Environmental Assessment of the Alaskan Continental Shelf

VOLUME 1

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VOLUME 2

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VOLUME 3

Environmental Assessment of the Alaskan Continental Shelf

July-September 1977 quarterly reports from Principal Investigators participating in a multi-year program of environmental assessment related to petroleum development of the Alaskan Continental Shelf. The program is directed by the National Oceanic and Atmospheric Administration under funding from and for use by the Bureau of Land Management.

ENVIRONMENTAL RESEARCH LABORATORIES
Boulder, Colorado
December 1977

NOTICE

VOLUME 1

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RECEPTORS (BIOTA)

MAMMALS

Quarterly Report

Contract # R7120804
Research Unit # 67
1 July-30 September 1977
4 pages

Baseline Characterization of Marine Mammals in the Bering Sea

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September 1977

I. Abstract.

A pilot project for land-based surveys of northern sea lion rookeries was made on Ugamak Island in order to establish ground-truthing for aerial censusing. St. Lawrence Island was reconnoitered as a site for gray whale behavior and feeding studies. Five opportunistic aerial surveys were made of parts of the Pribilof Islands. Two surveys of the north coast of the Alaska peninsula were made en route to and from the Ugamak Island camp. Observers made a near-continuous daylight hour watch onboard the NOAA ship Surveyor from 22 June to 15 July. All original data for 1975-77 have been logged on computer format. Analysis of northern sea lion and harbor seal counts has begun.

II. Objectives.

The primary objectives for RU 67 this quarter were (1) ground-truthing for aerial surveys of sea lion hauling areas; (2) gray whale feeding behavior; (3) continued distribution and abundance studies of marine mammals in the Bering and southern Chukchi Seas; and (4) compilation and synthesis of all data collected to date.

III. Field or Laboratory Activities.

A. Ship or field trip schedule.

10 June-12 July. Field camp on Ugamak Island.

22 June-15 July. NOAA ship Surveyor, including 12 aerial surveys in the Bell 206B helicopter.

28 June-5 July. Field camp on St. Lawrence Island.

B. Scientific Party.

	Marine Mammal Division	
Clifford Fiscus	NWAFC, NMFS, NOAA	
Howard Braham	"	P. I.
David Rugh	"	P. I.
Teresa Bray	"	Research Asst.
Robert Everitt	"	"
Bruce Krogman	"	"
Roger Mercer, Lt.	"	"
Mary Nerini	"	"
Ronald Sonntag	"	"
David Withrow	"	"

C. Methods.

Aerial surveys. See Braham et al. (1977, p. 17-18) for a detailed description of methods used in surveying from the Bell 206B helicopter. During the 27 June-6 July St. Lawrence stay, 8 flights were made in order to photograph gray whale behavior and count animals. Five flights surveying for marine mammals were made 8-10 July in the Pribilofs.

Shipboard surveys. A near-continuous watch was maintained during daylight hours by 1 to 4 observers (weather permitting) during the cruise of the NOAA ship Surveyor between 22 June and 15 July.

Land-based surveys. Frequent, systematic surveys of northern sea lion rookeries on Ugamak Island were made between 10 June and 11 July. Details of procedures used will appear in the 1977-78 annual report. St. Lawrence Island camp was maintained from 28 June to 5 July. Gray whale blow timings and allometric studies of gray whale skulls were made.

Laboratory. All photographs have been logged and filed after using them for counts. All original data have been logged in computer format and are being checked before keypunching.

D. Sample Collection Localities.

No samples were collected.

E. Data Collected and/or Analyzed.

1. Number and type of observations.

10 June-12 July (31 days):	frequent land-based surveys on Ugamak Island
22 June-15 July (24 days):	387 observations of marine mammals over 173 hour accumulative watch period.
8-10 July (3 days) :	5 helicopter flights totaling 8 hours; 72 observations
28 June-5 July (8 days) :	Dive sequences of 11 gray whales; 114 skulls measured at 9 points; 11 carcasses measured
28-30 June (3 days) :	Synthesis of data from aerial survey of south Bering Sea coastline; 938 observations over 1820 nm; total 17 hr., 15 min. survey time.

2. Number and type of analyses.

15 Wilcoxon's Signed Rank Tests (non-parametric)
12 Theil Tests for Regression with related parameters (non-parametric)
3 Regression Analyses (classical statistics)
Plus many forms of syntheses using means, medians and percentile correlations
Computer dump of Phoca vitulina sighting records

IV. Results.

No reports have been concluded since the last quarterly report. Data syntheses and analyses are progressing rapidly with regard to northern sea lion and harbor seal counts. Research needs have become more glaringly evident as the data is processed. Reports now in preparation will summarize research to date, but the full scope of the respective studies awaits further funding and finalization of aspects enumerated in the research proposal for FY78.

Briefly, there is evidence of a 40-50% decline in northern sea lion populations in the eastern Aleutian Islands over the past 20 years, with a significant downward regression eastward when rookeries alone are examined.

V. Preliminary Interpretation of Results.

The decline in northern sea lion populations in the eastern Aleutian Islands may indicate an unstable or deteriorating ecological condition. An analysis of the data indicate that further survey work west of the study area is essential if we are to better assess why this condition exists. Also, a more complete picture is needed in order to develop a monitoring program in conjunction with future oil development activities.

VI. Auxiliary Material.

A. Bibliography of references

Braham, H. W., C. H. Fiscus, and D. J. Rugh. 1977. Marine mammals of the Bering and southern Chukchi Seas. OCSEAP Annual Report, RU 67, p. 17-18.

B. Manuscripts in preparation or in print

Braham, H. W. Spring migration of the gray whale (Eschrichtius robustus) in Alaska. (In preparation; submitted as a talk to the Second Conference on the Biology of Marine Mammals, 12-15 December 1977, San Diego, CA.)

Braham, H. W., G. A. Fedoseev, J. J. Burns, B. D. Krogman, and D. J. Rugh. Distribution and abundance of Phocine seals and walruses in the Bering Sea pack ice in the spring, 1976. (In preparation as a book chapter, US-USSR Conv. Env. Conserv. Marine Mammals.)

Braham, H. W., and B. D. Krogman. Spring distribution and abundance of the Pacific walrus (Odobenus rosmarus) in the Bering Sea. (In preparation as a processed report.)

Braham, H. W., D. J. Rugh, R. D. Everitt, and D. E. Withrow. Population decline of the northern sea lion (Eumetopias jubatus) in the eastern Aleutian Islands, Alaska. (In preparation; submitted as a talk to the Second Conference on the Biology of Marine Mammals, 12-15 December 1977, San Diego, CA.)

Everitt, R. D., H. W. Braham, and D. J. Rugh. Distribution and abundance of the land breeding harbor seal (Phoca vitulina richardii) in the Bering Sea (in preparation).

C. Oral presentations and meetings

16,17,23 August. OCSEAP employees presented current research efforts to the Marine Mammal Division.
25 August. David Rugh presented a lecture to the American Cetacean Society concerning OCSEAP marine mammal research.
2 September. Howard Braham presented information on sea lion, walrus, and Dall porpoise to the Marine Mammal Commission, Seattle, Washington.
Preparations are now underway for local presentations of OCSEAP marine mammal research 14-17 October (Fish Expo '77) and 29 October (Cousteau Day) and at San Diego, 12-15 December.

VII. Problems Encountered and Recommended Changes.

Financial restrictions have inhibited comprehensive studies in several cases, especially on coastal aerial surveys and land-based camps. With a more liberal allowance here, our research conclusions may be less tentative, with more of the pertinent data gaps filled and more questions answered. We have already identified most of the major data gaps and research of greatest need.

VIII. Estimate of Funds Expended.

Salaries/Overtime	$15,500
Travel/Per Diem	900
Equipment/Supplies/Computer	1,105
Charter Aircraft	3,347
	$20,852

Quarterly Report

Contract # R7120806
Research Unit 68
1 July - 30 September 1977

Distribution and Relative Abundance of Marine Mammals in the Gulf of Alaska

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Roger W. Mercer

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September 1977

I. Abstract.

All data from Platforms of Opportunity from 1971 through 1976 were re-audited and the ADP filing structure was revised to allow faster and more efficient accessibility of the data. A comprehensive literature search was begun on the Dall porpoise (Phocoenoides dalli) to complement our sighting records as a first step toward finalizing our knowledge of this species.

II. Objectives.

Objectives for this quarter were to complete final preparation of our coded data for translation into the EDS 027 Marine Mammal format and to begin plotting and analysis of data for certain key marine mammal species in the survey area.

III. Field or Laboratory Activities.

A. Ship or field trip schedule.

Field activities during this quarter were limited to the latter portion of the Surveyor cruise into the Bering Sea, ending 12 July 1977. Although several of our personnel were aboard the Surveyor during portions of this cruise, only Teresa Bray was assigned as a full time shipboard marine mammal observer.

B. Scientific party.

Howard Braham	Marine Mammal Division	P.I.; Administration; participant, Surveyor cruise
Roger Mercer	"	P.I.; Data processing; Platforms of Opportunity; literature review
Bruce Krogman	"	Data processing
Ronald Sonntag	"	Data processing; programming
Mary Nerini	"	Biology technician; observer
Teresa Bray	"	Technician; observer

C. Methods.

Most data have been collected by non-Marine Mammal Division observers participating in our Marine Mammal Platforms of Opportunity Project. Logbooks from all sources are examined in the laboratory for general quality; acceptable sighting records are then coded for computer processing and archival. The computerized data are subjected to two manual quality checks and to one comprehensive computer check.

After the data have passed all three verification stages they will be translated into EDS 027 format for submission through the Juneau Project Office. Analyses of the data will be made on the same "batches" that are submitted to Juneau.

D. Sample collection localities.

Nearly all data collected by our own observers have come from Kodiak, Bristol Bay, St. George and Norton Basins, as outlined for OCSEAP research activities. Platforms of Opportunity data have been acquired from the Bristol Bay area and the Gulf of Alaska.

E. Data collected or analyzed.

1. Number and type of observations.

Approximately 110 marine mammal sightings were recorded by Marine Mammal Division observers from 1 to 12 July 1977 aboard the NOAA ship Surveyor in the Bering Sea and en route back to Kodiak.

Data collected by most other POP observers during 1977 had not been submitted to our office at the time of this writing.

2. Number and types of analyses.

Crosstabulations of all marine mammal species reported from 1971 through 1976 were produced by month for all 10° Latitude by 10° Longitude blocks of area within the survey area. Plots of all Dall porpoise sightings each month have been prepared for most of the range of the species, which includes all of the survey area.

IV. Results.

Preliminary results on Dall porpoise indicate that this species is ubiquitously distributed within the survey area, with perhaps the highest concentrations being found along the hundred fathom contour (continental slope). Dall porpoise are present in the survey area during all seasons. However, there does not appear to be strong evidence to suggest that any major portion of the population migrates into or out of any particular area on a seasonal basis.

V. Preliminary Interpretation of the Results.

None.

VI. Auxiliary Material.

A. Bibliography or references.

We are producing an annotated bibliography on *Phocoenoides dalli* which will be made available on request.

B. Manuscripts in preparation or in print.

Mercer, R. W., H. W. Braham, and T. W. Bray. Distribution of Dall porpoise (*Phocoenoides dalli*) in the North Pacific Ocean. (in preparation)

VII. Problems Encountered and Recommended Changes.

Some delays in computer programming were experienced early in the quarter, but these have been essentially resolved.

VIII. Estimate of Funds Expended.

Salaries/Overtime	$ 4,211
Travel/Per Diem	350
Equipment/Supplies (Computer)	1,510
	$ 6,071

Quarterly Report

Contract # R7120807
Research Unit 69
1 July - 30 September 1977
8 pages

Distribution and Abundance of Bowhead and Beluga Whales in the Bering, Chukchi and Beaufort Seas

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September 1977

I. Abstract.

Summary of spring 1977 survey work is near completion. Results indicate that ice camp data are providing reliable indices to population abundance of bowhead whales. A more complete picture is starting to develop of migration corridors, timing and duration of movement. The relationship between the bowhead and beluga during spring migration is being examined. Results of the fall 1977 survey effort are inconclusive pending the termination of survey effort on or about 15 October 1977.

II. Objectives.

The primary objectives for RU 69 this quarter were to (1) analyze spring 1977 ice camp data and (2) conduct fall field surveys based out of Barrow, Alaska (surveys are still in progress at this writing).

III. Field or Laboratory Activities.

A. Ship or field trip schedule.

24 August - 23 September	Field camp and aerial survey.
29 September - 15 October	Field camp and aerial survey.

B. Scientific party.

	Marine Mammal Division	
Howard Braham	NWAFC, NMFS, NOAA	P. I.
Geoff Carroll	"	Research Asst.
Robert Everitt	"	Research Asst.
Bruce Krogman	"	P. I.

C. Methods.

Aerial survey. A Cessna 185 was flown along coast and barrier islands in the Cape Simpson area. A twin engine Aztec was used for offshore survey. Both aircraft were contracted through Fell-Air Inc., Barrow, Alaska. A second twin engine Otter was also used for offshore survey and was contracted from NARL, Barrow.

Shipboard surveys. A round trip from Barrow to Prudhoe Bay aboard the Alumiak, operated by NARL, was cancelled because of mechanical failure.

Land-based surveys. Cape Simpson field station was reconnoitered as a possible base for land observations of bowhead whales which have been observed congregated near the area during fall migration (Braham and Krogman, 1977). The communication relay tower was found to be a satisfactory platform for whale observation. However, aerial survey revealed that no whales were in the area, and the land-based survey was indefinitely postponed. We speculate that because pack ice is so far offshore, whale migration may be protracted and diffuse this year.

Laboratory. Most aerial survey data have been logged on keypunch abstracts. Land-based data will be logged, pending development of a suitable computer format for storage and analysis.

D. Sample Collection Localities.

No samples were collected.

E. Data Collected and/or Analyzed.

1. Number and type of observations.

As of 15 September approximately 300 aerial observations of marine mammals were made. A table summarizing counts for each species by day is listed below:

Date	Spotted seals	Walrus	Beluga whale	Bowhead whale	Polar bear
26 August	75	0	0	0	0
29 August	133	0	0	0	0
1 September	3	100	0	0	0
8 September	0	1	0	0	0
10 September	0	2000	54	0	1
14 September	0	9	27	0	0
15 September	0	2	16	0	0

2. Number and type of analyses.

Spring 1976 ice camp data has been summarized in a series of tables and figures, and information is being extracted regarding timing and duration of migration. Indices are being developed for estimating the number of whales which pass eastward of Barrow during the spring migration. Other aspects of natural history are also being addressed. The methodology of collecting data from ice and land-based camps is being reviewed and improved.

IV. Results.

Tables 1, 2, and 3 provide summaries of animals sighted respectively from Pt. Barrow, Cape Lisburne and Point Hope, Alaska. Comparison of results of 1977 Barrow ice camp data with 1976 data suggests that reliable indices for estimating bowhead population size can be made. For 1977, the average number of bowheads sighted at Pt. Barrow per hour equalled .83, whereas during 1976, this value was .61.

Peak movement of bowheads past Pt. Barrow occurred during mid-May, whereas at Pt. Hope peak movement occurred in late April. More precise determinations of patterns and timings of movement are being made.

On 3 June, 83 beluga whales were observed at Pt. Barrow, and a large proportion of the whales were identified as newborn or extremely immature. This observation suggests more beluga whales may give birth during migration than had previously been suspected.

Analysis of data collected this fall will begin when personnel return from the field.

V. Preliminary Interpretation of Results.

Ice station research is providing information which allows, at the very least, estimates of the minimum population size of bowhead whales which enter the Beaufort Sea shelf area. Comparison of 1976 and 1977 ice station data indicates that reliable population indices can be developed.

Information coming in on the beluga whale is not quite so clean, and further study is underway as to how research methods can be modified to enhance our knowledge of beluga numbers and movements. Observations of young of the year beluga passing by Pt. Barrow indicate that parturition is occurring during spring migration. Because the distribution of beluga whales east of Pt. Barrow is so poorly documented, it is not possible to determine what effects oil development will have on calves and cows with calves. It can be conjectured that this segment of the population will be least able to avoid oil spills, but on the other hand, we do not even know if beluga move proximal to oil lease sites.

VI. Auxiliary Material.

A. Bibliography or references.

Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead (Balaena mysticetus) and beluga (Delphinapterus leucas) whale in the Bering, Chukchi and Beaufort Seas. U. S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Northwest & Alaska Fisheries Center, Processed Report, 29 p.

B. Manuscripts in preparation or in print.

Braham, H. W., and B. D. Krogman. Second report on the population biology of the bowhead (Balaena mysticetus) and beluga (Delphinapterus leucas) whale in the Bering, Chukchi and Beaufort Seas. (in preparation)

Krogman, B. D., H. W. Braham, G. Carroll, R. E. Everitt, E. Iten, and J. Smithhisler. Preliminary report on the bowhead whale (Balaena mysticetus) in Alaska. (In preparation; submitted as a talk to the Second Conference on the Biology of Marine Mammals, 12-15 December 1977, San Diego, CA.)

C. Oral presentations and meetings.

16, 17, 23 August — OCSEAP employees presented current research efforts to the Marine Mammal Division.

VII. Problems Encountered and Recommended Changes.

Spring and Fall Survey: Aircraft support from NARL is not adequate in that aircraft suitable for offshore aerial survey are not always available. Secondly, the electronic navigation equipment aboard the NARL twin engine Otter has failed so frequently that the quality of perhaps half of our recent aerial surveys suffered significantly.

Recommendation: NARL repair/maintain On-Track II navigation equipment.

A large data gap exists in that distribution of bowhead and beluga whales east of Barrow in the Beaufort Sea lease site area remains essentially unknown.

Recommendation: Increase support for aerial survey and provide long range aircraft for extended offshore survey (e.g. Dep. of Interior, Office of Aircraft Services, Grumman "Super" Goose, N780).

VIII. Estimate of Funds Expended.

Salaries/Overtime	$10,724
Travel/Per Diem	5,017
Equipment/Supplies/Computer	963
Charter/Logistics	10,657
	$27,361

Table 1. Summary of bowhead whale (Balaena mysticetus) and beluga whale (Delphinapterus leucas) sightings by day, hours observed, and whales per hour at Barrow, Alaska, during the spring of 1977. Dash marks indicate that no watches took place.

Date	Hours Observed	Number of Bowhead Observed	Bowhead/ Hour	Number of Beluga Observed	Beluga/ Hour
19 April	1:00	0	.00	0	.00
20 "	-				
21 "	-				
22 "	-				
23 "	13:05	2	.15	0	.00
24 "	4:00	0	.00	0	.00
25 "	-				
26 "	-				
27 "	-				
28 "	-				
29 "	1:20	0	.00	0	.00
30 "	23:00	0	.00	0	.00
1 May	15:00	16	1.07	1	.07
2 "	14:55	25	1.68	0	.00
3 "	7:30	4	.53	0	.00
4 "	6:14	16	2.57	20	3.21
5 "	22:00	30	1.36	463	21.05
6 "	18:10	2	.11	7	.39
7 "	16:31	88	5.33	0	.00
8 "	16:28	31	1.88	0	.00
9 "	17:20	11	.63	0	.00
10 "	13:00	10	.77	0	.00
11 "	2:15	18	8.00	0	.00
12 "	19:00	4	.21	0	.00
13 "	14:00	19	1.36	0	.00
14 "	22:07	18	.81	0	.00
15 "	19:10	1	.05	0	.00
16 "	4:30	4	.89	0	.00
17 "	4:30	0	.00	0	.00
18 "	3:00	0	.00	0	.00
19 "	-				
20 "	-				
21 "	6:47	0	.00	0	.00
22 "	21:55	17	4.79	2	.09
23 "	18:11	8	.44	5	.27
24 "	-				
25 "	6:24	0	.00	30	4.69
26 "	8:10	0	.00	0	.00
27 "	22:45	0	.00	0	.00
28 "	7:15	1	.14	0	.00
29 "	1:00	0	.00	0	.00
30 "	-				
31 "	-				

Table 1. Cont.

Date	Hours Observed	Number of Bowhead Observed	Bowhead/ Hour	Number of Beluga Observed	Beluga/ Hour
1 June	7:35	0	.00	0	.00
2 "	11:15	0	.00	0	.00
3 "	5:50	2	.34	83	14.23
Total	395:12	327	.83	611	1.55

Table 2. Summary of bowhead whale (Balaena mysticetus) and beluga whale (Delphinapterus leucas) sightings by day; hours observed; and whales per hour observed at Cape Lisburne, Alaska, during the spring of 1977.

Date	Hours Observed	Number of Bowhead Observed	Bowhead/ Hour	Number of Beluga Observed	Beluga/ Hour
6 May	4:42	16	3.4	0	.0
7 "	3:37	5	1.4	55	15.0
8 "	8:35	5	.6	0	.0
9 "	18:20	9	.5	34	1.8
10 "	8:00	7	.9	0	.0
11 "	10:30	5	.5	0	.0
15 "	13:03	3	.2	66	5.1
16 "	5:00	0	.0	0	.0
Total	71:47	54	.75	155	2.16

Table 3. Summary of bowhead whale (Balaena mysticetus) and beluga whale (Delphinapterus leucas) sightings by day, hours observed, and whales per hour at Pt Hope, Alaska, during the spring of 1977. Dash marks indicate days when leads were closed and no watches took place.

Date	Hours Observed	Number of Bowhead Observed	Bowhead/ Hour	Number of Beluga Observed	Beluga/ Hour
18 April	9:00	0	.00	0	.00
19 "	10:00	0	.00	0	.00
20 "	13:00	0	.00	0	.00
21 "	15:30	0	.00	18	1.16
22 "	6:45	0	.00	0	.00
23 "	14:33	3	.21	0	.00
24 "	-				
25 "	-				
26 "	-				
27 "	10:48	2	.19	0	.00
28 "	16:38	75	4.51	0	.00
29 "	20:00	8	.40	161	8.05
30 "	12:01	19	1.58	160	13.32
1 May	13:06	3	.23	28	2.14
2 "	11:14	4	.36	31	2.76
3 "	15:00	0	.00	0	.00
4 "	2:00	0	.00	89	44.50
5 "	16:30	2	.12	0	.00
6 "	17:01	7	.41	0	.00
7 "	8:09	18	2.21	0	.00
8 "	8:00	8	1.00	0	.00
9 "	:30	0	.00	0	.00
10 "	-				
11 "	13:00	0	.00	0	.00
12 "	4:38	0	.00	0	.00
13 "	24:00	2	.08	0	.00
14 "	20:45	0	.00	34	1.64
15 "	3:00	0	.00	0	.00
16 "	8:00	0	.00	0	.00
17 "	22:38	1	.04	133	5.87
18 "	22:55	5	.22	279	12.17
19 "	22:28	4	.18	284	12.63
20 "	23:28	4	.17	162	6.90
21 "	17:00	2	.12	36	2.12
22 "	16:19	7	.43	37	2.27
23 "	19:45	0	.00	3	.15
24 "	23:09	1	.04	10	.43
25 "	23:19	3	.13	209	8.96
26 "	23:00	5	.22	32	1.39
27 "	23:19	2	.09	0	.00
28 "	16:19	0	.00	0	.00
Total	546:47	185	.34	1706	3.12

QUARTERLY REPORT

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

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

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30 September 1977

QUARTERLY REPORT

I. Task Objectives This Quarter

A. To continue the processing of pathological and parasitological materials collected in the previous quarter during marine mammal field work via NOAA vessels in the Bering Sea.

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

II. Field and Laboratory Activities

A. Field trip schedule

8-17 June (Dieterich) Alaska Peninsula stranding survey

24 June-5 July SURVEYOR Leg II (Fay) St. Matthew and St. Lawrence Island carcass survey

11-13 August (Fay) Marine mammal stranding workshop, Athens, Georgia

B. Laboratory activities

Identification of microbiological isolates and parasites collected from pinnipeds during field work aboard NOAA vessels was completed.

C. Methods

Survey and necropsy methods for the stranding surveys were as described previously (see Annual Report 31 March 1976).

III. Results

A. Stranding surveys

The Alaska Peninsula survey was underway at the time of writing of the 30 June quarterly report. In the 754 km of coastline surveyed between 10 and 14 June, only 5 fresh and 12 old carcasses were sighted. This was a much lower number than had been found in either of the previous two years. The reasons for this are not entirely clear, but it appears to have been a result of the occurrence of low pressure areas north of the Alaska Peninsula, causing strong offshore winds. Such winds tend to move carcasses away from shore rather than deposit them onshore. Offshore winds prevailed also at the time of the survey and made beach landings with the fixed wing aircraft especially difficult. Hence, only four of the carcasses were necropsied. These were all adult male walruses, two of which had apparently died of gunshot wounds, and the cause of death of the other two could not be determined.

Enroute to St. Lawrence Island via the NOAA ship SURVEYOR, a survey was made of St. Matthew Island on 26 June with the ship's heliocopter. Approximately 75 miles of coastline were surveyed, in which only three marine mammal carcasses were sighted. Two of these were adult male walruses; the third was either a walrus or a sea lion, which could not be examined due to adverse landing conditions. The two walruses had been in place at least six months and had been reduced to skeletons by scavengers. Since there were no signs of gunshot wounds in the bones it is presumed that the animals had died of natural causes during the previous autumn or winter.

At St. Lawrence Island approximately 160 miles of shoreline along the southern and eastern coasts were surveyed between 28 June and 1 July. Due to unusually cool weather, the entire northern coast of the island remained bound in shore-fast ice at least until 5 July making it unsuitable for a stranding survey. The southern and eastern coasts were mainly ice free. Surveys of the latter yielded 51 identifiable carcasses, 3 of which were considered "fresh" (i.e. less than 2 months old), 29 were from the 1976 ice-free season, and 19 had lain in place for at least two years. Necropsies were performed on the three fresh carcasses with the following results: The first, a walrus calf appeared to be in excellent condition except for possible nephritis of unknown origin; the second, a ringed seal less than one year old, appeared to be normal in all respects except that it was emaciated; the third, a bearded seal pup, had been too thoroughly scavenged for diagnosis other than to determine that it had not died of gunshot and that it too was extremely lean, apparently from malnutrition. Of the carcasses from the 1976 ice-free season, 17 were young and adult gray whales, 1 was a young bowhead whale, and 11 were adult walruses. None of these appeared to have died from gunshot wounds or killer whale predation, but each was in such a state of decay and dismemberment (by scavengers) that necropsy was not feasible. The older remains, consisting mainly of bones, were those of 14 gray whales, 1 bowhead, and 4 walruses, several of which were recognizable as the same specimens examined in 1975.

A survey of the Punuk Islands, off the eastern end of St. Lawrence Island, showed the remains of 81 walruses on the northernmost island, in an area that is utilized as a haulout by these animals during their southward migration in autumn. The carcasses evidently had lain in place there since October or November 1976. There was no evidence of gunshot wounds in any of these, but due to their advanced state of decay and to scavenged condition (evidently by arctic foxes and polar bears) determination of cause of death was not possible. The majority of these animals were adult females.

B. Marine Mammal Stranding Workshop

Fay participated in the Marine Mammal Stranding Workshop, organized by the New England Aquarium and the University of Guelph, sponsored mainly by the Marine Mammal Commission, and held at the University of Georgia from 10 to 12 August, in conjunction with the annual meeting of the Wildlife Disease Association. Session topics included (a) a review of available information on the nature and causes of marine mammal strandings, (b) an analysis of the kinds and quantities of scientific data that can be obtained from stranded animals, (c) a review of problems and solutions in the salvage of live-stranded animals for use in public display facilities, (d) formulation of plans for a nationally expanded stranding alert network, through which investigators concerned with certain species or with live salvage could be promptly informed of available specimens, and (e) plans for development of a national data bank, for storage of information on marine mammal strandings. The meeting was well attended by about 50 participants, and the exchange of information and ideas was at a lively pace throughout the meeting. Among the points of especial relevance to this project that were brought out in the sessions were the following:

1. In the areas most closely monitored, the stranding rate is about 1 carcass per 5 miles of shore per year, at least 17 per cent of which are alive on arrival.

2. Species that inhabit deep waters offshore are the least well represented and usually are alive on arrival. Inshore (shallow water) species are best represented and usually float ashore, dead. Probably, one of the principal reasons for this differenc is that hydrostatic pressure on animals that sink to the bottom in deep water tends to keep the gases from post mortem degeneration in solution, preventing the carcasses from bloating and floating to the surface. Those sinking in shallow waters bloat and float ashore.

3. The principal primary causes of death appear to be malnutrition (principally in the youngest age classes), gunshot, parasitism, and stress.

The proceedings of the workshop will be provided as a report to the Marine Mammal Commission and probably will be available for general distribution within 6 months.

C. Laboratory Activities

Microbiological isolates collected in the field from pathological lesions and transported to the laboratory in Amies transport media were submitted to the Alaska Department of Health laboratory for identification, with the following results:

Bearded seal lung: *Escherichia coli*

Bearded seal liver: *Staphlococcus epidermidis*
Edwardsiella tarda
Enterobacter hafria

Spotted seal lung: *Pseudomonas* sp.

Spotted seal liver:	Citrobacter freundii Escherichia coli Staphylococcus epidermidis
Ringed seal liver:	Escherichia coli
Ringed seal wound:	Moraxella sp. Beta Streptococcus not group A
Steller sea lion lung:	Corynobacterium sp.
Ribbon seal liver:	Moraxella sp.
Ribbon seal wound:	Moraxella sp. Beta Streptococcus not group A Alpha Streptococcus

The significance of these, as regards their role in the pathological lesions observed, is not yet clear. Further work to elucidate the normal microbiological flora of pinnipeds will be undertaken in the near future as an aid in that evaluation.

Histopathological studies on collected tissues are continuing and should be completed during the next quarter.

Parasitological investigations have revealed that, while almost one hundred percent of the pinnipeds examined were infected with one or more kinds of parasites, only in unusual instances did the parasites appear to cause any debilitating lesions. Parasite-caused pathology occurred in every bearded seal. One had severe mechanical damage to the pylorus due to heavy infection with the cestode Pyramicocephala phocarum; four had acute biliary fibrosis with associated calcification caused (at least in part) by heavy infection of Orthosplanchnus fraterculus, a trematode; another had many ulcerations in the lower small intestine due to the acanthocephalan Corynosoma validum. Tables 1-6 show the pinnipeds examined and the parasites associated with them.

IV. Preliminary Interpretation of Results

No further interpretation is feasible at this time.

V. Problems encountered/Recommended Changes

None

Table 1. Helminth parasites of ribbon seals, *Phoca fasciata*

Specimen number	*Anophryocephalus ochotensis*	*Orthosplanchnus fraterculus*	*Contracaecum* sp.	*Phocanema* sp.	*Corynosoma strumosum*	*Corynosoma semerme*	*Corynosoma validum*	*Bulbosoma* sp.	*Dipetalonema* sp.
42251			X	X	X				
42252			X	X	X	X			
42253		X	X		X	X			
42256			X	X	X				
42261			X						
42276			X		X				
42277				X	X				
42279			X		X	X		X	
42284			X		X	X	X		X
42289	X		X		X	X	X		
42290			X		X				
42294			X	X	X	X			
42297			X		X	X			
42299			X		X				

Table 2. Helminth parasites of Steller sea lion, Eumetopias jubata.

Specimen number	Anophryocephalus ochotensis	Phocanema sp.	Corynosoma villosum	
42274	X	X	X	

Table 3. Helminth parasites of walrus, Odobenus rosmarus.

Specimen Number	Diphyllobothrium sp.	Orthosplanchnus fraterculus	Corynosoma validum	
42267	X	X	X	

Table 4. Helminth parasites of the spotted seal, *Phoca largha*.

Specimen number	*Diphyllobothrium* sp.	*Anophryocephalus ochotensis*	*Phocanema* sp.	*Contracaecum* sp.	*Dipetalonema* sp.	*Phocitrema fusiforme*	*Corynosoma strumosum*	*Corynosoma semerme*	*Bulbosoma* sp.	*Diplogonoporus tetrapterus*
42254				X			X	X		
42269	X	X	X	X			X	X		
42270	X	X	X				X	X	X	X
42271	X	X		X			X	X	X	X
42273		X	X				X	X		
42278		X	X		X	X	X	X		
42280	X	X	X				X	X	X	
42282				X			X	X		
42285		X	X	X			X	X		
42286		X	X	X		X	X	X		
42287		X	X	X			X	X		
42288		X	X	X		X	X	X		
42291		X		X			X	X		
42292		X		X			X			
42293		X		X			X	X		
42298		X		X			X			

Table 5. Helminth parasites of the ringed seal, *Phoca hispida*.

Specimen number	*Diplogonoporus tetrapterus*	*Diphyllobothrium* sp.	*Anophryocephalus ochotensis*	*Phocanema* sp.	*Contracaecum* sp.	*Corynosoma strumosum*	*Corynosoma semerme*	*Corynosoma validum*	*Corynosoma hadweni*
42272			X	X		X			
42295						X			
42296	NEGATIVE FOR HELMINTHS								

Table 6. Helminth parasites of the bearded seal, *Erignathus barbatus*.

Specimen number	*Pyramicocephala phocarum*	*Diphyllobothrium lanceolatum*	*Diphyllobothrium cordatum*	*Diphyllobothrium* sp.	*Orthosplanchnus fraterculus*	*Phocanema* sp.	*Contracaecum* sp.	*Corynosoma validum*
42255	X	X	X					X
42257	X	X	X	X	X	X		X
42258	X	X	X	X	X	X		X
42263	X	X	X	X		X	X	X
42265	X	X	X	X			X	X
42275	X	X	X	X	X	X		X
42281	X	X	X			X		X

QUARTERLY REPORT

Contract #03-5-002-69
Research Unit #229
Reporting Period 1 July
thru 30 September 1977

Number of Pages - 2

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

Principal Investigators:

Kenneth Pitcher, Marine Mammals Biologist
Donald Calkins, Marine Mammals Biologist

Alaska Department of Fish and Game

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

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

Two field trips to Tugidak Island were made during the past quarter to test techniques which we plan to utilize next year for harbor seal research. Radio transmitters were attached to six harbor seals and monitored at intervals through the summer. Performance of the radio equipment was satisfactory and plans have been made to expand the program next contract period.

Laboratory activities dominated much of the quarter. To date in 1977, 117 harbor seals have been collected in the Gulf of Alaska. Teeth have been sectioned, stained and mounted for 102 animals but have not yet been read. Laboratory analyses for both male and female reproductive tracts are completed. All food habit material was sorted and assigned tentative identifications. Final identifications await examination by outside experts.

Considerable effort was expended toward fulfilling data management obligations. This facet of the OCSEAP program has consumed an inordinate amount of time and thus far has proven to have little utility. Thought should be given to streamlining our present data management program. For some research units which do not handle extensive volumes of data it would probably be more efficient to waive requirements for an automated data system.

Proposals for FY'78 were written and then modified after discussion with the staff at the Juneau Project Office.

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

Quarterly Report

Contract #02-5-022-53
Research Unit #230
Reporting Period: July-September 1977
Number of Pages: 13

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

Principal Investigators:

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1300 College Road
Fairbanks, Alaska 99701

Assisted by: Kathryn Frost, Larry Shults, Lloyd Lowry, Glenn Seaman, Richard Tremaine, Dan Strickland and John Matthews

30 September 1977

I. Task Objectives

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

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

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

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

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

6. Acquisition of additional information on seasonal migrations.

II. Field and Laboratory Activities

A. Schedule

Date	Location	Activity	Personnel
July-September	Fairbanks	Analyses of seal specimen and data	Burns, Eley
July-September	Fairbanks	Data management	Burns, Eley, Frost
July	Shishmaref	Collection of seal specimens	Seaman, Tremaine, Strickland
July	Wainwright	Collection of seal specimens	Seaman
July	Wales	Collection of seal specimens	Seaman, Strickland
August-September	USCGC GLACIER (Beaufort Sea)	Collection of seal specimens and data on regional densities	Burns, Frost, Shults
September	Fairbanks	Preparation of quarterly report	Burns, Eley

*We are especially grateful to L. Shults, University of Alaska, for his able assistance throughout the GLACIER cruise.

During this quarter a major field effort was undertaken in the Beaufort Sea aboard the USCGC GLACIER. We were fairly successful in acquiring a sample of ringed and bearded seals in the Beaufort during a period (August-September) and in an area (Beaufort Sea) in which our previous samples were inadequate. In addition, collections at Shishmaref during the seal harvest by Native hunters was successful.

Laboratory activities consisted mainly of processing male and female reproductive tracts and determining ages of seals by examination of claw annuli. In addition, parasitological determinations were made.

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

B. Scientific Party

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

C. Analytical Methods

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

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

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

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

III-IV. Results and Preliminary Interpretation

A. Specimens

During July-September 1977 our major efforts were devoted to collections of specimens in Bering Strait (Wales), in Chukchi Sea (Shishmaref and Wainwright) and in Beaufort Sea (USCGC GLACIER) and to laboratory analyses of specimens collected from January to September 1977.

A total of 154 male, 163 female and 5 ringed seals of undetermined sex were obtained (Table 1) yielding a 1:1 sex ratio. One hundred seventy-three bearded seals were obtained and consisted of 68 males, 99 females, and 6 of unknown sex. The sex ratio of bearded seals was 1.45 females to 1 male.

Table 1. Seal specimens obtained during July-September, 1977.

Location	Sex			Total
	Male	Female	Unknown	
Shishmaref				
Ringed seal	137	147	4	288
Bearded seal	63	88		151
Wales				
Ringed seal	9	8	1	18
Bearded seal	3	4	6	13
Wainwright				
Bearded seal		4	0	4
USCGC GLACIER				
Ringed seal	8	8		16
Bearded seal	2	3		5
Total				
Ringed seal	154	163	5	322
Bearded seal	68	99	6	173

B. Ringed Seal

1. Ringed seal sex and age composition

The sex composition of ringed seals obtained from 1975 through 1977 is presented in Table 2. The overall sex ratio is 1.24 males to 1.00 females. The sex ratio of pups does not depart significantly from unity (1:1). The sex ratio of seals one year old and older is 1.3 males to 1.0 females. The preponderance of males in our samples is probably due to our major collection efforts centering in the spring when males are more available. In the spring females are involved in birth and birth-related activities and are less readily available for collection. A 1:1 sex ratio has been found by other investigators (McLaren 1958; Johnson et al. 1966; and Smith 1973), whose collections have been spread more evenly over a year or have not centered during the spring.

The age composition of ringed seals obtained from 1975 through 1977 also are presented in Table 2. This age composition generally conforms to that of Smith (1973) for the Canadian arctic. However, there is wide variation in the age composition at various collection locations. The significance of these variations in age composition with location which may be indicative of segregation by age cohort or reproductive status is under investigation at this time.

2. Reproductive Biology

The reproductive tracts of 229 female ringed seals collected between 1962 and September 1977 have been examined. Of these 229 females, 127 (55%) were nulliparous, 34 (15%) were primaparous, and 68 (30%) were multiparous.

Table 2. Sex and age distribution of ringed seals collected under OCSEAP.

Ages	Mekoryuk		Gambell			Savoonga		Nome			Diomede		Shishmaref 1977			Shishmaref 1976		
	Male	Female	Male	Female	Unknown	Male	Female	Male	Female	Unknown	Male	Female	Male	Female	Unknown	Male	Female	Unknown
Pup	-	1	8	7	-	-	4	-	-	-	-	1	13	14	-	12	13	-
1	3	2	7	10	1	1	1	2	2	2	6	3	12	12	-	3	5	-
2	2	1	3	2	-	2	1	3	-	-	3	3	8	9	-	1	2	-
3	-	1	2	-	1	-	1	4	1	-	1	7	-	1	-	5	2	-
4	-	-	-	-	-	2	-	1	1	2	11	4	-	4	-	2	5	-
5	-	2	-	-	-	-	1	2	2	2	5	4	1	1	-	4	7	-
6	-	1	1	-	-	-	2	5	1	-	5	1	-	-	-	7	5	-
6+	-	-	-	-	-	-	-	1	-	-	2	1	-	-	-	-	-	-
7	-	-	1	-	-	-	-	6	6	1	-	-	-	1	-	3	5	-
7+	-	-	1	1	-	-	-	-	-	1	5	1	1	-	-	-	-	-
8	-	-	-	1	-	-	-	3	-	-	-	1	3	-	1	4	8	-
8+	-	1	1	-	-	-	-	1	4	-	3	2	2	2	-	-	-	-
9	-	-	-	-	-	-	-	2	2	1	-	-	2	2	-	1	3	-
9+	-	-	-	1	-	1	1	1	4	-	1	-	4	4	-	-	-	-
10	-	-	1	-	-	-	-	2	-	-	-	-	1	-	-	5	3	-
10+	-	-	-	-	-	1	-	-	1	-	1	2	3	6	-	-	-	-
11	-	-	-	-	-	-	-	1	2	-	-	-	1	1	-	1	3	-
11+	-	-	-	-	-	1	-	-	-	-	-	-	4	1	-	-	-	-
12	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	1	1	-
12+	-	-	-	-	-	1	-	-	3	-	-	-	2	2	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	-
13+	-	-	-	-	-	-	-	-	2	-	-	-	2	1	-	-	-	-
14	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	1	-
14+	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-
15+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-
16+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
17+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
18+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-
19+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
20+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unknown	4	4	-	-	-	-	-	3	-	1	2	-	-	-	-	2	3	1
Total	9	13	25	22	2	10	11	37	33	10	45	30	60	61	1	59	83	1

Table 2 (Cont'd)

Ages	Point Hope			Cape Lisburne (Polar bear kills)			Wainwright		Barrow			USCGC GLACIER (Beaufort Sea 1977)		Total		
	Male	Female	Unknown	Male	Female	Unknown	Male	Female	Male	Female	Unknown	Male	Female	Male	Female	Unknown
Pup	-	-	-	-	-	-	3	3	3	2	-	-	-	39	45	0
1	2	-	-	-	-	-	1	2	-	-	-	1	-	38	37	3
2	1	1	1	-	-	-	-	1	-	-	-	1	-	24	20	1
3	2	2	-	1	-	-	1	1	-	1	-	-	1	16	18	1
4	6	1	-	-	-	-	2	-	1	-	1	1	-	26	15	3
5	5	4	-	-	-	-	1	1	1	-	-	-	-	19	22	2
6	5	2	-	1	-	-	1	3	2	-	-	-	-	27	15	0
6+	2	1	-	-	-	-	-	-	-	-	-	-	-	5	2	0
7	1	-	-	1	-	-	3	1	-	-	-	-	-	15	13	1
7+	3	-	-	-	-	-	-	-	-	-	-	-	-	10	2	1
8	6	-	-	1	-	-	1	2	4	1	-	3	1	25	14	1
8+	2	2	4	1	-	-	-	-	-	-	-	-	1	10	12	4
9	2	-	-	1	-	-	1	-	1	-	-	-	-	10	7	1
9+	4	-	4	1	-	-	-	-	1	-	-	-	-	13	10	4
10	4	-	-	1	-	-	1	-	2	-	-	-	-	17	3	0
10+	1	-	1	2	-	-	-	-	-	-	-	1	1	9	10	1
11	5	1	-	1	-	-	4	-	2	1	-	-	-	15	8	-
11+	-	-	-	1	-	-	-	-	-	-	-	1	-	7	1	-
12	-	-	-	-	-	-	1	-	-	-	-	1	1	4	3	-
12+	-	-	-	-	-	-	-	-	-	1	-	-	-	3	6	
13	1	-	-	-	-	-	1	-	-	1	-	-	-	5	2	-
13+	-	-	-	-	-	-	-	-	-	-	-	-	1	2	4	-
14	1	-	1	-	-	-	1	-	2	-	-	-	-	5	2	1
14+	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-
15	1	-	1	-	-	-	-	-	-	-	-	-	-	2	4	1
15+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	1	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-
16+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	1	-	-	-	-	-	1	1	-	-	-	-	1	6	
17+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	1	-	-	-	-	1	2	-
18+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-
19+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
20+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-
22	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-
23	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-
29	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Unknown	2	-	-	-	-	7	-	-	2	-	1	-	-	15	7	10
Total	60	15	12	12	0	7	22	16	23	8	2	9	7	371	299	35

Some confusion of meaning may arise in terminology referring to reproductive status, therefore the terminology used in this study is defined as follows:

1. Nulliparous: A female that has never given birth to an offspring at the normal birth time.

2. Primaparous: A female that has given birth to one offspring at the normal birth time.

3. Multiparous: A female that has given birth to more than one offspring at the normal birth time.

In a sample of 33 adult female ringed seals, obtained between 1962 and 1973, 30 were or had just been pregnant (Table 3) yielding a pregnancy rate of 91 percent. The reproductive tracts of 44 adult females collected during 1975 and 1976 have been examined and 31 (71%) were pregnant or recently had given birth. Specimens examined thus far in 1977 have yielded a 68 percent pregnancy rate, with 15 pregnant females of those 22 examined.

Johnson et al. (1966) found 240 of 280 (86%) adult females (collected near Cape Thompson, Alaska during 1960 and 1961) pregnant. The decline in the pregnancy rates of our samples between 1964-1973 and 1975-1977 corresponds to the decline in the pregnancy rates reported by Stirling et al. (1975) for ringed seals in the Beaufort Sea. However, the magnitude of the decline in pregnancy rates in Canadian ringed seals from the Beaufort Sea is significantly greater; in 1972 a pregnancy rate of 59 percent was found and in 1974 and 1975 a 0 percent and 11 percent pregnancy rate was found, respectively (Stirling et al. 1975).

The reason for the decline in the pregnancy rates of female ringed seals is unknown and it is presently under investigation. Our parasitological and pathological examinations have not found evidence of parasite or disease agents which might be responsible for the decline, however this possibility is still being pursued. Blubber thickness at the sternum and total weight are good indicators of a seal's physical condition. The parameters were compared (Table 3) for sexually mature females collected from 1962 and 1977 during essentially the same seasons and locations. Blubber thicknesses of females collected during 1962-1973 are not significantly different ($P > 0.05$) than those of females collected during 1975-76 or 1977.

Total weights of adult females collected during 1962-1973 are not significantly different ($P > 0.05$) from those of females collected during 1975-76. However, females collected during 1977 are significantly heavier ($P < 0.05$) than females collected during 1962-1973 and 1975-1976. The reason for the weight change and the relationship, if any, of this change to the decline in fertility is unknown. There appears to have been no dramatic changes in ringed seal food habits between 1962 and the present. However, essentially nothing is known about changes in densities of ringed seal food species.

Table 3. Pregnancy rates, blubber thicknesses and weights of sexually mature females collected from 1962 to 1977.

	1962-1973	1975-1976	1977
Number examined	33	44	22
Number pregnant	30	31	15
Percent pregnant	91	71	68
Mean blubber thickness(cm)	5.0	3.4	5.2
Range blubber thicknesses	2.5-10.2	2.5-4.1	4.2-6.3
Number measured	16	8	14
Mean weight (kg)	45.5	37.4	69.9
Range weights	24.1-63.6	25.9-53.6	44.5-111.4
Number weighed	10	29	14

The Soviets have examined large numbers of ringed seal specimens from the Bering and Chukchi seas and suggest that there are two morphs (which may be subspecies) of ringed seals. The larger morph is supposedly found in the shorefast ice and a smaller morph in the drifting ice. It is possible that our 1962-1976 collections may have centered on the smaller morph while our 1977 collections centered on the larger morph. However, our 1962-1973 specimens were collected primarily from the shorefast ice (hence theoretically the larger morph) while specimens collected from 1975 to 1977 appear to be similarly distributed between shorefast and drifting ice. Not enough is known about the ecology and behavior of ringed seals to ascertain the relationships between the drifting and shorefast ice seals. Based on specimen material and collecting programs, there appears to be age-specific, seasonal movements of seals between shorefast and drifting ice. In our future work we hope to delineate these movement patterns more clearly.

3. Pathology and Parasitology

A considerable amount of material for pathological and parasitological examinations has been collected by this project. The bulk of this material has been provided to Drs. F. H. Fay and R. A. Dieterich and Mr. L. M. Shults (RU#194 - Morbidity and Mortality of Marine Mammals) for examinations and analyses. Within the limits of available time and funding, some material has been examined by personnel of this Research Unit. Mr. L. Shults has identified some of the parasites of ringed seals and provided verification of others tentatively identified by us. Results of our examinations will be combined with those of RU#194. A paper on the helminth parasites is in the early stages of preparation.

A total of 29 ringed seals were examined this quarter for helminth parasites, and 28 seals (96%) were found to harbor at least one species of helminth parasite (Table 4). Seven species of parasites were recovered. The acanthocephalas Corynosoma semerme and C. strumosum were the most prevalent, followed by the cestode Diplogoniporus tetrapterus and the stomach nematode, Phocanema decipiens. The acanthacephalan Corynosoma validum, the cestode Anophryocephalus ochotensis, and the heart nematode Dipetalonema spirocauda were rare.

Marine mammal hearts, either obtained from specimens collected by personnel working on RU#230 and 232 or those provided by RU#194, 229 and 243, are examined for marine mammal heartworms, Dipetalonema (Acanthocheilonema) spirocauda (Lidey 1858) Anderson 1959. Examinations are still underway but findings thus far are presented in Table 5. The pathological and resultant physiological, behavioral and ecological effects of marine mammal heartworms is presently under investigation.

C. Bearded Seal

Ovarian analyses were completed on all female bearded seals from which reproductive tracts were obtained in 1977, up to 31 July. This sample consisted of 95 animals. Of these, 42 (44%) were sexually immature and 53 (56%) had ovulated at least once.

Analysis of the age-specific productivity is currently in progress, as is examination of uteri for comparison with ovarian analysis.

Table 4. Helminth parasites recovered from ringed seals.*

	Sex	*Diplogoniporus tetrapterus*	*Anophyyocephalus ochotensis*	*Dipetalonema spirocauda*	*Phocanema decipiens*	*Corynosoma semerme*	*Corynosoma strumosum*	*Corynos validu*
NP-09-77	F	X	-	-	-	X	X	-
NP-10-77	F	X	-	-	X	X	X	-
NP-11-77	M	-	-	-	-	X	-	X
NP-12-77	M	X	-	-	-	X	X	-
NP-13-77	F	X	-	-	X	X	X	-
NP-14-77	F	-	-	-	unk	X	X	-
NP-15-77	F	X	-	-	unk	X	X	-
NP-16-77	M	-	-	-	-	X	-	-
NP-17-77	F	-	-	-	-	X	X	X
NP-18-77	F	X	-	-	-	X	X	-
NP-19-77	F	-	-	-	X	X	X	-
NP-20-77	M	-	-	-	X	X	X	-
NP-21-77	F	X	-	-	X	-	X	-
NP-22-77	M	X	-	-	-	X	X	-
NP-23-77	F	-	-	-	X	X	-	-
NP-28-77	F	X	-	-	-	X	X	-
NP-29-77	F	X	X	X	X	X	X	-
NP-30-77	F	X	-	-	-	X	X	-
NP-31-77	F	X	-	-	-	X	-	-
NP-32-77	M	-	-	-	X	X	X	-
BP-1-77	M	-	-	-	-	X	-	-
BP-2-77	M	-	-	-	-	X	-	-
BP-7-77	M	X	-	-	-	X	X	-
BP-8-77	M	-	-	-	-	X	X	-
BP-9-77	F	X	-	-	X	X	X	-
BP-10-77	M	X	-	-	X	X	X	-
SUVP-22-77	F	-	X	-	X	-	X	-
DISP-12-77	M	-	-	-	X	-	X	-
DISP-13-77	M	-	-	-	-	-	-	-
Number infected		15	1	1	12	24	22	2
Percent infected		52	3	3	41	83	76	7

*Many of the identifications were made or confirmed by Mr. L. Shults, OCS RU#194.

Table 5. Examinations for marine mammal heartworms (*Dipetalonema* (*Acanthocheilonema*) *spirocanda*).

Species	Location	Number examined	Number positive	Percent Positive
Phoca hispida	Beaufort Sea	16	0	0
Phoca hispida	Barrow	4	1	25.0
Phoca hispida	Point Hope	9	0	0
Phoca hispida	Shishmaref	275	3	1.1
Phoca hispida	Nome	31	3	9.6
Phoca hispida	Bering Sea	3	0	0
Phoca vitulina largha	Shishmaref	20	2	10.0
Phoca vitulina largha	Wales	2	0	0
Phoca vitulina largha	Bering Sea	18	1	5.6
Phoca vitulina richardii	Kodiak	87	15	17.2
Phoca fasciata	Bering Sea	15	0	0
Erignathus barbatus	Beaufort Sea	5	0	0
Erignathus barbatus	Barrow	5	1	20.0
Erignathus barbatus	Wainwright	4	0	0
Erignathus barbatus	Shishmaref	16	0	0
Erignathus barbatus	Nome	6	0	0
Erignathus barbatus	Bering Sea	10	0	0
Odobenus rosmarus	Bering Sea	1	0	0
Eumetopias jubatus	Bering Sea	1	0	0
Eumetopias jubatus	Gulf of Alaska	31	0	0
Delphinapterus leucas	Point Hope	23	0	0

Based solely on examination of ovaries, 1 of the 53 animals (1.9%) which had ovulated at one time or another was barren when collected (had not ovulated during the current year). All of the remaining 52 (98.1%) showed an active corpus luteum. This compares with presence of a corpus luteum in 96 percent of 54 females obtained in 1975 and 1976.

The age distribution of nine females, obtained in 1977, which had ovulated for the first time was: age 2, 2 animals; age 3, 1 animal; age 4, 3 animals; age 5, 1 animal; and age 6, 2 animals. Some of these ovulations would not have resulted in pregnancy and examination of uteri will be necessary before age at initial pregnancy can be determined. However, it appears to be between ages 2 and 6. Two females had hard, large follicles, larger than 12 mm, but had not ovulated. Both of these were two year olds.

During 1976 most bearded seals taken at Shishmaref were killed between 30 June and 12 July and exhibited a high proportion of newly implanted fetuses. In 1977, most bearded were taken earlier, between 24 June and 2 July. The incidence of implanted fetuses in uteri obtained at Shishmaref and examined to date is very low. It appears that implantation begins in early July.

The heavy field schedule of project personnel during this quarter did not permit extensive analysis of data or specimens other than ovaries. Laboratory work and data analysis will be our major involvement during the ocming two quarters.

V. Problems Encountered and Recommended Changes

None, with the exception of the anticipated difficulty of obtaining seal specimens from the Beaufort Sea during summer and fall. We are directing more effort toward collection of specimens from the Beaufort Sea.

VI. Estimates of Funds Expended

As of August 31 we have expended the following approximate amounts during FY77.

Salaries and benefits	-	$52,387.65
Travel and per diem	-	3,262.93
Contractual services	-	5,636.21
Commodities	-	2,153.95
Equipment	-	15.65
Total Expenditures	-	$63,456.39

VII. Literature Cited

Burns, J. J. and S. J. Harbo, Jr. 1972. An aerial census of ringed seals, northern coast of Alaska. Arctic 25(4):279-290.

Johnson, M. L., C. H. Fiscus, B. T. Ostenson and M. X. Barbour. 1966. Marine Mammals. Pages 877-924 In Environment of the Cape Thompson Region, Alaska. N. J. Wilimovsky and J. N. Wolfe, eds. USAEC, Oak Ridge, Tennessee.

McLaren, I. A. 1958. The biology of the ringed seal (*Phoca hispida* Schreber) in the eastern Canadian arctic. Fish. Res. Bd. Can. Bull. 118:97pp.

Smith, T. G. 1973. Population dynamics of the ringed seal in the Canadian eastern arctic. Fish. Res. Bd. Can. Bull. 181:55pp.

Stirling, I., R. Archibald and D. DeMaster. 1975. The distribution and abundance of seals in the eastern Beaufort Sea. Victoria, Canada. Beaufort Sea Tech. Rept. No. 1 58pp.

Quarterly Report

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Research Unit #232
Report Period: 1 July-30 September 1977
Number of Pages: 17

Trophic Relationships Among Ice Inhabiting Phocid Seals

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October 1, 1977

I. Task Objectives

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

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

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

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

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

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

II. Field and Laboratory Activities

As was the case during the previous two years, efforts during the late spring and early summer months were mostly directed at specimen collections in the coastal villages. Collections at several previously sampled locations were repeated. In addition a sample was obtained from the village of Wales from which no material was previously available. See Fig. 1 for sampling locations.

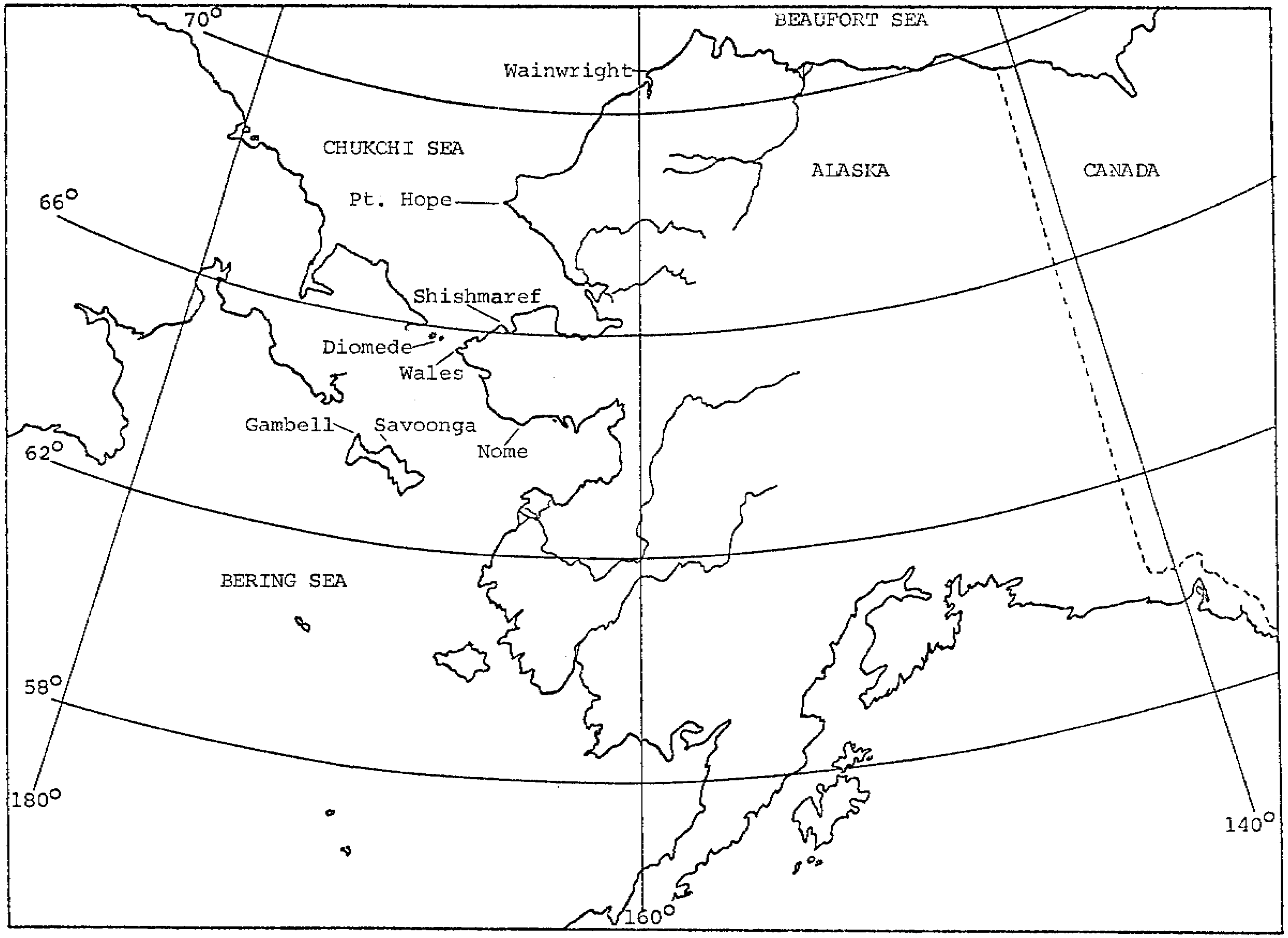

Figure 1. Locations mentioned in this report.

Two personnel from this project participated in the 5-1/2 week cruise of the USCGC GLACIER in the northeastern Chukchi and Beaufort Seas. In addition to collection of seals, 34 otter trawls were done in order to assess food availability and investigate some biological characteristics of important prey species.

Laboratory activities consisted of intermittent processing of seal stomach contents and trawl samples. Considerable lab work was done on board the GLACIER.

Data management occurred on an intermittent basis. Specimen records and stomach contents data sheets were completed in the field and submitted for keypunching immediately upon return to Fairbanks.

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, 20 May-15 September 1977.

Activity	Dates	Personnel
Specimen collection at St. Lawrence Island	20 May-24 June	D. Strickland
Specimen collection at Diomede	20 May-24 June	J. Matthews
Specimen collection at Wales	28 May-2 July	G. Seaman, D. Strickland
Specimen collection at Shishmaref	24 June-21 July	G. Seaman, R. Tremaine, D. Strickland
Specimen collection at Nome, SURVEYOR cruise to conduct otter trawls in Norton Sound and the north Bering Sea	26 June-4 July	K. Frost
Specimen collection at Wainwright	22 July-24 July	G. Seaman
Northeastern Chukchi and Beaufort Sea cruise on USCGC GLACIER, collection of specimens and otter trawls	1 Aug. - 6 Sept.	K. Frost, J. Burns
Laboratory processing of specimen material	continuous	L. Lowry, K. Frost
Compilation and analysis of data	intermittent	L. Lowry, K. Frost
Data management	intermittent	K. Frost
Preparation of quarterly report	1 Sept. - 15 Sept.	L. Lowry, K. Frost, J. Burns

Methods

Field collection procedures at coastal hunting villages and methods for laboratory analysis of specimen material are described in our 1977 annual report for RU #232. The GLACIER cruise was utilized to collect seals for food habits, parasitology and natural history information (RU#s 230,232, and 194) and to make observations of seals and ice in conjunction with RU#s 230 and 248. All hunting on the GLACIER was done from small boats. Animals were collected, returned to the ship and processed. Stomach contents were analyzed immediately when time permitted. In addition, contents of the small intestines were examined for otoliths.

Bottom sampling for fishes and invertebrates was conducted on the GLACIER with a 16 foot otter trawl. Trawls were of 10 minute duration, at a ship speed of 3-4 knots. Contents of each trawl were identified, enumerated, weighed and representative specimens of organisms retained. All fish were preserved for additional study of life history parameters.

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

Data Collected or Analyzed

Table 2 summarizes the results of our collection efforts from 20 May to 15 September 1977. A total of 592 stomachs were collected. One hundred and thirty were from the northern Bering Sea, 445 were from the Chukchi Sea and 17 were from the Beaufort Sea.

Table 2. Seal stomachs collected during the period 20 May-15 September 1977. Not all stomachs contained food.

Location	*Phoca (Pusa) hispida*	*Erignathus barbatus*	*Phoca vitulina largha*
Gambell	41	33	1
Savoonga	3	1	1
Diomede	16	2	0
Wales	18	11	3
Shishmaref	286	128	23
Wainwright	0	4	0
Chukchi Sea (USCGC GLACIER)	1	3	0
Beaufort Sea (USCGC GLACIER)	15	2	0
Total	380	184	28

Seventeen otter trawls were conducted from the SURVEYOR. Fifteen were done in Norton Sound and north along the coast to Bering Strait. Two trawls were done in the southeastern Chukchi Sea. Thirty-four otter trawls were conducted from the GLACIER. Ten were done in the northeastern

Chukchi Sea and 24 were done in the Beaufort Sea. Otoliths were collected from any unusual fishes. A series of otoliths was taken from polar cod for use in determining age and size of fish in relationship to otolith size. Length frequencies, individual fish weights and lengths, and stomach contents were determined for the most common species of fishes. Weights, lengths, sex, and reproductive state were noted for several species of crabs and shrimps.

III. Results

SOUTHEASTERN AND SOUTHCENTRAL BERING SEA

Seal specimens from the southeastern and southcentral Bering Sea were collected on three cruises: SURVEYOR, 15 March-6 April; SURVEYOR 14 April-3 May; and DISCOVERER 18 May-11 June.

Bearded Seals

Seven bearded seals were collected in the southeastern Bering Sea during the months of March and April. Three of the animals had no food in their stomachs. Two of the animals with empty stomachs had large amounts of tanner crab (*Chionocetes opilio*) carapaces in the large intestine. The stomach contents of the remaining four animals are shown in Table 3. Collection locations are shown in Fig. 2. The three animals collected in the westerly area had all eaten mostly tanner crabs while the animal collected to the east had eaten spider crabs (*Hyas coarctatus*) and crangonid shrimps. Overall, crabs were by far the most common food item followed by shrimp, polychaete worms, snails and fishes. Eelpout (*Lycodes* sp.) were the fishes most commonly eaten.

No bearded seals were collected from the DISCOVERER.

Ribbon Seals

Eight ribbon seals collected in the southeastern Bering Sea in March and April were examined. Five of these animals had no food remains in the stomach or intestine. The remaining three animals had only persistent hard parts in the stomachs and intestines. An estimate of the number of individuals of each species consumed was made and is shown in Table 4. Collection locations are shown in Fig. 2. Octopus and fishes were the primary food items. Pollock (*Theragra chalcogramma*), capelin (*Mallotus villosus*) and eelpout were the fishes most commonly eaten. Otoliths of pollock and eelpout are much larger than those of capelin. The importance of capelin in the diet may therefore be somewhat underestimated. Judging from the sizes of otoliths, the pollock consumed were all one year old, ranging in body length from 8 to 14 cm long.

Six ribbon seals were collected in the southcentral Bering Sea from the DISCOVERER in May and June. All six seals had empty stomachs. One animal had two polar cod otoliths in the small intestine.

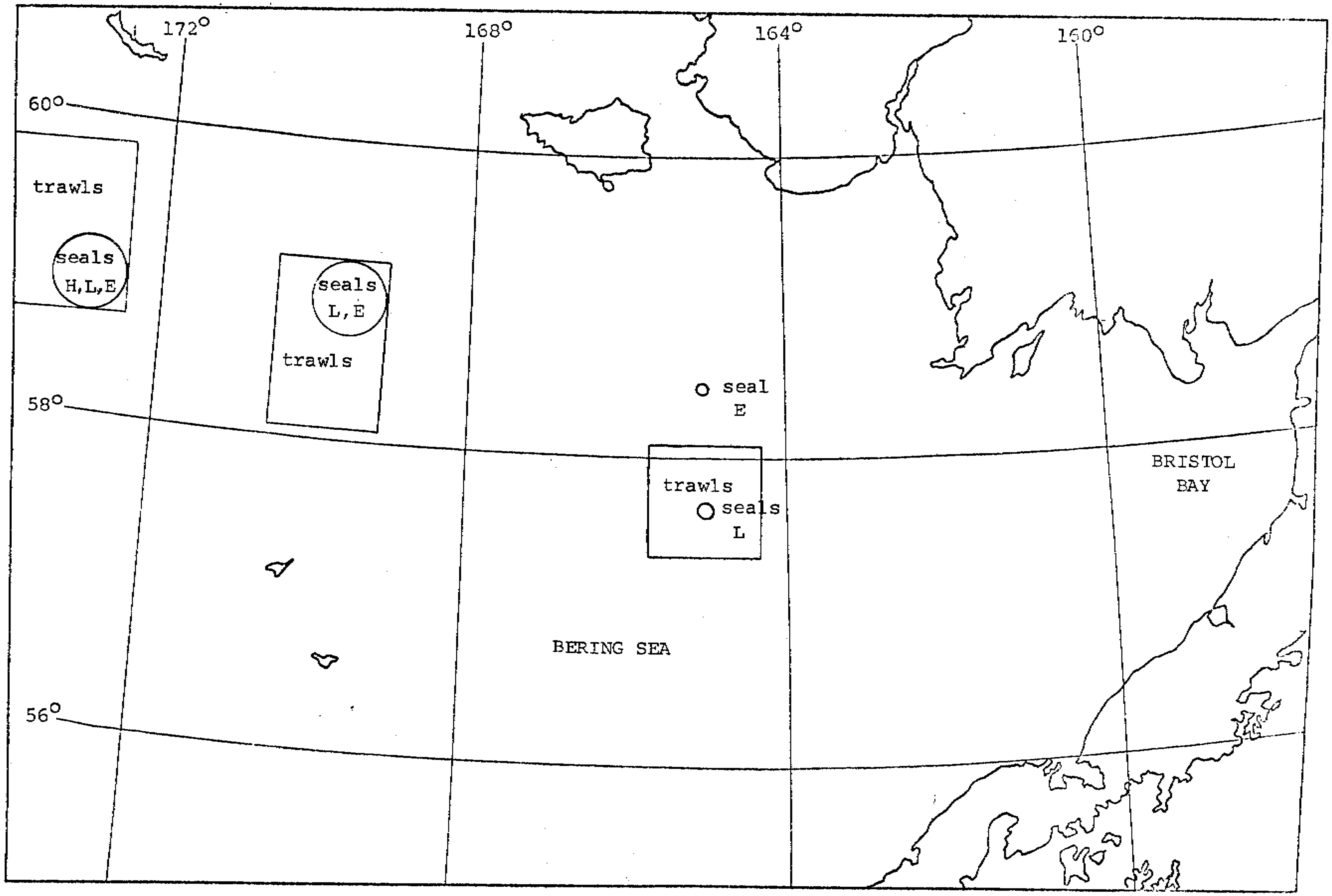

Figure 2. Map of the southeastern Bering Sea showing collection locations and areas where trawls were conducted. H = Ribbon seals, L = Spotted seals, E = Bearded seals

Table 3. Food items identified from stomachs of bearded seals taken in the southeastern Bering Sea. Data are presented in part A as volume (ml) or percent of total volume made up by each species or group and in part B as number or percent of total number made up by each species or group.

Specimen Number Collection Date Location	SUVE-5-77 22 Mar 77 59°00.6N 173°15.0W	SUVE-7-77 26 Mar 77 58°43.9N 169°32.9W	SUVE-13-77 29 Mar 77 58°25.3N 164°50.1W	SUVE-25-77 23 Apr 77 59°00.0N 169°53.4W	Total N = 4	Percent
Food Item						
A. Octopus sp.	2.0				2.0	0.1
Buccinum sp.		35.0		*	35.0	1.0
Polinices sp.				20.0	20.0	0.6
Polychaetes	135.0				135.0	4.0
Echiurus echiurus	*				*	*
Neomysis rayi				0.2	0.2	*
Parathemisto sp.		0.2			0.2	*
Pagurus sp.			16.0		16.0	0.5
Total Brachyurans	450.0	1290.0	76.0	1050.0	2866.0	85.6
Chionocetes opilio	450.0	1290.0		1050.0	2790.0	83.3
Hyas coarctatus			76.0		76.0	2.3
Total Shrimp			220.0		220.0	6.6
Argis sp.			80.0		80.0	2.4
Crangon sp.			140.0		140.0	4.2
Total Invertebrates	587.0	1325.0	312.0	1070.2	3294.2	98.4
Total Fishes	*	52.0	*		52.0	1.6
B. Theragra chalcogramma	1				1	4.0
Lycodes sp.	11	5			16	64.0
Family Pleuronectidae	1	1	2		4	16.0
Family Cottidae			4		4	16.0
Total number of fishes	13	6	6	0	25	mean volume =
Total volume (ml)	587.0	1377.2	312.0	1070.2	3346.4	836.6

* indicates food items which comprised less than 0.1 ml or 0.1 percent of the total volume.

Table 4. Food items identified from remains found in stomachs and intestines of ribbon seals collected in the southeastern Bering Sea on 21 and 22 March 1977. Numbers indicate estimated number of individuals consumed. Percent represents the percent of the total fishes consumed which was made up by each individual species.

Food Item	Stomach contents		Intestinal contents			Total individuals	Percent of total fishes
	SUVH-2-77	SUVH-6-77	SUVH-2-77	SUVH-3-77	SUVH-6-77		
Crangonid shrimp		1				1	
Octopus sp.	3	1	2		1	7	
Clam	1					1	
Theragra chalcogramma	1	9	8	45	18	81	72.9
Lycodes sp.	1	1	2		2	6	5.4
Mallotus villosus		1	1	1	11	14	12.6
Lumpenus sp.		1	1			2	1.8
Reinhardtius hippoglossoides			2		2	4	1.8
Family Cottidae			1			1	0.9
Family Liparidae			2		1	3	2.7

Spotted Seals

Nine spotted seals taken in the southeastern Bering Sea in March and April were examined. Four animals had no food remains in the stomachs or intestines. The collection locations of the other five animals are shown in Fig. 2. SUVL-4-77 collected on 3/23/77 had eaten 336 milliliters of pollock. The other four animals were collected on 4/20/77. The stomachs of these animals all contained entirely capelin with a mean volume of 145 ml. A few otoliths of pollock and one otolith of saffron cod (Eleginus gracilus) were recovered from the stomachs and intestines.

Eight spotted seals were collected in the southcentral Bering Sea in May and June. The stomachs of only three animals contained food. One seal taken northwest of St. Matthew Island had eaten Octopus sp. and eelpouts. The small intestine contained otoliths of eelpouts, pollock and a sculpin. Two seals taken northwest of Nunivak Island had very full stomachs, the contents of which were very fresh. One stomach contained over 1500 ml of herring and the other 700 ml of a mixture of herring and capelin. Most of the herring were reproductively mature and ready to spawn.

Ringed Seals

One ringed seal was collected in the southeastern Bering Sea on 20 April 1977. This animal had no food remains in the stomach or intestine. Two ringed seals were collected northwest of Nunivak Island on 1 June. No food remains were found in the stomachs or intestines.

NORTON SOUND

Seal specimens were collected in Norton Sound at three times of year. Village hunters provided a small collection of ringed seals in January and a larger collection of ringed and bearded seals in June. A helicopter based at Nome was used in March to make a collection of ringed and bearded seals.

