Iniskin Beach--the transect line extends normal to the shoreline from a boulder outcrop east of a stream crossing the beach at its center; this is the first sand beach east of Iniskin Bay (Figure 1), about 1 mile.
d. Cottonwood Bay--about 0.6 mile west of the OCS base camp (Figure 1); transect based on a large white rock at base of cliff.
e. Mud Bay--general locations in the bay east of Homer Spit, at depths of 20 and 30 feet (Figure 1).

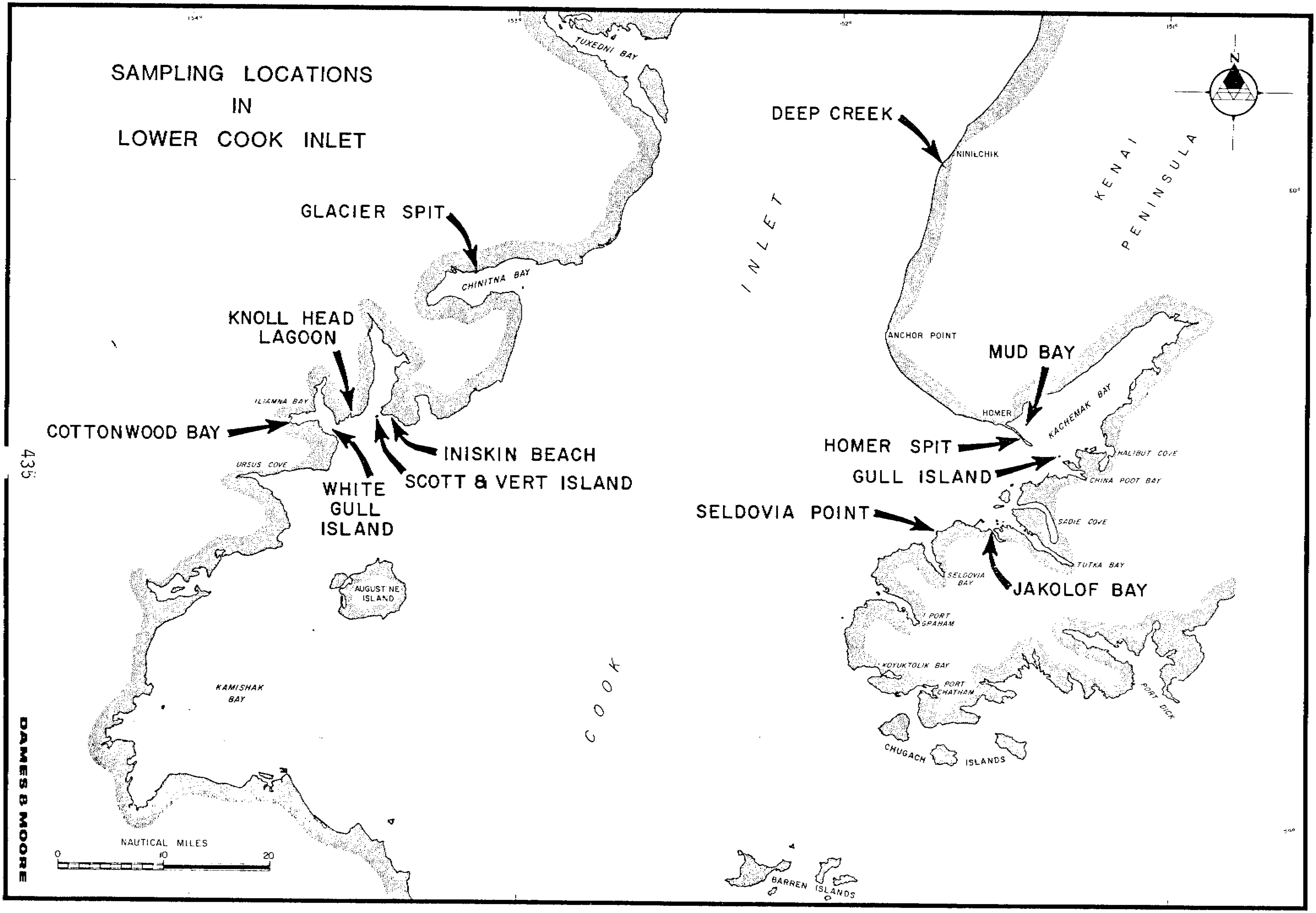

SAMPLING LOCATIONS
IN
LOWER COOK INLET
TUXEDNI BAY
DEEP CREEK
NINILCHIK
KENAI PENINSULA
INLET
GLACIER SPIT
CHINITNA BAY
KNOLL HEAD LAGOON
ILIAMNA BAY
COTTONWOOD BAY
INISKIN BEACH
URSUS COVE
WHITE GULL ISLAND
SCOTT & VERT ISLAND
AUGUSTINE ISLAND
KAMISHAK BAY
COOK
ANCHOR POINT
MUD BAY
HOMER
KACHEMAK BAY
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
N
NAUTICAL MILES
0
10
20
DAMES & MOORE

FIGURE 1

2. Rock Substrates

a. Gull Island, in Kachemak Bay--Gorilla Rock at west end of island (Figure 1);
b. Jakolof Bay, in Kachemak Bay--on the reef at the mouth of Jakolof Bay, under the overhead high tension wires (Figure 1);
c. Seldovia Point, in Kachemak Bay--directly at the point; transect based on a very large boulder, marked by a painted arrow, at the base of the cliff (Figure 1).
d. Archimandritof Shoals, in Kachemak Bay--southwest of spit offshore of North Wind Welding building.
e. Barabara Bluffs, in Kachemak Bay--between Seldovia Point and Barabara Point, toward the outer edge of kelp.
f. Bluff Point--the north side of Kachemak Bay.
g. Troublesome Creek--the north side of Kachemak Bay, near Anchor Point.
h. Scott Island, in the entrance to Iniskin Bay--near the southwest point; transect based on a painted marker on cliff (Figure 1).
i. Knoll Head Lagoon--east of lagoon between Knoll Head and White Gull Island; transect based on a painted marker on cliff (Figure 1).
j. White Gull Island--on east face of the island (Figure 1) for intertidal and west side for subtidal.
k. Oil Bay--subtidal, in the middle of the bay, on the north shore of Kamishak Bay.
l. Turtle Reefs--a large rock outcrop southeast of Cottonwood and Iliamna Bay entrance.
m. Observation Point, Danger Island--on the southeast side of the island, toward its middle.
n. Sea Lion Pinnacles, Danger Island--on the south end of Danger Island (Figure 2).
o. Latouche Point, Latouche Island--on the southwest corner of Latouche Island (Figure 2).
p. "The Hook", Latouche Island--east of the southwest corner of Latouche Island.
q. Zaikof Point, Montague Island--on the south side of Zaikof Bay, in Hinchinbrook Entrance (Figure 2).
r. NMFS site, Zaikof Bay, Montague Island--the second point inside Zaikof Bay on the south shore.

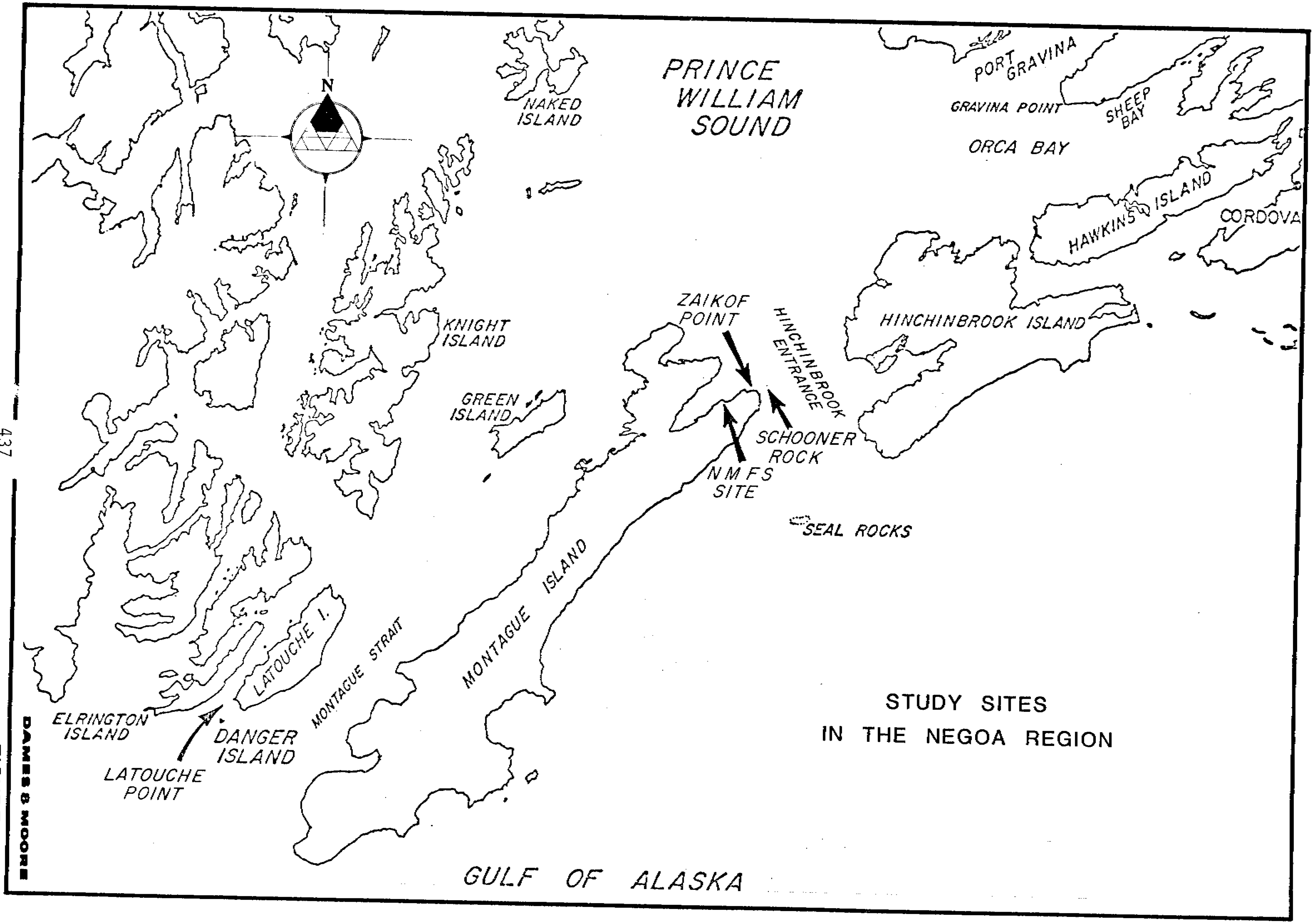
E. <u>Data Collected or Analyzed</u>

1. Soft Substrates

a. Mud Bay Subtidal Survey (10 July 1978)

(1) Large quadrat for invertebrates and fish

0.5 x 30 m - 3
0.5 x 50 m - 2



STUDY SITES IN THE NEGOA REGION

FIGURE 2

(2) 1/4 m^2 square quadrats for density of a major invertebrate--11

b. Deep Creek (16 August 1978)--Thirty core samples collected-sorted
c. Homer Spit (17 August 1978)--Thirty core samples collected-sorted
d. Iniskin Beach (18 August 1978)--Thirty core samples collected-sorted
e. Cottonwood Bay (19 August 1978)

(1) Thirty core samples collected-sorted
(2) 1/16 m^2 square quadrats for Mya spp. siphon counts--109

2. Rock Substrates

a. Archimandritof Shoals Subtidal Survey (10 July 1978)

(1) Reconnaissance survey
(2) Large quadrats for fish

1 x 25 m - 2

(3) 1/4 m^2 square quadrats for density of major invertebrates--10
(4) Feeding observations--4
(5) Size distribution for one species

b. Seldovia Point Subtidal Survey (11, 12 July 1978)

(1) Large quadrats for plants

0.5 x 25 m - 4

(2) Large quadrats for fish

0.5 x 30 m - 2
0.5 x 50 m - 2

(3) 1/4 m^2 square quadrats for plant cover, density and biomass--21
(4) 1/4 m^2 square quadrats for cover and density of plants and invertebrates--10
(5) Size distribution for three species

c. Barabara Bluff Subtidal Survey (13 July 1978)

(1) Reconnaissance survey
(2) Large quadrats for plants

0.5 x 5 m - 6
0.5 x 30 m - 1

(3) Large quadrats for plants, fish and large invertebrates

2 x 25 m - 3

(4) 1/4 x 1/2 m quadrats for plant cover, density, and biomass and invertebrates--10
(5) Feeding observations--1
(6) Size distribution for two species

d. Gull Island Intertidal Survey (18 July 1978)

(1) 1/4 m^2 square quadrats for plant cover and density--3
(2) 1/4 m^2 square quadrats for cover and density of plants and animals--32
(3) Size distribution for one species

e. Seldovia Point Intertidal Survey (19 July 1978)

(1) 1/4 m^2 square quadrats for plant density and biomass--1
(2) 1/4 m^2 square quadrats for plant cover, density and biomass and invertebrates--30
(3) Feeding observations--7
(4) Size distribution for three species

f. Knoll Head Lagoon Intertidal Survey (20 July 1978)

(1) 1/4 m^2 square quadrats for plant cover, density and biomass and invertebrates--18
(2) Size distribution for two species

g. Scott Island Intertidal Survey (21 July 1978)

(1) 1/4 m^2 square quadrats for plant cover, density and biomass and invertebrates--26
(2) Size distribution for one species

h. White Gull Island Intertidal (22 July 1978)

(1) 1/4 m^2 square quadrats for plant cover, density and biomass and invertebrates--20
(2) Feeding observations--1
(3) Size frequency for two species

i. Bluff Point Subtidal Survey (31 July 1978)

(1) Reconnaissance survey
(2) Large quadrats for major invertebrates

0.5 x 25 m - 2

(3) Feeding observations--3

(4) Size frequencies for one species

j. Troublesome Creek Subtidal Survey (1 August 1978)

(1) Large quadrats for plants and large invertebrates

0.5 x 25 m - 2
0.5 x 30 m - 2

(2) 1/4 m^2 square quadrats for cover and density of plants and animals--6
(3) 1/4 m^2 square quadrats for invertebrate cover and densities--19
(4) Feeding observations--5

k. Knoll Head Lagoon Subtidal Survey (2, 5 August 1978)

(1) Reconnaissance survey
(2) Large quadrats for plants and animals

0.5 x 5 m - 41

(3) Large quadrats for invertebrates

0.5 x 5 m - 10

(4) Large quadrats for fish

2 x 30 m - 2
1 x 50 m - 1

(5) 1/4 m^2 square quadrats for plant cover, density and biomass--20
(6) 1/4 m^2 square quadrats for plant and animal cover and density--4
(7) Feeding observations--4
(8) Stomach analyses--5
(9) Size frequencies for three species

l. White Gull Island Subtidal Survey (3, 5 August 1978)

(1) Reconnaissance survey
(2) 1/4 m^2 square quadrats for cover and density of plants and animals--4
(3) Feeding observations--3

m. Oil Bay Subtidal Survey (4 August 1978)

(1) Reconnaissance survey
(2) Large quadrats for large invertebrates and fish

0.5 x 30 m - 2

n. Scott Island Subtidal Survey (4 August 1978)

(1) Reconnaissance survey
(2) Large quadrats for plants, large invertebrates and fish

0.5 x 5 m - 12

(3) Feeding observations--5

o. Turtle Reefs Subtidal Survey (5 August 1978)

(1) Reconnaissance survey

p. Jakolof Bay Subtidal Studies (8 August 1978)

(1) Plants measured and retagged:

Agarum cribrosum--5
Alaria fistulosa--1
Laminaria groenlandica--4

(2) Tagged plants measured:

Agarum cribrosum--13
Alaria fistulosa--10
Laminaria groenlandica--8

q. Danger Island, Observation Point Subtidal Survey (11 August 1978)

(1) Large quadrats for Phaeophytes

1 x 30 m - 1

(2) Large quadrats for fish

1 x 30 m - 1

(3) 1/2 x 1/2 m quadrats for plant cover, density and biomass--3
(4) 1/4 m^2 square quadrats for plant cover, density and biomass--8
(5) Feeding observations--1
(6) Size frequencies for four species

r. Latouche Point, "The Hook" Subtidal Survey (11, 12 August 1978)

(1) Large quadrats for Phaeophytes

0.5 x 5 m - 3
0.5 x 10 m - 1
0.5 x 30 m - 1
1 x 30 m - 2
2 x 30 m - 1

(2) Large quadrats for macro-invertebrates

0.5 x 5 m - 6

(3) 1/4 m^2 square quadrats for plant cover, density and biomass--6
(4) 1/4 m^2 square quadrats for plant cover, density and biomass and invertebrates--7
(5) Size frequencies for two species
(6) Feeding observations--2

s. Latouche Island, Latouche Point Intertidal Survey (13 August 1978)

(1) Algae reconnaissance
(2) 1/4 m^2 square quadrats for plant cover and biomass and invertebrates--3

t. Danger Island, Sea Lion Pinnacles Subtidal Survey (14 August 1978)

(1) Large quadrats for Phaeophytes

0.5 x 30 m - 2

(2) Large quadrats for macro-invertebrates and fish

0.5 x 50 m - 2

(3) 1/4 m^2 square quadrats for plant cover, density and biomass--5
(4) 1/4 m^2 square quadrats for plant and animal cover and density--6
(5) Size frequencies for three species
(6) Feeding observations--3

u. Montague Island, Zaikof Point Subtidal Survey (15 August 1978)

(1) Large quadrats for large invertebrates

0.5 x 25 m - 1
0.5 x 30 m - 1

(2) 1/4 m^2 square quadrats for plant cover, density and biomass--15
(3) 1/4 m^2 square quadrats for plant and animal cover and density--11
(4) Size frequencies for two species
(5) Feeding observations--6

v. Montague Island, Zaikof Bay at NMFS Study Site, Subtidal Survey (16 August 1978)

(1) Reconnaissance Survey

(2) Large quadrats for macro-invertebrates

0.5 x 25 m - 2

(3) 1/4 m^2 square quadrats plant cover, density and biomass--9
(4) 1/4 m^2 square quadrats for plant and animal cover and density--8
(5) Size frequencies for three species
(6) Feeding observations--31

w. Jakolof Bay Subtidal Studies (9 September 1978)

(1) Plants tagged:

Alaria _fistulosa_--5

(2) Plants measured and retagged:

Agarum _cribrosum_--1
Alaria _fistulosa_--2
Laminaria _groenlandica_--5

(3) Tagged plants measured:

Agarum _cribrosum_--16
Alaria _fistulosa_--8
Laminaria _groenlandica_--17

x. Knoll Head Lagoon Intertidal Survey (15 and 17 September 1978)

(1) 1/4 m^2 square quadrats for plant cover, density and biomass and invertebrates--21
(2) Size frequencies for one species

y. Scott Island Intertidal Survey (16 September 1978)

(1) 1/4 m^2 square quadrats for plant cover, density and biomass and invertebrates--20
(2) Size frequencies for one species

z. White Gull Island Intertidal Survey (16 September 1978)

(1) 1/4 m^2 square quadrats for cover and density of plants and animals--1
(2) 1/4 m^2 square quadrats for plant cover, density and biomass and invertebrates--18
(3) Size frequencies for two species

F. Milestone Chart and Data Submission Schedule

Except for one sand beach site and several days of diving, the field work scheduled for the intertidal and subtidal survey of Lower

Cook Inlet is completed. Weather permitting, sampling will be completed by 1 November. Sample processing has been completed up through field work conducted September, except for measurement of size and wet weight from the sand and mud habitat samples. The data processing problems reported last quarter are being rapidly resolved and processing is expected to resume within the month. The existing milestone chart (Figure 3) requires no change.