Ringed Seals

Food items identified from ringed seal stomachs taken in January, March and June are shown in Table 5. In January polar cod (Boreogadus saida) and saffron cod were the only foods eaten. Of the two, polar cod was by far the most important food item. In March, polar and saffron cods were again the main foods. Their relative importance of the two species was similar to that found in the January sample. In addition shrimps (primarily Pandalus goniurus) were important dietary items. In June saffron cod was essentially the only food eaten.

Since exact collection locations were determined for the seals collected by helicopter in March, it was possible to look at small scale variation in foods at the various collection points. Collection locations are plotted in Fig. 3. The specimens were divided into three groups: nearshore in water less than 10 fathoms deep (specimens 9, 10, 11, 12, 13, 19, 20, 30, 31, 32), nearshore in water more than 10 fathoms deep (specimens 16, 17, 18, 21, 22, 23, 28, 29, 35) and offshore (specimens 14 and 15). The results are shown in Table 6. The sample taken nearshore

Table 5. Food items identified from stomachs of ringed seals collected in Norton Sound. Data are expressed in part A as percent of total volume of contents made up by each species or group. Part B indicates the species composition of fishes expressed as percent of the total number of fishes identified.

	Food Item	27-28 Jan 1977 N=4 % Vol/#	9-18 March 1977 N=21 % Vol/#	1-26 June 1977 N=13 % Vol/#
A.	Neomysis rayi		1.1	*
	Shrimp Total		29.5	1.2
	Pandalus hypsinotus		3.8	*
	P. goniurus		24.2	*
	Argis lar		1.2	
	Others		0.3	*
	Invertebrates Total	0	30.6	1.3
	Fishes Total	100.0	69.4	98.6
B.	Fishes			
	Boreogadus saida	87.0	85.7	*
	Eleginus gracilus	13.0	10.6	99.8
	Pungitius pungitius		1.4	
	Family Cottidae		1.5	
	Others		0.7	*
Total number of fishes identified		192	701	3349
Mean volume of contents		85.8	246.5	427.1

*indicates food items which constituted less than one percent of the total volume or number

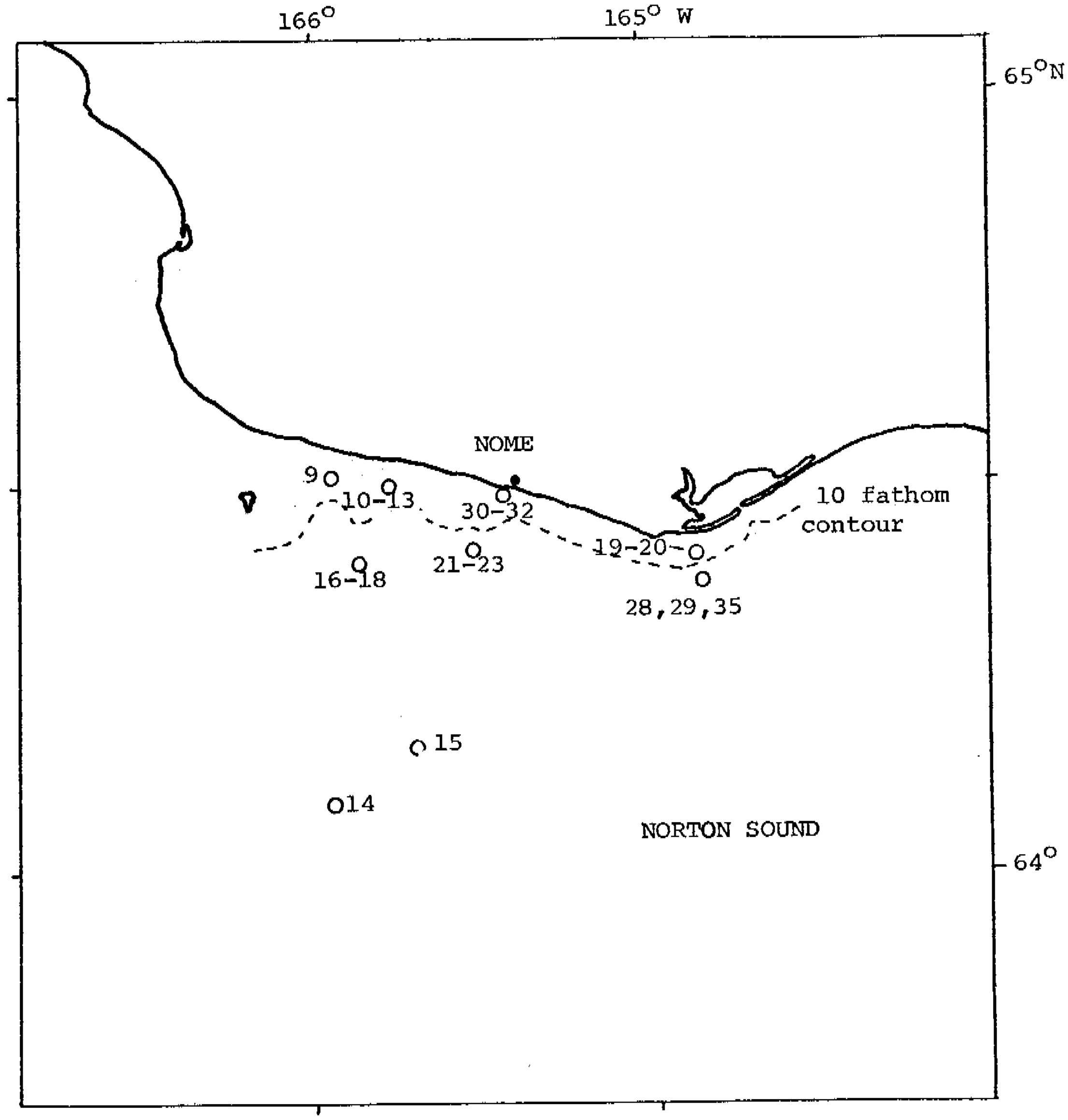

Figure 3. Locations at which ringed seals were collected in Norton Sound in March 1977. Positions of collections are indicated by small open circles. Numbers correspond to the specimens collected at each location.

Table 6. Food items identified from stomachs of ringed seals collected in Norton Sound in March. Data are expressed in the same manner as in Table 5.

	Nearshore less than 10 fathoms N = 10	Nearshore More than 10 fathoms N = 9	Offshore N = 2
A. *Neomysis rayi*	2.6	*	2.7
Shrimp Total	45.6	18.6	31.4
Pandalus hypsinotus	7.8	1.2	0.5
P. goniurus	37.4	16.6	0.5
Argis lar	0.2	0.5	27.2
Others	0.1	0.3	3.1
Invertebrates Total	48.2	18.7	34.0
Fishes Total	51.8	81.3	66.0
B. Fishes			
Boreogadus saida	81.9	93.8	13.5
Eleginus gracilus	10.2	4.8	81.0
Pungitius pungitius	2.2	1.1	
Family Cottidae	4.0	0.2	2.7
Others	1.8		2.7
Total number fishes identified	226	438	37
Mean volume contents	200.6	334.0	82.6

in water less than 10 fathoms deep showed shrimps (mostly Pandalus goniurus and P. hypsinotus) and fishes (mostly polar cod and lesser amounts of saffron cod) to be of about equal importance in the diet. Seals taken nearshore in water deeper than 10 fathoms had eaten primarily the same species as those taken in shallower water. However fishes were over four times more abundant than shrimps in the seals from deeper water. The food items found in two seals taken further offshore were quite different from those nearshore. Argis lar was the most commonly eaten shrimp and saffron cod were eaten in greater number than were polar cod.

Bearded Seals

Results of analysis of bearded seal stomachs collected at Nome are shown in Table 7. In March by far the majority of food was shrimps. Few fish were eaten, the majority of those were sculpins (family Cottidae). In June bivalves and shrimps made up almost the entire stomach contents.

POINT HOPE

Small samples of ringed seals were collected at Point Hope in the spring seasons of 1976 and 1977. The results for the two years have been combined and broken down for the months of April and May (Table 8). In April, fishes and invertebrates were eaten in approximately equal amounts. Fishes eaten were mostly polar cod and invertebrates were mostly amphipods and shrimps. In May the importance of mysids, euphausiids (Thysanoessa sp.) and shrimps in the diet increased considerably. Fishes were much less important in the diet in May. The principal species eaten were saffron cod and sand lance (Ammodytes hexapterus).

IV. Discussion of Results

Southeastern Bering Sea

Seals collected on the SURVEYOR in spring 1977 provided material for comparison with those seals collected in the Bering ice front during spring 1976.

Spotted seals in both years ate almost exclusively capelin with the exception of a single seal taken this year at the westernmost station, which had eaten pollock. Five ribbon seals collected northwest of the Pribilofs last April contained remains of pollock, eelpout, capelin, octopus and shrimp. Five ribbon seals collected in much the same area this March also contained pollock, capelin, eelpout, octopus and small amounts of miscellaneous other fish and invertebrates. No bearded seals with full stomachs were collected last spring. Of the four collected this spring three ate primarily tanner crabs and the fourth crangonid shrimps.

The stomachs of seals collected later in the spring from the DISCOVERER were for the most part empty. However, although many seals appear not to feed during this time of molting, some do. Stomachs of three spotted seals collected contained some food. Two of the spotted seal stomachs were very full of fish. As at other times of the year

Table 7. Food items identified from stomachs of bearded seals collected at Nome. Data are expressed in the same manner as in Table 5.

		14-18 March 1977 N=4	6-27 June 1977 N=8
A.	Bivalves Total		43.8
	Serripes sp.		28.3
	Tellina sp.		15.1
	Others		0.4
	Pagurus sp.	1.5	*
	Brachyuran Crabs Total	1.0	6.4
	Hyas coarctatus	*	1.3
	Chionocetes opilio	*	4.3
	Others		*
	Shrimp Total	87.2	45.3
	Pandalus hypsinotus	73.3	
	P. goniurus	*	1.2
	Crangon dalli	1.0	1.6
	C. septemspinosa		1.0
	Argis lar	1.8	28.3
	Sclerocrangon boreas	4.1	7.6
	Lebbeus groenlandicus	6.7	4.6
	Others	0.3	1.0
	Other Invertebrates	1.3	3.2
	Invertebrates Total	91.0	99.1
	Fishes Total	9.0	0.1
B.	Fishes		
	Eleginus gracilus	10.5	28.6
	Boreogadus saida	15.1	
	Family Pleuronectidae	3.5	7.1
	Family Cottidae	69.8	64.3
	Lycodes sp.	1.2	
Total number of fishes identified		86	14
Mean volume of contents		855.9	340.0

*indicates items which constituted less than one percent of the total volume or number.

Table 8. Food items identified from the stomachs of ringed seals collected at Point Hope in April and May of 1976 and 1977. Data are presented in the same manner as in Table 5.

	Food Item	April 1976 & 1977 N = 29 % Vol/#	May 1976 & 1977 N = 27 % Vol/#
A.	Thysanoessa sp.	1.5	6.8
	Echiurus echiurus	1.7	
	Amphipods Total	28.2	26.9
	Ampetisca spp.	28.2	24.0
	Anonyx hugax	*	2.7
	Others	*	*
	Mysids Total	*	10.6
	Mysis litoralis	*	7.0
	Neomysis rayi	*	3.6
	Shrimp Total	15.5	38.5
	Eualus gaimardii	1.3	1.5
	E. fabricii		1.5
	Pandalus goniurus	12.0	1.2
	Argis lar	*	23.9
	Sclerocrangon boreas	*	4.4
	Others	2.2	6.0
	Other Invertebrates	1.6	7.0
	Invertebrates Total	48.5	89.8
	Fishes Total	51.5	9.8
B.	Fishes		
	Boreogadus saida	75.9	15.5
	Eleginus gracilus	4.3	41.7
	Mallotus villosus		1.2
	Ammodytes hexapterus	7.8	36.9
	Lumpenus sp.	2.8	
	Family Cottidae	98.2	4.8
Total number of fishes identified		141	84
Mean volume of contents		71.1	35.1

*indicates items which constituted less than one percent of the total volume or number.

food items were pelagic schooling fish, but mostly herring instead of exclusively capelin as was the case in March and April.

During the spring, ribbon, spotted and, to a lesser extent, bearded seals are all found in the ice front of the Bering Sea where they bear their young, breed and molt. Some differences in preferred ice types occur among the three species, but their distributions broadly overlap and in many cases coincide. Feeding activity appears to diminish as the seals approach the molting period. Nonetheless some individuals of each species feed throughout the spring. From the last two years samples, limited though they may be, the three species seem to utilize different food resources and thus do not directly compete for food when in the same areas. Bearded seals in the ice front, as at all other locations sampled, feed primarily on epibenthic invertebrates, especially decapod crustaceans. Spotted seals utilize pelagic schooling fishes, primarily capelin, at this time of year. Ribbon seals seem to feed closer to the bottom on demersal fishes such as eelpout and pollock and on octopus.

Norton Sound

The analysis of collections from Norton Sound has shown some very interesting and significant results. Both ringed seals and bearded seals show seasonal variation in primary prey items. Bivalve molluscs were not eaten at all by bearded seals in March but they comprised over 40 percent of the stomach contents of animals collected in June. Bearded seals collected in June 1976 had also eaten mostly bivalves. These results agree with previous observations of Burns (1967) who noted that bivalves were eaten only in the late spring and early summer. An interesting change in the primary species of shrimp eaten by bearded seals occurred from March to June. This may be related to temporal changes in abundance of the various shrimp species or the exact location at which the seals were collected.

Ringed seals in Norton Sound feed mostly on fishes at all times of year. Saffron cod is the species eaten most commonly in November and June. Polar cod was the species eaten most in January and March. The feeding of ringed seals is obviously closely tied to the biology and seasonal movements of these two species of gadids. Information on the biology of saffron and polar cods is critically needed. Shrimps were important in the diet of ringed seals collected in March. Spatial breakdown of the sample into three subsamples suggests that diet can vary in a very local manner. Shrimps were much more common in the stomachs of seals taken in shallow water nearshore. This certainly merits further investigation. An opportunity to collect seals and do otter trawls in several discrete areas would be extremely valuable.

Point Hope

The principal food items of ringed seals at Point Hope also showed marked seasonal changes. The increase in importance of euphausiids, mysids and shrimps from April to May is very similar to that reported by Johnson et al. (1966). The increased proportion of saffron cod in the diet in May is perhaps parallel to the seasonal change in abundance of polar cod and saffron cod indicated by our data from Nome.

V. Problems Encountered/Recommended Changes

None

VI. Estimate of Funds Expended

As of August 31 we have expended approximately the following amounts during FY77.

Salaries and benefits	-	$60,868
Travel and per diem	-	8,408
Contractual services	-	3,542
Commodities	-	6,132
Equipment	-	293
Total Expenditures	-	$79,243

References

Burns, J. J. 1967. The Pacific Bearded seal. Alaska Department of Fish and Game, Juneau. 66pp.

Johnson, M. L., C. H. Fiscus, B. T. Ostenson and M. L. Barbour. 1966. Marine Mammals. Pages 894-924 In N. J. Wilimovsky and J. N. Wolfe, eds. Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Commission, Oak Ridge, Tennessee.

QUARTERLY REPORT

An amendment to RU#232 Trophic relationships among ice inhabiting Phocid seals, and RU#230 Natural history of ringed and bearded seals

Principal Investigator

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Associate Professor of Marine Science
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University of Alaska
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Assisted by:

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

October 1, 1977

QUARTERLY REPORT

I. Task Objectives this quarter

A. To accompany USCG GLACIER for field work in the Beaufort Sea.

B. To begin analyses of materials collected during this field period.

II. Field and Laboratory Activities

A. Field Trip Schedule

1 August 1977 to 6 September 1977 - USCG GLACIER (L. Shults)

B. Laboratory Activities

Histopathological materials and parasites were prepared for further study.

III. Results

A. Pathology

A total of 5 bearded seals and 16 ringed seals were examined for pathological conditions. Of these 21 pinnipeds, 2 bearded and 9 ringed seals showed evidence of gross pathology.

One bearded seal had a one centimeter hepatic abscess due to a bile duct plugged with the trematode, *Orthosplanchnus fraterculus*. The other individual had severe ulcerations of the lower small intestine caused by a heavy infection of the acanthocephalan *Corynosoma validum*.

Seven of the ringed seals had micro-abscesses in the liver. Identification of the causitive organism is pending. Two other ringed seals had healed puncture wounds on their ventral surface. The cause of such wounds has not been determined.

B. Parasitology

Helminth parasites from the above 21 pinnipeds are being identified at this time.

IV. Preliminary Interpretation of Results

No further interpretation is feasible at this time.

V. Problems Encountered/Recommended Changes

No problems or recommended changes. A note should be made of the excellent assistance and cooperation given us by the officers and crew of the USCG GLACIER. Without their willingness to carry on operations at unusual times and in extreme weather conditions, our research efforts would have been severely hampered.

QUARTERLY REPORT

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

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 Departmen of Fish and Game

October 1, 1977

I. Task Objectives

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

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

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

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

II. Field or Laboratory Activities

A. No field activities were scheduled during this quarter. Laboratory activities consisted of the following:

1. A tooth was prepared for aging from all remaining sea lions not previously aged.
2. Laboratory analyses of both male and female reproductive tracts were completed, all food habit material was sorted

and assigned tentative identifications. Verification of the identifications await examination by outside experts.

3. Considerable effort was expended toward fulfilling data management obligations. This facet of the OCSEAP program has consumed an inordinate amount of time and thus far has proven to have little utility. Thought should be given to streamlining our present data management program. For some research units which do not handle extensive volumes of data it would probably be more efficient to waive requirements for an automated data system.

4. Proposals for FY'78 were written and then modified after discussion with the staff at the Juneau Project Office.

B. Methods

1. See Annual Report.

C. Data Analyzed

1. Data analysis is awaiting final assignment of ages and verifications of food species.

III. Results

1. No results available at this time.

IV. Preliminary Interpretation of Results

1. None available at this time.

V. Problems Encountered.

1. None.

Quarterly Report

Contract #03-5-022-55
Research Unit Number: 248
Report Period: 1 July-30 September 1977
Number of Pages: 5

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

Principal Investigators:

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Alaska Department of Fish and Game
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University of Alaska
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Lewis H. Shapiro
Geophysical Institute
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Assisted by: Kathryn J. Frost and Larry M. Shults

October 1, 1977

I. Task Objectives

The specific project objectives are:

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

II. Field and Laboratory Activities

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

Table 1. Field and laboratory activities from 28 June to 30 September 1977.

Activity	Dates	Personnel
Survey - Ice remnants around St. Lawrence Island	28 June-5 July	Fay
Survey - Ice remnants and pack in eastern Chukchi and Beaufort Seas	31 July-6 September	Burns (assisted by L. Shults, RU#194; K. Frost, RU#232)
Data compilation - ice remnants	intermittent	Burns, Fay
Data compilation - marine mammal and sea ice associations	intermittent	Fay, Burns
Data compilation - historical weather records	begin late Sept.	Burns
Review of satellite imagery	intermittent	Shapiro, Burns, Fay
Quarterly report	late September	Burns, Shapiro, Fay

Dr. Shapiro was on annual leave during most of this quarter. The other principal investigators were mainly involved in field programs such as the extended cruise of the icebreaker GLACIER or in the accumulation of historical data pertinent to annual variations in sea ice conditions.

C. Data collected or analyzed

Results of the June 1977 surveys of ice conditions in near shore areas of the Beaufort and northern Chukchi Seas, and correlation of ringed seal density in areas of different ice conditions is now almost completed.

During the cruise of the GLACIER, data about sea ice conditions and the distribution of marine mammals was obtained.

To the extent that available time allowed, broad scale ice conditions occurring in 1977, as evident from satellite imagery, were compared with results of shipboard and aircraft surveys of ice and marine mammals.

III. Results

During the cruise of the GLACIER, observations of ice conditions and marine ammmals were obtained in an area extending from 143°W to 164°W. This includes the central and western Beaufort Sea and the northeastern Chukchi Sea.

In the Chukchi Sea the southern margin of drifting ice was very distinct with no extensive, disjunct ice fields south of the main pack within view of the ship. The ice edge had not moved north of the continental shelf during early August. Ringed and bearded seals were both present in and near the ice edge. The bottom feeding bearded seals were more abundant than the ringed seals.

Ice conditions in the Beaufort Sea were considerably different in that a large remnant of drifting, open pack occurred near shore in the area between Harrison Bay and Flaxman Island. The main body of the late summer pack ice was very far off shore varying from 40 miles north of Point Barrow to more than 180 miles at 143°W longitude. These two masses of ice were loosely connected by a comparatively narrow ice tongue mainly between about 149°W and 151°W. The near shore remnant was in shallow water over the continental shelf.

Density and species composition of seals was markedly different in the near shore and off shore areas. These differences are presented in Table 1. Figure 1 indicates general locations of stations where observations were obtained.

In the Beaufort Sea ringed seals were significantly more abundant than bearded seals. The latter species occurred mainly near shore.

Ringed seals were most abundant in the near shore remnant and in the tongue of ice extending north from that remnant. Very few were observed far off shore, in the main pack ice.

IV. Problems encountered

None

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

Table 1. Stations whre small boat operations were conducted during the August-September 1977 cruise of the GLACIER, and the observed densities of bearded and ringed seals seen from the small boats.

Station No.	Position	Small boat hours	Bearded seals /boat hour	Ringed seals /boat hour	Total seals /boat hour
1	71°18' 157°48'	2.0	4.5	0.5	5.0
2	71°19' 160°01'	5.0	0.6	0.2	0.8
3	71°28' 163°47'	3.7	1.1	0.5	1.6
4	71°17' 161°10'	2.5	1.2	0.4	1.6
5	71°12' 158°45'	4.0	0.0	0.0	0.0
6	71°45' 155°43'	6.3	0.2	0.9	1.1
7	72°24' 154°37'	7.2	0.0	0.3	0.3
8	71°13' 151°23'	2.3	0.0	0.9	0.9
9	71°47' 150°49'	3.9	0.0	0.8	0.8
10	71°09' 150°09'	7.5	0.4	1.2	1.6
11	71°00' 150°45'	3.0	0.3	2.3	2.6
12	70°40' 147°46'	6.5	0.6	1.1	1.7
13	72°48' 146°28'	2.0	0.0	0.0	0.0
14	72°46' 146°15'	4.0	0.0	0.2	0.2
15	72°58' 143°30'	5.9	0.0	0.0	0.0
16	70°11' 145°38'	2.0	0.0	0.0	0.0
17	70°22' 146°26'	2.2	0.0	0.9	0.9
18	70°32' 147°42'	2.0	3.0	8.5	11.5
19	70°47' 149°03'	8.1	0.5	2.8	3.3
20	70°45' 148°58'	10.8	0.3	4.2	4.5

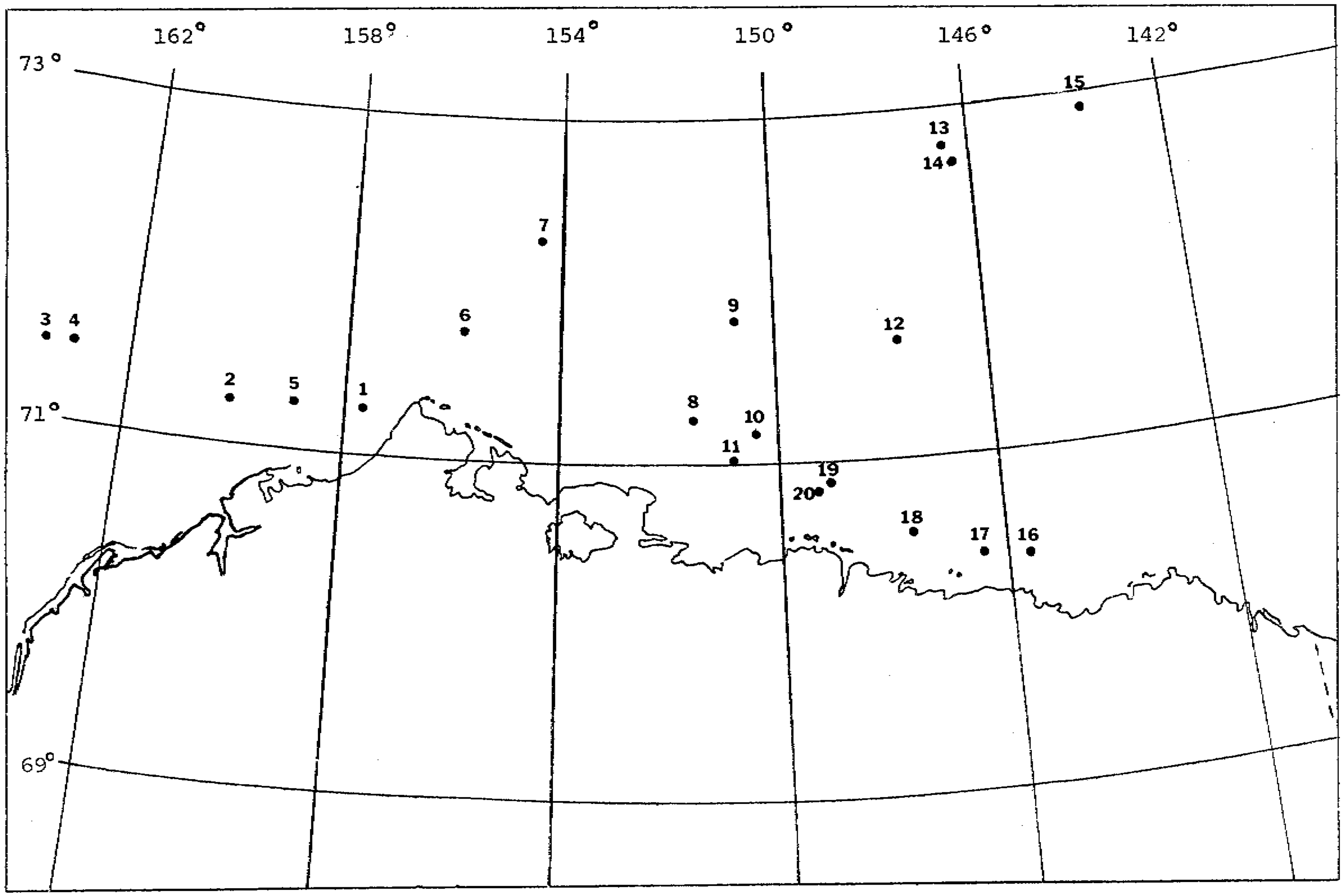

Fig. 1 General locations of stations at which small boats were used to observe and collect seals during the August-September 1977 cruise of the GLACIER. Information for each station is presented in Table 1.

Contract:
Period: 1 April - 30 June 1977
RU: 481

QUARTERLY REPORT

A SURVEY OF CETACEANS OF PRINCE WILLIAM SOUND AND ADJACENT VICINITY

Principal Investigators
John D. Hall and James H. Johnson

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Office of Biological Services - Coastal Systems
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I. ABSTRACT: During this quarter we completed two (2) surface surveys aboard the charter vessel "Shelby D" and one aerial survey utilizing the OAS Turbo-goose, N-754. The surface cruises covered a total of 625 nautical miles and the aerial survey covered 475 nautical miles.

Numerous humpback whales were located in southwest area of Prince William Sound, as was a large (75) herd of killer whales. Dall porpoise were sighted throughout the Sound, and Dall porpoise calves were sighted with their mothers in August.

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

3. To determine food habits of the Dall porpoise, *Phocoenoides dalli*.

III. Field Activities:

A. Field Schedule

1. Ship surveys - 8/18 - 8/29 aboard F/V Shelby D (chartered) and 9/30 - 10/7 aboard F/V Shelby D (chartered).

2. Aircraft survey - 9/12 aboard OAS Turbo-goose, N-754.

B. Scientific Party

John D. Hall - U.S. Fish & Wildlife Service
Craig S. Harrison - U.S. Fish & Wildlife Service
James H. Johnson - National Marine Fisheries Service

IV. Results

Unusual concentrations of killer whales were found near the southern end of Knight Island from 8/20 through 9/12. The main group of whales numbered at least 75, and associated sub-groups may have increased the total number to over 100, an unusually large gathering of killer whales.

Many harbor porpoises were sighted just offshore of Hinchinbrook Pt. on 9/12. We sighted 89 individuals over a 6 mile transect.

Minke and fin whales appeared to be almost absent from Prince William Sound by the end of this quarter. No fin whales and only a few minke whales were sighted in October.

Dall porpoise continue to be abundant, and cow/calf pairs were sighted again in August. No cow/calf pairing had been observed between the May and October cruise.

Humpback whales, again in 1977, concentrated in the area of Whale Bay, Icy Bay and Jackpot Bay during this quarter. The population in this area didn't exceed 15 individuals until 10/5 when an additional 15 humpback whales entered Prince William Sound via Hinchinbrook Entrance.

We were unsuccessful again in our attempts to live capture Dall porpoise so no food habit or telemetry work was completed.

RECEPTORS (BIOTA)

BIRDS

RECEPTORS (BIOTA)

BIRDS

RECEPTORS (BIOTA)

BIRDS

QUARTERLY REPORT

Contract #03-5-022-69
Research Unit #3
Reporting Period June 15-Sept.30, 1977

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

Paul D. Arneson

October 1, 1977

I. Task Objectives

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

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

II. Field Activities

A. Field Trip Schedule: From June 16 to July 14, 1977 an Avon rubber raft was used to do shoreline and pelagic bird surveys around the Walrus Islands, Bristol Bay, Alaska.

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

C. Methods: Pelagic bird surveys were conducted between islands by an observer recording all birds within 100 meters on either side of the Avon raft. Numbers of birds by species or group and their activity were recorded on cassette recorders for minute intervals along the entire distance between islands.

We cruised the shoreline of all islands by raft, and bird observations along the coast were recorded. When colonies were encountered, we stopped and often anchored to record specific information about the colony. Black-legged Kittiwake and cormorant nests were counted. Individuals were counted for Pigeon Guillemots, Parakeet Auklets, Horned Puffins and Tufted Puffins, and estimates of population size were made for Common Murres. Other bird information was recorded and photographs were taken of many of the colonies.

D. Sample Localities: See Figure 1.

E. Data Collected: Approximately 160 kilometers of coastline was surveyed and information about bird colonies was recorded. Eighteen different pelagic boat surveys totaling 34.5 kilometers were done on 10 transects lines between islands. From these pelagic transects, 266 observations were recorded for computer storage.

Also during this quarter, data from five previous surveys was transcribed and sent to the keypuncher. For those surveys, just over 7500 records will be computerized.

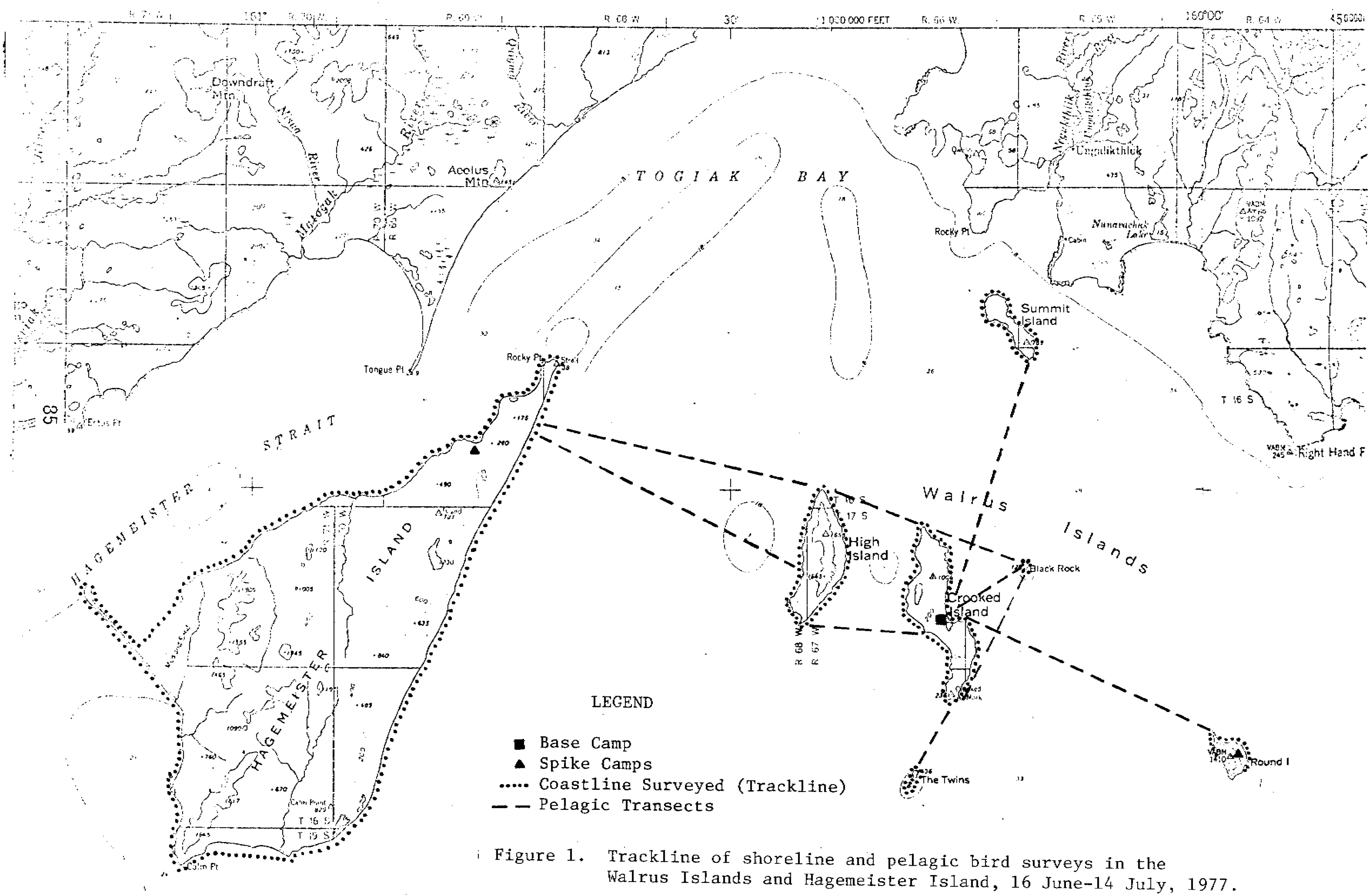

Figure 1. Trackline of shoreline and pelagic bird surveys in the Walrus Islands and Hagemeister Island, 16 June-14 July, 1977.

III. Results

<u>Shoreline Surveys</u>: Thorough shoreline surveys for birds were conducted around the perimeters of all the Walrus Islands with the exception of portions of Round Island. The trackline for these surveys is shown in Figure 1. Accurate counts were made of breeding birds on the colonies (Table 1), and from these counts, estimates were made of population sizes of seabirds using the islands during the breeding season, 1977 (Table 2). On Round Island only 44 percent of the west side and 70 percent of the east side were surveyed, and therefore population estimates were extrapolated from those portions that were surveyed.

Although Hagemeister Island is not a member of the Walrus Island group, it was also surveyed, but inclement weather prevented us from making accurate counts on portions of the south end of the island.

Besides recording breeding seabird data, we recorded the use of the islands by other species of birds, locations of roost areas, presence or absence of predators, human activity on the islands, marine mammal data and any other noteworthy information. This information was summarized on "Colony Status Record" forms and submitted to the U.S. Fish and Wildlife Service for inclusion in the Catalog of Seabird Colonies, RU#338/343.

Common Murres (*Uria aalge*) were by far the most abundant breeding bird on the islands. North Twin supported the largest population where it appeared that all available breeding habitat was utilized. No Thick-billed Murres (*Uria lomvia*) were positively identified. Murres nested on all the islands except Crooked and Summit as did Black-legged Kittiwakes (*Rissa tridactyla*), the next most abundant breeding bird. Only one Red-legged Kittiwake (*Rissa brevirostris*) was sighted, and it was roosting on the beach rocks of High Island. It was not determined if this species was breeding on the islands.

Pelagic Cormorants (*Phalacrocorax pelagicus*) were commonly seen and were breeding on all areas except Black Rock. Double-crested Cormorants (*P. auritus*) were found in small numbers on only Summit Island, and Red-faced Cormorants (*P. urile*) nested in small numbers on only Hagemeister Island.

Puffins were the next most numerous nesting seabirds, but neither species was abundant. Horned Puffins (*Fratercula corniculata*) were most common on the eastern shore of Round Island and Tufted Puffins (*Lunda cirrhata*) on the talus slopes of the north end of North Twin. Both species were fairly common on High Island where they were often seen in rock outcrops high on the hillsides. Parakeet Auklets (*Cyclorrhynchus psittacula*) were found on all islands except Summit and South Twin but were common on only Round and High. Pigeon Guillemots (*Cepphus columba*) were relatively ubiquitous but were surprisingly dense on the north side of Summit Island and also on the east side of Round Island.

Table 1. Number of seabirds actually counted or estimated on colonies of Walrus Islands, 16 June-14 July, 1977.

	ISLAND								
Species	Round[1]	Summit	Black Rock	Crooked	North Twin	South Twin	High	Hagemeister	TOTAL
DC Co [2]	0	6	0	0	0	0	0	0	6
Pe Co [2]	406	204	0	1,213	318	4	2,208	905	5,258
RF Co [2]	0	0	0	0	0	0	0	8	8
Gl Gu [2]	?	0	P	?	P	0	0	P	P
GW Gu [2]	1	50	1	12	67	?	6	13	150
BL Ki [2]	8,386	0	558	0	3,475	630	8,438	4,347	25,834
RL Ki	0	0	0	0	0	0	1	0	1
Ar Te	0	0	0	0	0	0	0	48	48
Al Te	0	0	0	0	0	0	0	5	5
Co Mu	17,206	0	18,500	0	75,735	17,750	13,500	5,485	148,176
Pi Gu	119	165	4	131	30	0	133	60	642
Pa Au	280	0	3	14	6	0	268	158	729
Cr Au	15 min.	0	0	0	0	0	0	0	15
Rh Au	1	0	0	0	0	0	0	0	1
Ho Pu	580	26	3	122	3	1	260	108	1,103
Tu Pu	143	4	3	37	750[3]	2	127	17	1,083
TOTAL	27,137	455	19,072	1,529	80,384	18,387	24,941	11,154	183,059

[1] Only 44% of the west side and 70% of the east side of Round Island were surveyed. All other islands were surveyed in their entirety.

[2] Numbers for these species represent nests counted. All other numbers represent number of individuals sighted (estimated or counted individually).

[3] Extrapolation from a subsample.

P = Present ? = Status Unknown

Table 2. Estimated population sizes of seabirds inhabiting the Walrus Islands during June-July, 1977.

	ISLAND								
Species	Round	Summit	Black Rock	Crooked	North Twin	South Twin	High	Hagemeister	TOTAL
DC Co	0	15	0	0	0	0	0	0	15
Pe Co	2,000	530	30	2,700	830	30	5,740	2,350	14,210
RF Co	0	0	0	0	0	0	0	20	20
GW Gu	150	150	75	125	175	30	125	350	1,180
BL Ki	43,000	0	1,450	0	9,000	1,600	22,000	11,300	88,350
Co Mu	93,000	0	55,500	0	228,000	53,300	40,500	16,500	486,800
Pi Gu	400	330	10	270	60	0	270	120	1,460
Pa Au	1,500	0	5	30	15	0	540	320	2,410
Cr Au	100	0	0	0	0	0	0	0	100
Ho Pu	1,750	55	8	250	10	4	520	220	2,817
Tu Pu	400	20	10	75	1,500	4	260	40	2,309
TOTAL	142,300	1,100	57,088	3,450	239,590	54,968	69,955	31,220	599,671

Although Glaucous-winged Gulls (*Larus glaucescens*) were commonly observed on all islands, the only breeding "concentration" was a small island off the middle of the southwest side of Summit Island where 36 nests were counted. The only other nesting concentration was among the Tufted Puffin burrows on the talus at the north end of North Twin. Second year Glaucous Gulls (*Larus hyperboreus*) were occasionally observed, but the breeding status of that species on the islands was not determined.

Terns were observed on only Hagemeister Island where both species - Arctic (*Sterna paradisaea*) and Aleutian (*Sterna aleutica*) - likely nested, although no sites were located. Arctic Terns far outnumbered Aleutian's in abundance.

Only two other seabird species were observed in the vicinity of the islands during our month-long stay. A small group of Crested Auklets (*Aethia cristatella*) was observed on the east coast of Round Island near the cabin. Only one of these birds came ashore to roost on the rocks, and the breeding status of this species on the island was not determined. A single Rhinocerous Auklet (*Cerorhinca monocerata*) in breeding plumage was observed July 4, 1977 on the water, east of the cabin on Round Island. To my knowledge this is the first record for this species in the Walrus Islands or Bristol Bay. The nesting status of this auklet on Round Island was not determined.

Seaducks were the only other marine bird commonly seen on nearshore waters of the islands. Steller's Eiders (*Polysticta stelleri*), White-winged Scoters (*Melanitta deglandi*), and Harlequin Ducks (*Histrionicus histrionicus*) were the most abundant and numbered in the hundreds around the four largest islands. Species observed in lesser numbers were Oldsquaw (*Clangula hyemalis*), Common Eiders (*Somateria mollissima*), King Eiders (*S. spectabilis*), Surf Scoters (*Melanitta perspicillata*), Black Scoters (*M. nigra*) and Red-breasted Mergansers (*Mergus serrator*).

We will attempt to publish a report on other bird species observed on our stay in the Walrus Islands.

<u>Pelagic Transects</u>: While travelling between islands to document seabird colony information, pelagic transects were conducted to determine use of inshore waters by marine birds. In all, 18 surveys were conducted along the 10 transect lines (Figure 1). The most frequently surveyed transect was the one between Crooked Island and North Twin, and it was conducted four times. Another transect was surveyed three times, three were completed twice and five done only once.

From these transects a relative measure of species abundance, diversity, and density was determined (Table 3). The most frequently observed birds were those nesting in greatest numbers on nearby colonies - murres, cormorants and kittiwakes. However, densities on pelagic waters between islands were not directly proportional to

Table 3. Bird abundance in pelagic transects conducted between islands of the Walrus Island group, Bristol Bay, Alaska.

Species	Total No. of Birds	Frequency of Occurrence % of Total Transects	Mean No. of Birds/Transect	Density Birds/KM^2
RT Lo	1	6	Tr	Tr
Corm	521	100	29	15.1
Olds	6	17	Tr	0.2
Harl	30	6	2	0.9
Eide	2	11	Tr	Tr
WWSc	232	83	13	6.7
Su Sc	2	11	Tr	Tr
Bl Sc	3	11	Tr	0.1
Scot (unid)	97	44	5	2.8
Subtotal	372	83	21	10.8
Me Sh	6	6	Tr	0.2
GW or Lg Gu	42	67	2	1.2
BL Ki	166	100	9	4.8
Tern	1	6	Tr	Tr
Subtotal	209	100	12	6.1
Murr	3484	100	194	101.0
Pi Gu	68	72	4	2.0
Pa Au	7	11	Tr	0.2
Ho Pu	36	72	2	1.1
Tu Pu	39	78	2	1.1
Subtotal	3634	100	202	105.3
TOTAL	4743	100	264	137.5

actual numbers of birds breeding on the islands. Although murres were most dense on the transects (101 birds/Km^2 and 194 birds/transect), this was largely a result of large rafts of murres roosting on nearshore waters off murre colonies. If transects had been terminated a greater distance from colonies, a substantial reduction in murre densities would have been evident. When murres observed during the last two minutes of a transect were subtracted from the total number in the transect, only 1,632 murres were censused and the density drops from 101 to 47 murres/Km^2. By comparison, 15.1 cormorants/Km^2 were recorded, a three-fold difference from the corrected murre density. However, in total estimated populations for the islands, murres were over 34 times more abundant than cormorants (486,800 vs. 14,245). Kittiwakes were over six times more abundant than cormorants in total numbers on colonies, but their density in pelagic transects was only 4.8 birds/Km^2 or one-third as many.

Surprisingly, the third most numerous bird on the transects was the White-winged Scoter. This species was seen on 83 percent of the transects in densities of 6.7 birds/Km^2. The only other noteworthy finding was the abundance of Pigeon Guillemots on transects in relation to their relative abundance on shoreline counts. They were almost twice as abundant as puffins on pelagic transects but only one-half as abundant on shoreline counts. Almost 70 percent of the total number of guillemots on the pelagic surveys (47 of 68) were observed on the four transects between Crooked Island and North Twin.

Sea Watches: Often strong winds prevented bird surveys from the rubber raft, and we were relegated to gather bird information near base camp on Crooked Island. This included bay watches to the east of camp on an irregular basis. The area surveyed is shown in Figure 2. A summary of the species observed is presented in Table 4.

Glaucous-winged Gulls were the only species observed on all watches (assuming that large gulls were mostly Glaucous-winged). They frequently roosted at the mouth of a creek at the north end of the beach or fed upon a walrus carcass that had washed up on the beach. Kittiwakes, White-winged Scoters, and murres were the next most frequently observed species although murres were present in much smaller numbers than the other two.

A colony of 778 Pelagic Cormorants nested within a few hundred meters of the north end of the watch area, and yet cormorants were seen on only four of the bay watches.

The number and species composition present in the bay appeared to vary with weather conditions and wind direction and velocity. Occasionally an unusually large group of birds (particularly seaducks) would roost and feed in the bay when it was in the lee of the wind.

Brackish Lagoon Usage: Because it was noticed that many Black-legged Kittiwakes were stopping into the brackish lagoon near base

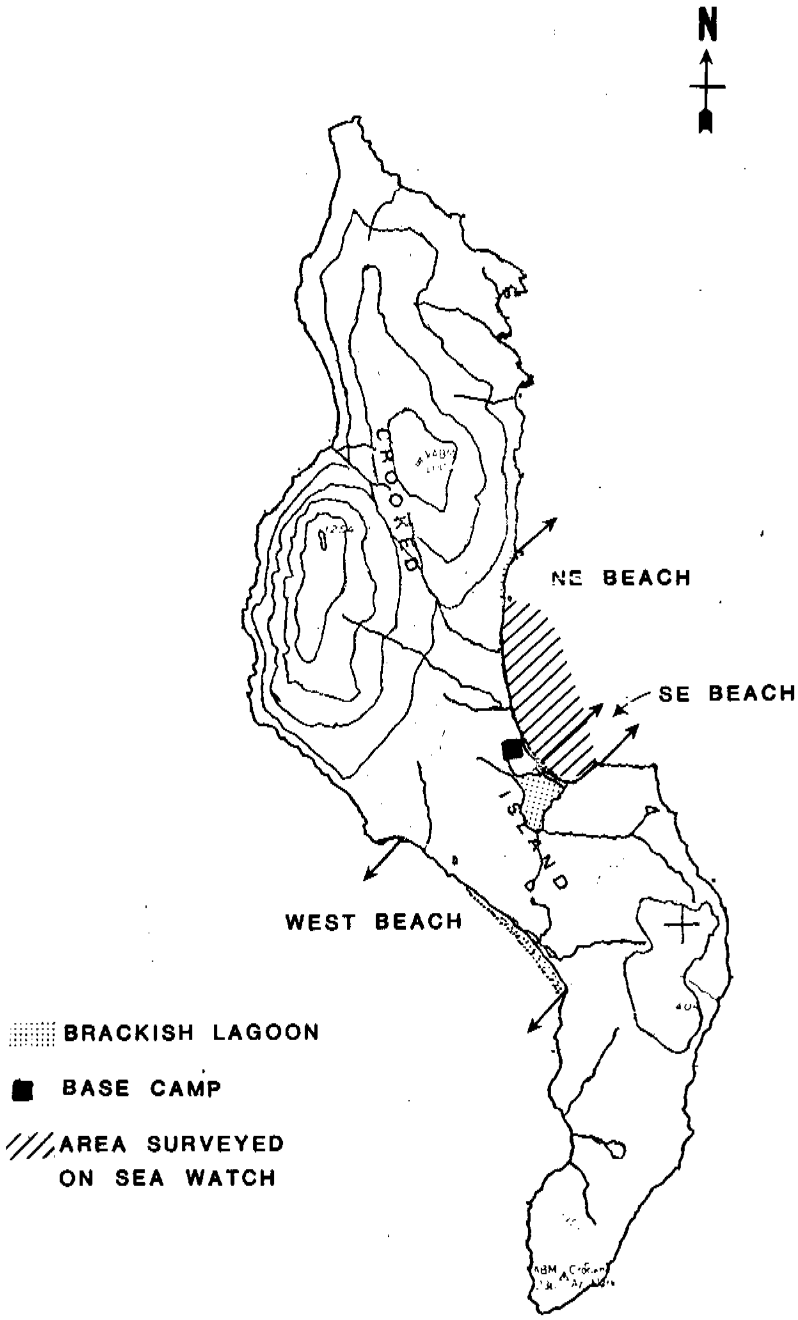

Figure 2. Location of nearshore waters censused on sea watches, brackish lagoon used by kittiwakes and beaches walked for beached birds on Crooked Island, Walrus Islands, Bristol Bay, Alaska, June-July 1977.

Table 4. Numbers of birds observed on nearshore waters during sea watches from Crooked Island, Walrus Islands, June-July 1977.

Species \ Date-Time	6-22 10:35	6-22 19:30	6-23 10:20	6-23 19:50	6-24 9:45	6-25 8:45	6-26 10:30	6-26 21:00	6-27 11:00	6-27 21:45	6-28 11:00	6-28 21:40	6-29 11:00	7-7 16:30	7-8 15:50	7-8 20:30	7-12 10:50	7-12 16:10	7-13 11:10
Co Lo	1																		
Ar Lo	2	3		1			1		2		1	2							
RT Lo					1								1			2			
RN Gr							1		1	1					1				1
Corm	2					6									1	1			
Olds										11			7		2				
Harl												2			1				
St Ei														41		31			
Ki Ei									34					1		1			1
WW Sc	69	8		1					8	8	23	8	18	4	11	14	7	7	3
Su Sc	6								15	2					6	5		3	
Bl Sc									4	1					8	3		2	1
Scot	40				1	3				3		5	8		13		5		
RB Me									4	10	1		12		1	3			
Pa Ja									1										
Gl Gu								1											
GW Gu	2	2		27	44		23	5	29	3	19	12	19	5	5	21	25	17	27
Lg Gu			22			24		24											
Kitt	1	62	1	46			2		7	1	4	4	11	6	154	9	5	32	
Murr	1	1		1		6				2	2	14	6		2	5	2	1	1
Pi Gu	2													1	1				
Ho Pu															3				

camp on Crooked Island, we spent a day determining peak use of the lagoon. For 15 minutes every hour, kittiwakes flying into or out of the lagoon were counted. As many as 45 per minute and 346 per 15 minute interval were counted flying from east to west into the lagoon. Peak use was in late afternoon/early evening (Figure 3).

Few birds moved back out of the lagoon in an easterly direction. Most preened and bathed for a few minutes in the lagoon and then continued westerly over the island to roost on the sandy west beach or flew southerly along the west coast of Crooked Island in the direction of the Twins.

It was difficult to determine the direction whence the birds were coming, but it appeared many came in the direction of the point on the south end of the cove east of camp. The day of the survey (25 June, 1977) seemed to be a "typical" day for kittiwake movements. Westerly winds prevailed, and it blew up to 20 knots most of the day. However, on other days no matter what the wind direction or weather conditions, kittiwakes moved in a similar manner. Even when fog was too dense for us to navigate in our raft, kittiwakes still utilized the lagoon.

Glaucous-winged Gulls used the lagoon to a much lesser degree for preening and bathing during the day but often would alight on the water late in the evening. Apparently it was a traditional roost site for 30-40 individuals.

The lagoon was also frequented by a variety of other species of birds including waterfowl, shorebirds and passerines.

Beached Bird Surveys: As time permitted, beaches were walked to obtain baseline information on beached birds from natural mortality. After the initial cleaning of the beach when relatively large numbers of carcasses were found, few new carcasses washed ashore. In order of their frequency of occurrence, shearwaters, murres and kittiwakes were the most often encountered species. Ten different bird species were identified on beached bird surveys (Table 5).

Drift lines on all beaches that were walked did not contain much organic matter, but each beach seemed to be specific in the type of debris that was at the high tide line. On SE beach of Crooked Island the most common pelecypods were blue mussels (*Mytilus edulis*) and cockles (*Clinocardium* sp.). Algae (*Fucus* sp.) also frequently washed ashore on this beach. Horse crabs (*Telmessus cheiragonus*) often were found dead on both the SE and NE beaches. Little else washed up on the NE beach, however, a dead harbor seal pup (*Phoca vitulina*) was recorded. On the west beach of Crooked Island the most common organism of the drift line was an unidentified sponge. Also present in relatively large numbers were several starfish species and horse crabs.

On the north side of Summit Island the debris on the high tide line consisted largely of horse crabs, *Fucus* and eelgrass (*Zostera marina*). Drift lines on south side beaches contained many starfish, some horse crabs and both *Fucus* and *Lamineria* algaes.

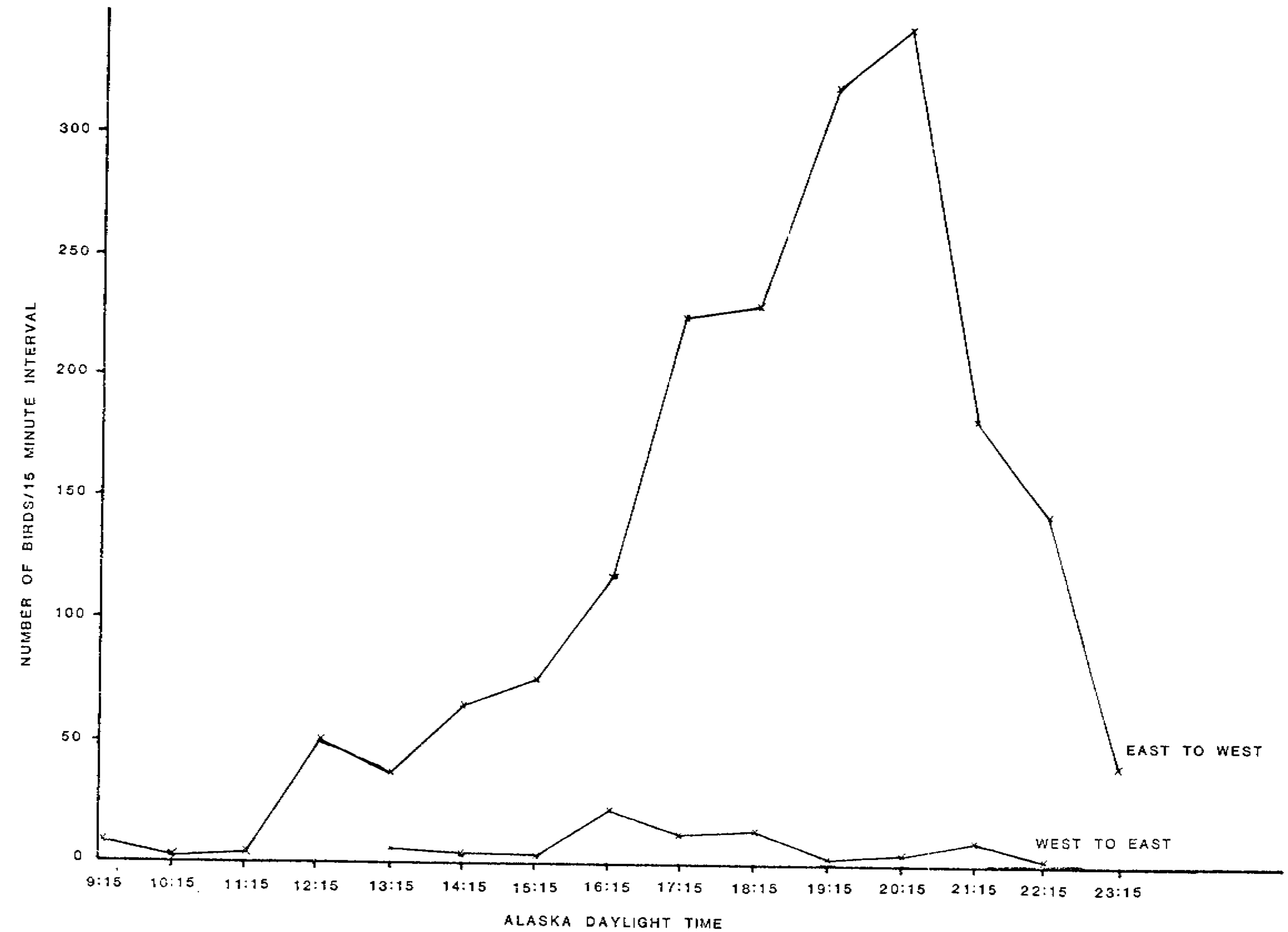

Figure 3. Black-legged Kittiwake diurnal movements into a brackish lagoon on Crooked Island, Bristol Bay, Alaska, June 25, 1977.

Table 5. Numbers of dead birds by species found on beached bird surveys of Crooked and Summit Island, Walrus Islands, June-July 1977.

	CROOKED ISLAND											SUMMIT IS.	
	Northeast Beach					Lagoon Mouth	Southeast Beach				Beach West	NE	SW
Species	6-17*	6-21	6-24	6-27	7-7	6-24*	6-19*	6-21	6-23	6-27	6-20*	7-11*	7-11*
Shearwater	12	2	No Birds	No Birds	1	2	2		No Birds	3	1	No Birds	
Cormorant	2					1		1		1			
Emperor Goose											1		
Pintail											1		1
Oldsquaw	1												
King Eider											1		
Kittiwakes	5				1	5	3				6		
Murre	12	3				3	6	1			7		
Horned Puffin							1						
Unid. Alcid	1												
Wilson Warbler		1											
Unid. Bird	3				4								
TOTAL	36	6	0	0	6	11	12	2	0	4	17	0	1

* Original cleaning of beach, accumulation for an unspecified period of time.

IV. Preliminary Interpretation of Results

Shoreline Surveys: The Walrus Islands and Hagemeister Island are extremely important to nesting seabirds. The population of nearly 600,000 birds likely represents an underestimation of the total bird population utilizing the islands. Survey conditions were ideal for most of the colony work, and therefore reasonably accurate counts and estimates were made. However, an accurate correction factor for breeding birds away from the cliffs and shoreline and for non-breeding birds using the colony could not be made. It is my feeling that population estimates were on the conservative side of a reasonable estimate of the true value.

Summit and Crooked Islands were the least productive for seabirds both in total numbers of birds and species diversity. Because of its habitat diversity however, Crooked supports large numbers of other species of marine and terrestrial birds. Little cliff-nesting habitat is available on Hagemeister Island and therefore seabird colonies were not large, but due to its large size, extensive habitat is available for other marine and terrestrial species.

North Twin supported the largest populations, and it appeared that all available habitat was utilized. Species diversity of nesting seabirds was greatest on Round Island and population sizes of most seabird species were relatively large. Several additional seabird species are presumably present on Round, but we did not observe them on our six-day stay on the island. In July 1962 D.N. Weir (unpublished data) reported seeing over 100 pair of nesting Red-faced Cormorants on the east side of Round Island. We did not observe this species in our surveys, but it may have nested on portions that we did not cover. T.J. Eley, Jr. spent two weeks on Round Island in July 1974 and reported seeing several Fork-Tailed Storm-Petrels (*Oceanodroma furcata*) and a possible burrow area on the east side of the island. He also reported that Mew Gulls (*Larus canus*) were common but no nests were found. We did not observe this species on any of the islands even though they are abundant on the mainland of North Bristol Bay. Five Least Auklets (*Aethia pusilla*) including two young and a pair of Black Oystercatchers (*Haematopus bachmani*) with two young were also observed by Eley (unpublished report).

Because of the species diversity and abundance and the relatively ready access to colony sites, Round Island should be considered the best site in the island group for future studies. North Twin is less desirable because access to the colony is very limited.

During shoreline surveys an incidental observation was made concerning Glaucous-winged Gulls. This species was not breeding in large numbers and no major breeding concentrations were found. These gulls often nested in close association with cormorant nests. They either nested among the cormorants or in close proximity to them. The reason for this association was not ascertained.

Pelagic Surveys: Without further analysis and more pelagic surveys farther from the islands, only tentative conclusions can be drawn about the species composition and abundance of the pelagic transects. It appeared that of the major seabird species nesting on the islands, only cormorants remained near the islands to feed. Murres and kittiwakes presumably foraged some distance to the west and south of the islands. Few of these two species were found in transects between islands in proportion to numbers nesting on colonies. Large flocks were seen in the air on the horizon southwest of both South Twin and Round Island. Pigeon Guillemots were likely foraging near the islands whereas both puffin species probably flew greater distances to feed.

Large numbers of non-breeding or molting sea ducks also inhabited nearshore waters of the islands. The area between Crooked and High Islands was a particular concentration area as well as rocky promontories on all the islands.

Sea Watches: No major conclusions were drawn about the results of sea watches except that it appeared that an inordinate amount of feeding was done at the mouth of the creek on the north end of the beach in comparison to other parts of the beach. Sea ducks (in particular scoters) were the most frequently encountered foraging species. The Arctic Loon (*Gavia arctica*) was commonly observed in the bay but no nests were found on nearby freshwater ponds. Murres often fed close to shore but only as scattered individuals. Only one kittiwake feeding "frenzy" was observed in the bay but the long, narrow fish on which they were feeding was not identified.

Brackish Lagoon Usage: Use of the brackish lagoon on Crooked Island by kittiwakes apparently pointed out the importance of a "fresh" water rinse (the salinity of the lagoon was not taken) in the daily habits of the birds. Birds were coming long distances often during adverse weather to use the lagoon, and approximately 7500 kittiwakes would stop during the day. Because no fresh water was available for bathing on both Round Island and The Twins, it was assumed that birds were coming from those islands.

We hypothesized that the early evening peak of abundance meant that the birds were returning to bathe after a day of feeding. Two individuals were collected to test the hypothesis, but one Black-legged Kittiwake's stomach was empty and the other contained only one otolith tentatively identified as that from a cottid. Either food had been digested on their return from pelagic foraging areas, or possibly the kittiwakes were incubating birds relieved of their duties and flew to fresh water for bathing and preening.

On other islands where large fresh water streams were available, large (several hundred individuals) groups of kittiwakes were often observed bathing at the mouth or roosting nearby. Travelling to the lagoon on Crooked was not necessary for them.

The lagoon on Crooked Island was very important to other species of birds also and should not be disturbed in the future if development occurs in the area.

Beached Bird Surveys: The only noteworthy outcome of beached bird surveys was that although no shearwaters were observed during the month-long stay on the islands, they frequently washed ashore. [Only Slender-billed Shearwaters (*Puffinus tenuirostris*) were identified.] Large numbers must have been frequenting nearby waters and their carcasses must have remained afloat for several days. Some newly arrived carcasses were fresh while others were already well-decayed.

Miscellaneous Observations: The only mammalian predator observed on the islands was the red fox (*Vulpes fulva*). It was most abundant on Round and Hagemeister Islands. A minimum of 10 adults were suspected on Round Island. Only two sightings of a fox occurred on Crooked Island, and it may have been the same individual. Their population on that island appeared to be very low. Fresh tracks were observed on Summit Island but no fox was sighted. There appeared to be no fox on High Island (no tracks or other sign and many bird nests were very accessible but untouched), and no suitable fox habitat was present on the smaller islands.

V. Problems Encountered.

No major problems were encountered during this report period.

VI. Funds Expended

Salaries	$11,400
Per Diem/Travel	330
Contractual Services	1,700
Commodities	105
Equipment	-0-
Total	$13,535

Quarterly Report

Contract # 03-5-022-72
Research Unit 83
Reporting Period 1 July to
30 September 1977

REPRODUCTIVE ECOLOGY OF PRIBILOF ISLAND SEABIRDS

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1 October 1977

I. Task Objectives

The task objectives for the 10th quarter were:

a) To obtain data on the phenology of reproductive activity of Pribilof Island seabirds.
b) To obtain data on the reproductive success of Pribilof Island seabirds.
c) To obtain samples of foods used by adult birds prior to chick hatching as well as samples of foods brought to young.
d) To conduct radial transects within 100 nautical miles of the Pribilofs to locate foraging areas of major importance.

II. Field or Laboratory Activities

A. Ship and field trip schedule

1 July 1977 - Ron Squibb and Sam Sharr on St. George Island.
George Hunt, Barbara Mayer and Bill Rodstrom on St. Paul Island.
7-11 July 1977 - George Hunt, Bill Rodstrom, Ron Squibb, Barbara Burgeson on NOAA OSS Surveyor for radial transects.
11-24 July 1977- Sam Sharr on St. George Island.
George Hunt, Barbara Mayer, Bill Rodstrom and Ron Squibb on St. Paul Island.
24 July 1977 - George Hunt and Ron Squibb to St. George Island.
1-5 August 1977- George Hunt, Bill Rodstrom, Sam Sharr, Maura Naughton and Melody Roelke on NOAA OSS Surveyor for radial transects.
6 August 1977 - George Hunt departs Pribilof Islands.
5-14 August 1977-Ron Squibb, Sam Sharr and Bill Rodstrom on St. George Island.
Barbara Mayer, Maura Naughton on St. Paul Island.
14 August
7 September 1977-Barbara Mayer and Bill Rodstrom on St. Paul Island.
14 August
22 September 1977-Ron Squibb and Sam Sharr on St. George Island.
7 September - Barbara Mayer departs St. Paul Island.
22 September - Bill Rodstrom, Ron Squibb and Sam Sharr depart Pribilofs.

B. Scientific Party

George L. Hunt, Jr., Associate Professor, University of California, Irvine, Principal Investigator.
Barbara Mayer, Assistant Specialist, University of California, Irvine, Project Leader.
Bill Rodstrom, Laboratory Assistant, University of California, Irvine, Field Observer.
Ron Squibb, Laboratory Assistant, University of California, Irvine, Field Observer.
Sam Sharr, Laboratory Assistant, University of California, Irvine, Field Observer.

Barbara Burgeson, Administrative Assistant, University of California, Irvine, Field Observer July cruise.

Maura Naughton, Laboratory Assistant, University of California, Irvine, Field Observer August cruise and early August, St. Paul Island.

Melody Roelke, National Marine Fisheries Service, Marine Mammal Division, Observer, August cruise.

C. Methods

1) Data on phenology, reproductive success and foods were gathered using the same methods as described in the 1 April 1977 Annual Report. They will not be repeated here.

2) Cruise tracks for the radial surveys followed the proposed cruise tracks with only minor modifications for the July cruise. On the basis of data gathered in July, the August cruise tracks were modified to improve coverage of areas believed important for foraging murres (Table 1).

Shipboard observations were made from the compass deck (eye level, 42 feet above waterline). All Birds from directly ahead to 90° off the side of the ship were counted, each observation being logged in one of three concentric zones, each zone being 100 meters wide. Bird activity was noted (foraging, sitting on water, flying, etc.) and when flying, flight direction was recorded.

Helicopter surveys were conducted once or twice daily during cruises. Areas surveyed were chosen in order to check areas a) unapproachable by the ship, b) of particular biological interest (continental slope) or c) areas of potential interest for which there was insufficient ship time to provide complete coverage.

Turning points for the helicopter surveys in August are provided in Table 2. Turning points for the July helicopter surveys are not yet transcribed.

Helicopter surveys were made at an altitude of 125 feet and a speed of 75 miles per hour. The observer sat in the co-pilot's seat and called all sightings of birds in a 5.0 m wide track into a tape recorder. Position and time updates were called in at frequent intervales. The census strip was generally directly ahead of the aircraft, except when glare conditions required using a track paralled and to one side of the helicopter.

D. Sample localities

1) Studies of phenology, reproductive ecology and food habits were conducted on St. Paul and St. George Islands.

2) Shipboard and helicopter surveys at sea foraging areas of Pribilof Island seabirds were conducted within 100 nautical miles of the Pribilofs (See Fig. 1 and Tables 1 and 2).

E. Data collected

1) Tables 3 and 4 summarize data gathered on reproductive ecology and foods respectively. The 1977 effort represents approximately a doubling of the number of nests followed in 1976 for phenology and reproductive success. This increase in effort is reflected by more complete coverage of St. George Island and improved coverage of Murres on St. Paul. The level of acquisition of data on food habits in 1977 is similar to that 1976.

2) During the Surveyor cruise 7-11 July over 340 ten-minute transect segments were run, while on the 1-5 August cruise approximately 350 transect-segments were completed. Helicopter survey data, from 5 flights in July and 6 in August, are in addition to the above standard ship tracts. This compares to the 185 transect segments surveyed in 1976, although most of these were longer than 10 minutes in duration.

III & IV. Results and Interpretation

Field parties are only just returning from the Pribilofs, and virtually all of our data remain to be worked up. Until that work-up is complete, it will be impossible to make broad comparisons between islands or between years. However, some comparisons are possible, based either on general impressions or upon preliminary work-ups of one or two sites.

A. Reproductive ecology and phenology

The winter spring and summer of 1977 were unusually warm and mild and kittiwakes and murres appeared to be breeding earlier on St. George than in past years and earlier than on St. Paul. Timing of breeding on St. Paul appeared roughly equivalent to what it had been in 1975 and 1976, although complete analysis of the data will be necessary before this can be confirmed.

Rough calculations of reproductive success of kittiwakes are available for two 1977 St. George Island sites, Tolstoi and Staraya Artil. At Tolstoi 1977 reproductive success for both Black-legged and Red-legged Kittiwakes was markedly reduced from 1976 levels. In contrast at Staraya Artil reproductive success in 1977 was at or above that found in in 1976. The contrasting results from these two sites are of considerable interest. Tolstoi is a much more exposed area than Staraya Artil and its cliffs are much more crumbly and prone to rock falls. In 1977 several Red-legged Kittiwake nests were lost due to cliff falls, and at least one severe storm lashed the Tolstoi area when

Table 1

Approximate Turning Points - Radial Surveys, 1-5 August 1977, OSS Surveyor.

	Way Point	Latitude	Longitude
Day 1	Start	57^{o} 05'N	170^{o} 17'W
	2	57^{o} 39'N	170^{o} 19'W
	3	57^{o} 38'N	169^{o} 30'W
	4	57^{o} 04'N	169^{o} 30'W
	5	57^{o} 04'N	168^{o} 33'W
	6	56^{o} 14'N	168^{o} 33'W
	end	56^{o} 22'N	168^{o} 52'W
Day 2	Start	56^{o} 42'N	169^{o} 23'W
	2	56^{o} 35'N	169^{o} 24'W
	3	55^{o} 30'N	168^{o} 40'W
	4	55^{o} 30'N	169^{o} 40'W
	end	56^{o} 20'N	169^{o} 40'W
Day 3	Start	56^{o} 35'N	169^{o} 52'W
	2	55^{o} 52'N	170^{o} 32'W
	3	56^{o} 05'N	171^{o} 10'W
	4	57^{o} 07'N	170^{o} 36'W
	end	57^{o} 06'N	170^{o} 22'W
Day 4	Start	56^{o} 35'N	169^{o} 24'W
	2	57^{o} 24'N	168^{o} 32'W
	3	57^{o} 24'N	170^{o} 15'W
	4	58^{o} 00'N	170^{o} 15'W
	5	58^{o} 00'N	170^{o} 42'W
	end	57^{o} 50'N	170^{o} 40'W
Day 5	Start	57^{o} 26'N	171^{o} 19'W
	2	57^{o} 12'N	170^{o} 30'W
	3	57^{o} 08'N	170^{o} 30'W
	4	57^{o} 05'N	170^{o} 18'W
	end	56^{o} 50'N	169^{o} 48'W

Table 2

NOAA Ship SURVEYOR S-132 RP-4-SU-77B Leg III August 01 - 05 1977
NOAA Bell Helicopter Way Points for Marine Bird Transects

Day 1-August 01: Helicopter flight to St. George Island and reef area about 12 miles east of St. George Island. No fixed way points recorded by pilot; observer has way points.

Day 2-August 02: Morning flight; continental shelf; 30 miles SE of St. George.

1)	56° 22.3'N	169° 13.5'W
2)	56° 29.5'N	169° 11.6'W
3)	56° 29.5'N	168° 33.0'W
4)	56° 25.0'N	168° 33.0'W
5)	56° 25.0'N	169° 02.0'W
6)	56° 19.6'N	169° 02.0'W
7)	56° 19.6'N	168° 19.0'W
8)	56° 14.6'N	168° 19.0'W
9)	56° 14.6'N	169° 03.9'W

Day 2-August 02: Afternoon flight; continental shelf-slope break; 60 miles SSE of St. George Island.

1)	55° 52.5'N	168° 44.0'W
2)	55° 52.5'N	169° 25.0'W
3)	55° 45.8'N	169° 25.0'W
4)	55° 45.8'N	168° 30.0'W
5)	55° 38.5'N	168° 30.0'W
6)	55° 38.5'N	169° 21.0'W
7)	55° 30.5'N	169° 21.0'W
8)	55° 30.5'N	168° 39.0'W

Day 3-August 03: Afternoon flight; continental shelf; 30 miles SW of St. Paul.

1)	56° 36.0'N	170° 53.0'W
2)	56° 36.0'N	171° 14.0'W
3)	56° 42.0'N	171° 14.0'W
4)	56° 42.0'N	170° 23.0'W
5)	56° 48.0'N	170° 23.0'W
6)	56° 48.0'N	171° 14.0'W
7)	56° 53.0'N	171° 14.0'W
8)	56° 53.0'N	170° 45.0'W

-continued-

Helicopter Way Points For Marine Bird Transects continued

Day 4 - August 04: Morning flight; continental shelf; 25 miles NE of St. George Island.

1) Departure from St. George Island
2) 56° 45.0'N 169° 29.0'W
3) 56° 45.0'N 168° 53.0'W
4) 56° 51.5'N 168° 53.0'W
5) 56° 51.5'N 169° 31.0'W
6) 57° 01.0'N 169° 31.0'W
7) 57° 01.0'N 168° 23.0'W
8) 57° 03.5'N 168° 23.0'W
9. 57° 03.5'N 168° 52.0'W

Day 4 - August 04: Afternoon flight; continental shelf; 30 miles NE of St. Paul Island.