III. Results

The results are presently being compiled and analyzed. A report on the FY77 data from sand and mud intertidal habitats is about 95 percent complete.

IV. Preliminary Interpretation of Results

None at this time.

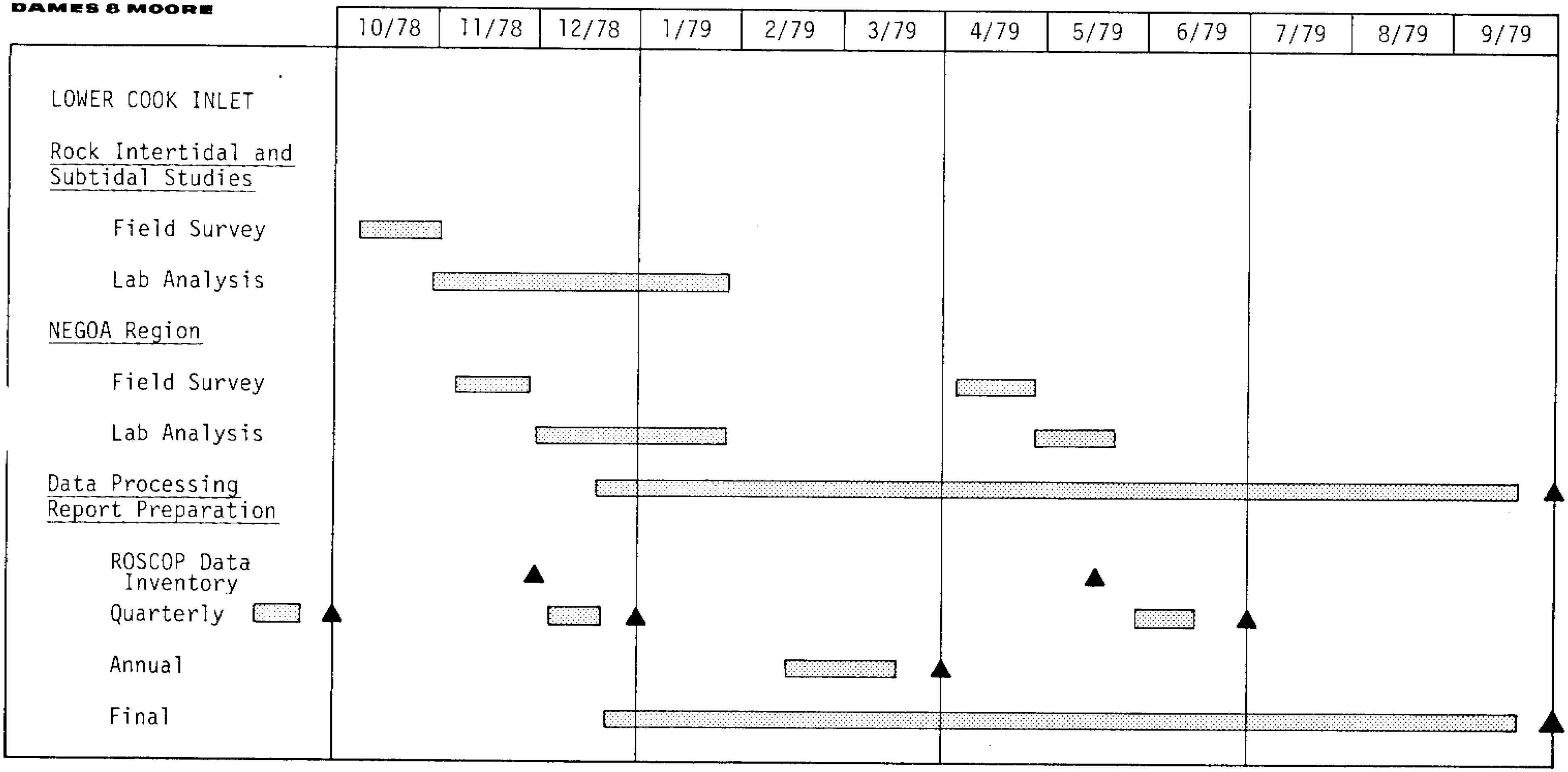
V. Problems Encountered

As usual, inclement weather caused delays and precluded the last (September) subtidal survey in Kamishak Bay; storms made the water too turbid to permit satisfactory work.

VI. Estimate of Funds Expended

$125,000; the balance will be used for completing the Fall season field work.

DAMES & MOORE



KEY:

IN PROGRESS

MILESTONES

XII. MILESTONE CHART

PI: Dennis C. Lees

R.U. #417

FIGURE 3

Research Unit # 423
Report Period: July - Sept. 1978

Quarterly Report

INFLUENCE OF PETROLEUM ON EGG FORMATION AND EMBRYONIC DEVELOPMENT IN SEABIRDS

D. G. Ainley
C. R. Grau

University of California
Davis, California

Progress Report
July-September 1978
Contract No. 03-7-022-35163
"Influence of petroleum on egg formation and embryonic development in seabirds"

During the past quarter, July-September 1978, hatching of Cassin's Auklet eggs in experimental and control burrows and nest boxes was observed, and auklet chicks were followed to fledging. In order to read bands and confirm identities, adult auklets were captured in experimental boxes and burrows; capture was undertaken at each nest as soon as the chicks were large enough to survive the disturbance.

Beginning 42 days after hatching, all experimental boxes and burrows were checked for hatching, in order to obtain data on hatching success. A sample of chicks in each experimental group was weighed daily until fledging to determine fledging weight. All remaining experimental boxes and burrows with chicks were checked every four days beginning on day 30 (after hatching) in order to determine fledging success. The last chick in an experimental burrow fledged on 1 September.

Nighttime checks of experimental burrows and boxes for adult Cassin's Auklets revealed that 38% of the females were different from those dosed earlier at the same sites, while 62% were the same. These findings were used to improve accuracy of data analysis.

The field work in July and August required an average of 35 hours per week and was performed by Craig Strong, Harriet Huber, and Stephen Morrell of the Point Reyes Bird Observatory. Data analysis took place in September and required 150 hours. A first draft of the final report has been completed, and work on a revised version is in progress.

QUARTERLY REPORT

Contract # 03-5-022-67-TA8 #4
Research Unit # 424
Reporting Period: 1 JUL 78 - 30 SEP 78
Number of Pages: 17

Lower Cook Inlet Meroplankton

T. Saunders English
Department of Oceanography
University of Washington

1 October 1978

Departmental Concurrence:

George C. Anderson
Associate Chairman for Research

REF: A78-18

I. Task Objectives

Our main objective is to conduct a quantitative survey to determine the seasonal distribution of commercially or ecosystem important species of ichthyoplankton, crab and shrimp larvae in Lower Cook Inlet, Alaska.

II. Field Activities

A. Ship Cruises

1. 26 June 1978, *Humdinger*
2. 28-29 June 1978, *Humdinger*
3. 5-6 July 1978, *Humdinger*
4. 11-12 July 1978, *Humdinger*
5. 15 July 1978, *Humdinger*
6. 6-7 August 1978, *Humdinger*
7. 11 August 1978, *Kasitsna Whaler*
8. 13-14 August 1978, *Humdinger*
9. 22 August 1978, *Kasitsna Whaler*
10. 24-25 August 1978, *Humdinger*
11. 28 August 1978, *Humdinger*
12. 31 August 1978, *Kasitsna Whaler*
13. 1-2 September 1978, *Humdinger*
14. 21 September 1978, *Kasitsna Whaler*, scheduled
15. 22-23 September 1978, *Humdinger*, scheduled
16. 28 September 1978, *Humdinger*, scheduled

B. Scientific Party

1. Leanne Legacie Stahl, Cruise Leader, University of Washington. Cruises 1-5, 12-13.
2. David Roetcisoender, Cruise Leader, University of Washington. Cruises 6-11.

3. Kendra Daly Tennant, Cruise Leader, University of Washington, Cruises 14-16.

4. Marc Weinstein, Oceanographer, University of Washington. Cruises 12-13.

5. Gordy Vernon, undergraduate, Antioch College, Ohio. Cruises 1-5, 9-11.

6. Paul Morley, undergraduate, University of Washington. Cruises 4, 6-8.

C. Methods

All stations were located in the Lower Cook Inlet area between Kachemak and Kamishak Bay (Figs. 1 and 2, Tables 1 and 2). About 30 min were spent on each station aboard the *Humdinger*. About 25 min were spent on each station aboard the *Kasitsna Whaler*.

The *Humdinger* is a 37-foot troller, chartered by OCSEAP from R. Rosenthal at Homer, Alaska, and used at offshore stations. The *Kasitsna Whaler* is a 21.5-foot Boston Whaler owned by OCSEAP and kept at the NMFS Kasitsna Bay Lab, and used for East inshore stations (1-5).

Zooplankton and ichthyoplankton were sampled during cruises on board the *Humdinger* with a bongo net in a double oblique tow. The bongo net consisted of a double-mouthed frame (each mouth with an inside diameter of 60 cm and a mouth area of 0.2827 m^2) made of fiberglass and weighing 95 lbs. A 50 lb cannonball weight was attached to the bottom of the frame. A 505 µm mesh net with an open area ratio (OAR) of 8:1 and a 333 µm mesh net, 8:1 OAR, were attached to the frame. PVC collecting cups and brass collars were attached to the cod ends of each net.

Beginning on 13 August, additional samples were taken at each station with a neuston net. The neuston net consisted of a stainless steel box frame with a mouth opening of 50 cm wide by 30 cm (area 0.15 m^2) and weighed 25 lbs. A 505 µm mesh net with 8:1 OAR was attached to the frame.

A Hydro-Products winch was used to deploy both nets. The winch did not have a power-out capability, so the MARMAP-required deployment for bongo nets of 50 m/min was estimated. There was a 30-second sinking time and a retrieval rate of approximately 40 m/min, the slowest speed the winch would operate without stalling. Ship speed was adjusted to keep a 45° wire angle during sinking and retrieval. Towing speed was approximately 2-3 knots. Sampling depth was generally within 10 m above the bottom, to the surface. The fishing depth of the net was determined by the product of the cosine of the wire angle at depth and the amount of wire out. Volumes of water filtered are estimated until the 11 August cruise, when one flowmeter was attached in each mouth opening of the bongo frame.

The neuston net was towed from the port quarter of the *Humdinger* clear of the vessels wake at a speed of about 3 knots.

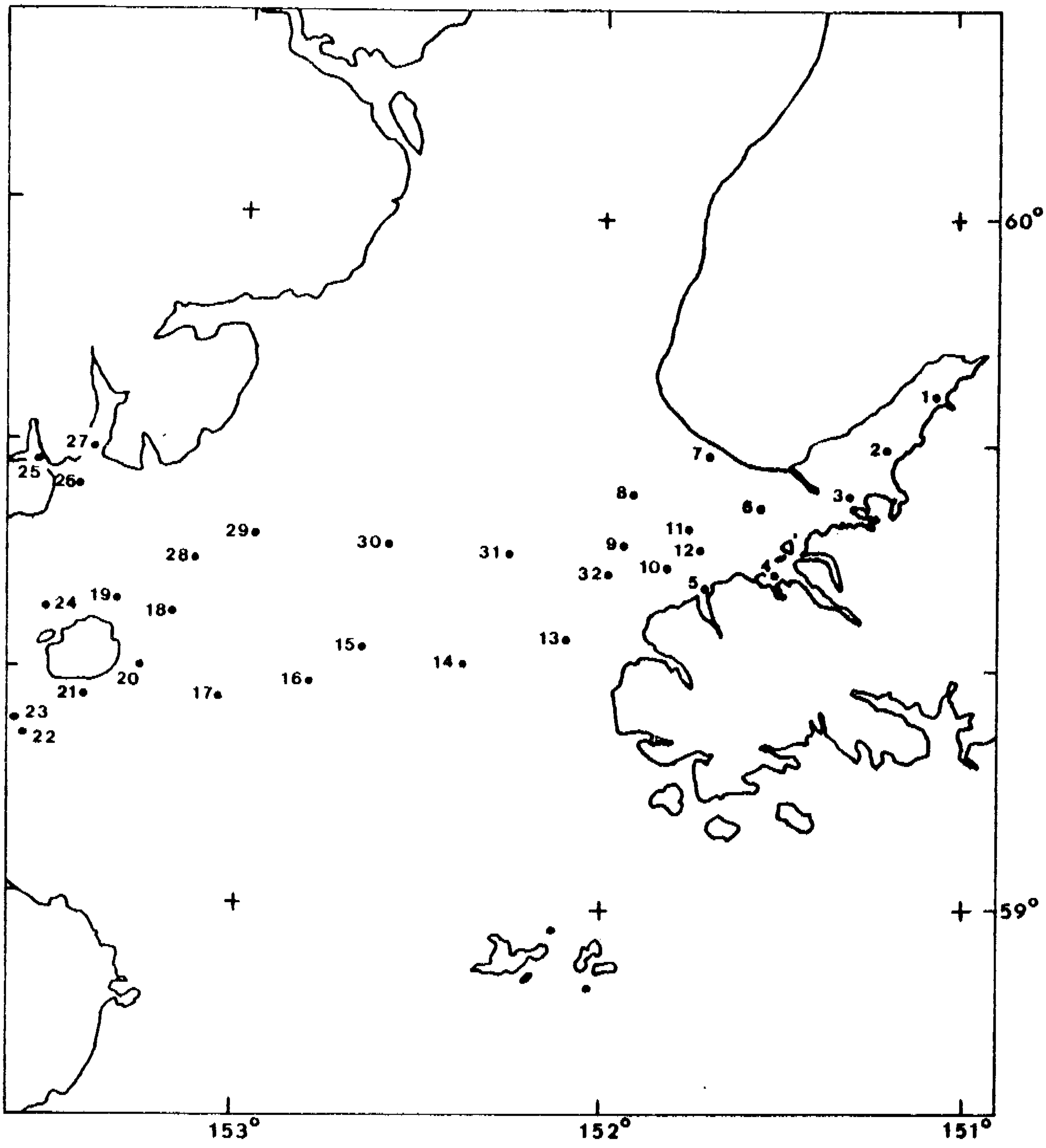


Figure 1. Station locations, Lower Cook Inlet.

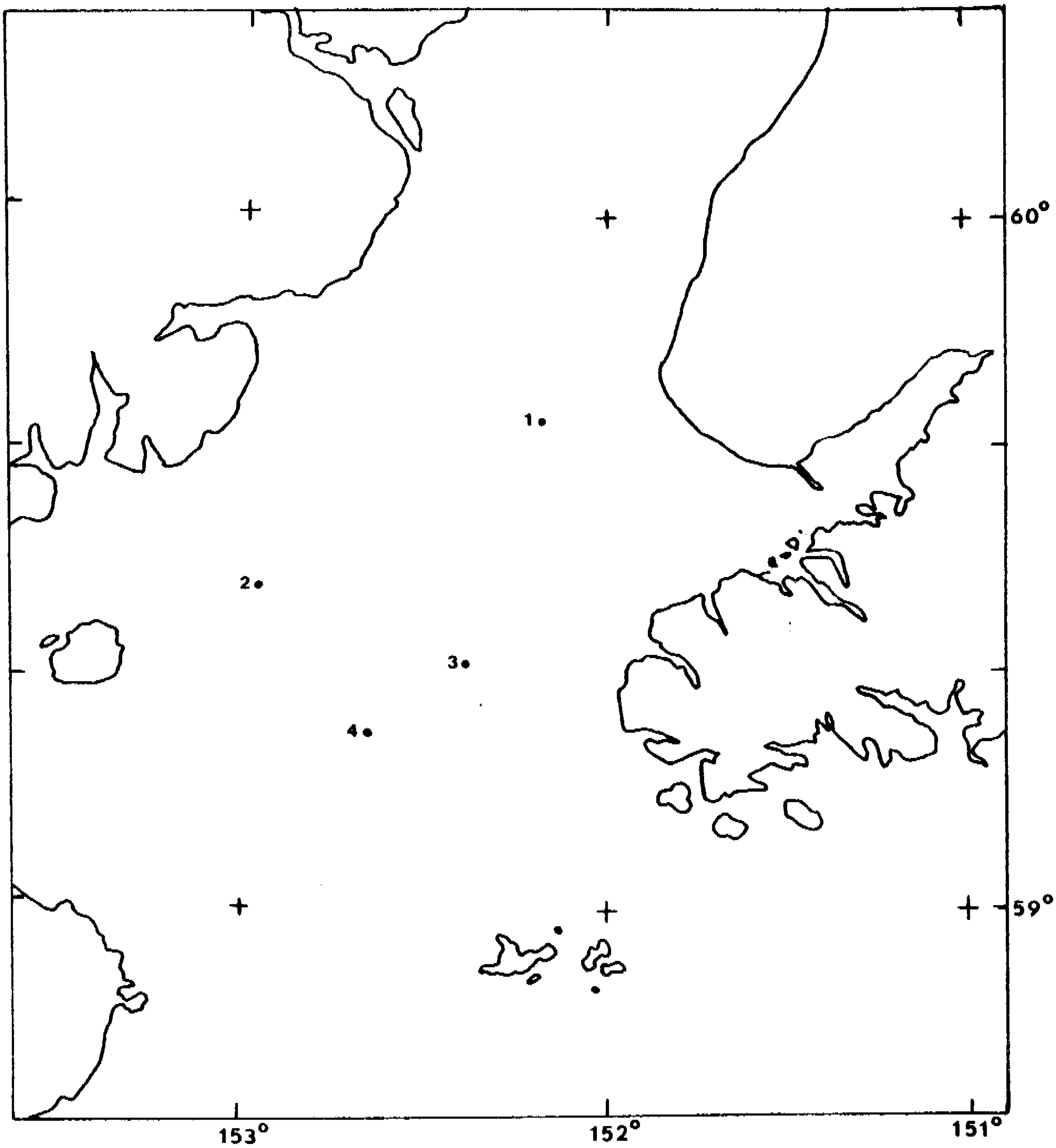


Figure 2. BLM station locations, Lower Cook Inlet.