1) 57° 23.0'N 168° 51.5'W
2) 57° 27.5'N 168° 51.5'W
3) 57° 27.5'N 169° 51.0'W
4) 57° 33.0'N 169° 51.0'W
5) 57° 33.0'N 168° 51.5'W
6) 57° 38.5'N 168° 51.5'W
7) 57° 38.5'N 169° 51.0'W
8) 57° 44.0'N 169° 51.0'W
9) 57° 44.0'N 169° 37.0'W
10) 57° 23.0'N 169° 37.0'W

the kittiwakes had small chicks. These factors could explain the differences between the two sites in 1977. This variation between sites points to the need for data from a number of sites in order to develop reasonable estimates of reproductive success for any one colony in a given year.

As of this writing no data on 1977 growth rates are available.

B. Food samples have yet to be analyzed and it would be premature to comment on food habit data from 1977 at this point.

C. Ship surveys in August confirmed the existence of an apparently important murre foraging area N.E. of St. George Island. Satelite imagry showed this to be an area of cooler surface waters. This area was first located on the July cruise. Enormous concentrations of murres were again found on both cruises east of St. George Island between Tolstoi point and an off-shore reef. Helicopter flights proved most valuable in assessing the extent and magnitude of murre concentrations in this area.

The extent of which murres forage far to the northwest of St. Paul Island is still not clear. In the early A.M. on the July cruise we found murres flying toward St. Paul over 80 miles N.N.W. of St. Paul. When we surveyed this area in the late P.M. in early August, no murres were found. Tuck (the murres, Canadian Wildlife Series 1, 1961) has emphasized how murres from various Atlantic colonies rarely forage more then 10-20 miles from their colonies. In the Pribilofs, murres forage at considerably greater distances from their colonies.

V. Problems Encountered

We were unable to conduct experiments to determine the effect of aircraft on cliff nesting birds as the U. S. Fish and Wildlife Service failed to respond to our requests for permits or clearance. It is suggested that that agency should provide data on the distances at which various kinds of aircraft cause incubating and brooding birds, especially murres, to leave the cliffs.

In other respects the summer's field season went very well and was relatively trouble free. Our success in gathering field data, however, has led to a monumental data management task especially if data are to be coded and punched in the detail originally envisioned.

Table 3

Summary of Reproductive Biology Studies
1977 Field Season

	St. Paul		St. George		Total	
	Nests Followed	Chicks Weighed	Nests Followed	Chicks Weighed	Nests Followed	Chicks Weighed
Northern Fulmar	35	0	73	0	108	0
Red-faced Cormorant	67	2	33	14	100	16
Black-legged Kittiwake	149	26	113	22	262	48
Red-legged Kittiwake	95	3	234	43	329	46
Common Murre	287	17	12	3	299	20
Thick-billed Murre	297	28	116	35	413	63
Horned Puffin	14	11	0	0	14	11
TOTAL	944	87	581	117	1525	204

Table 4

Summary of Foods Data Collected
1977 Field Season

	St. Paul Island	St. George Island	Total
Northern Fulmar	0	1	1
Red-faced Cormorant	19	65	84
Black-legged Kittiwake	82	41	123
Red-legged Kittiwake	34	66	100
Common Murre	27	3	30
Thick-billed Murre	39	31	70
Horned Puffin	10	1	11
Tufted Puffin	3	0	3
Crested Auklet	7	0	7
Least Auklet	40	45	85
Parakeet Auklet	14	0	14
TOTAL	275	253	528

VI. Estimate of Funds Expended

	Estimated Accumulated Expense to 30 September 1977	Total Funds Allocated
		$118,505.00
Salaries	$ 59,224	
Employee benefits	4,290	
Supplies and expenses	14,963	
Equipment	8,647	
Travel and per diem	24,618	
Other	2,281	
Total Expended	$113,523	

Estimated funds remaining $4,982

The remaining funds will be sufficient to cover all remaining expenses within the Fy 77 contract year. The excess is due in part to George L. Hunt not being paid for the second of the two summer months worked ($2,200 saved). This was not charged because at the start of the field season it appeared that we might be critically short of funds. A second $1,500 was saved when at the last minute, due to a back injury, a staff member was not brought to the Pribilofs to participate in a cruise. Substitute help was arranged by borrowing help from the National Marine Fisheries Serice Marine Mammal Division when one of their people was allowed to use three days of weekend leave to participate on the August cruise.

#RU 108

NO REPORT WAS RECEIVED

QUARTERLY REPORT

Contract No. 03-5-022-84
Research Unit #172
Reporting Period: 1 July - 30 Sept. 1977
Number of Pages: 3

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, 1977

I. Task Objectives

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

1. Seasonal occurrence of shorebirds by species, in a variety of arctic littoral and near-littoral habitats.

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

3. Comparison of habitat use patterns, densities, and timing of shorebird littoral and tundra events at multiple sites along the Beaufort and Chukchi coasts.

II. Field Activities

A. (1) Field seasons continued at NARL, Barrow, July 15, 1977 - September 16, 1977; at Cape Krusenstern, Kotzebue Sound, July 1, 1977 - September 8, 1977; at Wales, July 1, 1977 - September 14, 1977.

(2) Brief survey visits from late July through early September. Beaufort: Colville Delta, Oliktok, Prudhoe Bay. Chukchi: Peard Bay, Icy Cape, Point Hope to Cape Krusenstern, Noatak Delta, Cape Espenberg to Arctic Lagoon.

B. Scientific Party

Research Coordinator:	Peter G. Connors, Univ. of California, Bodega Marine Laboratory
Research Assistants:	Carolyn S. Connors, UC-BML
	Katherine Hirsch, UC-BML
	Douglas Woodby, UC-BML
	Bonnie Bowen, UC-Berkeley
	Frank Gress, UC-BML

C. Methods

Objective 1. Marked transects were established at the 3 main study sites. Cape Krusenstern: 17 transects, 14.5 km total, 50 or 100 m wide, plus one gridded census plot, 350 m x 850 m; in littoral and near-shore tundra habitats. Wales: 19 transects, 16 km total, 50 or 100 m wide, plus one gridded census plot, 250 m x 1000 m; in littoral and nearshore tundra habitats. Barrow: 19 transects, 17 km total, 50 or 100 m wide, in littoral habitats.

All transects and gridded plots were censused every 5 days, recording all species by age and sex wherever possible.

Objective 2: Shorebirds foraging in littoral areas were collected throughout the season for stomach content analysis. Stomach contents were preserved with formalin or ethanol by injection immediately after collection, and were removed later in the laboratory, thus preserving the skins for museum specimens. Benthic or plankton samples were taken at the foraging locations of most collected birds for comparison of potential prey to selected prey.

Other diet information was obtained by direct observation of foraging birds, often supplemented with benthic or plankton samples taken at the foraging site.

In addition, a regular schedule of zooplankton sampling was conducted at 4 stations at each of the 3 main study sites (Barrow, Wales, Cape Krusenstern) during August. These samples will allow comparison with earlier seasons at Barrow and between sites during this season.

Objective 3: At sites away from the 3 main study areas, densities of shorebirds in various littoral habitats were estimated for comparison with transect data at intensive sites. Comparison of intensive and extensive site observations will reflect on the timing of migrational movements and habitat use patterns.

D. Samples Localities. See Section A.

E. Data Collected.

(1) Approximately 800 transect censuses were completed during this period. 54 birds were collected and stomachs removed. Approx. 70 plankton samples were collected and preserved.

(2) Since the field season continued until 16 September 1977, no analyses have been yet completed.

(3) Not applicable.

III. Results

Because the field season continued almost to the date of this report, the bulk of the data gathered have not been analyzed or even tabulated. However, several general results of the season's work are discussed below.

IV. Preliminary Interpretation

Conditions at Barrow in the third season of this study again demonstrated the high variability of events in the littoral zone. Ocean ice moved out early in the season, greatly increasing shoreline foraging by early migrating birds, especially male Red Phalaropes in late July. Preliminary indications are that zooplankton composition and density during August differed considerably from the previous two summers. In general, however, plankton foraging by migrant shorebirds remained very important, in contrast to the situation observed on the Seward Peninsula and Kotzebue Sound. At Wales and Cape Krusenstern, phalaropes were uncommon in August, and other species were most abundant in areas of saltmarsh and mudflat. Brief visits found Western Sandpipers, Long-billed Dowitchers, Pectoral Sandpipers, and especially Dunlins to be abundant on the extensive saltmarsh and mudflat areas of the Noatak Delta and the long lagoon strip east and west of Shishmaref. This pattern suggests differences in species susceptibility to littoral disturbances between the Seward Peninsula-Kotzebue Sound area and regions farther north, as well as differences in the habitat and topographic features which comprise areas of critical importance to migrant shorebirds.

V. Problems - None

VI. Estimate of Funds Expended

For FY77, funds expended through August 31, 1977 totalled approximately 36,760 of the allocation of 44,158.

Quarterly Report

Contract # 03-7-022-35140
Research Unit: 196
Report Period: 1 July - 30 September 1977
Number of Pages: 4

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

George J. Divoky
Principal Investigator

Assisted by:

Robert J. Boekelheide
A. Edward Good
Harriet R. Huber
Karen A. Oakley
Kenneth Wilson

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

1 October 1977

I. Abstract of Quarter's Accomplishments

Studies of breeding birds on Cooper Island in June, July and August and two cruises in the Beaufort Sea in August showed that the early decomposition of ice along the Alaskan arctic coast played a major role in reducing bird numbers. This was apparently due to the absence of the ice-associated fish and zooplankton populations that many of the seabirds rely on for food. In the extreme western Beaufort an area of warm (9°C) water was found to be highly productive and supported large zooplankton populations that in turn supported high bird densities.

II. Task Objectives

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

III. Field Activities

A & B. Field Schedule and Personnel

Dates	Ship or Field Camp	Personnel
1 July - 16 August	Cooper Island	Boekelheide, Divoky Huber and Oakley
1 August - 4 September	USCGC GLACIER	Divoky and Wilson
2 August - 26 August	R/U ALUMIAK	Good

C. Methods

Pelagic censusing - While the ship is steaming in daylight, continuous 15-minute watches are conducted. All birds within 300 meters of one side of the ship are counted. Information on ice conditions and sea surface temperatures are taken during every observation period. The number of birds per km^2 are computed for each 15-minute period.

Stationary watches (Cooper Island) - Watches are conducted on the north and south sides of the island in order to observe the movements and feeding behavior of breeding birds. All migrants seen during these watches are also recorded.

Habitat transects (Cooper Island) - The north and south side of the island are walked and all birds encountered are recorded with notes on their activity and habitat use.

Plankton tows (Cooper Island) - Horizontal plankton tows (usually a 1-ft. net towed for 3 meters) are taken next to the island in order to correlate findings with observations of feeding behavior.

Bird collections - Birds are collected with a shotgun in order to obtain information on prey items as well as fat, molt and reproductive condition.

III. Field Activities (cont.)

D. Sample localities

Cooper Island - 71°13'N, 155°40'W

GLACIER - Northeastern Chukchi to Demarcation Bay

ALUMIAK - Pt. Barrow to Barter Island

E. Data collected

Cooper Island

1-hr. stationary watches	212
Habitat transects	132
Breeding bird surveys	28
Plankton tows	160
Birds collected	65

GLACIER cruise

15-minute transects	504
Birds collected	66

ALUMIAK cruise

15-minute transects	226
Birds collected	76

IV. Results

Cooper Island - The breeding populations of Arctic Terns and Black Guillemots were greater this year than in the two preceding years. (Fig. 1). As in 1976 two arctic foxes visited the island early in the breeding season. Both were collected soon after they reached the island thus limiting the number of nests lost to predation. Hatching success for both species was moderate to high but the early disappearance of ice from the area of the island made it difficult for Arctic Terns (and probably Black Guillemots) to find food for the young. When ice was close to the island Arctic Tern chicks were gaining weight rapidly but when the ice was blown offshore many of the chicks starved to death.

Use of the island and surrounding waters by migrant birds was much lower than in 1976. The large flocks of phalaropes, Sabine's Gulls and Arctic Terns that were present in early August 1976 did not appear. Apparently little food was available once the ice had left the island.

Arctic Tern

	1975	1976	1977
No. of nests	51	58	65
Avg. clutch size	1.9	1.7	1.5
Hatching success(%)	86	21	77

Black Guillemot

	1975	1976	1977
No. of nests	17	21	37
Avg. clutch size	1.8	2.0	1.8
Hatching success(%)	97	78	60

Fig. 1. Numbers, clutch size, and hatching success of Arctic Terns and Black Guillemots breeding on Cooper Island.

GLACIER cruise - The 505 15-minute transects had an average of 4.7 birds per km^2. Two-hundred and forty-one of the transects had densities of zero. Coverage of the Beaufort was sufficient to show that distance from shore and ice had little effect on densities. Black-legged Kittiwakes and Glaucous Gulls were the most common species. Sea surface temperatures were less than 5°C for most of the cruise but at the 10-fathom curve north of the Plover Islands water of 8.5° to 9°C was found. Large feeding flocks of terns and gulls were associated with this water mass. Examination of specimens from these flocks showed abundant euphausids and *Parathemisto* sp. in the stomachs. In most other areas birds were too scarce to collect but the limited specimens available show Arctic Cod to be the most important prey.

ALUMIAK cruise - All observations from the ALUMIAK were made inside the ten-fathom contour with the bulk of the work being done at the five-fathom contour. Densities averaged 36 birds per km^2 with 42 of the 226 transects having no birds. Shoreline migrants such as loons, Oldsquaw, eiders and phalaropes constituted the bulk of all birds seen.

V. Preliminary interpretations of Results

Data gathered in the 1977 season provide excellent data from a year when breakup and decomposition of nearshore ice occurred early in the season. The inability of the breeding birds on Cooper to find sufficient food and the lack of large feeding flocks near the island show that the ice-associated fish and amphipods play a major role in the diet of nearshore species. In 1975 and 1976 much of the prey obtained by birds around the island was associated with ice.

The information from the two cruises in the Beaufort provides information on densities when much of the Beaufort is ice free. As with the Cooper Island data, the importance of the ice associated fish and zooplankton is evident. Densities in both the nearshore and offshore waters were approximately half of what had been found on cruises when ice was closer to shore. The higher densities found north of the Plover Islands and the one large feeding flock associated with a warm water mass show that the Bering Sea water that moves east past Pt.

V. Preliminary interpretations of Results (cont.)

Barrow has a major effect on productivity. Physical and biological oceanographic studies should be conducted in this area to determine the process involved.

VI. Auxillary Material

A. Papers in preparation

Pomarine Jaeger preys on adult Black-legged Kittiwake (submitted for publication)

VII. Problems Encountered

None

VIII. Estimate of funds expended

As of 30 September the following amounts have been expended:

Salaries		24,953
Travel		5,972
Commodities and supplies		1,310
Equipment		1,257
	Total expenditures	$ 33,494
	Overhead	6,698

QUARTERLY REPORT

RESEARCH UNIT #: 237
REPORTING PERIOD: July 1, 1977 to
September 1, 1977
CONTRACT #: 03-6-022-35208

BIRDS OF COASTAL HABITAT ON THE SOUTH SHORE OF THE SEWARD PENINSULA, ALASKA

William H. Drury

College of the Atlantic
Bar Harbor, Maine 04609

October 1, 1977

QUARTERLY REPORT

Research Unit # 237

Reporting Period: July 1 to September 30, 1977

TITLE: Birds of Coastal Habitat on the South Shore of the Seward Peninsula, Alaska.

PRINCIPLE INVESTIGATOR: William H. Drury

AFFILIATION: College of the Atlantic
Bar Harbor, Maine 04609

AGENCY: NOAA Contract # 03-6-022-35208

DATE SUBMITTED:

I. Abstract

A. The numbers of seabirds nesting at Sledge Island, Topkok Head, Bluff Cliffs, Rocky Point and Cape Denbigh in 1977 were similar to the numbers recorded in 1975 and 1976.

B. Fledging of Pelagic Cormorants' young appeared to occur earlier in 1977 than in previous years; that of Common Murres at the same time; and that of Black-legged Kittiwakes to occur later than in previous years.

C. Murres reproduced comparatively well. Kittiwakes did poorly, as compared to 1975. Cormorants and Glaucous Gulls appeared to do about as well as in 1975 and 1976.

D. Predation by Ravens had an important impact on early eggs and on late chicks. The circumstances under which predation was successful usually included absence of most Murres from the ledges leaving the remaining eggs or chicks isolated. Glaucous Gull predation, although intense in a few places, appeared to have little effect on the breeding success of Murres and Kittiwakes.

E. Kittiwakes and Murres which had failed to reproduce persisted in defending breeding areas and continued to perform courtship, nest building, and pseudo egg- or chick-tending actions.

F. Aerial surveys indicated that most birds were feeding within 20 miles of the cliffs. Apparently many birds feed near the mouth of the Golovnin Lagoon.

G. The whimbrel migration was more conspicuous during August 1977 than it had been during 1975 or 1976. Other shorebird migrations did not appear to be unusual, but we did not spend much time surveying for shorebirds.

H. An unusually large number of "prairie waterfowl" continued to stay in the area through this period. Especially large numbers of Pintails and large numbers of Canada Geese were seen in the wetlands on the southeast shore of Seward Peninsula in late August.

II. Task Objectives

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

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

C. To examine trophic relations by estimating reproductive success, by finding where birds feed at sea, and by collecting samples of the food brought to the cliffs.

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

III. Field Activities

A. Schedule

1. At Bluff Cliffs and Square Rock we visited study sites on foot regularly from May 20 until September 12, 1977. These visits were made every other day. We made continuous watches for 24-hours and censuses of cliffs twice a month.

2. We flew a transect of feeding areas at sea on August 23 when first Murre chicks were swimming offshore.

3. We flew waterfowl surveys between Cape Spencer and Cape Denbigh on four days between August 25 and August 31.

B. Scientific Party

William H. Drury, College of the Atlantic, Principle Investigator, present August 6-September 6.

J. B. French, graduate student at the University of Wisconsin, field assistant in charge of field party, present July 1-August 24.

J.O. Biderman, field assistant, present July 1-September 12.

D. M. Rand, field assistant, present July 1-August 6 and August 23-September 12.

Craig Kesselheim, Maine Reach, Wiscasset, Maine, field assistant, present July 1-August 23.

Mary Drury, field assistant and in charge of accounts, present July 28-August 25.

John Drury, field assistant, present July 1-August 6.

Sarah Hinckley, College of the Atlantic, field assistant, present August 12-September 12.

C. Methods

Field methods have been described in detail in previous annual reports and proposals. These include:

1. Censuses of cliffs by counting or estimating birds from a small boat moving in front of the cliffs.

2. Counts made hourly for 24 hours at sample areas, at a regular study site.

3. Every-other-day visits to study sites to record the events at mapped Kittiwake nests and mapped sections of ledges on which Murres nest.

4. A record was kept of each observation of Glaucous Gulls or Ravens at the cliffs.

5. Surveys were made of wetlands from aircraft flying at about 50 feet and 90 knots. Because these flights sought to find waterfowl rather than to sample areas, each flock of birds seen was investigated and all of each wetland area surveyed.

D. Sample Localities

1. Surveys of seabird cliffs at Cape Denbigh, Cape Douglas, Sledge Island, Topkok Cliffs, Bluff Cliffs, Square Rock, Little Rocky Point and Rocky point.

2. Detailed studies at Bluff Cliffs and Square Rock.

3. Samples of reproductive success at Sledge Island, Topkok Cliffs, Bluff Cliffs, Square Rock, Little Rocky Point and Rocky Point.

4. Air surveys for feeding grounds in Norton Sound from south of Cape Darby to south of Sledge Island.

5. Air surveys for waterfowl in the wetlands from Woolley Lagoon to Cape Spencer, in the Imuruk Basin, in the basin of Fish River and Etchepuk River, in the wetlands and delta of the Fish River and Golovnin Lagoon, in the wetlands around the Flambeau and Eldorado Rivers which flow into Safety Lagoon, in the wetlands at the mouth of the Bonanza River and the lagoons from Bonanza to Taylor Lagoon, in the wetlands and deltas of the Kwiniuk, Tubutulik and Kwik Rivers, in the wetlands and deltas of the Koyuk and Inglutalik Rivers, and in the wetlands around the Shaktoolik River east of Cape Denbigh.

E. Data Collected

1. Visits to study sites, about 700
Colony censuses, 12
Observations of feeding, 28
Air transects of feeding grounds, approximately 25 five-minute samples
Waterfowl surveys, approximately 75 five-minute samples

2. Approximately 1200-1500 miles of air survey trackline

IV. Results

A. Our work at study sites indicated that 1977 was another year when Kittiwakes reproduction failed. Approximately one nest in 10 or 15 was successful. The main period of loss seems to have been in late June and early July, as was the case in 1976. Our work in 1977 paid special attention to the behavior of birds which, although their nesting efforts have already failed, continue to hold territories and "go through the motions" suitable for hatching eggs and raising young.

Murres, in contrast to Kittiwakes, apparently had a good year for reproduction in 1977. The unfledged chicks apparently stayed on the ledges before jumping an unusually long time and thus their behavior resembled that described by Tuck (1960). This year we concentrated on making maps of the positions occupied by individual Murres. These maps were made for small sections of ledge. We observed the behavior of individuals after eggs hatched, a time when parental behavior is likely to give the observer a chance to see the chick. The chick often stands in the open and beside the adult during a couple of days before it jumps. We also observed the behavior of birds after they have lost an egg or chick.

We have many notes on the behavior of Ravens and Glaucous Gulls and their interactions with Murres and Kittiwakes. Raven predation was especially noticeable when eggs were first laid and when chicks first appeared. However, Ravens appeared to feed their fledged young on Murre chicks and 15-30 Ravens gathered at the Bluff Cliffs when Murres' chicks were on the cliffs.

B. Our censuses of colonies indicated that there have been only minor changes in the number of birds at those cliffs which we are monitoring. Sledge Island apparently had unusually high numbers of Murres in late June of this year, but no more than in other years in August.

A long period of bad weather in mid-August prevented our getting good estimates of reproductive success for Pelagic Cormorants.

C. During air transects of feeding grounds we found virtually no birds feeding beyond 30 miles from the Bluff Cliffs. Feeding birds were regularly dispersed between 15 and 20 miles and conspicuous inside of 10 miles. In contrast, birds seemed to feed at extremely long distances in 1976.

D. On our waterfowl surveys we found unusually large numbers of "prairie waterfowl" on the south shore of the Seward Peninsula, especially the southeastern shore. The totals of birds counted in the area surveyed in late August was: Pintail - 28,000; Canada Goose - 15,000; Baldpate - 2,500; Whistling Swan - 1,350; Greater Scaup - 1,050; Green-winged Teal - 210; Mallard - 150; Lesser Scaup - 30; Shoveller - 8; Canvasback - 8; Redhead - 4; Sandhill Crane - 400; Dowitcher - 1,300; Whimbrel - 1,800.

We made our surveys at a time that was not suitable for recording the movement of shorebirds. We still are unable to identify several species of shorebirds from the air. The 1977 air surveys and ground observations suggest that a large number of Whimbrels gathered on the southern Seward Peninsula in August, 1977.

E. Springer, of Nome, reported that his detailed search of the islands in Safety Lagoon showed that about 100 pairs of Aleutian Terns nested on 11 islands there. In contrast, Arctic Terns aggregated into two large colonies and were otherwise widely dispersed as solitary nesters.

V. Preliminary Interpretation of Results

A. 1977 was a poor year for reproduction in Black-legged Kittiwakes. It seems to have been a good year for reproduction in Common Murres at Bluff Cliffs and an average year for Glaucous Gulls and Pelagic Cormorants.

B. Pairs of birds which occupy territories on the breeding cliffs evidently find it "worth their while" to continue to defend those territories throughout the season, even though they have lost their egg, chick, or nest. It may be that suitable nesting sites are in such critically short supply that birds gain by investing their energy in maintaining a territory in anticipation of another try the following year. We are interested in the behavioral mechanisms by which the attachment is expressed and reinforced. We are also in a position now to compare the performance and behavior of birds at individual successful and unsuccessful sites over several years. These data will offer valuable insights into the activities of birds where food is short and failure high in contrast to studies made by John Coulson on birds at colonies in northeastern England where food was abundant and failure low.

C. Our observations indicate that Murres and Kittiwakes are very sparce over most of the water in Norton Sound, even considering the effects of a "random dispersal" over the whole area of the number of birds nesting at Sledge, Bluff and Cape Denbigh. This supports our impression that the waters of the sound do not supply as productive feeding grounds as do the areas where birds concentrate west of King Island.

D. Our waterfowl surveys reinforced our impression of the importance of gathering places at Eldorado-Flambeau, Bonanza-Taylor Lagoon, the lower Fish River, the Kwiniuk-Kwik Rivers, and the Koyuk-Inglutalik Rivers. It was especially noteworthy that ducks gathered in large concentrations in tidal areas and the edges between deltas and mudflats.

E. More surface surveys during early June and early August and more flights to search for the distribution of shorebirds are needed.

VI. Problems Encountered

A. Housing at Nome is still an annoying inconvenience. We will be trying yet another combination of storage/housing arrangements in 1978.

B. Access to Sledge Island dependably and frequently enough to get data we want proved to be a problem again. We tried to hire a boat in Nome during 1977, but that proved unsatisfactory, because any day that the large boat was willing to go we could go ourselves in our small boat. We would have very little control over when or how the large boat operated and the cost was very high.

VII. Estimate of Funds Expended

Bluff-Sledge

$ 2,665.00
6,230.00
310.00
135.00
$ 9,340.00

QUARTERLY REPORT

Contract:	01-5-02202538
Research Unit:	RU-337
Reporting Period:	July 1977 to September 1977
Principal Investigators:	C. Lensink & K. Wohl

SEASONAL DISTRIBUTION AND ABUNDANCE OF MARINE BIRDS

Project Leaders

Patrick J. Gould
Shipboard Survey

Craig S. Harrison
Aerial Survey

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

I. Title: SEASONAL DISTRIBUTION AND ABUNDANCE OF MARINE BIRDS

II. Original Objective: The primary objective of this study is to determine the seasonal distribution and abundance of marine birds associated with areas proposed for OCS development.

III. Present Status: Seven shipboard and their aerial operations were completed during the summer field season of 1977. Shipboard surveys included five site-specific operations in the Kodiak Island area aboard a chartered vessel (Yankee Clipper), one cruise from Kodiak through Unimak Pass to St. Matthew Island aboard the NOAA R/V Surveyor, and one cruise in the Kōdiak Island, Northwest Gulf and Northeast Gulf of Alaska aboard the NOAA R/V Surveyor. All aerial surveys covered Lower Cook Inlet and Kodiak Island, and the April Survey additionally covered Alaska Peninsula South, Bristol Bay and St. George Basin (Table 1).

Transcription of data onto coding forms has been completed for most of the above field operations and key punching has been completed for four. Two operations have been taped and submitted to Juneau for final error checking by Hal Petersen.

The process of data verification for all RU 337 data is continuing and nearing completion. Final taped submissions of all RU 337 data will depend on the turn-around time between the U. S. Fish & Wildlife Service and Hal Petersen who is using his computers for final data verification and error checking. A reasonable estimate for final submission of all RU 337 data would be 15 November 1977.

IV. Budget Analysis:

Budget Items	Cost
Salaries	$ 70,000.00
Travel/Per Diem	9,500.00
Equipment	200.00
Logistics	55,000.00
Supplies/Services	2,500.00
Admin. O/H	56,150.00
Data Mgmt.	12,000.00
Total	$ 204,350.00

Table 1. RU 337 Summer Field Operations, 1977.

OPERATION NUMBER	DATES	NUMBER OF TRANSECTS COMPLETED
FW7029	20 April-26 April	450
FW7031	19 May-20 May	175
FW7032	23 May-06 June	265
FW7033	18 June-28 June	245
FW7034	06 July-29 July	312
FW7035	11 August-22 August	240
FW7036	06 September-18 September	200
FW7042	23 June-26 June	36
FW7045	17 June-18 June	159
FW7046	05 September-15 September	163

QUARTERLY REPORT

Contract: 01-5-022-2538/
01-06-022-11437
Research Unit: RU-338
Reporting Period: July 1977 to
September 1977
Principal Investigators: C. Lensink
and K. Wohl

CATALOG OF ALASKAN SEABIRD COLONIES

by

Project Leader

Arthur L. Sowls

and

Jay Nelson

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

QUARTERLY REPORT
Research Unit - 338
July/September 1977

I. Title: CATALOG OF ALASKAN SEABIRD COLONIES

II. Original Objectives: The primary objective of the RU is directed at mapping and summarization of existing data on seabird colonies in Alaska. More specifically this study provides the basic information on colony location, composition and size needed to permit identification of vulnerable areas or species. In addition this cataloging effort will prove invaluable since:

> "The number of individual organisms per species is frequently a decisive factor in the economy or "metabolism" of a biotic community, so much so that monospecific populations might well be considered the basic units of ecological study. In the modern trend of ecological thinking, the question "How many animals or plants per unit area?" is paramount. The answer to this basic question is involved in such useful concepts as annual yield of population, carrying capacity, food web, pyramid of numbers, and biomass (Elton, 1927; Leopold, 1933; Allee et al., 1949), as well as in considerations of genetics and speciation (Simpson, 1944; Wright, 1943, 1945)." (Fay & Cade 1959).

Seabird colony sites represent critical habitat that warrants special management consideration by resource planners. While the catalog information will substantially improve in time the present form nonetheless identifies critical habitat, provides a base for which information may be added, upgraded or corrected and identifies deficiencies in the data base.

III. Present Status: Primary emphasis this quarter has been on revising the colony catalog computer format and format description. Ms. Marcy Butcher of the Juneau Project Office visited our office this quarter specifically to help get the colony catalog format in an "approved" status. The format and description will be forwarded to JPO in early October for final approval. Data submitted on the computer format when known, will include information on location, land ownership, island size or mainland location, occurences of foxes and other disturbances, number of birds by species and their status (breeding, roosting, etc.), the habitat in which they occur, number of nests present, date of data, and "quality" of data.

Emphasis this quarter was also placed on revising our catalog map format. A mock-up of the final map format is attached to this report, (appendix 2) Seabird colonies in the Beaufort, Chukchi, and northern Bering Sea regions were cataloged this quarter and is attached (appendix 1).

Table 1 summarizes the schedule for our colony catalog digital and visual data submissions. For the next quarter we will emphasize submitting digital data for the entire State including extensive revisions, and compiling data in the Aleutian Islands and Southeast Alaska. Upon completion of these two regions the entire State will have been cataloged. Continuing importance will be given to having computer data kept as current as possible to allow for the best available product for data users.

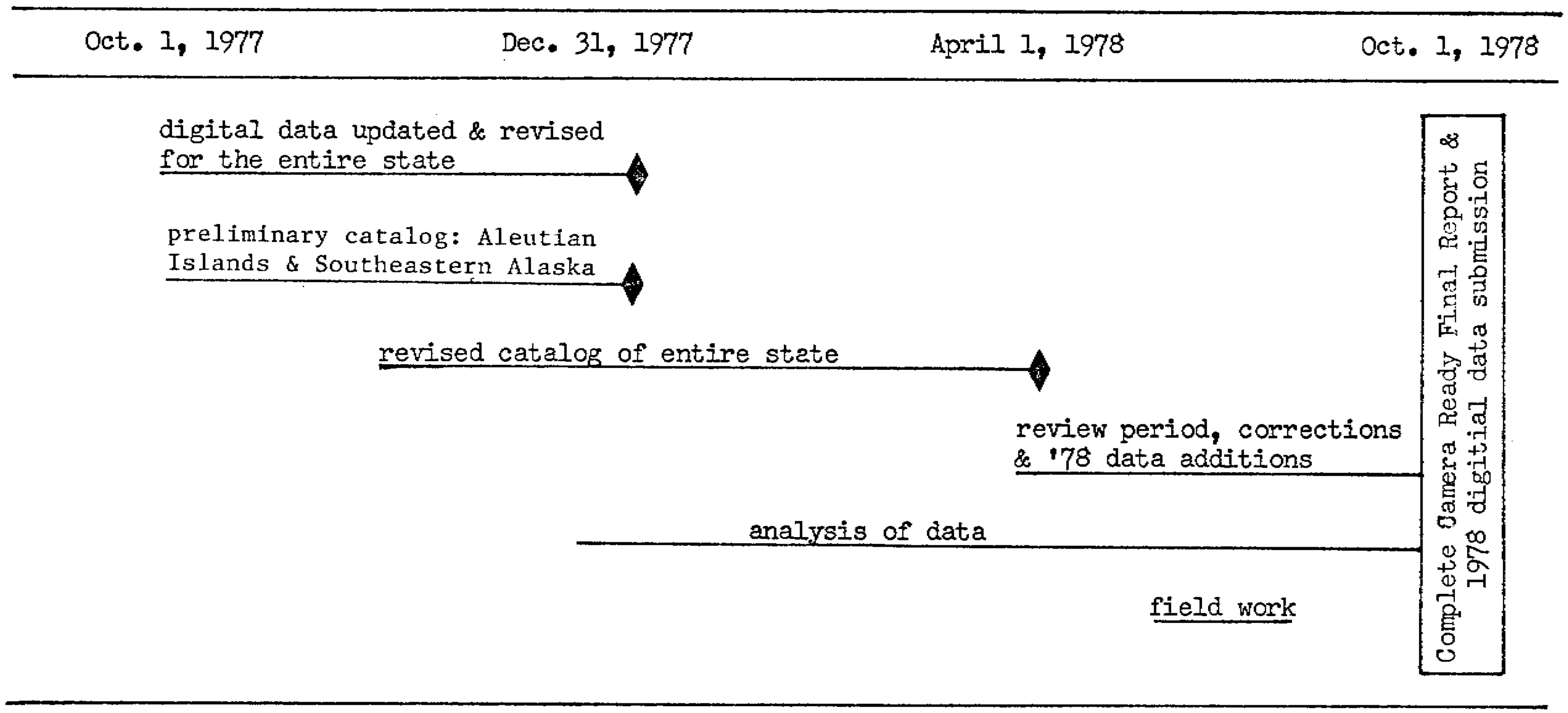
The Annual Report (April 1978) will be a revised catalog (using the new format) for the entire State and will contain substantial new information on the Gulf of Alaska and Bristol Bay regions. A narrative, analysis, maps and tables will be completed (including all summer 1978 data) in camera ready form by October 1978.

After April 1, 1978 our effort will be on : (1) continued analysis of data for the Final Report, (2) reviewing data for completeness and accuracy, (3) coordination with all OCSEAP bird studies and other data sources to insure that as much data as possible from the 1978 field season can be included in the Final Report, (4) final preparation of catalog in a camera ready form, and (5) a field effort to complete colony catalog coverage of Kodiak Island.

IV. Budget Analysis:

Budget Items	Cost
Salaries	$15,000.00
Travel/Per Diem	500.00
Equipment	0
Logistics	0
Supplies/Services	2,500.00
Data Mgmt.	3,500.00
Admin. O/H	11,500.00
	$33,000.00

TABLE 1. Data management schedule for Seabird Colony Catalog.



LITERATURE CITED

BeDard, Jean 1969. The nesting of the crested, least and parakeet auklet on St. Lawrence Island, Alaska. The Condor 71:386-398.

Fay, Francis H. and Cade, Tom J. 1969. An ecological analysis of St. Lawrence Island, Alaska. University of California Press, Berkeley and Las Angeles.

LeResche, R. E. and Hinman R. A., eds. 1973. Alaska's wildlife and habitat. Alaska Dept. of Fish and Game, Juneau. 144p. + 564 maps.

Thompson, C.F. 1967. Notes on the birds of the Northeast Cape of St. Lawrence Island and the Punuk Islands, Alaska. Condor 69( ):411 - 419.

Swartz, L. G. 1966. Sea-cliff birds. Pages 611 - 678, in N. J. Wilimousky and J. N. Wolfe, eds., Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Comm., Div. Tech. Infor. 1250 p.

APPENDIX I

"Catalog of Seabird Colonies: Beaufort, Chukchi and Northern Bering Sea"

STATE OF KNOWLEDGE

Probably all major colonies in this region (Figure 1) have been identified, unfortunately many totally lack population estimates or estimates are of a very crude nature. Figure 2 shows areas of the poorest and the best colony catalog information for the region covered by this report. Those areas identified as having the poorest data have had incomplete or only aerial surveying. Areas of good data have had total coastline coverage and in some cases intensive censusing efforts.

Many small gull, cormorant and especially tern colonies are probably present that have not yet been reported. Species composition information at identified sites is generally more complete than for colony data for the rest of Alaska, due primarily to the total lack of nocturnals in this region. Fork-tailed Storm Petrels are commonly seen near the Pribilofs on pelagic surveys (Harrison pers. comm.), but no evidence of colonies there has been found.

STUDY AREA

While contract requirements stipulate gathering information for those regions being considered for oil and gas leasing, the U. S. Fish & Wildlife Service is cataloging all seabird colonies within Alaska as well as the Atlantic, Gulf and Pacific states. In this report we summarize data for the Beaufort, Chukchi and Bering Sea north of Bristol Bay. While many people are contributing information to the colony catalog, the following and their assistants deserve special thanks: George Divoky, Jerry Ruehle (ADF&G), William Drury (College of the Atlantic), Joseph Hickey and Lance Craighead (University of Wisconsin), Francis Fay (University of Alaska), Tom Cade (Cornell University), and Jean BeDard (University of British Columbia), Jim Bartonek, Dave Cline and Tony DeGange (U.S.F.W.S.).

METHODS

See annual report "Catalog of Seabird Colonies", March 1977.

RESULTS

Data presented in this catalog includes 136 colony areas with an estimated 11,500,000 total birds. This represents an increase of 60 colony areas and approximately 6,500,000 more birds than we had on file in March 1977. This increase is due to censusing efforts done in 1977 of previously uncensused areas, improvement of some very crude aerial data and incorporation of data from cooperators.

Seabirds nesting on the northern coast from Cape Lisburne east are associated primarilly with barrier islands. Populations on islands may vary significantly between years with presence or absence of foxes, thus data is representative only for the year in which it was collected. All barrier islands are probably of long term importance for nesting birds. The entire coast from Cape Lisburne east to Demarcation Bay was surveyed by A.D.F.&G. in 1976, but for other years only local data or no data is available.

RECOMMENDATION FOR FURTHER STUDY

During the 1978 field season emphasis for colony cataloging in the Bering Sea should be placed on Nunivak Island, Cape Vancouver and Cape Ramanzof. Nunivak Island seabirds most certainly are extremely important in the "metabolism" of the eastern Bering Sea and better data from there should be of primary importance.

In the Chukchi Sea a 40 mile stretch of coastline in Kotzebue Sound, near Deering, is in most need of data refinement. The area probably has relatively low numbers of seabirds, but likely comprises a high percent of the seabird life for the sound.

The Chukchi Sea north of Kotzebue and the Beaufort have relatively good colony catalog data and although further censusing is desirerable, it is considered of secondary importance to those areas listed above.

MAPS

Colony Catalog Beaufort, Chukchi and Northern Bering Sea

Maps submitted with this report have been deleted. They will be included in the final report due in October 1978.

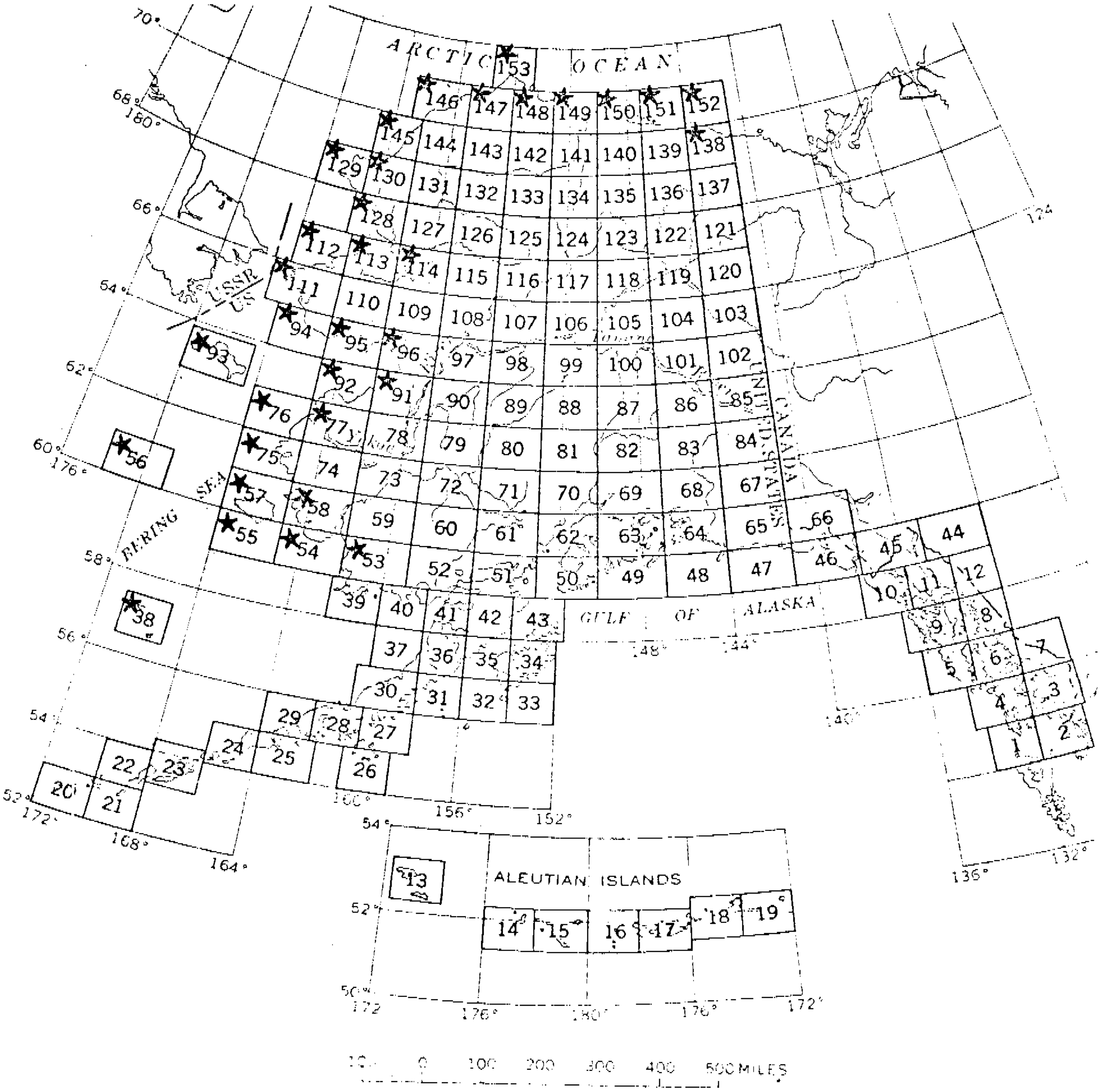


Figure 1. Location of U.S. Geological Survey maps used in the colony catalog and maps (✱) covered by this report on the Beaufort, Chukchi and Bering Sea north of Bristol Bay.

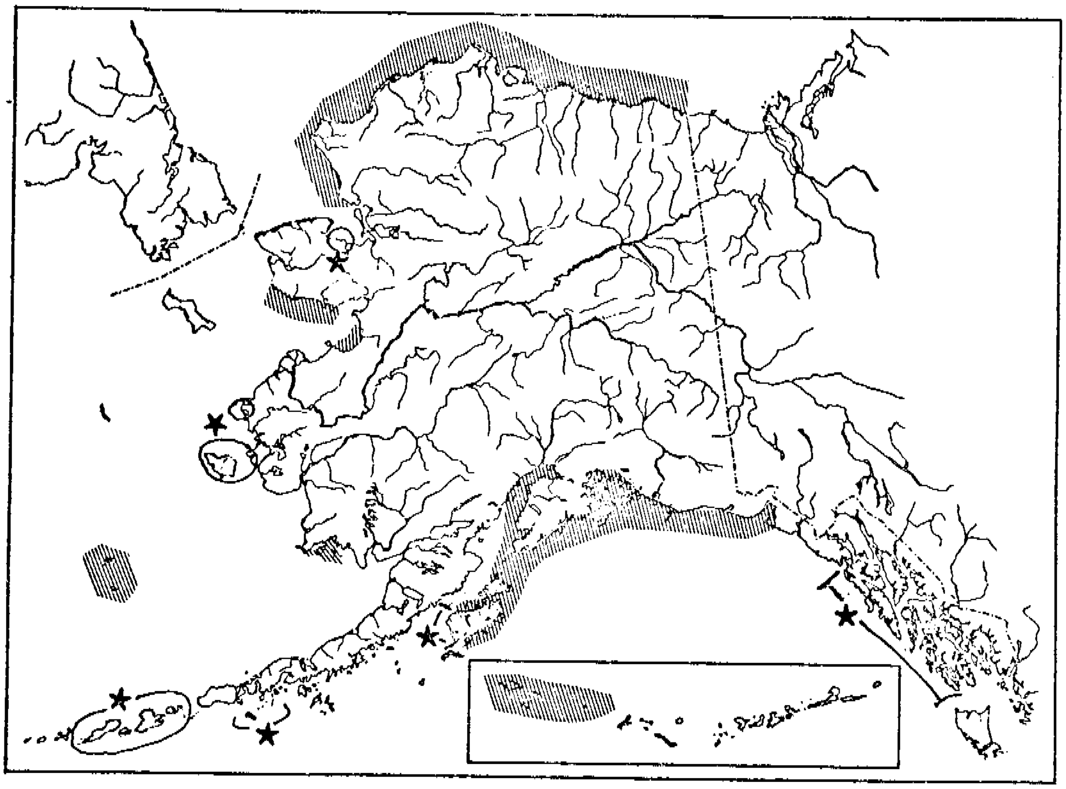


Figure 2. Areas of most complete coverage for seabird colony data (▥) and areas of poorest or no data (★).

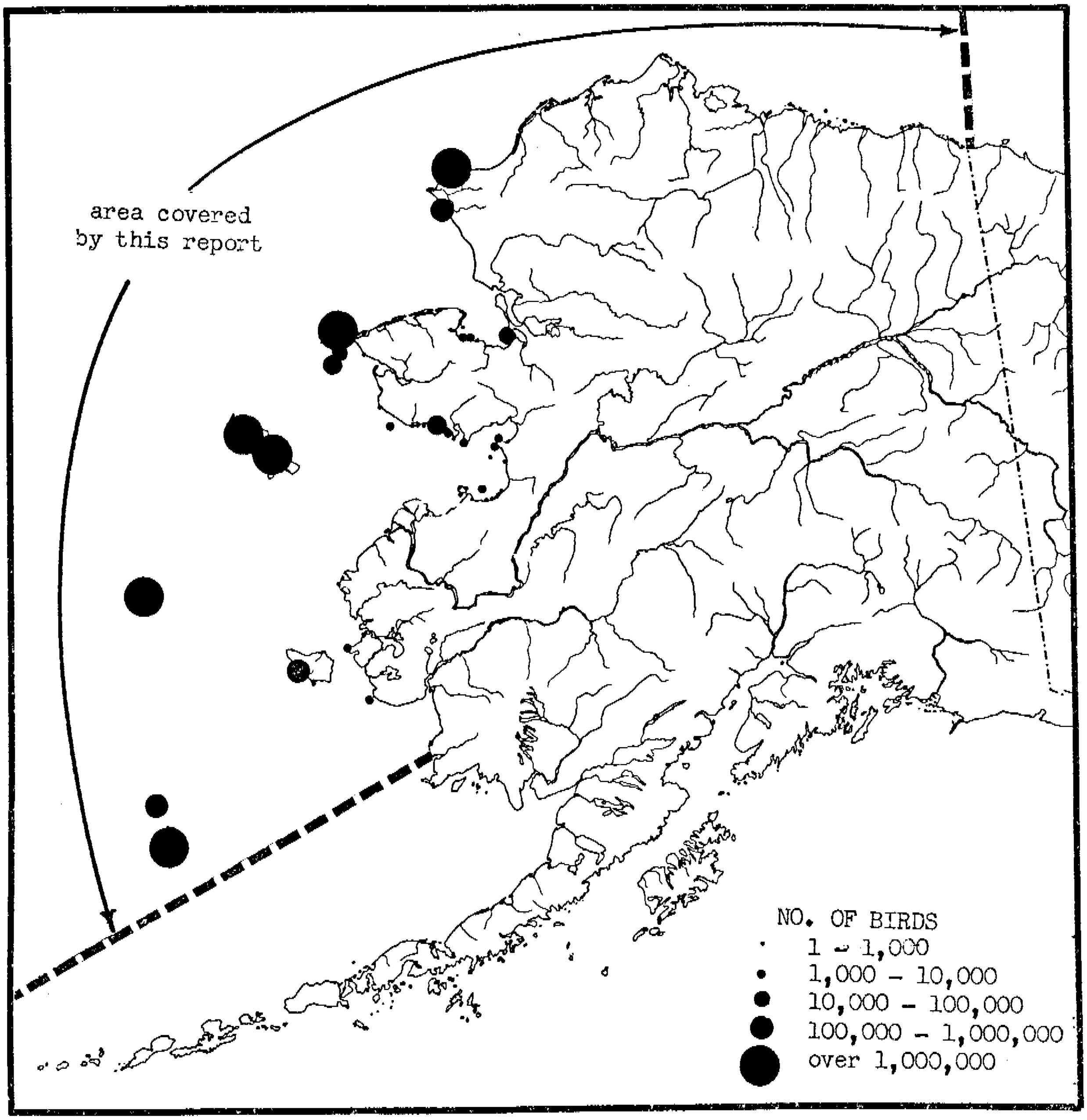


Figure 3. Relative size of seabird colonies in the Beaufort, Chukchi and Northern Bering Sea.

Table 1. Area number, colony name and information source of colonies covered by this report.

AREA NO.	COLONY NAME	INVESTIGATORS	DATE
038 001	St. George Island	Craighead, Hickey	1976
002	St. Paul Island		
003	Walrus Island	Hunt	
004	Otter Island		
053	NO KNOWN COLONIES		
054 001	Kwigluk Island	Bartonek, Cline	
002	13 Foot Island		
003	Pingurbek Island		
004	Kikegtek Island		
055 001	SEE MAP 057		
056 001	Pinnacle Island	Handel	7-26-76
002	Cape Upright	DeGange, Sowls	7-15-77
003	1070 Cliff		
004	Ghost Seal Island		7-14-77
005	Sugarloaf Mountain		
006	Spit Rock & Cliffs		7-13-77
007	West Colony		
008	NW Colony		7-12-77
009	Hall Island		7-09-77
010	Glory of Russia Cape		6-29-77
011	Bull Seal		
012	Receipt Bluffs		
013	Middleast Colony		6-28-77
014	1150 Peak Cliffs		
015	S. Big Lake Cliffs		
057 001	Nunivak Island	Hont	
002	Cape Vancouver	Bartonek, Cline	1973
058	NO KNOWN COLONIES		
075 001	Cape Ramonzof	Bartonek, Cline	1973
076	NO KNOWN COLONIES		
077	NO KNOWN COLONIES		
091 001	Egg Island	Drury et al.	8-01-76
002	Eider Duck Island	Ruehle	1976
003	Tolukowuk Bluffs		
004	Unnamed Colony		
005	Black Cove Island		
006	Black Point		
007	Tolstoi Point		

Table 1 (cont.). Area number, colony name and information source of colonies covered by this report.

AREA NO.	COLONY NAME	INVESTIGATORS	DATE
092 001	North Point	Bartonek, Cline	6-26-73
002	S. Stuart Island	Drury et al.	1976
003	St. Michael Island	Bartonek, Cline	6-26-73
004	Whale & Beulah Island	Drury et al.	8-??-73
		Fay & Cade	1959
093 001	SW Cape	Bedard	1966
002	Sevuokok Mountain		
003	Cape Kagh-Kasalik		
004	Savoonga		
005	Cape Myanghee		
006	Stolbi Rocks		
007	Reindeer Camp		
008	SE Cape	ADF&G	
009	Kinnipaghulghat Mt.	Thompson	1967
010	Punuk Island		
011	Niyghapak Point	ADF&G	
094 001	Sledge Island	Drury et al.	1976
002	Cape Douglas		1975
095 001	Safety Lagoon	Drury et al.	1975
002	Topkok Head		6-01-76
003	Topkok East		1976
004	Tonok		1975
005	Bluff		
006	Square Rock		
007	Little Rocky Point		7-10-76
008	Rocky Point		
009	Cape Darby		8-01-76
096 001	Egavik	Drury et al.	1976
002	Besboro Island		1975
003	Cape Denbigh, South		8-01-76
004	Cape Denbigh, North		
111 001	King Island	Drury et al.	1976
002	Point Spencer		
003	Cape Riley		9-10-76
004	E. York Mountain Cliffs	Bartonek, King	
005	W. York Mountain Cliffs		
006	Tin City	Handel, Harrison, Sowls	8-24-76
007	Cape Mountain	Bailey	
008	Fairway Rock	Drury et al.	
009	Little Diomede Island		
112	NO KNOWN COLONIES		

Table 1 (cont.). Area number, colony name and information source of colonies covered by this report.

AREA NO.	COLONY NAME	INVESTIGATORS	DATE
113 001	Unnamed Island	Bartonek,King	1972
002	Sullivan Bluffs		
003	Near Toawlevic Point	Bartonek,Cline	6-27-73
004	Cape Deceit	Button	1977
005	Near Ninemile Point	Bartonek,Cline	6-27-73
006	Motherhood Point		
114 001	Chamisso Island	DeGange,Sowls	8-13-77
002	Puffin Island		
003	SW Choris Peninsula		8-15-77
004	W. Choris Peninsula		
005	NE Choris Peninsula		
006	E, Choris Peninsula		
007	Elephant		8-14-77
128 ...	NO KNOWN COLONIES		
129 001	Crowbill Point	Swartz	1966
002	Artigotrat		
003	Agate Rocks		
004	Cape Thompson		
005	Imnakpak Cliff		
006	Angmakrok Mountain	Thompson et. al.	
007	Kowtuk	Bartonek, King	8-11-72
008	Kilikralik Creek		
009	Siuiktaneyak Creek		
010	Sigrikpak Creek		
011	Iviagik Mountain		
012	Cape Dyer		
013	Section Line		
014	Cape Lewis		
015	Noyalik Peak		
016	Seesawk		
017	Cape Lisburn		
130	NO KNOWN COLONIES		
138	NO KNOWN COLONIES		
145 001	Omalik Spit	Divoky,Good	7-14-76
002	S. Kasegaluk Spit		7-13-76
003	Sitkok Point Barrier Is.	Gibson,MacDonald	6-28-76
004	Point Lay Barrier Is.	Gibson,Kessel,MacDonald	7-08-76
005	S. Utukok Pass Island		7-13-76

Table 1 (cont.). Area number, colony name and information source of colonies covered by this report.

AREA NO.	COLONY NAME	INVESTIGATORS	DATE
146 001	Solovik Island	Divoky,Gibson,Good, Kessel,MacDonald	7-23-76
002	Icy Cape Spit	Gibson,Kessel,MacDonald, Oakley	7-25-76
003	E. Akoliakatat Pass	Gibson,Oakley,MacDonald	7-25-76
147 001	Seahorse Island	Good,Oakley	8-05-76
002	SE Spit, Peard Bay	Bartonek,Divoky	7-07-73
148	NO KNOWN COLONIES		
149 001	Thetis Island	Hirsch,Oakley,Woodby	1976
150 001	Spy Island	Hirsch,Oakley	6-11-76
002	Long Island	Hirsch,Harvey,Oakley Woodby	1976
003	SE of Long Island	Hirsch,Harvey,Oakley	
004	Egg Island	Hirsch,Oakley,Woodby	
005	Stump Island	Hirsch,Oakley	7-08-76
006	Midway Islands		
007	Narwal Island	Hirsch,Oakley,Woodby	7-06-76
008	Cross Island		
009	Duck Island	Hirsch,Harvey,Oakley, Woodby	1976
010	Point Brower Spit	Harvey,Oakley,Woodby	
011	Spit E. of Pt. Brower		
012	Niakuk Islands	Hirsch,Harvey,Oakley, Woodby	
013	Lion Point	Harvey,Oakley,Woodby	
014	Pole Island	Hirsch,Oakley,Woodby	7-06-76
151 001	Belvedere Island	Hirsch,Oakley,Woodby	7-05-76
002	Challenge Island		1976
003	Alaska Island	Oakley	7-05-76
004	S. of Kangigivik Point	Hirsch,Oakley	7-14-76
152 001	Jago Spit	Hirsch,Oakley	7-13-76
153 001	Point Barrow Spit	Oakley et al.	1976
002	Deadman Island	Forsell,Oakley	8-11-76
003	Cooper Island	Buekelheide,Chiodo,	1976
004	Igalik Island	Harvey,HirschHirsch	8-01-76

Table 38. Summary of data on seabird colonies of map 38, Pribilof Islands.

SPECIES	AREA NUMBER 038 001	038 002	038 003	038 004	Total
Northern Fulmar	70,000	700			70,700
Fork-tailed Storm Petrel					
Leach's Storm Petrel					
Cormorant					
Double-crested Cormorant					
Pelagic Cormorant					
Red-faced Cormorant	5,000	2,500			7,500
Harlequin Duck					
Common Eider					
Bald Eagle					
Black Oystercatcher					
Glaucous Gull					
Glaucous-winged Gull					
Mew Gull					
Black-legged Kittiwake	72,000	31,000			103,000
Red-legged Kittiwake	220,000	2,200			222,200
Arctic Tern					
Aleutian Tern					
Murre			X		X
Common Murre	190,000	39,000			129,000
Thick-billed Murre	1,500,000	110,000			1,610,000
Black Guillemot					
Pigeon Guillemot					
Ancient Murrelet					
Cassin's Auklet					
Parakeet Auklet	150,000	34,000			184,000
Crested Auklet	28,000	6,000			34,000
Least Auklet	250,000	23,000			273,000
Whiskered Auklet					
Rhinoceros Auklet					
Horned Puffin	28,000	4,400			32,400
Tufted Puffin	6,000	1,000			7,000
other					
Total	2,519,000	253,800			2,772,800

X = Present P = Probably Present

Table 54. Summary of data on seabird colonies of map 54, Kuskokwin Bay.

SPECIES	AREA NUMBER 054 001	054 002	054 003	054 004												Total
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant																
Red-faced Cormorant																
Harlequin Duck																
Common Eider	X	P	X	X												X
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	X	P	X	X												X
Glaucous-winged Gull	X	P	X	X												X
Mew Gull																
Black-legged Kittiwake																
Red-legged Kittiwake																
Arctic Tern	P	P	P	P												P
Aleutian Tern																
Murre																
Common Murre																
Thick-billed Murre																
Black Guillemot																
Pigeon Guillemot																
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin																
Tufted Puffin																
other																
Total	X	X	X	X												3,000

X = Present P = Probably Present

Table 56. Summary of data on seabird colonies of map 56, St. Matthew.

SPECIES	AREA NUMBER															Total
	056 001	056 002	056 003	056 004	056 005	056 006	056 007	056 008	056 009	056 010	056 011	056 012	056 013	056 014	056 015	
Northern Fulmar	50,000	15,000	1,500		6,000	1,000	2,000	20,000	112,000	10,000	22				200	217,722
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant	50	200	82	6	200	180	300	700	1,000	140		20		30	60	2,968
Red-faced Cormorant																
Harlequin Duck	P	P	P	P	45	10	30	17	X	20	41		P	P	P	163
Common Eider	P	P	P	P	P	P	P	P	P	26	P	P	P	P	P	X
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	10	50	2	1,000	10	50	20	8	500	10	170	30	8	15		1,863
Glaucous-winged Gull																26
Mew Gull																
Black-legged Kittiwake	3,000	5,000	68		1,200	20	350	6,000	40,000	2,000	1,540	800		270	7,000	67,248
Red-legged Kittiwake																
Arctic Tern																
Aleutian Tern																
Murre	50,000	70,000	500		2,500	5,000	2,000	50,000	300,000	25,000	12,000	2,000		1,300	8,000	528,670
Common Murre	X	X	X		X	X	X	X	X	X	X	X	200	X	X	X
Thick-billed Murre	X	X	X		X	X	X	X	X	X	X	X	170	X	X	X
Black Guillemot																
Pigeon Guillemot	150	200	50		100	50	150	200	1,000	150	100	100	40	20	100	2,410
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet		2,000			600		50	10,000	3,000	100	30	1,500	30		200	17,510
Crested Auklet		25,000			15,000			35,000	20,000			200			200	95,400
Least Auklet		25,000			20,000			50,000	20,000			25,000	60		2,000	142,060
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin	500	1,000	40		100	50	200	300	3,000	300	100	200	100	30	200	6,120
Tufted Puffin	250	P		1,000	4	4	P	10	200	4	1,100	20		P	14	2,606
other																
Total	103,960	143,450	2,242	2,006	45,759	6,364	5,100	172,235	500,700	37,750	15,103	29,870	608	1,665	17,974	1,034,786

X = Present P = Probably Present

Table 57. Summary of data on seabird colonies of map 57, Nunivak Island.

SPECIES	AREA NUMBER														Total
	057 001	057 002													
Northern Fulmar															
Fork-tailed Storm Petrel															
Leach's Storm Petrel															
Cormorant		X													
Double-crested Cormorant															
Pelagic Cormorant	X	P													
Red-faced Cormorant															
Harlequin Duck	X														
Common Eider	X	X													
Bald Eagle															
Black Oystercatcher															
Glaucous Gull	X														
Glaucous-winged Gull	X														
Mew Gull															
Black-legged Kittiwake	X	X													
Red-legged Kittiwake															
Arctic Tern	P														
Aleutian Tern															
Murre		X													
Common Murre	X														
Thick-billed Murre	X														
Black Guillemot															
Pigeon Guillemot	X														
Ancient Murrelet															
Cassin's Auklet															
Parakeet Auklet	X														
Crested Auklet	X														
Least Auklet															
Whiskered Auklet															
Rhinoceros Auklet															
Horned Puffin	X	P													
Tufted Puffin	X	X													
other	X[j]														
Total	>1,000,000	1,000													

X = Present P = Probably Present j = Gyrfalcon,

Table 75. Summary of data on seabird colonies of map 75, Hooper Bay.

SPECIES	AREA NUMBER															
	075 001															
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant	X															
Double-crested Cormorant																
Pelagic Cormorant	P															
Red-faced Cormorant																
Harlequin Duck																
Common Eider																
Bald Eagle																
Black Oystercatcher																
Glaucous Gull																
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake																
Red-legged Kittiwake																
Arctic Tern																
Aleutian Tern																
Murre																
Common Murre																
Thick-billed Murre																
Black Guillemot																
Pigeon Guillemot																
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin	X															
Tufted Puffin	P															
other																
Total	< 1,000															

X = Present P = Probably Present

Table 91. Summary of data on seabird colonies of map 91, Unalakleet.

SPECIES	AREA NUMBER															Total
	091 001	091 002	091 003	091 004	091 005	091 006	091 007									
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant	1		8	8		18	60									95
Red-faced Cormorant																
Harlequin Duck																
Common Eider	4	25			X											29
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	2	25			X	X	50									77
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake	525															525
Red-legged Kittiwake																
Arctic Tern					4											4
Aleutian Tern																
Murre																
Common Murre	2,000															2,000
Thick-billed Murre	40															40
Black Guillemot																
Pigeon Guillemot																
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet	5															
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin	210				100		14									324
Tufted Puffin	25				2											27
other																
Total	2,812	50	8	8	106	18	124									3,121

X = Present P = Probably Present

Table 92. Summary of data on seabird colonies of map 92, St. Michael.

SPECIES	AREA NUMBER															Total
	092 001	092 002	092 003	092 004												
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant	X															X
Red-faced Cormorant																
Harlequin Duck																
Common Eider	X	X	P													X
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	X	X	X	X												X
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake			X	P												X
Red-legged Kittiwake																
Arctic Tern	X	X														X
Aleutian Tern																
Murre		P	X													X
Common Murre																
Thick-billed Murre																
Black Guillemot																
Pigeon Guillemot				X												X
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin	X	X		10												X
Tufted Puffin	X	X		X												X
other			X[c]													X[c]
Total	20	X	200	X												220

X = Present P = Probably Present c = Sabine's Gull,

Table 93. Summary of data on seabird colonies of map 93, St. Lawrence.

SPECIES	AREA NUMBER 093 001	093 002	093 003	093 004	093 005	093 006	093 007	093 008	093 009	093 010	093 011					Total[1]
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant	X	P	P			P				X						100,000
Red-faced Cormorant																
Harlequin Duck																
Common Eider										X						100,000
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	X															10,000
Glaucous-winged Gull	P															X
Mew Gull																
Black-legged Kittiwake	X		X				X									100,000
Red-legged Kittiwake																
Arctic Tern																X
Aleutian Tern																
Murre																
Common Murre	X		X			X										1,000,000
Thick-billed Murre	P		P			X										1,000,000
Black Guillemot																
Pigeon Guillemot		X								P						10,000
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet	X	X	X	X	X		X			X						100,000
Crested Auklet	238,000	72,000	8,000	34,000	185,000		37,000									57,400
Least Auklet	311,000	111,000	14,000	51,000	446,000		20,000			P						963,000
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin	X	X	X	X												100,000
Tufted Puffin	X	X	X	X						X						10,000
other									X^b							X^b
Total																4,067,000

X = Present P = Probably Present b = Kittlitz's Murrelet.

[1] Totals for Crested and Least Auklets are from BéDard, Jean 1969. The Nesting of the Crested, Least and Parakeet Auklet on St. Lawrence Island, Alaska. The Condor 71:386-398. Totals for other species are from Fay, Francis H. and Cade, Tom J. 1969. An Ecological Analysis of the Avifauna of St. Lawrence Island, Alaska. University of California Press, Berkeley and Las Angeles.

Table 94. Summary of data on seabird colonies of map 94, Nome.

SPECIES	AREA NUMBER 094 001	094 002														Total
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant	280															280
Red-faced Cormorant																
Harlequin Duck	11															11
Common Eider	4															4
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	12	160														172
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake	1,300															1,300
Red-legged Kittiwake																
Arctic Tern																
Aleutian Tern																
Murre																
Common Murre	2,500															2,500
Thick-billed Murre	400															400
Black Guillemot	1															1
Pigeon Guillemot	4															4
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet	85															85
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin	160															160
Tufted Puffin	13															13
other	X^k, P^b															X^k, P^b
Total	4,770	160														4,930

X = Present P = Probably Present b = Kittlitz's Murrelet. k = Peregrine Falcon

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Table 95. Summary of data on seabird colonies of map 95, Solomon.

SPECIES	095 001	095 002	095 003	095 004	095 005	095 006	095 007	095 008	095 009	Total
	AREA NUMBER									
Northern Fulmar										
Fork-tailed Storm Petrel										
Leach's Storm Petrel										
Cormorant										
Double-crested Cormorant										
Pelagic Cormorant		319	59	2	125	13	12	416	448	1,394
Red-faced Cormorant										
Harlequin Duck		7	25	30				31	19	112
Common Eider										
Bald Eagle										
Black Oystercatcher										
Glaucous Gull	60	40	32	2	120	80	100	71	290	795
Glaucous-winged Gull										
Mew Gull	1									X
Black-legged Kittiwake					3,700	550	40			4,290
Red-legged Kittiwake										
Arctic Tern	10									10
Aleutian Tern	35									35
Murre										
Common Murre					38,600	3,200				41,800
Thick-billed Murre					400					400
Black Guillemot										
Pigeon Guillemot		20								20
Ancient Murrelet										
Cassin's Auklet										
Parakeet Auklet					65					65
Crested Auklet										
Least Auklet										
Whiskered Auklet										
Rhinoceros Auklet										
Horned Puffin		50	31	5	3,000	100	10	68	575	3,839
Tufted Puffin		30			10	1		4	52	97
other		2^k	2^j		2^k	2^k	1^k	1^d	2^k	$1^d, 2^j, 10^k$
Total	106	468	149	39	46,022	3,946	163	591	1,386	52,870

X = Present P = Probably Present d = Herring Gull, j = Gyrfalcon, k = Peregrine Falcon,

Table 96. Summary of data on seabird colonies of map 96, Norton Bay.

SPECIES	AREA NUMBER															Total
	096 001	096 002	096 003	096 004												
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant	12	90	75	75												252
Red-faced Cormorant																
Harlequin Duck			12													12
Common Eider			3													3
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	5	30	20	30												85
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake			650	1,200												1,850
Red-legged Kittiwake																
Arctic Tern																
Aleutian Tern																
Murre																
Common Murre			4,000	5,300												9,300
Thick-billed Murre			400	600												1,000
Black Guillemot																
Pigeon Guillemot																
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin	12	250	35	40												337
Tufted Puffin				3												3
other			2j	2j												4
Total	29	370	5,197	7,250												12,846

X = Present P = Probably Present j = Gyrfalcon.

Table 111. Summary of data on seabird colonies of map 111, Teller.

SPECIES	AREA NUMBER 111 001	111 002	111 003	111 004	111 005	111 006	111 007	111 008	111 009							Total
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant				X	X											
Double-crested Cormorant																
Pelagic Cormorant	140		100	P	P	20		25	160							420
Red-faced Cormorant																
Harlequin Duck	10															
Common Eider																
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	120	71		X	X			140	135							466
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake	4,000					P		650	35,000							39,65[illegible]
Red-legged Kittiwake																
Arctic Tern																
Aleutian Tern																
Murre																
Common Murre	45,000							5,000	35,000							5,000
Thick-billed Murre	45,000							15,000	25,000							[illegible],000
Black Guillemot									X							X
Pigeon Guillemot	700							100	275							1,075
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet	42,000							500	20,000							62,500
Crested Auklet	22,000							10,000	140,000							172,000
Least Auklet	80,000							15,000	980,000							1,075,000
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin	4,700		100	X		X		75	25,000							29,875
Tufted Puffin	2,300							300	1,000							3,600
other	1^{l}						X^{b}	2^{k}	X^{l}, X^{k}							X^{b}, X^{l}, X^{k}
Total	245,970	71	200	X	X	20	X	46,792	1,261,570							1,554,623

X = Present P = Probably Present b = Kittlitz's Murrelet, k = Peregrine Falcon, l = Dovekie

Table 113. Summary of data on seabird colonies of map 113, Kotzebue.

SPECIES	AREA NUMBER 113 001	113 002	113 003	113 004	113 005	113 006	Total
Northern Fulmar							
Fork-tailed Storm Petrel							
Leach's Storm Petrel							
Cormorant							
Double-crested Cormorant							
Pelagic Cormorant							
Red-faced Cormorant							
Harlequin Duck							
Common Eider	X						X
Bald Eagle							
Black Oystercatcher							
Glaucous Gull	X	X		X		X	X
Glaucous-winged Gull							
Mew Gull							
Black-legged Kittiwake		X		7,000		X	7,000
Red-legged Kittiwake							
Arctic Tern	P						P
Aleutian Tern							
Murre		X	X	200		X	200
Common Murre		P	P	P	X		X
Thick-billed Murre		P	P	P	P		P
Black Guillemot							
Pigeon Guillemot				P	P		P
Ancient Murrelet							
Cassin's Auklet							
Parakeet Auklet							
Crested Auklet							
Least Auklet							
Whiskered Auklet							
Rhinoceros Auklet							
Horned Puffin		P	P	50			50
Tufted Puffin		P	P				P
other	X[f]						X[f]
Total	150	1,000	2,000	7,250	100	300	10,800

X = Present   P = Probably Present   f = Black Brant.

Table 114. Summary of data on seabird colonies of map 114, Selawik.

SPECIES	AREA NUMBER							Total
	114 001	114 002	114 003	114 004	114 005	114 006	114 007	
Northern Fulmar								
Fork-tailed Storm Petrel								
Leach's Storm Petrel								
Cormorant								
Double-crested Cormorant								
Pelagic Cormorant	4	5	5					14
Red faced Cormorant								
Harlequin Duck								
Common Eider	2							X
Bald Eagle								
Black Oystercatcher								
Glaucous Gull	80	75	6	72	6	7		246
Glaucous winged Gull								
Mew Gull								
Black legged Kittiwake		4,000	X	50				4,050
Red legged Kittiwake								
Arctic Tern							21	21
Aleutian Tern								
Murre								
Common Murre	260	7,500						7,760
Thick-billed Murre	60	2,500						2,560
Black Guillemot								
Pigeon Guillemot								
Ancient Murrelet								
Cassin's Auklet								
Parakeet Auklet								
Crested Auklet								
Least Auklet								
Whiskered Auklet								
Rhinoceros Auklet								
Horned Puffin	4,500	10,000	70	80	50	30		14,730
Tufted Puffin	10	10	4					24
other	3j		2j					5j
Total	4,919	24,090	187	202	56	37	21	29,410

X = Present P = Probably Present j = Gyrfalcon.

Table 129. Summary of data on seabird colonies of map 129, Point Hope.[1]

SPECIES	AREA NUMBER															
	129 001	129 002	129 003	129 004	129 005	129 006	129 007	129 008	129 009	129 010	129 011	129 012	129 013	129 014	129 015	129 016
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant	8	36		2			X	75								
Red-faced Cormorant																
Harlequin Duck																
Common Eider							P	25								
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	120	40	104	4	32											
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake		10,400	5,900	3,400	3,400											
Red-legged Kittiwake																
Arctic Tern																
Aleutian Tern																
Murre	5,797	123,000	44,000	8,500	208,000					20	20		3,000	20	200	10
Common Murre	X	X	X	X	X											
Thick-billed Murre	X	X	X	X	X											
Black Guillemot		2			2											
Pigeon Guillemot		4			10											
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin	140	470	190	154	540											
Tufted Puffin	6	34														
other																
Total	6,071	133,986	50,194	12,060	211,984		X	100		20	20		3,000	20	200	10

X = Present P = Probably Present

continued

[1] 1976 & 1977 data on this region (by Renewable Resources Consulting Services, Fairbanks, Ak.) will be incorperated into the colony catalog shortly and will represent much higher quality data for Cape Lisburne and many of the other areas.

Table 129 continued. Summary of data on seabird colonies of map 129, Point Hope.