A 20 cm (diameter) bongo net (mouth area $0.0314m^2$) was towed from a davit mounted on the port side of the *Kasitsna Whaler*. The net frame was similar in construction to the 60 cm bongo, but smaller scale and made of PVC plastic pipe. On cruise 7 only, four inshore stations were sampled using nets with meshes of 165 μm and 133 μm. New nets of the correct mesh sizes arrived a few days later, were mounted to the frame and used thereafter.

A small Hydro-Products winch was mounted forward on the whaler. A 10 lb. lead weight was attached to the end of the line below the net. The drum is free wheeling on the winch so wire was played out at approximately 50 m/min by controlling speed with the hand brake. The net was towed at the slowest speed the engines on the whaler could be idled, about 2 knots. Retrieval rate was approximately 30 m/min, the slowest speed the winch would run. Other procedures were similar to those of the 60 cm bongo net.

The neuston net was towed from the port quarter of the whaler at the same speed as towed on board the *Humdinger*.

Nets were washed down with a hose attached to a low pressure salt water pump. Samples were preserved on board the vessels with a 4% sodium borate buffered formalin. Within 24 hours, samples were represerved with a fresh solution of 4% formalin, propylene phenoxytol and propylene glycol.

D. Sample Localities

For sample stations see Figure 1.

E. Data Collected or Analyzed

1. The number and kinds of net hauls are given in Table 3.

2. Samples were sorted at the Kasitsna Lab into rough categories of fish eggs, fish, crab or shrimp larvae. They were then identified to the lowest taxonomic category and life history stage at the University of Washington. In most cases the entire sample was examined; subsamples were taken when organisms in a group were relatively very abundant. Subsamples were split with a Folsom splitter. Only samples from the 505 μm mesh nets were and will be examined.

3. Miles of Trackline

The miles of trackline for the thirteen cruises between 26 June and 2 September 1978 totaled 1362.

Cruise	miles	Cruise	miles
1	124	8	88
2	99	9	60
3	104	10	55
4	153	11	84
5	124	12	60
6	185	13	182
7	44		

F. Milestone Chart and Data Submission Schedule

The revised milestone chart is attached.

III. Results

Some shrimp and crab larvae and fish eggs and larvae have been identified from scattered samples on cruises between 19 May and 1 July 1978 (Tables 4-7). These counts are preliminary and minor adjustments may be necessary.

IV. Preliminary Interpretation of Results

Not enough samples have been analyzed to interpret results at this time.

V. Problems Encountered

The major problem was bad weather, resulting in some stations not sampled. There will apparently be a hiatus in funding from 1 October 1978 until some unspecified date in the future.

VI. Estimate of Funds Expended

We estimate that 100% of the funds will have been expended by 30 September 1978.

MILESTONE CHART

RU #: 424 PI: T. Saunders English

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

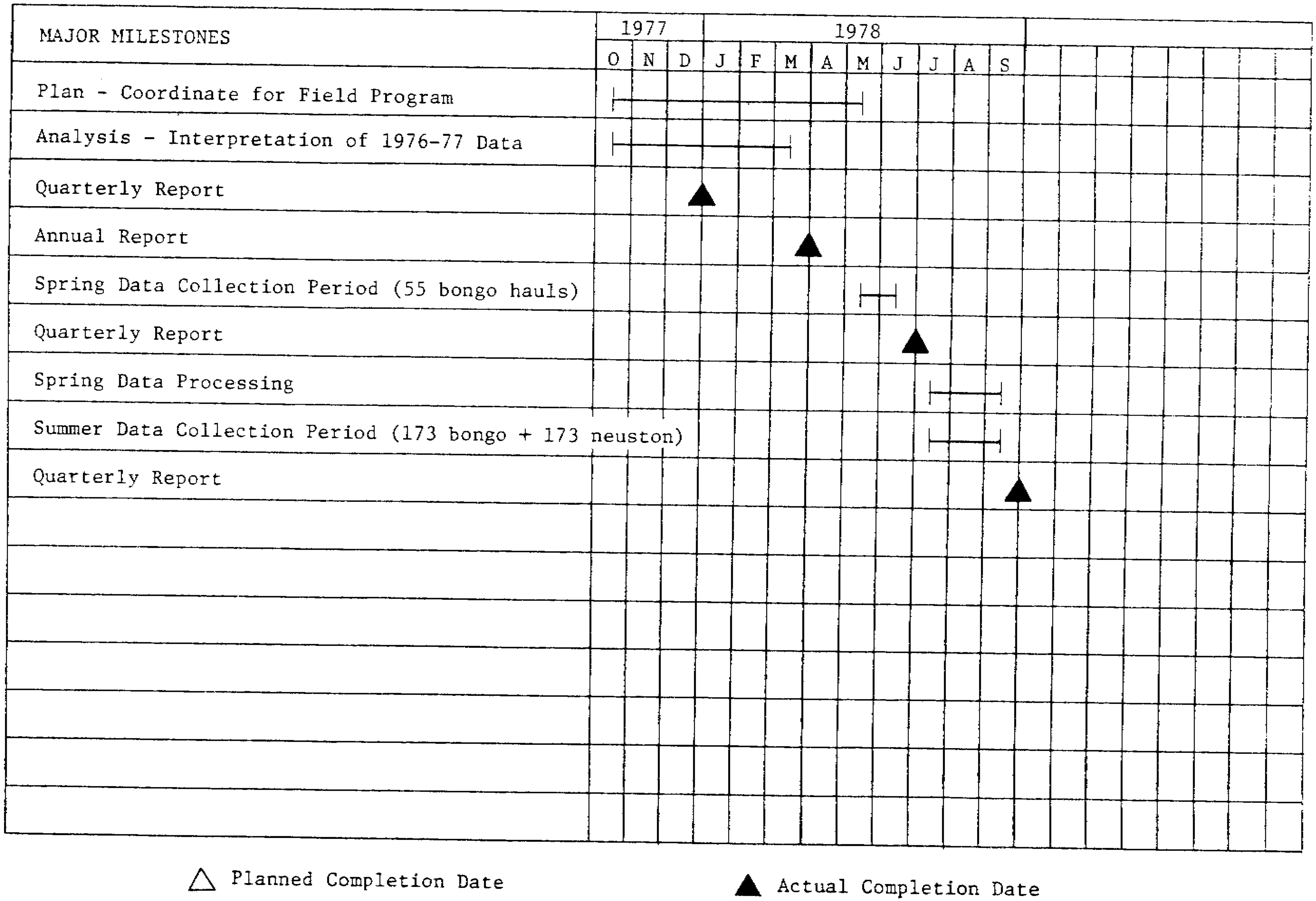


Table 1. Station locations

Station	Latitude (N)	Longitude (W)	Depth (m)	Location
1	59° 44.0'	151° 04.0'	36	Inner Kachemak Bay
2	59° 40.0'	151° 12.0'	64	Inner Kachemak Bay
3	59° 36.0'	151° 18.0'	79	Inner Kachemak Bay
4	59° 28.5'	151° 32.0'	18	Jakalof Bay
5	59° 28.0'	151° 44.5'	18	Seldovia
6	59° 34.0'	151° 32.5'	75	Outer Kachemak Bay
7	59° 39.0'	151° 48.0'	31	Outer Kachemak Bay
8	59° 37.0'	151° 52.0'	26	Outer Kachemak Bay
9	59° 33.0'	151° 55.0'	38	Outer Kachemak Bay
10	59° 29.0'	151° 51.0'	62	Outer Kachemak Bay
11	59° 34.0'	151° 44.0'	73	Outer Kachemak Bay
12	59° 31.0'	151° 45.0'	98	Outer Kachemak Bay
13	59° 23.0'	152° 06.0'	53	Lower Cook Inlet
14	59° 20.0'	152° 22.0'	84	Lower Cook Inlet
15	59° 22.5'	152° 40.0'	60	Lower Cook Inlet
16	59° 16.3'	152° 49.5'	91	Lower Cook Inlet
17	59° 15.9'	153° 08.5'	53	Lower Cook Inlet
18	59° 26.0'	153° 14.0'	38	Lower Cook Inlet
19	59° 27.5'	153° 22.0'	27	Kamishak Bay
20	59° 20.0'	153° 14.0'	48	Kamishak Bay
21	59° 17.0'	153° 26.0'	26	Kamishak Bay
22	59° 14.0'	153° 40.0'	30	Kamishak Bay
23	59° 15.9'	153° 41.0'	27	Kamishak Bay
24	59° 27.0'	153° 34.0'	20	Kamishak Bay
25	59° 38.0'	153° 35.0'	7	Cottonwood Bay
26	59° 36.0'	153° 29.0'	13	Iliamna Bay
27	59° 39.0'	153° 26.0'	6	Iniskin Bay
28	59° 30.0'	153° 10.0'	35	Lower Cook Inlet
29	59° 32.0'	152° 58.0'	40	Lower Cook Inlet
30	59° 31.0'	152° 36.0'	62	Lower Cook Inlet
31	59° 33.0'	152° 14.0'	48	Lower Cook Inlet
32	59° 28.0'	151° 58.0'	66	Lower Cook Inlet

Table 2. BLM station locations

Station	Latitude (N)	Longitude (W)	Depth (m)	Location
BLM-1	59° 42.5'	152° 09.0'	37	Lower Cook Inlet
BLM-2	59° 27.0'	152° 59.0'	46	Lower Cook Inlet
BLM-3	59° 20.0'	152° 22.0'	84	Lower Cook Inlet
BLM-4	59° 11.0'	152° 39.0'	93	Lower Cook Inlet

Table 3. Haul summary sheet, 26 June-2 September 1978.

Date (1978) (GMT)	Time (GMT)	Station	Haul	Net	Sampling Depth (m)
26 JUN	1627	25	1	60 cm bongo	5
	1747	26	1	"	11
	1723	27	1	"	3
	1910	19	1	"	16
	2006	24	1	"	18
	2153	23	1	"	21
	2219	22	1	"	23
	2345	21	1	"	20
27 JUN	0055	20	1	60 cm bongo	42
	0144	17	1	"	49
	0318	16	1	"	85
	0433	15	1	"	54
	0559	14	1	"	69
	0658	13	1	"	50
	0910	10	1	"	49
28 JUN	2249	6	1	60 cm bongo	69
29 JUN	0022	11	2	60 cm bongo	69
	0128	7	1	"	23
	0157	8	1	"	20
	0302	9	1	"	35
	0406	12	1	"	81
	0516	4	1	"	10
	1744	2	1	"	44
	1853	1	1	"	37
	2016	3	1	"	52
	2121	6	1	"	87
30 JUN	0922	6	1	60 cm bongo	85
6 JUL	0140	32	1	60 cm bongo	72
	0308	31	1	"	39
	0506	30	1	"	51
	0721	29	1	"	33
	0802	28	1	"	27
	0916	19	1	"	21
	2140	19	1	"	21
11 JUL	1902	6	1	60 cm bongo	92
	1958	11	1	"	71
	2105	7	1	"	22
	2149	8	1	"	20
	2228	9	1	"	28
	2325	12	1	"	81

Table 3. (cont.)

Date (1978) (GMT)	Time (GMT)	Station	Haul	Net	Sampling Depth (m)
12 JUL	0036	4	1	60 cm bongo	10
	2341	10	1	"	52
13 JUL	0027	32	1	60 cm bongo	65
	0206	31	1	"	37
	0358	30	1	"	64
	0614	29	1	"	35
	0735	28	1	"	30
	0824	18	1	"	29
15 JUL	1837	25	1	60 cm bongo	5
	1913	26	1	"	10
	2045	19	1	"	21
	2148	24	1	"	18
	2342	23	1	"	21
16 JUL	0011	22	1	60 cm bongo	24
	0124	21	1	"	21
	0234	20	1	"	42
	0325	17	1	"	51
	0458	16	1	"	81
	0615	15	1	"	58
	0756	14	1	"	75
	0922	13	1	"	49
6 AUG	1558	18	1	60 cm bongo	28
	1718	17	1	"	55
	1854	16	1	"	76
	2015	15	1	"	49
	2158	14	1	"	74
	2321	13	1	"	47
7 AUG	0035	10	1	60 cm bongo	48
	0107	12	1	"	88
	2037	6	1	"	71
	2107	7	1	"	25
	2140	8	1	"	20
	2230	9	1	"	34
	2320	11	1	"	63
8 AUG	0930	6	1	60 cm bongo	71
	2134	6	1	"	71
11 AUG	2210	1	1	20 cm bongo	42
	2317	2	1	"	50

Table 3. (cont.)

Date (1978) (GMT)	Time (GMT)	Station	Haul	Net	Sampling Depth (m)
12 AUG	0058	3	1	20 cm bongo	92
	0233	4	1	"	10
13 AUG	2335	32	1	60 cm bongo	79
	2358	32	2	neuston	0
14 AUG	0125	31	1	60 cm bongo	43
	0130	31	2	neuston	0
	0310	30	1	60 cm bongo	57
	0314	30	2	neuston	0
	0455	29	1	60 cm bongo	35
	0501	29	2	neuston	0
	0603	28	1	60 cm bongo	30
	0615	28	2	neuston	0
	0852	19	1	60 cm bongo	22
	2057	19	2	"	22
22 AUG	1810	3	1	20 cm bongo	74
	1828	3	2	neuston	0
	1854	2	1	"	0
	1908	2	2	20 cm bongo	58
	1948	1	1	"	26
	2000	1	2	neuston	0
	2120	4	1	20 cm bongo	13
	2130	4	2	neuston	0
24 AUG	2135	5	1	20 cm bongo	11
	2147	5	2	neuston	0
25 AUG	0006	6	1	60 cm bongo	96
	0015	6	2	neuston	0
	0120	11	1	60 cm bongo	70
	0126	11	2	neuston	0
	0212	8	1	"	0
	0221	8	2	60 cm bongo	21
	0313	9	1	"	35
	0319	9	2	neuston	0
	2329	32	1	"	0
	2340	32	2	60 cm bongo	79
26 AUG	0058	31	1	60 cm bongo	43
	0104	31	2	neuston	0
	0230	30	1	"	0
	0240	30	2	60 cm bongo	52
	0428	29	1	"	35
	0431	29	2	neuston	0

Table 3. (cont.)

Date (1978) (GMT)	Time (GMT)	Station	Haul	Net	Sampling Depth (m)
26 AUG	0528	28	1	neuston	0
	0538	28	2	60 cm bongo	30
28 AUG	1717	18	1	60 cm bongo	71
	1732	18	2	neuston	0
	2016	16	1	60 cm bongo	86
	2023	16	2	neuston	0
	2135	15	1	"	0
	2145	15	2	60 cm bongo	55
	2318	14	1	"	76
	2325	14	2	neuston	0
29 AUG	0047	13	1	neuston	0
	0100	13	2	60 cm bongo	50
	0230	10	1	"	55
	0235	10	2	neuston	0
31 AUG	1747	3	1	20 cm bongo	70
	1800	3	2	neuston	0
	1822	2	1	"	0
	1833	2	2	20 cm bongo	47
	1858	1	1	"	22
	1906	1	2	neuston	0
	2020	5	1	"	0
	2030	5	2	20 cm bongo	13
	2054	4	1	"	12
	2101	4	2	neuston	0
1 SEP	2002	6	1	60 cm bongo	96
	2021	6	2	neuston	0
	2107	11	1	"	0
	2119	11	2	60 cm bongo	64
	2214	7	1	"	30
	2230	7	2	neuston	0
	2251	8	1	"	0
	2309	8	2	60 cm bongo	25
2 SEP	0004	9	1	60 cm bongo	34
	0024	9	2	neuston	0
	0054	12	1	"	0
	0107	12	2	60 cm bongo	96
3 SEP	0009	BLM-1	1	60 cm bongo	32
	0022	BLM-1	2	neuston	0
	0440	BLM-2	1	"	0
	0450	BLM-2	2	60 cm bongo	41

Table 4. Pandalid shrimp collected in the Lower Cook Inlet region, 19 May to 1 July 1978.

Order Decapoda

Suborder Natantia

Section Caridea

Family Pandalidae

Pandalopsis dispar Rathbun side stripe shrimp
(larval stages I-III)

Pandalus borealis Kröyer northern pink shrimp
(larval stages I-IV)

Pandalus danae Stimpson dock shrimp
(larval stages II-III)

Pandalus goniurus Stimpson humpy shrimp
(larval stages I-V)

Pandalus hypsinotus Brandt coon stripe shrimp
(larval stage II)

Pandalus montagui tridens Rathbun no common name
(larval stages III-IV)

Pandalus stenolepis Rathbun no common name
(larval stage I)

Table 5. Commercially important species of crab larvae collected in Lower Cook Inlet region, 19 May to 1 July 1978.