SPECIES	AREA NUMBER															Total
	129 017															
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant	X															X
Red-faced Cormorant																
Harlequin Duck																
Common Eider																X
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	X															X
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake	X															X
Red-legged Kittiwake																
Arctic Tern																
Aleutian Tern																
Murre																
Common Murre	X															X
Thick-billed Murre	X															X
Black Guillemot	X															X
Pigeon Guillemot	X															X
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin	X															X
Tufted Puffin	X															X
other																
Total	1,000,000															1,417,665

X = Present P = Probably Present

Table 145. Summary of data on seabird colonies of map 145, Point Lay.

SPECIES	AREA NUMBER															Total
	145 001	145 002	145 003	145 004	145 005											
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant																
Red-faced Cormorant																
Harlequin Duck																
Common Eider		6	8	28	22											64
Bald Eagle																
Black Oystercatcher																
Glaucous Gull				4												4
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake																
Red-legged Kittiwake																
Arctic Tern	10	2	28	54	16											110
Aleutian Tern																
Murre																
Common Murre																
Thick-billed Murre																
Black Guillemot																
Pigeon Guillemot																
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin																
Tufted Puffin																
other			$2^h, 2^i$	$4^c, 6^i$	4^f											$4^c 4^f 2^h 8^i$
Total	10	8	40	96	42											196

X = Present P = Probably Present c = Sabine's Gull, f = Black Brant, h = Pintail, i = Oldsquaw,

Table 146. Summary of data on seabird colonies of map 146, Wainwright.

SPECIES	AREA NUMBER															Total
	146 001	146 002	146 003													
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant																
Red-faced Cormorant																
Harlequin Duck																
Common Eider	586	62	442													1,090
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	40	2	10													52
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake																
Red-legged Kittiwake																
Arctic Tern	36	6	42													84
Aleutian Tern																
Murre																
Common Murre																
Thick-billed Murre																
Black Guillemot																
Pigeon Guillemot																
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin																
Tufted Puffin																
other	$4^i, 34^f$	12^f	6^i													$10^i, 46^f$
Total	700	82	500													1,282

X = Present P = Probably Present f = Black Brant, i = Oldsquaw,

Table 147. Summary of data on seabird colonies of map 147, Meade River.

SPECIES	AREA NUMBER															Total
	147 001	147 002														
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant																
Red-faced Cormorant																
Harlequin Duck																
Common Eider																
Bald Eagle																
Black Oystercatcher																
Glaucous Gull																
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake																
Red-legged Kittiwake																
Arctic Tern	24	25														49
Aleutian Tern																
Murre																
Common Murre																
Thick-billed Murre																
Black Guillemot	21															21
Pigeon Guillemot																
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin																
Tufted Puffin																
other																
Total	45	25														70

X = Present P - Probably Present

Table 149. Summary of data on seabird colonies of map 149, Harrison Bay.

SPECIES	AREA NUMBER															
	149 001															
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant																
Red-faced Cormorant																
Harlequin Duck																
Common Eider	76															
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	8															
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake																
Red-legged Kittiwake																
Arctic Tern	2															
Aleutian Tern																
Murre																
Common Murre																
Thick-billed Murre																
Black Guillemot																
Pigeon Guillemot																
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin																
Tufted Puffin																
other	4[e]6[f]															
Total	96															

X = Present P = Probably Present e = King Eider, f = Black Brant,

Table 150. Summary of data on seabird colonies of map 150, Beechey Point.

SPECIES	AREA NUMBER 150 001	150 002	150 003	150 004	150 005	150 006	150 007	150 008	150 009	150 010	150 011	150 012	150 013	150 014		Total
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant																
Red-faced Cormorant																
Harlequin Duck																
Common Eider	8	48	2	48	20	8	66	280	4	10	2	24	12	128		660
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	6	28	22	47	10	6	2	4	70	142	26	275	10	2		650
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake																
Red-legged Kittiwake																
Arctic Tern		4					2									6
Aleutian Tern																
Murre																
Common Murre																
Thick-billed Murre																
Black Guillemot																
Pigeon Guillemot																
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin																
Tufted Puffin																
other		2[e]						2[c]	65[f]	14[f]	2[g]	10[f]	2[i]			2[e]2[c]99[f]2[g]2[i]
Total	14	82	24	95	30	14	70	286	139	166	30	309	24	130		1413

X = Present P = Probably Present c = Sabine's Gull, e = King Eider, f = Black Brant, g = Canada Goose, i = Oldsquaw.

Table 151. Summary of data on seabird colonies of map 151, Flaxman Islands.

SPECIES	AREA NUMBER															Total
	151 001	151 002	151 003	151 004												
Northern Fulmar																
Fork tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double crested Cormorant																
Pelagic Cormorant																
Red faced Cormorant																
Harlequin Duck																
Common Eider	20	8	24	16												68
Bald Eagle																
Black Oystercatcher																
Glaucous Gull	2	8	2	56												68
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake																
Red legged Kittiwake																
Arctic Tern	4	2														6
Aleutian Tern																
Murre																
Common Murre																
Thick-billed Murre																
Black Guillemot																
Pigeon Guillemot																
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin																
Tufted Puffin																
other																
Total	26	18	26	72												142

X = Present P = Probably Present

Table 152. Summary of data on seabird colonies of map 152, Barter Island.

SPECIES	AREA NUMBER															
	152 001															
Northern Fulmar																
Fork-tailed Storm Petrel																
Leach's Storm Petrel																
Cormorant																
Double-crested Cormorant																
Pelagic Cormorant																
Red-faced Cormorant																
Harlequin Duck																
Common Eider	8															
Bald Eagle																
Black Oystercatcher																
Glaucous Gull																
Glaucous-winged Gull																
Mew Gull																
Black-legged Kittiwake																
Red-legged Kittiwake																
Arctic Tern	6															
Aleutian Tern																
Murre																
Common Murre																
Thick-billed Murre																
Black Guillemot	2															
Pigeon Guillemot																
Ancient Murrelet																
Cassin's Auklet																
Parakeet Auklet																
Crested Auklet																
Least Auklet																
Whiskered Auklet																
Rhinoceros Auklet																
Horned Puffin																
Tufted Puffin																
other																
Total	16															

X = Present P = Probably Present

Contract: 01-5-022-2538
Research Unit: 341
Period: July 1 to September 30, 1977
Principal Investigators: C. Lensink & K. Wohl

QUARTERLY REPORT

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

Project Leaders

G. A. Sanger
Feeding Ecology and Trophic Relationships

R. E. Gill, Jr.
Population Dynamics

U.S. Fish & Wildlife Service
Office of Biological Service - Coastal Ecosystem
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Research Unit - 341
July/September 1977

I. Title: Population Dynamics and Trophic Relationships of Marine in the Gulf of Alaska and Southern Bering Sea.

II. Objectives: Research Unit 341 is designed to help satisfy OCSEAP task objective E which is "what are the biological populations and ecological systems most subject to impact from petroleum exploration and development?" More specifically, this RU helps satisfy tasks E-3 and E-4 which are to "determine the seasonal density distribution, critical habitats, migratory routes, and breeding locales of key marine bird species "and" to describe dynamics and trophic relationships of key marine bird species at offshore and coastal study sites" (FY 78 OCSEAP TDP). More specifically, our objectives are:

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

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

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

While some of our investigators are still in the field most camps were deactivated in late September; consequently, this report is necessarily brief and cursorily reports those activities which occurred from 1 July to 31 September 1977.

III. Present Status: Field activities under this RU were restricted to the Gulf of Alaska and southern Bering Sea (see Table 1). Major field accomplishments during this quarter included continued data collection at our site-specific intensive colony study areas at Wooded Islands, Barren Islands, Chiniak Bay, Sitkalidak Straits, Ugaiushak Island, Chowiet Island and Nelson Lagoon. In addition, we completed our 70-day, 5-leg charter cruise which was associated with our pelagic feeding

FWS Field Schedule

Study Site	Camp Activation	Camp Deactivation	FWS Personnel	Task Objectives
Wooded Islands	Mid Apr.	Mid Oct.	P. Mickelson et al.	Pop. Dynamics/Breeding Success Beached Bird Survey & Colony Inventory
Barren Islands	Early May	Late Aug.	D. Manuwal et al.	Pop. Dynamics/Breeding Success Feeding Ecology & Colony Inventory
Chiniak Bay	Late May	Early Sept.	D. Nyeswander, E. Hoberg, & J. Nelson	Pop. Dynamics/Breeding Success Beached Bird Survey Colony Inventory and Feeding Ecology
Sitkalidak Straits	Late May	Mid Sept.	P. Baird, A. Moe, et al	Same as above
Ugaiushak Island	Mid Apr.	Late Aug.	D. Wehle et al.	Same as above
Chowiet Island	Mid Apr.	Early Sept.	S. Hatch et al.	Same as above
Nelson Lagoon	Mid Apr.	Mid Oct.	R. Gill, C. Handel, M. Petersen, et al.	Same as above
Kodiak Pelagic Feeding Ecology Study (Charter Vessel)	23 May-6 June 18 June-28 June 6 July-29 July 11 Aug-22 Aug 6 Sept.-18 Sept.		G. Sanger, D. Forsell et al.	Feeding ecology and at sea population assessment & distribution
Unimak Pass	Early Apr.	Mid May	J. Nelson, et al.	Migration Survey

Table 1 (cont'd.)

B. Laboratory Schedule

	Total thru June 1977	Total thru July 1977	Total thru August 1977	Total thru September 1977
Collected Food Samples	951	1069	1187	1875
Samples Accessioned into Collection	951	1069	1187	1265
Final Analysis	305	305	305	364

C. Methods

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

and trophic relationship study task. Seabird distribution and abundance observations were also collected in support of RU-337. The vessel was also used to a limited extent in resupplying and supporting our data collection efforts at our Sitkalidak Straits field camp.

Field work at our Sitkalidak Straits camp was initiated on 28 May, and continued to 12 September 1977. Pat A. Baird and R. Allen Moe participated in the project for the entire period, and Tim Keyser assisted from 1-28 July.

The area of Sitkalidak Straits that was studied supported breeding populations of 10,000 Tufted Puffins, 5,000 Black-legged Kittiwakes, 3,000 terns (both Arctic and Aleutian), 2,000 Glaucous-winged Gulls, and lower numbers of Red-faced and Pelagic Cormorants, Horned Puffins, Mew Gulls, and Pigeon Guillemots. Various aspects of the habitat requirements, feeding ecology and breeding biology of the birds were examined. Most of the research effort concentrated on Tufted Puffins and Black-legged Kittiwakes, with a lesser emphasis on Glaucous-winged Gulls and terns.

In addition to determining the distribution and abundance of marine birds in the Sitkalidak area the field work included:

1. Establishing 27 permanent sample plots to determine breeding density, reproductive success and habitat requirements of the various species. From these plots annual fluctuations in the above parameters may be identified.

2. Determining the growth rates of the major species to serve as an indication of the abundance of food resources during the 1977 season.

3. Collecting the stomachs from 97 adult birds engaged in feeding activities and collecting 402 chick regurgitations and food found at the nests to determine what food resources were selected by each of the major species, and if this selection changed as the season progressed.

4. Establishing two permanent beach transects for beached bird surveys. One of these was on the inside waters of Sitkalidak Strait, and one was on the ocean side of Sitkalidak Island. From these surveys we can then monitor any changes in pelagic mortality rates of birds and mammals as oil development progresses.

In general, field work at Sitkalidak Straits was performed in a very smooth and efficient manner. Data analysis is now underway and our prognosis for achieving relevant data results is very good.

Eric Hoberg and David Nyeswander initiated the intensive breeding studies of marine birds in the Chiniak Bay vicinity in early June.

Ten island and two mainland (Kodiak Island) study sites of breeding colonies of marine birds were utilized for census, chronology, and productivity studies. Information was gathered primarily on the following eight species with the number in parentheses indicating number of nests or burrows used in productivity studies: Black-legged Kittiwake (365), Pelagic (111) and Red-faced (70) Cormorants, Mew (66) and Glaucous-winged (63) Gulls, Arctic (96) and Aleutian (45) Terns, and Tufted Puffin (106). Incidental data was gathered on birds such as Common Eider (19), Horned Puffin (1), Pigeon Guillemot (1), Black Oystercatcher (5), Red-breasted Merganser (2), Least Sandpiper (1), Semipalmated Sandpiper (1), and Raven (1). On 22 August breeding biology studies were terminated.

Nine beached bird surveys covering a total of 14.9 km were continued or begun. These transects sampled areas that stretched between Womens Bay and Narrow Cape.

Between 13 June and 1 August, 111 seabirds were collected for analysis of stomach contents and parasites. Between 4 and 8 August we banded 349 Mew and Glaucous-winged Gulls.

Again, field work in the Chiniak Bay area went smoothly and without encountering major obstacles. The study was well planned and our prognosis for achieving solid results is excellent.

Scott Hatch and Duff Wehle initiated their marine bird studies at Chowiet and Ugaiushak Islands, respectively, around late April and completed those studies around the first part of September. Like the previous field season, Hatch concentrated his efforts on the Fulmar while Wehle concentrated on Tufted Puffin, Black-legged Kittiwake and Glaucous-winged Gull. Feeding ecology and beached bird survey studies were also an integral part of those studies.

More specifically, at Chowiet Island data of a similar nature to those obtained during the 1976 breeding season were collected in a similar manner for purposes of comparison. As before, the principal areas of study included phenology, survival of eggs and young, chick growth, details of the incubation rhythm in breeding birds as an indicator of environmental conditions, and the seasonal patterns of colony attendance and molt. In addition, the diurnal pattern of colony attendance was observed in some detail this year. Contrasts in several of these areas between the two years of study were associated with a better than three-fold increase in overall breeding success in 1977 over 1976.

Data are now available on events at some 300 nest-sites observed in both 1976 and 1977. By utilizing the color polymorphism in the Semidi Islands population as a research tool the study is designed to provide certain types of data on population dynamics otherwise difficult to obtain. This involves the identification of selected nest-sites in photographs which can be followed for more than one breeding season. The sample of breeding sites established to date totals about 540. In over half of these one or both of the occupants are individually recognizable, i.e., they may be identified again in subsequent years or their disappearance may be detected.

Generally, they both had very successful field seasons and the prognosis for sound results from their two seasons worth of data is excellent and will provide valuable baseline information for BLM.

Robert Gill, Margaret Petersen, and Colleen Handel initiated the Nelson Lagoon study in mid April; field studies are schedule for completion in mid-October. Spring and fall bird migrations have been monitored in this study. Aerial and ground surveys are helping to establish habitat use and distribution patterns in the vicinity of Nelson Lagoon.

The intertidal invertebrate sampling scheme at Nelson Lagoon was continued this quarter. Two 50-meter transect lines have been established adjacent to the Nelson Lagoon field camp. Five stations have been established along each transect whereby five samples each are periodically obtained. The sample equipment is a clam gun which is used to obtain a sample 14 cm in depth, i.e., equal to a volume of 1 liter. Each sample is sorted through 2 mm and .59 mm sieves. All organisms retained in both sieves are preserved in 10% formalin and later transferred to 50% isopropanol solution.

During this quarter a concentrated effort has been directed at banding shorebirds. Gill encountered spectacular migrant populations and experienced significant success in banding shorebirds. We are already receiving many significant banding reports from as far away as California and we are cautiously optimistic about establishing turnover patterns and migration routes for several shorebird species.

This study has experience somewhat unexpected, significant, and pleasant results and our prognosis for contributing significantly to the relevant baseline data base is excellent.

Stan Senner began field work during the spring shorebird migration at the Copper-Bering River Delta, Kachemak Bay, Hooper Bay, Cape Espenberg, and Cape Krusenstern. At all locations specimens of migrating Calidris alpina and C. mauri were secured for analyses of their lipid levels, calcium levels, and stomach contents. In total, 185 calidridine sandpipers were collected at the five sites. Additionally, about 300 sandpipers, primarily C. mauri, were live-captured, banded, and weighed at Kanak Island in the Bering River Delta. Weights and measurements from these birds will supplement data from the sacrificed birds.

At present, laboratory analyses of the shorebird carcasses and their stomach contents are proceeding. It is anticipated that the food habits portion of this study will be completed in the following quarter.

One of the interesting aspects of the study which can be commented on at this stage is the migration at Kachemak Bay. Dave Erikson, our field assistant at Kachemak Bay, recorded a peak of over 600,000 small sandpipers, about 98 percent of which were C. mauri, on 6 May at the Fox River flats. His observations at the Fox River flats and at Mud Bay consistently showed that C. mauri far outnumbered alpina. These observations are consistent with the investigator's hypothesis that C. mauri leaving the western end of the Copper-Bering system need intermediate stops at places such as Lower Cook Inlet before reaching breeding grounds in the Yukon-Kuskokwim Delta. We predicted, however, that C. alpina leaving the Copper-Bering system had fat reserves sufficient to reach the Bering Sea coast without other feeding stops. Following analyses of the specimen lipid levels and morphometric body measurements, we should better be able to evaluate the hypothesis and observations.

A concerted effort has been spent on getting our feeding, specimen, beached bird survey, and breeding biology digital data formats in an OCSEAP "approved" status.
We believe we have finally gotten those formats and their descriptions in an approved form. We are now proceeding with transcription of our field data onto our new forms. Our schedule for digital data submission is to have the data transcribed, key punched, verified, and taped by 31 December 1977. To date, we have final sorted all 1975 and 1976 food samples for our key species. In addition, we have already completed final sorts on about 50% of our 1977 food samples. With our formats revised and approved our prognosis for our data management is very good. We foresee no significant data management problems now which is a substantial change over our past performance.

QUARTERLY REPORT

Contract #03-5-022-56

Research Unit #441

Task Order #27

1 July -- 30 September 1977

Avian Community Ecology at Two Sites on Espenberg Peninsula in Kotzebue Sound, Alaska.

Principal Investigator: P. G. Mickelson, Institute of Arctic Biology

Report Prepared By: Douglas Schamel, Diane Tracy and Anne Ionson

I. TASK OBJECTIVES

1. To determine phenology of events from spring arrival through departure of birds,

2. to determine the distribution and abundance of birds and their predators,

3. to describe habitat utilization of birds and their predators during migration, the nesting season, and the brood rearing season,

4. to estimate production of all avian species nesting on Cape Espenberg,

5. to determine the abundance of small mammals which are utilized by avian and mammalian predators,

6. to describe availability of food and utilization by shorebirds,

7. to determine distribution and abundance of sea mammals,

8. to provide recommendations to lessen the impact of developments on the avian community and avian habitat at Cape Espenberg,

9. to establish baseline study plots to evaluate the impact of developments on the avian community and avian habitat at Cape Espenberg,

   and

10. to assess bird use of coastal habitats in southern Kotzebue Sound by flying aerial surveys at regular intervals.

II. FIELD ACTIVITIES

A. Field Trip Schedule

Investigator	Days in Field	Dates 1977
Anne Ionson	131	19 May-26 Sept.
Diane Tracy	122	28 May-26 Sept.
Douglas Schamel	106	19 May-1 Sept.
Steven Long	80	28 May-15 Aug.
Dena Matkin	78	28 May-13 Aug.

One special trip to evaluate hatching success on an island in Kotzebue Sound southeast of Cape Espenberg was taken in the private boat of Fred Goodhope, Jr. on 28 July.

Aerial surveys were flown from Cape Espenberg to Kiwalik Lagoon, southeast of the Cape on: 1) 3 June, 2) 15 July, 3) 1 August, 4) 15 August, 5) 1 September, and 6) about 15 September.

Schamel and Long took a day-long hike along the Kotzebue Sound coast, south of Espenberg on 2 August.

B. Methods

Techniques of study in 1977 remained unchanged from 1976 for the following: 1) shorebird nesting plots, 2) predator distribution and numbers, 3) predator pellet and scat collection, 4) small mammal trapline, 5) sticky boards, 6) beach carcass surveys, 7) bird census transects, 8) avian phenology, 9) marine mammals, and 10) native and reindeer use. We refer the reader to the September 1976 Quarterly Report for details of methods involving the above topics. Certain phases of the study were either modified, expanded or added after the 1976 field season. These are explained below.

Waterfowl Nesting Plots

Three waterfowl nesting plots were studied in 1977. Plots 1 and 2 (each ca. 1.0 km^2) were established in 1976 and studied both years. Plot 3 (ca. 0.001 km^2) was an island, located in a large lake in the south-eastern portion of the Cape, which supported a high nesting density of eiders in 1976.

Plots 1 and 2 were systematically searched for nests using a 50 m rope. With one person positioned at either end of the rope, investigators walked easterly and westerly covering a 50 m swath. The only departure from this procedure occurred in the marshy area of Plot 1. Here, three people searched all possible nesting sites as they progressed abreast through the marsh.

When a bird flushed, the immediate area was searched for a nest. Each nest was assigned a number and the date, species, number of eggs, and approximate location recorded. In addition, waterfowl, loon and Arctic Tern eggs were floated to determine the stage of incubation (Westerkov, 1950).

Waterfowl, loon, Arctic Tern, and Parasitic Jaeger nests were visited until either destroyed or hatched (after the initial visit, egg number, flotation position, and fate were noted). When predation occurred, the predator if known, was recorded.

After hatch, waterfowl, Arctic Tern, and Parasitic Jaeger nests were located more accurately and surrounding vegetation examined. The former was accomplished by measuring the distance of each nest from two stakes of grids placed earlier in the 1977 field season. Vegetation around the nest was delimited by placing a hoop 1 m in diameter over the nest bowl. The percent cover of each plant species was recorded. A measure of vegetation height within the quadrat was obtained by recording the height at which approximately half the vegetation was taller and half the vegetation was shorter - the median height.

Plot 3 was searched by two people without the aid of a rope. This plot was small enough that all nests could be easily found by walking through the area. This plot, as of 31 August, had been visited twice this year. In July, each nest was assigned a number, located on a map and fate recorded. The number of eggs in each nest was also recorded. In addition, the eggs of approximately 65 Common Eider nests were floated. After hatch, the island was visited again and nest fate determined.

Dune Nesting Plot

This plot was located in the dunes of the north-central portion of the Cape and was approximately 82 m wide by 1 km long (0.082 km^2).

Nests were found by three investigators walking through the area on 7-8 June. When a bird flushed, the vicinity was searched. Each nest was assigned a number and the species and number of eggs recorded.

Plant Phenology and Floristics

Flowering plants were collected, pressed, and tentatively identified. Flowering dates were noted for all pressed specimens. A range of flowering dates was recorded for approximately forty species.

Weather

Weather information recorded daily included: 1) maximum and minimum temperatures, 2) wind direction, 3) wind velocity, 4) sky cover, and 5) precipitation.

Aerial Mapping of Vegetation and Habitat

The vegetation and habitat map created by Principal Investigator Mickelson from aerial photographs taken in 1976 is presently being checked (on the ground) for accuracy and consistency by Diane Tracy.

Banding, Tagging, and Marking

We continued our banding program on breeding shorebirds and their young in 1977. Banding effort was increased for young Parasitic Jaegers and Glaucous Gulls. Since Emperor Goose broods left the Cape soon after hatching in 1976, we did not attempt to web-tag any young in 1977.

Two colonies of Glaucous Gulls were color-marked, one with pink and one with black dye, by placing dye-soaked cotton near the nests. Several Sabine's Gulls and Arctic Terns were color-marked with black dye in the same manner. The locations, habitats, and activities of color-marked birds were recorded.

Predator Watch

In order to assess the importance of the various predators to breeding birds, a predator watch was established at the Marsh Shorebird Plot from mid-June through mid-July. During a watch, one person observed a 15 ha part of the Marsh Plot. Data recorded on all predators included: 1) species, 2) time of entry into the plot, 3) movements, 4) predatory activities, 5) interactions with nesting birds, 6) interactions with other predators, 7) time of exit from the plot, and 8) activities outside of plot. Watches generally lasted from 18:00-22:00, 5 or 6 days each week.

Intertidal Invertebrate Collection

The intensive intertidal sampling initiated in 1976 was repeated in mid-August at all six sampling locations on the Cape. An additional site, on the mudflats at the south edge of Espenberg Bay, was added in 1977. In mid-July, one station along the Chukchi coast, two stations on the bay coast, and the mudflats were sampled less intensively. Five replicate samples were taken 1) in 2 cm deep water and 2) at the water edge. Hopefully, Diane Tracy will be able to repeat this less intensive sampling in mid-September, weather permitting.

Mud samples were collected from the Cape and the south mudflats as a preliminary assessment of shorefly larvae and pupae density. These insects were important food items for shorebirds in 1976.

Baited traps were set in the Chukchi Sea and in Espenberg Bay in an effort to capture the isopod *Saduria entomon*.

Shorebird Stomach Analysis

A total of 10 shorebirds were collected for food habits studies: 8 Dunlin and 2 Sanderlings. All birds were weighed and measured. Sex was determined by dissection. Stomachs were removed from all birds within 10 min after collection and preserved in 10% buffered formalin.

Mudflats Survey

Estimates of bird numbers on the south mudflats were made regularly in 1977, usually between 16:00 and 18:00. Except during late July and early August, when smoke from nearby forest fires obscured the mudflats, counts were conducted at least three times weekly. Occasional visits to these mudflats in the 2-man raft provided species composition estimates for waterfowl and shorebirds.

Aerial Surveys

Beginning in mid-July, we flew fixed-wing aerial surveys of coastal Kotzebue Sound (Espenberg Bay to Kiwalik Lagoon) at two-week intervals through mid-September. An additional survey was conducted in early June. Surveys were flown in a Maule at an altitude of about 30-40 m and a ground speed of 53.6 m/sec (120 mph). Surveys through 1 September involved three observers and the pilot. Two observers estimated bird numbers within approximately 200 m of either side of the plane, while the third observer called out landmarks. Bird numbers for each coastal section were recorded using tape recorders. Birds over somewhat larger distances (≈ 300 m) from the plane were recorded in river deltas. After 15 July, we avoided the seabird nesting cliffs at Sullivan Bluffs and Cape Deceit.

C. Sample Localities

Figure 1 gives the locations of: 1) study area, 2) south mudflats, 3) intertidal sampling stations, 4) camp, and 5) eider island (waterfowl Plot 3). Figure 2 gives the locations of nesting plots (except waterfowl Plot 3) and census transects.

D. Samples Collected

1.	Glaucous Gull pellets	ca. 3000
2.	Parasitic Jaeger pellets	ca. 25
3.	Fox scats	ca. 50
4.	Intertidal invertebrate samples	210
5.	Bird stomachs	10

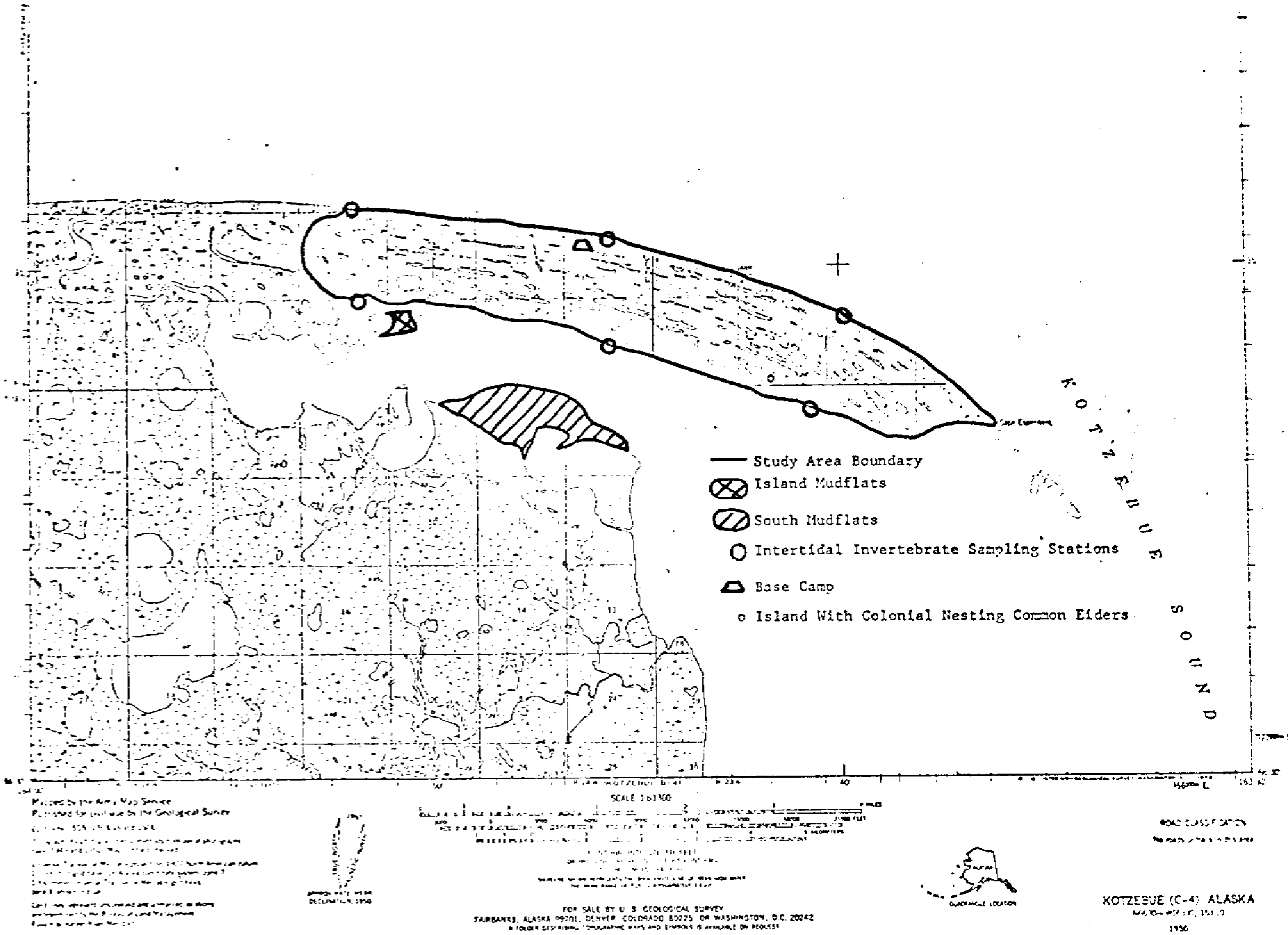

FIGURE 1. LOCATIONS OF STUDY AREA, ISLAND MUDFLATS, SOUTH MUDFLATS, INTERTIDAL SAMPLING STATIONS, CAMP, AND, ISLAND WITH COLONIAL NESTING COMMON EIDERS.

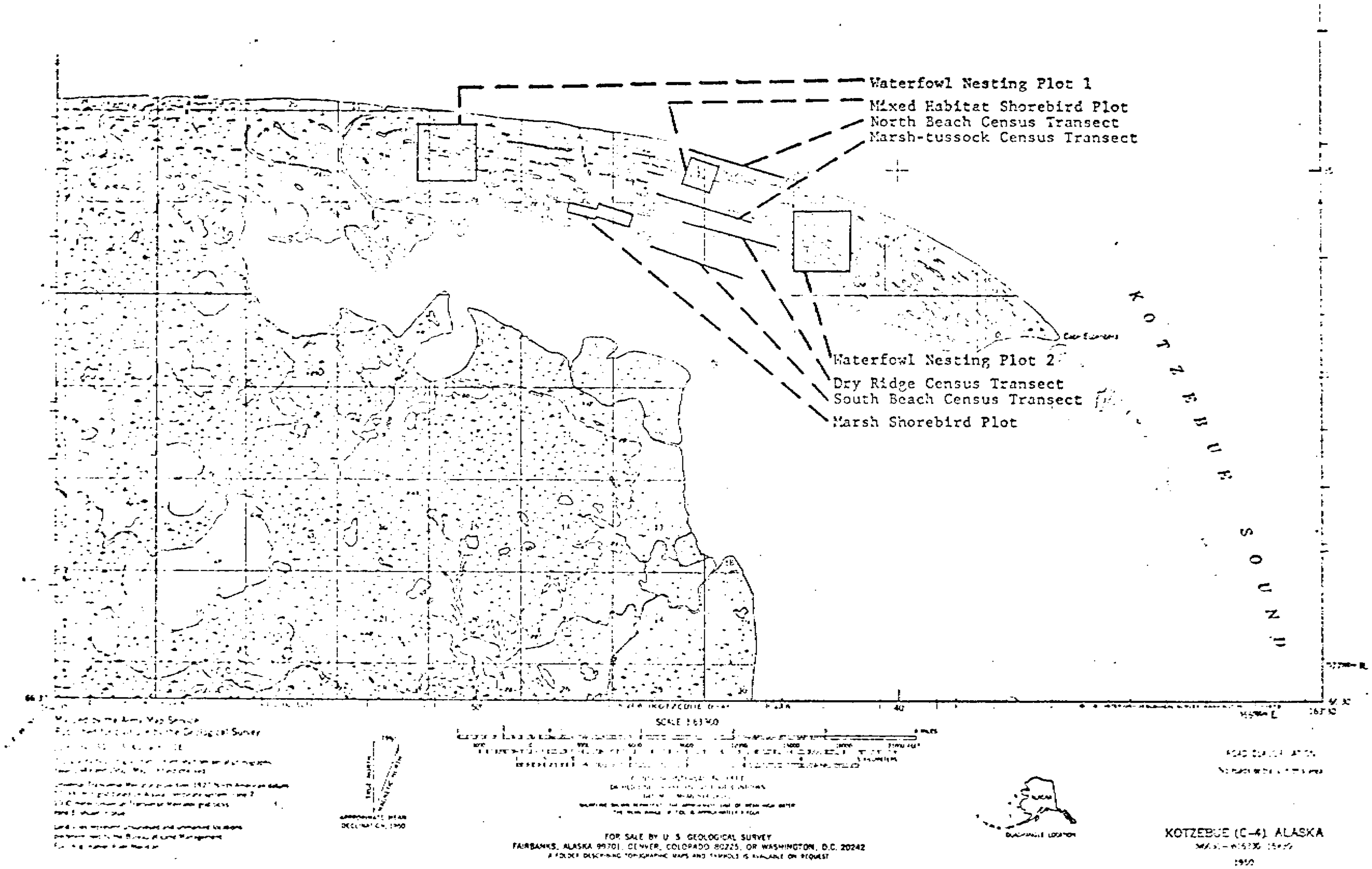

FIGURE 2. LOCATIONS OF NESTING PLOTS AND CENSUS TRANSECTS.

III AND IV. RESULTS AND PRELIMINARY DISCUSSION OF RESULTS

A list of 83 bird species seen on Cape Espenberg during 1976 and 1977 and the breeding status of each is given in Table 1. This figure represents an increase of 15 species over the total for 1976. Five new nesting species were added in 1977: Pintail, Northern Shoveler, American Golden Plover, Black-bellied Plover, and Pectoral Sandpiper. With the exception of Pintails, these birds nested in very low densities. Pintails nested in moderate numbers on the Cape, as well as at Kitluk River, west of our study area (John Wright, pers. comm.). Based upon conversations with other investigators throughout the state, there was a large influx to Alaska of ducks which normally breed in the prairie pothole regions of North America. The displacement was caused by drought in their normal breeding areas, a phenomenon which has been recorded in the past (Hansen and McKnight, 1964).

Breeding status categories in Table 1 are defined as follows: 1) common nesting - high breeding densities throughout the Cape, 2) moderate nesting - either found in moderate breeding densities throughout the Cape or locally abundant only, 3) uncommon nesting - only a few nests found, 4) probable nesting - established and defended territories or acted "broody" but neither nests nor young were found, and 5) not nesting - all others.

Results of studies in the nesting plots are provided in Tables 2-4. In general, plot data yielded remarkably similar data for the two summers. The most noticeable difference is the addition of Pintails in 1977. Shorebird plots (Table 2) showed a decided drop in Greater Scaup nests in 1977. In contrast, scaup were decidedly more numerous in waterfowl plots (Table 3) in 1977. The increase in Oldsquaw and Arctic Tern nests in the marsh shorebird plot in 1977 (Table 2) is most likely due to renesting attempts. At least some of the increase in Semipalmated Sandpiper nests in 1977 in the marsh plot can be attributed to renesting and/or early predation and resultant space availability. A more complete discussion of these nesting plots will appear in a future report.

We were constantly on the alert for returning color-banded shorebirds that had been marked in 1976. When they were encountered, we recorded: 1) species, 2) color combination, 3) location, and 4) activity of each bird. Although final figures are not yet complete, a few general comments are appropriate at this time. Several species had high return rates (ca. 50% of the adults). These include: Ruddy Turnstones, Dunlins, Semipalmated Sandpipers, and Northern Phalaropes. Western Sandpipers and Red Phalaropes had much lower return rates. Adult Parasitic Jaegers (marked only with aluminum bands in 1976) also showed a high rate of return. A detailed analysis of site tenacity will be forthcoming.

Because many of the adult shorebirds were strongly site tenacious, the results of our banding activities (Table 5) are somewhat misleading

Table 1. Birds observed at Cape Espenberg. 1976 and 1977.

Species	Year[1]	Nesting Status[2] 76	77
Yellow-billed Loon (Gavia adamsii)	6,7	pn	n
Arctic Loon (Gavia arctica)	6,7	n	n
Red-throated Loon (Gavia stellata)	6,7	cn	cn
Red-necked Grebe (Podiceps grisegena)	7	-	o
Whistling Swan (Olor columbianus)	6,7	o	o
Canada Goose (Branta canadensis)	6,7	un	pn
Black Brant (Branta bernicla nigricans)	6,7	un	un
Emperor Goose (Philacte canagica)	6,7	n	n
White-fronted Goose (Anser albifrons)	7	-	o
Snow Goose (Chen caerulescens)	6,7	o	o
Mallard (Anas platyrhynchos)	6,7	o	o
Pintail (Anas acuta)	6,7	o	n
Green-winged Teal (Anas crecca)	6,7	un	un
American Wigeon (Anas americana)	6,7	o	o
Northern Shoveler (Anas clypeata)	7	-	un
Redhead (Aythya americana)	7	-	o
Canvasback (Aythya valisineria)	7	-	o
Greater Scaup (Aythya marila)	6,7	n	n
Oldsquaw (Clangula hyemalis)	6,7	n	n
Common Eider (Somateria mollissima)	6,7	cn	cn
King Eider (Somateria spectabilis)	6,7	un	un
Spectacled Eider (Somateria fischeri)	6,7	un	un
Surf Scoter (Malanitta perspicillata)	6	o	-
Black Scoter (Melanitta nigra)	7	-	o
Red-breasted Merganser (Mergus serrator)	6,7	o	o
Goshawk (Accipiter gentilis)	6,7	o	o
Rough-legged Hawk (Buteo lagopus)	6	o	-
Marsh Hawk (Circus cyaneus)	6,7	o	o
Peregrine Falcon (Falco peregrinus)	7	-	o
Willow Ptarmigan (Lagopus lagopus)	6,7	n	n
Sandhill Crane (Grus canadensis)	6,7	cn	cn
American Golden Plover (Pluvialis dominica)	6,7	o	un
Black-bellied Plover (Pluvialis squatarola)	6,7	o	un
Ruddy Turnstone (Arenaria interpres)	6,7	n	n
Black Turnstone (Arenaria melanocephala)	6,7	un	un
Common Snipe (Capella gallinago)	6,7	o	o
Whimbrel (Numenius phaeopus)	6,7	o	o
Bristle-thighed Curlew (Numenius tahitiensis)	6,7	o	o

Table 1. Birds observed at Cape Espenberg. 1976 and 1977. Continued

Species	Year[1]	Nesting Status[2] 76	77
Red Knot (Calidris canutus)	6,7	o	o
Sharp-tailed Sandpiper (Calidris acuminata)	6,7	o	o
Pectoral Sandpiper (Calidris melanotos)	6,7	pn	un
Baird's Sandpiper (Calidris bairdii)	6,7	o	o
Curlew Sandpiper (Calidris ferruginea)	6	o	-
Dunlin (Calidris alpina)	6,7	n	n
Semipalmated Sandpiper (Calidris pusilla)	6,7	cn	cn
Western Sandpiper (Calidris mauri)	6,7	cn	cn
Sanderling (Calidris alba)	6,7	o	o
Long-billed Dowitcher (Limnodromus scolopaceus)	6,7	n	n
Bar-tailed Godwit (Limosa lapponica)	6,7	o	o
Hudsonian Godwit (Limosa haemastica)	6,7	o	o
Red Phalarope (Phalaropus fulicarius)	6,7	n	n
Northern Phalarope (Phalaropus lobatus)	6,7	cn	cn
Pomarine Jaeger (Stercorarius pomarinus)	6,7	o	o
Parasitic Jaeger (Stercorarius parasiticus)	6,7	cn	cn
Long-tailed Jaeger (Stercorarius longicaudus)	6,7	o	o
Glaucous Gull (Larus hyperboreus)	6,7	cn	cn
Mew Gull (Larus canus)	6,7	o	o
Black-legged Kittiwake (Rissa tridactyla)	6,7	o	o
Sabine's Gull (Xema sabini)	6,7	n	n
Arctic Tern (Sterna paradisaea)	6,7	n	n
Aleutian Tern (Sterna aleutica)	6	o	-
Common Murre (Uria aalge)	6,7	o	o
Thick-billed Murre (Uria lomvia)	6,7	o	o
Horned Puffin (Fratercula corniculata)	6,7	o	o
Tufted Puffin (Lunda cirrhata)	6,7	o	o
Snowy Owl (Nyctea scandiaca)	6,7	o	o
Short-eared Owl (Asio flammeus)	6,7	o	o
Say's Phoebe (Sayornis saya)	7	-	o
Horned Lark (Eromophila alpestris)	7	-	o
Tree Swallow (Iridoprocne bicolor)	7	-	o
Bank Swallow (Riparia riparia)	7	-	o
Cliff Swallow (Petrochelidon pyrrhonota)	7	-	o
Common Raven (Corvus corax)	6,7	o	o
Wheatear (Oenanthe oenanthe)	6,7	o	o

Table 1. Birds observed at Cape Espenberg. 1976 and 1977. Continued

Species	Year[1]	Nesting Status[2] 76	77
Arctic Warbler (*Phylloscopus borealis*)	6,7	o	o
Yellow Wagtail (*Motacilla flava*)	6,7	o	o
Redpoll (*Acanthis* sp.)	6,7	un	o
White-winged Crossbill (*Loxia leucoptera*)	7	-	o
Savannah Sparrow (*Passerculus sandwichensis*)	6,7	un	un
Dark-eyed Junco (*Junco hyemalis*)	7	-	o
White-crowned Sparrow (*Zonotrichia leucophrys*)	6,7	o	o
Lapland Longspur (*Calcarius lapponicus*)	6,7	n	n

[1]Year observed: "6" = 1976, "7" = 1977.

[2]cn = common nesting; n = moderate nesting; un = uncommon nesting; pn = probable nesting, but no nests or broods seen; o = not nesting.

Table 2. Nests located in shorebird nesting plots (each 0.25 km^2). Cape Espenberg, Alaska. 1976 and 1977.

Species	Number of Nests			
	Marsh Plot		Mixed Habitat Plot	
	1976	1977	1976	1977
Arctic Loon	1	2	1	0
Red-throated Loon	5	6	1	2
Emperor Goose	1	0	0	0
Pintail	0	7	0	4
Greater Scaup	4	0	1	0
Oldsquaw	21	32	1	5
Common Eider	34	27	13	17
King Eider	1	2	0	0
Spectacled Eider	1	1	0	0
Willow Ptarmigan	0	1	1	0
Sandhill Crane	1	0	0	0
Black Turnstone	1	1	0	0
American Golden Plover	0	1	0	0
Pectoral Sandpiper	0	1	0	0
Dunlin	5	4	4	4
Semipalmated Sandpiper	15	22	2	2
Western Sandpiper	15	15	1	1
Long-billed Dowitcher	1	2	1	1
Red Phalarope	18	16	0	1
Northern Phalarope	26	25	8	6
Parasitic Jaeger	0	0	0	1
Glaucous Gull	0	0	1	1
Sabine's Gull	11	14	0	0
Arctic Tern	27	33	0	0
Savannah Sparrow	0	1	1	0
Lapland Longspur	6	12	3	6
Total	194	225	40	51

Table 3. Nests located in waterfowl nesting plots. Cape Espenberg, Alaska. 1976 and 1977. (Plots 1 and 2 ≈ 1.0 km^2; Plot 3 ≈ 0.001 km^2).

Species	Number of Nests					
	Plot 1		Plot 2		Plot 3	
	1976	1977	1976	1977	1976	1977
Arctic Loon	0	0	1	2	1	0
Red-throated Loon	13	22	10	7	0	0
Loon sp.	0	1	0	0	0	0
Black Brant	1	3	0	0	0	0
Emperor Goose	3	1	1	4	0	0
Pintail	0	2	0	1	0	0
Greater Scaup	1	2	0	5	0	0
Oldsquaw	3	5	0	0	1	6
Common Eider	73-90	111	52	100	272	323
King Eider	0	2	0	0	0	0
Spectacled Eider	1	1	0	0	0	0
*Willow Ptarmigan	-	0	-	0	0	0
*Sandhill Crane	0	0	1	2	0	0
*Dunlin	2	6	4	3	0	0
*Semipalmated Sandpiper	6	4	1	2	0	0
*Western Sandpiper	-	13	-	2	0	0
*Long-billed Dowitcher	-	0	1	0	0	0
*Red Phalarope	5	3	1	4	0	0
*Northern Phalarope	1	1	4	5	0	0
Parasitic Jaeger	1	1	0	1	0	0
Glaucous Gull	32-35	27	41	62	2	3
Sabine's Gull	3	0	0	0	0	0
*Arctic Tern	2	5	4	6	17	20
*Savannah Sparrow	-	0	-	0	0	0
*Lapland Longspur	-	1	-	1	0	0
Total	147-167	211	121	207	293	352

* Nesting density data are not quantitative.

Table 4. Nests located in dune nesting plot (0.082 km^2). Cape Espenberg, Alaska. 1977.

Species	Number of Nests
Pintail	1
Common Eider	1
Ruddy Turnstone	1
Semipalmated Sandpiper	6
Lapland Longspur	8
Total	17

Table 5. Numbers of birds banded at Cape Espenberg, Alaska. 1976 and 1977.

	Number Banded					
	1976			1977		
Species	Adults	Young	Total	Adults	Young	Total
Sandhill Crane	0	7	7	0	0	0
Ruddy Turnstone	6	2	8	1	0	1
Pectoral Sandpiper	0	0	0	0	2	2
Dunlin	28	64	92	15	32	47
Semipalmated Sandpiper	33	66	99	18	56	74
Western Sandpiper	26	50	76	39	61	100
Long-billed Dowitcher	0	7	7	0	1	1
Red Phalarope	29	53	82	20	34	54
Northern Phalarope	46	75	121	38	74	112
Parasitic Jaeger	24	1	25	0	8	8
Glaucous Gull	0	30	30	0	176	176
Sabine's Gull	0	13	13	0	19	19
Arctic Tern	5	45	50	0	36	36
Savannah Sparrow	0	0	0	0	4	4
Lapland Longspur	1	6	7	2	10	12
Total	198	418	616	133	513	646

Table 6. Flowering plants collected at Cape Espenberg, Alaska. 1977. (Tentative and incomplete list).

Family	Species
Graminae	*Poa* sp.
	Elymus arenarius
Cyperaceae	*Eriophorum* sp.
	Carex sp.
Juncaceae	*Juncus* sp.
Iridaceae	*Iris setosa*
Polygonaceae	*Polygonum bistorta*
	Rumex sp.
Caryophyllaceae	*Cerastium* sp.
	Stellaria humifusa
	Honkenya peploides
	Melandrium sp.
Ranunculaceae	*Ranunculus Eschscholtzii*
	R. Pallasii
	Caltha palustris
	Delphinium sp.
Cruciferae	*Cochlearia officinalis*
	Cardamine praetensis
Crassulaceae	*Sedum rosea*
Saxifragaceae	*Boykinia Richardsonii*
	Saxifraga hirculus
	S. exilis
	S. foliolosa
	Parnassia palustris
	Chrysosplenium sp.
Rosaceae	*Potentilla* sp.
	P. palustris
	P. Hookeriana
	Rubus chamaemorus
Leguminosae	*Lathyrus maritimus*
	Oxytropis sp.
Onagraceae	*Epilobium angustifolium*
	Epilobium palustre
Haloragaceae	*Hippuris* sp.
Umbelliferae	*Bupleurum triradiatum*
	Angelica lucida
Pyrolaceae	*Pyrola grandifolia*
Empetraceae	*Empetrum nigrum*

Table 6. Continued

Ericaceae	*Loiseleuria procumbens*
	Cassiope tetragona
	Arctostaphylos sp.
	Vaccinium uliginosum
	V. vitis-idaea
	Andromeda polifolia
	Ledum palustre
Primulaceae	*Androsace* sp.
Plumbaginaceae	*Armeria maritima*
Gentianaceae	*Gentiana* sp.
Polemoniaceae	*Polemonium acutiflorum*
Boraginaceae	*Myosotis* sp.
Scrophulariaceae	*Castilleja elegans*
	Pedicularis capitata
	Pedicularis sp.
Campanulaceae	*Campanula* sp.
Compositae	*Petasites frigidus*
	Taraxacum sp.
	Tripleurospermum phaeocephalum
	Chrysanthemum arcticum
	Aster sibiricus
	Saussurea nuda
	Senecio sp.

and deserve clarification. We banded considerably fewer Dunlins, Semipalmated Sandpipers, and Northern Phalaropes in 1977 than in 1976. This was not due to a lax banding program, but, rather, to the fact that many of the adults nesting in the study plots were returning, banded birds. As a consequence, we concentrated banding efforts on the small number of unbanded birds. Thus, although fewer adults were banded in 1977, we had a very high percentage of total banded adults in the study areas.

In 1976, juvenile isopods and shorefly pupae were the most important food items for fall migrant sandpipers. Isopods were also numerous in intertidal mud samples that year. Preliminary impressions from 1977, after opening sandpiper stomachs and rough-screening of mud samples, are: 1) isopods were virtually absent from the mud and were not seen in stomachs and 2) clams (rare in 1976) were quite numerous in mud samples in 1977 and were seen in at least one shorebird stomach. Processing of samples will begin soon.

Preliminary impressions from aerial surveys indicate that river deltas are key areas for waterbirds throughout the summer. Large numbers of pintails were seen in these areas on each flight. Many of these birds (particularly in June) may have represented a non-breeding segment of drought-displaced prairie pothole immigrants. Numerous migrant geese were noted on the 15 August survey, several days before any were seen at the Cape. This suggests a westward goose movement along the coast of Kotzebue Sound.

A preliminary (and tentative) list of flowering plants from the Cape is provided in Table 6.

V. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

We encountered no major problems in 1977; the field operation (as of 15 September) has proceeded smoothly. Logistical support by Maxson Aviation of Kotzebue has proved quite satisfactory.

VI. LITERATURE CITED

Hansen, H. A. and D. E. McKnight. 1964. Emigration of drought-displaced ducks to the arctic. Trans. N. Am. Wildl. Nat. Res. Conf. 29:119-127.

Westerkov, K. 1950. Methods for determining the age of game bird eggs. J. Wildl. Manage. 14(1):56-67.

QUARTERLY REPORT

RESEARCH UNIT #: 447
REPORTING PERIOD: July 1, 1977 to
September 1, 1977
CONTRACT #: 03-6-022-35208
NUMBER OF PAGES: 7

SITE SPECIFIC STUDIES OF SEABIRDS AT KING ISLAND AND LITTLE DIOMEDE ISLAND

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October 1, 1977

QUARTERLY REPORT

Research Unit # 447

Reporting Period: July 1 to September 30, 1977

TITLE: Site Specific Studies of Seabirds at King Island and Little Diomede Island.

PRINCIPLE INVESTIGATOR: William H. Drury

AFFILIATION: College of the Atlantic
Bar Harbor, Maine 04609

AGENCY: NOAA Contract # 03-6-022-35208

DATE SUBMITTED:

I. Abstract

A. The numbers of seabirds at Little Diomede Island were counted or estimated. The number of Kittiwakes breeding there is higher than at King Island or Bluff; the number of Murres is comparable to those at Bluff and smaller than those at King Island; the numbers of Horned Puffins and Auklets are larger than the numbers of these species at King Island.

B. Observations on the breeding schedule and success of seabirds at the Island indicated that the breeding schedule of Kittiwakes was later, density higher, and success higher than at the study sites at Bluff Cliffs. Breeding of Murres appeared to be at the same time as at the Norton Sound Cliffs. The party left before final measurements of success were made.

C. Aerial surveys over the Chirikov Basin confirmed our previous observations that feeding seabirds are concentrated in the western part of the area searched. Large pods of Gray Whales were seen between King Island and Saint Lawrence Island in June and August.

D. Peregrine Falcons, an endangered species, were seen at Fairway Rock and at Little Diomede.

II. Task Objectives

A. To determine the numbers and distribution of species of seabirds.

B. To describe the schedule and phenology of events during occupation of the cliffs, the breeding period, and the period when the birds leave.

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

D. To provide data to compare with results in other parts of the Seward Peninsula and in other regions.

III. Field Activities

A. Schedule:

1. All members of the party (3) were on the island from July 1-August 5, when A. Watson left. B. Steele and T. Steele left on August 12, and arrived at Nome on August 20.

2. Visits to study sites were made approximately every other day during this period; censuses of the perimeter of the island were made from a boat and transects of the island's slopes and top were made on foot.

3. Aerial surveys over the Chirikov Basin were made on August 21 and 22, covering the area between Saint Lawrence Island and Cape Prince of Wales.

B. Scientific Party:

Benjamin Steele, graduate student at the Utah State University, field assistant in charge of the party.

Theodore Steele, University of New Hampshire, field assistant.

Alan Watson, M.A., The White Mountain School, field assistant.

C. Methods

1. Censuses of cliffs by counting or estimating birds from a small boat moving in front of the cliffs.

2. Counts made hourly for 24 hours at sample areas at a regular study site.

3. Every-other-day visits to study sites to record the events at mapped Kittiwake nests and mapped sections of ledges on which Murres nest.

4. Surveys were made of the island to measure the area of rock cliffs, rock slides, and other topographic types and to measure the density of birds by species. This technique was used to estimate the numbers of Horned Puffins, Parakeet Auklets, Crested Auklets, and Least Auklets nesting on the island.

5. Air transects were made at 150 feet and at 100 knots from a Cessna Skymaster along the routes shown on the map.

D. Sample localities on the island will be shown on a map in the annual report.

E. Data Collected

1. Eight circuits of the island were made to count birds from the water. One circuit was made to estimate area. One hundred twenty counts were made of the proportion of Thick-billed to Common Murres. Three visits were made to Fairway Rock.

2. Fourteen transects and twenty counts of Auklets were made to estimate area of breeding habitat and density of occupation.

3. Two 24-hour counts were made of Cliffbirds and two 24-hour counts made of Auklets.

4. During the whole season 18 visits were made to 15 study sites, 27 visits to 5 other study sites, and 8 visits to a further 5 study sites.

5. Approximately 650 miles of air transects were flown in this period.

IV. Results

A. Censuses indicated the following numbers of individuals.

Species	Little Diomede Island	Fairway Rock (low reliability)
Pelagic Cormorant	160	20-30
Glaucous Gull	135	125-150
Black-legged Kittiwake	35,000	650
Common Murre	35,000	5,000 ?
Thick-billed Murre	25,000	15,000-20,000
Pigeon Guillemot	275	75-125
Parakeet Auklet	15,000-25,000 (18,000)	500 ?
Crested Auklet	130,000-150,000 (135,000)	10,000 ?
Least Auklet	900,000-1,200,000 (980,000)	15,000 ?
Horned Puffin	20,000-35,000 (25,000)	25-100
Tufted Puffin	1,000	100-500
Peregrine	1	2
Raven	2 ad	2 ad
Snow Buntings	600-800	

B. Egg laying in Common Murres appeared to begin about July 1, a week or 10 days later than at Bluff Cliffs. Thick-billed Murres laid a week or 10 days after Common Murres. The party saw no Murre chicks before August 12 when they left. The eastern side of the Island, which was made of more broken rolls, had a higher percentage of Thick-billed Murres than did the north side. Fairway Rock appeared to be wholly Thick-billed Murres. The Diomede Islanders believe that Murres have increased in the last decades. They believe that the numbers of Crested Auklets have markedly decreased. The party reported that Kittiwakes nest at especially high densities at Little Diomede. Almost all nests studied had hatched before August 12. The first Least Auklet chicks were found on August 4. No Horned Puffin eggs had hatched by August 11. The party found that a large proportion of the Horned Puffins present are non-breeders.

C. Air transects over the Chirikov Basin (see map) indicated that concentrations of feeding seabirds occurred between King Island and Saint Lawrence Island and in the area west and north of King Island. Fog prevented our surveying the Bering Strait or waters north of the Diomede Islands.

Pods of 100-200 Gray Whales occurred in the same areas in which groups of Murres and Auklets were seen. When the whales surfaced, they left a smudge of tan-brown water in which Kittiwakes and Murres gathered, presumably to feed. The majority of Kittiwakes seen away from breeding cliffs was associated with whales.

V. Preliminary Interpretation of Results

Comparing data from the several nesting colonies and considering our data as to the distribution of birds feeding at sea, we believe that the numbers and kinds of cliffnesting seabirds at each colony is determined by a combination of the food available and by the structure of the ledges on the cliffs. This seems to apply especially to the distribution of Kittiwakes, Horned Puffins, Pelagic Cormorants and Murres.

We believe that the kinds of food influence the relative abundance of Thick-billed and Common Murres. We believe further that the restriction of Auklets to the Bering Strait, Chirikov Basin and Saint Lawrence Island waters is primarily determined by food.

It is interesting that there are relatively few Kittiwakes and relatively many Murres on King Island as compared to Diomede and Bluff. The numbers of Murres at each site appear to be limited by the number of ledges, but the changes in proportion of Kittiwakes to Murres is not explained.

It appears that Arctic Foxes may affect the absolute numbers of Tufted Puffins, because of the abundance of Tufted Puffins on Fairway Rock, an area reported not to support summering foxes.

The Eskimos at both Diomede and King Island report an increase in Murres during the last decades. The King Islanders have said they believe the increase to be related to less predation on eggs. It may be that with the influx of many federal and state subsidies, the Diomeders are also making markedly less use of Murre eggs. Consistent with this, the Diomeders report less intense hunting of Crested Auklets in the last decades, nevertheless, a decrease in numbers of Crested Auklets.

VI. Problems Encountered

A. Until we develop an adequate system for measuring reproductive success in Auklets (especially Least and Crested Auklets), we will have difficulty relating events on the islands to feeding areas and to food available at sea. We see no practical solution at present because the Auklets nest in galleries deep under loose boulders of rock debris.

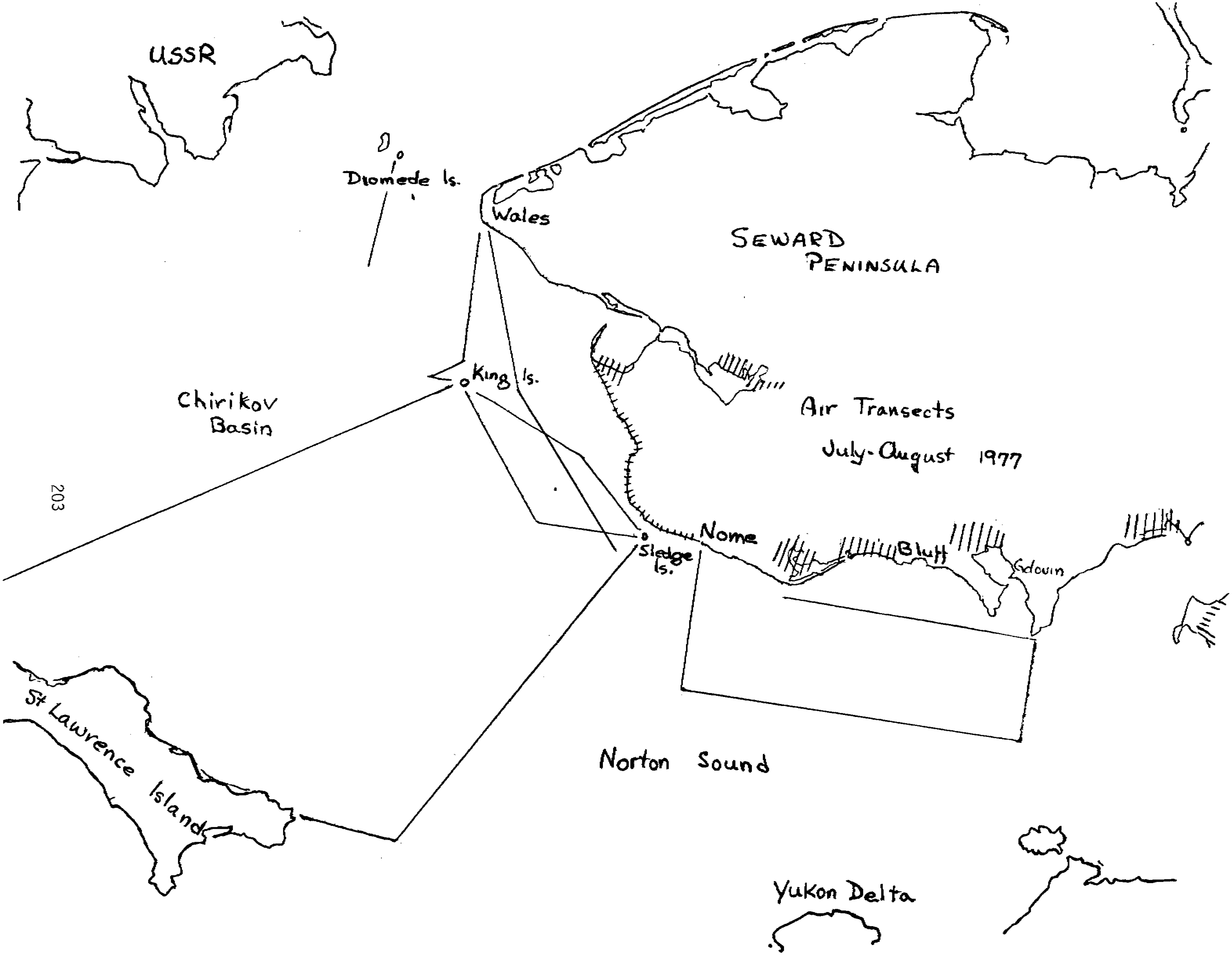
B. Our group, living as they did in the midst of a community, found much of their time went into socializing. One difficult problem related to the fact that some people, especially children, spent a lot of time visiting with our group. Another problem was the free running of children, which made it inadvisable to leave the Zodiac boat out on the beach. The laborious process of setting up and dismantling had to be gone through each time the boat was used.

The living facilities and acceptance by the local people is much better on Diomede than at King Island, but neither of the islands offer favorable conditions for scientific research.

We think that the group did pretty well in solving their problems, but we wonder how much of our scientific effort for future years' work should be assigned to this relatively difficult area to work.

VII. Estimate of Funds Expended

CPF -1	$8,135.00
CPF -2	4,570.00
CPF -3	125.00
CPF -4	100.00
	$12,930.00


USSR
Diomede Is.
Wales
SEWARD PENINSULA
King Is.
Chirikov Basin
Air Transects
July-August 1977
Nome
Sledge Is.
Bluff
Golovin
St Lawrence Island
Norton Sound
Yukon Delta

Quarterly Report

Contract # 03-5-022-56
Task Order # 28
Research Unit # 458
Reporting Period 7/1/77-
9/30/77
Number of Pages 19

AVIAN COMMUNITY ECOLOGY OF THE AKULIK-INGLUTALIK RIVER DELTA NORTON BAY, ALASKA

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and

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Fairbanks, Alaska 99701

October 1, 1977

I. Field Activities

A.) Scientific Party

Name	Affiliation	Role
Gerald F. Shields	Institute of Arctic Biology	Co-principal Investigator
Leonard J. Peyton	Institute of Arctic Biology	Co-principal Investigator
Declan Troy	Institute of Arctic Biology	Graduate Student
Richard Gustafson	Institute of Arctic Biology	Research Assistant

B.) Research Schedule

Field activities were greatly expanded in 1977 to include observations of both spring and fall migrations. Our research camp was established on May 8 when we were transported to the Inglutalik River study site via NOAA support helicopter. The camp was dismantled on September 21 when we left the area via boat. Our activities thus spanned a period of 138 days. The duration of the field activities of each investigator are listed below:

Investigator	Dates	Duration
Gerald F. Shields	7 May-1 August	86 days
Leonard J. Peyton	7 May- 15 June	
	15 Aug.- 21 Sept.	77 days
Declan Troy	7 June- 31 Aug.	86 days
Richard Gustafson	7 June- 21 Sept.	107 days
		356 man days

All research activities were conducted on the Akulik-Inglutalik River Delta; on occassion observations were made near the head waters of the Inglutalik River.

C.) Methods

1.) Avifaunal surveys

Daily surveys of the birds on the Akulik-Inglutalik River Delta were conducted from May 10 to Sept. 20. These surveys were carried out in such a way as to maximize our observation efforts in relation to the activities of the birds (i.e. spring migration, breeding period, fall migration). The following methods were used:

a.) Delta Surveys - from May 10 to Sept. 20 surveys of all birds on the delta were made with spotting scopes. Observations were made from an elevated area (cal. 15 m.) near the research camp. From this vantage point the entire delta, including the mouths of both the Akulik and Inglutalik Rivers, could be observed. To maximize our efforts, twice daily (morning and evening) surveys were conducted during the periods of intense migratory activity (spring migration May 10 - June 15 and fall migration August 1 - September 20). Surveys of the area were conducted daily regardless of weather conditions.

b.) Tundra Transects - to correct for sample bias that may have been inherent in the delta surveys we conducted a

1 km transect across the tundra at midday. During this transect an observer walked the same path daily at a constant rate (60 paces/min.) and recorded all birds seen with the naked eye and 35 X binoculars. The observer stopped only to record data (cassette recorder) and the entire walk lasted about one hour. No other field activities were conducted in the area of the tundra transect and therefore, it served as an accurate estimate of species diversity, density, and phenology of the birds on a "typical" delta area.

c.) Nesting Study Plot - in order to obtain a more accurate estimate of species diversity and nesting densities on the delta we expanded our nesting plot to twice its 1976 size. During 1977 a 2 X .3 km study plot was constructed in homogeneous lowland wet tundra (see figure 1). The entire area was divided into 50 X 50 m sections and monitored for the following parameters: nest initiations, nest failures, laying dates, clutch sizes, hatching dates, predation, and relative productivity. The majority of the nesting plot was constructed prior to the spring arrival of most breeding species and therefore nest failures due to our presence were minimal. All daily observations taken from the delta survey, tundra transect, and nesting plots have been recorded on IBM sheets, key punched on cards and are now ready for final analysis.

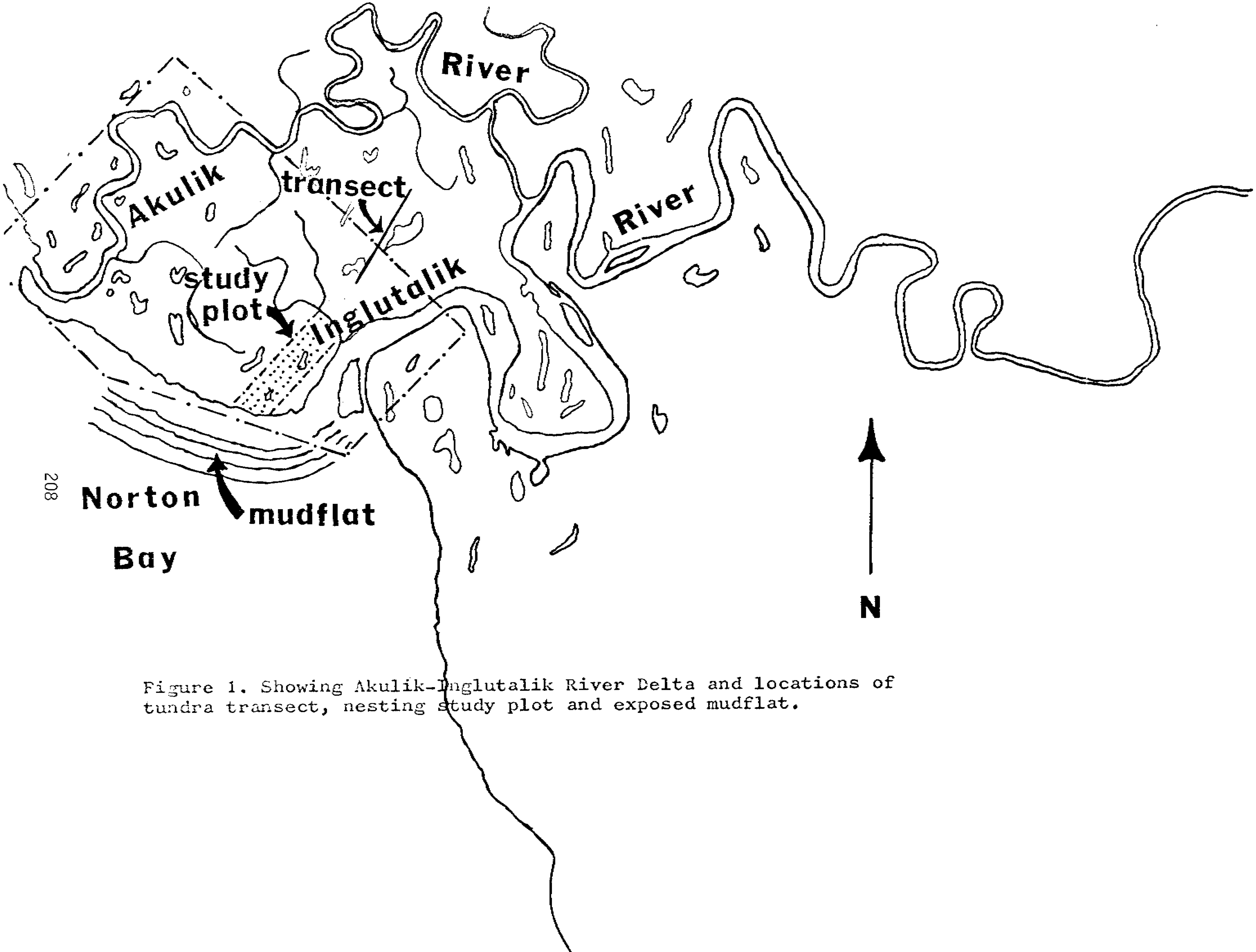

Figure 1. Showing Akulik-Inglutalik River Delta and locations of tundra transect, nesting study plot and exposed mudflat.

2.) Bird Banding - a variety of capture methods was employed to band resident birds. Methods included: nest snap-traps, mist-nets, drop-nets, and Bal Chatri traps. Nestlings were banded in the nest while shorebird chicks were banded when they hatched or immediately after leaving the nest. All banding data including returns from the 1976 field season have been coded and sent to the U.S. Fish and Wildlife Service.

3.) Small Mammal Trap Line - in order to monitor the occurance and relative densities of small mammals on the delta a series of live-snap trap lines was employed. Traps were set in a variety of habitat types and monitored daily. Captures were scored as to species, sex, age, and location. All individuals were toe-clipped in order to estimate relative densities using the capture-recapture method. Densities were determined by computations of numbers per trap days (one trap day equals a single trap set for 24 hours).

4.) Predator Distribution - the entire study area was monitored for the presence and behavior of various predators. All data relevant to predation were recorded and coded daily. The area was systematically searched for the presence of dens of Arctic and Red Foxes, and nests of Glaucous Gulls and Parasitic Jaegers. Predation by other mammals (e.g. Least

Weasel, Short-tailed Weasel, and Grizzly Bear) or other birds (e.g. Marsh Hawk, Merlin, Northern Shrike, and Raven) was recorded.

5.) Invertebrate Distributions - species diversity and distributions on the delta were determined by the following methods:

a.) sweep-netting - the entire nesting plot was sampled at weekly intervals in order to monitor the occurance and relative abundance of insects. Each section was sampled by sweeping a transect at a constant rate (30 sweeps/60 paces/min.). Samples have been preserved in 70 % ethyl alcohol and await further analysis.

b.) pond samples - invertebrate distribution in ponds and tidal pools was sampled opportunistically with dip nets.

c.) pond shore and mud-flat samples - we used standard mud samplers to determine occurance and abundance of invertebrates near ponds and mud-flats where shorebirds were feeding.

d.) soil samples - samples of soil from all habitat types were taken with standard samplers.

6.) Flora and Habitat Descriptions - representatives of all plant species on the delta were collected in flower, identified and pressed. Dates of collection, flowering times, and collection locations were recorded.

a.) The entire nesting plot has been mapped as to diversity and distribution of plants.

b.) Aerial descriptions - a series of aerial photographs (color, black and white, and infrared)were taken at various intervals. These will be used in conjunction with the mapping of plant data to determine habitat types and nesting preferences.

7.) Climatological Data - a temporary weather station was constructed at the research camp on May 12. We recorded the following variables: wind speed and direction, amount and duration of precipitation, snow melt, maximum and minimum temperatures, dry bulb/wet bulb ratios, and relative humidity. These data will be coded and sent to the National Weather Service in Fairbanks.

Results

This report is based largely on data which have been analyzed in only a prliminary way. Indeed, banding and fall migration data were returned from the field this past week. At any rate, some of the data are included here.

One hundred and one species were observed on the delta during the summer of 1977 including 20 bird species not observed during 1976.(see table 1). With the exception of the Canvasback all other new species for 1977 were observed as migrants. Our extended observations in the spring and fall

Table 1. Birds observed at the Akulik-Inglutalik River Delta (summer 1977)

	Species	Nesting Status
	Yellow-billed Loon (*Gavia adamsii*)	O
	Arctic Loon (*Gavia arctica*)	CN
	Red-throated Loon (*Gavia stellata*)	CN
	Whistling Swan (*Olor columbianus*)	N
	Canada Goose (*Branta canadensis*)	O
	Black Brant (*Branta nigricans*)	O
*	White-fronted Goose (*Anser albifrons*)	O
*	Snow Goose (*Chen caerulescens*)	O
	Mallard (*Anas platyrhynchos*)	UN
	Gadwall (*Anas strepera*)	O
	Pintail (*Anas acuta*)	CN
	Green-winged Teal (*Anas crecca*)	PN
	American Wigeon (*Anas americana*)	PN
	Northern Shoveler (*Anas clypeata*)	PN
*	Canvasback (*Aythya valisineria*)	UN
	Greater Scaup (*Aythya marila*)	UN
	Common Goldeneye (*Bucephala clangula*)	O
	Oldsquaw (*Clangula hyemalis*)	N
	Common Eider (*Somateria mollissima*)	UN
	White-winged Scoter (*Melanitta deglandi*)	O
	Surf Scoter (*Melanitta perspicillata*)	UN
	Black Scoter (*Melanitta nigra*)	UN

Table 1. (cont.)

	Species	Nesting Status
*	Common Merganser (*Mergus merganser*)	O
	Red-breasted Merganser (*Mergus serrator*)	CN
*	Bald Eagle (*Haliaeetus leucocephalus*)	O
	Marsh Hawk (*Circus cyaneus*)	UN
	Gyrfalcon (*Falco rusticolus*)	O
*	Peregrine Falcon (*Falco peregrinus*)	O
	Merlin (*Falco columbarius*)	O
	Willow Ptarmigan (*Lagopus lagopus*)	PN
	Sandhill Crane (*Grus canadensis*)	CN
	Semipalmated Plover (*Charadrius semipalmatus*)	O
	American Golden Plover (*Pluvialis dominica*)	O
	Black-bellied Plover (*Pluvialis squatarola*)	O
	Black Turnstone (*Arenaria melanocephala*)	O
	Common Snipe (*Capella gallinago*)	O
	Whimbrel (*Numenius phaeopus*)	O
*	Spotted Sandpiper (*Actitis macularia*)	O
	Lesser Yellowlegs (*Tringa flavipes*)	O
*	Red Knot (*Calidris canutus*)	O
*	Sharp-tailed Sandpiper (*Calidris acuminata*)	O
*	Pectoral Sandpiper (*Calidris melanotos*)	O
*	Baird's Sandpiper (*Calidris bairdii*)	O
	Least Sandpiper (*Calidris minutilla*)	PN

Table 1. (cont.)

Species	Nesting Status
Dunlin (*Calidris alpina*)	CN
Semipalmated Sandpiper (*Calidris pusilla*)	CN
Western Sandpiper (*Calidris mauri*)	CN
Sanderling (*Calidris alba*)	O
Long-billed Dowitcher (*Limnodromus scolopaceus*)	O
Bar-tailed Godwit (*Limosa lapponica*)	O
Hudsonian Godwit (*Limosa haemastica*)	O
Red Phalarope (*Phalaropus fulicarius*)	O
Northern Phalarope (*Lobipes lobatus*)	CN
Pomarine Jaeger (*Stercorarius pomarinus*)	O
Parasitic Jaeger (*Stercorarius parasiticus*)	N
Long-tailed Jaeger (*Stercorarius longicaudus*)	O
Glaucous Gull (*Larus hyperboreus*)	CN
Glaucous-winged Gull (*Larus glaucescens*)	O
Herring Gull (*Larus argentatus*)	O
Mew Gull (*Larus canus*)	UN
Bonaparte's Gull (*Larus philadelphia*)	O
Black-legged Kittiwake (*Rissa tridactyla*)	O
Sabine's Gull (*Xema sabini*)	UN
Arctic Tern (*Sterna paradisaea*)	CN
Snowy Owl (*Nyctea scandiaca*)	PN
Short-eared Owl (*Asio flammeus*)	PN
Belted Kingfisher (*Megaceryle alcyon*)	UN

Table 1. (cont.)

	Species	Nesting Status
*	Common Flicker (*Colaptes auratus*)	0
*	Downy Woodpecker (*Dendrocopos pubescens*)	0
*	Alder Flycatcher (*Empidonax alnorum*)	0
	Tree Swallow (*Iridoprocne bicolor*)	0
	Bank Swallow (*Riparia riparia*)	CN
*	Cliff Swallow (*Petrochelidon pyrrhonota*)	0
	Gray Jay (*Perisoreus canadensis*)	0
	Common Raven (*Corvus corax*)	0
*	Black-capped Chickadee (*Parus atricapillus*)	0
*	Boreal Chickadee (*Parus hudsonicus*)	0
	Robin (*Turdus migratorius*)	0
	Varied Thrush (*Ixoreus naevius*)	0
	Gray-cheeked Thrush (*Catharus minimus*)	0
	Wheatear (*Oenanthe oenanthe*)	0
*	Arctic Warbler (*Phylloscopus borealis*)	0
	Ruby-crowned Kinglet (*Regulus calendula*)	0
	Yellow Wagtail (*Motacilla flava*)	CN
	Waterpipit (*Anthus spinoletta*)	0
	Northern Shrike (*Lanius excubitor*)	0
	Orange-crowned Warbler (*Vermivora celata*)	0
	Yellow Warbler (*Dendroica petechia*)	0
	Northern Waterthrush (*Seiurus noveboracensis*)	0

Table 1. (cont.)

Species	Nesting Status
Wilson's Warbler (*Wilsonia pusilla*)	0
Rusty Blackbird (*Euphagus carolinus*)	0
Redpoll (sp.) (*Carduelis*)	CN
White-winged Crossbill (*Loxia leucoptera*)	0
Savannah Sparrow (*Passerculus sandwichensis*)	CN
Dark-eyed Junco (*Junco hyemalis*)	0
Tree Sparrow (*Spizella arborea*)	UN
White-crowned Sparrow (*Zonotrichia leucophrys*)	UN
* Golden-crowned Sparrow (*Zonotrichia atricapilla*)	0
Fox Sparrow (*Passerella iliaca*)	0
* Lincoln's Sparrow (*Melospiza lincolnii*)	0
Lapland Longspur (*Calcarius lapponicus*)	CN

CN = common nester, N = moderate nester, UN = uncommon nester,
PN = probable nester, 0 = nonnester

* indicates species observed in 1977 but not in 1976

are reflected in the data. The breeding status of the birds on the delta is also given in table 1.

Preliminary nesting densities for birds on the delta are given in table 2. The majority of the birds has nesting densities similar to those of 1976. However, some birds which nested on the study plot in 1977 but not in 1976 may appear to have densities which are biased. Final comparisons of nesting densities for the two summers must await computation of all data and correction for sample error.

Clutch sizes for the most common nesters on the delta are given in table 3. Little variation exists for clutch sizes for both years. Hatching dates for the most common breeders are given in table 4. Again, there is little variation in hatching dates for both years.

Since our field season was greatly expanded in 1977 we banded nearly twice as many birds as the previous year. Banding data and return data are shown in tables 4 and 5 respectively. In addition, we have data on banded birds which will allow us to determine the duration of post-breeding residence on the delta.

Final Report

The following projects are to be completed and included in the final report.

1.) Total analysis of delta survey, tundra transects and nesting data.

2.) Total analysis of vegetation mapping and nest site preferences.

Table 2. Nesting densities of the most common breeders on the delta (1977).

Common name	Scientific name	Nests/km^2
Arctic Loon	*Gavia arctica*	6.0
Red-throated Loon	*Gavia stellata*	3.0
Whistling Swan	*Olor columbianus*	1.0
Mallard	*Anas platyrhynchos*	1.0
Pintail	*Anas acuta*	1.0
Canvasback	*Aythya valisineria*	1.0
Greater Scaup	*Aythya marila*	1.0
Oldsquaw	*Clangula hyemalis*	1.0
Sandhill Crane	*Grus canadensis*	3.0
Dunlin	*Calidris alpina*	5.0
Semipalmated Sandpiper	*Calidris pusillus*	61.0
Western Sandpiper	*Calidris mauri*	5.0
Northern Phalarope	*Lobipes lobatus*	30.0
Parasitic Jaeger	*Stercorarius parasiticus*	1.0
Arctic Tern	*Sterna paradisaea*	8.0
Savannah Sparrow	*Passerculus sandwichensis*	15.0
Lapland Longspur	*Calcarius lapponicus*	16.0

Table 3. Clutch sizes of the most common breeders on the Akulik-Inglutalik River Delta (1977).

Species	Number of nests	Clutch size
Semipalmated Sandpiper	37	3.73
Western Sandpiper	3	4.00
Dunlin	3	4.00
Northern Phalarope	18	3.72
Savannah Sparrow	9	5.00
Lapland Longspur	10	5.25

Table 4. Hatching dates for the most common breeders on the Akulik-Inglutalik River Delta (1977).

Species	Range of hatching dates
Semipalmated Sandpiper	June 17 - July 10
Western Sandpiper	June 26 - July 7
Dunlin	June 20 - June 26
Northern Phalarope	June 22 - July 13
Savannah Sparrow	June 17 - July 15
Lapland Longspur	June 13 - June20

Table 4. Birds banded at the A ulik-Inglutalik River Delta (summer - 1977).

Species	Adults	Young	Total
Pintail	0	3	3
Spotted Sandpiper	0	1	1
Dunlin	0	23	23
Sharp-tailed Sandpiper	0	21	21
Pectoral Sandpiper	0	6	6
Least Sandpiper	7	14	21
Semipalmated Sandpiper	1	485	486
Western Sandpiper	0	160	160
Northern Phalarope	3	85	88
Glaucous Gull	0	10	10
Arctic Tern	0	1	1
Alder Flycatcher	?	?	2
Tree Swallow	9	6	15
Bank Swallow	2	1	3
Gray Jay	0	3	3
Boreal Chickadee	?	?	2
Black-capped Chickadee	0	1	1
Yellow Wagtail	18	24	42
Arctic Warbler	1	7	8
Ruby-crowned Kinglet	1	6	7

Table 4. (con't)

Species	Adults	Young	Total
American Robin	1	1	2
Varied Thrush	0	1	1
Gray-cheeked Thrush	1	11	12
Northern Shrike	0	6	6
Orange-crowned Warbler	1	3	4
Yellow Warbler	8	7	15
Blackpoll Warbler	0	1	1
Northern Waterthrush	1	3	4
Wilson's Warbler	3	6	9
Redpoll (sp.)	676	414	1093
Savannah Sparrow	130	1025	1155
Tree Sparrow	15	107	122
Dark-eyed Junco	1	1	2
White-crowned Sparrow	38	98	136
Golden-crowned Sparrow	7	1	8
Fox Sparrow	1	7	8
Lincoln's Sparrow	1	0	1
Lapland Longspur	42	267	309

totals:

species 38 3761

Table 5. Summary of birds banded in 1976 which returned to the Akulik-Inglutalik River Delta in 1977.

Species	Number of return birds
Western Sandpiper	1
Semipalmated Sandpiper	1
Redpoll	3
Tree Sparrow	3
Fox Sparrow	1
White-crowned Sparrow	2
Savannah Sparrow	39
Lapland Longspur	3

3.) Completion of invertebrate analysis and feeding activities of birds.

4.) Completion of return data on banded birds.

5.) Completion of comparative aspects of the study for both field seasons.

6.) Final recommendations.

A COMPARATIVE SEA-CLIFF BIRD INVENTORY OF THE CAPE THOMPSON VICINITY, ALASKA
(R.U. No. 460)

A SEA-CLIFF BIRD SURVEY OF THE CAPE LISBURNE - PT. HOPE, ALASKA COASTLINE
(R.U. No. 461)

(Contract 03-6-022-35210)

Quarterly Report
1 October 1977

RENEWABLE RESOURCES CONSULTING SERVICES, Ltd.

Principal Investigators

David G. Roseneau
Alan M. Springer

I. Field Activities

FY77 field work began on 7 June when a trip to collect murres and kittiwakes was made to Cape Thompson and Cape Lisburne. A second collecting trip only to Cape Thompson occurred on 19 June; attempts to land at Cape Lisburne on 19 and 20 June were thwarted because of heavy fog. Permanent occupation of the study sites commenced on 6 July and continued until 26 August at Cape Thompson and until 5 September at Cape Lisburne.

II. Laboratory Activities

Stomach contents of murres and kittiwakes are being identified. Skeletons of most birds which we collected are being cleaned and measured and selected specimens have been analysed for lipid content.

Field data is being transformed and formatted for archiving. Some comfusion concerning computer format still exists and completion of this task awaits resolution of these questions with NOAA/OCSEAP.

III. Selected Observations

A. Cape Lisburne

The uncompensated raw total of the 1977 murre census at this colony was approximately 135,000 individuals. This raw total is very similar to and supports the raw total of about 131,000 individuals obtained in 1976. When the 1977 raw plot scores were compensated for daily activity patterns, a total of about 190,000 birds was calculated; similar corrections for 1977 raw plot scores were not obtained. Even during times of peak ledge attendence many murres were known to be at sea; we therefore believe that the calculated 190,000 individuals should be considered a minimum estimate of the current population. Actual numbers of murres currently utilizing the Cape Lisburne colony is likely to be about 200,000+ birds.

Murre laying dates were not obtained because most birds were incubating upon our 6 July arrival. The first eggs probably hatched about 1 August; most eggs hatched during the 5 - 12 August interval. Data obtained with respect to hatch dates suggest that egg laying may have commenced as early as about the fourth week of June. Most eggs were probably laid during about the 30 June - 9 July interval. The first sea-going by murre chicks was noted on 20 August, and numbers of chicks leaving the cliff ledges increased through 25 August. Sea-going by murre chicks in 1977 occurred approximately one week earlier at this colony than it had in 1976.

Approximately 15,000 Black-legged Kittiwakes were counted occupying the cliffs at Cape Lisburne. Most of the birds defended sites but not all sites contained evidence of a nest. Our data suggest that about 53% of the pairs which did construct nests laid eggs; this compares to only about 22% in 1976. The average clutch size this summer was 1.02. Laying dates for kittiwakes were not obtained at this colony. Hatching began about 28 July and continued at least through 26 August with the peak occurring 7 - 13 August. These data suggest that egg laying may have commenced as early as about 27 - 30 June. We estimate that phenologically, kittiwakes were about one week ahead of the 1976 schedule at Cape Lisburne.

B. Cape Thompson

The uncompensated raw total of the 1977 murre census at this colony was approximately 142,000 individuals. This raw total is about 12,000 individuals less than that obtained in 1976 (about 154,000 individuals). Some of this difference may result from the fact that in 1976, Colony 5 was estimated by 100's. In 1977, good weather/sea conditions allowed observers to estimate this major colony for the first time by 10's. The 1977 compensation figures are still being calculated at this time; similar corrections for 1976 raw plot scores resulted in a total of about 200,000 individuals that year. Tentative calculations and analyses of 1977 data suggest that there may have been a reduction from the 1976 estimate of the murre population at Cape Thompson. Murres were laying eggs upon our 6 July arrival; some birds were already incubating. The first known hatching of a murre egg (Thick-billed) occurred on 1 August; most eggs were observed to hatch during about the 10 - 21 August interval. Some hatching probably continued to occur as late as about the first week in September. Data obtained on hatch dates suggests that egg laying may have commenced as early as about 24 - 28 June. Most eggs were probably laid during the 5 - 16 July interval. Some eggs, possibly replacements, were laid as late as 29 July - 1 August. The first sea-going by murre chicks (two individuals) was noted on 23 August, a date when a number of other chicks appeared ready to leave the ledges.

The hatching of the first murre chick in 1977 was observed eight days earlier at this colony than it was in 1976. Sea-going was not observed as late as 25 August in 1976 and probably commenced about one week later; in 1977, sea-going by murre chicks commenced about eight days earlier than it had in 1976.

In 1976 we found that a virtual complete breeding failure of Black-legged Kittiwakes had occurred at the Cape Thompson colonies (Springer and Roseneau, 1977). Since few nests were constructed and attendance at the cliffs was erratic, we felt that a reliable estimate of the kittiwake population could not be obtained. Uncompensated counts of all plots were conducted however, and these counts yielded a total of 10,500 individuals. In 1977, these counts were repeated and totaled 10,225 individuals, a figure which is only 2.6% less than that obtained in 1976.

Though analyses plot by plot is not complete, these data suggest that little change in total numbers of kittiwakes occurred between 1976 and 1977. Thus the 1976 figure may be more reliable as an index than first suspected.

The reproductive success of Black-legged Kittiwakes at the Cape Thompson colonies was markedly better in 1977 than that recorded in 1976. In 1976, though all collected specimens showed evidence of gonodal development, brood patch development was not observed. In 1977 all specimens showed evidence of good gonodal development and brood patch development.

In 1976 we had direct evidence to account for only 13 eggs. In 1977 our data suggest that up to about 73% of the pairs which attempted to construct nests laid eggs. Of these pairs about 18% failed during either the egg or early chick stages. The remaining about 55% produced young to at least the near fledgling stage. The average clutch size this summer was approximately 1.1. The average number of young reaching at least the near fledgling stage was about 1.0. Laying dates for first eggs were not obtained, though it is known that a few eggs were laid as late as 21 - 30 July. At least five chicks hatched prior to 29 July. The weights of two of these chicks suggest that these hatching's occurred about 24 - 28 July. On the basis of one chick observed fully fledged on 23 August, it is possible that the first egg may have been laid as early as about 12 - 16 June and that the first hatch may have occurred as early as 10 - 14 July. The bulk of the data, however, suggest that most laying did not commence until about 26 June and that the majority of the eggs were probably laid during the 2 - 13 July interval. In 1976 the first egg was observed on 4 July. The majority of the eggs appeared to have hatched during the 30 July -.10 August interval with a peak about 30 July - 3 August. At least one egg hatched as late as 21 August. In 1976 the first known hatch occurred on 9 August. Although the first fully fledged young was observed on 23 August in 1977, most young probably made their first flights during early to mid-September. We estimate that phenologically, kittiwakes were about one week earlier than the 1976 schedule at Cape Thompson.

C. Other locations of interest

Additional data on seabird numbers was gathered along the Chukchi Sea coast between Cape Thompson and Cape Lisburne and east of Cape Lisburne to Thetis Creek. Data are available from Kilikralik Point, Cape Dyer, Cape Lewis, Noyalik Peak, Niak Creek, Sapumik Ridge and Corwin Creek. Of most interest is Cape Lewis where uncompensated counts totaled about 19,000 murres. Tentatively we estimate the Cape Lewis colony to currently support the following species in order of abundance:

Murres	uncompensated counts totaled 19,130 individuals and actual numbers are tentatively estimated at ± 25,000 individuals.
Black-legged Kittiwakes	minimum est. 2305 individuals; we estimate that actual numbers exceed this total by some unknown per cent and that actual numbers are unlikely to exceed about 4000 individuals.
Horned Puffins	est. 200 - 400 individuals
Pelagic Cormorants	est. 28 - 30 pairs
Glacous Gulls	est. 20 - 30 pairs
Black Guillemots	est. 12 - 15 pairs
Pigeon Guillemots	not observed
Tufted Puffins	1 - 2 pairs

D. Other Highlights

Valuable data on foraging flights by murres and kittiwakes were obtained at Cape Thompson and Cape Lisburne. Foraging flights by murres at Cape Thompson shifted from a south and southwest direction (1976) to a northwesterly direction (1977).

Observations of large concentrations of sand launce (Ammodytes sp.) were observed at both Cape Lisburne and Cape Thompson. This food resource was apparent at Cape Lisburne about 3 weeks earlier than at Cape Thompson. Data suggest a major downcoast movement of these fish during late July - August. This resource proved very important to all seabirds in this region, particularly murres and kittiwakes, becoming almost the sole food source exploited by them. Comparatively, in 1976 sand launce were of minor importance to the seabirds at Cape Thompson.

Literature Cited

Springer, A.M. and D.G. Roseneau. 1977. A comparative sea-cliff bird inventory of the Cape Thompson vicinty, Alaska. Annual Report. Research Unit 460/461. Outer Continental Shelf Environmental Assessment Program. Boulder. 54 pp.

QUARTERLY REPORT

Contract: 01-022-2538
Research Unit: 488
Reporting Period: July 1 to Sept. 30, 1977

CHARACTERIZATION OF COASTAL HABITAT FOR MIGRATORY BIRDS: NORTHERN BERING SEA

Calvin J. Lensink

and

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Co-principal Investigators

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Office of Biological Services - Coastal Ecosystems
800 A Street - Suite 110
Anchorage, Alaska 99501

Research Unit 488

July 1 to September 30, 1977

I. Title: Characterization of Coastal Habitat for Migratory Birds - Northern Bering Sea.

II. Objectives:

1. To characterize coastal habitat utilized by marine birds by:

   a. Describing extent and characteristics of unvegetated intertidal beaches.

   b. Describing extent and characteristic of intertidal plant communities.

   c. Identifying, where possible, the maximum limit of tidal influence on terrestrial habitat by mapping the occurrence of drift lines.

   d. Identify ownership status (private or public) and responsible land management agency.

   e. Identify and quantify existing land uses.

2. To characterize use of habitat by birds including:

   a. Identification of principal species.

   b. Identification and/or description of habitat use or dependencies by principal species.

   c. Identify relative and/or approximate numbers of birds utilizing habitats seasonally.

3. To identify habitats which may be considered of unique or critical importance to any species considering overall populations of the species relative to the number present, and the availability of similar alternative habitat.

III. Present Status:

Field work accomplished during the quarter included the completion of an aerial survey of coastal habitat from Cape Newenham to the Bering Straits, and an intensive study of habitat use on the north delta of the Yukon River. This work completed all field study requirements for the project.

The aerial survey of coastal habitat was conducted between August 17 and 20 by Calvin Lensink, Margaret Petersen and Chris Dau. Objectives of the survey were:

a. To enumerate species and numbers of birds using major habitat types.

b. To provide information for describing coastal habitat with emphasis on use by birds, dominant vegetation types, and vulnerability to coastal flooding.

c. To identify habitat areas of major or critical importance.

Transcription of tape recorded observations is incomplete. Preliminary impressions of observations suggest that other than the major breeding colonies of seabirds on cliffs near Cape Newenham and near Bluff on Seward Peninsula, the coastal lowlands of the Yukon Delta were of major importance although smaller areas such as at the head of Golovin Bay were also of significant value. The value of lowland habitat to birds appeared generally to be related to the extent and/or frequency of coastal flooding, the most vulnerable areas being most used by birds, chiefly waterfowl and several species of shorebirds.

Few marine mammals were observed except for harbor seals which were abundant at Cape Newenham. In excess of 80 carcasses of Walrus were observed beached between Kipnuk and Tununuk. These were all remains of animals killed by Eskimo hunters during the preceding spring.

An intensive study of habitat and its use by birds was conducted on a study area west of Kotlik and extended from late April through August. The area was of major importance for both breeding and migrant populations of waterfowl and shorebirds. Much of the study area was subject to almost daily inundation by tides. A marsh dominated by Potamegeton filiformis occupied the coastal fringe while a low sedge, Carex Ramenskii was found in areas of slightly higher elevation, although still subject to frequent flooding.

IV. Schedule

All mapped and tabular data, and a final report will be submitted to the OCSEAP Project Office, Juneau on or before December 31, 1977.

EFFECTS

EFFECTS

CONTENTS

QUARTERLY REPORT

RESEARCH UNIT #: 71
REPORTING PERIOD: July 1, 1977 to
September 30, 1977
CONTRACT #: 03-7-022-35130
NUMBER OF PAGES: 4

EFFECTS OF OILING ON TEMPERATURE REGULATION IN SEA OTTERS

Daniel Costa
John Caggiane

Univ. of California
Scripps Institue of Oceanography
Scripps Inst. of Oceanography
La Jolla, California

October 1, 1977

PROGRESS REPORT ON NOAA CONTRACT #03-7-022-35130
TO SUPPORT RESEARCH ENTITLED
"EFFECTS OF OILING ON TEMPERATURE REGULATION IN SEA OTTERS"

I. Personnel engaged in research study:

A. Dr. Walter Garey has left the research project.

B. Mr. Daniel Costa, a doctoral candidate from U.C. Santa Cruz has replaced Dr. Garey and will take over Garey's duties. Mr. Costa has had 3 years of intensive experience with sea otters (his doctoral work). His doctoral research has qualified him particularly in otter physiology and husbandry.

C. John Caggiane, a student volunteer from South Hampton College, will be assisting with animal care and experimental runs.

II. Metabolic chamber and instrumentation:

The metabolic chamber has been running smoothly.

III. Experimental animals:

A. Animal M's condition as outlined in the last report has improved, but it appears that she retains a low level chronic infection. We have therefore decided to transfer custody of animal M to Sea World.

B. On 2 September, 1977 a 15.2 kg female sea otter was collected under our permit # PRT 2-183 off Monterey, California by the personnel of California Department of Fish and Game. This animal has been designated animal D.

C. Animal B's health has remained excellent. She has been maintaining or gaining weight.

D. Animal D lost 1.4 kg 1 week after she was collected, but has since acclimatized to captivity and has begun to regain her original weight.

IV. Experiments:

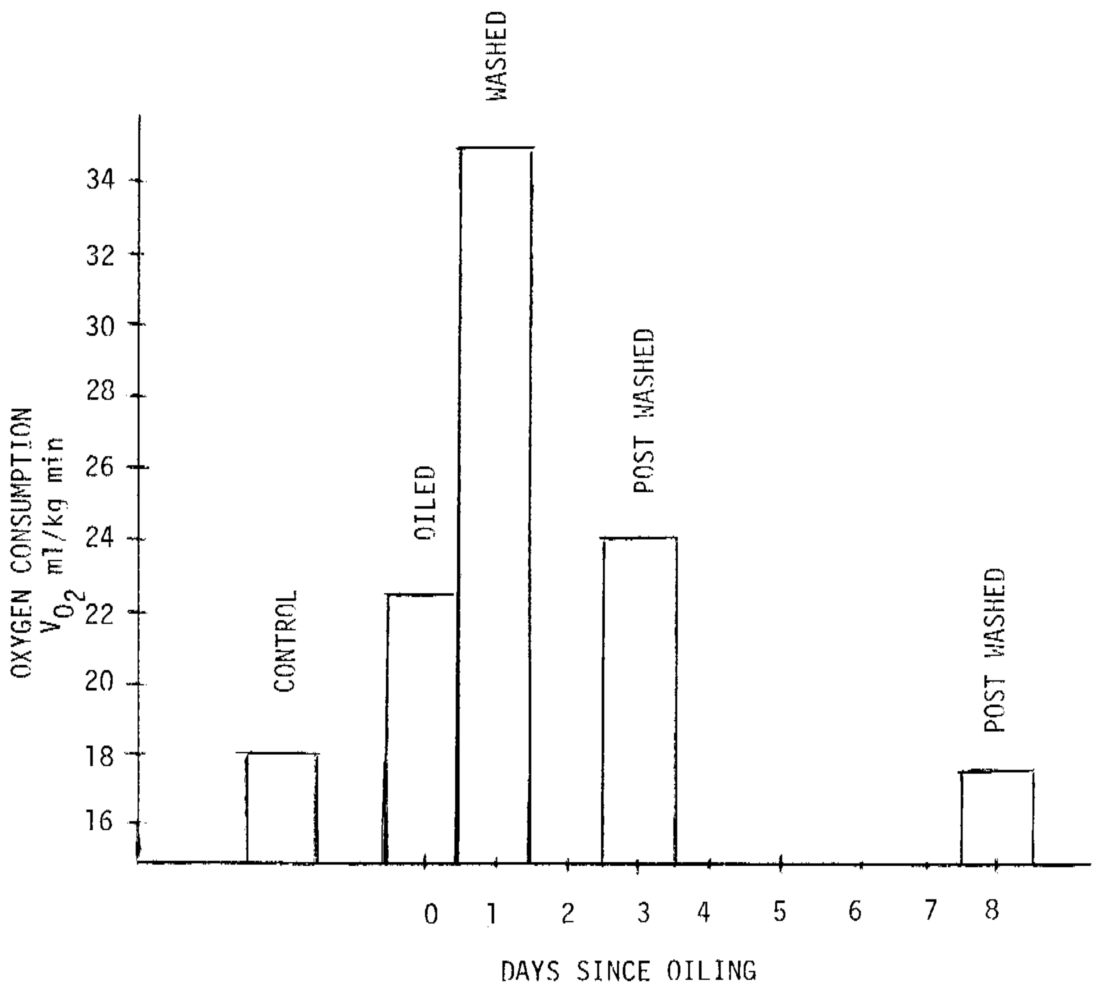
A. To date 24 6 hr. experimental runs have been made on the captive sea otters. Oxygen consumption has been measured with the water temperature at 5°C, 20°C, and 30°C on otter M (4 runs); 5°, 10°, 15°, 20°, and 25°C on otter B (19 runs) and 15°C for otter D.

B. Otter B was oiled with 38 ml of Prudhoe crude oil. The oil covered an area of 740 cm^2. The oil covering approximately 40% of the animals dorsal aspect. Prior to oiling a subcutaneous temperature telemetry transmitter was implanted beneath the area to be oiled. After oiling, O_2 consumption was monitored for 6 hours and then the oil was removed with amberlux detergent. After washing, the otter was returned to the holding tank and fed. The following day the otter was washed again and the oxygen consumption measured for 6 hours.

V. Results:

Average Oxygen Consumption (VO_2) ml/min · kg

Number of Runs	T_{H_2O}	$\dot{V}O_2$ of Entire Run	$\dot{V}O_2$ of Quiet Periods	$\dot{V}O_2$ of Grooming Period
5	25°C	16.6	12.9	20.2
4	20°C	18.4	13.5	19.2
5	15°C	18.1	14.6	23.4
1	10°C	22.3	13.4	23.1
4	5°C	27.1	18.8	30.5



The above figure compares the average oxygen for otter B prior to oiling (control), after oiling and after washing. The water temperature was 15°C.

A. The measured resting oxygen consumption of the 3 otters is 2.9 times the predicted rate for a terrestrial mammal of equal size. This value is in good agreement with previously reported values.

B. The metabolic rate of otter B after oiling was 124% of the control value. The metabolic rate after washing increased to 193% of the

the control value. After washing appearance of fur indicated loss of the air layer normally present. Within 24 hours, subsequent grooming activity apparently restored the air layer to much of the fur. Two days after washing, the otters metabolic rate was 133% of the pre-oiling value.

VI. Upcoming work:

A. We plan to oil the otter B again, but this time we will oil a larger fraction of the animals total surface area.

B. Control values for otter D are currently being measured. This animal will probably be oiled by December, 1977.

C. A fourth otter will probably be collected from Monterey, California during January, 1978.

D. Plans are being made for the upcomming field work in Alaska during the summer of 1978.

E. A permit amendment requesting clearance for work with 25 sea otters in Prince William Sound, Alaska will be submitted in the near future.

QUARTERLY REPORT

Contract No.
Research Unit #72
Report Period - July 1, 1977 to Oct. 1, 1977
Number of Pages - 7

ACUTE AND CHRONIC TOXICITY, UPTAKE AND DEPURATION, AND SUBLETHAL METABOLIC RESPONSE OF ALASKAN MARINE ORGANISMS TO PETROLEUM HYDROCARBONS

by

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October 1, 1977

Introduction

The July-September quarter has been productive, with intensive data collection bringing several experiments to an end. Some sample analyses are continuing and a few experiments are continuing into October, especially those requiring small shrimp which are not collectable during warmer weather in July, August and September. Staffing problems were resolved during the summer, but new problems are eminent. The experiments requiring intensive expertise of chemists, and gas chromatography, have been delayed and have been reprogrammed to continue into next fiscal year. Data evaluation and manuscript synthesis will be emphasized in the first quarter of FY 1978.

I. Task Objectives and Progress

1. Determine the acute toxicity of the water-soluble fraction (WSF) of crude oil (1.3 man years):

a. Continue experiments with species not tested previously. Static tests will be phased out and flow-through tests phased in.

Progress: The shore crab Hemigrapsus nudus was tested with benzene, toluene, and naphthalene using flow-through dosing methods, and was found to be a tolerant animal. The final manuscript of comparative sensitivities determined by static tests is almost completed.

b. Continue experiments with molting larvae. Tests will be static. Larvae of previously untested species (such as mussels, barnacles, snails, and sea urchins) will be tested with WSF, toluene and naphthalene.

Progress: There has been little change since the April-June quarterly report. Tests with additional species were cancelled because of administrative delays in hiring key personnel. Tests with coonstripe larvae that were completed during the third quarter have been analyzed and manuscript synthesis is in progress.

c. Determine sensitivity changes of several salmonid species when transferred to seawater at time of normal seaward migration.

Progress: Data acquisition and analyses have been completed, and the manuscript is currently in lab review. The previous observation of increased sensitivity upon transfer to seawater has been confirmed with three other species and with toluene, naphthalene and WSF.

2. Determine which components of oil account for toxicity (3.25 man years):

a. Assess the toxicity role of phenols and heterocycles by determining quantities in oil and WSF's, and determining the acute toxicity to three species of the major compounds found in the WSF. Toxicity tests will be static.

Progress: All bioassay and uptake tests have been completed. Detailed analyses by National Analytical Laboratory at Seattle are completed. Some phenols and cresols are present. Toxicity and uptake tests with phenol and cresol have been completed with shrimp and fish. Data evaluation is in progress.

b. Determine toxicity of natural WSF and a synthetic WSF to three species with flow-through tests to determine whether the synthetic WSF accounts for all the toxicity. Compounds that are difficult to analyze, or that may be in trace quantities, can probably be eliminated as major components responsible for toxicity. Future test will be with altered synthetic WSF's.

Progress: This study was delayed by the death of Lauren Cheatham, chemist, and resignation of chemist Sue Way, who operated the GC. The new chemist Steve Lindsay has mastered the GC analyses which has been calibrated with standards from NOAA analytical facility at Seattle. R&D for WSF generation is now in progress, and this project has been reprogrammed to continue into next fiscal year.

c. Determine time-dependent toxicity recovery curves with mono- and dinuclear aromatics to three species with flow-through tests. Tests will be with individual compounds and combined mixtures. This will be a beginning effort to assess the relative importance of mono- and dinuclear aromatics.

Progress: The R&D for flow-through exposures has been developed for compounds used singlely, and the apparatus is in use. We have started conducting exposures to two compounds simultaneously with brine sthrimp. This experiment will extend into FY 78 with additional species before completion.

3. Determine the effects of short-term exposures to WSF's on the survival of tagged marine organisms that are returned to the natural environment. Scallops will be tagged, exposed, and returned to pens in Auke Bay, with exposed and nonexposed starfish (*Pycnopodia helianthodes*) also being introduced into the pens. Their survival will be monitored for up to 3 months. Tests with pure aromatic fractions will also be used.

Progress: Preliminary tests with scallops exposed to sublethal doses of oil and returned to pens in the natural environment indicated that oil exposure reduced survival. Control and exposed scallops were preyed upon by the sunflower star *Pycnopodia helianthodes* which entered the pens. A follow-up study with scallops and *Pycnopodia* was completed; however reduced feeding by both control and oil exposed starfish made the results of the experiment inconclusive. Handling of starfish is believed to have disrupted their incentive to feed. As we have found previously, field studies are unpredictable and often require large samples, difficult logistics, and much R&D due to the many uncontrollable variables.

4. Determine the effects of WSF's of oil and pure aromatics on the metabolic rate of invertebrate species. Oxygen uptake will be monitored by a blood-gas analyzer, and heart rate will be measured. Experiments will be coordinated with uptake-depuration experiments (tissue burden experiments) to assess the animal's oil uptake capacity. (2 man years).

Progress: Studies to determine effects of petroleum oil components on *Hemigrapsus* crab heart rate and O_2 consumption are continuing. Crabs were exposed to concentrations of benzene, toluene and naphthalene contінously while the heart rate and O_2 consumption was monitored. Studies will be completed by November 1977.

5. Determine the tissue burden of several species exposed to oil or labelled aromatics, and their ability to rid themselves of hydrocarbons. Analyses will be by NOAA National Analytical Laboratory or by liquid scintillation. (1 man year).

a. Larvae will be tested with WSF's spiked with labelled isotopes. The form of the isotope (parent hydrocarbon vs metabolite) will be checked by the method of Roubal et al. (1976). No determinatiion of metabolite identity will be attempted.

Progress: Experiment completed and manuscript is being written describing results of coonstripe shrimp larvae experiments.

b. The tissue burden of animals was to be determined by exposure in long-term flow-through tests (see Objective 3). Mono- and dinuclear aromatic hydrocarbon concentrations were to be determined by two GC runs per sample, and verified by two GC-MS determinations per series of 12.

Progress: Cancelled during spring quarter; no chemist available to do the R&D.

c. Determine the aromatic hydrocarbon uptake depuration pattern in salmonid smolts when exposed in seawater and in fresh water.

Progress: Experiments completed in early summer; data analyses is in progress.

6. Determine the pathway and rate of elimination of labelled mono- and dinuclear aromatics in fish and invertebrates; identify the labelled compounds as "parent" or "metabolite". Gills and excretory organs will be treated separately. Isotope form (parent hydrocarbon introduced vs metabolite) will be determined using the method of Roubal et al. (1976). (0.4 man year).

Progress: Experiments determining the excretory pathway for toluene and naphthalene by salmonids were completed in August. Toxicants were administered orally and the fish were placed in partitioned chambers with the ureters catheterized. Samples were analyzed radiometrically. Several experimental conditions were tested, such as comparisons between fresh- and saltwater acclimated animals, and the results are currently being analyzed. In general, toluene was eliminated more rapidly, primarily via the gills, and in a nonmetabolized form. An additional study with _Hemigrapsus nudus_ concerning uptake and metabolism and depuration of naphthalene was completed. Adult crabs were exposed to ^{14}C naphthalene and the blood, hepatopancreas, muscle, gut, and nerve ganglion sampled periodically during exposure and a depuration period. The Roubal method was used to determine metabolite level. Crabs were exposed to naphthalene in their bath then divided into three groups for depuration in water, in air, or normal tidal cycle. Exposures have been completed but radiometric measurements have not been completed for each of the tissues.

7. Determine the rate of byssal thread extrusion of mussels exposed to WSF, toluene and naphthalene.

Progress: Static tests were completed previously (first quarter) and manuscript synthesis is in progress.

8. Determine the effect of temperature on fish and shrimp sensitivity to toluene and naphthalene, and the effect on uptake-depuration. Tests are flow-through, and Roubal samples will be taken during the uptake tests.

Progress: Tests with pink salmon juveniles are complete. Flow-through assays and uptake studies were completed at 4°, 8° and 12°C with toluene, and naphthalene. During the uptake studies, viscera, muscle and whole body residues were determined. Bioassays and uptake studies at the three temperatures will be repeated with Eualus shrimp this fall, when the shrimp are available.

9. Compare sensitivities of tolerant and sensitive species to toluene and naphthalene when exposed in static and flow-through tests.

Progress: Pink salmon, the black sea cucumber Cucumaria vegae, and the shore crab Hemigrapsus were tested with naphthalene and toluene using both static and continuous-flow bioassay methods. Shrimp will be tested in October. So far, the differences between static and flow-through tests have been insignificant with the sensitive fish, and dramatically different with tolerant species.

Part III. Interpretation of Results

Interpretations of results will be supplied in reviewed manuscripts. Progress on manuscripts has increased after the bulk of summer experiments were completed.

Part IV. Problems Encountered

1. We are approaching the point where new chemists, hired to replace Cheatham, Short and Way, are becoming valuable team members. To accelerate the training of the new chemist Steve Lindsay, we have sent him to the NMFS Seattle and Tiburon laboratories to learn current oil analyses methods. Two additional inexperienced chemists have been hired, and we are attempting to stabilize this section through permanent appointments.

Two temporary employees have been or will be terminated, to meet the October 1 personnel ceilings. We will be attempting to rehire one of them shortly after October 1 to complete one of the studies in progress. Short will complete analyses and three manuscripts before resigning in October.

2. Field studies are inherently more expensive and less productive due to the many uncontrolled variables in the natural environment. With funding cutbacks scheduled for FY 78, it will be necessary to terminate field efforts and concentrate on laboratory studies.

Part V. Estimate of Funds Expended for FY 77. Budget Summary as of September 30.

	Annual Plan	Costs to Sept. 30, 1977
Salary Costs	$ 216.4K	$ 209.3K
Travel	30.1	22.9
Contracts	68.0	37.8
Equipment & Supplies	99.4	143.9
Other Direct & Indirect Costs	86.1	86.1
Total	$ 500.0K	$ 500.0K

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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Edward H. Gruger, Jr.*

Harold O. Hodgins*

Neva L. Karrick*

Douglas D. Weber*

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for Contract #R7120819
Research Unit #73/74
OUTER CONTINENTAL SHELF ENERGY ASSESSMENT PROGRAM
Sponsored by
U.S. Department of the Interior
Bureau of Land Management

October 1, 1977

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TABLE OF CONTENTS

ABSTRACT

The responses of marine organisms to environmental contaminants are reflected in a number of changes detectable at population and organismic levels, as well as at cellular, subcellular, and molecular levels. The general scope of this study is to evaluate effects on the various levels by multidisciplinary investigations of behavioral, morphological, chemical, and pathological changes in subarctic and arctic marine animals exposed to petroleum hydrocarbons and trace metals.

Behavior

Studies were conducted to assess the effect of the seawater soluble fraction (SWSF) of Prudhoe Bay crude oil (PBCO) on the embryonic development of a dorid nudibranch (Onchidoris bilamellata). At the highest exposure level (278 ppb) egg deposition and development was retarded, and approximately half of the eggs laid were either not encapsulated or showed other abnormalities. At lower levels of exposure (28 and 8 ppb) the effect of the SWSF on egg development was reduced accordingly.

Chemistry

A study was completed on the accumulation and distribution of 1-methylnaphthalene (1-MN) which was force-fed to coho salmon (Oncorhynchus kisutch) at 10°C. When compared to previous work with naphthalene, the accumulation and distribution of 1-MN in tissues of coho salmon and starry flounder (Platichthys stellatus), which were exposed to 1-MN under flow-through conditions, indicate that more alkylated naphthalene than naphthalene accumulates in muscle, gills, and livers of exposed fish. For the first time, studies are underway to elucidate the influence of temperature on the formation of metabolites of alkylated naphthalenes in starry flounder by challenging the fish at 4° and 10°C to 2,6-dimethylnaphthalene.

Mussels (Mytilus edulis) were induced to spawn and the gametes maintained in seawater solutions containing approximately 10, 1, and 0.1 ppb ^{3}H-labeled naphthalene. Each container of gametes was sampled at varying intervals for 24 hr. The samples are being processed to determine any differences in embryology attributable to the different exposures. Postlarval shrimp (Pandalus danae) and coho salmon fry were exposed to a solution of ^{14}C- and ^{3}H-naphthalene. The animals were sacrificed after 12 and 24 hr and samples are being extracted and examined by high performance liquid chromatography for characterization of naphthalene metabolites.

Rainbow trout (Salmo gairdneri), exposed to ^{3}H-1,4,5,8-naphthalene through force-feeding, intraperitoneal injection, or in flowing water, accumulated significant concentrations of both naphthalene and its metabolic products in skin, regardless of the mode of exposure. Naphthalene and its metabolites in skin both increased in concentration with time initially; how-

ever, after reaching maxima, the concentrations of naphthalene decreased more rapidly than the metabolites in all three modes of exposure. At the end of each experiment, the percent of total radioactivity in the skin attributable to the metabolites was 17.6% (force-feeding study), 15.1% (injection study), and 52.0% (water-immersion study). The pattern of uptake and release of naphthalene and its metabolites in skin were comparable to that revealed for these compounds in the liver.

Coho salmon were exposed for 3 weeks to 200 ppb lead in seawater and were fed Oregon moist pellets containing 334 ppm aromatic hydrocarbons during the last week of the metal exposure. The fish received an injection of ^{14}C-naphthalene at 24 hr before the end of the experiment. Initial results indicate that in the metal-exposed coho salmon the level of the naphthalene metabolite, 1,2-dihydrodiol, was 70% higher than in control fish. Results indicate that lead can influence the metabolism of petroleum aromatic hydrocarbons. However, at present, it cannot be stated whether lead induces the conversion of naphthalene to the dihydrodiol or inhibits its elimination from the liver. Results suggest that a cadmium-binding protein[a] in cytosol of key organs may sequester cadmium from the environment and provide a defense mechanism for such organisms.

Specific activities of aryl hydrocarbon hydroxylases (AHH) were determined for 89 tissue samples from six species of fish, a gastropod, and a crab. The usual wide range of activity values were noted for individual fish of a single species. AHH activity was found for all species except the gastropod. Importantly, the results indicate that the AHH are present in certain species and absent in others from Alaskan waters. Fish and crabs should be capable of metabolic transformations of petroleum aromatic hydrocarbons.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-contaminated Sediment

Histological, chemical, and statistical analyses of specimens and data from an experiment involving exposure of English sole (Parophrys vetulus) to PBCO-contaminated sediments for 4 mo have been essentially completed. Histological examinations with the electron and light microscopes have further defined the structure and prevalence of previously reported hepatocellular lipid vacuolization, and have detected a high frequency of parasitic infestation in the gills of oil-exposed fish. Chemical analyses for petroleum hydrocarbons in skin, muscle, and liver showed that, at 1 and 2 mo of exposure to the oiled sediments, detectable levels of petroleum polycyclic aromatic hydrocarbons were found only in the liver.

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[a] Cadmium-binding protein (CdBP) corresponds to "metallothionein," a low molecular weight protein believed to "detoxify" cadmium.

Effects of Petroleum on Fish Disease Resistance

The significantly reduced spleen to somatic weight ratio previously observed in oil-exposed rainbow trout (1,000 ppm fed for 10 mo) was found to correlate with reduced numbers of spleenic leukocytes, but no reduction in red blood cells or leukocytes from peripheral blood was evident. Tests of immunological function, including response to selected mitogens, polyclonal lymphoid cell activation, and vaccination-live-bacterial challenge experiments, failed to identify any additional negative effects of oil exposure.

Morphology

Flatfish exposed to PBCO-contaminated sediment were examined this quarter. Tissues from English sole were processed and examined with a transmission electron microscope. The structural changes observed in liver cells of oil-exposed fish (cf., Pathology section) are interpreted as a general stress reaction and not necessarily unique to oil exposure. Concurrently, a scanning electron microscopy examination of eggs and larvae of fish collected in the Bering Sea and Gulf of Alaska has been completed as well as a survey of the structure of lenses of 17 species of pelagic and benthic fish from the Gulf of Alaska. The latter samples will serve as a reference collection for future studies of oil-exposed environments.

OBJECTIVES

In this multidisciplinary approach to evaluate the effects of petroleum on marine organisms, there are a series of objectives. The specific objectives performed during the current quarterly reporting period of July 1 to September 30, 1977 are as follows:

Behavior

To evaluate the effect of the seawater soluble fraction (SWSF) of Prudhoe Bay crude oil (PBCO) on dorid nudibranch egg deposition and development.

Chemistry

In studies of the biological transformations of petroleum hydrocarbons, there are three objectives: (1) to determine the distribution and concentration of 1-methylnaphthalene (1-MN) in coho salmon receiving this compound by force-feeding; (2) to determine the distribution and concentration of 1-MN in coho salmon and starry flounder exposed to ppb levels of 1-MN for 4 and 2 weeks, respectively, under flow-through conditions; and (3) to determine the influence of temperature on the metabolism of alkylated naphthalenes in fish.

To determine in mussels (1) the contribution that impurities found in radioactive test hydrocarbons have on previous results, (2) whether or not biological exchange of the ^3H-label in naphthalene takes place, and (3) at what concentration does naphthalene begin to affect gamete viability and early embryology of mussels.

To evaluate the importance of skin and epidermal mucus in accumulation, metabolism, and excretion of polycyclic aromatic hydrocarbons in fish. Specifically, to determine concentrations of naphthalene and its metabolic products in skin of salmonid fish exposed to naphthalene by different methods, namely, injection, force-feeding, and immersion.

To identify the possible influences of lead and cadmium on the metabolism of petroleum aromatic hydrocarbons in coho salmon and starry flounder.

To measure specific activities of aryl hydrocarbon hydroxylases (AHH) in different marine species representing a range of phyla.

Pathology

To characterize the long-term pathological effects of exposing flatfish to petroleum hydrocarbons in sediment.

To determine if exposure to petroleum hydrocarbons affects disease resistance and immune responses in salmonid fish.

Morphology

To identify cellular changes in liver of English sole, which had been exposed to PBCO-contaminated sediments, along with other pathological alterations.

To establish a reference collection of eggs and larvae of pelagic fish for species indigenous to the Bering Sea and the Gulf of Alaska.

FIELD OR LABORATORY ACTIVITIES

SHIP OR FIELD TRIP SCHEDULE

Morphology

Miller Freeman, May 3-19, 1977, Cruise RP-4-MF-77B, Leg VI.
Professor Siedlecki, July 1-18, Cooperative cruise:
NOAA-Fisheries Institute of Godynia, Poland.

SCIENTIFIC PARTY

The following persons are affiliated with the Environmental Conservation Division of the Northwest and Alaska Fisheries Center.

Name	Role
D. Malins, PhD, DSc	Principal investigator; hydrocarbon metabolism
W. Roubal, PhD	Research chemist; hydrocarbon metabolism
D. Lazuran	Chemist; sample preparation; assistant to Dr. Roubal
J. Parker	Pathobiology; fish handling
H. Sanborn	Oceanographer; invertebrate zoology
C. Short	Graduate student; assistant to Mr. Sanborn
F. Stephan	Biological aide; assistant to Mr. Sanborn
U. Varanasi, PhD	Research chemist; metal/hydrocarbon studies on skin/mucus
D. Gmur	Chemist; assistant to Dr. Varanasi
W. Reichert, PhD	Chemist; studies on metals/ hydrocarbons
D. Federighi	Chemist; assistant to Dr. Reichert
E. Gruger, Jr., PhD	Principal investigator; coordinator of chemical analyses/ enzyme-hydrocarbon studies
L. Folmar	Fishery research biologist; assistant to Dr. Gruger, enzyme studies
D. Dungan	Chemist; assistant to Dr. Gruger, enzyme studies
D. Weber	Principal investigator; behavioral studies
F. Johnson	Fishery biologist; part-time, assistant to Mr. Weber, behavioral studies

L. Mumaw	Marine biologist; graduate student, assistant to Mr. Weber
N. Karrick	Principal investigator; chemical investigations
H. Hodgins, PhD	Principal investigator; physiological and pathological studies
W. Gronlund	Fishery research biologist; assistant to Dr. Hodgins
B. McCain, PhD	Microbiologist; effects of petroleum in sediments on flatfish, coinvestigator with Dr. Hodgins
M. Myers	Fishery biologist; part-time assistant to Dr. McCain
K. King	Fishery biologist; part-time assistant to Dr. McCain
M. Schiewe	Fishery research biologist; disease resistance studies
E. Warinsky	Biological aide; part-time assistant to Mr. Schiewe
L. Rhodes	Biological aide; part-time assistant to Dr. McCain
J. Hawkes, PhD	Fishery research biologist; electron microscopy
C. Stehr	Technician; assistant to Dr. Hawkes
S. Gazarek	Technician; assistant to Dr. Hawkes
L. Thomas, PhD	Research chemist; analyses of hydrocarbon metabolites

METHODS

Behavior

Twenty mature dorid nudibranchs (Onchidoris bilamellata) were placed in each of four 2,000 ml flow-through aquaria and supplied with filtered seawater at $13.6^{\circ} \pm 0.6^{\circ}C$. The SWSF of

PBCO used for exposure was generated by a system described by Roubal et al. (1977a), and water samples were analyzed for petroleum components by gas chromatography (GC).

The first egg masses laid were placed in rearing cages in the aquaria. Replicate egg aliquots from these masses were taken daily 5 days per week and fixed in buffered preservative (Hawkes 1974; with addition of 17 g "Instant ocean" per liter of buffer). In addition, eggs laid each day were collected and weighed, and a count was made of dorids that were present in aggregations. Analysis of ontogenetic development was conducted with light microscopy.

Chemistry

Coho salmon were force-fed ^{14}C-labeled 1-MN in a salmon oil carrier, or were exposed to 1-MN in a flow-through system (Roubal et al. 1977a). Excised tissues from the salmon were digested by methods of MacLeod et al. (1976), and hydrocarbon fractions were assayed for radioactivity by scintillation counting. Metabolites of alkylated naphthalenes are being analyzed by high performance liquid chromatography (HPLC).

^{3}H-Naphthalene was administered in a water-borne solution to gametes of artificially spawned mussels. Each concentration (10, 1, and 0.1 ppb) of the naphthalene and the controls were triplicated. Samples were removed from the container of gametes at 30 min, and 1, 2, 3, 6, 12, and 24 hr. They were preserved in 5% buffered formalin solution for future analysis. Water samples were taken at each time period to determine the concentration of naphthalene.

^{3}H- and ^{14}C-Naphthalene were administered in solutions under flow-through conditions to 150 shrimp and 24 coho salmon fry. The shrimp were removed after 12 hr, washed, and prepared for analysis. Six salmon fry were sacrificed and the gut removed. The gut samples were extracted and analyzed by HPLC.

Rainbow trout (Salmo gairdneri) were injected intraperitoneally with 40 μl of salmon oil containing 94.6 μCi of ^{3}H-naphthalene. The fish were kept in flow-through aquaria until the sampling time at 4, 16, 24, 48, and 168 hr after injection.

Water-immersion exposures of the trout were performed. With the aid of a peristaltic pump, cold, oxygenated fresh water (flow rate of 600 ml/min) was mixed with a refrigerated stock solution containing ^{3}H-naphthalene (flow rate of 2 ml/min) prior to its entering a test aquarium containing 12 fish. The fish were exposed to 9.2 ± 1.8 ppb of naphthalene under these conditions at 10°C and were sampled at 24, 48, and 72 hr during exposure and after 72 hr of depuration. Methods employed in force-feeding of naphthalene to trout are described in the previous quarterly report (OCSEAP Quarterly Report, RU 73/74, June 1977).

The methods used for determining ^{109}Cd distribution were described in the OCSEAP Annual Report, RU 73/74, April 1977. Injections of ^{109}Cd were employed to obtain sufficient radioactivity in the organisms to allow for the determination of subcellular distributions of cadmium. Exposure conditions for studies concerning influence of heavy metals on hydrocarbon metabolism were described in OCSEAP Quarterly Report, RU 73/74, June 1977.

Specific activities of aryl hydrocarbon hydroxylases (AHH) were measured using tritium-labeled benzo(a)pyrene as the enzyme substrate (Gruger et al. 1977). The samples analyzed for AHH activities were held at -60°C since their collection and included fish livers, tanner crab (Chionoecetes sp.) visceral organs, and whole body tissues of gastropods (Fusitriton sp.).

Pathology

Pathological Changes in Flatfish from Exposure to Oil-contaminated Sediment

English sole (Parophrys vetulus) were exposed to PBCO-contaminated sediments in a flow-through seawater system (for procedures see OCSEAP Annual Report, RU 73/74, April 1977).

Chemical analyses of tissue and sediment samples were performed by methods described in MacLeod et al. (1976). Analyses for petroleum hydrocarbons were performed on skin, muscle, and liver samples collected from control and test fish after 11, 27, and 60 days of exposure to PBCO in sediments. Light microscope examination of tissue prepared by standard histological procedures was performed on all tissues collected from oil-exposed and control fish.

Effects of Petroleum on Fish Disease Resistance

Disease resistance was compared among groups of immunized juvenile rainbow trout which were maintained on diets containing (1) a high level of PBCO (1,000 ppm), (2) a low level of PBCO (10 ppm), and (3) no PBCO (control), for 11 mo prior to testing. Fish were vaccinated against and challenged with Vibrio anguillarum and LD_{50} values were calculated. Additional tests of immunocompetence on similarly exposed fish included determination of response to selected mitogens (Etlinger et al. 1976) and polyclonal lymphoid cell activation.

Follow-up studies on the reduced spleen/somatic weight ratio previously observed in oil-exposed fish were also conducted; red blood cell (RBC) and leukocyte counts from peripheral blood as well as spleenic leukocyte counts were determined using standard hematological techniques.

Morphology

During the Bering Sea cruise, ichthyoplankton samples were obtained from a neuston surface sampler with a 40 cm Sameoto net (333 μ mesh), mounted on a metal frame 31 cm x 47 cm, that was towed at 2 knots for 5 min. Bongo nets were used to sample plankton populations at either 212 m below the surface or 10 m above the bottom. Bottom and pelagic fish species from the Gulf of Alaska were obtained by trawls operating at depths ranging from 7 to 130 m.

SAMPLE COLLECTION LOCALITIES

Chemistry

All exposures of fish in seawater were conducted in the laboratory at the Northwest and Alaska Fisheries Center (NWAFC) Mukilteo facility. Postlarval shrimp were reared in the laboratory from captured gravid shrimp. Mussels were collected as ripe adults and conditioned for spawning in the laboratory.

Rainbow trout were obtained from Hatchery Trout Lodge in Tacoma, Washington and maintained at the NWAFC laboratory in Seattle.

Samples of marine phyla used for determinations of AHH activities were those collected during a cruise of the Miller Freeman in Alaska, as reported in the OCSEAP Annual Report, RU 73/74, April 1977.

Morphology

Samples were collected during May in the Bering Sea (Fig. 1) and during July in the Gulf of Alaska (Fig. 2).

DATA COLLECTED AND/OR ANALYZED

Chemistry

Number and type of samples or observations

Coho salmon force-fed ^{14}C-labeled 1-MN were sampled at 4, 16, 24, and 48 hr intervals from initial feeding (six fish per sample). Coho salmon exposed to 1-MN under flow-through conditions were sampled weekly during a period of 4 weeks, and during a 2 week period of depuration. A total of 120 fish were sampled. In addition, replicate water samples were collected weekly.

In studies with radioactive tracer experiments using naphthalene, 15 water samples, 100 shrimp samples, and 12 fish samples were collected.

The species and number of samples taken for measurements of AHH activities are as follows:

Flathead sole (Hippoglossoides elassodon), 12
Rock sole (Lepidopsetta bilineata), 24
Arrowtooth flounder (Atharesthes stomias), 12
Butter sole (Lepidopsetta isolepis), 3

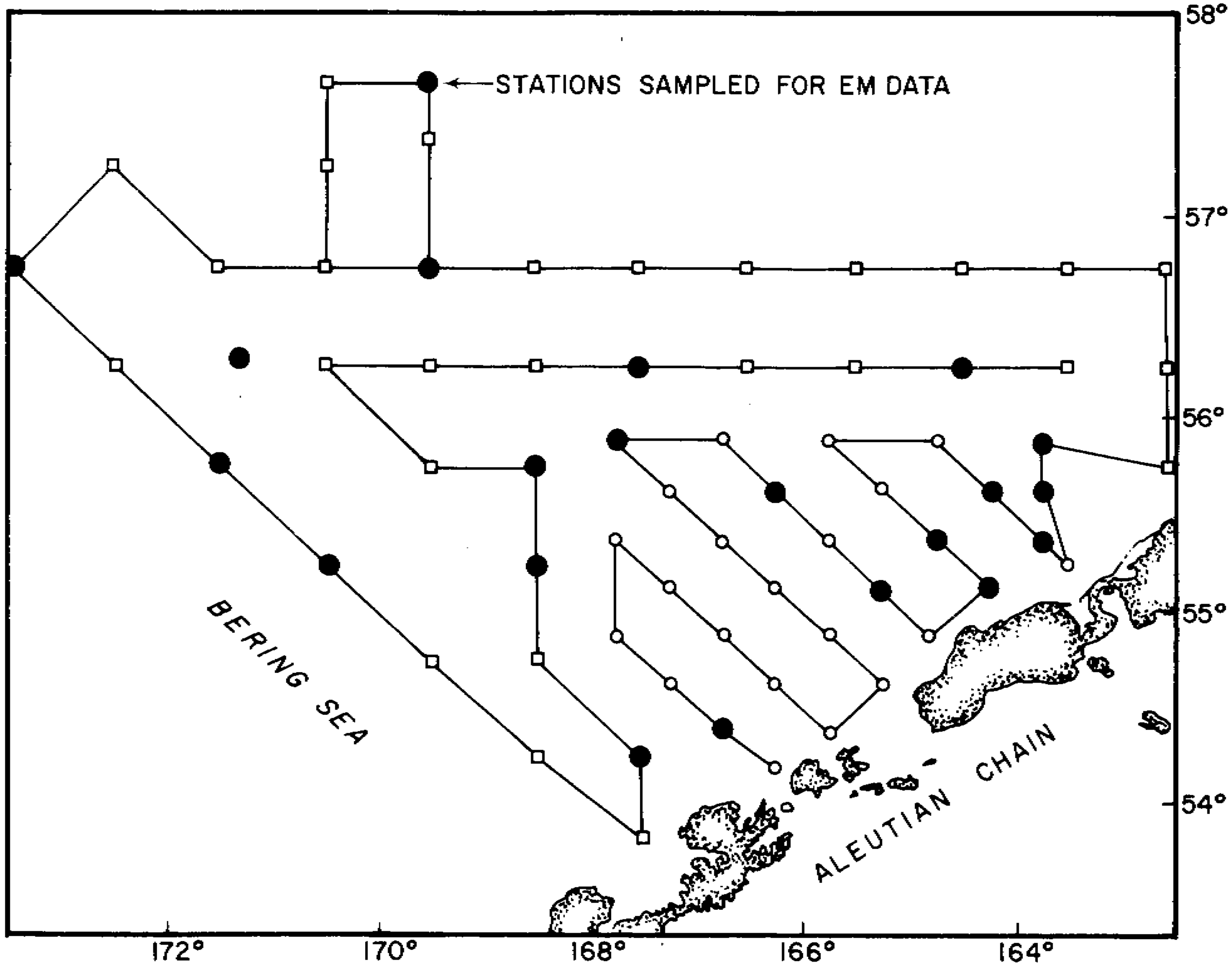


FIGURE 1. *Map showing the collecting sites in the Bering Sea where samples were taken on the* *Miller Freeman* *cruise, May 13-19, 1977.*

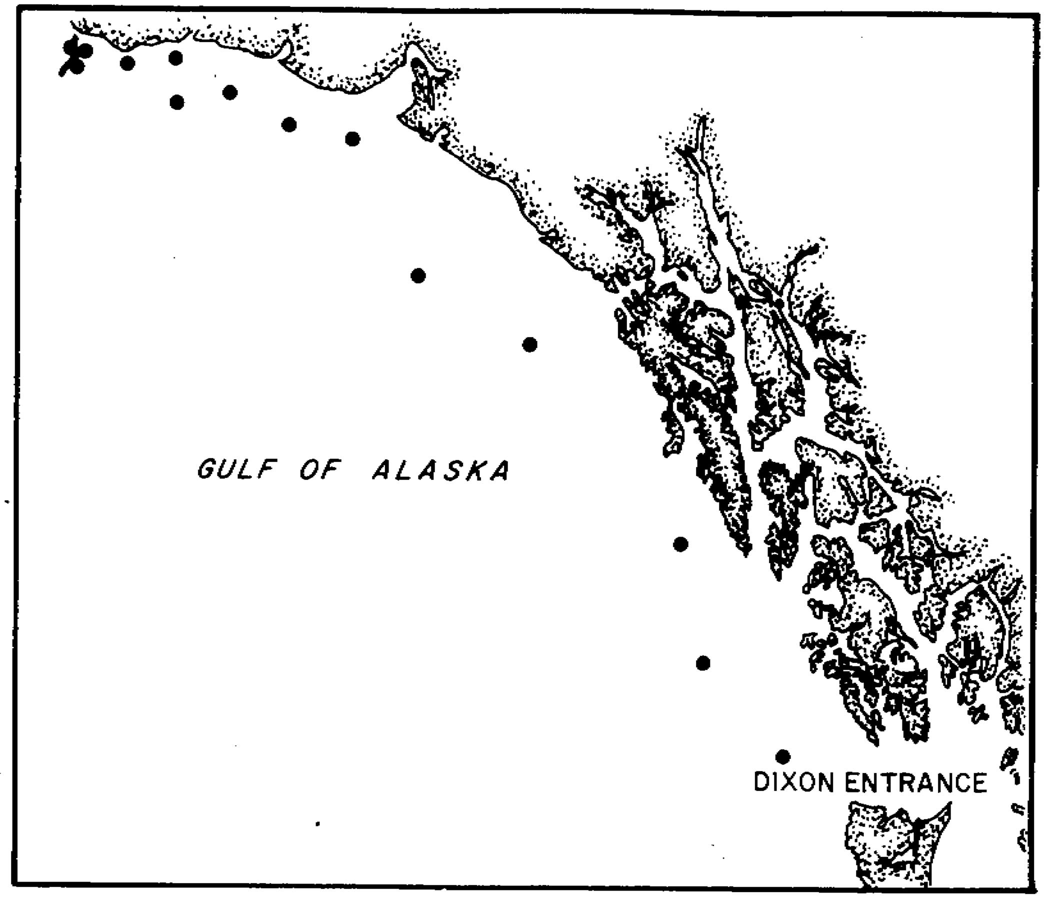


FIGURE 2. *Map of the collecting sites in the Gulf of Alaska where samples were taken from the* *__Professor Siedlecki__* *cruise, July 1-18, 1977.*

Pollock (*Theragra chalcogramma*), 13
Pacific cod (*Gadus macrocephalus*), 16
Gastropod (*Fusitriton* sp.), 4
Tanner crab (*Chionoecetes* sp.), 5

Number and type of analyses

Extracts of organs from individual coho salmon force-fed ^{14}C-labeled 1-MN were analyzed for parent hydrocarbon via liquid scintillation counting. Kidney, blood, brain, muscle, and liver were used for a total of 120 analyses. Triplicate 7 g composite samples of muscle, triplicate 1-2 g samples of liver, and 4-5 g samples of gills from three separate groups of five test fish and from one group of controls for automated GC analysis of 1-MN were analyzed, for a total of 72 analyses.

In metabolic studies with shrimp and mussel gametes, there were 25 metabolite extractions, 3 HPLC separation/analyses, and 500 liquid scintillation samples were counted.

A total of 89 sample analyses were carried out in duplicate and triplicate for specific activities of AHH for the different marine species.

Pathology

Pathological Changes in Flatfish from Exposures to Oil-contaminated sediments

Number and type of samples or observations

Tissue samples (34) for histology and sediment samples (10) for hydrocarbon analyses were employed.

Number and type of analyses

Histological slides (474) were examined and interpreted.
Hydrocarbon analyses (10) of sediment were performed.
Hydrocarbon analyses (32) of tissues were performed.

Effects of Petroleum on Fish Disease Resistance

Number and type of samples or observations

Spleens for lymphoid cell counts and mitogenesis studies (23); peripheral blood leukocyte suspensions for polyclonal activation studies (6); serum for antibody titration (40); whole blood for red blood cells (RBC) and leukocyte counts (20).

Number and type of analyses

Jerne plaque determinations for antibody forming cells (6); mitogenesis assays (8); antibody titrations (40); spleenic leukocyte counts (3); peripheral RBC counts (20); peripheral blood leukocyte counts (20); LD_{50} determinations (4).

Morphology

For light and electron microscopy, 850 blocks of tissues from English sole were embedded.

Samples for microscopic examinations of the following species were taken during Alaskan cruises.

Bering Sea

- Pleuronectidae (right-eyed flounder)
  - Atheresthes stomias
  - Reinhardtus hippoglossoides
- Cottidae (sculpins)
  - Hemilepoidotus jordani
  - Hemilepidotus sp.
  - Cottidae spp. (2)
- Hexigrammidae (greenlings)
  - Hexagrammos spp. (2)
- Zoareidae (eel pouts)
  - Zoarcidae
- Macrouridae (grenadier - rat-tail)
  - Macrouridae
- Ammodytidae (sand lance)
  - Ammodytes hexapterus
- Stichaeidae (pricklebacks)
  - Lumpenis maculatus
  - Bryozoichthys sp. or Chirolophis sp.
  - Stichaeidae spp. (2)
- Osmeridae (smelt)
  - Mallotus villosus
  - Bathylegus pacificus
  - Leuroglossus schmidti
- Bathymasteridae (ronquils)
  - Ronquilis jordini
- Gadidae (codfish)
  - Theragra chalcogramma
- Cyclopteridae (lampfish and snailfish)
  - Aptocyclus ventricosus
  - Nectoliparis pelagicus
- Myctophidae (lanternfish)
  - Stenobrachius leucopsarus

Gulf of Alaska

- Theragra chalcogramma (pollock)
- Anoplopoma fimbria (black cod)
- Hippoglossoides elassodon (flathead sole)
- Sebastes helvomaculatus (rosethorn rockfish)
- Sebastolobus alascanus (idiot rockfish)
- Sebastes borealis (rougheye rockfish)
- Atharesthes stomias (arrowtooth flounder)
- Hippoglossus stenolepis (halibut)

Glyptocephalus zachirus (rex sole)
Sebastes variegatus (harlequin rockfish)
Trichodon trichodon (Pacific sandfish)
Sebastes ciliatus (dusky rockfish)
Zaprova silenus (prowfish)
Lycodes brevipes (shortfin eelpout)
Sebastes crameri (dartblotched rockfish)
Thaleichthys pacificus (euchalon)
Clupea harengus pallasi (Pacific herring)

Any parasitized fish were also sampled, as well as fish with tumors or abnormal growths. These included:

1. Damaged tissue from gill area of Sebastes alutus (Pacific ocean perch)
2. Liver parasites from S. alutus
3. Liver samples of Oncorhynchus gorbuscha (pink salmon)
4. Liver, gill, and intestinal parasites from Theragra chalcogramma (pollock)
5. Liver parasites from Anoplopoma fimbria (black cod)
6. Liver parasites from Trichodon trichodon (Pacific sandfish)
7. Liver parasites from Lycodes brevipes (shortfin eelpout)
8. Gill tumor tissue from Sebastes alutus
9. Liver and mesenteric abnormal growth from S. alutus
10. Ectoparasite from Hippoglossus stenolepis (halibut)

Occasional subsamples from neuston tows were also taken for scanning electron microscopy (SEM) observations. These included:

1. 2 species of teleost larvae
2. 2 species of pelagic amphipods (unidentified)
3. Various crustacean larva
4. Unidentified fish eggs
5. Pelagic pteropod - Speratella helicina

NOTE: Neuston tows that were taken in the vicinity of oil platforms appeared to have a number of small tar particles among the plankton. Exact location and dates of these tows are available.

RESULTS

Behavior

Onset of dorid oviposition was delayed 4 days at the highest hydrocarbon concentration (278 ppb), and the total weight of eggs deposited and average number of aggregations per day was reduced (Table 1). If the number of dorids which appeared to be actively participating in oviposition is con-

TABLE 1. *Concentrations of SWSF, exposure conditions, and related data on egg depositions of dorid nudibranchs**

Exposure concentration of SWSF** (ppb)	Day eggs laid	No. egg masses laid 1st day***	Egg weight over 14 days (mg)	Wt. eggs per dorid (mg)	Average no. of aggregations per day
Control	1	16	938	10.1	1.8
8	1	14	832	8.3	1.9
27	1	10	821	10.2	1.4
278	4	5	516	10.7	0.9

* Each aquaria contained 20 mature dorids weighing 2.1 g at start of experiment.

** Based on an average of four GC samples (278 ± 180 ppb range) of solubilizer SWSF and dilutions of SWSF.

*** Number of egg masses laid on first day of oviposition constitute number of egg masses from which samples were taken for ontogenetic analysis.

sidered, then the average weight of eggs laid per dorid was the same for all test groups. The delay in egg laying for the high exposure group was not a factor in total weight of eggs deposited, since all groups had sharply declined oviposition by the end of the experiment.

Tables 2-5 show, for control and three groups exposed to SWSF, the percent of normally developing eggs found in each of six to eight ontogenetic stages, and the percent with abnormal development. Replicate egg samples taken from each group, commencing with day of deposition, were combined. Groups exposed at the two lower levels of exposure (8 and 27 ppb) showed no evidence of developmental retardation; but there was a increase in percent of abnormalities with increasing hydrocarbon concentration. At 278 ppb, developmental delay was evident, with some eggs never advancing beyond the celled stage, and the incidence of abnormalities was nearly 50%. A comparison of data from the control group and the group for the highest level of exposure is shown in Figure 3.

Examples of moderate and severe abnormalities are shown in Figure 4. Of the severe abnormalities, 100% in the group exposed to 278 ppb were a result of non-encapsulation, as compared to 12 and 18% of the severe abnormalities being non-encapsulated in the 27 and 8 ppb SWSF-exposure groups. Moderate abnormalities were distributed throughout all developmental stages; however, in the high exposure (278 ppb) group, moderate abnormalities occurred predominately in the first four stages of development. The result of moderate abnormal development on hatching and larval viability is unknown.

Chemistry

The force-feeding study showed that key organs of coho salmon contained substantial amounts of 1-MN at 24 hr after the time of feeding. For example, concentrations of 1-MN in brain, liver, kidney, and muscle were 3,000, 3,040, 1,960, and 1,040 ng 1-MN/g dry tissue, respectively. At 24 hr, the brain, liver, kidney, and muscle contained 0.05%, 1.3%, 0.4%, and 6.7%, respectively, of the administered dose. The data for the re-evaluation of accumulation and distribution of 1-MN in salmon exposed to this compound in the water column are presently being collected.

Attempts to study the influence of temperature on the metabolism of alkylated naphthalenes, using ^{14}C-1-MN, was thwarted by the interference of radioactive impurities in the starting material. The problem of the metabolism of alkylated naphthalenes is being addressed by determining the biological conversions of pure 2,6-dimethylnaphthalene in starry flounder at 4° and 10°C. The results of the study will be reported later.

Data evaluating the effects of naphthalene exposures on mussel gametes, postlarval shrimp, and coho salmon fry, from the last quarter and this quarter, will be combined in the next

TABLE 2. *Percent of dorid eggs in each ontogenetic stage and percent abnormal for control group*

Post-lay days	No. eggs sampled	ONTOGENETIC STAGE Blastula (%)	Gastrula (%)	Pre-veliger I (%)	Pre-veliger II (%)	Veliger (%)	Hatch (%)	Abnormalities Moderate (%)	Abnormalities Severe (%)
1	180	99.4	0.6						
2	260	22.7	71.9					4.6	0.8
4	216		52.8	47.2					
5	217			98.6				0.9	0.5
8	624				3.8	95.4		0.2	0.6
9	465				12.7	87.1		0.2	
10	275*	0.4			7.6	41.5	50.0	0.1	0.4
11	NA						100.0		

* Replicate sample hatched; consider number hatched equal to number observed.