Order Decapoda

Suborder Reptantia

Section Anomura

Family Lithodidae

Paralithodes camtschatica (Tilesius) Alaska king crab (larval stages II-IV and megalopae)

Section Brachyura

Superfamily Brachyrhyncha

Family Cancridae

Cancer magister Dana Dungeness crab (larval stages I-II)

Superfamily Oxyrhyncha

Family Majidae

Subfamily Oregoniinae

Chionoecetes bairdi Rathbun tanner crab (larval stages I-II and megalopae)

Table 6. List of possible fish for egg size categories collected in the Lower Cook Inlet region, 19 May to 26 June 1978.

< 1 mm (0.73-0.88 mm)

Limanda aspera (Pallas) yellowfin sole

∿1 mm (0.89-1.28 mm)

Isopsetta isolepis (Lockington) butter sole
Parophrys vetulus Girard English sole
Platichthys stellatus (Pallas) starry flounder
Psettichthys melanostictus Girard sand sole

∿2 mm (1.30-2.54 mm)

probably *Theragra chalcogramma* (Pallas) walleye pollock

∿3 mm (2.56-3.90)

Hippoglossoides elassodon Jordan & Gilbert flathead sole

Table 7. Fishes collected in the Lower Cook Inlet region 19 May to 26 June 1978.

Family Clupeidae-herrings

Clupea harengus pallasi Valenciennes Pacific herring

Family Osmeridae-smelts

Mallotus villosus (Müller) capelin

Family Gadidae-codfishes

Gadus sp. Pacific cod
Theragra chalcogramma (Pallas) walleye pollock

Family Stichaeidae-pricklebacks

Anoplarchus sp. cockscomb
Lumpenus sp. prickleback

Family Pholidae-gunnels

Family Ammodytidae-sand lances

Ammodytes hexapterus Pallas Pacific sand lance

Family Cottidae-sculpins

"Cottid 4, 5", and "6" from Blackburn (1973) plus one unidentified species

Family Agonidae-poachers

Two unidentified species

Family Cyclopteridae-lumpfishes and snailfishes

Family Pleuronectidae-right-eyed flounders

Hippoglossoides elassodon Jordan & Gilbert flathead sole
Lepidopsetta bilineata (Ayres) rock sole
Limanda aspera (Pallas) yellowfin sole

QUARTERLY REPORT

Research Unit #425

Reporting Period: April-September 1978

ORGANIC DETRITUS AND PRIMARY PRODUCTIVITY IN LOWER COOK INLET

Principal Investigator: Jerry D. Larrance

Pacific Marine Environmental Laboratory
Environmental Research Laboratories
National Oceanic and Atmospheric Administration
7600 Sand Point Way N.E.
Seattle, Washington 98115

October 17, 1978

I. ABSTRACT

Five cruises to lower Cook Inlet were conducted between March and April 1978 for purposes of measuring vertical fluxes and composition of organic detritus, and primary productivity and related variables. On four of the five cruises, dual sediment traps of PMEL design were deployed 10 meters off the bottom at three stations and retrieved after five days. From the samples obtained, downward daily fluxes of total particulate matter ranged from 2 to 22 g m^{-2}, except for one extreme value of 72 g m^{-2} in an area and period of high runoff. By an analysis of chlorophyllous pigments in the water column and in the sediment traps, we estimate that an average of 8% of the phytoplankton standing stock in various forms sinks to near bottom depths each day.

Although analyses of the primary productivity data are not complete, preliminary results are consistent with those from the 1976 study of primary productivity. Daily productivities as high as 7-8 g C m^{-2} were measured, the highest occurring in Kachemak Bay. In addition to measurements planned initially along a cross-inlet transect, a grid of closely spaced stations in Kachemak Bay was occupied on four cruises at which pigments, salinity, temperature and nutrients were measured. Preliminary analyses of the data show coherent patterns of chlorophyll variability which may be related to circulation or stratification of the water column.

II. TASK OBJECTIVES

Specific objectives for the period of late March through September were:

1. To complete design, fabrication and testing of sediment traps and moorings.
2. To complete five cruises in March (not reported previously), May, June, July, and August for sampling sinking particles by sediment traps and measurement of phytoplankton standing stock and productivity and related variables.
3. To commence analyses of samples and data acquired during the summer field activity.

III. FIELD ACTIVITIES

A. NOAA ship schedule

Cruises were conducted according to the following schedule:

		Cruise Numbers	
Dates	Vessel	NOS	PMEL*
March 23-27	SURVEYOR	RP-4-SU-78A	LCI 78-1
May 7-14	MILLER FREEMAN	RP-4-MF-78A I	LCI 78-2
June 6-13	MILLER FREEMAN	RP-4-MF-78A III	LCI 78-3
July 12-20	MILLER FREEMAN	RP-4-MF-78A V	LCI 78-4
August 13-20	SURVEYOR	RP-4-SU-78B	LCI 78-5

*Numbers assigned for internal PMEL use. These numbers will be used in texts of reports to OCSEAP.

B. Scientific personnel

Name	Affiliation	Role	LCI Cruises
Booth, Beatrice	PMEL/UW	Oceanographer	78-2
Campbell, Christine	PMEL	Technician	78-3 - 78-5
Chester, Alex	PMEL	Oceanographer	78-1 - 78-5
Foster, Joan	MESA (Boulder)	Technician	78-2
Glendening, Marcia	PMEL	Oceanographer	78-2
Hennig, Susan	PMEL	Technician	78-3 - 78-5
Larrance, Jerry	PMEL	Chief Scientist	78-1 - 78-3, 78-5
Tennant, David	PMEL	Oceanographer	78-3 - 78-4

C. Methods

The sampling and analytical procedures were constant for all five cruises with the exception that sediment traps were not deployed on LCI 78-1.

1. Sediment trap deployment and sample treatment and analysis

The sediment traps and moorings employed were designed, fabricated, and tested at PMEL for use during this study. The moorings consist of a 1700-kg steel and concrete anchor; an acoustic release; dual gimballed sediment traps; a streamlined (torpedo-shaped) subsurface float with buoyancy of about 500 kg; and tethering cables, chains, and hardware (Figure 1). Special features were included in the mooring's design to counteract for high current speeds sometimes occurring in Cook Inlet; to meet sampling requirements of the study; and to minimize damage to the gear of local commercial fishermen. Unusually heavy anchors were used to prevent their shifting along the bottom in strong currents. These anchors were smooth concrete hemispheres to minimize the chances for entanglement with fish trawls. The sediment traps were made of polyvinylchloride and incorporated a butterfly valve closure actuated by a battery-powered electronic timer housed in the trap casing below the sample chamber. Two traps side-by-side were placed on each mooring and gimballed to maintain the trap mouth in a horizontal plane. A vertical stainless steel shaft free to rotate about the axis of the tethering cable secured the traps and current vane. The vane functioned to maintain the traps upstream of the cable for uniform sampling conditions without interference by the mooring's hardware.

Three sediment-trap moorings were deployed at the beginning of each cruise (except LCI 78-1) and retrieved at the end of the cruise. Sampling times were 5 or 6 days. The moorings were placed at stations 1, 4, and 7 on each cruise (Figure 2). All moorings were successfully deployed and retrieved throughout the study. Various malfunctions of the timer-fuse apparatus for closing the traps were encountered and corrected in subsequent operations. The overall success rate of obtaining adequate samples in the traps was 63%. All the traps on the last cruise (LCI 78-5) functioned properly and all the samples were recovered. Trap malfunctions were somewhat ameliorated by paired traps; thus if one failed, a sample at that time and location was obtained from the other trap. Of twelve moorings during the study, reliable samples were obtained from ten.

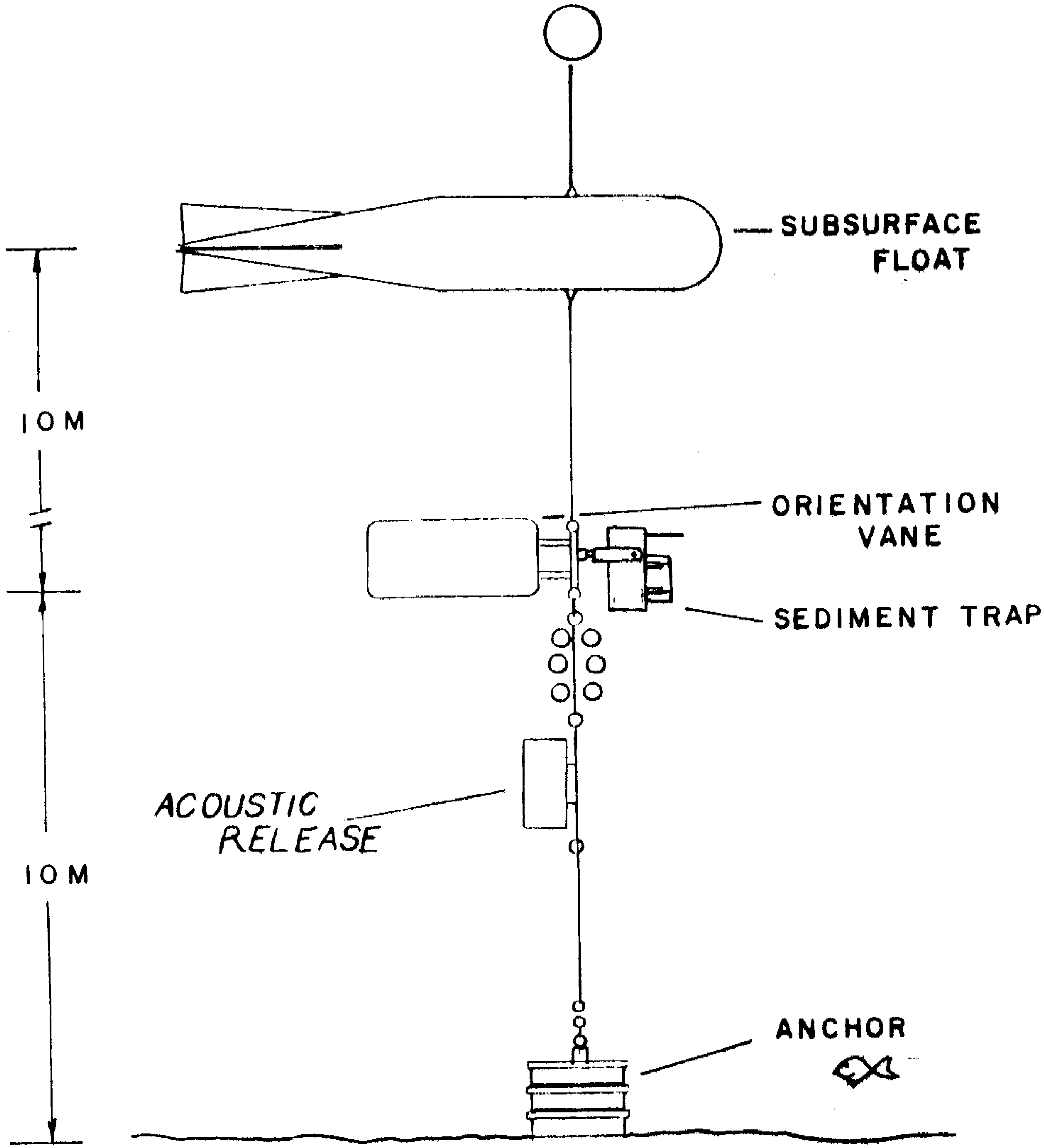


Figure 1. Diagram of Sediment Trap Mooring.

Upon recovery of the sediment traps, the sample was drained and washed into a volumetric cylinder, measured, and transferred to a 10-ℓ polyethylene jug. The contents of the jug was thoroughly shaken immediately before drawing aliquot portions of the water-particle mixture for pigment analysis, microscopical analysis, and stable isotope analysis. The pigment analyses were conducted immediately after subsampling by fluorometric methods identical to those used for chlorophyll and pheopigments in seawater (Strickland and Parsons, 1972). The subsamples for microscopical examination were preserved in formalin and returned to Seattle where they are being analyzed for numbers of fecal pellets, phytoplankton cells, zooplankton carapaces, and other identifiable particles. The subsample for isotopic analysis was filtered through glass-fiber filters and returned to Seattle for analyses of stable carbon and nitrogen isotopes by mass spectrometry after combustion and conversion of organic carbon and nitrogen to CO_2 and N_2.

The remainder of the sample was filtered through preweighed 142 mm 0.4 μm Nuclepore^R filters, washed with deionized water, dried in a desiccator, and reweighed in the laboratory to obtain the weight of total particulate matter (TPM) caught in the sediment trap. To obtain particulate carbon and nitrogen concentrations (as weight-% of the TPM), portions of the material collected on the Nuclepore filter were carefully removed, weighed, and analyzed by the micro-Dumas combustion method using a Hewlett Packard C-H-N analyzer (Sharp, 1974).

2. Water sampling and analysis

Station sampling began following deployment of sediment trap moorings. Routine CTD-rosette casts were made to obtain temperature and salinity profiles. Water samples were collected from several depths with 5-ℓ PVC Niskin bottles. Aliquots withdrawn from these samplers were used to measure various biological and chemical parameters. Subsamples for phytoplankton species determination were preserved in acetate buffered formalin and returned to the laboratory for analysis by inverted microscope techniques (Lund, Kipling and LeCren, 1958). Plant pigments were analyzed aboard ship using fluorometric methods (Strickland and Parsons, 1972). Seawater samples for determination of dissolved inorganic nutrients were frozen, and returned to the University of Washington Department of Oceanography where they were analyzed by Auto Analyzer methods (Strickland and Parsons, 1972). Half-day primary productivity experiments were conducted using standard carbon-14 methodology (Strickland and Parsons, 1972). Samples were taken from eight light depths ranging from 100% to 1% of surface light intensity and incubated on deck under comparable neutral density light screens. The carbon-14 radioactivity in the resulting samples was determined by liquid scintillation spectrometry.

During each cruise, sunlight was continuously monitored with a Lamda Instruments quantum sensor sensitive to light in the photosynthetically active region (approx. 400-680 nm). Light penetration in the water column was measured with a similar sensor adapted for underwater use.

D. Sample locations

Seven stations (Figure 2) were routinely occupied each day except for the first and last days of each cruise when sediment traps were deployed and recovered. In addition, a grid of closely spaced stations in the Kachemak Bay area was occupied on all cruises except 78-1. The nominal locations for stations 1-7 are given below:

Station	Latitude (N)	Longitude (W)
1	59° 14.0'	153° 40.0'
2	59° 17.0'	153° 20.0'
3	59° 20.0'	153° 00.0'
4	59° 23.0'	152° 40.0'
5	59° 26.6'	152° 20.0'
6	59° 30.0'	152° 00.0'
7	59° 33.3'	151° 40.0'

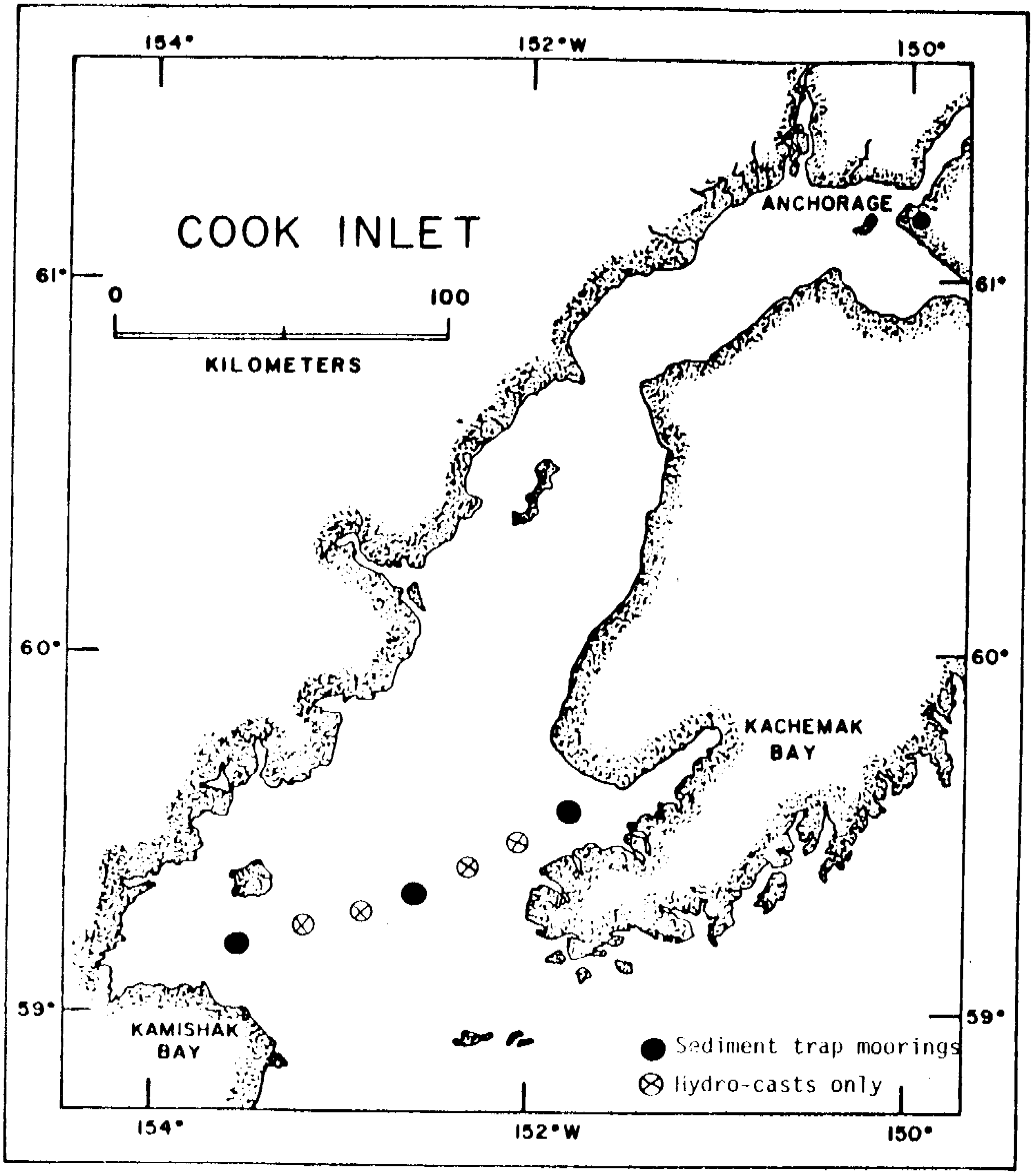


Figure 2. Station Locations.