TABLE 3. *Percent of dorid eggs in each ontogenetic stage and percent abnormal for group exposed to 8 ppb SWSF*

Post-lay days	No. eggs sampled	ONTOGENETIC STAGE Cell stage 1 (%)	Blastula (%)	Gastrula (%)	Pre-veliger I (%)	Pre-veliger II (%)	Veliger (%)	Hatch (%)	Abnormalities Moderate (%)	Abnormalities Severe (%)
1	316	2.5	50.3	45.3					1.3	0.6
2	295	1.7	14.6	58.9					3.1	21.7
4	521	0.2		49.5	48.2				1.3	0.8
5	384	1.6		26.8	68.5				2.9	0.2
8	609	0.2				1.0	97.9		0.9	
9	NA							100.0		
10	241*					39.4	2.3	50.0	1.7	6.6
11	132*					47.0	2.3	50.0	0.7	
12	NA							100.0		

* Replicate sample hatched; consider number hatched equal to number observed.

TABLE 4. *Percent of dorid eggs in each ontogenetic stage and percent abnormal for group exposed to 27 ppb SWSF*

Post-lay days	No. eggs sampled	ONTOGENETIC STAGE: Cell stage 1 (%)	Cell stage 2 (%)	Blastula (%)	Gastrula (%)	Pre-veliger I (%)	Pre-veliger II (%)	Veliger (%)	Hatch (%)	Abnormalities: Moderate (%)	Severe (%)
1	264	2.3	0.8	62.1	34.1					0.7	
2	368	1.9			95.4					2.4	0.3
5	454	2.0					81.1			13.2	3.7
6	318				0.3		51.6			15.4	32.7
7	392	1.8					42.1	49.0		5.6	1.5
8	272						1.5	61.8		3.6	33.1
9	288	1.0					17.4	71.5		10.1	
10	277	3.3				13.0	62.8	2.5		7.2	11.2
11	NA								100.0		

TABLE 5. *Percent of dorid eggs in each ontogenetic stage and percent abnormal for group exposed to 278 ppb SWSF*

Post-lay days	No. eggs sampled	ONTOGENETIC STAGE: Cell stage 1 (%)	Cell stage 2 (%)	Cell stage 4 (%)	Blastula (%)	Gastrula (%)	Pre-veliger I (%)	Pre-veliger II (%)	Veliger (%)	Abnormalities: Moderate (%)	Severe (%)
1	149	28.2	5.4		4.7					51.0	10.7
3	176	12.5	4.5							29.5	53.5
4	344	24.1	2.3			20.1				3.2	50.3
5	294	47.6	3.1	0.3		5.1	32.7			7.8	3.4
6	164	15.9	0.6			5.5	18.3			9.8	49.9
7	395	17.7	0.5		2.0	44.6	10.8	4.1		17.0	3.3
8	528	43.0	4.7			8.0	14.0	21.0		8.5	0.8
9	385	4.7	1.6		1.3	8.5	1.6	10.6	9.3	48.6	13.8
10	291	8.9	0.7			2.8	2.4	6.5	14.8	49.1	14.8

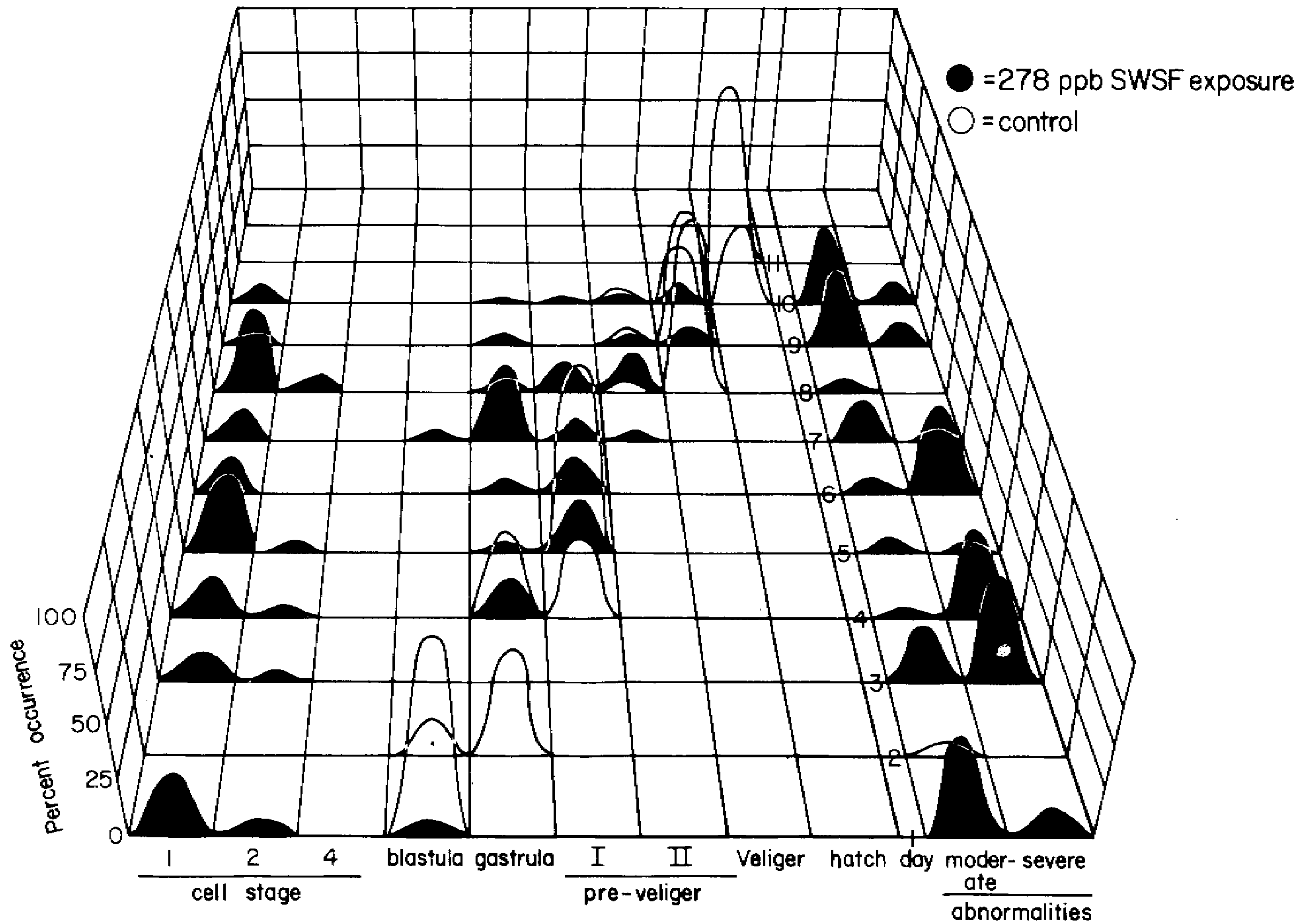
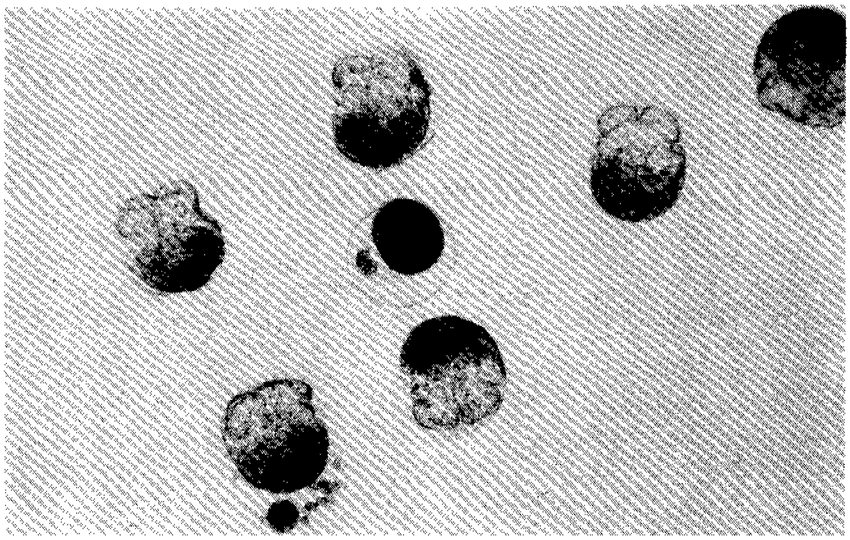


FIGURE 3. *Percent of dorid eggs in each ontogenetic stage and percent abnormal for control and 278 ppb SWSF-exposed groups. Data are from Tables 2 and 5 (percentages less than 2 in any category are not shown).*



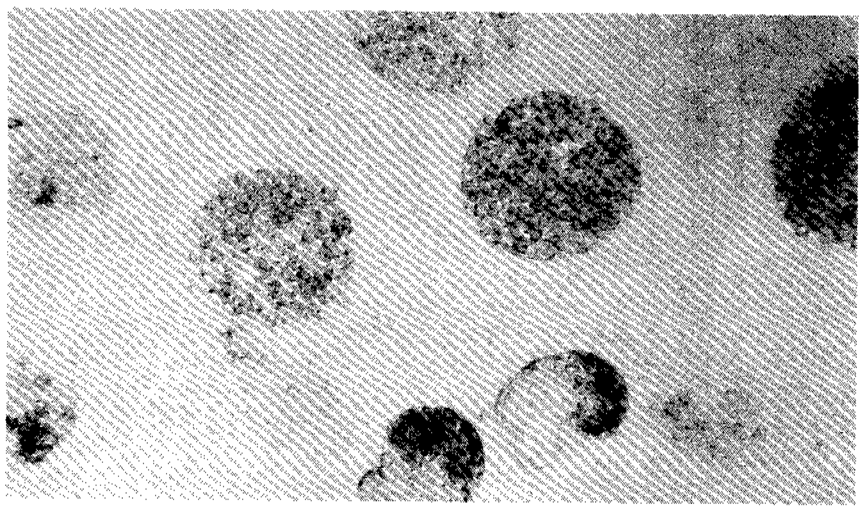


FIGURE 4. *Developmental abnormalities during ontogenesis of dorid nudibranchs exposed to the SWSF of PBCO. Each photomicrograph (40 x) is from one egg mass.* A. *Ten days after oviposition at SWSF exposure concentration of 8 ppb. There are five normally developing eggs in the pre-veliger II stage and two with "moderate" abnormalities represented by additional material within the egg capsule. One of the eggs with "moderate" abnormalities remains in the one-celled stage.* B. *Same level and duration of exposure as above. There are two normally developing eggs in the pre-veliger II stage and the remainder have "severe" abnormalities including lack of capsule for three eggs.*

quarterly report. The results will include the effect of purity on metabolic studies, the determination of biologic exchange of ^3H-labeled compounds, and the chemical identification of naphthalenic metabolites formed by shrimp.

Results of force-feeding rainbow trout with ^3H-1,4,5,8-naphthalene were detailed earlier (OCSEAP Quarterly Report, RU 73/74, June 1977). Only salient features of the experiment are discussed below to permit a comparison of results of force-feeding with the injection and water-immersion studies.

Skin of rainbow trout, which were fed 74.6 μCi (114 μg) of ^3H-1,4,5,8-naphthalene, was found to contain 35 ppb of naphthalene and 4.7 ppb of the metabolites at 4 hr after the treatment (Fig. 5). At 24 hr, 95.6% of the total radioactivity in the skin was represented by naphthalene. Subsequently, however, the naphthalene concentration declined, and at 168 hr the metabolites represented 17.6% of the total radioactivity in the skin.

Skin of rainbow trout, which were injected intraperitoneally with 94.6 μCi (145 μg) of ^3H-1,4,5,8-naphthalene, contained 114 ppb of naphthalene and 6.2 ppb of the metabolites at 4 hr after the injection (Fig. 5). A maximum value of 244 ppb of naphthalene was reached at 16 hr following the injection and subsequently declined to 28 ppb at 168 hr. The concentration of metabolites continued to increase in the skin reaching a maximum value of 14 ppb at 48 hr and then decreasing to 4.9 ppb at 168 hr. The relative proportion of the metabolites increased steadily, thereby comprising as much as 15.1% of the total radioactivity in the skin of fish at 168 hr.

Results of a water-immersion study are as follows: Skin taken from rainbow trout exposed to 9.2 ppb of naphthalene in flowing water accumulated substantial concentrations of both naphthalene and its metabolic products (Fig. 6). Interestingly, the concentrations of naphthalene in trout skin reached a maximum (4,230 ppb) after 48 hr of exposure, then began to decline (2,100 ppb) during the remaining 24 hr of exposure. It continued to decline (223 ppb) for 72 hr during depuration in clean water. Concentrations of the metabolites in skin continued to increase throughout the exposure period reaching a value of 441 ppb at the end of 72 hr of exposure (Fig. 6). At the end of the exposure, 15.8% of the total radioactivity in skin was attributable to a metabolite fraction. After 72 hr of depuration in clean water, metabolites constituted 52% of the total radioactivity.

Skin of trout from the water-immersion study accumulated substantially larger amounts of both naphthalene and its metabolites than skin from either the force-feeding or the injection study. Livers from the water-immersion study also contained considerably higher radioactivity than livers from force-feeding and injection studies (Collier and Malins 1977).

A test group of coho salmon were exposed to 200 ppb lead for the duration of the 3-week experiment. Both control and lead-exposed coho salmon were then fed Oregon Moist Pellets

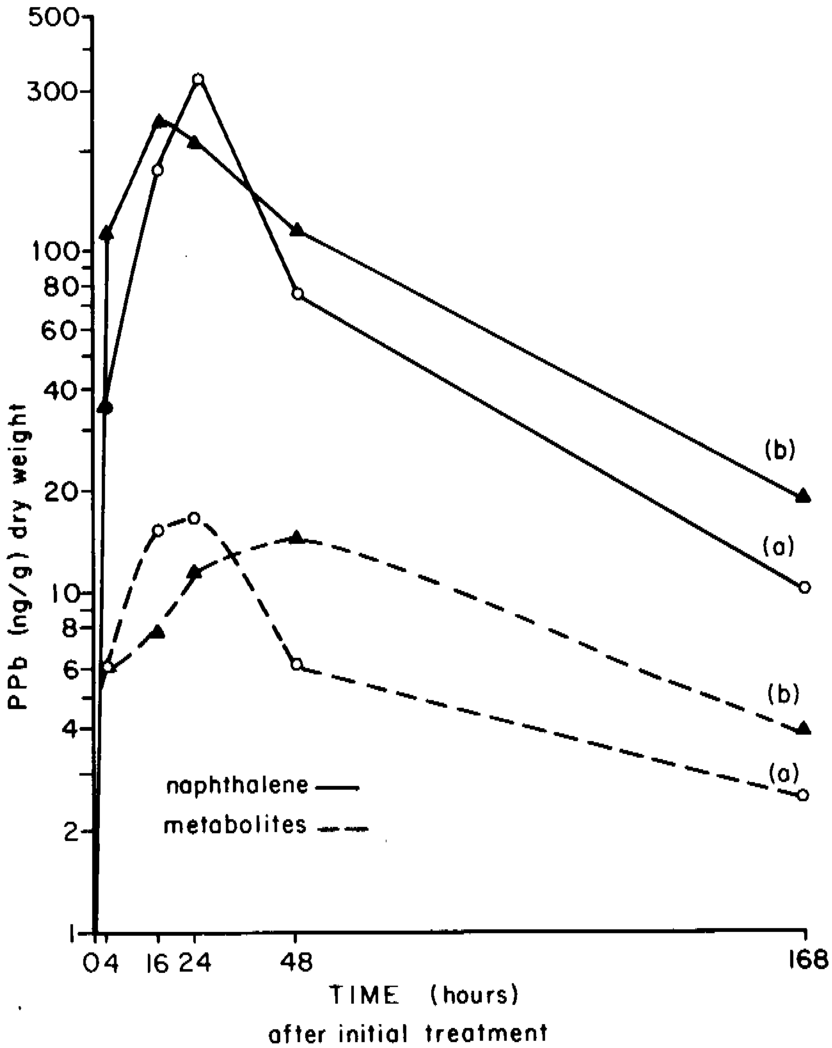


FIGURE 5. *Concentrations of naphthalene and metabolites in skin of rainbow trout exposed to* ^{3}H*-naphthalene via (a) force-feeding, or (b) intraperitoneal injection (Varanasi et al., submitted 1977).*

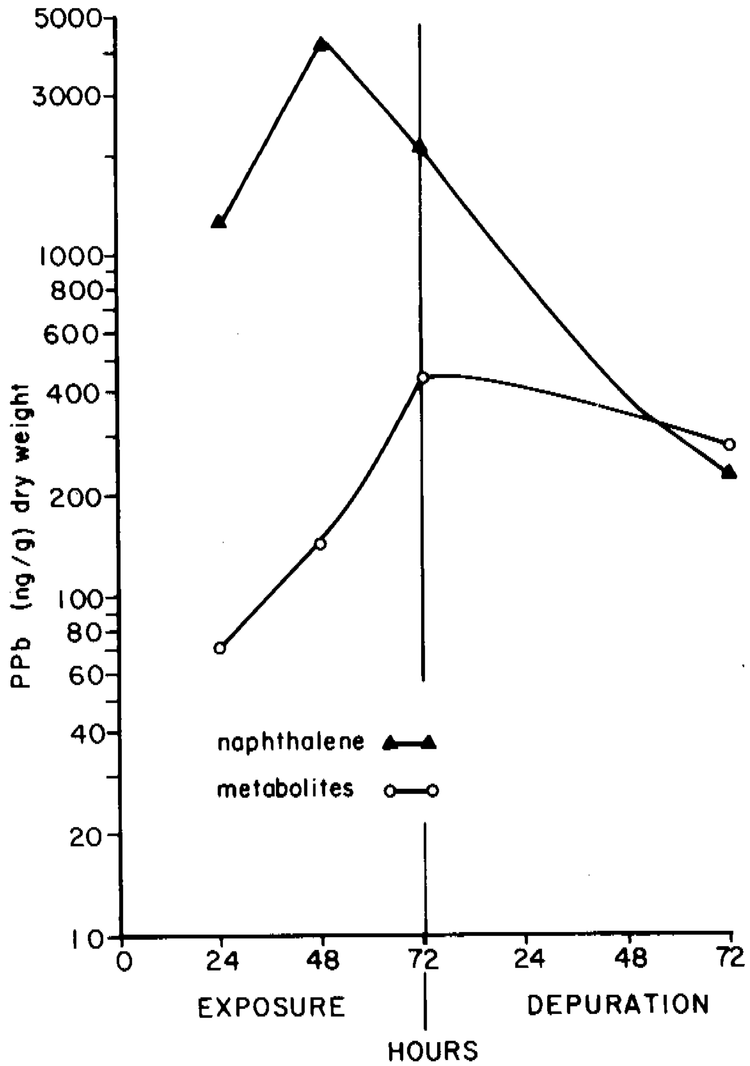


FIGURE 6. *Concentrations of naphthalene and its metabolites in skin of rainbow trout exposed to 9.2 ppb of ^{3}H-naphthalene in flowing water (Varanasi et al., submitted 1977).*

(OMP) containing 334 ppm aromatic hydrocarbons one week before intravenous injection with 0.2 ml of a solution containing 7.35 μCi of ^{14}C-naphthalene (0.29 mg) in 40% EtOH. The lead-exposed fish had $9.76 \times 10^{-5} \pm 2.18 \times 10^{-5}$ μCi of the metabolite, ^{14}C-1,2-dihydrodihydroxynaphthalene, in the liver as compared to $5.78 \times 10^{-5} \pm 0.75 \times 10^{-5}$ μCi for controls ($P<0.05$). These numbers are the mean values of three pooled samples corrected to a single fish basis. A typical HPLC elution pattern of ^{14}C-naphthalene metabolites from the liver of a coho salmon, which was injected intravenously with ^{14}C-naphthalene, is shown in Figure 7. The 1,2-dihydrodiol structure was assigned on the basis of retention time on a calibrated HPLC column.

The influence of lead on hydrocarbon metabolism was investigated in fish by exposing them to metal in seawater and feeding them a model mixture of polycyclic aromatic hydrocarbons (PAH) to induce or activate the metabolic enzymic system, then injecting them with naphthalene to elucidate possible alterations in the conversion of PAH in relation to metal exposure. Work was completed on the administration of radioactive naphthalene to a group of starry flounder (Platichthys stellatus). The fish were exposed for 4 weeks to 200 ppb of ionic lead in seawater and, at the same time, were fed a 334 ± 4 ppm aromatic hydrocarbon mixture (phenanthrene at 107 ppm, 2-methylnaphthalene at 128 ppm, 2,6-dimethylnaphthalene at 99 ppm) in OMP. Twenty-four hours before the sampling time, they were injected with ^{14}C-naphthalene. Extracts of tissue samples from exposed fish are presently being separated by HPLC and resultant chromatographic fractions are being analyzed for ^{14}C-naphthalene metabolites by liquid scintillation techniques.

Radiotracer techniques were employed in determinations of the subcellular distribution of Cd in gill, kidney, and liver of coho salmon, which were exposed to 200 ppb Cd in seawater. Analyses of ^{109}Cd in cytosol and cytosolic fractions were completed. Results of the analyses are reported in Table 6. The percentage of the total ^{109}Cd in cytosol bound to CdBP was greater in those fish which had been exposed to 200 ppb Cd in seawater for 2 weeks, compared to controls in seawater only. Accordingly in Table 6, for example, at 3 hr post-injection, the percentage of total ^{109}Cd bound to CdBP of posterior kidney samples, increased from 34% for salmon in seawater only to 77% for salmon exposed to 200 ppb Cd. Likewise, ^{109}Cd bound to CdBP increased from 79 to 89% for liver samples, and from 9 to 55% for gill samples. In contrast, the anterior kidney at 3 hr did not have a major change in the amount of ^{109}Cd bound to CdBP.

Specific activities of xenobiotic enzyme AHH were determined for 89 samples of livers from six species of fish, a gastropod, and a tanner crab. The resultant AHH activities and standard deviations are presented in Table 7. The samples of gastropod showed no AHH activity in cell-free homogenates of whole body tissue. The results for the other species show the wide range of values among individuals within a species group or similar to that found in other studies (Gruger et al. 1977).

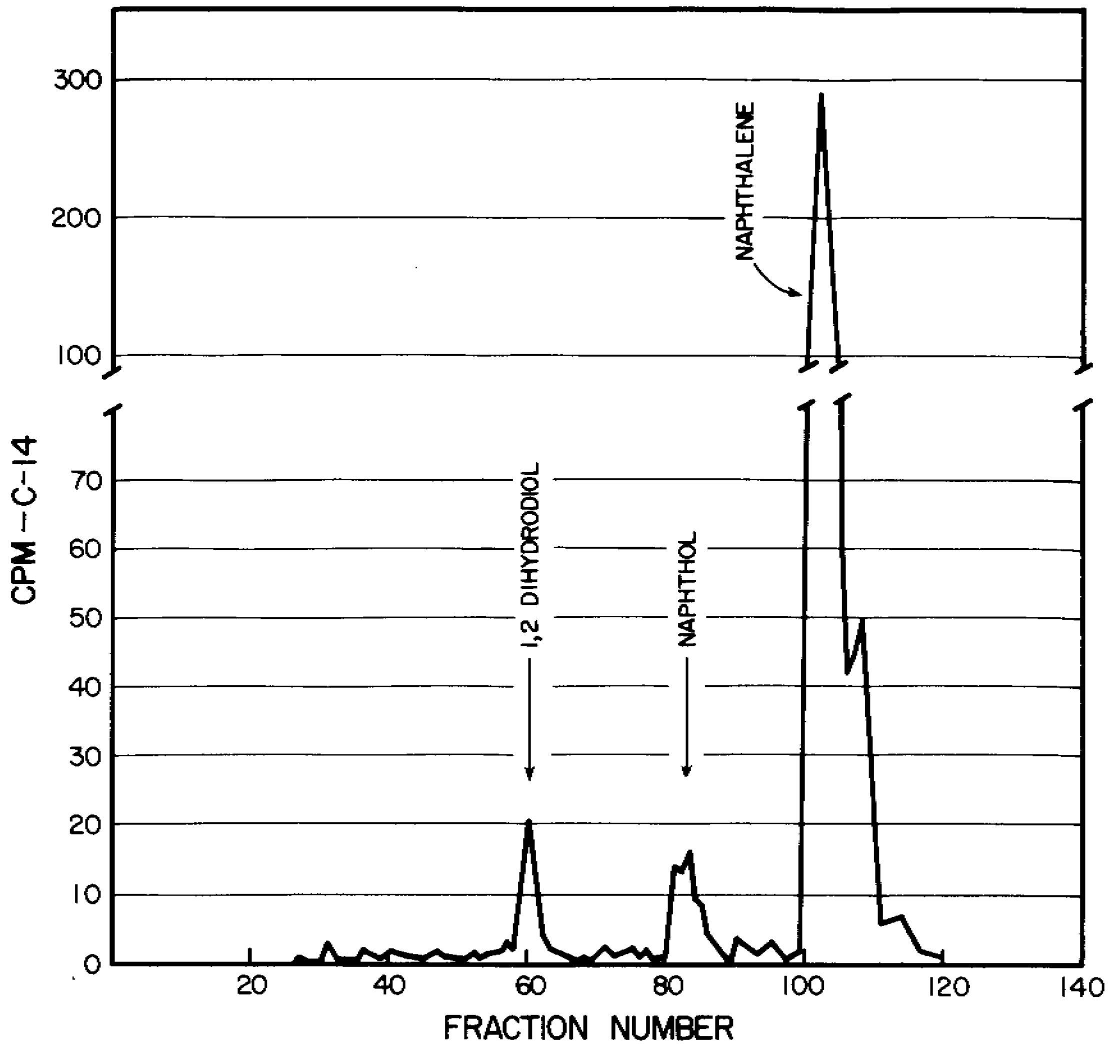


FIGURE 7. *HPLC chromatogram of ^{14}C-naphthalene and its metabolites that have been extracted from coho salmon liver.*

TABLE 6. *Distribution of cadmium-109 in coho salmon (Oncorhynchus kisutch) cytosols from gill, kidney, and liver at 3, 24, and 48 hours after injection**

Sample	Treatment	Sampling time	Cd bound to high MW fractions (>55,000 daltons)	Cd bound to CdBP fractions	Cd bound to remaining fractions	Cd in cytosol
		hr	ng ^{109}Cd/mg cytosolic protein			
GILLS	Seawater only	3	16.0	2.0	3.7	21.7
		24	14.4	5.3	3.1	22.8
		48	29.3	14.0	14.0	57.3
	200 ppb Cd in seawater**	3	9.5	16.3	3.8	29.6
		24	16.8	17.3	5.4	39.5
ANTERIOR KIDNEY	Seawater only	3	9.6	10.1	8.6	28.3
		24	9.1	9.2	7.5	25.8
		48	20.0	40.0	20.7	80.7
	200 ppb Cd in seawater**	3	7.8	5.6	3.1	16.5
		24	11.8	11.8	6.5	30.1
POSTERIOR KIDNEY	Seawater only	3	18.3	21.2	23.5	63.0
		24	30.1	23.9	29.4	83.4
		48	--***	55.6	--***	149.0
	200 ppb Cd in seawater**	3	5.3	29.5	3.7	38.5
		24	16.1	42.8	11.1	70.0
LIVER	Seawater only	3	12.6	67.5	5.2	85.3
		24	49.0	46.2	7.8	103.0
		48	24.3	167.4	8.5	200.2
	200 ppb Cd in seawater**	3	5.6	73.8	3.1	82.5
		24	16.0	6.0	5.2	27.2

* Fish were maintained at 10°C during exposures to cadmium-109.
** Fish were exposed to 200 ppb cadmium for 2 weeks prior to injection of cadmium-109.
*** Analytical samples of the collected fractions are not available.

TABLE 7. *Specific activities of aryl hydrocarbon hydroxylase (AHH), as benzo(a)pyrene hydroxylase, for tissues from samples of different marine species*

Species	Sample	Number	AHH activity*
Arrowtooth flounder	Liver	12	0.061 ± 0.027
Flathead sole	"	12	0.187 ± 0.113
Rock sole	"	24	0.213 ± 0.192
Butter sole	"	3	0.099 ± 0.055
Pacific cod	"	16	0.327 ± 0.251
Pollock	"	13	0.169 ± 0.087
Fusitriton sp.	Whole body	4	0
Tanner crab	Visceral organs	5	0.187 ± 0.163

* Specific activity as nmoles of hydroxylated products of benzo(a)pyrene/20 minutes/mg protein. The proteins were from a 10,000 x g-15 min supernatant fraction of a 20% (w/v) tissue homogenate in 0.25 M-sucrose.

Of the six species of fish, arrowtooth flounder and butter sole had hepatic AHH activities noticeably lower than the others. Pacific cod had the highest mean value of hepatic AHH activity, but, at the same time, the individual values for that species were highly variable. Tanner crab viscera seem to possess AHH activities comparable to those activities found for livers of fishes.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-contaminated Sediment

An extensive histopathological examination of tissues collected from oil-exposed and control English sole was completed. Tissues examined included liver, gills, spleen, kidney, intestine, fins, and skin. Ultrastructural properties of the liver are given in the Morphology section of this report; thus, only the prevalence of hepatocellular lipid vacuolization (HLV) is presented here (Table 8). While both the oil-exposed and control fish exhibited some form of HLV, only the oil-exposed fish had the most severe form of HLV, where 95% or more of the volume of hepatocytes were vacuolated. Most of the severe HLV was observed during the first 9 weeks of oil exposure.

Although the gills of both groups displayed some histopathology, such as mucous cell and epithelial hyperplasia, the oil-exposed fish had a much higher incidence of parasitic infestation. Trichodinid ciliates, microsporidia, flagellates (Costa sp.), and trematodes were the most prominant forms of parasites. Trematodes did not appear to cause severe host effects and were found on 14% of the oil-exposed fish and on 10% of the controls. Flagellates caused severe histopathology but were found on the gills of only two test fish and none of the control fish. The microsporidia infestation increased as the experiment progressed, with 22% (6 out of 27) of the oil-exposed fish and 5% (1 out of 19) of the control group being involved. Trichodinid infestation was the most common; it affected 70% (19 out of 27) and 58% (11 out of 19) of the test and control fish, respectively.

There was no histological evidence of pathology in tissues from spleen, kidney, intestine, and fins from oil-exposed and control fish. Preliminary observations suggest that skin from oil-exposed fish was damaged; this possibility is presently being explored further.

Pooled samples from three fish collected at 27 and 60 days had detectable polycyclic aromatic hydrocarbons only in the liver. The most predominant of the many hydrocarbons found in livers was tentatively identified as 1,2,3,4-tetramethylbenzene. The latter was at concentrations of 863 and 124 ng/g (dry wt) at 27 and 60 days, respectively.

TABLE 8. *Number of English sole categorized by degree of hepatocellular lipid vacuolization during exposure to Prudhoe Bay crude oil-contaminated sediments*

Degree of hepatocyte lipid vacuolization	TEST Weeks 2	4	7	9	13	18	21	CONTROL Weeks 2	4	7	9	13	18	21
0-1*	0	0	1	2	2	5	5	2	1	0	3	2	4	1
2		1	2				2							
3		1					1		1	3		1		1
4	1						2	1						2
5	2	1		1	1									

Total test fish examined = 30
Fish with severe form = 5
Frequency of severe form = 17%

Total control fish examined = 22
Fish with severe form = 0
Frequency of severe form = 0%

* Degree of vacuolization was quantitated by visual examination. The numerical units and the approximate percentage of cytoplasm composed of lipid vacuoles were as follows: 0-1 (considered normal range), 10%; 2, 25%; 3, 50%; 4, 70%; and 5, 95%.

Effects of Petroleum on Fish Disease Resistance

Mortality patterns among the immunized and control groups of oil-exposed rainbow trout are presented in Figure 8. LD_{50} values calculated from these data (Table 9) show that no significant differences existed in disease resistance. All immunized oil-fed and control fish survived bacterial challenge at a comparable level which was, in all cases, higher than survival of nonimmunized controls.

Results of the mitogenesis and the polyclonal activation experiments (Tables 10 and 11, respectively) likewise suggest that long-term oil exposure has little effect on immune response. Peroral exposure to 1,000 ppm PBCO for 10 mo neither reduced the mitogenic effect of concanavalin A or affected polyclonal activation of lymphoid cells by a purified protein derivative of the tuberculin bacillus.

Total spleenic leukocyte counts decreased with increasing exposure to PBCO (Table 12); however, no concommitant decrease in RBC or leukocyte counts could be demonstrated in peripheral blood (Table 13).

Morphology

Light microscopy of paraffin sections of livers from flatfish exposed to oiled sediments revealed hepatocellular lipid vacuolization in some fish (cf., Pathology section). However, this condition was also observed in control fish, but at frequencies less than in the test group.

In affected fish, lipid droplets were evident in virtually every cell (Figs. 9,10). Whorls of rough endoplasmic reticulum surround the nucleus and fill the cell spaces not occupied by lipid droplets and associated vacuolar space. Mitochondria appear to be small in length and fewer in number in the fatty liver compared with non-fatty livers.

Other features of the liver appeared normal; as follows: the sinusoids and lining endothelial cells were intact; the membranes of the space of Disse were normal and not infiltrated with collagen, as found previously in rainbow trout fed petroleum (Hawkes 1977).

The surfaces of eggs of Alaska pollock (Fig. 11), starry flounder (Fig. 12), and flathead sole were examined with the scanning electron microscope. The pollock eggs averaged 1.5 mm in diameter. Elevated circular patches 1 µm in diameter with 0.2 µ openings in the center were regularly distributed 1-2 µm apart over the entire egg. The micropyle was 10 µm in diameter at the outer surface and tapered slightly as it extends through the egg membrane to the surface of the ooplasm. Flathead sole eggs were distinctively larger (3.3 mm in diameter) and had 0.4 µm openings evenly spaced every 3-4 µm on the egg surface.

The comparative morphology of lens fibers from herring, black cod, pollock, several flatfish, and 6 species of rockfish were examined with the scanning electron microscope. The

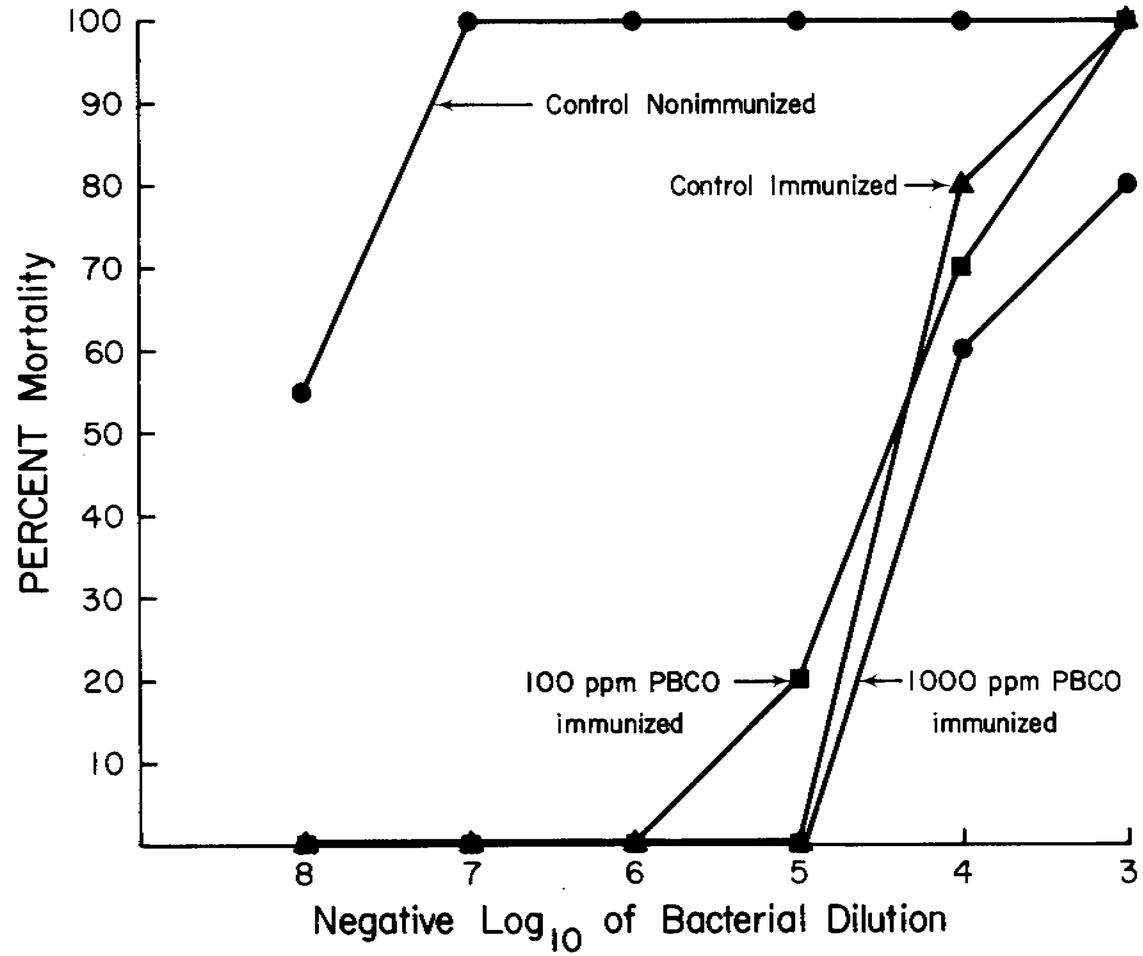


FIGURE 8. *Mortality patterns among oil-exposed and control rainbow trout challenged with* *<u>Vibrio anguillarum</u>*.

TABLE 9. *LD_{50} values for oil-exposed and control rainbow trout immunized against Vibrio anguillarum and challenged with the homologous bacterium*

Group	Concentration of PBCO in diet	Dilution of Vibrio anguillarum to give LD_{50}*
Immunized	1,000 ppm (high)	$10^{-4.4}$
	10 ppm (low)	$10^{-4.4}$
	None (control)	$10^{-4.4}$
Non-immunized	None (control)	10^{-8}

* LD_{50} based on original suspension of 2.3×10^9 Vibrio anguillarum per ml.

TABLE 10. *Comparison of stimulation indices of concanavalin A (Con A)-induced mitogenesis of spleenic leukocytes in fish exposed to PBCO and controls*

Fish No.	Stimulation index* PBCO-exposed (1,000 ppm)	Stimulation index* Control
1	14	27
2	13	12
3	23	36
4	10	23
Average	15	23

* Stimulation indices represent the ratio of ^{3}H-thymidine incorporation by 10^6 Con A treated leukocytes/^{3}H-thymidine incorporation by 10^6 nontreated leukocytes (Etlinger et al. 1976).

TABLE 11. *Effect of long-term exposure to Prudhoe Bay crude oil (PBCO) on polyclonal activation in rainbow trout peripheral blood leukocytes by purified protein derivative of the tuberculin bacillus**

Fish No.	No. of PFC/10^6 lymphoid cells		
	PBCO-exposed (1,000 ppm)		Control
1		10	8
2		10	10
3		32	26
	Average	17	12

* Activation was quantified by determination of the number of plaque forming cells (PFC) per 10^6 lymphoid cells in a modified Jerne plaque assay (Mischell and Dutton 1967).

TABLE 12. *Comparison of total spleenic leukocytes in Prudhoe Bay crude oil (PBCO)-exposed and control rainbow trout*

	PBCO-concentration exposure group		
	1,000 ppm high oil	10 ppm low oil	none control
No. of spleenic leukocytes*	13×10^6	35×10^6	60×10^6

* Values represent a 5-fish pool.

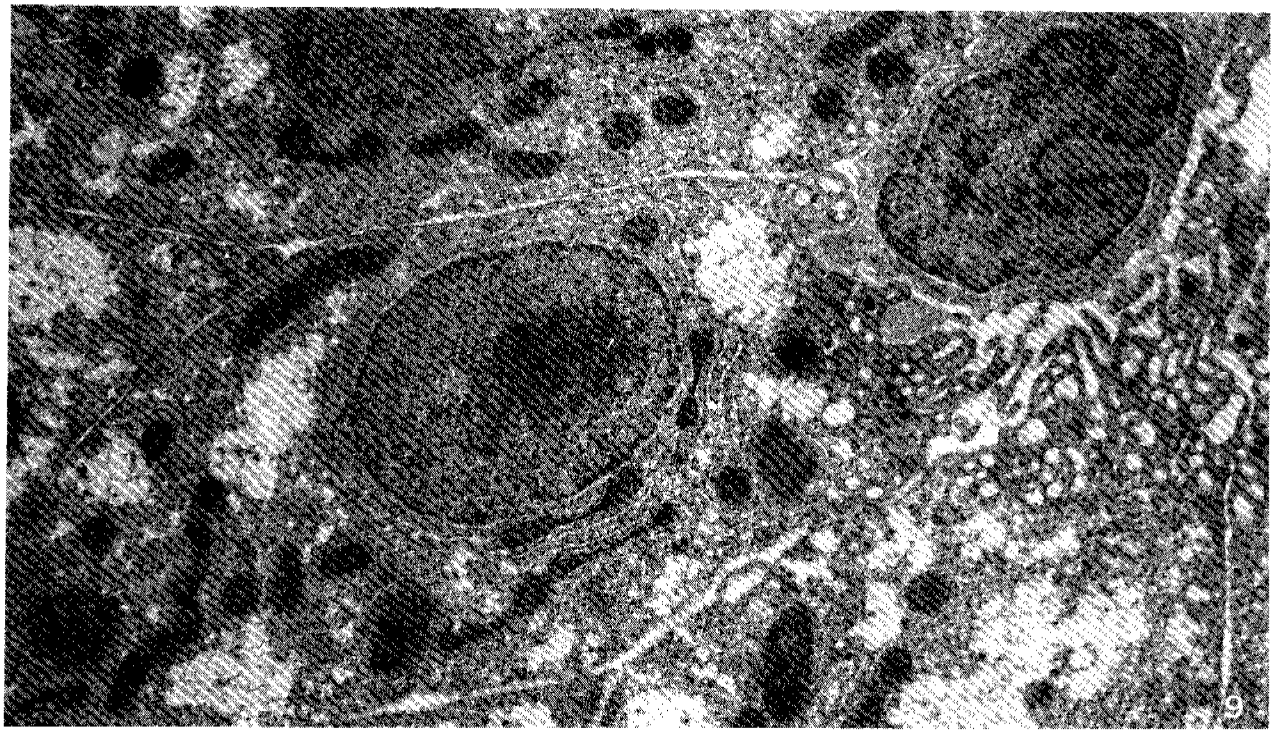
TABLE 13. *Effect of Prudhoe Bay crude oil (PBCO)-exposure on peripheral red blood cell and leukocyte counts in juvenile rainbow trout*

	Exposure group	
	1,000 ppm PBCO	Control
No. of red blood cells*	1.2×10^6	1.4×10^6
No. of leukocytes*	4.1×10^5	4.2×10^5

* Values expressed are cells per mm^3 and represent the average of 10 fish.

FIGURE 9. *Liver cells from an untreated English sole. The cells have an average amount of endoplasmic reticulum, mitochondria, and areas of glycogen accumulation. Glycogen has been partially removed in processing, leaving light areas in the hepatocytes. X 4,000.*

FIGURE 10. *Hepatocytes from English sole exposed to PBCO in sediment for 34 days. There is an increase in endoplasmic reticulum (er) which is apparent around the nucleus as concentric layers of granular er. Extensive lipid deposits in the cells are conspicuous as electron dense, membrane bound droplets of variable size. X 3,200.*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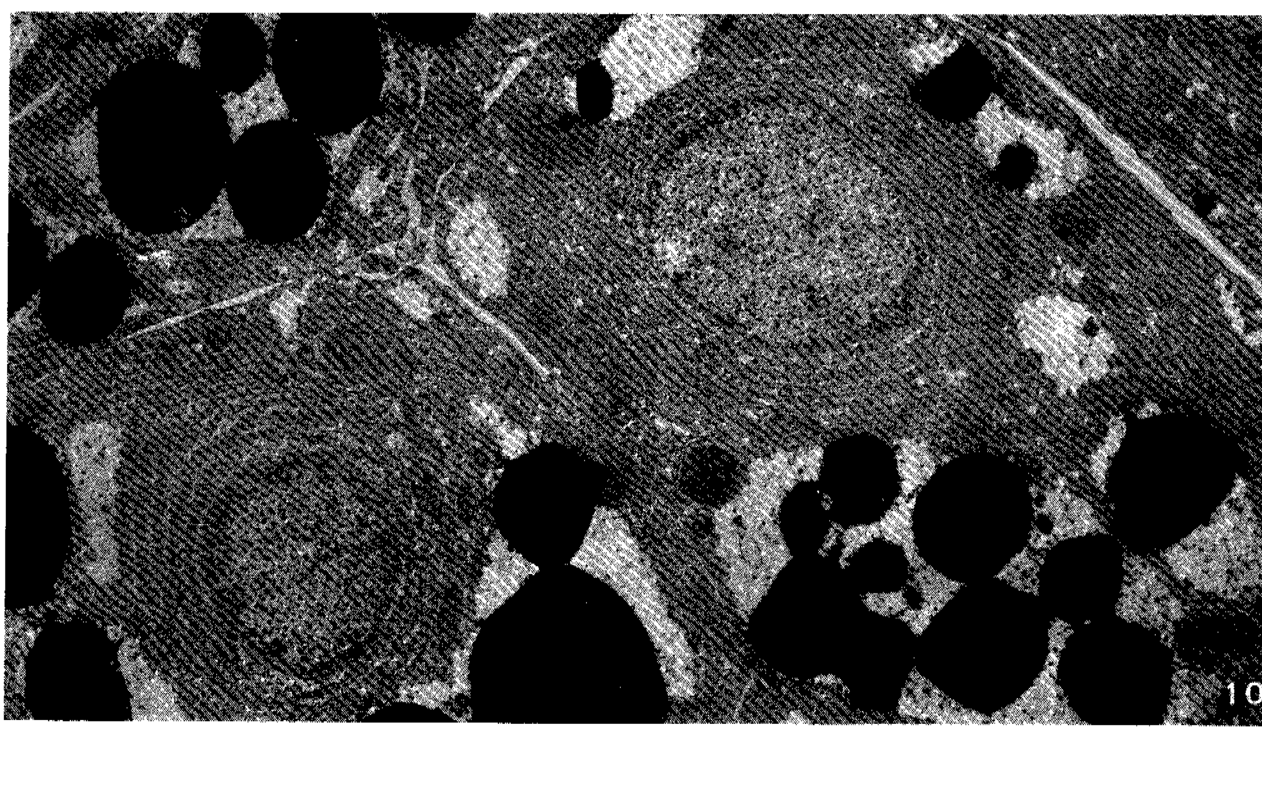
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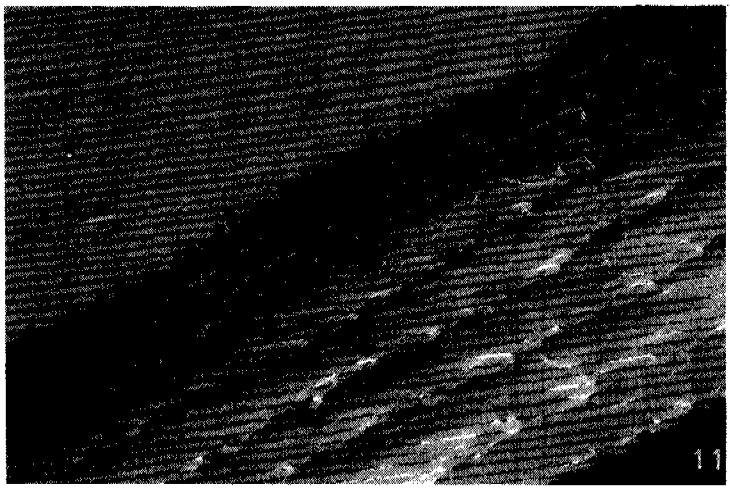

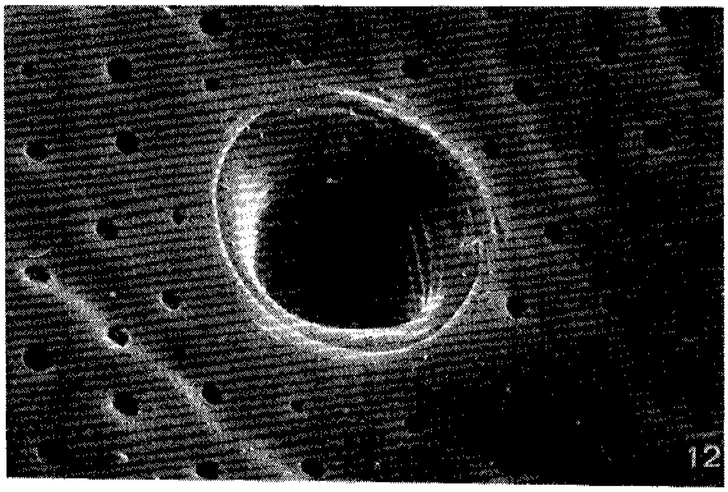

FIGURE 11. *Surface and cut edge of the egg membrane of the Alaskan pollock, Theragra chalcogramma. The chorion has two zones of different width lamellae. X 5,000.*

FIGURE 12. *Micropyle and surrounding surface of the unfertilized egg of a starry flounder, Platichthys stellatus. X 4,600.*

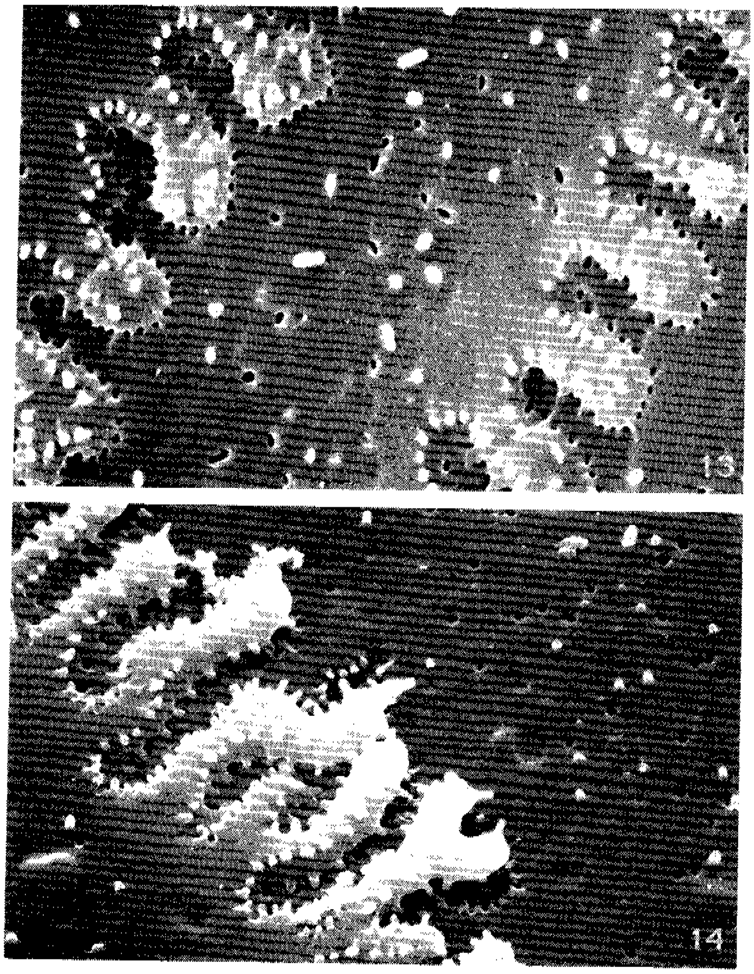

FIGURE 13. *Scanning electron micrograph of lens fibers from the rockfish, Sebastes variagatus. The fiber width (4.0 μ) as well as the length of the projections (1.5-2.0 μ) are smaller than in the flatfish. However, the eyes and lenses of the rockfish are much larger with respect to body size than are the eyes of the flatfish. X 5,000.*

FIGURE 14. *Scanning electron micrograph of lens fibers from the flatfish, Hippoglossoides elassodon. The fibers are 10 μ wide and the lateral projections are 2.3-4.0 μ wide, which is approximately twice the dimensions of the rockfish lenses. X 5,000.*

lenses of the rockfish had shorter lateral projections (Figs. 13,14) and were larger in proportion to body size than the lenses of any of the other species. Flatfish lenses had much larger lateral projections than lenses from any of the other species. No trends in lens dimensions were evident for pelagic fishes. No fibers showed the wrinkled and disrupted appearance of lenses from experimental fish exposed to petroleum (Hawkes 1977).

PRELIMINARY INTERPRETATION OF RESULTS

Behavior

Exposure of adult dorid nudibranchs to the SWSF of PBCO for 3 days at concentrations of 500 ppb and less results in a decrease in reproductive success by (1) reduction in capability to locate other conspecifics for mating (OCSEAP Quarterly Report, RU 73/74, June 1977), (2) decrease in quantity of eggs deposited, and (3) disruption of ontogenic development. It is intended that these experiments will be verified with additional experiments in FY 78.

Chemistry

A comparison of the data from the present study for coho salmon force-fed 1-MN with the data of an earlier study with naphthalene (Collier, Malins, and Thomas, unpublished data) shows that during 16 hr substantially more 1-MN than naphthalene accumulates at 10°C in liver, brain, and kidney. Likewise, previous work (Roubal et al. 1977b) showed a similar relationship between alkylated naphthalenes vs. naphthalene in muscle of coho salmon and in muscle, gills, and liver of starry flounder exposed to a water-soluble fraction of crude oil. These preliminary findings imply that tissues of fish in arctic and subarctic waters impacted by petroleum will accumulate more alkylated than non-alkylated aromatic hydrocarbons contained in the water column. However, there are insufficient data on the metabolism and excretion of the alkylated aromatic hydrocarbons in marine organisms (Varanasi and Malins 1977) to know whether the tendency to accumulate these compounds in fish is related to slower rates of enzymatic oxidation of the hydrocarbons to excretable products, compared to the rates for non-alkylated aromatic hydrocarbons.

Rainbow trout accumulated significant concentrations of both naphthalene and its metabolites in the skin within a few hours regardless of the mode of exposure. Moreover, a comparison of the data with those obtained for liver (Collier and Malins 1977) reveals that the pattern of uptake and release of naphthalene and its metabolites in skin was similar to that observed for the liver. Data show that in all three experiments involving different modes of exposure, naphthalene concentrations declined more rapidly than the metabolite concentrations in skin. These results indicate a tendency of skin to preferentially retain metabolites. The latter is in agreement with findings of Sanborn and Malins (1977), Lee et al. (1976), and Roubal et al. (1977b) with other tissues. It remains to be seen whether metabolic products detected in the skin of the test fish can arise from the direct transport of these compounds in blood to the skin and/or from transformation of naphthalene by mixed-function oxidases which may be present in the skin.

In general, it is particularly noteworthy that significant amounts of metabolic products are accumulated in arctic and subarctic organisms (e.g., salmonids and flatfish) on exposures to aromatic hydrocarbons. These metabolites appear to be resistant to depuration as exemplified by the studies on the accumulation of metabolites in various fish tissues. These findings should be viewed in light of the known chronic toxicities of certain aromatic metabolites to mammalian systems (Varanasi and Malins 1977).

The results of the cytosol distribution studies with ^{109}Cd shows that in key organs of coho salmon, i.e., liver, gills, and kidney, a major fraction of the ^{109}Cd is bound to CdBP. In coho salmon that have been challenged by Cd in seawater prior to injection of ^{109}Cd, a higher percentage of cytosolic ^{109}Cd was bound to CdBP than was found for controls in seawater only. These findings imply that fish exposed to Cd ions responded by an induction of the binding protein. The increase in the percentage of cytosolic ^{109}Cd bound to CdBP in the gills, after cadmium exposure, suggests that the CdBP in the gills might act as a defense against water-borne cadmium. However, despite the presence of specialized low molecular weight proteins (CdBP) for binding cadmium, the arctic and subarctic organisms examined show a significant tendency to accumulate this metal in cellular proteins of high molecular weight (>55,000 daltons). The findings support the previous results (cf., OCSEAP Quarterly Report, RU 73/74, June 1977) and infer that accumulated cadmium in fish, resulting from ppb exposures, can alter cellular proteins and may perturb cellular biochemical processes. Whether these perturbations are deleterious to the viability of organisms is an important question for consideration.

Studies that evaluate the effects of lead on aromatic hydrocarbon metabolism showed significantly higher levels of the metabolite of naphthalene (i.e., 1,2-dihydrodiol) in exposed coho salmon as compared to controls. This suggests that lead affects the metabolism of naphthalene and, perhaps, other aromatic hydrocarbons. At present, it cannot be stated whether the presence of lead induces the conversion of naphthalene to the corresponding dihydrodiol and other metabolites or inhibits the elimination of naphthalenic metabolites from the liver. The findings imply that lead and other divalent heavy metals may possibly alter the disposition of petroleum aromatic hydrocarbons in marine fish.

The study of AHH activities in a range of marine species has revealed some important considerations about that particular xenobiotic enzyme system. It is particularly important that very little or no AHH activity has been found by us or others (Payne 1976) in shellfishes. The mussel (Mytilus edulis) was previously found to be without AHH activity in some samples while others had very little activity (Gruger and Wekell, unpublished data). From the present work, the gastropod (Fusitriton sp.) appears to be among those species without AHH activity. The absence of AHH activity leads to the assumption that aromatic hydrocarbons accumulate in marine organisms without the presence of metabolites.

Comparisons of results on AHH activities from flatfish caught locally (cf., OCSEAP Quarterly Report, RU 73/74, June 1977) with those for flatfish taken from Alaskan waters (cf., Table 7) indicate one to two orders of magnitude higher AHH activities in the local fish. The difference may be related to different environmental exposures but they may also be due to reduction of AHH activity from freezing of samples for such extensive a time as in the present work before actual AHH analyses could be performed. This latter possibility and the phenomenon of wide variability of specific activities of AHH among individual organisms may preclude the value of AHH as a monitoring index, as proposed by Payne (1976), for petroleum pollution in any practical sense. Our results, however, indicate that certain species from Alaskan waters should be capable of metabolic transformations of petroleum aromatic hydrocarbons.

Pathology

Pathological Changes in Flatfish from Exposure to Oil-contaminated Sediment

Long-term exposure of English sole to oil-contaminated sediments in the laboratory resulted in the several detrimental manifestations including severe HLV, weight loss, and increased parasitic infestation of the gills. Severe HLV was more prevalent during the early part of the experiment when concentrations of petroleum hydrocarbons were highest in tissue, thereby suggesting a direct relationship between HLV and oil exposure. The other two effects were most pronounced later in the experiment when low concentrations of petroleum hydrocarbons were present in the oil-exposed fish. Weight loss and parasitic infestation appear to have resulted from indirect effects of oil exposure. Oil-treated fish were probably less resistant to parasitic invasion; thus, they were more susceptible to infestation. Weight loss was observed in both test and control groups during the first 2 mo of the experiment. Following this period, the control fish began to regain weight, while many oil-exposed fish continued to lose weight leading to emaciation and morbidity. In this latter effect, and possibly the other two effects, oil-exposure may have caused an accentuation of normal stress responses.

Effects of Petroleum on Fish Disease Resistance

Long-term exposure of rainbow trout to PBCO resulted in a reduction in the number of spleenic lymphoid cells, yet no marked impairment of immune response could be detected. These data, taken together with our previous work showing little or no depression of natural disease resistance, suggest oil exposure does little to alter susceptibility to bacterial disease in salmonid fish. Future effort will be directed toward assessment of oil exposure on disease resistance in various flatfish species.

Morphology

The incidence of lipid vacuolization of liver cells in flatfish exposed to PBCO-contaminated sediment was more frequent but was not unique to exposed fish. Thus, the lipid vacuolated cells may reflect an adaptation of the fish to experimental conditions, which may be stress related. An increase in endoplasmic reticulum was evident in the livers of both petroleum-exposed and control fish and may also be an adaptive or stress-related phenomenon. Flatfish, obtained from the natural environment, therefore, may present certain problems as laboratory animals in their individual variability in adapting to laboratory conditions. The data support the concept that petroleum in sediments enhances an abnormal liver condition, but that the lipid vacuolization is not unique to exposures to petroleum.

Reference collections of tissues from Alaskan adult fishes and eggs and larval fishes are now available for comparison with petroleum-exposed species from either experimental or natural sources.

AUXILIARY MATERIAL

Bibliography of References

COLLIER, T.C. AND D.C. MALINS. 1977. Occurrence and identification of metabolites of naphthalene in tissues of rainbow trout (In preparation).

ETLINGER, H.M., H.O. HODGINS, AND J.M. CHILLER. 1976. Evolution of the lymphoid system. I. Evidence for lymphocyte heterogeneity in rainbow trout revealed by the organ distribution of mitogenic responses. J. Immunol. 116:1547-53.

GRUGER, E.H., JR., M.M. WEKELL, P.T. NUMOTO, AND D.R. CRADDOCK. 1977. Induction of hepatic aryl hydrocarbon hydroxylase in salmon exposed to petroleum dissolved in seawater and to petroleum and polychlorinated biphenyls, separate and together, in food. Bull. Environ. Contam. Toxicol. 17: 512-20.

HAWKES, J.W. 1974. The structure of fish skin. I. General organization. Cell Tissue Res. 149:147-58.

HAWKES, J.W. 1977. The effects of petroleum hydrocarbon exposure on the structure of fish tissues. In: Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms (D. Wolfe, ed.), p. 115-28. Pergamon Press, New York.

LEE, R.F., C. RYAN, AND M.L. NEUHAUSER. 1976. Fate of petroleum hydrocarbons taken up from food and water by the blue crab, Callinectes sapidus. Mar. Biol. (Berl.) (In press).

MacLEOD, W.D., R.W. BROWN, R.G. JENKINS, L.S. RAMOS, AND V.D. HENRY. 1976. A pilot study on the design of a petroleum hydrocarbon baseline investigation for Northern Puget Sound and Strait of Juan de Fuca. NOAA Tech. Memo. ERL MESA-8, 53 p.

MISCHELL, R.I. AND R.W. DUTTON. 1967. Immunization of dissociated spleen cell cultures from normal mice. J. Exp. Med. 126:423.

PAYNE, J.F. 1976. Field evaluation of benzopyrene hydroxylase induction as a monitor for marine petroleum pollution. Science 191:945-6.

ROUBAL, W.T., D.H. BOVEE, T.K. COLLIER, AND S.I. STRANAHAN. 1977a. Flow-through system for chronic exposure of aquatic organisms to seawater-soluble hydrocarbons from crude oil: Construction and applications. In: Proceedings 1977 Oil Spill Conference (Prevention, Behavior, Control, Cleanup), p. 551-5. American Petroleum Institute, Washington, D.C.

ROUBAL, W.T., T.K. COLLIER, AND D.C. MALINS. 1977b. Accumulation and metabolism of carbon-14 labeled benzene, naphthalene, and anthracene by young coho salmon. Arch. Environ. Contam. Toxicol. 5:513-29.

SANBORN, H.R. AND D.C. MALINS. 1977. Toxicity and metabolism of naphthalene: A study with marine larval invertebrates. Proc. Soc. Exp. Biol. Med. 154:151-5.

SOKAL, R.R. AND F.J. ROHLF. 1969. Biometry. The Principles and Practice of Statistics in Biological Research. W.H. Freeman and Co., San Francisco, 776 p.

VARANASI, U. AND D.C. MALINS. 1977. Metabolism of petroleum hydrocarbons: Accumulation and biotransformation in marine organisms. In: Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms (D.C. Malins, ed.), Vol. II, p. 175-270. Academic Press, New York.

VARANASI, U., M. UHLER, AND S. STRANAHAN. 1977. Uptake and release of naphthalene and its metabolites in skin and epidermal mucus of salmonids. Toxicol. Appl. Pharmacol. (Submitted).

Papers in Preparation

COLLIER, T.C. AND D.C. MALINS. Occurrence and identification of metabolites of naphthalene in tissues of rainbow trout (In preparation).

McCAIN, B.B., H.O. HODGINS, W.D. GRONLUND, AND J.W. HAWKES. Effects of long-term exposure of flatfish to sediment contaminated with Alaskan crude oil. J. Fish. Res. Board Can. (To be submitted).

ROUBAL, W.T., S.I. STRANAHAN, AND D.C. MALINS. The accumulation of low molecular weight aromatic hydrocarbons of crude oil by coho salmon (Oncorhynchus kisutch) and starry flounder (Platichthys stellatus). Arch. Environ. Contam. Toxicol. (Submitted).

VARANASI, U. AND D. MARKEY. Uptake and release of lead and cadmium in skin and mucus of coho salmon (Oncorhynchus kisutch). Comp. Biochem. Physiol. (Submitted).

VARANASI, U., M. UHLER, AND S. STRANAHAN. Uptake and release of naphthalene and its metabolites in skin and epidermal mucus of salmonids. Toxicol. Appl. Pharmacol. (Submitted).

PROBLEMS ENCOUNTERED AND RECOMMENDED CHANGES

Chemistry

The investigations on the accumulation and distribution of 1-MN in tissues of coho salmon and starry flounder was repeated because of wide variations in 1-MN accumulation among individual fish. The initial sampling method was inadequate for a thorough statistical treatment of the widely variable data.

Need for caution in using radiotracer compounds without first substantiating their chemical purity

We arranged for the custom synthesis of ^{14}C-labeled 1-MN from a reputable manufacturer for use in studies of this compound and its metabolites in fish. We received the material dissolved in ethanol and sealed in glass ampules. Confirmatory data was received with the shipment substantiating the purity of the 1-MN. The sealed ampules were placed in a freezer prior to use. The 1-MN in sealed ampules contained about 20% ^{14}C-labeled polar impurities, which chromatographed along with polar metabolites present in fish tissues. The impurities made it impossible to ascertain how much recovered radioactivity was due to impurities and how much was due to metabolites. Thus, an analysis of metabolites *per se* was impossible.

The manufacturer maintains that the original shipment was indeed pure, and that the impurities arose during cold storage as a result of radiation-induced decomposition of the 1-MN. We cannot prove or disprove this. Such findings point to the need, however, for a critical examination of radiochemicals received from commercial sources immediately prior to their use in accumulation and metabolism studies with aquatic organisms.

ESTIMATE OF FUNDS EXPENDED

Total spent: 360.0 K

QUARTERLY REPORT

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Number of Pages:

NUMERICAL ECOSYSTEM MODEL FOR THE EASTERN BERING SEA

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QUARTERLY REPORT

I. Highlights of Quarter's Accomplishments

A Dynamical Numerical Marine Ecosystem model, DYNUMES II, with 25 major biological components was completed and used for preliminary studies of the dynamics of total ecosystem in the eastern Bering Sea and its possible large-scale response to offshore oil development. A report on this task is enclosed, which includes an abstract and summary of principal results.

II. Task Objectives

To prepare a relatively complete 25-component ecosystem model for the eastern Bering Sea for evaluation of the possible effects of offshore oil development on the marine ecosystem - for details of the objectives see the attached report.

III. Field and Laboratory Activities

N/A

IV. Results

See attached report.

V. Preliminary Interpretation of Results

See attached report.

VI. Auxiliary Material

See attached report.

VII. Problems Encountered/Recommended Changes

1. Only half of the required and requested funds were provided by OCSEAP. Half of the funds were obtained from NWAFC. RU funding for FY 1978 remains at $50K.

2. The numerical model became so large (requiring an extensive amount of computer core) that locally available computer systems (CDC 6400 and comparable computers) are no longer adequate for the operational use of the final version of the model (DYNUMES III). CDC 7600 series computers in LRL in Berkeley will be used in future production runs.

VIII. Estimate of Funds Expended

All OCSEAP funds for FY 77 ($50K) have been expended.

PRELIMINARY REPORT ON
DYNAMICAL NUMERICAL MARINE ECOSYSTEM
MODEL (DYNUMES II) FOR EASTERN BERING SEA

By

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Supplement to Research Unit #77

Environmental Assessment of the Alaskan Continental Shelf

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ABSTRACT

A second generation, four-dimensional Dynamic Numerical Marine Ecosystem model (DYNUMES II) has been programmed for the eastern Bering Sea. This model serves a number of purposes: for diagnostic evaluation of marine resources, for prognostic studies of the effects of exploitation, and for quantitative determination of the effects of offshore oil developments.

The logic and outline of the model is given together with formulas and computation procedures used. A brief summary of the sensitivity of the model to input variability is also presented. Values for essential parameters and coefficients are given in tabular form.

Selected outputs of the trophodynamics and time changes of abundance and distribution of major species and groups of species are presented, both to demonstrate the capability of the model, and to present conditions and processes of the marine ecosystem in the eastern Bering Sea that are of concern to oil developments.

The model shows that the patchy distribution of many species is caused mainly by space and time variability in feeding. The marine ecosystem is rather unstable and most species have long-period fluctuations in abundance. It appears that it will be difficult, if not impossible, to distinguish between any local, small-scale disturbances and fluctuations that may be caused by oil developments and naturally occurring fluctuations in the ecosystem. Any small-scale (1 = <50 km) disturbance in the marine ecosystem, caused e.g. by oil development, is relatively rapidly smoothed out due to the dynamics of the ecosystem.

The ecosystem internal consumption (predation and cannibalism) is high, resulting in a high annual turnover rate of most biomasses (0.86). The most sensitive part of the ecosystem is near the coastal boundaries (e.g., shallow water and beaches).

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I. INTRODUCTION

Ecologists and fishery scientists have long recognized the interaction among the components of an ecosystem, however, any attempts to quantify these phenomena were very limited until recently due to the unavailability of or limitations in computers vis a vis the volume and complexity of the numerical analyses required. Modern ecosystem modeling concepts originated in the 1940's when relatively simple quantitative explanations of plankton production and standing crop changes with time were attempted. Simple quantitative models connecting different trophic levels in the ecosystem were also attempted. These attempts and subsequent refinements are still continuing, especially in university research institutions. Though a necessary step in the development of modeling concepts, these earlier studies did not produce much in the way of applicable results, while diverse empirical research on different aspects of the ecosystem continued to produce knowledge that emphasized the complexity of process in the ecosystem *per se*.

The development of single-species population dynamics models for various commercial fish was also intensified in the 1940's and especially in the mid-50's, and these studies provided some useful bases for single-species fisheries management decisions. Without exception, conventional fisheries production models consider environmental interactions only to the extent of assuming stability or long-term equilibria in the environment. The validity of such assumptions is, of course questionable and it is now realized that these models are insufficient for modern fisheries management. Clearly, the future development of fisheries management models must consider environmental effects and interspecies interactions.

Several numerical two- and three-dimensional ecosystem models have been developed, however, these deal with essentially planktonic organisms and are too simplistic if the total ecosystem is under consideration, and they do not consider the requirements of fisheries management schemes. The applied interests of man are focused on the upper end of the food web, where harvesting is profitable, rather than on the lower end (nutrients, phytoplankton, zooplankton). Furthermore, the nutrient-plankton-fish energy pathways are greatly variable, with great lateral losses that are not yet fully understood or accounted for quantitatively. There are also many textbook-style graphical and descriptive ecosystem models available in the literature. Although some of these are useful in provoking thought, few produce any quantitative results. The large-scale, intensive numerical modeling of the environment, especially the synoptic numerical analysis-forecasting models in meteorology and lately also in oceanography, have been developed, especially in the 1960's, and provide methods and approaches which are suitable for, but have not heretofore been applied to ecosystem modeling. Many simulation techniques that could be applied to ecosystem models have also been developed in other fields.

The purpose of this study is to apply available simulation modeling techniques to the construction of a complete as possible ecosystem model that is tailored to man's needs from a scientific as well as applied points of view. The objectives of numerical ecosystem models can be grouped into three categories:
--Investigative and digestive, that permit quantitative biological resource evaluations, including:

- Synthesis of information, including quantification of descriptive data and quantitative summarization of exploratory and baseline studies.
- Simulation of the ecosystem with all of its essential interactions, including those between the ecosystem *per se* and the physical-chemical environment.

-Determination of the effects of environment and interspecies interactions and other natural fluctuations.

--General management guidance and effects of exploitation, including:

-Magnitude or status of the biological resources, their past and expected future fluctuations.

-Determination of effects of fishing intensity variations (including spatial and temporal changes in distribution of fishing effort) on the resources, and determination of the effects of proposed regulations.

-Establishment of research priorities.

--Oil exploration/exploitation (developments) effects on marine ecosystem, including:

-Determination of the effects of oil "developments" on the ecosystem (and exploitable resources) as compared to natural fluctuations, including the determination of Contaminant Baselines - OCSEAP Tasks A and E.

-Quantitative determination (in space and time) of the possible ecosystem components susceptible to petroleum "development" - OCSEAP Task E.

-Quantitative determination (by means of numerical (model) simulation) of the effects the contaminants and other possible detrimental effects of petroleum "developments" on the marine ecosystem and its components - OCSEAP Task E.

In order to simulate the complex processes in the ecosystem, the numerical model becomes, by necessity, extensive and complex. In this report earlier results (e.g., Laevastu and Favorite 1976 a, b) are reviewed, the current model structure is described, and some initial assessments are discussed. A detailed description and program documentation will be compiled in a subsequent report.

II. THE DYNAMICAL NUMERICAL MARINE ECOSYSTEM (DYNUMES II) MODEL

A. THE BASIC PRINCIPLES, LOGIC AND OUTLINE OF THE MODEL

The accumulated knowledge on marine ecosystem and modeling/simulation experiences provides some of the basic principles related to a complete ecosystem model:

--An abundant species (and/or group of ecologically similar species) that interacts extensively with other species/groups of species should be selected as a reference species. This species should be subject to exploitation and past research so that reasonably reliable estimates of standing stocks of the exploitable part of the species biomass are available, and the general or specific nature of the interactions (e.g., predation) are known. An estimate of the "minimum sustainable biomass" - a biomass which is in quasi-equilibrium with growth and consumption within the ecosystem - of the reference species must be prescribed in the initiation of the model. The total biomass of a species, for which estimates of the exploitable biomass are available, can be computed, with some assumptions, by extrapolating from the exploitable portion (Laevastu and Favorite 1977a).

--The amounts of space-time distributions of the end consumers (i.e., the (highest) part of the "food chain", i.e., man, mammals and birds) must be prescribed (estimated) with the basic input into the model, and the consumption of other biomasses by these consumers must be computed.

--Analysis (determination of the initial state) is basic to all multi-dimensional dynamic models. Thus, the model must be started with estimated magnitudes of all species biomasses and their estimated distributions, obtained from available pertinent data. The iterative estimation of the magnitudes of the biomasses was an integral part of the initiation of DYNUMES, although a separate model (Bulk Biomass Model, BBM) was developed later (Laevastu and Favorite 1976b, 1977b) for this purpose. The basic principle of the BBM model is: $gB_t = G_t + F_t + M_t$, or in words: growth of biomass (B) in unit time t with growth rate g equals consumption (G) plus fishery catches (F) plus natural mortality (M) in the same unit time; g and F are known, M is relatively small and is estimated, and G is computed within the model with known data (composition of food and food coefficients). Thus, an estimate of B can be obtained with a relaxation method (Laevastu and Favorite 1977b).

--The trophodynamic computations (i.e., types and amounts of food consumed) in a given time step in the model commence with the computation of consumption by mammals, followed by computations of consumption by fish species and zooplankton and benthos. The simple food web (food pyramid) approach, so prevalent in the past, has been abandoned as unrealistic in light of the complex food relations (Figure 1).

--The model must account for all processes, including trophodynamic ones, in the ecosystem which affect the distribution and abundance of any component, such as migrations, environment effects, and biological functions (e.g., spawning). Dominant processes (Figure 2) must be quantitatively evaluated in time steps not exceeding one month. Obviously the smaller time steps for which adequate supporting data are available the more promising the result.

--There must be an open pathway into the model to enter actual and potential effects of man on the ecosystem (fishery, oil developments, etc.).

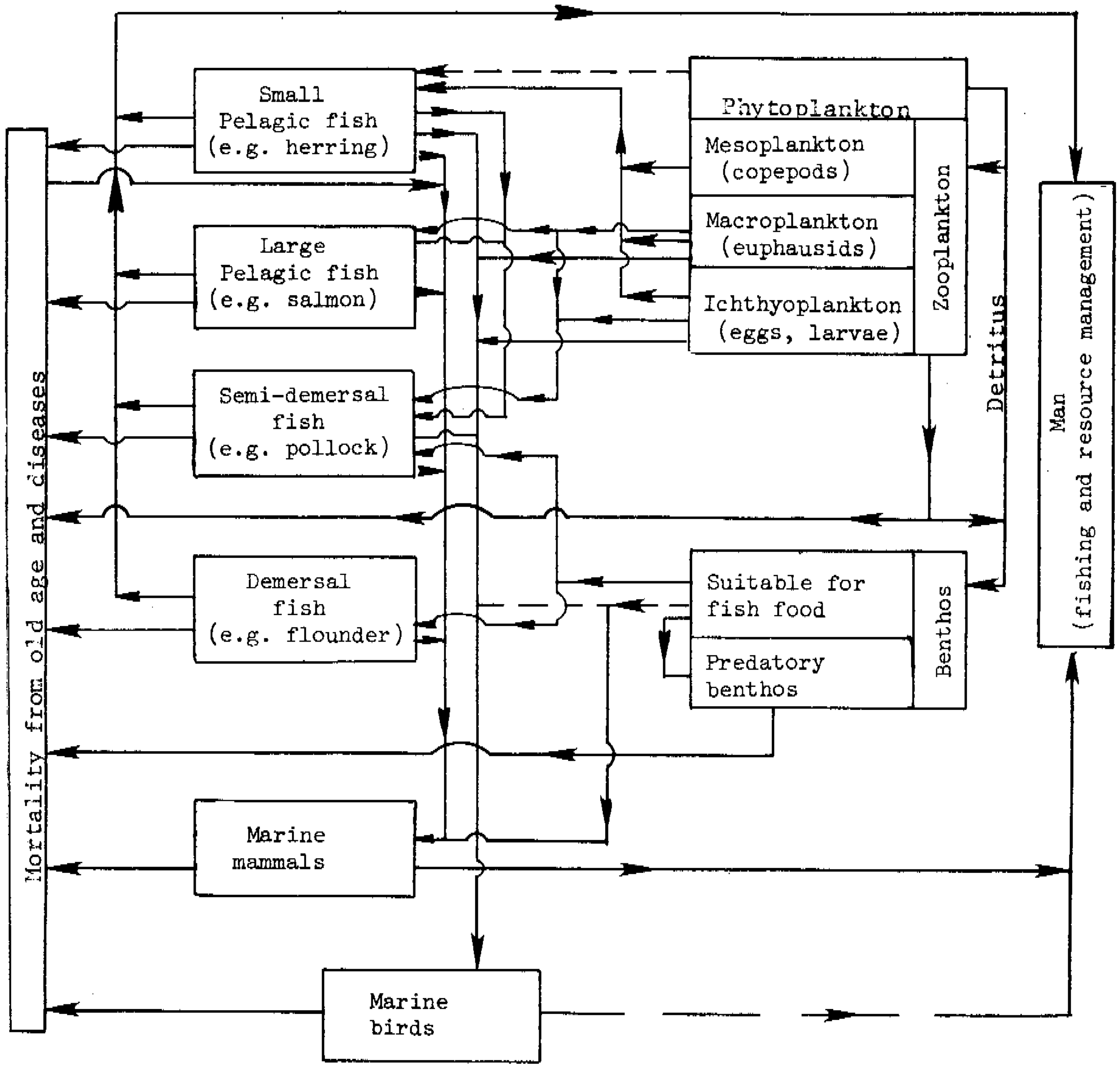

Figure 1. Generalized scheme of complex food relations in marine ecosystem.

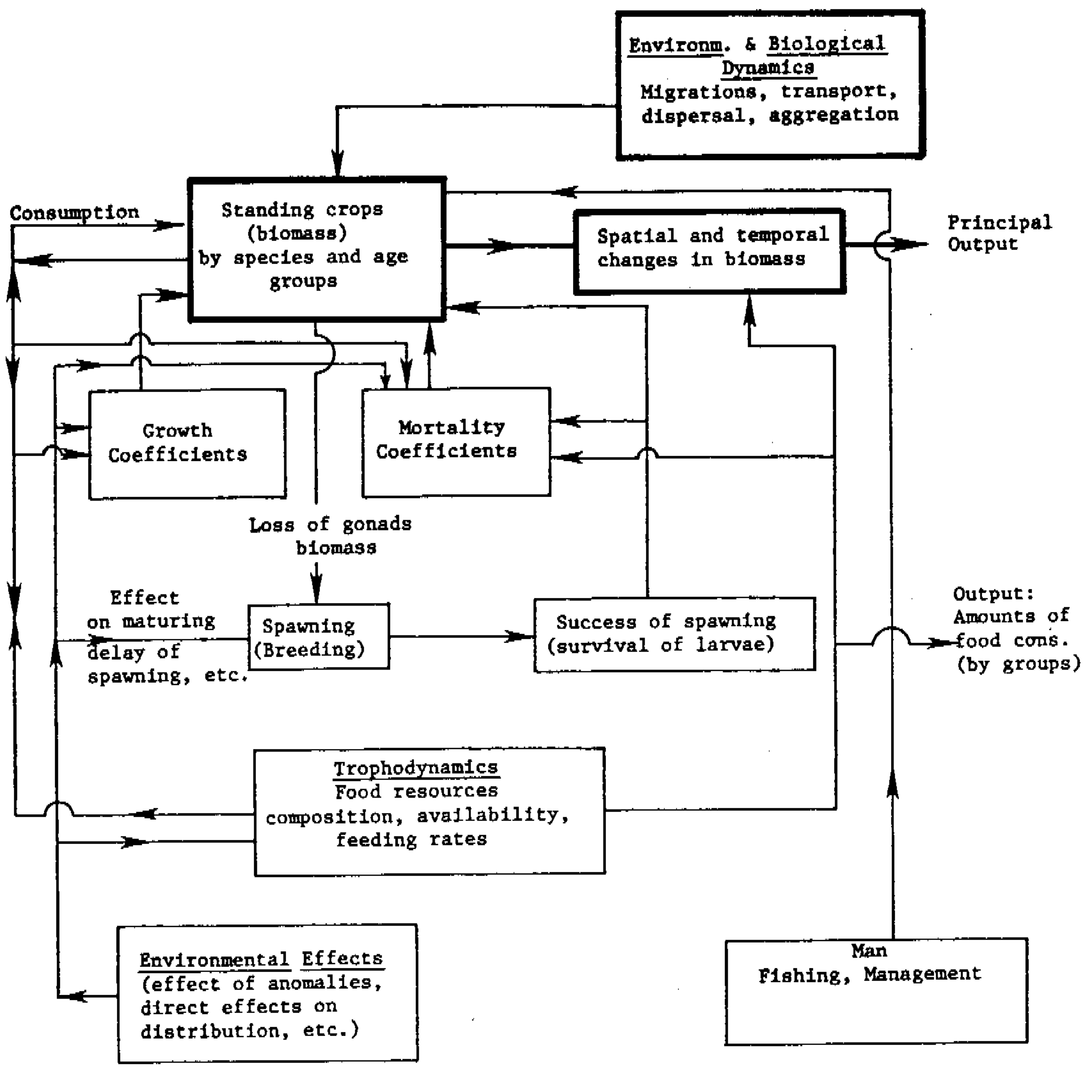

Figure 2. Scheme of principal processes and interactions in the marine ecosystem.

The preceding six principles require the following general logic to be the basis of the model development:

- The ecosystem simulation is, to a large extent, a bookkeeping of changing balance (imbalance) in nature.
- The model must be based on available basic knowledge and must provide multiple checking (verification) possibilities. Unsubstantiated assumptions and beliefs, such as the widely held belief that the number of spawners determines largely the year class strength in all species, have been avoided. To the contrary, the early model results indicate that predation on 0+ and 1+ year classes determines largely the exploitable year class strength of most species.
- The grouping of similar species in the model must be possible in order to have a program of manageable size. On the other hand, provision must exist to consider single species or even year classes, if so desired.

The schematic sequencing of the main body of the program is presented (Figure 3) and a more detailed outline is also given (Figure 4). A few additional explanations are listed below:

(1) Inputs, initiation

Grid - equal area two dimensional grid, grid size 95.25 km. Third dimension (depth) either implied and/or used in zoomed areas.

Fixed data - depth, monthly mean environmental conditions (ice, temperature, etc., for anomaly computation), sea-land and special subregion tables.

Coefficients - e.g., food requirement, growth, fishing intensity, etc., coefficients, some specific for species, some specific for area and time (detailed data given in discussions on specific species).

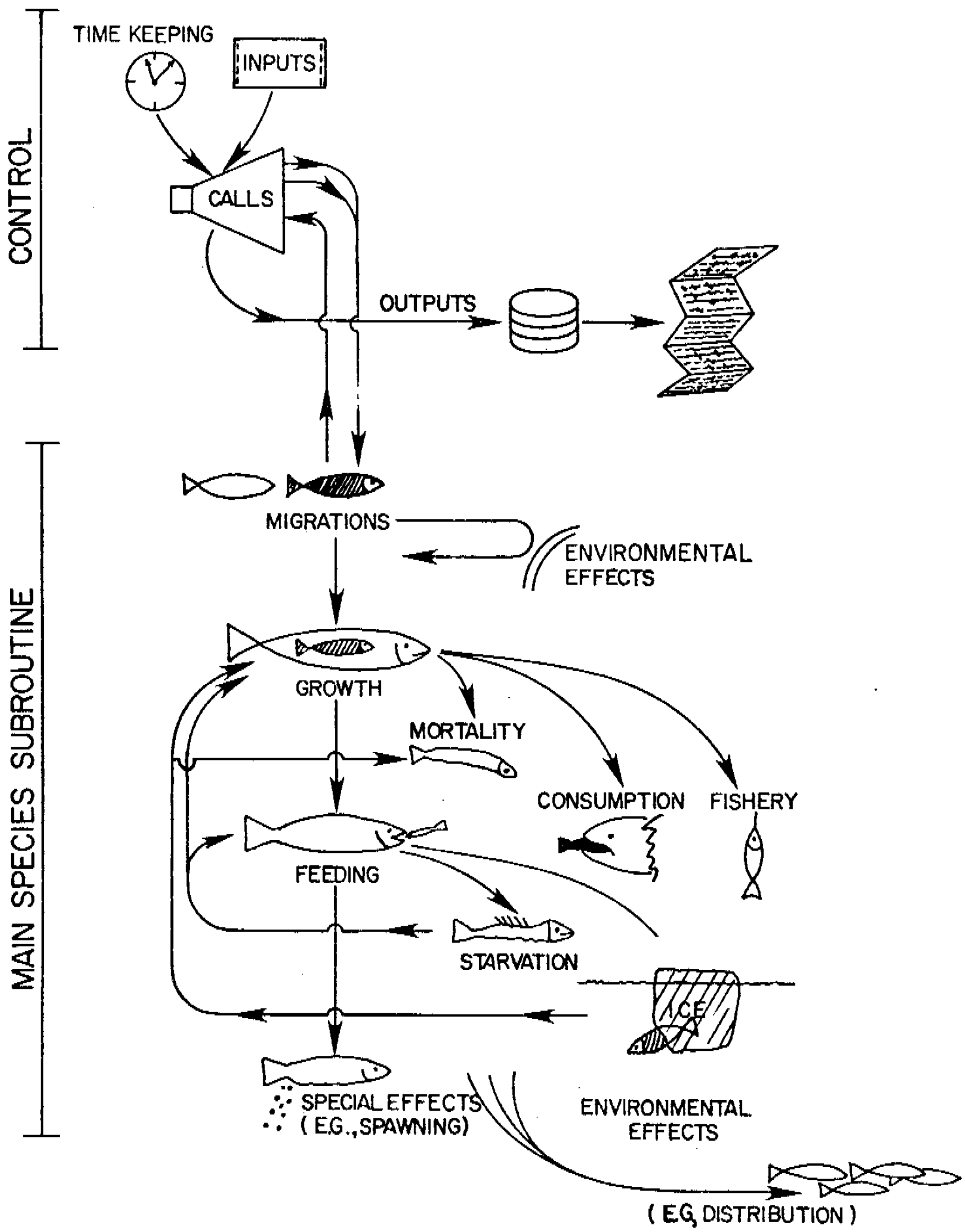

Figure 3. Schematic sequencing in species subroutines.

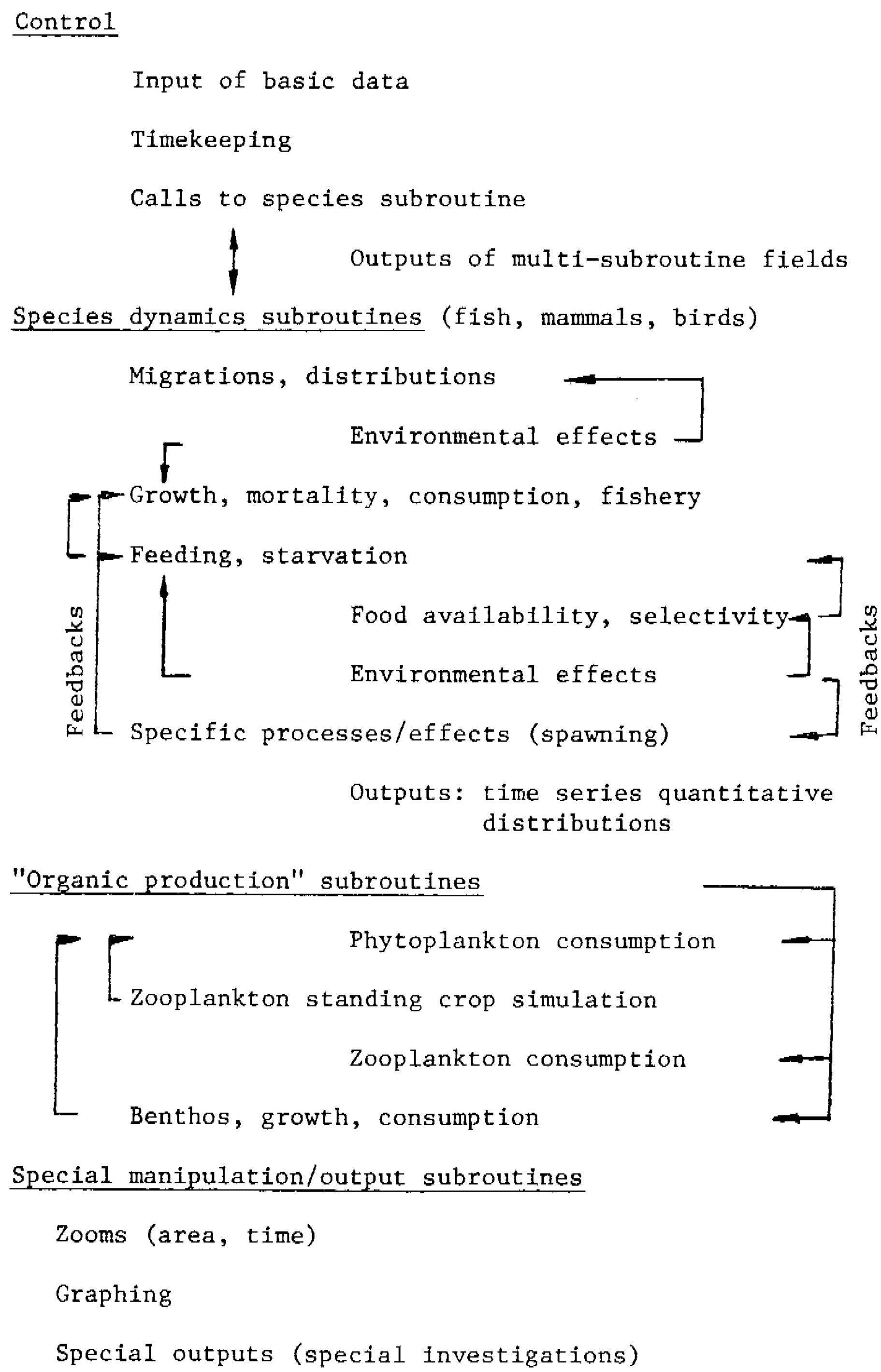

Figure 4.-Schematic outline of the DYNUMES II model.

<u>Biological (species) data</u> - initial quantitative distributions of fish, division of "important" species into age (size) groups; monthly distribution of mammals and birds.

(2) Control program

The control program includes timekeeping, calling of subroutines, and month-end outputs of fields which are computed in several subroutines. Inputs are also done with the control program which also prints the input fields and other data for verification purposes.

(3) Species dynamics subroutines (fish)

The migrations of the species and resulting distribution is computed in each time step (weekly or monthly). The effects of environment (e.g., ice, temperature, depth, nature of the bottom) on migration will be incorporated in version III of DYNUMES model.

Growth, consumption (grazing), fishery, and natural mortality is computed using the monthly consumption of the given species from the previous time step. The food consumption (for growth and maintenance) is computed with constant coefficients and composition, however, the DYNUMES III will have time and space varying composition of food (adjusted to availability and preference) and the food uptake, as well as growth, as influenced by environment (temperature).

(4) Mammal and bird subroutines

Monthly quantitative distributions of mammals and birds is prescribed. As these estimates have certain margins of error, it is not rewarding at this time to compute growth and mortality of mammals and birds, but only consumptions (grazing) by them.

(5) "Organic production" subroutines

Phytoplankton and zooplankton consumptions are computed throughout the model even though present knowledge of phytoplankton production is too scanty for meaningful simulation. Zooplankton standing crop is simulated as a function of location, latitude and time (season). Benthos computations (growth, grazing, distribution) are carried out only on the portion of benthos which is suitable as fish food; no predatory benthos, about which the knowledge is scanty, is taken into consideration.

(6) Special manipulation/output subroutines

Special graphing subroutines and printout subroutines are incorporated and special ancilliary graphic programs are available externally. DYNUMES III will contain a zooming subroutine, which will allow detailed computations with small mesh; the boundary conditions for zooming subroutine being extracted from regular model run.

B. FORMULAS AND COMPUTATION PROCEDURES

Because of large computer core and intermediate storage requirements, the model makes extensive use of random access mass storage. Although in the initial modeling stages many of the input fields were created in the program (e.g., bearded seal distribution field in relation to ice edge), without additional cores it will be necessary in subsequent versions to punch these fields after creation on cards and read these into storage in the initiation of the program. The "minimum sustainable biomass" of each species was initially also established by model outputs. Now a separate model (Bulk Biomass Model, BBM) is used for this purpose.

In the following paragraphs only some essential formulas and computation procedures are presented. Extensive use is made in the program of a variety of "restrained functions"; these are best explained in program documentation, which is in preparation.

(1) Migration speed

The migration speed (u and v components) is simulated within the program for each species or is prescribed with input fields. The migration, including diffusion and "smoothing" is computed in weekly time steps (shorter time steps in zoomed models) with the following finite difference formula:

$$B_{t,n,m} = B_{t-1,n,m} - C_1 B_{t-1,n,m} + C_2 (B_{t-1,n-1,m} + B_{t-1,n+1,m}$$
$$+ B_{t-1,n,m-1} + B_{t-1,n,m+1} - 4B_{t-1,n,m}) - T_d C_3 C_4$$
$$- T_d C_5 C_6 + C_2 (B_{t-1,n-1,m-1} + B_{t-1,n-1,m+1} + B_{t-1,n+1,m-1}$$
$$+ B_{t-1,n+1,m\_1}) /4$$

Where:

$C_1 \quad = 2T_d A/L$

$C_2 \quad = T_d A/L$

$C_3 \quad = u$

$C_4 \quad = (B_{t-1,n,m} - B_{t-1,n,m+1}) /L$ (u neg)

$C_4 \quad = (B_{t-1,n,m} - B_{t-1,n,m-1}) /L$ (u pos)

$C_5 \quad = v$

$C_6 \quad = (B_{t-1,n,m} - B_{t-1,n-1,m}) /L$ (v neg)

$C_6 \quad = (B_{t-1,n,m} - B_{t-1,n+1,m}) /L$ (v pos)

Symbols:

A - "smoothing coefficient" (time step and grid size dependent) = 0.5 in present model

B - biomass

C_4C_6 - "upstream interpolation"

L - grid length (km)

n,m - grid point designations

T_d - time step (days)

t - time step designator (t - current, t-1 - previous)

u,v - migration speed components

Although the above migration formula is conservative, some minor loss of biomass can occur near open boundaries. This can be corrected by the following approach.

$$B_{t,n,m} = B_{t-1,n,m} \frac{B_{t-1(tot)}}{B\ (tot)}$$

where $B_{(tot)}$ indicates total biomass over the area (t-1 in previous time step and t in present time step).

The aggregation at boundaries (e.g., the spawning of herring and capelin near the coast) will be simulated with restrained functions in DYNUMES III.

(2) Growth of biomass

The growth of biomass is computed with a formula similar to those used in conventional population dynamics approaches:

$$B_{t,n,m} = B_{t-1,n,m}\ (2 - e^{-g})$$

g is growth coefficient for a given species. It changes with the age of the species. Therefore, it is necessary to know the mean age of the biomass (see Section II-D below). In this model version (II) the growth coefficient is either constant in some species or changing harmonically throughout the year. In DYNUMES III the growth coefficient will be a function of environment (temperature) and food availability (starvation).

(3) Fishing and mortality losses

Fishing and (natural) mortality (from old age and diseases) losses are also computed by an exponential function:

$$B_{t,n,m} = B_{t-1,n,m}\, e^{-f}$$

f is a fishing intensity coefficient, which is prescribed as a monthly field in some intensely exploited species (e.g., pollock), or applied to all species biomass at each grid point in some other species. It is tuned to a value which yields quantities corresponding to available catch data. In mortality computations f is replaced with a relatively low mortality coefficient. In DYNUMES III the latter coefficient will be made a function of unfavorable environment (e.g., temperatures below 0.5°C) and of availability of food (starvation).

The total biomass balance formula thus becomes

$$B_{t,n,m} = B_{t-1,n,m}\,(2-e^{-g})\, e^{-(f+m)} - C_{t-1,n,m}$$

where C is the consumption (grazing) in the previous month (see below).

(4) Trophodynamics

The trophodynamic formulas compute the food uptake (and requirements) and effect the bookkeeping of the consumption (grazing).

Food requirement formula:

$$F_{i,t} = B_{i,t-1}\,(2-e^{-g_t})\, K_{i,g} + B_{i,t}\, K_{i,m}$$

Food proportioning formula:

$$C_{i,j,t} = F_{i,t}\,\rho_{i,j}$$

$$C_{i,k,t} = F_{i,t}\,\rho_{i,k} \qquad \text{--etc.}$$

$$C_{i,t} = C_{j,i,t} + C_{k,i,t} + \ldots C_{n,i,t}$$

The symbols in the above equations are:

$B_{i,t}$ - biomass of ecological groups i in months t,

$g_{i,t}$ - growth coefficient (approximately growth in % per month),

$F_{i,t}$ - food requirement for growth and maintenance,

K_g - food coefficient for growth (e.g., 1:2 - 2 kg of food biomass gives 1 kg of growth),

K_m - food coefficient for maintenance (in terms of body (biomass) weight per time step),

$C_{i,t}$ - total amount of ecological groups consumed by other groups in unit time (months),

$\rho_{i,j}$ - proportion of ecological group in the food of group i,

i,j,k,n - ecological groups.

The ecosystem internal grazing is unevenly distributed over different ages (year classes) of the species, but in DYNUMES III there will be a provision for partitioning several biomasses into juveniles and adults and consequently obtaining separate growth and consumption computations. DYNUMES II has this provision only for pollock. DYNUMES III will also permit a space and time variable composition of food, depending on its availability, as well as bookkeeping of partial starvation, which in turn will modify growth and mortality rates.

(5) Special effects

Among special effect formulas, which have been described in previous reports (e.g., Laevastu, Favorite and McAlister 1976) the following could be listed: conversion between geographic and model grid coordinates, boundary treatment, general analysis program and graphing program, the last two being external to the model.

Zooplankton standing crop simulation formula can serve as an example for simulation of similar and/or related fields in the program:

$$Z_{t,n,m} = P_1 + C_1 \cos(\alpha T_d - \kappa_1) + C_k \, (\beta T_d - \kappa_2)$$

Z - is zooplankton standing crop (e.g., in mg/m^3)

P_1 - is a latitude and location (subarea) dependent annual mean zooplankton standing crop

C_1 - is the half-magnitude of annual change of zooplankton standing crop (function of latitude and specific location)

C_k - is a "modifying magnitude" (e.g., for reproduction of autumn "bloom"

α and β are phase speeds (time step dependent, 30° and 60° respectively for monthly time step)

κ_1 and κ_2 are phase lags

T_d - is time (in month)

Other specific formulas and procedures used in the model will be described in DYNUMES III documentation.

C. INPUTS AND OUTPUTS

The following is a list of two-dimensional field arrays which are either read (direct input) from cards (marked with i) or created in the program. If the species/group of species can be consider "indigenous" to the area, only the initial field is read (created). However, where considerable migrations through the boundaries occur, monthly distribution fields have been read from cards (marked im in the following list). Seasonal distributions are marked with s; whereas im, c indicates fields which were initially created with the model but are at present read from cards.

(1) Environment and model operation fields:

Sea-land table (depths in DYNUMES III) (i)

Special indices (subareas) (i)

Ice (im)

Bottom temperature (is)
Surface temperature (is) } (DYNUMES III only)

Surface currents (is) (DYNUMES III) only)

Actual temperature and current anomalies (im) (DYNUMES III only)

Operation fields (40) (Space in main core; output and intermediate fields on disc not accounted, the latter exceed 700 at present)

(2) Ecological groups and major single species:

Mammals

1. Fur seal (im)
2. Sea lion (im)
3. Bearded seal (im,c)
4. Ringed and ribbon seals (im,c)
5. Harbor seals (im,c)
6. Baleen (true) whales (im,c)
7. Toothed whales (including porpoises, dolphins (im,c)
8. Walrus (im,c)

Birds

9. Murres (im,c)
10. Shearwaters (im,c)
11. Other marine birds ("lumped" group) (im,c)

Fish

12-15. Pollock (3 age groups) (c)
total (i)

16. Other gadids ("lumped") (i)

17. Herring (i)

18. Other pelagic fish (capelin, smelts, etc.) (i)

19. Yellowfin (i)

20. Other flatfish (i)

21. Other demersal fish (sculpins, etc.) (i)

Plankton, benthos

22. Benthos ("fish food" benthos) (i,c)

23. Squids (i)

24. Euphausids (c)

25. Copepods (c)

26. Total zooplankton (c)

27. Phytoplankton (consumption only) (c)

For most of the above species/ecological groups, monthly consumption fields, migration speed fields, and "starvation" fields are created in the program. As the number of fields (arrays) to be operated on, exceeds 700 at present, and as the program is in excess of 6000 cards, it is obvious that a larger computer is required and that the program must be optimized in a multitude of way.

The outputs are in the form of field printouts and various tables and graphs. Most of the routine outputs are two-dimensional field printouts of monthly quantitative distributions and consumption. Special outputs are tailored to the problems and questions to be solved and usually include time series outputs at selected locations. Examples of outputs are found in the following Sections, (mainly in Section III).

D. SENSITIVITY OF THE MODEL TO INPUT VARIABILITY

The sensitivities of various aspects of the model, especially the linear and quasi-linear interactions of growths and mortalities, were investigated during the model design/programming and tuning stages using, among others, special outputs from runs with assumed (e.g., plausible minimum/maximum values) of input variables. Details of these more qualitative than quantitative sensitivity tests would require voluminous reports, which would have a limited audience. However, one of the main tasks, and also objectives, of the model is to study the sensitivity of the ecosystem and interactions within it to various changes and influences, internal as well as external to the system. These are studied with special investigative/production runs and will be reported separately as they are made and when a final model structure is arrived at. One example of such studies is found in the report on dynamics of pollock biomass in the eastern Bering Sea (Laevastu and Favorite 1976c).

The greatest sensitivity of the model to input parameters is in the nonlinear parts of the model, where exponential functions are used (e.g., growth and mortality computations). New scientific as well as applied questions and problems have arisen in the formulation and tuning of these parts of the model, which have required special studies and developments. This is illustrated below with an example of determining a mean growth coefficient for Pa^ific herring. The weight growth coefficients decrease with age of the species (Figure 5). Thus, for the computation of the biomass distribution for any given time it is necessary to know the age composition of the biomass of a species/ecological group. This composition can be computed using available data and some assumptions. First, the age distribution of the exploitable part of the biomass can be obtained by summarizing the distribution of year classes in the catches (Figure 6) and determining from this summary a mean age composition of catch (Figure 7). Next, a more subjective estimation of the consumption of the fish of different size (and age) must be performed (Figure 8). This estimation is first done by size categories, using knowledge of the size of prey (from stomach analyses), relative amounts of predators, and turnover rates. The estimates of the last two parameters are guided by the ecosystem model outputs (these estimates are given in Figure 9 on a linear age scale).

Next, iterative extrapolations of the numbers and biomass are carried through juvenile year-classes by taking into account that the biomass of the previous year class must deliver the biomass of the next year class with the experimentally (by measurement) determined growth rate (Figure 5) plus the biomass consumed within this year (Figure 9). This computing procedure is reported in another report (Laevastu and Favorite 1977a). The resulting biomass and number distribution of Pacific herring in the Bering Sea is given (Figure 10) which also indicates that only 30% of the biomass of this species is under exploitation and 70% is in the juvenile stage. The bulk of the biomass of many species is in juvenile stages, which explains the necessity of the use of relatively high growth coefficients in the model. Considering the formula for growth (see previous Section) it becomes obvious that the total biomass and its fluctuations are sensitive to the selection of a proper growth coefficient and its change. In DYNUMES III, the growth coefficient is a function of environment (temperature) and availability of food.

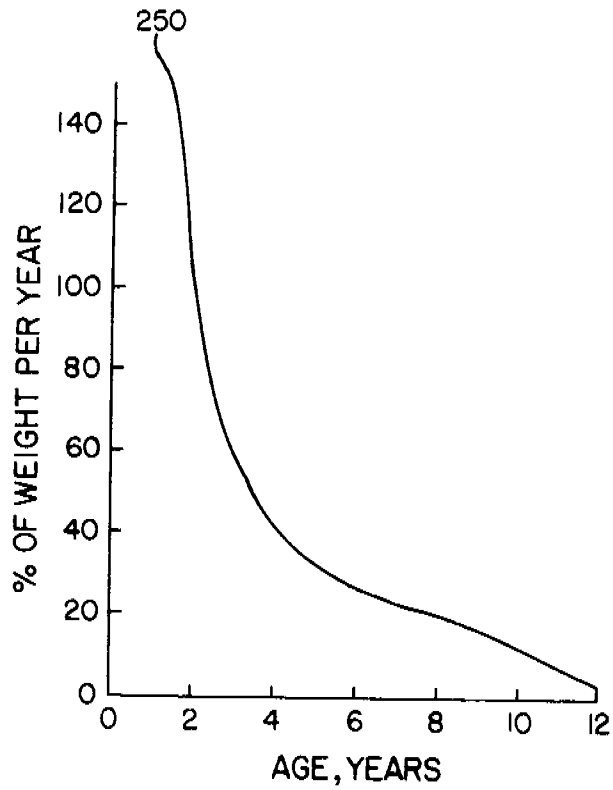

Figure 5. Growth of weight of Pacific herring in the Bering Sea (% per year).

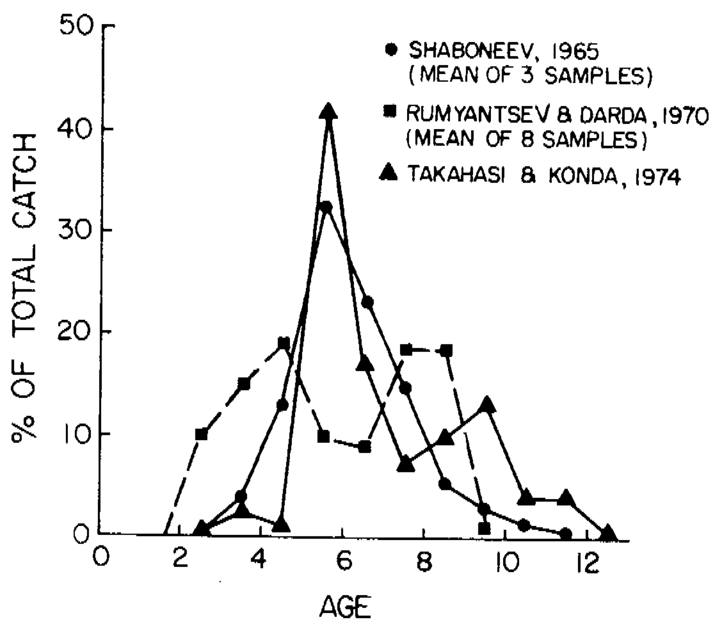

Figure 6. Age composition of catch of Pacific herring in the Bering Sea as reported by different investigators.

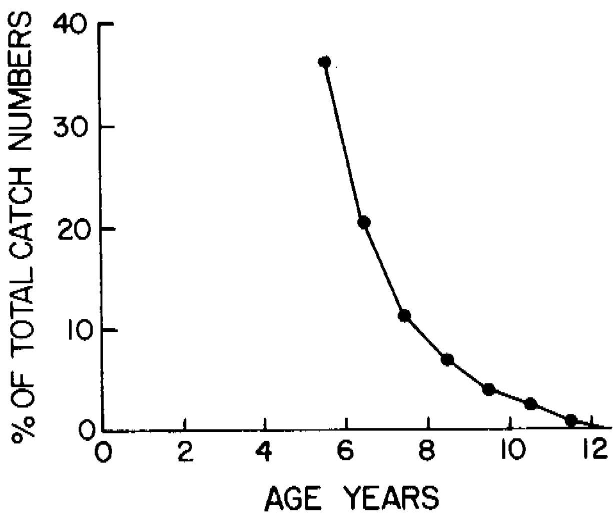

Figure 7. Estimated mean age composition of Pacific herring in the Bering Sea.

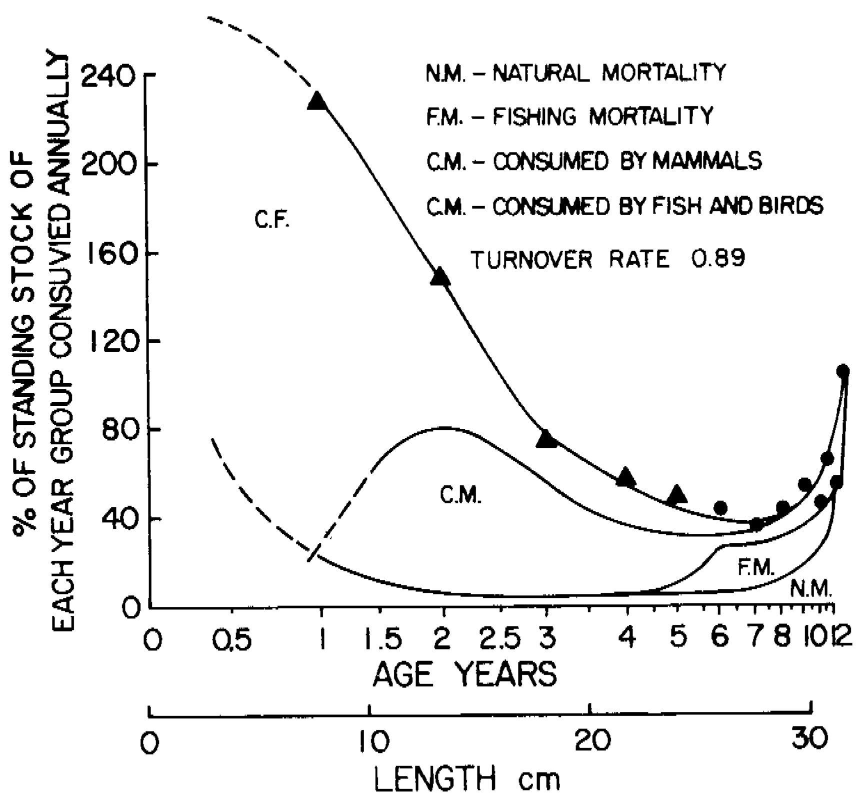

Figure 8. Percent of biomass consumed annually of different size (and age) groups of Pacific herring in the Bering Sea.

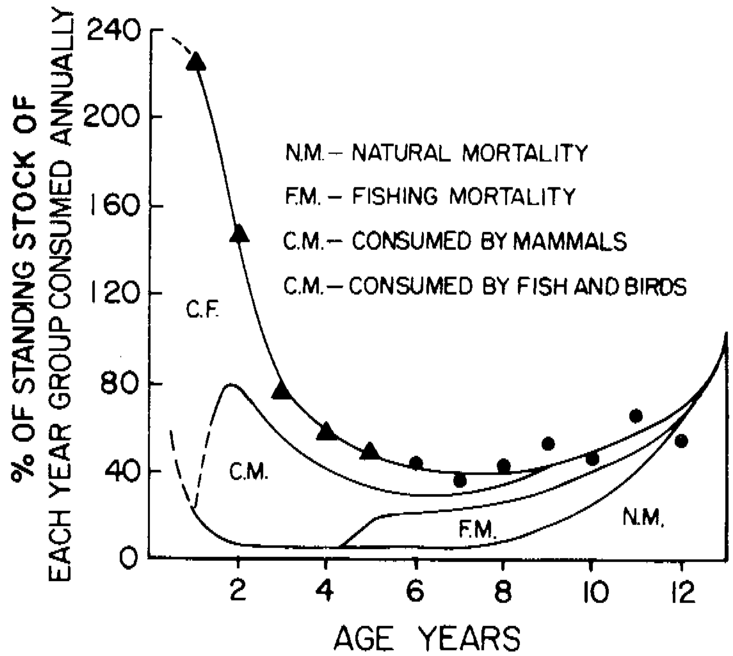

Figure 9. Percent of total biomass of each year class of Pacific herring consumed annually in the Bering Sea.

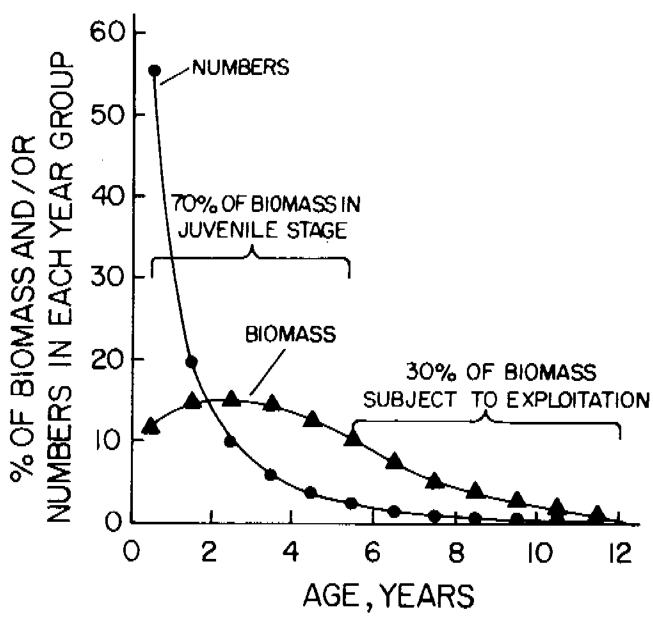

Figure 10. Distribution of biomass and numbers with age of Pacific herring in the Bering Sea.

III. QUANTITATIVE RELATIONS IN THE ECOSYSTEM OF THE EASTERN BERING SEA

A. GROWTH AND FOOD COEFFICIENTS AND COMPOSITION OF FOOD

The prognostic results from the model are greatly dependent upon the validity of the initial inputs, primarily the various coefficients and food compositions. The initial guess of the abundance of a given species and/or ecological group is determined by the Bulk Biomass Model (BBM) (Laevastu and Favorite 1976b) and the distribution of the given species is determined empirically from knowledge extracted from the rather extensive literature. The final adjusted distributions will be described in detail in a report on DYNUMES III. It has been observed in the course of using the model that the initial, relatively smooth, prescribed distributions are modified after about a 6 month computation period, resulting partly in somewhat patchy distributions (which is a known normal condition with most species), and in partial separation of the centers of bulk distribution of species into more than one cluster in some species. This is also a normal, known condition in the sea, where the bulk of the catches in some areas in medium and higher latitudes consist of one or two species, which are replaced in other not too distant locations by other species. Examples of patches and distributions are given later in this report.

The growth coefficients (Table 1) are empirically derived from available data. If the species is not divided into size (age) groups, the distribution of biomass with age must be used for computation of growth coefficients. Experiments with seasonal and area variable growth coefficients were carried out (in DYNUMES III growth coefficients will be functions of temperature and food availability at each grid point and at each time step).

Table 1

Growth and mortality coefficients
(% per month)

Species/ecological group	Growth coefficient	Natural mortality coefficient	Fishing mortality coefficient
Pollock, group 1	13.0	0.3	-
Pollock, group 2	5.0	0.3	} Time & space
Pollock, group 3	1.5	1.5	} variable
Herring	9.0	0.4	2.0 (4 months)
Other pelagic fish	12.0	0.5	-
Yellowfin	7.0	0.09	0.7
Other flatfish	8.0	0.07	0.7
Other gadids	11.0	0.3	0.3
Other demersal fish	10.0	0.3	0.35
Squid	12.0	3.0	-
Benthos ("fish food benthos")	12.0	3.0	0.05

Note: 1. Natural mortality refers to mortality from disease and old age only.

2. Fishing mortality does not reflect in all species present catches, but also potential catches.

The fishing mortality coefficients (Table 1) are, in most cases derived by tuning (adjustments) so that the computed results represent the present catch. Runs have also been made with "potential catch" coefficients. Where the time and space distribution of fishing intensity is known (e.g., with pollock), it has been prescribed with input.

The natural mortality coefficient refers to mortalities caused by diseases and "old age" only. It has been estimated by considering also the average life length of the species and fishery (if any).

The consumption (grazing) is computed within the model. It depends on food requirements and composition of food (preferred food items) of all model components. In addition, the size of the food item has been taken into consideration by adjusting the composition of food of a given species.

The food coefficients are given (Table 2) without discussion at this time. It could be pointed out here that the food coefficients are considerably lower than conventionally used and found in the literature. This is partly due to the model results which have led us to believe that the relatively few experimentally determined food coefficients are somewhat too high, having been determined in tanks and in fish culture ponds.

The composition of the food of different species and ecological groups (Table 3) are based on considerable literature review and synthesis of relatively scattered and variable notes on this subject. It has become apparent that the composition of food of any given species varies within relatively wide limits, not only with the age of the species, but also with the location and the season. Therefore, the food composition in DYNUMES III will be made variable in space and time, depending largely upon the availability of preferred and suitable food items.

Table 2

Food coefficients

Species/ecological group	Food for maintenance (% body weight daily)	Food for growth (ratio, growth/food)
Pinnipeds		
Fur seal	5	
Bearded seal	5	
Sea lion	5	
Harbor seal	5	
Ringed/ribbon seal	5	
Walrus	5	
Whales & ecologically related species		
Baleen whales	4	
Toothed whales, porpoises	3.3	
Birds		
Shearwaters	12	
Murres	12	
Other birds	12	
Fish		
Pollock, group 1	0.75	1.7
Pollock, group 2	0.65	1.4
Pollock, group 3	0.5	1.4
Herring	0.8	1.8
Other pelagic fish	0.75	1.8
Yellowfin	0.8	
Other flatfish	0.8	
Other gadids	1.0	
Other demersal fish	1.0	
Other ecological groups		
Squid	0.5	1.5
Benthos ("fish food benthos")	0.8	

Table 3

Composition of food (percentage)

PINNIPEDS

Fur seal	
Pollock	73
Other gadids	6
Herring	5
Salmon	2
Other pelagic	2
Benthos	2
"Others"	10

Sea lion	
Pollock	65
Salmon	8
Other gadids	7
Herring	6
Other pelagic	4
"Others"	10

Bearded seal	
Benthos	61
Pollock	10
Squids	8
Herring	5
Other flatfish	5
Other gadids	3
Other pelagic	3
Salmon	1
"Others"	4

Ringed/ribbon seals	
Pollock	28
Other pelagic	18
Benthos	14
Squids	12
Herring	12
Other gadids	10
Other flatfish	2
Salmon	1
"Others"	3

Walrus	
Benthos	95
Pollock	2
Other flatfish	1.5
Salmon	0.5
"Others"	1

Harbor seals	
Benthos	23.5
Pollock	20
Squids	20
Other gadids	15
Other pelagic	7
Herring	3
Other flatfish	2
Salmon	1.5
"Others"	8

WHALES, DOLPHINS, PORPOISES

Baleen whales	
Euphausids	80
Squids	9
Copepods	6
Other pelagic	2
Herring	1.5
Pollock	1
Other gadids	0.5

Toothed whales, dolphins	
Other pelagic	30
Pollock	25
Herring	17
Other gadids	5
Other flatfish	5
"Others"	18

Table 3 - Cont'd.

BIRDS

Murres	
Pollock	27
Other pelagic	27
Euphausids	14
Squids	7
Herring	7
Other flatfish	2
Salmon	1
"Others"	15

Other birds	
Euphausids	40
Other pelagic	20
Squids	8
Benthos	8
Copepods	8
Herring	4
"Others"	12

Shearwaters	
Euphausids	80
Other pelagic	10
Herring	5
Squids	5

FISH

Herring	
Copepods	68
Euphausids	19
Phytoplankton	3
Other pelagic	3
Squids	1
Pollock	0.5
Other gadids	0.3
Yellowfin	0.3
Other flatfish	0.3
"Others"	4.6

Other pelagic fish	
Copepods	45
Euphausids	35
Phytoplankton	10
Other pelagic	4
Squids	3
Pollock	2
Other gadids	0.5
Herring	0.5

Pollock	Group 1	Group 2	Group 3
Copepods	68	22	6
Euphausids	28	56	29
Pollock, Gr. 1		5	13
Pollock, Gr. 2			4
Herring	0.5	2	8
Other pelagic	1	2	5
Other gadids			3
Other demersal	2	3	5
Squids		1	8
Benthos	0.5	9	17
Yellowfin			1.5
Other flatfish			0.5

Table 3 - Cont'd.

Yellowfin	
Benthos	50
Euphausids	20
Other demersal	10
Pollock	8
Other flatfish	7
Squids	3
Other gadids	2

Other gadids	
Benthos	28
Euphausids	20
Copepods	14
Other demersal	10
Pollock	9
Other pelagic	8
Herring	4
Other flatfish	4
Yellowfin	3

Other flatfish	
Benthos	65
Euphausids	10
Pollock	10
Yellowfin	2
Other flatfish	2
Other pelagic	2
Other gadids	2
Other demersal	2
"Others"	5

Other demersal fish	
Benthos	37
Euphausids	22
Copepods	12
Other flatfish	9
Other gadids	6
Pollock	4.5
Yellowfin	4
Other pelagic	3.5
Herring	2

OTHER ECOLOGICAL GROUPS

Benthos ("fish food benthos")	
Phytoplankton (detritus)	75
Benthos	11
Copepods	7
Euphausids	4
Other demersal	1
Other flatfish	0.5
Yellowfin	0.3
"Others"	1.2

Squids	
Other pelagic	30
Euphausids	25
Pollock	15
Copepods	15
Herring	10
Other gadids	5

As the consumption is one of the more important factors (in fact quantitatively considerably higher than the intensive fishery) determining the dynamics and abundance of species, and as feeding depends on the space and time variable food composition of most species in an ecosystem, only large, multi-component, relatively complete ecosystem models such as DYNUMES II can simulate realistically marine ecosystem. The list of main consumers of different species and/or ecological groups (Table 4) demonstrates the complexity of food relations.

The subsequent discussions in this Section indicate only a few salient points of the distributions and interactions in the Bering Sea ecosystem and a few other poorly known facts about the populations in this area. However, there are several conditions and processes in the Bering Sea that must be ascertained by further field studies before the model results on these conditions can be considered fully valid. Among these problems the following are listed as examples:

-How large a part of the population of a given species remains under the ice? (Most of the fish species in the Baltic survive under the ice. However, the Baltic does not have any really cold bottom temperatures such as those occurring in the Bering Sea).

-Are the cold (subzero) bottom temperatures lethal to some species in the Bering Sea, and to what extent?

-What are the major spawning areas and times of the fish species in the Bering Sea (this information is still scant for many major species)?

-What is the biomass of some of the species which are indicated to be abundant forage fish such as capelin and smelt?

Table 4

Main consumers of various species and ecological groups in the eastern Bering Sea

Species/group of species	Consumers (minor consumers in parenthesis)
Pollock	Fur seal, sea lion, ringed/ribbon seals, harbor seals, (bearded seal, walrus); toothed whales; murres; pollock, other gadids, other flatfish, squids, yellowfin, other demersal
Herring	Sea lion, fur seal, ringed/ribbon seals, bearded seal (harbor seals); toothed whales, murres, shear-waters, other birds (baleen whales); pollock, other gadids, other demersal, squids, other pelagic
Other pelagic fish	Ringed/ribbon seals, harbor seals, sea lion, bearded seal, (fur seal); toothed whales (baleen whales); murres, other birds, (shearwaters); pollock, other gadids, other demersal, squids, other pelagic
Yellowfin	Pollock, other gadids, other demersal, other flatfish, (benthos)
Other flatfish	Bearded seal, harbor seals, ringed/ribbon seals, walrus; toothed whales; murres; pollock, other flatfish, other gadids, other demersal, yellowfin
Other gadids	Sea lion, fur seal, harbor seals, bearded seal, ringed/ribbon seals; toothed whales; pollock, other flatfish, other demersal, squids, (herring, other pelagic)
Other demersal fish	Pollock, yellowfin, other flatfish, benthos, other gadids
Squids	Harbor seals, bearded seal, ringed/ribbon seals; baleen whales; murres, shearwaters, other birds; pollock, herring, other pelagic
Benthos	Bearded seal, walrus, ringed/ribbon seals, harbor seals, yellowfin, other flatfish, other gadids, other demersal, benthos, pollock
Salmon	Sea lion, harbor seal, fur seal, bearded seal, (walrus); (toothed whales); (murres); (pollock, other gadids)

Table 4 - Cont'd.

Euphausids	Baleen whales; murres, shearwaters, other birds; herring, other pelagic, pollock, other gadids, other demersal, squids, yellowfin, (benthos)
Copepods	(Baleen whales); other birds; herring, other pelagic, pollock, other gadids, other demersal, squids, benthos.
Phytoplankton	Herring, other pelagic, benthos (as detritus)
"Others"	Fur seal, bearded seal; toothed whales; murres, other birds; herring, other flatfish, benthos

B. CONSUMPTION OF FISH BY MARINE MAMMALS AND BIRDS

The Bering Sea is a major feeding ground for whales in the North Pacific Ocean. Three species of the baleen whale are found there during the summer (Table 5), but only one species (Bowhead) remains there during the winter. Three species of the toothed whales also feed in the Bering Sea only during the summer. The conservatively estimated number of whales (Table 5) has been converted in the model into weight (Figure 11) and distributed in the area according to available information. The main food for baleen whales is euphausids; other food items, such as squids and 0 and 1 age group of mainly pelagic fish, are taken as "incidentals" during essentially "filtering" feeding process. Baleen whales consume about 1.2 million tons of euphausids (Table 6). If this amount of euphausid were consumed by fish, it would produce about 400,000 tons of fish biomass.

Toothed whales consume mainly "adult" (larger) fish and compete directly with man in the harvest of fishery resources. The total annual consumption of finfish by toothed whales is about 1.2 million tons, i.e., more than half of the total commercial catch.

The estimated numbers of pinnipeds in the eastern Bering Sea are also conservative (compare Figures 12 and 13 with data in McAlister and Perez 1976). The pinnipeds in the Bering Sea can be grouped into three groups by seasonal occurrence and migrations. Some species are associated with the ice edge and migrate to the Arctic Ocean with the retrogradation of ice to the north (e.g., bearded seal, walrus). In the behaviorally opposite group are species which migrate into the Bering Sea during the summer for feeding and spend the winter at lower latitudes (e.g., sea lion and fur seal). The third group consists of species which are found in the area year around (ringed and ribbon seals, harbor seals).

Table 5

Estimated number of whales and porpoises in the Bering Sea

Species	Average weight tons	Estimated Number Summer	Winter
Baleen whales			
Fin	50	5,000	-
Gray	40	5,000	-
Mink	9	2,000	-
Bowhead	10	2,000	2,000
Toothed whales			
Sperm	40	20,000	-
Humpback	10	300	-
Giant bottlenose	10	2,000	-
Killer	12	800	800
Beluga	3	2,000	2,000
Porpoises	0.1	5,000	5,000

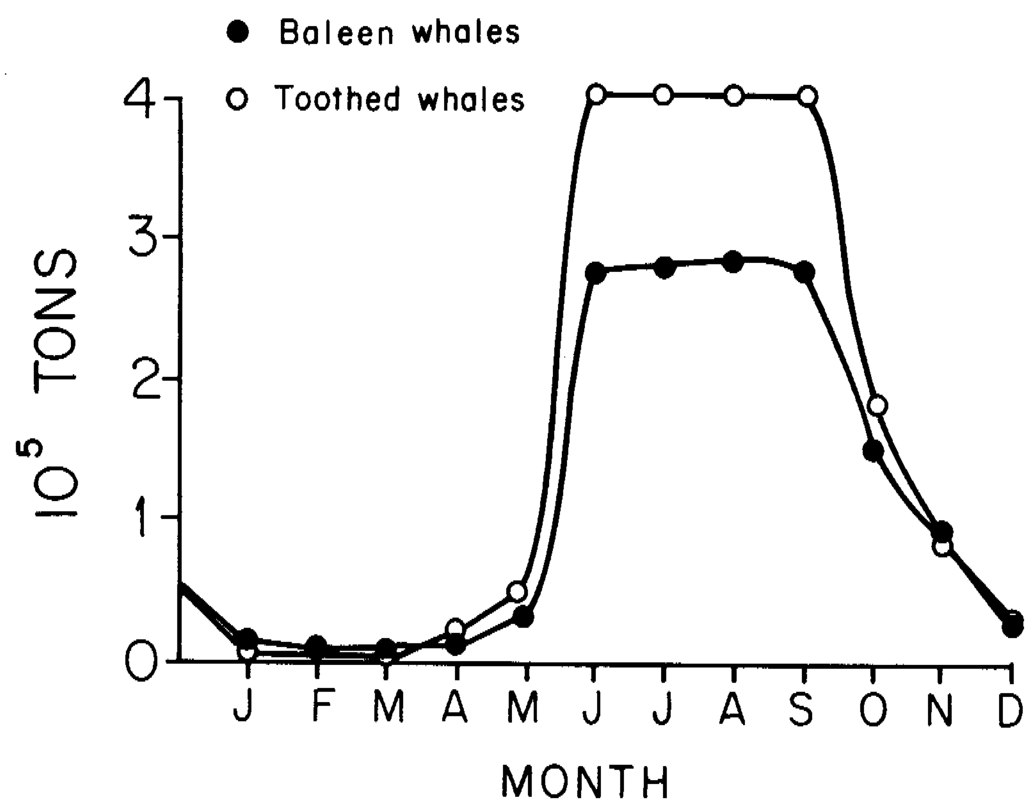

Figure 11. Estimated amounts of whales (including dolphins and porpoises) in the Bering Sea.

Table 6 .--Annual consumption by marine birds and mammals in the eastern Bering Sea (in 10^3 tons).

Species/group of species	Herring	Other pelagic	Salmon	Pollock	Other gadids	Flatfish	Total finfish	Zooplankton	Squids	Benthos	"Others" (Unspecified)
	Species/group of species consumed										
Marine birds	11.7	40.3	1.5	26.3	+	1.9	81.7	105.2	13.2	2.8	14.3
Fur seal	26.5	8.8	8.8	322.3	22.1	-	388.5	-	44.2	-	8.8
Sea lion	16.8	11.2	22.4	182.2	19.6	-	252.2	-	+	-	+
Bearded seal	25.0	25.0	8.3	83.5	41.7	41.7	225.2	-	66.8	509.2	33.4
Harbor seal	66.9	31.2	6.7	89.2	13.4	8.9	216.3	-	89.2	104.8	13.4
Ringed/ribbon seal	24.2	47.5	3.0	84.7	30.3	-	189.7	-	30.3	+	9.1
Walrus	+	+	1.6	6.6	+	4.9	13.1	-	+	311.4	3.3
Total pinnipeds	159.4	123.7	50.8	768.5	127.1	55.5	1,285.0	-	230.5	925.4	68.0
Baleen whales	20.7	27.7	-	13.8	6.9	-	69.1	1,189.3	124.5	-	+
Toothed whales	231.5	408.5	0.5	340.4	68.1	68.1	1,117.1	-	-	-	245.1
Total, whales, porpoises, dolphins	252.2	436.2	0.5	354.2	74.0	68.1	1,186.2	1,189.3	124.5	-	245.1
Total by birds and mammals	423.3	600.2	52.8	1,149.0	201.1	125.5	2,552.9	1,294.5	479.5	928.2	327.4

The general composition of food consumed by the pinnipeds permits grouping them into two categories: those species feeding mainly on benthos (e.g., walrus, bearded seals) and those who feed mainly on fish (e.g., fur seals). The latter are feeding mainly on larger fish and consume at least 1.3 million tons; a quantity comparable to that taken by man. Pollock is the main food for some species (Figures 14 and 15), and it is also the dominant fish species in the Bering Sea. However, there is considerable consumption of the most valuable fish in the area--salmon--during the summer months when salmon return to the rivers for spawning (Figure 16). The model computations show that 50,000 tons of salmon are consumed by pinnipeds (Table 6).

The estimated number of marine birds in the Bering Sea considered in our model is also conservative (compare Figure 17 with data in Sanger and Baird 1977). During the winter months the birds are feeding mainly in the ice free southern part of the area (Figure 18), whereas during the summer they penetrate further north, some species remaining nearer to the coast (e.g., murres, Figure 19), others feeding offshore all over the Bering Sea (e.g., shearwaters which breed in the southern hemisphere during the northern winter and feed in the Bering Sea during the summer).

Although the main food item for birds is euphausids, they consume at least 82,000 tons of fish, mainly small pelagic fish and 0 and 1 year classes of semipelagic species (Table 6). It should be noted that, besides the conservative number of birds, the food coefficient used for birds is also low (12% of body weight daily instead of the conventionally estimated 20%, Wiens and Scott 1975).

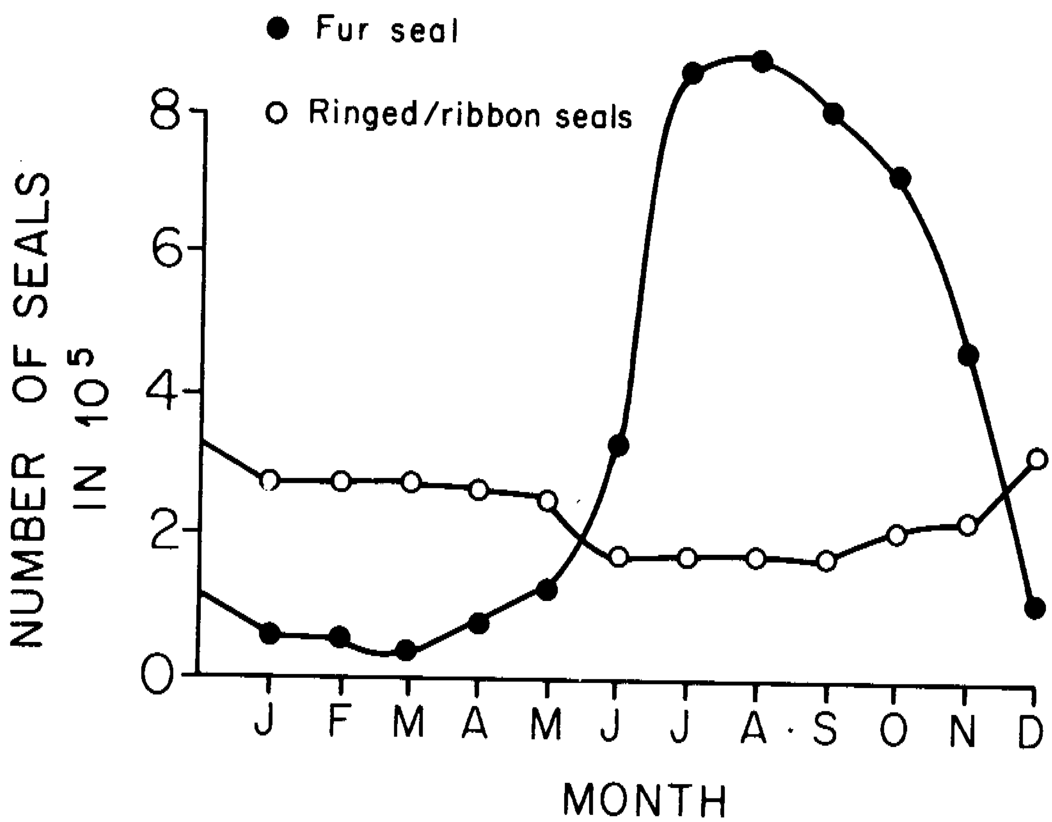

Figure 12. Estimated monthly numbers of fur seals and ringed/ribbon seals in the eastern Bering Sea.

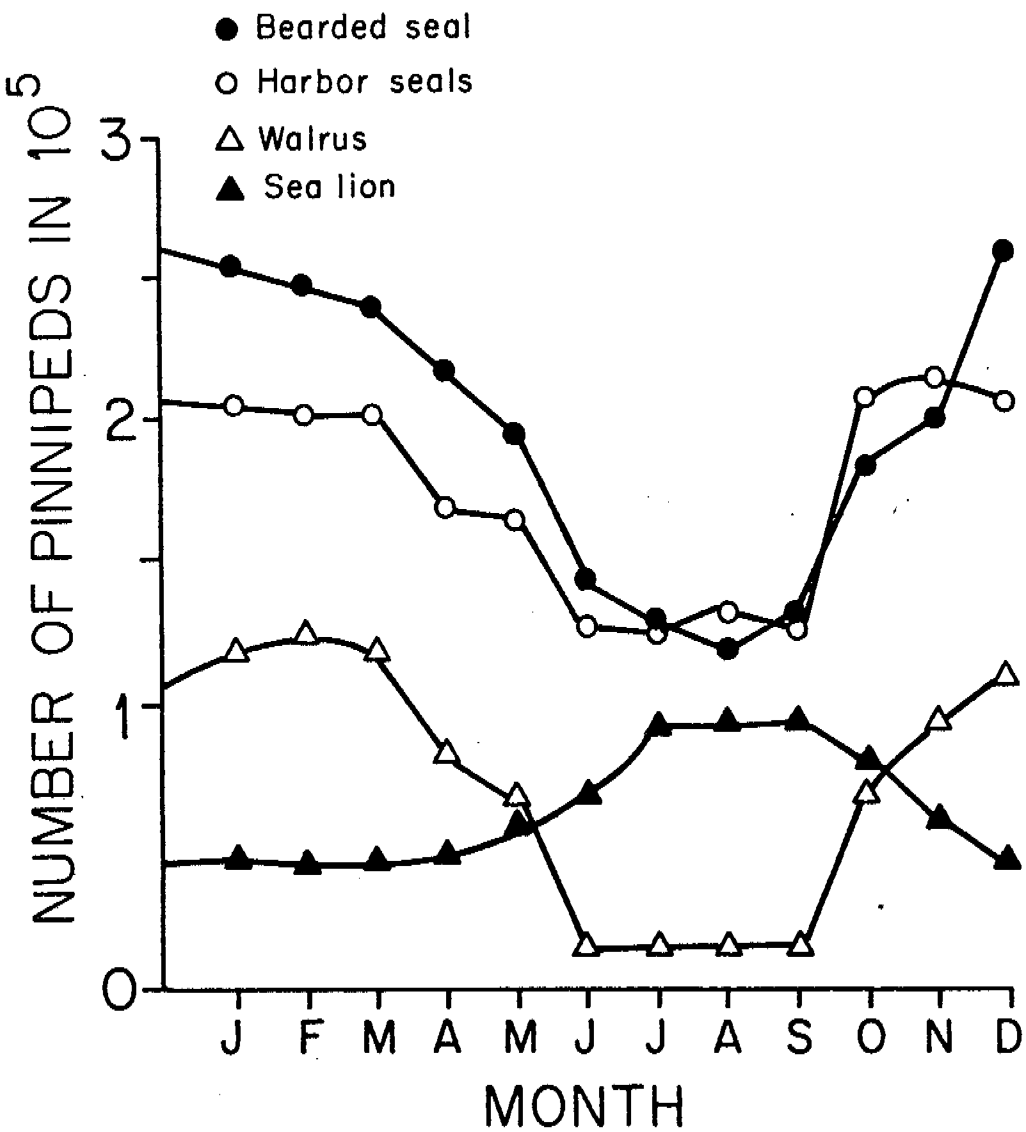

Figure 13. Estimated monthly numbers of bearded seals, harbor seals, walrus and sea lions in the eastern Bering Sea.

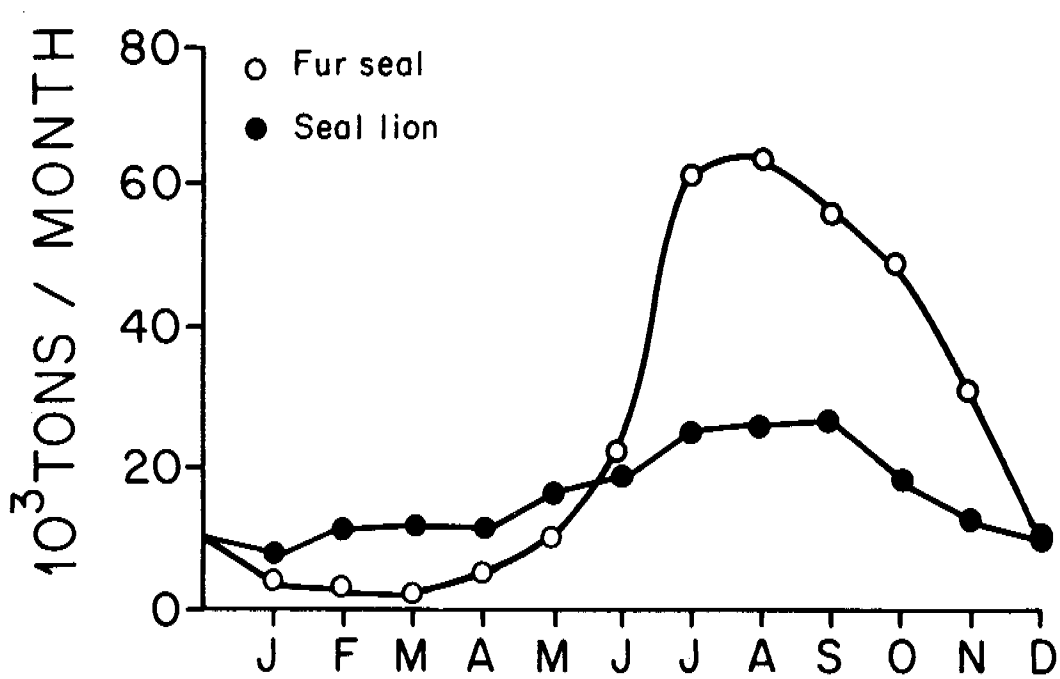

Figure 14. Consumption of pollock by fur seals and sea lions in the eastern Bering Sea.

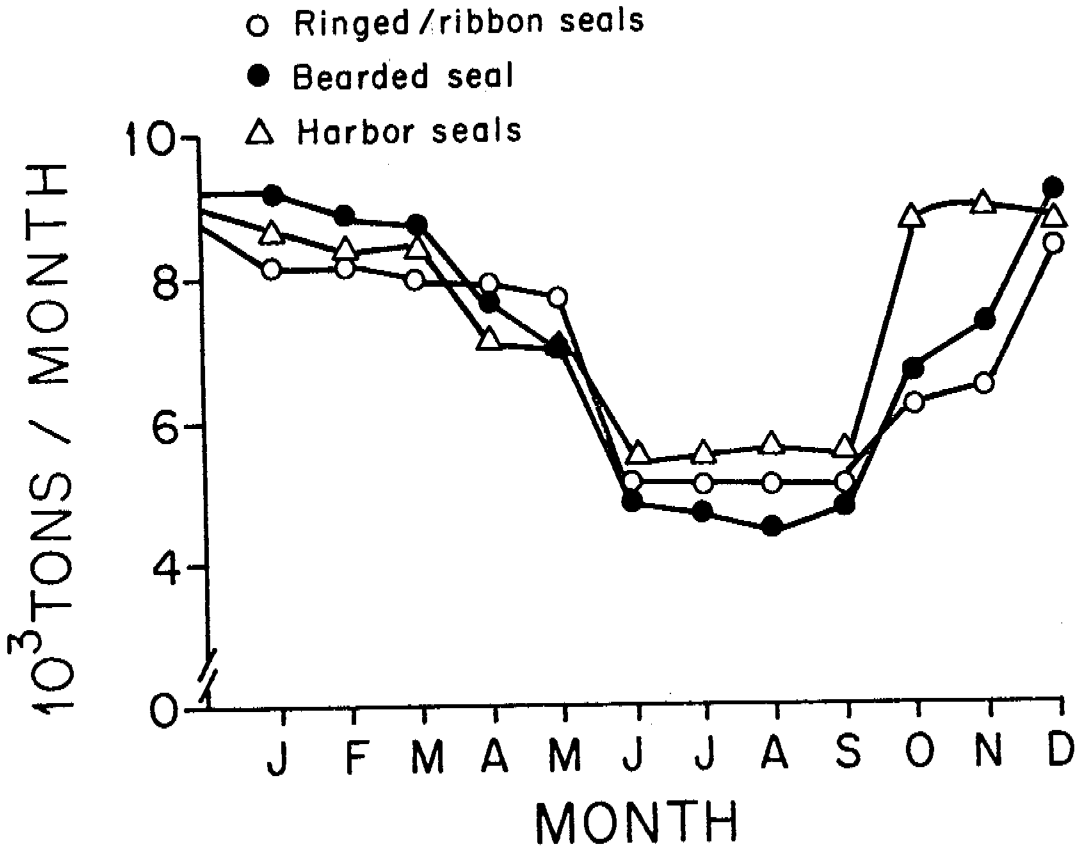

Figure 15. Consumption of pollock by bearded seals, harbor seals, and ringed/ribbon seals in the eastern Bering Sea.