The Kachemak Bay grid of stations varied in number from 8 to 18 and in precise location depending on the cruise. All grid stations were 1-2 miles from the nearest station and centered around station 7. Station locations are shown in Figures 3-6. Plant pigments, salinity, temperature, and nutrients in the upper 25 m of water were commonly measured during the Kachemak Bay grid sampling. The grid was completed in every case within 9 hours.

IV-V. RESULTS AND INTERPRETATION

A. Particulate matter sampled by sediment traps

The available information on material caught in the sediment traps is summarized in Table 1. The downward flux of particles ranged between 2 and 22 g/m^2 day except for a value of 72 g/m^2 day in May in Kamishak Bay (station 1). At that time the water was noticeably much more turbid than at other areas and times, and contained heavy loads of terrestrial particulate matter. The overall mean daily flux was 19.4 g/m^2, but was 13.5 g/m^2 if the high May value at station 1 is omitted. With the omission of that value, the largest mean daily (19.1 g/m^2) flux occurred in Kachemak Bay (station 7) as compared to a mean of 10.8 g/m^2 at both stations 1 and 4.

The highest chlorophyll and fecal pellet content was found also in the Kachemak Bay samples. The chlorophyll equivalent values given in Table 1 include pheopigment concentrations which have been adjusted for the molecular weight difference between chlorophyll and pheophorbide in order to obtain weights of pigments as if they were converted to chlorophyll (Shuman and Lorenzen, 1975). The pigment concentrations in sediment trap samples were distinctly greater at station 7 (Kachemak Bay) than at stations 1 and 4 for all sampling periods. The mean at station 7 was 14.3 mg/m^2 day contrasting with means of 2.6 and 2.4 mg/m^2 day for stations 1 and 4. The mean numbers of fecal pellets were 421, 780, and 1470 $\cdot$ $10^3/m^2$ day for stations 1, 4, and 7, respectively. These pigment and fecal pellet fluxes reflect the high biological production in Kachemak Bay

Table 1. Daily fluxes of total particulate matter, plant pigments, zooplankton fecal pellets, and derived estimates of losses from overlying phytoplankton populations, lower Cook Inlet, 1978.

Station	Month	Total Particulate Matter (TPM) g/m^2-day	Chlorophyll Equivalents mg/m^2-day	Standing Stock Lost %	Grazing Loss %	Fecal Pellets $10^3/m^2$-day
7	May	17.3	17.2	8.5	79	360
	June	22.1	14.4	5.7	81	930
	July	-	-	-	-	-
	August	18.0	11.3	7.6	89	3110
4	May	9.4	1.9	4.1	89	250
	June	22.1	5.0	18.2	85	2010
	July	1.9	1.0	2.6	88	79
	August	9.6	1.5	1.6	87	120
1	May	72.0	1.6	9.9	90	92
	June	-	-	-	-	-
	July	6.4	3.0	7.2	61	750
	August	15.2	3.1	9.2	81	1830

found in our 1976 studies and from preliminary analyses of productivity data obtained this year.

By comparing the pigment fluxes with chlorophyll concentrations in the overlying waters, an estimate was made of the portion of the phytoplankton population lost each day by sinking of algal particles which include whole cells, cell fragments, and fecal pellets. The percentage loss ranged between 2 and 24% with a mean of 7.5%. The pheopigment fraction of the total pigment flux is listed in Table 1 as grazing loss. The assumption was made that chlorophyll is converted to pheopigments only within the guts of grazers (Schuman and Lorenzen, 1975).

B. Water column data

Although most of the data obtained from the water column is being processed and not yet available, examples of chlorophyll patterns in Kachemak Bay are shown in Figures 3-6. The values for LCI 78-2 are integrated over the upper 10 m while those for the remaining cruises are integrated over the upper 25 m. The largest values were observed in June at the height of the spring phytoplankton bloom. In August the concentrations were more uniform and generally low. No consistent patterns from month to month are apparent; however, the patterns shown represent real patchiness and not merely random or sampling variation. These patterns serve to illustrate the natural variability in chlorophyll distributions on a spatial scale about one order of magnitude smaller than our routine station intervals. It should be expected, however, that variability in Kachemak Bay would be greater than elsewhere because the water column in Kachemak Bay is often stratified, more productive, and is an area of convergence of oceanic water and water from inner Kachemak Bay. A more thorough analysis of these and related data is forthcoming.

Typical cross sectional plots of chorophyll (Figure 7) show highest values generally at station 7 and usually lower values at mid-channel. These distributions are consistent with temperature and circulation information which indicates deep water rising toward the surface at mid-channel. This deep water contains low

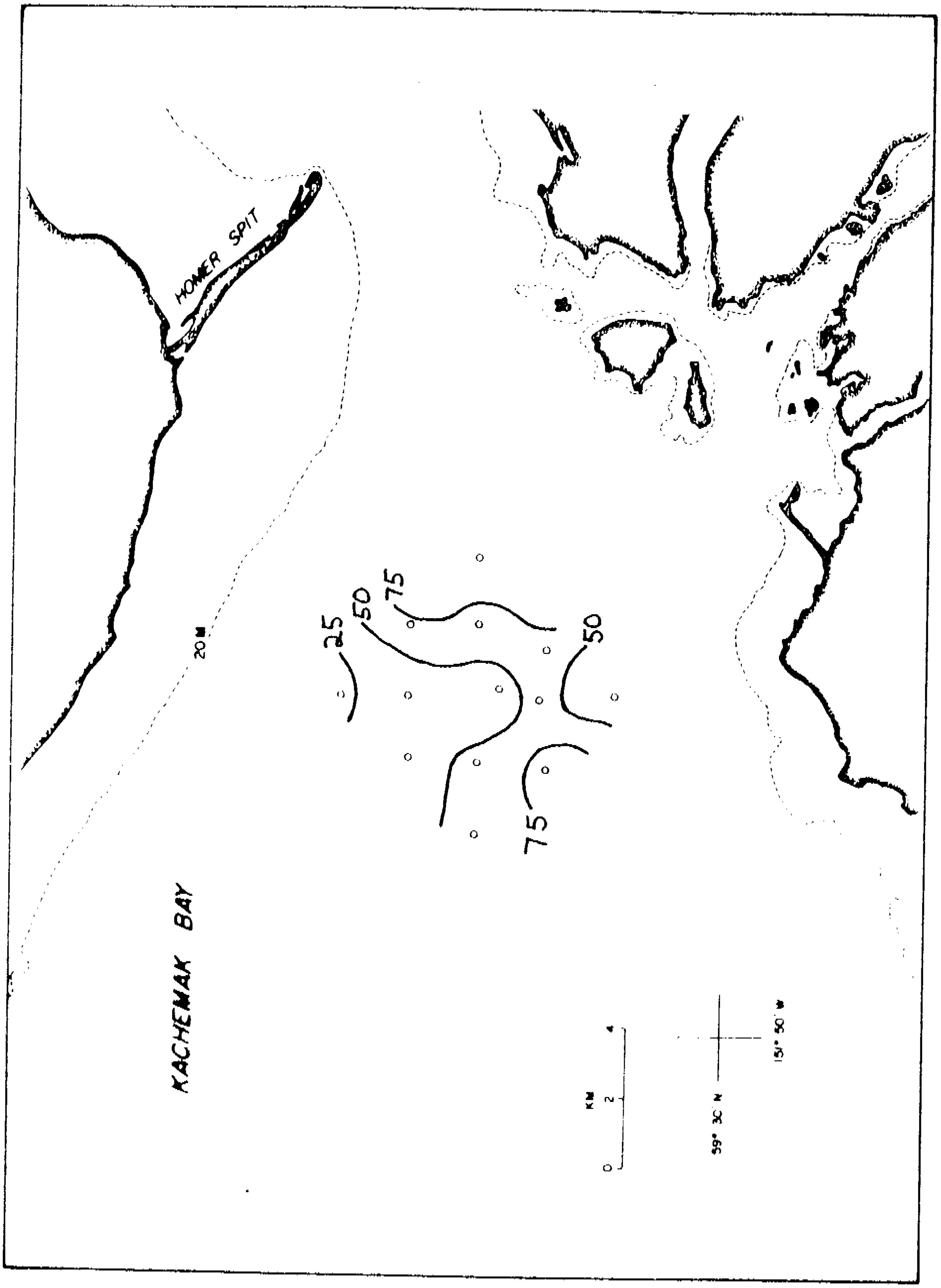


Figure 3. Chlorophyll a concentrations (mg m^{-2}) in upper 10 m, Kachemak Bay, lower Cook Inlet, 12 May 1978.

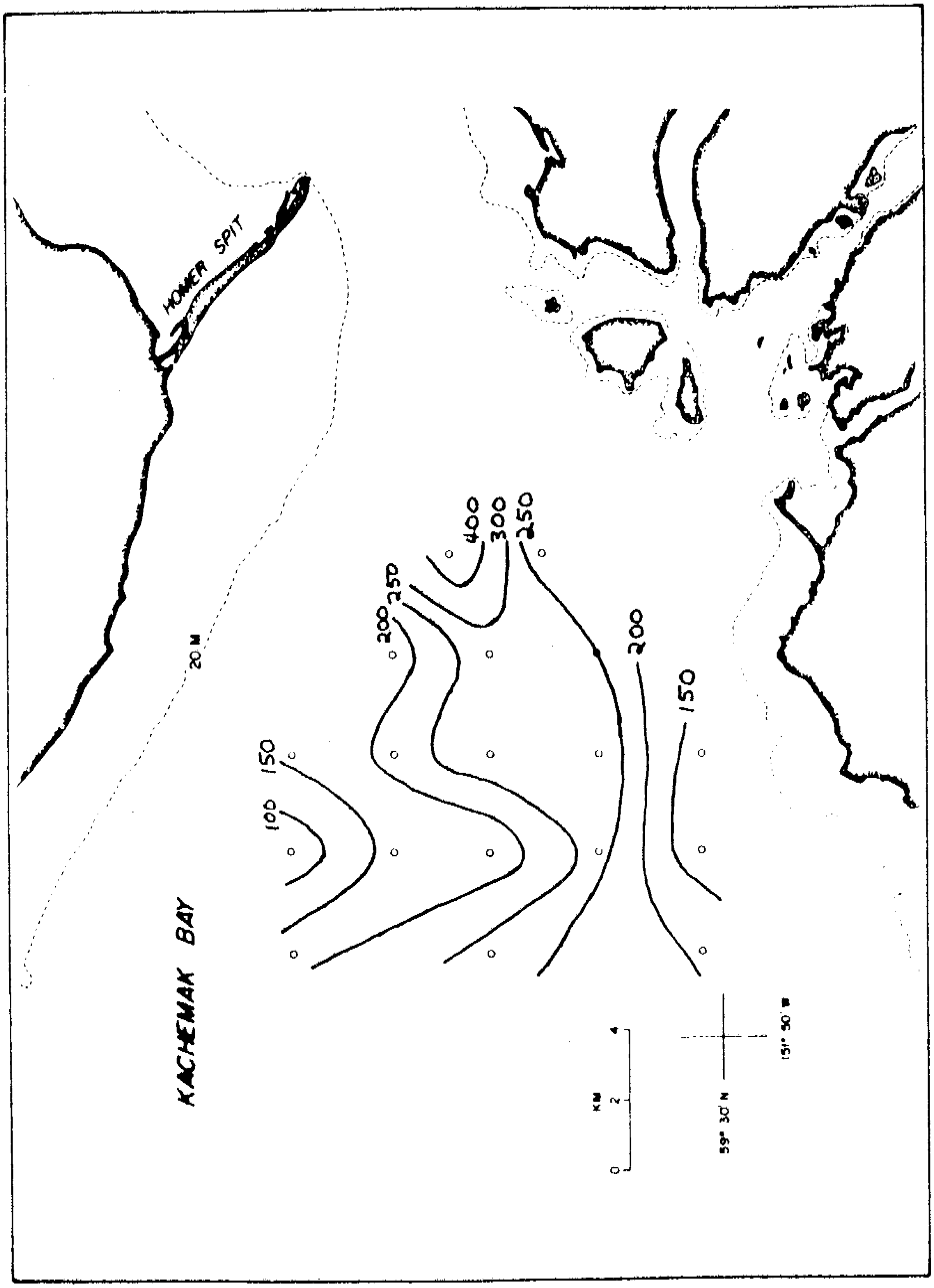


Figure 4. Chlorophyll a concentrations (mg m^{-2}) in upper 25 m, Kachemak Bay, lower Cook Inlet, 9 June 1978.

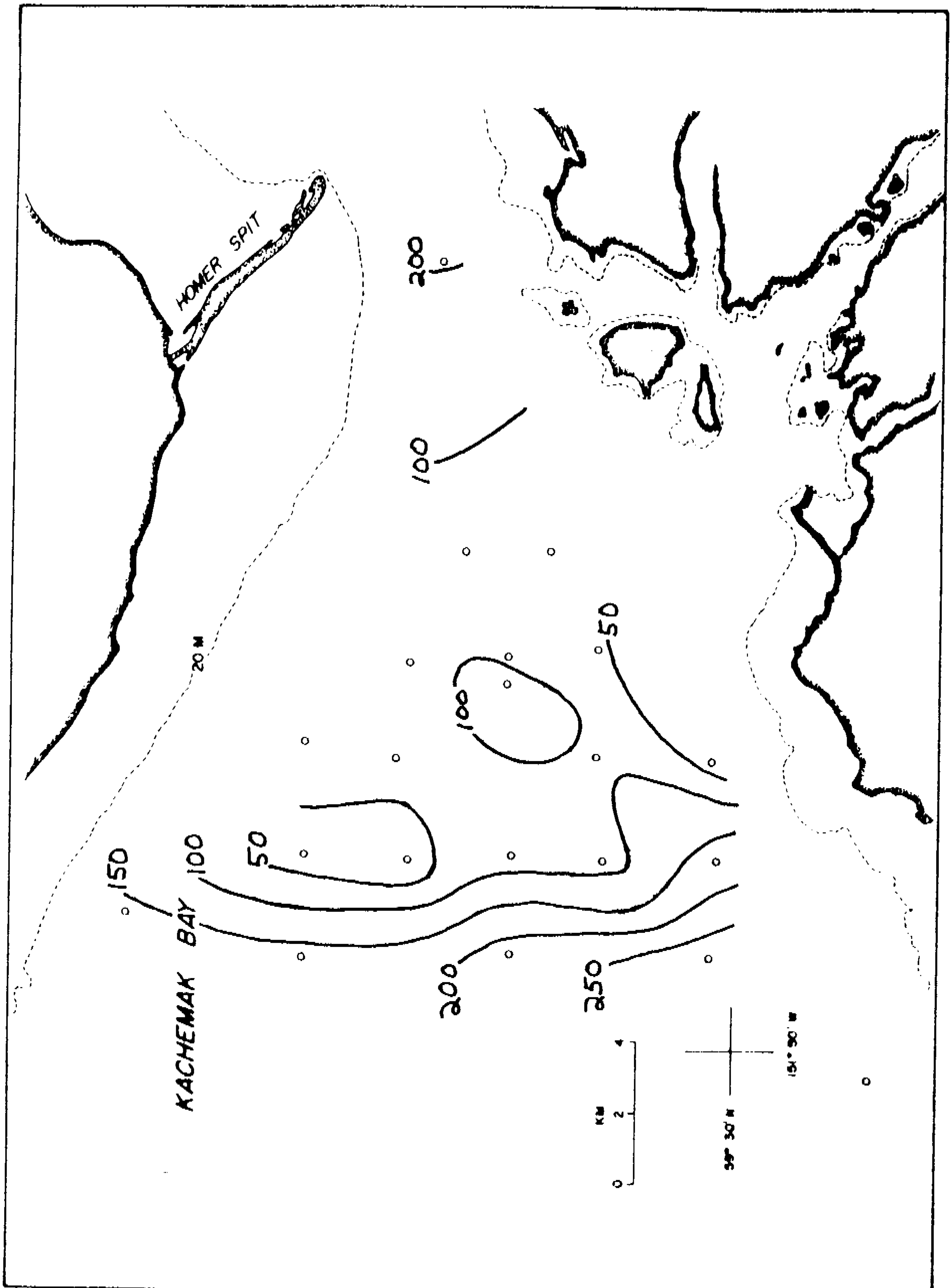


Figure 5. Chlorophyll a concentrations (mg m^{-2}) in upper 25 m, Kachemak Bay, lower Cook Inlet, 17 July 1978.

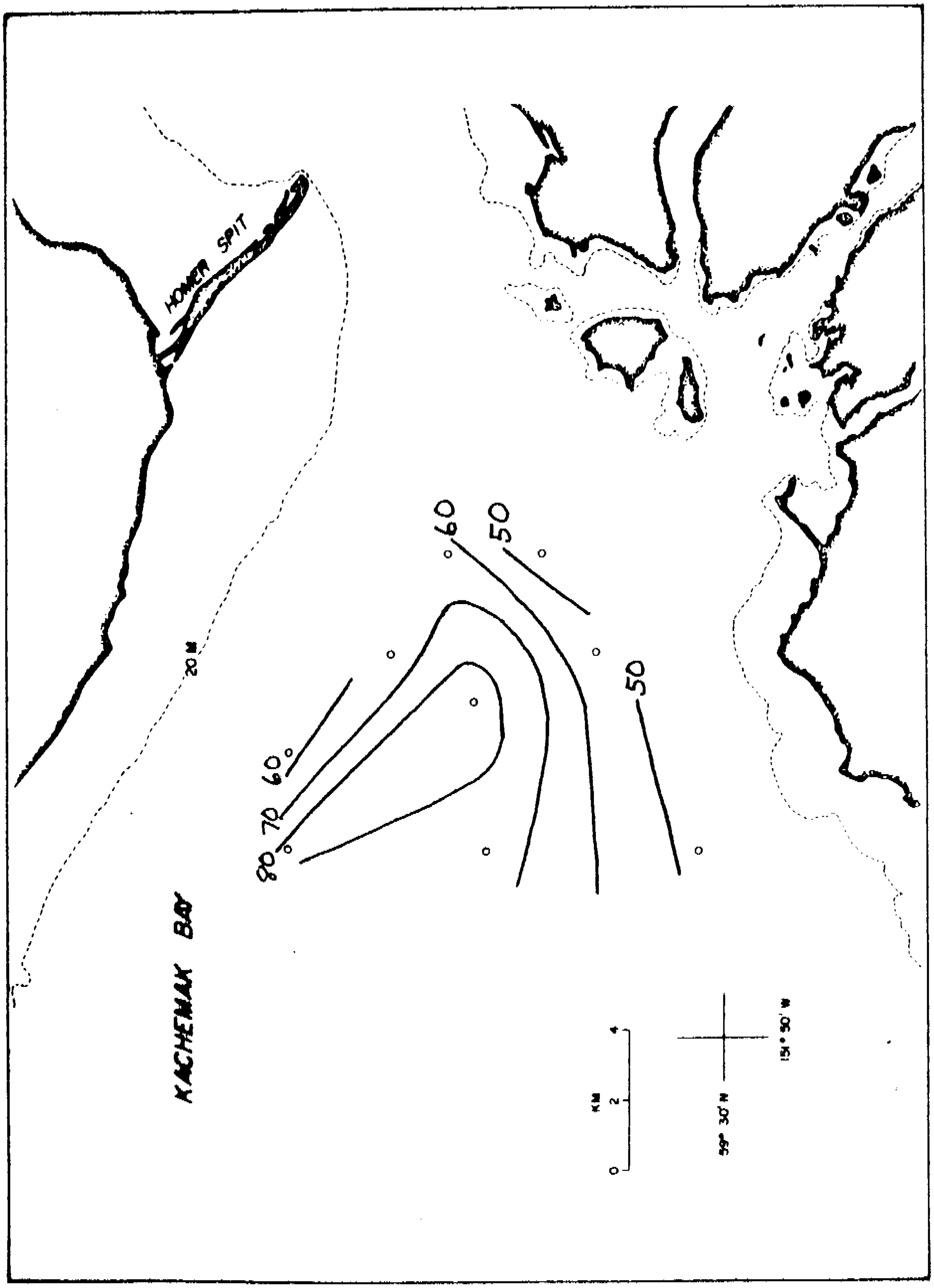


Figure 6. Chlorophyll a concentrations (mg m^{-2}) in upper 25 m, Kachemak Bay, lower Cook Inlet, 17 August 1978.

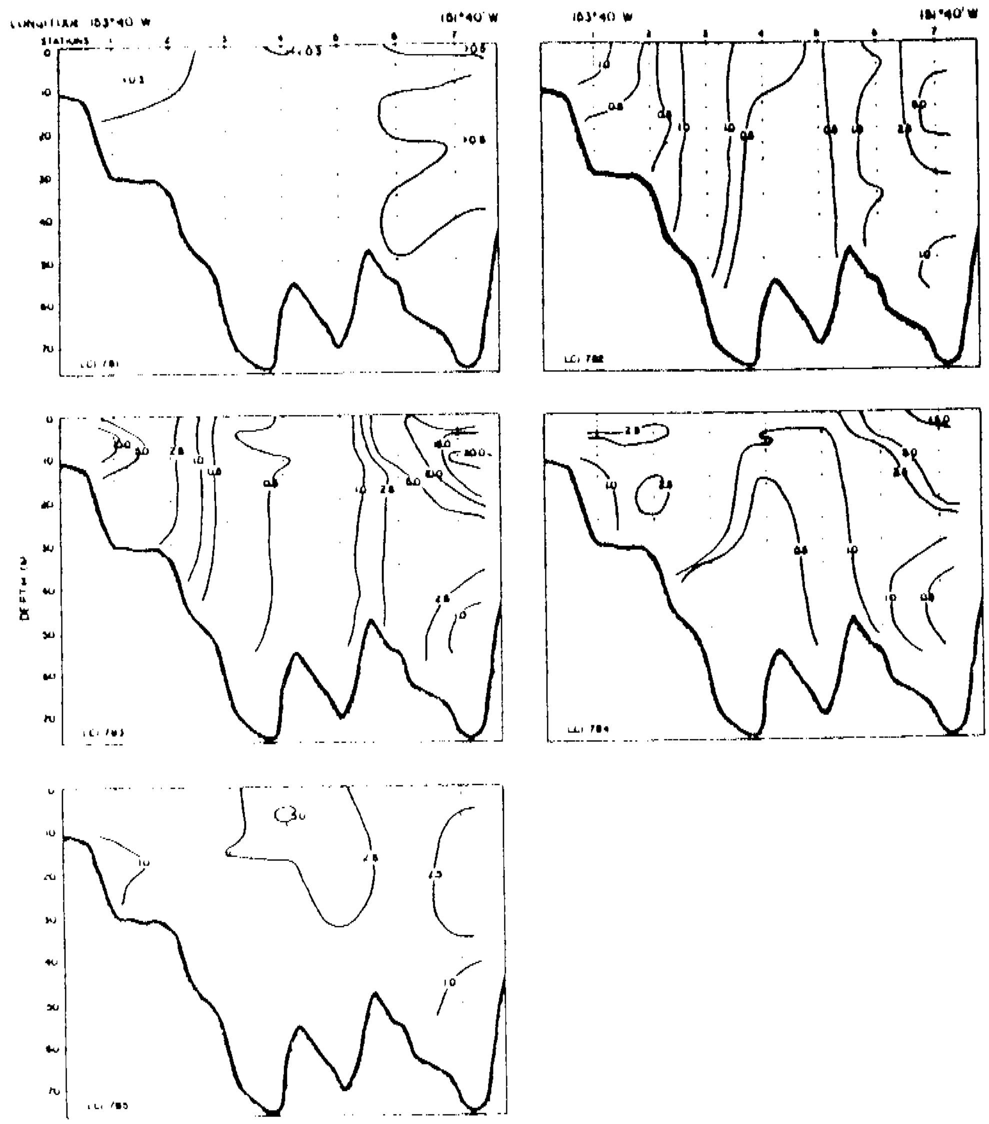


Figure 7. Chlorophyll $\underline{a}$ concentrations (mg m^{-3}), lower Cook Inlet, March-August 1978.

concentrations of chlorophyll. In March, chlorophyll was uniformly low (Figure 7). By May, the spring bloom had begun, especially in Kachemak Bay (station 7) where >5 mg chlorophyll/m^3 was measured. The peak of the bloom occurred around the June sampling and declined by July and August.

From phytoplankton productivity data obtained in 1976, the annual phytoplankton production for the entire lower Cook Inlet was estimated to be $6.64 \cdot 10^6$ metric tons of carbon. This contrasts with a maximum estimate of macrophyte production of $4.7 \cdot 10^5$ metric tons of carbon by roughly extrapolating macrophyte production data by Lees (1978). Organic detritus, therefore, is derived mainly from phytoplankton, except in shoreline areas where macroalgae dominate locally.

VI. REFERENCES

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VII. ESTIMATE OF FUNDS EXPENDED: $127,000 (FY 1978).

QUARTERLY REPORT
ON RESEARCH UNIT 454

RESEARCH TO DETERMINE THE ACCUMULATION OF ORGANIC CONSTITUENTS AND HEAVY METALS FROM PETROLEUM-IMPACTED SEDIMENTS BY MARINE DETRITIVORES OF THE ALASKAN OUTER CONTINENTAL SHELF

by

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OIL WEATHERING STUDY

Materials and Methods

Three large volume tanks measuring 1.6 m in diameter and 0.9 m deep ($2\ m^2$ area and 1,830 ℓ volume) were layered with 20 ℓ of Prudhoe Bay crude oil. Each tank received flowing seawater that was maintained at a constant level by an external standpipe.

Each tank simulated a different weathering condition:

Tank #1: To simulate weathering under violent weathering conditions inflow water was injected through a rectangular diffusor above the surface of the oil (without a sun shield).

Tank #2: To simulate weathering under calm conditions in the presence of sunlight, a slow flow of seawater was both injected and removed from below the oil slick.

Tank #3: To reduce the effects of sunlight (photo-oxidation of hydrocarbons), a system similar to tank #2 was prepared but with a shade cover over the oil.

Three replicate 25 ml samples were taken from each tank at days 1, 2, 4, 8, 16, and 24. These samples were placed in small vials that were completely filled with oil and then wrapped with foil to exclude light and sealed with a teflon lined cap and refrigerated. Each sample vial was washed in CCl_4 and N_2 dried before use.

At termination (24 days) additional samples were taken for future analysis. These samples consisted of a 1 liter sample from each tank that was packaged and immediately shipped to Alaska and a 1 gallon sample taken for use by other investigators. These samples were taken and prepared similarly to the routine samples described above.

Due to some unforeseeable circumstance, the 1 gallon termination samples from tanks #2 and #3 exploded and all the samples were lost. Therefore, a second gallon was taken from tanks #2 and #3 two days later to replace the lost ones. These samples were only filled 2/3 full, and the lids left slightly loosened to allow the pressure to escape. Approximately 2 ℓ of each oil has been placed in PVC tubes (with caps) and frozen at -70°C until needed.

All samples were removed from the tanks and transferred into containers by the same procedures.

Samples of the original and weathered oil were shipped frozen to the Battelle, Pacific Northwest Laboratories for hydrocarbon analyses. 6-100 mg samples of oil were chromatographed according to the method of Warner (1976) with the following modifications: fifteen grams of silica gel (Grace Davison Chemical Company, 100-200 mesh) was used to separate the oil into saturate (eluted with 40 ml in hexane) and aromatic (eluted with 86 ml of 20% CH_2Cl_2 in hexane) fractions. The fractions, collected in 40 ml conical tubes, were concentrated under a stream of nitrogen without the aid of external heat, transferred to 5 ml conical vials and concentrated to 1 ml. An internal standard (2,6,10-trimethyldodecane for saturate fraction, hexamethylbenzene for aromatic fraction) was added to each sample, and the samples were analyzed by capillary gas chromatography. Individual hydrocarbons were separated and quantitated on a Hewlett Packard 5840 A gas chromatograph employing 30 meter OV-101 glass capillary columns operating at 65^{o} with an initial 4 minute hold and then programmed at 4^{o}/min to 250^{o}. Data reported in Tables 2 and 3 were corrected based on the recovery data of aliphatic and aromatic hydrocarbon standards. Typical recoveries were 82-111% for saturate hydrocarbons (C_{12} to C_{24}) and 84-89% for aromatic hydrocarbons (napthalene to dimethylphenanthrenes).

Results and Discussion

Flow rates in each tank as well as several other weathering parameters were monitored daily during the course of the experiment. These data are summarized in Table 1.

Average relative decreases of saturate hydrocarbons (between C_{12} and C_{26}) in tanks #2 and #3 after 24 days of exposure ranged between 45% and 49% (Table 2). These results are in marked contrast to tank #1 where an average relative decrease of 83% was observed. The saturate hydrocarbons C_8 - C_{10}, although present in the original oil, were not detectable in any of the 24 day weathered oil samples (Figure 1).

Table 1. Parameters Measured During the Course of the Weathering Experiment

	$\bar{X} \pm$ S.D.	N	Range Maximum	Range Minimum
Air temperature by stem thermometer in ^{o}C. Randomly taken during day	12.20 ± 1.65	16	15.5	10.0
Water temperature by stem thermometer in ^{o}C taken at outfall of tank #3 randomly during day	9.88 ± 0.51	16	10.6	9.0
Salinity by refractometer in ppth taken at outfall of tank #3 randomly during day	30.19 ± 0.36	16	31.0	30.0
Light by meter in (Lux) ca over tanks @ 0800 hrs	$9.3X10^{4} \pm 5.1X10^{4}$	15	$1.75X10^{5}$	$2.2X10^{4}$
Light by meter in (Lux) ca over tanks @ 1200 hrs	$2.54X10^{5} \pm 9.0X10^{4}$	10	$3.5X10^{5}$	$1.31X10^{5}$
Light by meter in (Lux) ca over tanks @ 1600 hrs	$1.52X10^{5} \pm 6.9X10^{4}$	7	$2.7X10^{5}$	$6.6X10^{4}$
Flow rate in tank #1 in ℓ/min randomly during day	26.66 ± 4.37	16	30.0	15.0
Flow rate in tank #2 in ℓ/min randomly during day	8.95 ± 0.34	16	10.0	8.5
Flow rate in tank #3 in ℓ/min randomly during day	8.58 ± 1.93	16	15.0	5.0

Table 2. Concentrations of Saturate Hydrocarbons in Prudhoe Bay Crude Oil (PBC) and in 24 Day Weathered Oil Samples. Concentrations in mg/gram oil.

Compound	Concentration in Original Oil[1]	Concentration in Weathered Oil[2]			Relative Decrease in Concentration (%)[3]		
		Tank No. 1	Tank No. 2	Tank No. 3	Tank No. 1	Tank No. 2	Tank No. 3
C_8	4.20 ± 0.12	*	*	*	100	100	100
C_9	4.42 ± 0.10	*	*	*	100	100	100
C_{10}	4.44 ± 0.35	*	*	*	100	100	100
C_{11}	4.68 ± 0.08	0.15 ± 0.02	0.22 ± 0.01	1.68 ± 0.32	96.8	95.3	64.1
C_{12}	4.62 ± 0.15	0.54 ± 0.01	0.97 ± 0.02	2.19 ± 0.40	88.3	79.0	52.6
C_{13}	4.46 ± 0.26	0.63 ± 0.02	1.64 ± 0.05	2.38 ± 0.15	85.9	63.2	46.6
C_{14}	4.16 ± 0.05	0.69 ± 0.01	1.93 ± 0.06	2.26 ± 0.20	83.4	53.6	45.7
C_{15}	3.99 ± 0.22	0.70 ± 0.01	1.99 ± 0.05	2.15 ± 0.24	82.5	50.1	46.1
C_{16}	3.74 ± 0.24	0.64 ± 0.02	1.85 ± 0.05	1.99 ± 0.29	82.9	50.5	46.8
C_{17}	3.39 ± 0.42	0.58 ± 0.03	1.75 ± 0.04	1.85 ± 0.26	82.9	48.4	45.4
Pristane	2.07 ± 0.38	0.33 ± 0.02	1.04 ± 0.02	1.12 ± 0.12	84.1	49.8	45.9
C_{18}	2.50 ± 0.24	0.48 ± 0.05	1.38 ± 0.04	1.30 ± 0.23	80.8	44.8	48.0
Phytane	1.05 ± 0.24	0.22 ± 0.01	0.57 ± 0.03	0.58 ± 0.04	79.0	45.7	44.8
C_{19}	3.04 ± 0.76	0.46 ± 0.01	2.07 ± 0.24	1.73 ± 0.10	84.9	31.9	43.1
C_{20}	1.93 ± 0.24	0.38 ± 0.02	1.08 ± 0.04	0.99 ± 0.17	79.8	44.0	48.7
C_{21}	1.58 ± 0.20	0.33 ± 0.03	1.05 ± 0.27	0.85 ± 0.19	79.1	33.5	46.2
C_{22}	1.86 ± 0.30	0.31 ± 0.03	1.18 ± 0.01	1.24 ± 0.30	83.3	36.6	33.3
C_{23}	1.65 ± 0.29	0.30 ± 0.03	1.20 ± 0.12	1.26 ± 0.31	81.8	27.3	23.6
C_{24}	1.27 ± 0.26	0.30 ± 0.04	1.11 ± 0.19	1.00 ± 0.24	76.4	12.6	21.3
C_{25}	1.02 ± 0.55	0.24 ± 0.03	0.79 ± 0.16	0.71 ± 0.13	76.5	22.5	30.4
C_{26}	0.76 ± 0.23	0.21 ± 0.02	0.60 ± 0.15	0.53 ± 0.07	72.4	21.1	30.3
Total (C_{12}- C_{26})	43.39 ± 4.27	7.30 ± 0.10	21.98 ± 0.61	23.98 ± 4.27	Avg% 83.1	49.3	44.7

[1]Compounds C_8- C_{11} were corrected for recovery on the basis of the recovery of C_{12} hydrocarbon and, therefore, more than likely are low.

[2]* indicates compound not detected at the sensitivity level that analyses were conducted.

[3]$$\frac{\text{concentration in original oil} - \text{concentration in weathered oil}}{\text{concentration in original oil}} \times 100$$

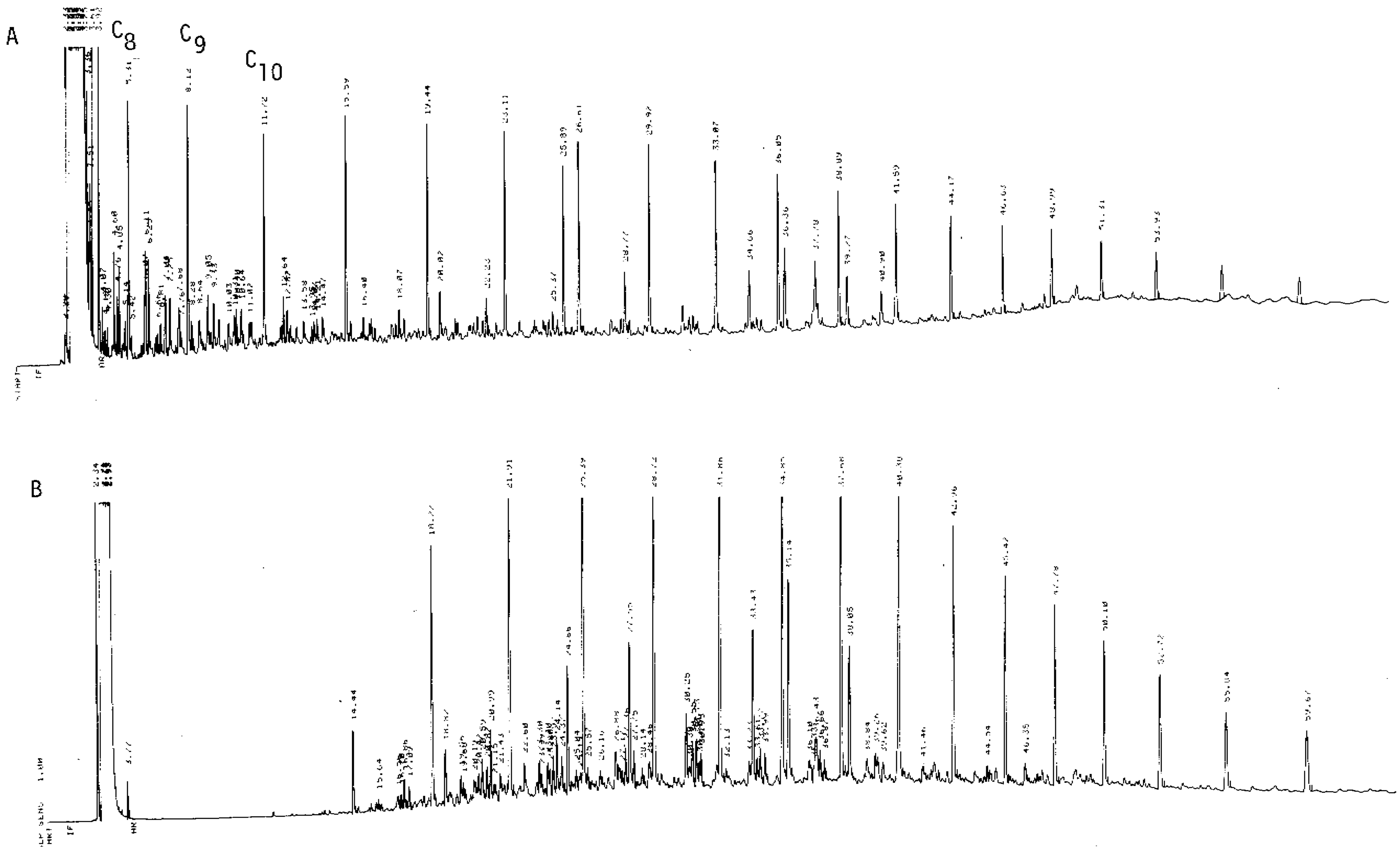

Figure 1. Gas Capillary Chromatograms of (A) Saturate Hydrocarbon Fraction from Original Prudhoe Bay Crude Oil and (B) Saturate Hydrocarbon Fraction from 24 Day Weathered Oil Sample from Tank #1.

Relative decreases in the concentrations of aromatic hydrocarbons were different from those observed for the saturate hydrocarbons in the three exposure systems. Decreases in aromatic hydrocarbons (napthalene - 3,6-dimethylphenanthrene) were 37% for tanks #1 and #2 and 9% for tank #3. The tricyclic aromatic hydrocarbons (phenanthrene - 3,6-dimethylphenanthrene) appeared to have the greatest persistence with relative enrichments occurring in tank #1 (Table 3). 3,6-dimethylphenanthrene showed relative enrichment in all three exposure systems. Also reported in Table 3 are concentrations for a variety of mono-aromatic hydrocarbons (toluene - 1,2,3,5-tetramethylbenzene). The concentration values reported for these compounds in the original oil were not corrected for recovery and were not a part of the original research. Nevertheless, they are reported because, with the exception of the tetramethylbenzenes, none of these compounds were detected in the 24 day weathered oil samples from any of the three exposure systems. These results are more graphically depicted in Figure 2 where the gas capillary chromatogram of the aromatics fraction of the original crude oil is compared to the aromatics fraction derived from the 24 day weathered oil sample of tank #1.

Confidence limits were determined for establishing the significance of differences observed between various saturate and aromatic hydrocarbons and hydrocarbon types in the three exposure systems. These results are compiled in Table 4. Variability associated with the sum of all saturate hydrocarbons C_{12}-C_{26} including pristane and phytane indicated differences between tank #1 vs. tanks #2 and #3 to be significant; however, total differences between tanks #2 and #3 were not significant. Significant differences were also found for the concentrations of all aromatic hydrocarbons and hydrocarbon types between tanks #1 and #3. Significant trends in the differences in concentrations of the aromatic components of tank #1 vs. tank #2 and tank #2 vs. tank #3 are more subtle. No significant differences in the concentrations of diaromatic hydrocarbons and hydrocarbon types are observed between tanks #1 and #2; however, significant differences are observed for the triaromatics. Although significant differences in the concentrations of napthalene, methylnapthalenes, and phenanthrene were observed, no trends were observed for the aromatic components of tanks #2 vs. tank #3.

Table 3. Concentrations of Aromatic Hydrocarbons in Prudhoe Bay Crude Oil (PBC) and in 24 Day Weathered Oil Samples. Concentrations in mg/gram oil.

Compound	Concentration in Original Oil[1]	Concentration in Weathered Oil[2]			Relative Decrease in Concentration %[3]		
		Tank No. 1	Tank No. 2	Tank No. 3	Tank No. 1	Tank No. 2	Tank No. 3
toluene	0.82 ± 0.08	*	*	*	100	100	100
ethylbenzene	0.56 ± 0.01	*	*	*	100	100	100
m+p-xylene	2.05 ± 0.04	*	*	*	100	100	100
o-xylene	0.79 ± 0.01	*	*	*	100	100	100
isopropylbenzene	0.16 ± 0.00	*	*	*	100	100	100
1-ethyl+4-methylbenzene	0.29 ± 0.00	*	*	*	100	100	100
1,3,5-trimethylbenzene	0.41 ± 0.00	*	*	*	100	100	100
1,2,4-trimethylbenzene	1.14 ± 0.01	*	*	*	100	100	100
secbutylbenzene	0.14 ± 0.00	*	*	*	100	100	100
methyl-4-isopropylbenzene	0.12 ± 0.00	*	*	*	100	100	100
indane	0.67 ± 0.00	*	*	*	100	100	100
1,3-dimethyl-5-ethylbenzene	0.27 ± 0.00	*	*	*	100	100	100
1,2-diethylbenzene	0.24 ± 0.02	*	*	*	100	100	100
1,2-dimethyl-4-ethylbenzene	0.24 ± 0.01	*	*	*	100	100	100
1,2,4,5-tetramethylbenzene	0.38 ± 0.00	0.03 ± 0.00	*	0.25 ± 0.03	**	100	**
1,2,3,5-tetramethylbenzene	0.27 ± 0.00	0.03 ± 0.00	*	0.18 ± 0.02	**	100	**
napthalene	0.92 ± 0.01	0.06 ± 0.01	0.16 ± 0.01	0.51 ± 0.08	93.5	82.6	44.6
2-methylnapthalene	1.63 ± 0.02	0.53 ± 0.07	0.76 ± 0.08	1.34 ± 0.18	67.5	53.4	17.9
1-methylnapthalene	1.29 ± 0.02	0.48 ± 0.06	0.69 ± 0.06	1.20 ± 0.16	62.8	46.5	7.0
1-ethyl+2-ethylnapthalene	0.48 ± 0.00	0.27 ± 0.03	0.43 ± 0.08	0.51 ± 0.06	43.8	10.4	-6.3
2,6+2,7-dimethylnapthalene	0.69 ± 0.01	0.52 ± 0.06	0.83 ± 0.13	0.94 ± 0.12	24.6	-20.3	-36.2
1,3+1,6-dimethylnapthalene	0.99 ± 0.01	0.51 ± 0.06	0.70 ± 0.05	0.91 ± 0.12	48.5	29.3	8.1
1,7-dimethylnapthalene	1.10 ± 0.01	0.51 ± 0.04	0.77 ± 0.06	0.94 ± 0.12	53.6	30.0	14.5
1,4+2,3+1,5-dimethylnapthalene	0.80 ± 0.01	0.52 ± 0.06	0.35 ± 0.11	0.90 ± 0.12	35.0	56.3	-12.5
1,2-dimethylnapthalene	0.40 ± 0.00	0.23 ± 0.03	0.21 ± 0.01	0.37 ± 0.04	42.5	47.5	7.5
2,3,6-trimethylnapthalene	0.51 ± 0.07	0.26 ± 0.03	0.39 ± 0.12	0.43 ± 0.04	49.0	23.5	15.7
phenanthrene	0.38 ± 0.05	0.61 ± 0.06	0.34 ± 0.05	0.22 ± 0.00	-60.5	10.5	42.1
1-methylphenanthrene	0.33 ± 0.02	0.77 ± 0.15	0.24 ± 0.02	0.31 ± 0.04	-133.3	27.3	6.7
2-methylphenanthrene	0.21 ± 0.01	0.53 ± 0.04	0.19 ± 0.01	0.22 ± 0.02	-152.4	9.5	-4.8
3,6-dimethylphenanthrene	0.11 ± 0.00	0.53 ± 0.04	0.24 ± 0.05	0.20 ± 0.04	-381.8	-118.2	-81.8
Total (napthalene - 3,6-dimethylphenanthrene)	9.91 ± 0.15	6.21 ± 0.42	6.27 ± 0.41	9.03 ± 1.05			

[1]Monoaromatic hydrocarbons have not been corrected for recovery.

[2]*compound not detected at the sensitivity level that analyses were conducted

[3]$\frac{\text{Concentration in original oil - concentration in weathered oil}}{\text{concentration in original oil}}$ X 100; minus sign indicates higher concentration of compound found in weathered oil on weathered oil basis as compared to original oil.

**Relative decrease in concentration % was not calculated because recovery data was not obtained on monoaromatic hydrocarbons.

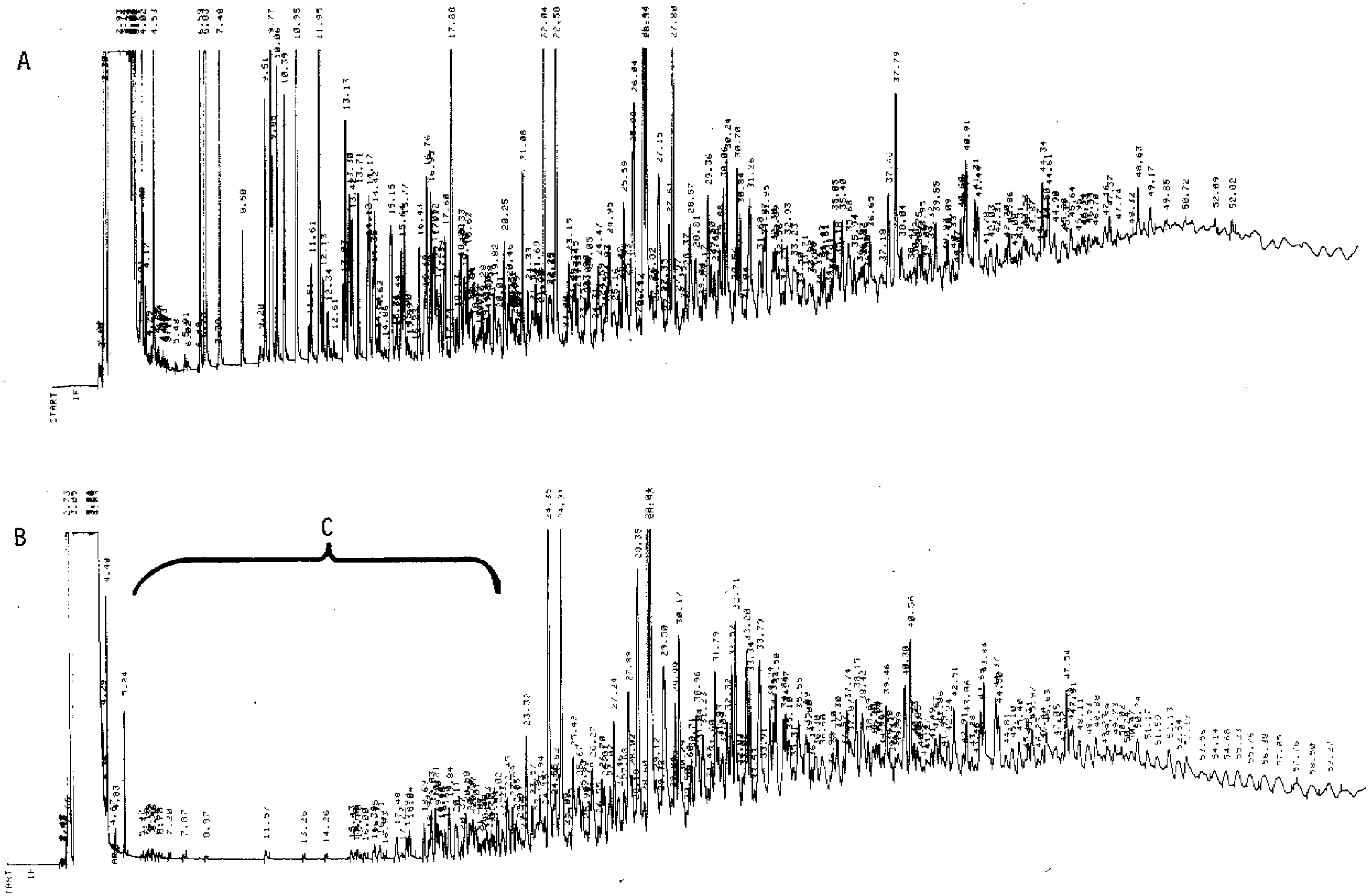

Figure 2. Gas Capillary Chromatograms of (A) Aromatic Hydrocarbon Fraction from Original Prudhoe Bay Crude Oil and (B) Aromatic Hydrocarbon Fraction from 24 Day Weathered Oil Sample from Tank #1. C denotes monoaromatic hydrocarbon region.

Table 4. Significance in the Relationships Between the Concentrations of Various Saturate and Aromatic Hydrocarbons and Hydrocarbon Types and the Type of Exposure. Confidence Limits are Measured at the 95% Level.

Hydrocarbon or Hydrocarbon Type	Concentration in mg/gram Oil				
	Tank #1		Tank #2		Tank #3
			S.D.[1]		
$(C_{12} - C_{26})$ + Pristane + Phytane	7.30 ± 0.10	S.D.	21.98 ± 0.61	N.S.D.[2]	23.98 ± 4.27
			S.D.		
Napthalene	0.06 ± 0.01	N.S.D.	0.16 ± 0.01	S.D.	0.52 ± 0.08
			S.D.		
Methylnapthalenes	1.01 ± 0.12	N.S.D.	1.43 ± 0.14	S.D.	2.54 ± 0.34
			S.D.		
Dimethylnapthalenes	2.29 ± 0.22	N.S.D.	2.83 ± 0.27	N.S.D.	4.12 ± 0.54
			S.D.		
2,3,6-Trimethyl-napthalene	0.26 ± 0.03	N.S.D.	0.39 ± 0.12	N.S.D.	0.43 ± 0.04
			S.D.		
Phenanthrene	0.61 ± 0.06	S.D.	0.34 ± 0.05	S.D.	0.22 ± 0.01
			S.D.		
Methylphenanthrenes	1.19 ± 0.06	S.D.	0.43 ± 0.03	N.S.D.	0.52 ± 0.05

Table 4 (cont.)

Hydrocarbon or Hydrocarbon Type	Concentration in mg/gram Oil Tank #1	 Tank #2	 Tank #3
		S.D.	
3,6-Dimethylphenanthrene	0.53 ± 0.04	0.26 ± 0.03	0.20 ± 0.04
	S.D.		N.S.D.
		S.D.	
Total Aromatics (Napthalene - 3,6-dimethylphenanthrene)	6.21 ± 0.42	6.27 ± 0.41	9.03 ± 1.05
	N.S.D.		N.S.D.

[1]S.D. = significantly different

[2]N.S.D. = not significantly different

Conclusions

The combination of light and water exposure parameters of Tank #1 produced the largest relative decreases in volatile saturate (C_{12} to C_{26}) and most aromatic (naphthalene -2, 3, 6-trimethylnaphthalene) hydrocarbons relative to the original oil of the three exposure systems. Detectable amounts of monoaromatic hydrocarbons were absent in all three weathered oils as were the saturate hydrocarbons from C_8 to C_{10}. The different exposure parameters of Tank #1 and #3 produced the greatest differences in the volatile hydrocarbon content of these oils following 24 days of weathering. The decreases in the content of most aromatic compounds were less for oil protected from light, water agitation, and somewhat from air circulation (Tank 3). The only components shown to increase somewhat in Tank 3 in proportion to the original oil was the heaviest compound, 3, 6-dimethylphenanthrene. This component was enriched to a greater extent in Tank 2 and in Tank 1 its contribution to the total was nearly four times as great. There was an increasing degree of enrichment in the weathered (mousse) oil in Tank 1 as molecular weight increased from phenanthrene to the 3, 6-dimethylphenanthrene. These data may well indicate that higher molecular weight compounds of 4 and 5 rings (polynuclear aromatics) are also enriched in weathered oil and perhaps relative to their molecular weight. The significance of this possibility is rather large since possible tainting and or effects from carcinogenic or mutagenic compounds in this class could be enchanced. The polynuclear aromatics are less water soluble than those identified in Table 3, so it is not likely that water column species would be affected. However, the mixing of weathered oil with sediments may produce an environment more hazardous to benthic species than contamination from fresh oil.

The results of this preliminary experiment on oil weathering have produced very interesting results regarding aromatic compounds up to dimethylphenanthrene. Other analytical methods should be used to characterize the alterations in polynuclear aromatics to determine the relative hazard of weathered oil compared to fresh oil. As the most dramatic effects from enrichment of polynuclear aromatics would be on benthic organisms, particularly detritivores, weathered oil should be used in laboratory and field exposures. Results of these tests could then be compared to our findings on effects from fresh oil to evaluate the potential hazard.

SUBLETHAL EFFECTS OF PETROLEUM-IMPACTED SEDIMENT ON AN INTERTIDAL DEPOSIT FEEDING POLYCHAETE

Previous data indicated that the behavior of the deposit feeding polychaete _Abarenicola pacifica_ was modified by contact with sediment contaminated with high levels (1000 ppm) of Prudhoe Bay crude oil, resulting among other effects in reduced rates of feeding. An experiment was carried out to examine this effect in greater detail and at different levels of exposure to oil. It is described in the accompanying manuscript, which we wish to have reviewed for submission to a recognized journal.

Effect of Prudhoe Bay Crude Oil Contamination on Sediment Working Rates of _Abarenicola pacifica_

Introduction

Accidentally spilled petroleum hydrocarbons (PHCs) which impact fine-grained sediments in intertidal zones may remain _in situ_ for periods of years (Mayo _et al_. 1978, Teal, Burns, and Farrington, 1978) resulting in long term effects on local populations (Krebs and Burns, 1977). One factor which may contribute to this persistence is the existence of anoxic conditions at depths of more than 1 cm below the surface of these habitats (Teal and Kanwisher, 1962; Pamatmat, 1968; Hylleberg, 1975). ZoBell (1964) has reported that PHCs are degraded at much slower rates in anaerobic sediments than under aerobic conditions.

The burrowing and feeding activities of certain organisms transport sediment from the lower anoxic areas to the surface, where aerobic microbes can metabolize hydrocarbons more rapidly. One such organism which occurs in high densities in fine-grained sediment along the shores of the North Pacific is the sedentary polychaete worm, *Abarenicola pacifica* Healy & Wells. Hobson (1967) has calculated that a population of *A. pacifica* located in False Bay, San Juan Island, Washington State could move all the sediment in the upper 10 cm of the area they inhabit to the surface in a little more than two years. Their activity could aid in the recovery of intertidal zones from the effects of oil pollution if they can continue to feed in contaminated sediment.

Gordon, Dale and Keizer (1978) reported that exposure in the laboratory to No. 2 fuel oil, Venezuelan Bunker C, South Louisiana Crude, Kuwait Crude oil, or to sediment which had been impacted by an accidental spill led to reductions of 51% to 82% in sediment-working rates of *Arenicola marina* L., a species which is found in sandy beaches around the Atlantic and is closely related to *A. pacifica*. Gordon *et al*., found that direct contact with sediment containing oil at concentrations as low as 153 ppm for as little as 5 days caused some of their worms to surface and some died at concentrations of 275 ppm.

In our laboratory *A. pacifica* has been found to tolerate direct contact with sediment containing 1000 ppm of Prudhoe Bay crude (PBC) oil for more than three weeks. It, therefore, seemed possible that the mud-dwelling Pacific species is more tolerant of oil contamination than the sand-dwelling Atlantic species. An experiment was designed to learn whether contamination of their habitat with various levels of PBC would reduce the amount of sediment which *A. pacifica* transports to the surface, making use of the fact that the worm deposits its feces in easily recognizable coils around the entrance to its burrow.

Materials and Methods

Forty specimens of *A. pacifica* and 12 kg sediment were collected from the high intertidal region of an almost enclosed lagoon adjacent to Sequim Bay, Washington State, U. S. A. The upper 10 cm of the sediment consisted of very fine grained, semi-liquid mud and a layer of firmer fine-grained sand lay beneath. In the laboratory the worms were kept in sediment under running sea water at 10°C and 30 ‰ salinity.

Sediment (2.5 kg) consisting of equal volumes of the mud and sand strata, were placed in each of four cylindrical metal containers of 3 liter capacity. Three different volumes of PBC (.625, 1.25 or 2.5 g) were added to three containers, and the contents of each, including the unoiled control, were stirred 6 minutes with a motor driven impeller. Previous trials with the dispersion of radio-labelled material have shown this time period to be adequate for thorough mixing. The resulting mixtures were injected into 40 pieces of tubing, 40 cm long and 17 mm i.d. The tubes were bent into U-shapes and placed in racks under running sea water for 20 hours to allow the more toxic low molecular weight components of the oil to wash out. Remaining sediment was placed under running sea water as a reserve supply.

One worm was placed in each tube and plastic trays, 64 mm on a side, were placed around the ends of the tubes. At 24 hour intervals the water levels in the tanks were lowered and the feces produced by each worm were collected from the trays and from the surface of the sediment within the tubes with a stainless steel spatula. At intervals of several days sediment from the appropriate reserve supply was added to the tubes to replace consumed material. The feces were dried in air for 24 hours and weighed. Preliminary studies indicated that this time period was long enough to achieve a constant weight. All calculations of fecal cast production were based on the mean daily dry weight produced by each individual worm.

After 11 days of exposure the sediment and worms were removed from the tubes. The worms were rinsed with sea water, blotted dry, weighed, and frozen. Samples of sediment were taken from tubes at each treatment level, frozen, and later analyzed for total hydrocarbon content by IR spectrophotometry.

Results

The level of PHC in the sediment changed little during the exposure period. The worms' native substrate used in the experiment has a fairly high endogenous content of hydrocarbon measurable by IR spectrophotometry. As Table 1 shows, the content of sediment at the three treatment levels, when corrected for the content of the control sediment, was between 80 and 100% of the amount originally added.

All the control worms survived, but two of them left their tubes and burrowed into detritus at the bottom of the tank, where their feces could not be collected. Mortality was slightly higher in the exposed groups, and some signs of behavioral stress were observed (Table 2). When the feces were collected, at 24 hour intervals, some of the worms exposed to medium and high levels of PBC were seen to extend their posterior segments from the burrows and slowly move them through the water. This behavior, which would obviously be maladaptive under natural conditions was never observed in the controls or in the field. Feeding behavior was apparently depressed during the first two days of exposure, to a greater extent in the higher concentrations. During the remaining nine days the frequency of defecation, based on 24 hour observation periods, was slightly, but not significantly lower, in the exposed animals. Data on fecal production was, therefore, taken from this nine day period, as being more representative of the long term effect of oil exposure.

Table 1. Hydrocarbon Content of Sediment After 11 Days in the Exposure System (ppm)

		Exposure Level		
	Control	Low	Medium	High
PBC Added	0	250	500	1000
Total HC Present	98	349	513	905
Net Added HC Recovered		251	415	807

Table 2. Effects of PBC on Survival and Behavior of *A. Pacifica*

		Exposure Level		
	Control	Low	Medium	High
Survival	10/10	9/10	8/10	7/10
Left Tubes	2/10	0	0	0
Tail Extended From Tubes	0	0	6	12
Cast Production* First 2 days	4.5	3.5	2	1
Cast Production* Next 9 days	5	4.9	4.6	4.5

* Mean number of casts/day produced by all surviving worms.

A strong negative correlation was found between weight-specific fecal production and wet body weight. The slope of the regression line relating these parameters was steeper in the control and the low level exposure groups than in the two higher level exposure groups (Figure 1). The degree of scatter around the regression lines was less in the exposed groups than in the control. Mean weight-specific fecal production was moderately depressed in low level exposed and severely depressed in the higher level exposed groups.

The regression of dry fecal weight, unadjusted for body weight, on body weight, was not significant within any treatment group. As Table 3 shows, the mean fecal weight is markedly reduced by exposure to hydrocarbon levels about 400 ppm. Pairwise comparison of the control with each treatment group by the Newman-Keuls test showed no significant difference between it and the low exposure level while the mean production rate at the medium and high exposure levels differed significantly at the .05 level from that of the controls.

Discussion

Exposure to oil reduces the degree of scatter around the regression lines relating weight-specific fecal production to body weight of *A. pacifica*, and at levels above 400 ppm greatly reduces the slope of the lines (Figure 1). Both of these effects may be attributed to a greater impact of exposure on the smaller and more active animals. Among control worms weighing less than 0.25 g, weight-specific fecal production varied between 0.9 and 2.1 g feces per g worm. Production by worms in this size class ranged from 0.84 to 1.3 g per g worm under exposure to a low level of oil. At the higher oil levels values for the smaller worms fell to between 0.27 and 0.45 g per g worm. By contrast, the maximum production of worms weighing more than 0.6 g was reduced only from 0.2 g per g worm in control animals to .08 g per g worm at the higher exposure levels. Exposure to oil clearly leads to a greater reduction in feeding activity at the lower end of the size range than at the upper end. The individual variability of production is lessened by a greater decrease in the maximum rate achieved by the smaller animals than in the minimum rates.

These data indicate some of the effects of hydrocarbon pollution on the biology of the worms. However, measures of weight-specific fecal production such as these, and those reported by Gordon _et al_. (1978) are less useful in predicting the effect of the affected worms on sediment turnover, since predictions based on them would require information on the size distribution of the affected population, which might not be available. Fortunately, the effect of the negative regression of fecal production on body weight is cancelled out by the increasing body weight itself, which accounts for the fact that none of the regressions of fecal weight per se on body weight, within any treatment group, is significant. The somewhat surprising conclusion is that under uniform conditions and within the weight range examined, the size of the worms has no significant effect on the average dry weight of feces produced per day. Therefore, if suitable control populations were available for comparison the defecation rate of _A. pacifica_ could be used as an indicator of a particular level of environmental stress, even if the size distribution of the worm population is not known.

The results also suggest that if pollution is not too severe, _Abarenicola_ may continue to turn over the equivalent of its own wet body weight per day in sediment. However, high concentrations of oil may reduce the sediment-working rate of surviving worms by as much as 70%. This effect, together with any mortality due to the environmental pollution would substantially retard the transportation of subsurface sediments to the surface. If these effects are found in the field, it is possible that sufficiently high levels of oil will retard the rate of sediment recovery by reducing the feeding behavior of ecologically significant species.

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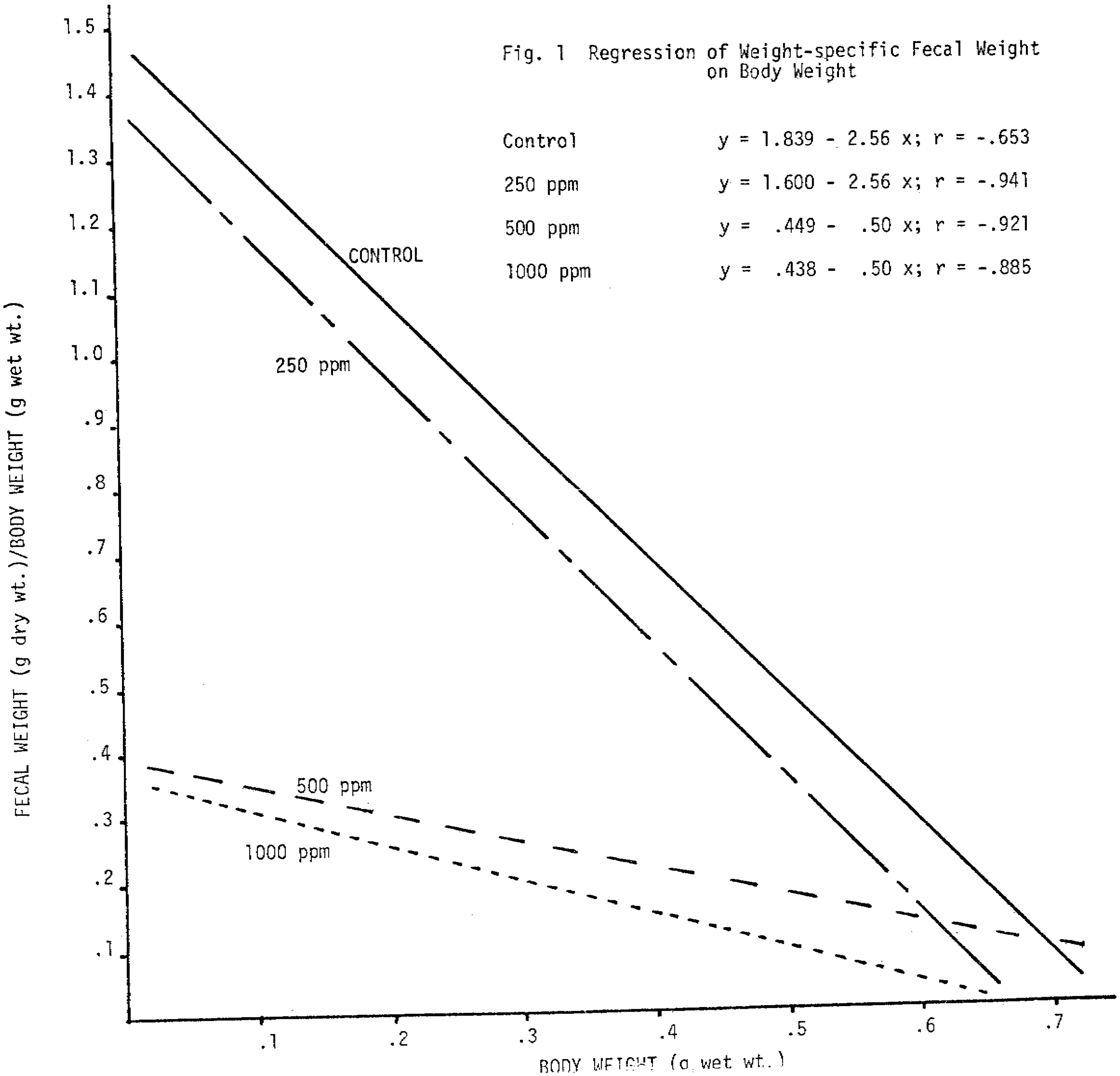

Fig. 1 Regression of Weight-specific Fecal Weight on Body Weight

Table 3. Concentrations of Aromatic Hydrocarbons in Prudhoe Bay Crude Oil (PBC) and in 24 Day Weathered Oil Samples. Concentrations in mg/gram oil.

Compound	Concentration in Original Oil[1]	Concentration in Weathered Oil[2]			Relative Decrease in Concentration %[3]		
		Tank No. 1	Tank No. 2	Tank No. 3	Tank No. 1	Tank No. 2	Tank No. 3
toluene	0.82 ± 0.08	*	*	*	100	100	100
ethylbenzene	0.56 ± 0.01	*	*	*	100	100	100
m+p-xylene	2.05 ± 0.04	*	*	*	100	100	100
o-xylene	0.79 ± 0.01	*	*	*	100	100	100
isopropylbenzene	0.16 ± 0.00	*	*	*	100	100	100
1-ethyl+4-methylbenzene	0.29 ± 0.00	*	*	*	100	100	100
1,3,5-trimethylbenzene	0.41 ± 0.00	*	*	*	100	100	100
1,2,4-trimethylbenzene	1.14 ± 0.01	*	*	*	100	100	100
secbutylbenzene	0.14 ± 0.00	*	*	*	100	100	100
methyl-4-isopropylbenzene	0.12 ± 0.00	*	*	*	100	100	100
indane	0.67 ± 0.00	*	*	*	100	100	100
1,3-dimethyl-5-ethylbenzene	0.27 ± 0.00	*	*	*	100	100	100
1,2-diethylbenzene	0.24 ± 0.02	*	*	*	100	100	100
1,2-dimethyl-4-ethylbenzene	0.24 ± 0.01	*	*	*	100	100	100
1,2,4,5-tetramethylbenzene	0.38 ± 0.00	0.03 ± 0.00	*	0.25 ± 0.03	**	100	**
1,2,3,5-tetramethylbenzene	0.27 ± 0.00	0.03 ± 0.00	*	0.18 ± 0.02	**	100	**
napthalene	0.92 ± 0.01	0.06 ± 0.01	0.16 ± 0.01	0.51 ± 0.08	93.5	82.6	44.6
2-methylnapthalene	1.63 ± 0.02	0.53 ± 0.07	0.76 ± 0.08	1.34 ± 0.18	67.5	53.4	17.8
1-methylnapthalene	1.29 ± 0.02	0.48 ± 0.06	0.69 ± 0.06	1.20 ± 0.16	62.8	46.5	7.0
1-ethyl+2-ethylnapthalene	0.48 ± 0.00	0.27 ± 0.03	0.43 ± 0.08	0.51 ± 0.06	43.8	10.4	-6.3
2,6+2,7-dimethylnapthalene	0.69 ± 0.01	0.52 ± 0.06	0.83 ± 0.13	0.94 ± 0.12	24.6	-20.3	-36.2
1,3+1,6-dimethylnapthalene	0.99 ± 0.01	0.51 ± 0.06	0.70 ± 0.05	0.91 ± 0.12	48.5	29.3	8.1
1,7-dimethylnapthalene	1.10 ± 0.01	0.51 ± 0.04	0.77 ± 0.06	0.94 ± 0.12	53.6	30.0	14.5
1,4+2,3+1,5-dimethylnapthalene	0.80 ± 0.01	0.52 ± 0.06	0.35 ± 0.11	0.90 ± 0.12	35.0	56.3	-12.5
1,2-dimethylnapthalene	0.40 ± 0.00	0.23 ± 0.03	0.21 ± 0.01	0.37 ± 0.04	42.5	47.5	7.5
2,3,6-trimethylnapthalene	0.51 ± 0.07	0.26 ± 0.03	0.39 ± 0.12	0.43 ± 0.04	49.0	23.5	15.7
phenanthrene	0.38 ± 0.05	0.61 ± 0.06	0.34 ± 0.05	0.22 ± 0.00	-60.5	10.5	42.1
1-methylphenanthrene	0.33 ± 0.02	0.77 ± 0.15	0.24 ± 0.02	0.31 ± 0.04	-133.3	27.3	6.7
2-methylphenanthrene	0.21 ± 0.01	0.53 ± 0.04	0.19 ± 0.01	0.22 ± 0.02	-152.4	9.5	-4.8
3,6-dimethylphenanthrene	0.11 ± 0.00	0.53 ± 0.04	0.24 ± 0.05	0.20 ± 0.04	-381.8	-118.2	-81.8
Total (napthalene - 3,6-dimethyl-phenanthrene)	9.91 ± 0.15	6.21 ± 0.42	6.27 ± 0.41	9.03 ± 1.05			
	Avg. % Decrease	37.3	36.7	8.9			

[1]Monoaromatic hydrocarbons have not been corrected for recovery.

[2]*compound not detected at the sensitivity level that analyses were conducted

[3]$\frac{\text{Concentration in original oil - concentration in weathered oil}}{\text{concentration in original oil}}$ X 100; minus sign indicates higher concentration of compound found in weathered oil on weathered oil basis as compared to original oil.

**Relative decrease in concentration % was not calculated because recovery data was not obtained on monoaromatic hydrocarbons.