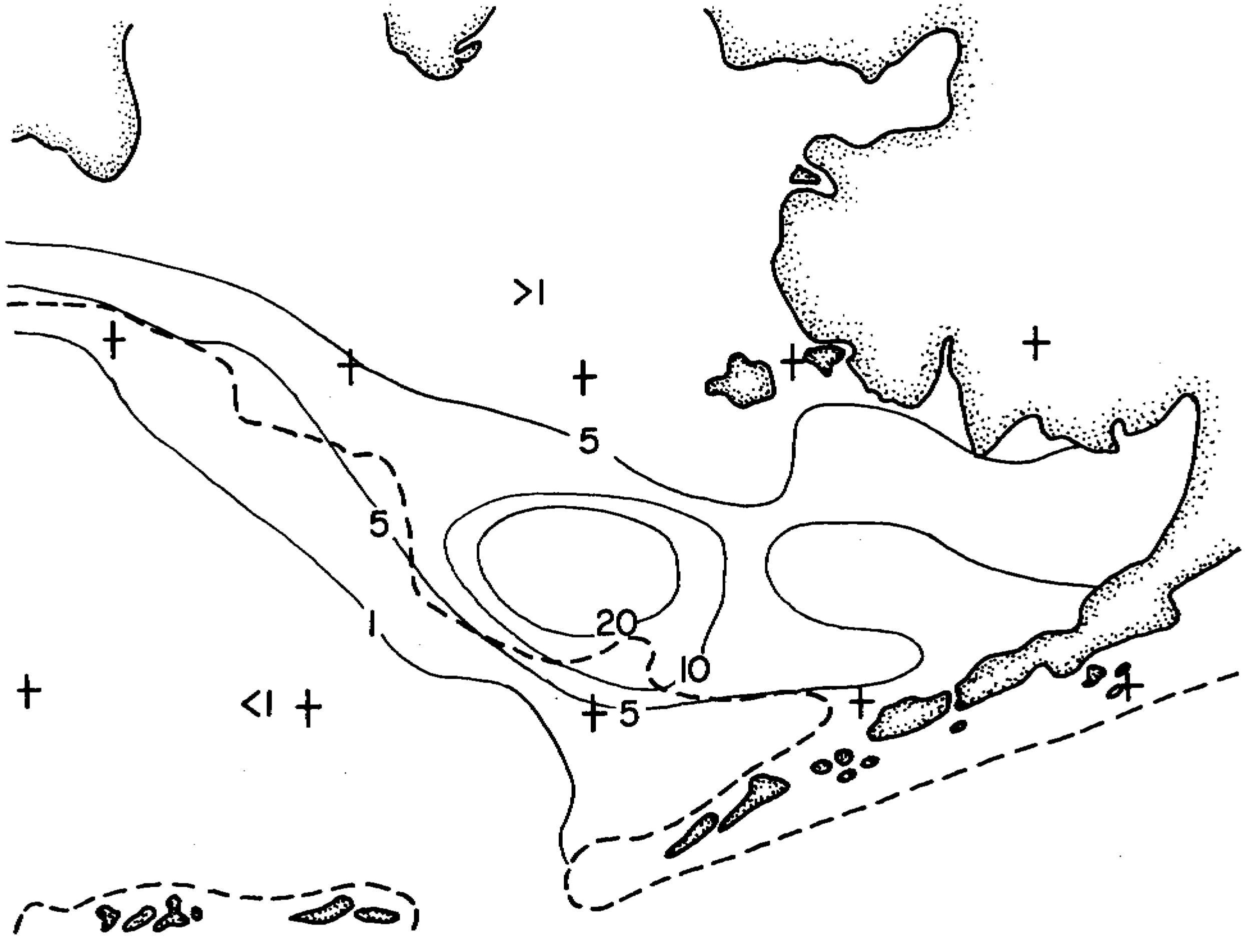

Figure 16. Consumption of salmon in August (tons/km^2).

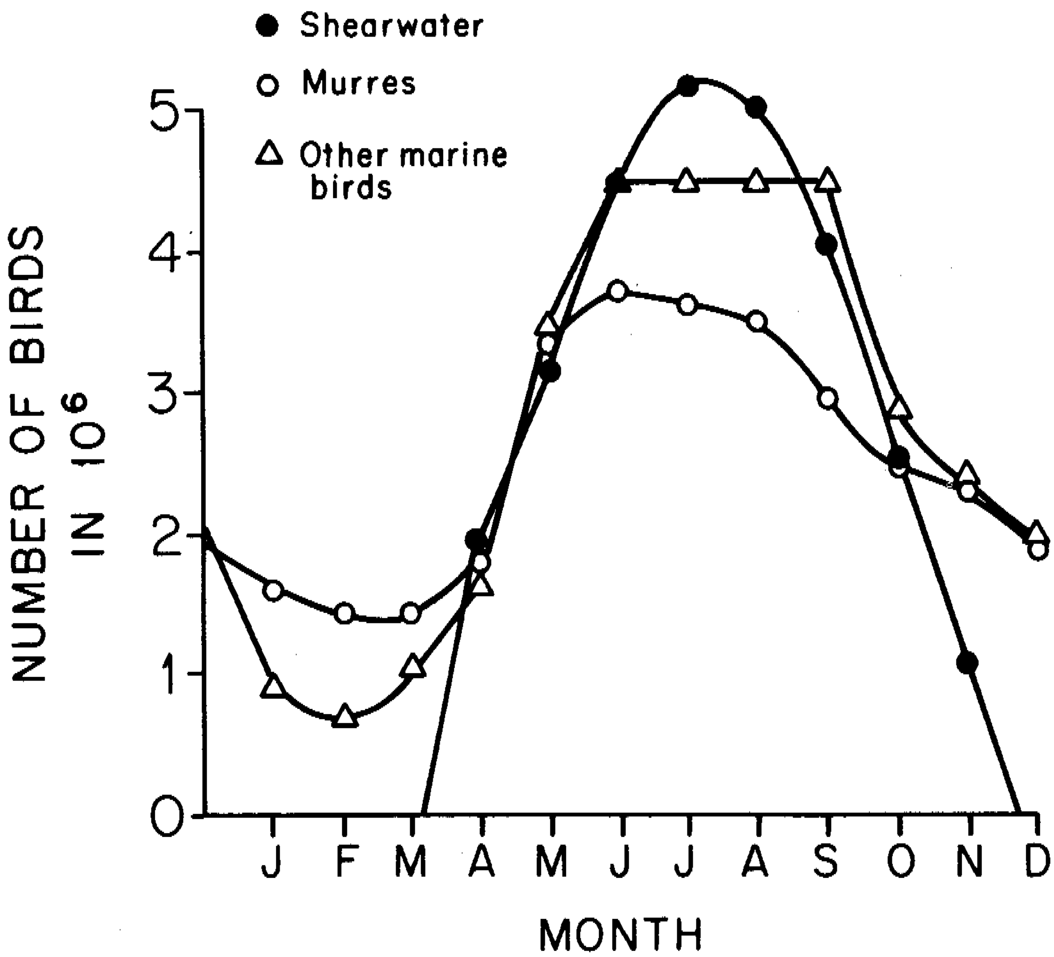

Figure 17. Estimated monthly numbers of adult marine birds in the eastern Bering Sea.

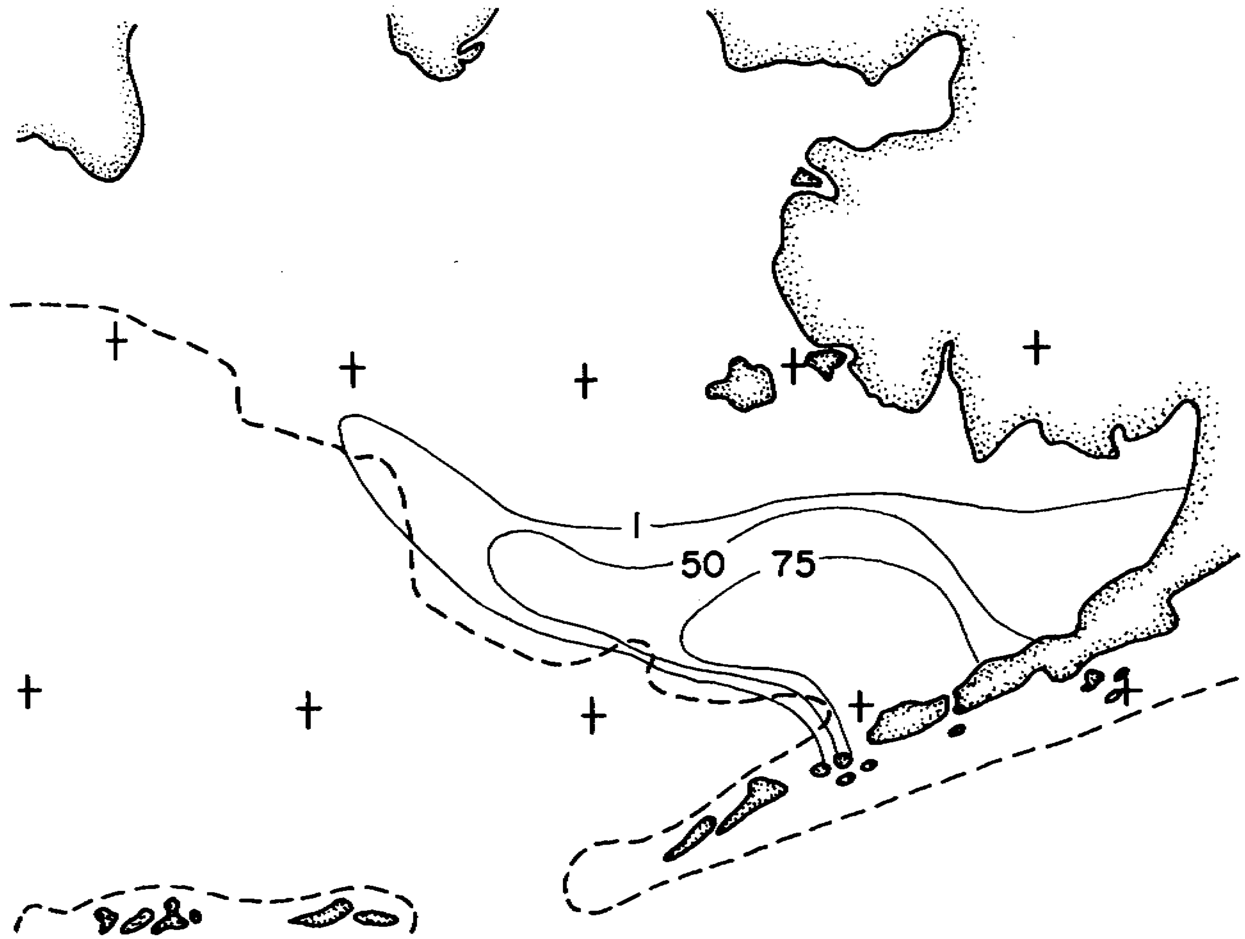

Figure 18. Distribution of murres in February (in thousands per $10^4 km^2$).

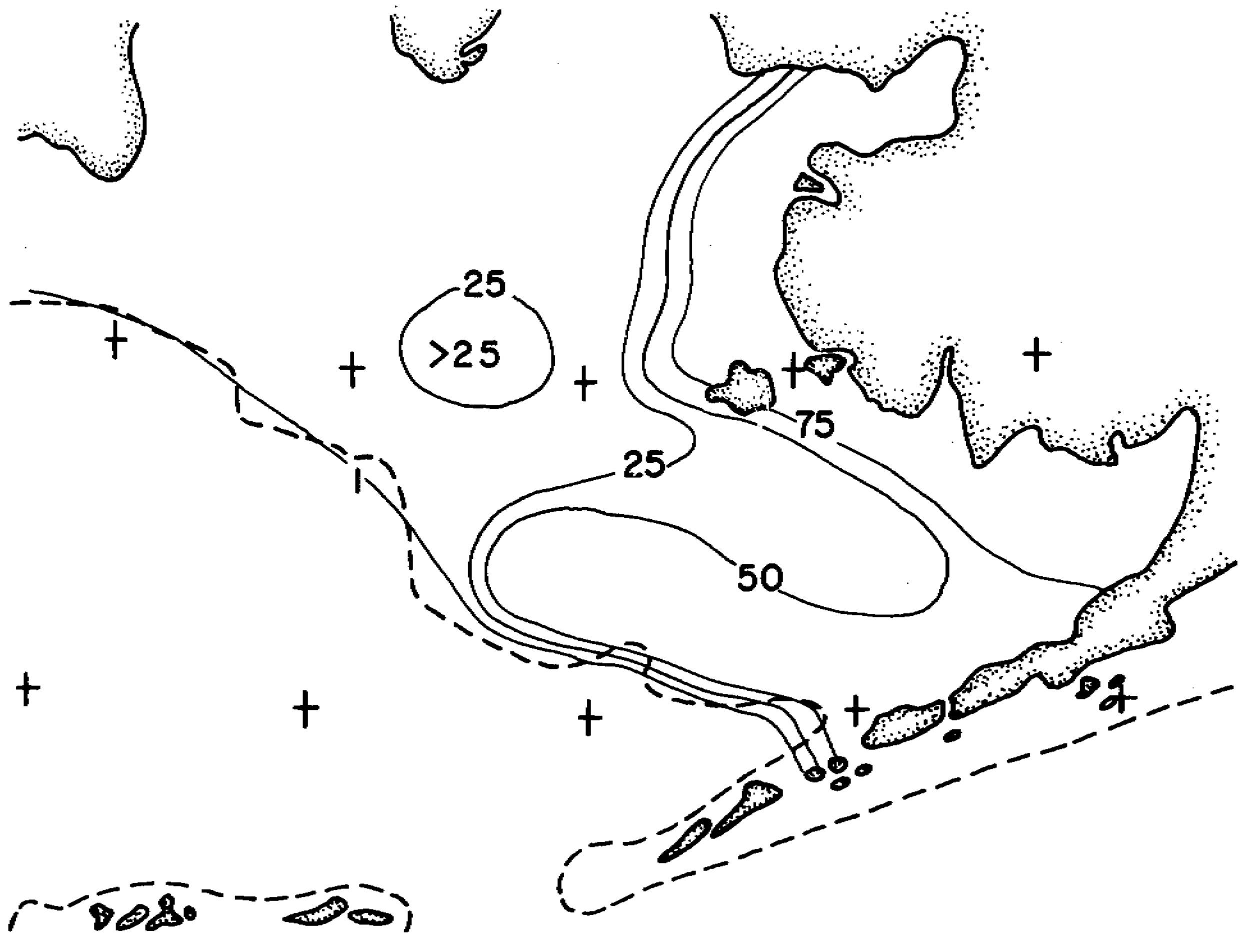

Figure 19. Distribution of murres in August (in thousands per $10^4 km^2$).

C. DISTRIBUTION, ABUNDANCE, AND DYNAMICS OF PELAGIC FISH

Pelagic fish (e.g., herring, capelin, other smelts) form an important food source (forage fish) for other fish species and mammals in the Bering Sea, as results of stomach analyses indicate. Only the herring has been subject to exploitation by man, primarily by Japanese and Soviet trawlers near the continental slope in the winter, and a subsistence fishery by native villagers near the coast during the summer. Research on pelagic species in the Bering Sea has been minimal, however, the recent surveys of coastal spawning of herring, capelin, and other smelts (Barton, Warner and Shafford 1977) show that the occurrence of spawning schools of these species is much more extensive that previously assumed.

The ecosystem model requires the presence of considerable quantities of pelagic fish in the eastern Bering Sea, dictated mainly by the food composition of predators. The herring has been considered separately and other smaller pelagic fish have been lumped into one ecological group--other pelagic fish. The model biomass requirements are 3.26 million tons for herring and 6.87 million tons for other pelagic fish (Table 7). The consumption of these species requires also that they be relatively widely distributed over the area (Figures 20 and 21). This requirement is in good agreement with a reasonable behavioral pattern of the principal species of pelagic fish, which must be dispersed during feeding during a large part of the year in order to be able to satisfy food requirements from the rather uniformly distributed zooplankton. The pelagic fish component is programmed to school near the continental slope, to move towards the coast during spring and early summer, and to disperse over the eastern Bering Sea during summer. The bulk of the pelagic fish biomass will move seaward towards the continental slope during autumn and early winter (Figure 22).

Table 7

Biomass, annual consumption, annual turnover rate, and relative monthly consumption of different species and/or ecological groups in the eastern Bering Sea.

Species/ecological group	Mean biomass (B) 10^3 tons	Annual consumption 10^3 tons	Annual turnover rate $T = \frac{C}{B}$	% of biomass consumed per month
Pollock	8,235	5,820	0.7	5.8
Herring	3,260	2,970	0.9	7.7
Other pelagic fish	6,870	6,595	1.0	8.7
Yellowfin sole	1,475	866	0.6	4.9
Other flatfish	2,030	1,630	0.8	6.7
Other gadids	2,840	2,680	0.9	8.1
Other demersal fish	2,550	2,790	1.1	9.0
Total finfish	27,260	23,350	0.86	
Squids	4,050	3,020	0.75	6.4
Benthos	25,600	19,730	0.77	6.3
Zooplankton		83,970		
Phytoplankton		(52,500)		

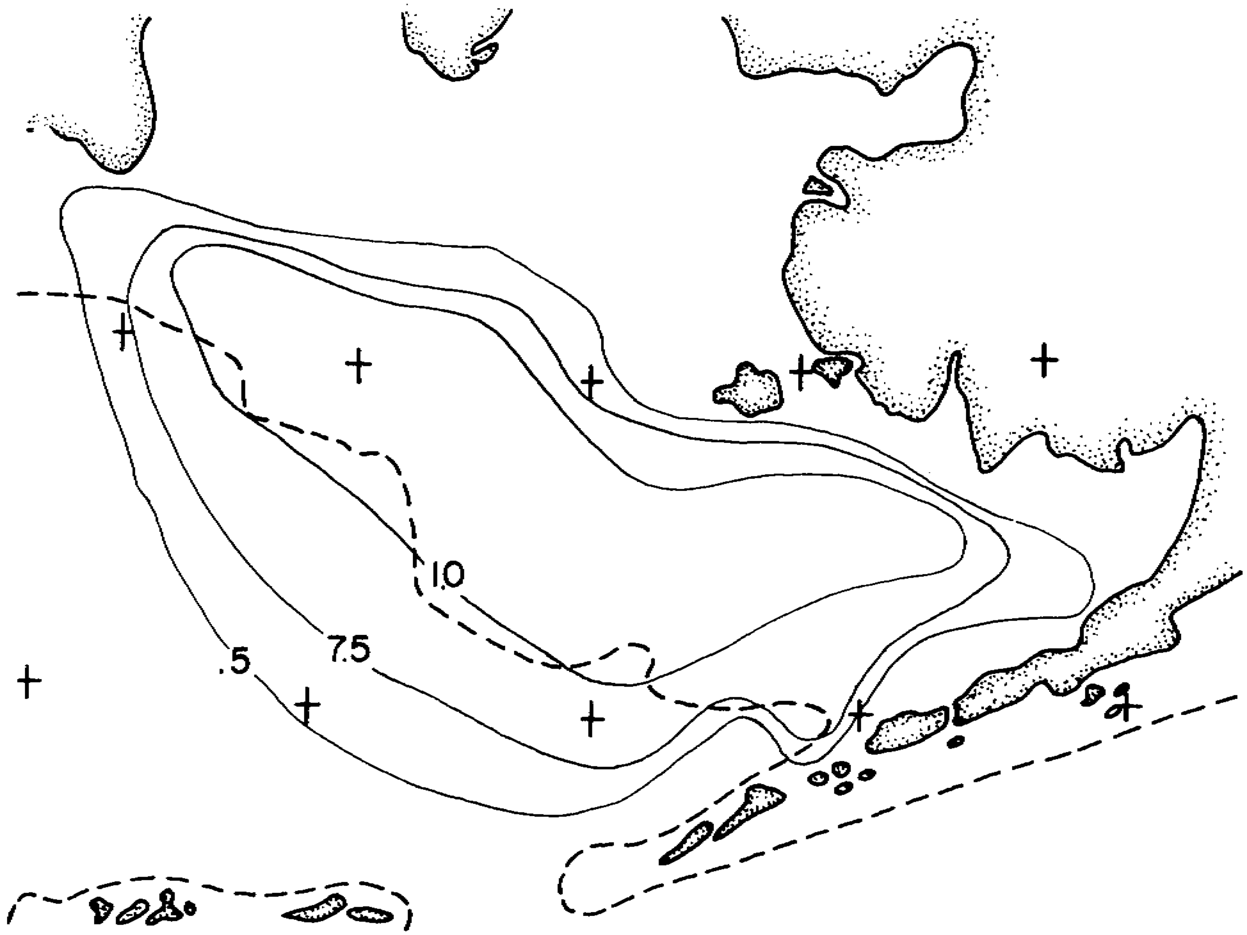

Figure 20. Consumption of herring in August in the eastern Bering Sea (tons/km^2).

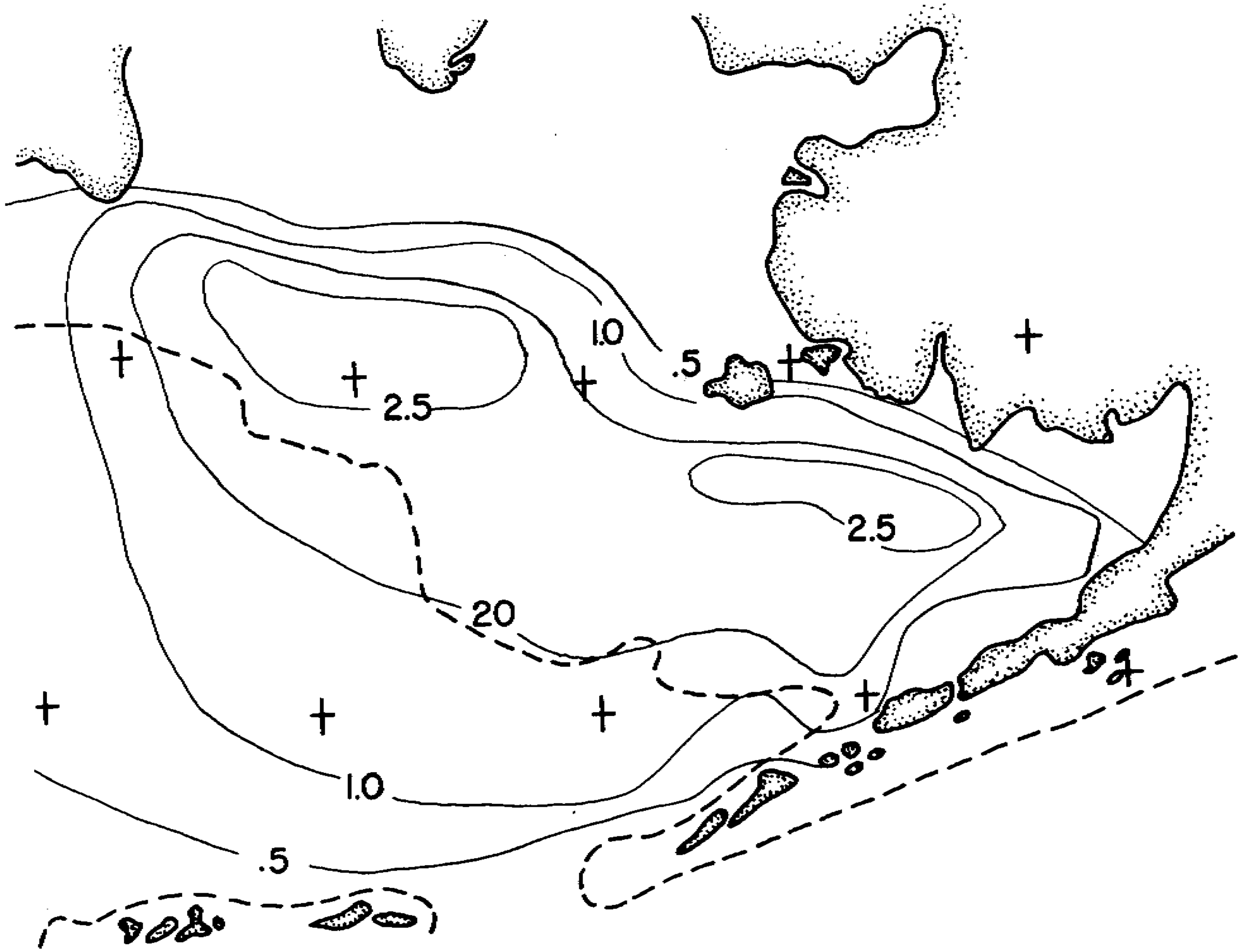

Figure 21. Consumption of other pelagic fish in August in the eastern Bering Sea (tons/km^2).

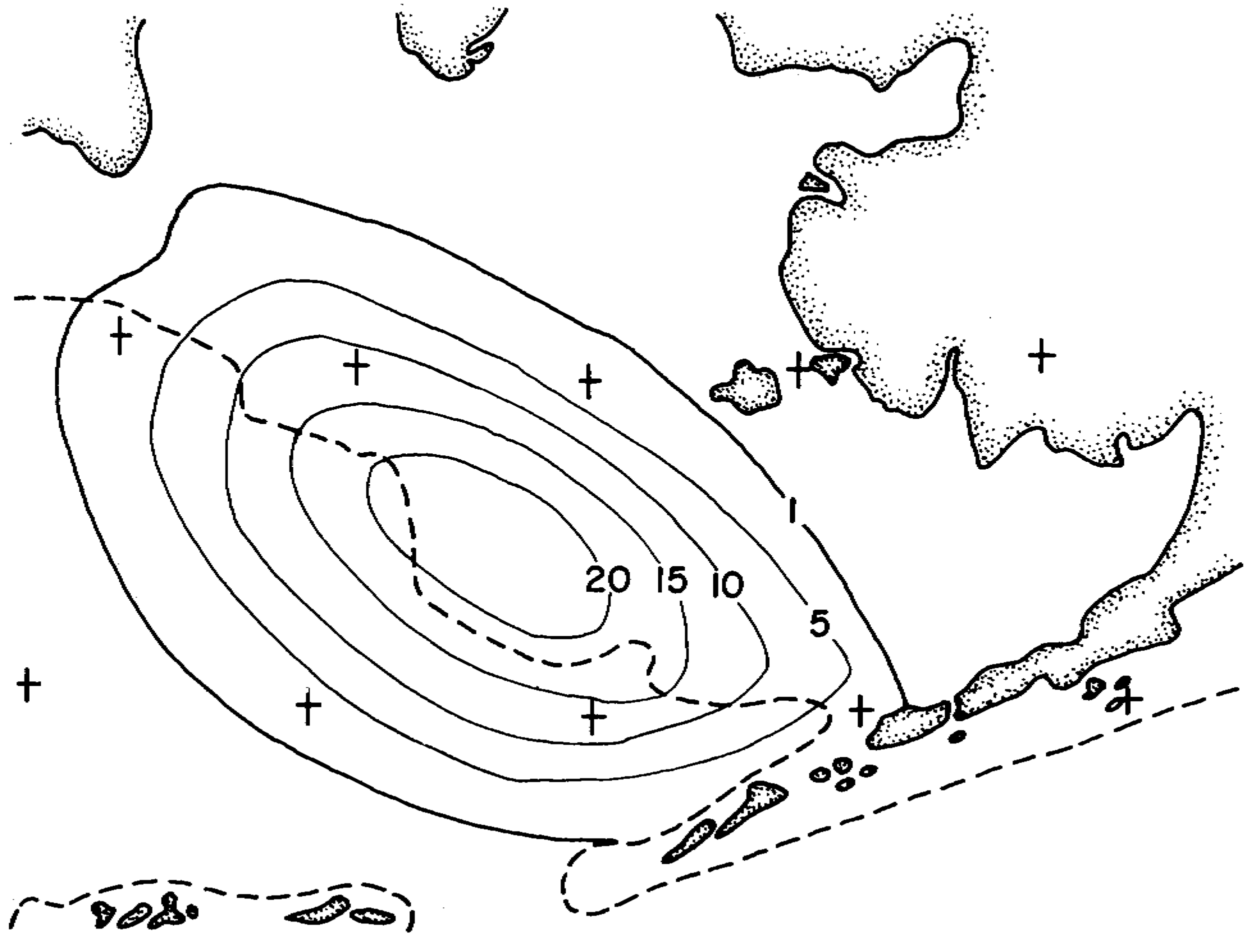

Figure 22. Distribution of herring in November (tons/km^2).

Some aspects of the herring and pollock populations interactions were studied with an earlier model (Laevastu and Favorite 1976c), and more detailed studies on the total ecosystem interactions and environmental effects on the pelagic fish populations will be conducted using DYNUMES III. The present model computes only the consumption of salmon, but a separate salmon migration model is being programmed at NWAFC.

D. DISTRIBUTION, ABUNDANCE, AND DYNAMICS OF SEMIDEMERSAL FISH

Semidemersal fish (generally gadids) are computed in four separate groups: pollock, in three size (age) groups, and other gadids. Pollock dynamics have been a subject of a special study, described in another report (Laevastu and Favorite 1976c). The ecological group referred to as other gadids consists of Pacific cod (mainly in the central and southern part of the area), polar or Arctic cod, and Saffron cod (in the northern part of the area), and longfin cod and black cod or sablefish on the continental slope and over deep water. Detailed distributions, migrations, and spawning areas of several of these species are not yet well known, therefore, the distribution of this group is relatively approximate (Figure 23) and no seasonal migrations were prescribed. The model requires a 2.84 million tons biomass of other gadids in the eastern Bering Sea. The initial distribution is modified by model computations particularly in the Pribilof Island area (Figure 24) because of increased consumption by pinnipeds during the summer months (Figure 25).

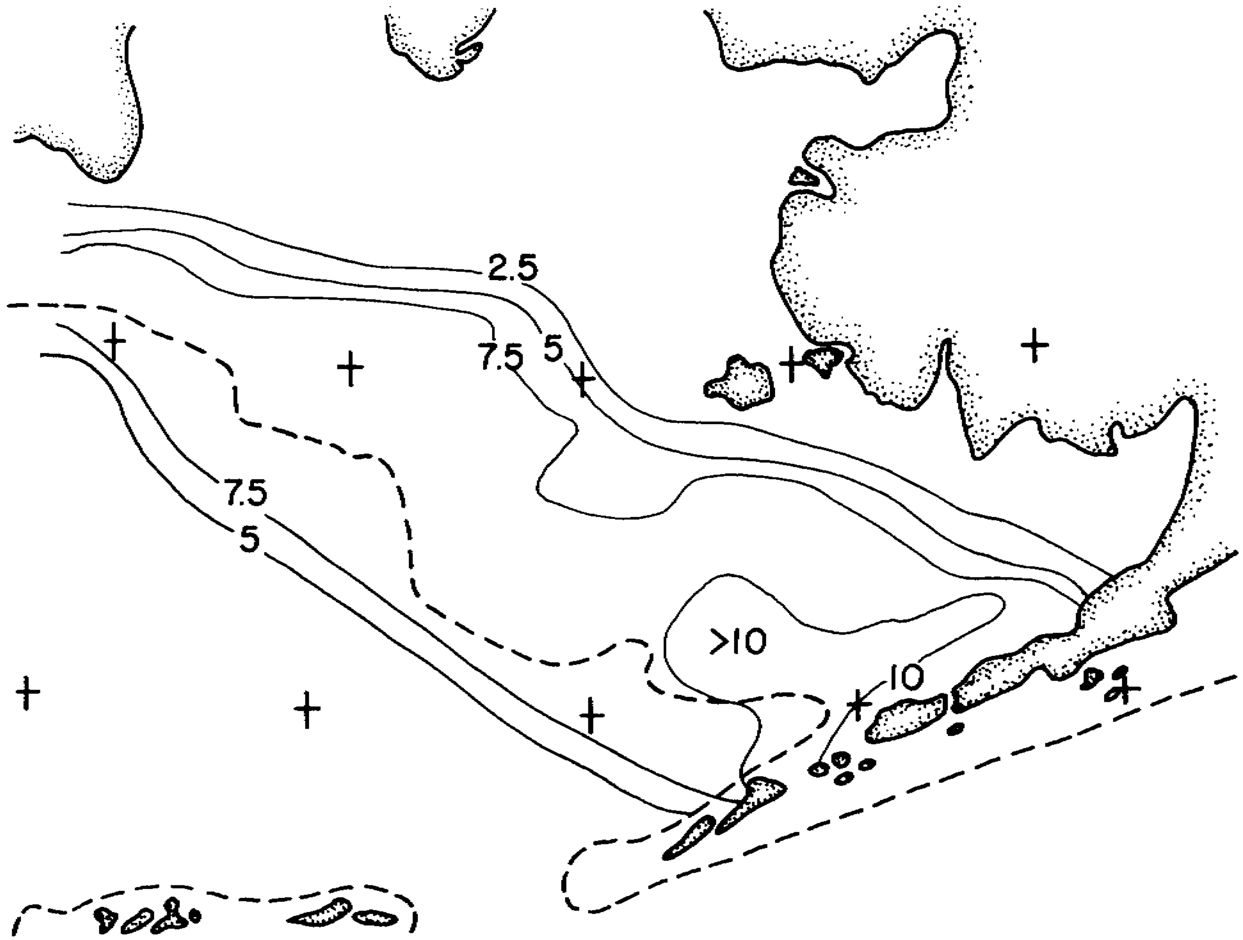

Figure 23. Distribution of other gadids in February (tons/km^2).

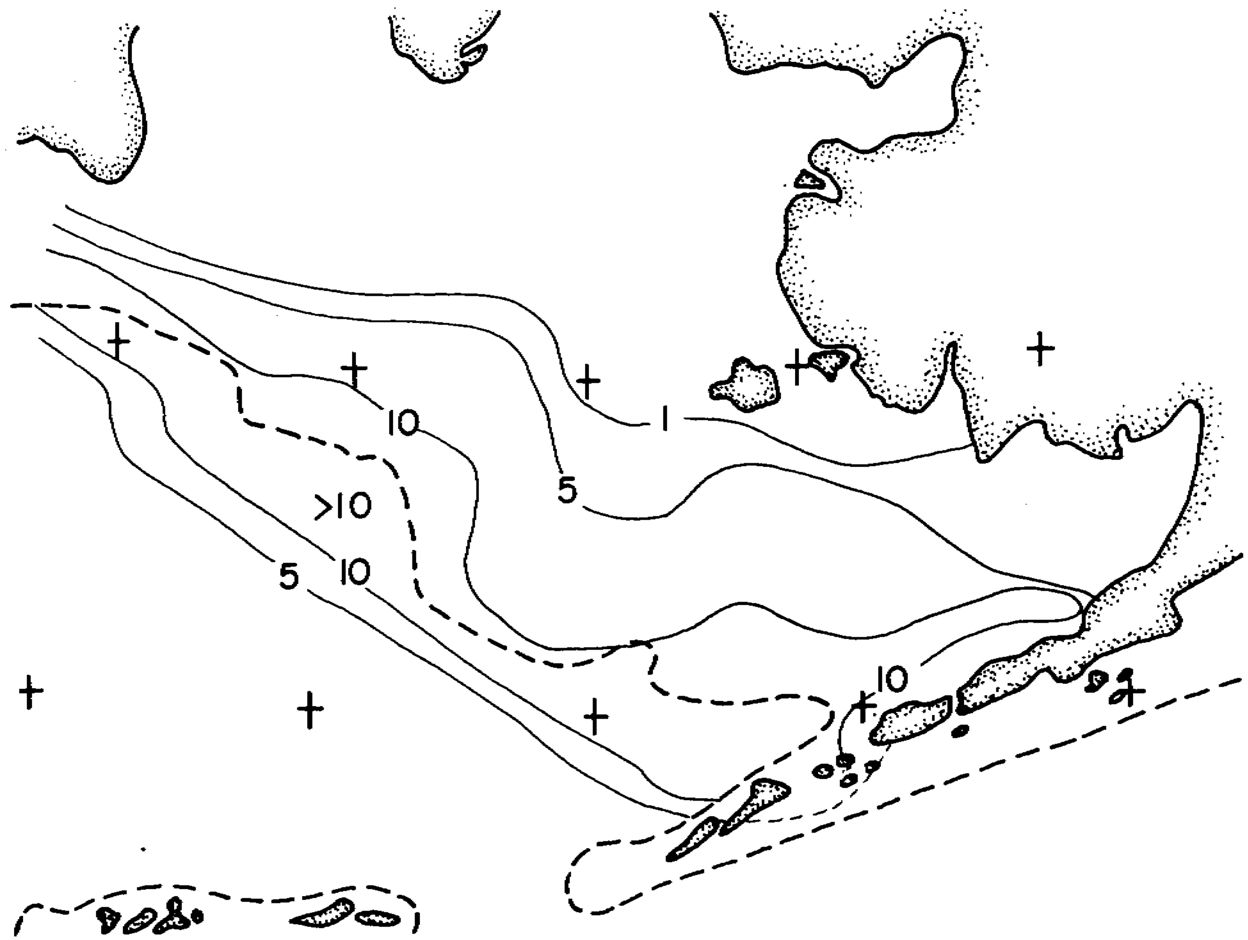

Figure 24. Distribution of other gadids in August (tons/km^2).

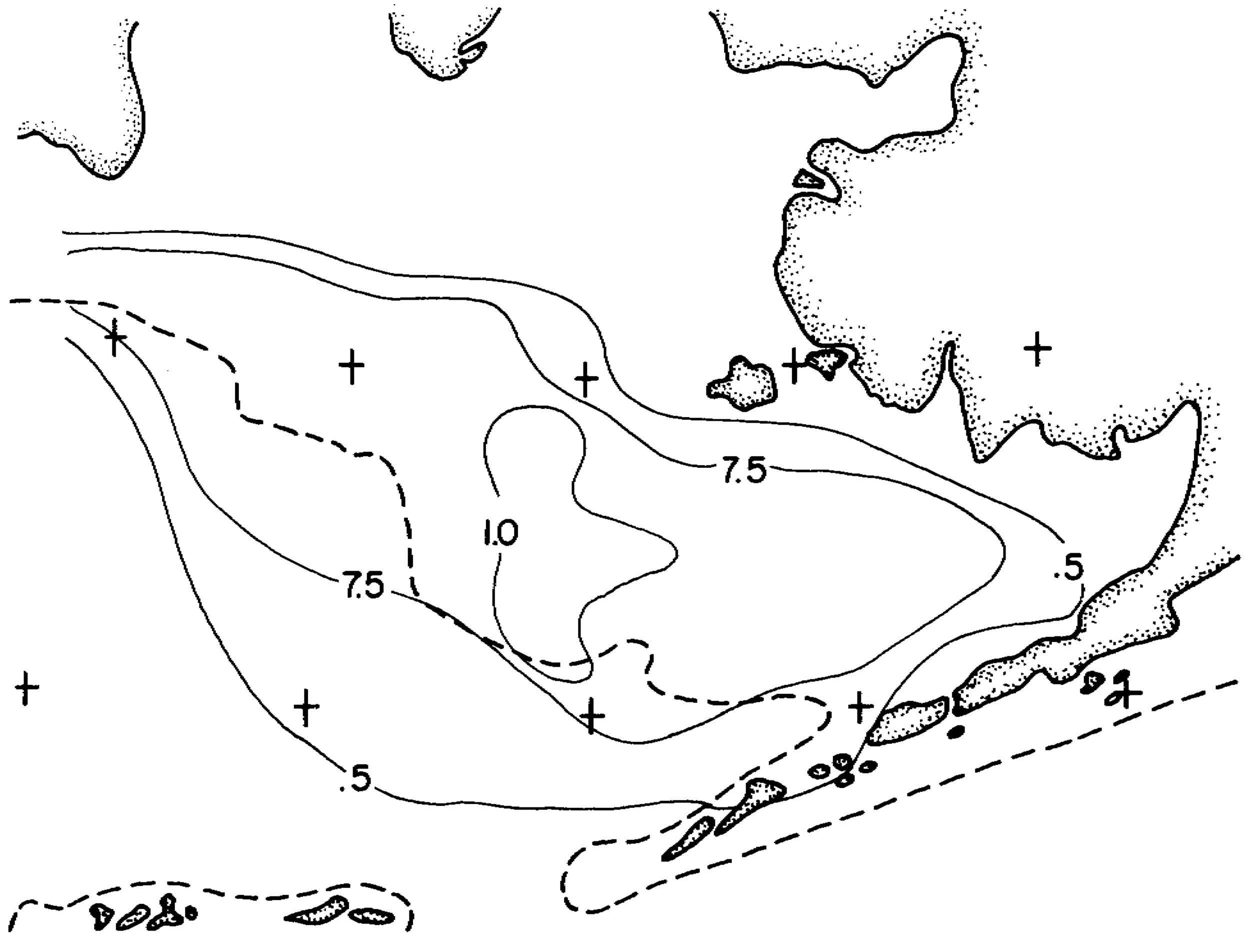

Figure 25. Consumption of other gadids in August (tons/km^2).

The semidemersal fish are the dominant group in the eastern Bering Sea. This is largely due to their ability to utilize both benthic and pelagic food, and the extensive cannibalism in the larger and older groups. Because of their flexible and voracious feeding habits, the semdemersal species grow fast in their juvenile years, with the exception of polar and saffron cods which live in cold environments where metabolic rates are suppressed.

The biomass of pollock, the most abundant species in the eastern Bering Sea (8.24 million tons), is computed in the model with time and space variable fishing intensity coefficients. The fishery is largely concentrated near the continental slope (e.g., see Figure 26).

E. DISTRIBUTION, ABUNDANCE, AND DYNAMICS OF DEMERSAL FISH

The demersal species are divided into three groups: yellowfin sole, which is the dominant flatfish species in the area (initial biomass ca 1.48 million tons, Table 7); other flatfishes (13 other species of family Pleuronectidae, such as arrowtooth flounder, Alaska plaice, and rock sole, and one species of family Bothidae, the lefteye flounder--initial biomass ca 2.03 million tons); and, other demersal fish (initial biomass 2.55 million tons), a group which consists mainly of sculpins and eelpouts. Rockfishes and rattails have also been included into this group as a minor constituent.

There are four basic characteristics common to demersal species and/or groups of species: 1) they spend most of their lives on or in close proximity of the bottom, having thus essentially a two-dimensional living space, and are mostly affected by the cold, subzero temperatures which occur over large areas of the continental shelf in the Bering Sea during winter and spring;

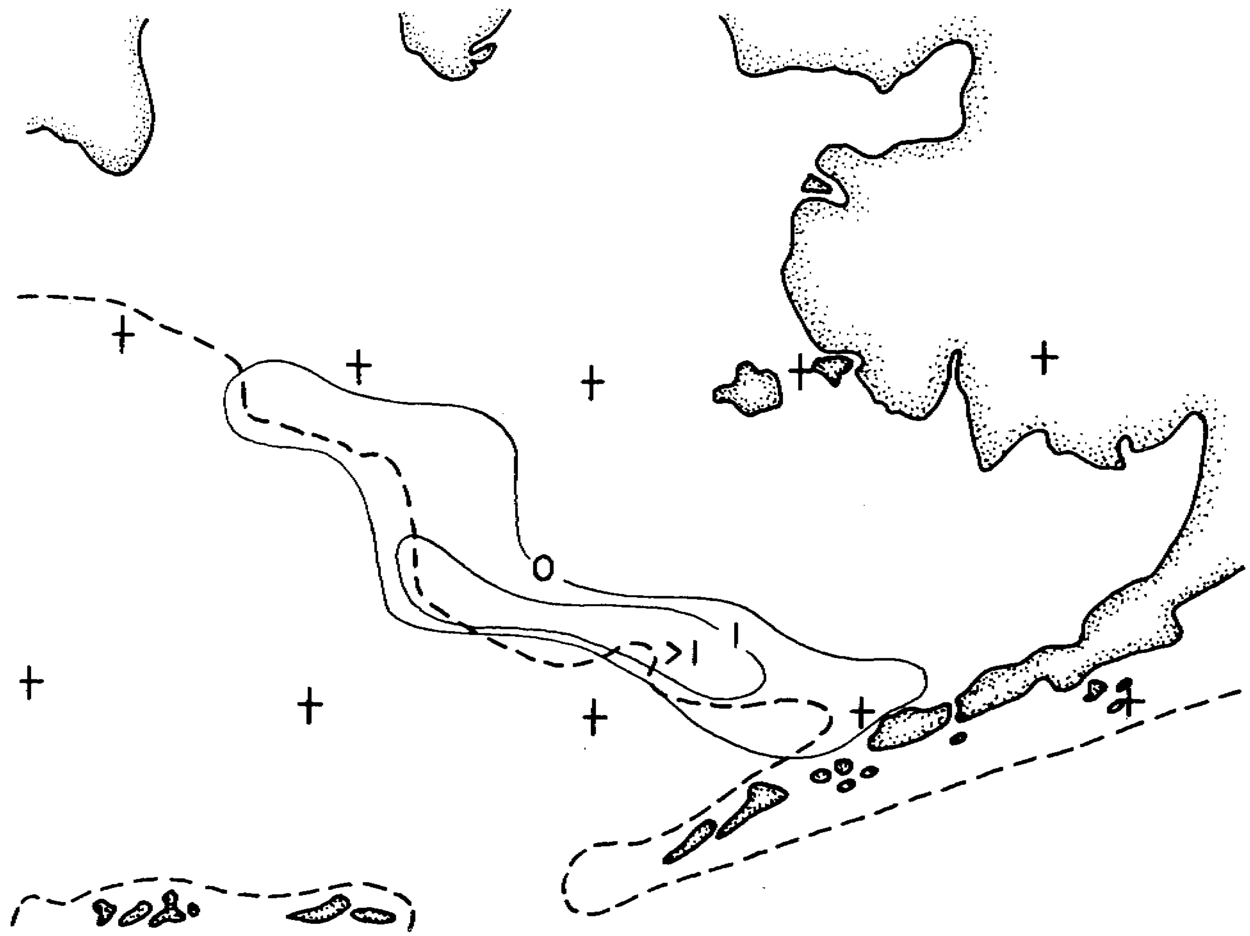

Figure 26. Pollock catches in February (tons/km^2).

2) their food consists mainly of benthos, although some species undertake short feeding migrations into the water mass; 3) seasonal migrations to considerable depth occur in most species; 4) most species are slow growing, thus being available a longer period for ecosystem internal consumption than faster growing species.

The yellowfin sole concentrations are found near the continental slope during the winter (Figure 27) and they migrate towards shallower water during the summer (Figure 28), when the cold bottom waters have warmed. Other flatfishes cover the central and southern part of the continental shelf (Figure 29); their seasonal migrations are not well known as yet and have been suppressed in the model (Figure 30). No seasonal migrations have been prescribed to the group, other demersal fish, either (Figure 31); however, this group is more abundant in the areas where other flatfish abundances are somewhat lower (compare Figures 30 and 31), and is a major ecosystem internal food source (Figure 32).

F. CONSUMPTION OF PLANKTON

In an earlier study with the model Laevastu, Dunn, and Favorite (1976) concluded that the past quantitative studies of zooplankton are deficient in reporting the standing stocks of zooplankton, especially euphausids. Furthermore, the same study indicated that the areas of high zooplankton consumption change seasonally due to seasonal migrations of the consumers (predation). In addition the abovementioned study suggested that starvation might be rather widespread in the sea. The latter aspect will be studied in greater detail with DYNUMES III.

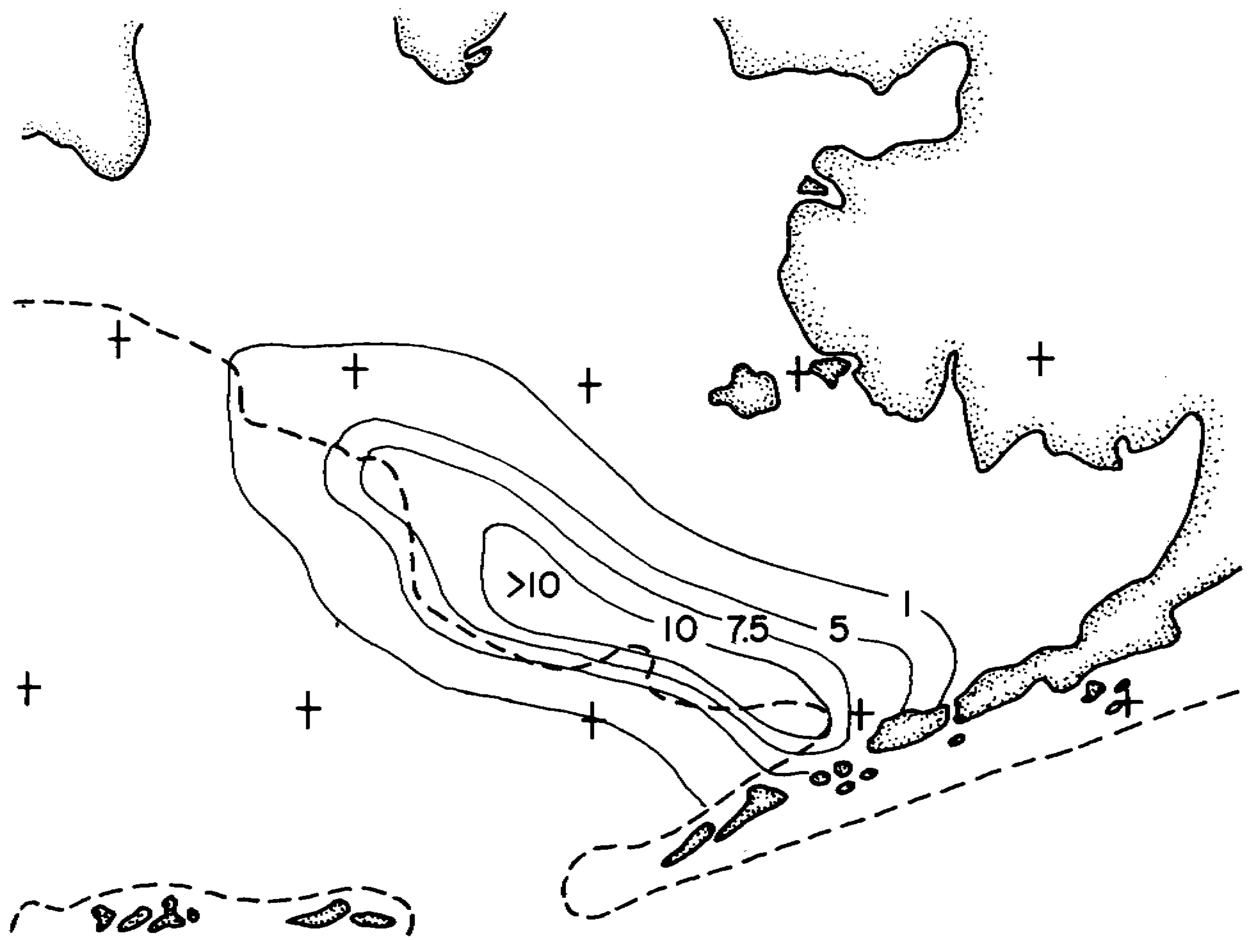

Figure 27. Distribution of yellowfin sole in February (tons/km^2).

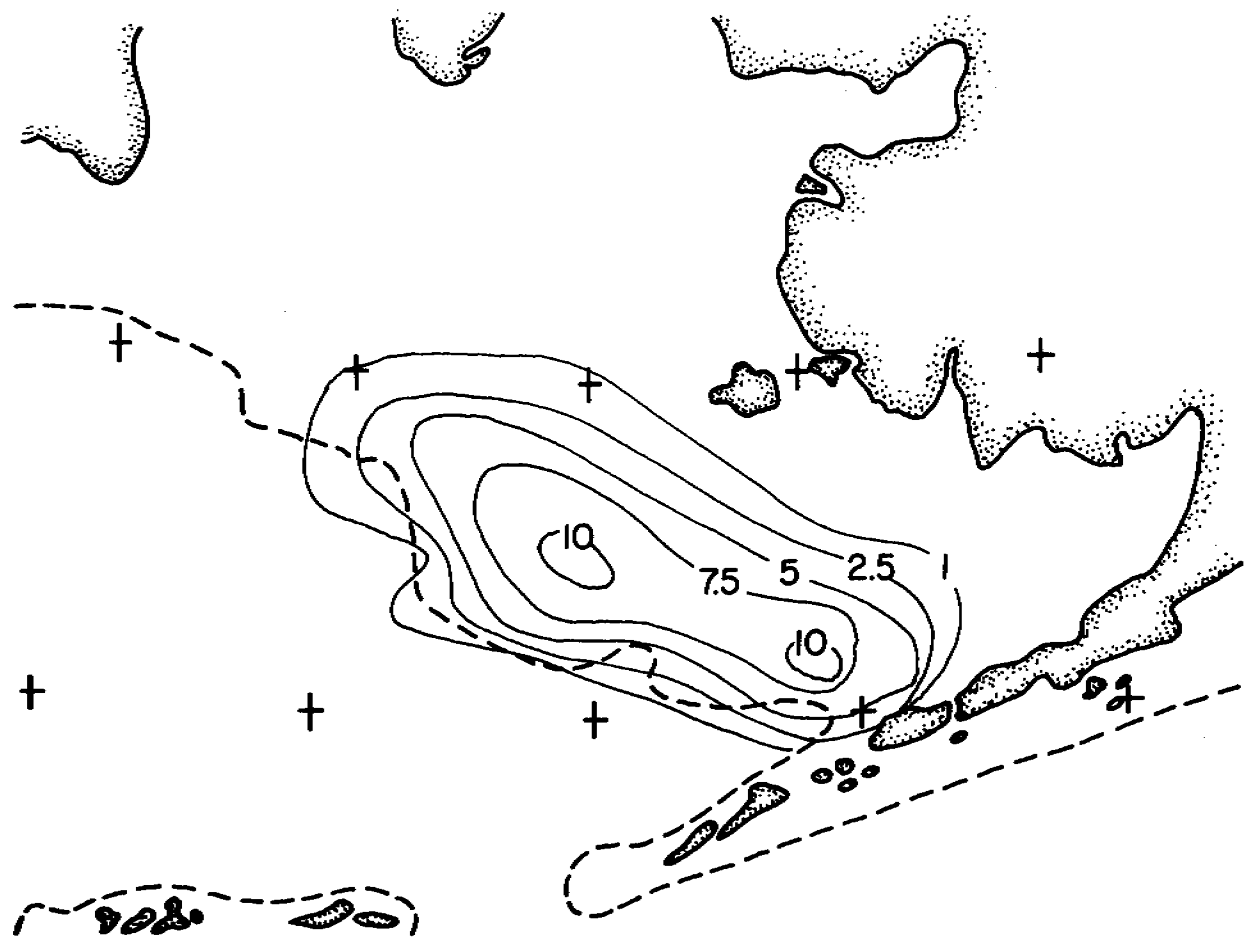

Figure 28. Distribution of yellowfin sole in August (tons/km^2).

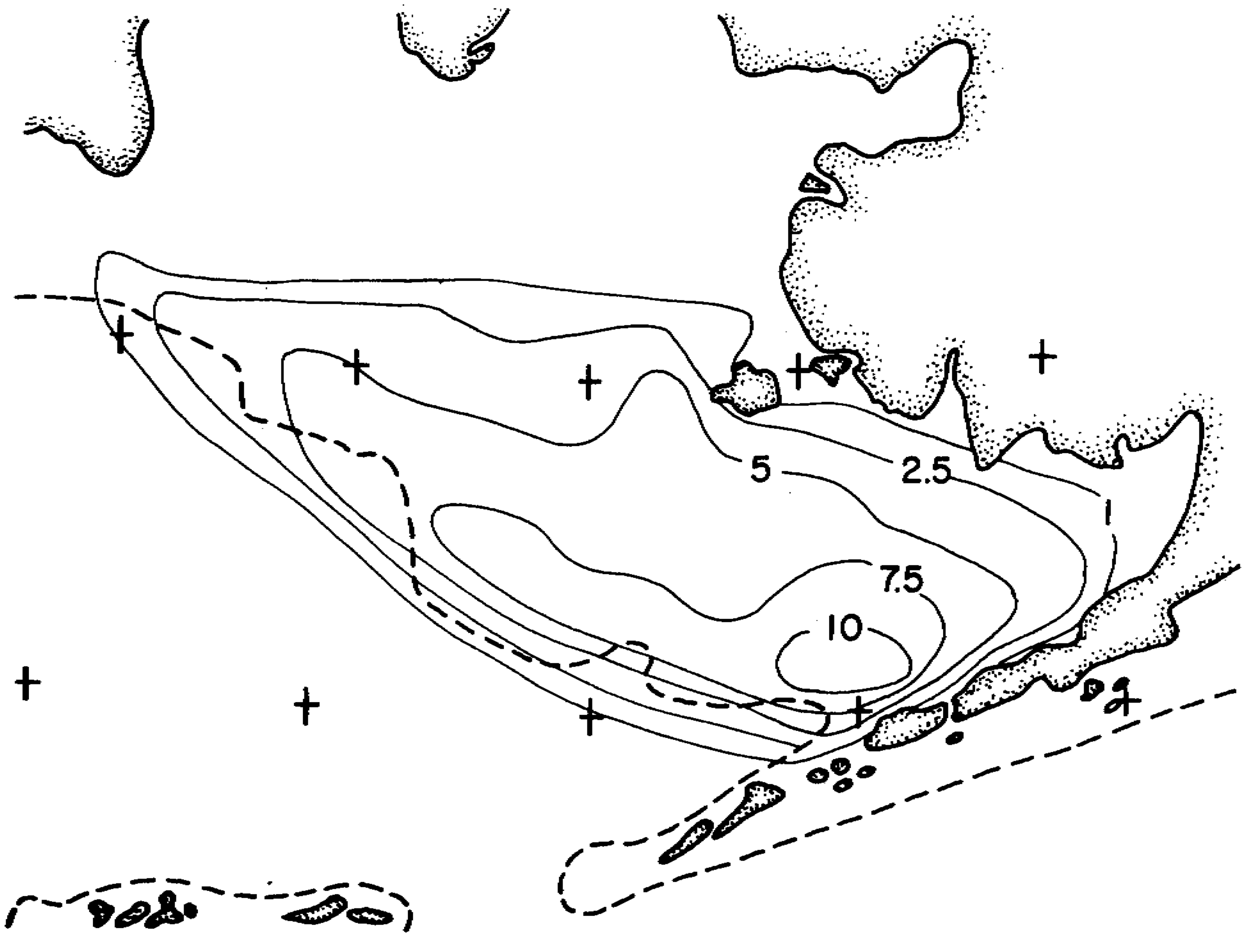

Figure 29. Distribution of other flatfish in February (tons/km^2).

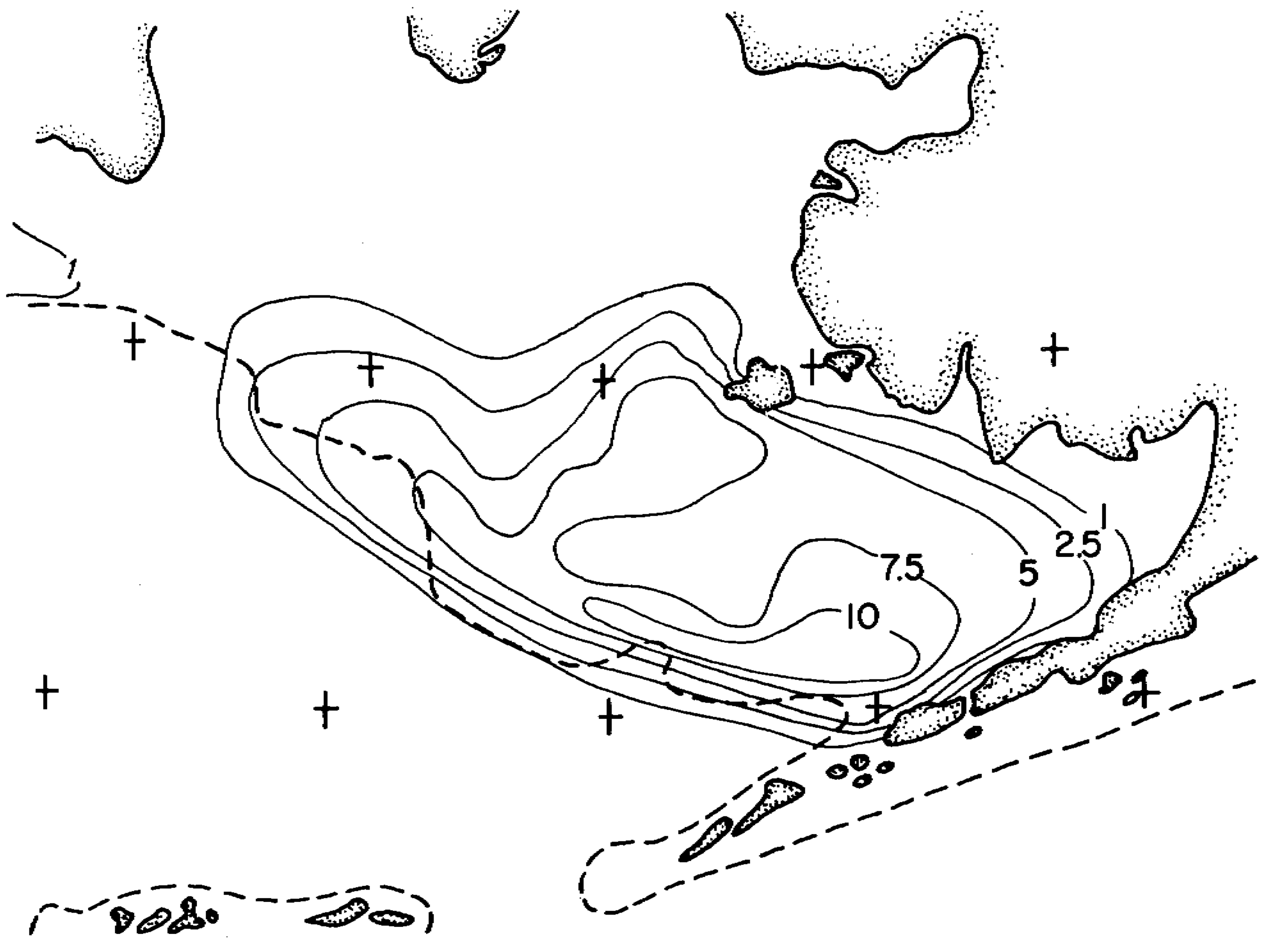

Figure 30. Distribution of other flatfish in November (tons/km^2).

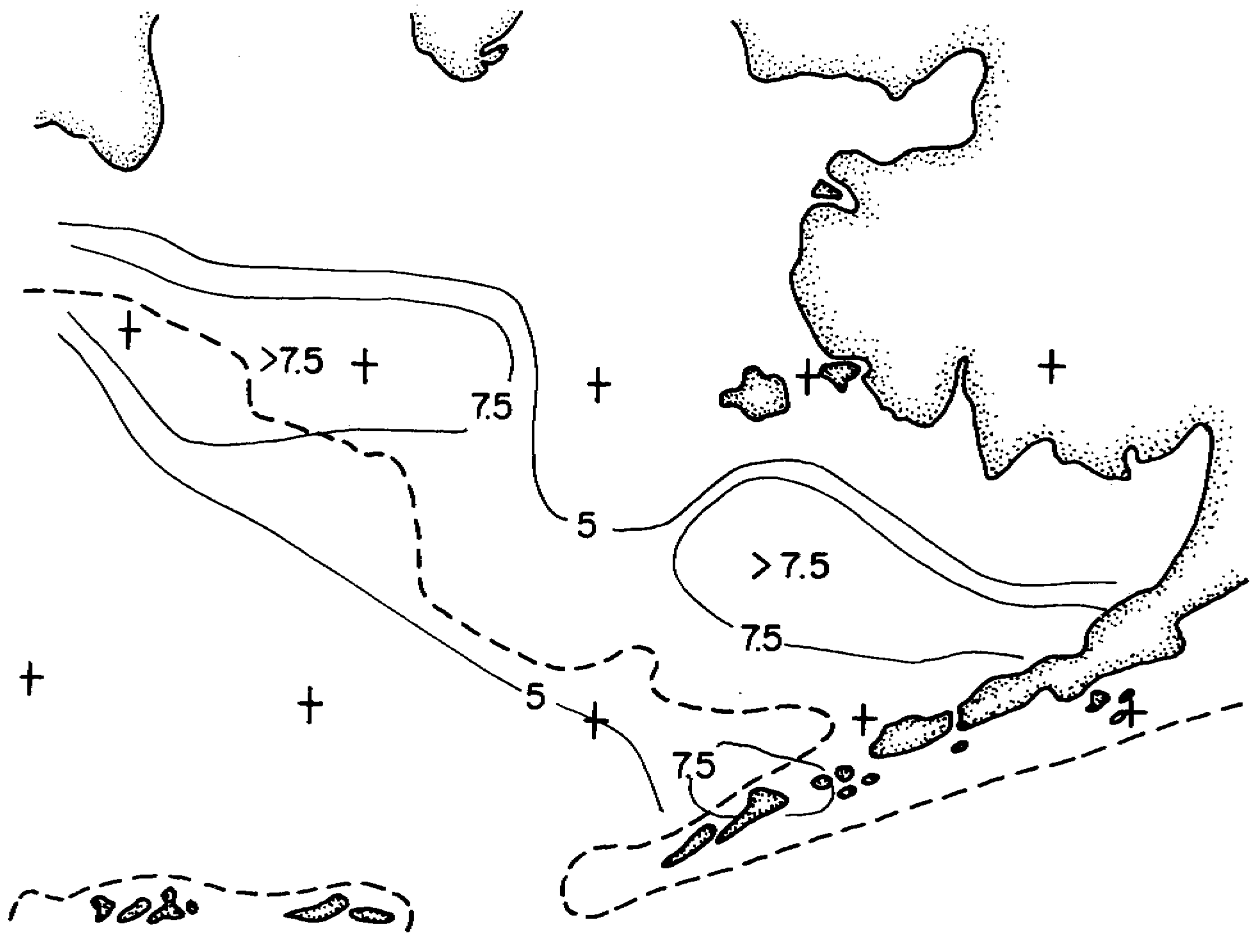

Figure 31. Distribution of other demersal fish in May (tons/km^2).

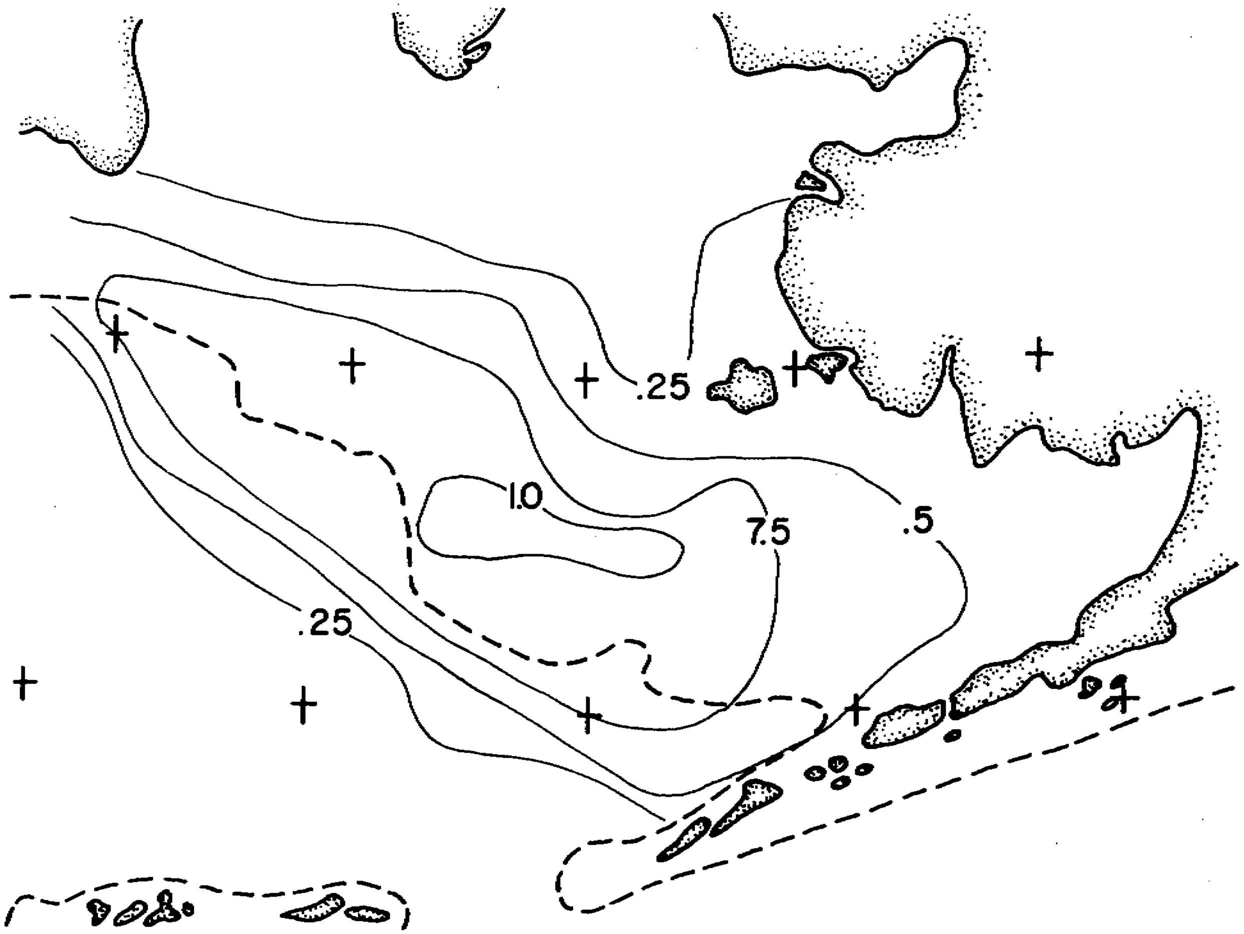

Figure 32. Consumption of other demersal fish in August (tons/km^2).

The simulation of zooplankton standing crop was the same as in DYNUMES I. The simulated quantities are thus in agreement with the highest reported mean zooplankton standing stock (see references in Laevastu, Dunn, and Favorite 1976), but are lower than required by the ecosystem model. An example of a simulated monthly mean standing stock of zooplankton is given in Figure 33. The minimum consumption of zooplankton is computed within the model in each time step and grid point, by summing the zooplankton (mainly euphausids and copepods) consumption by each species and/or ecological group. Assuming that the simulated zooplankton standing stock (g/m^3) is distributed evenly in the upper 50 meters, one can compute the percentage of zooplankton mean standing stock consumed in each month (examples in Figures 34 and 35). These figures show that more than 75% of the mean standing stock of zooplankton is consumed over large areas in May (Figure 34), substantiating the earlier conclusion that the reported amounts of zooplankton standing stock are too low. These figures also show that the areas of high consumption move seasonally, the consequences of which were described in the abovementioned earlier study. The zooplankton standing stocks (and production) in the northern part of the Bering Sea and in the southwestern part of the Bering Sea over deep water are not fully utilized by the ecosystem in these areas.

Phytoplankton consumption was computed only for the benthos (as detritus), and small pelagic fish, however, preliminary additional computations show that only less than a quarter of the phytoplankton production is utilized by the ecosystem, the rest going to a regeneration cycle. Phytoplankton production is apparently not a limiting factor of total biomass in the ecosystem in the eastern Bering Sea. Further detailed studies on this subject will be carried out with DYNUMES III.

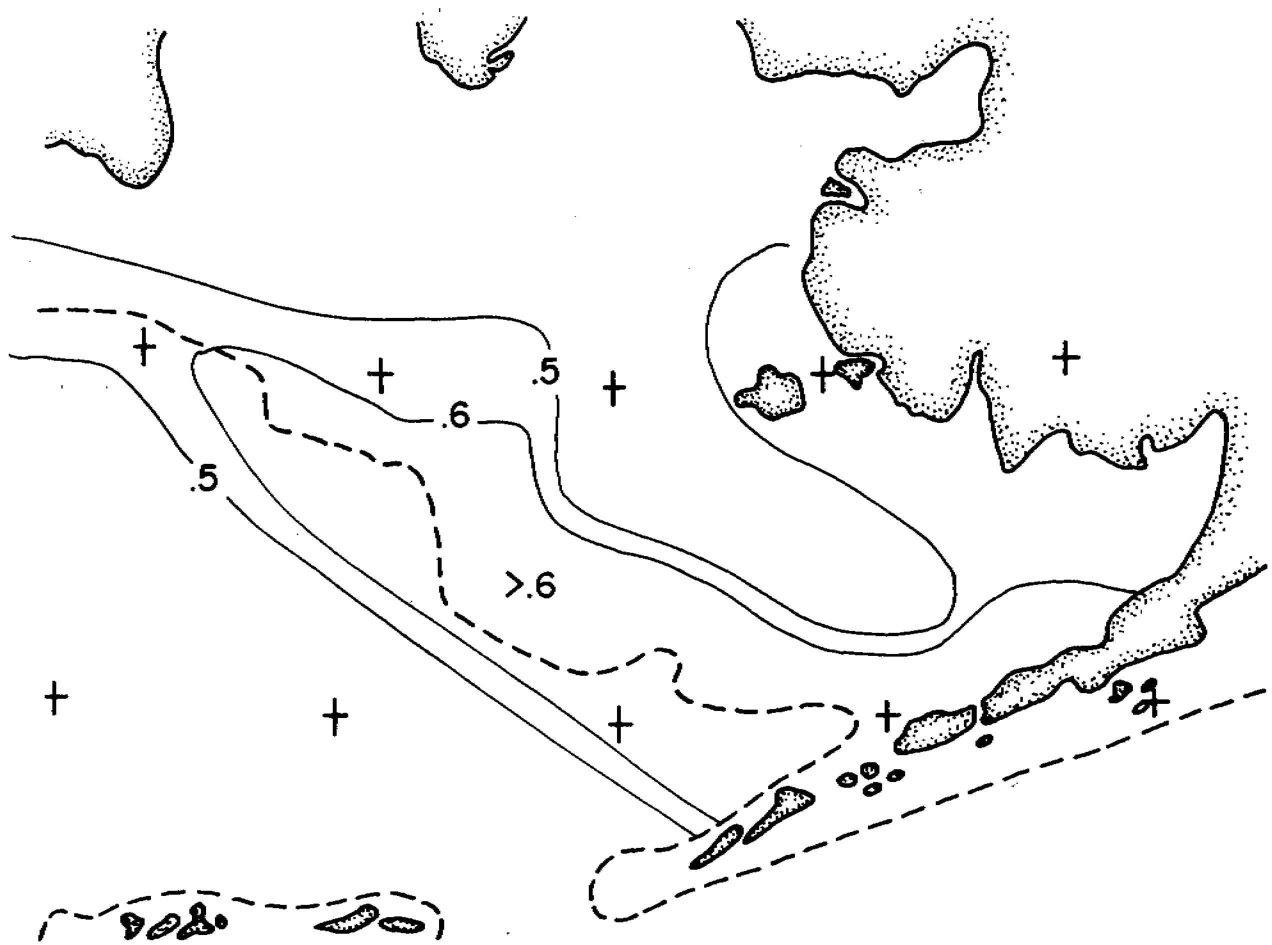

Figure 33. Simulated distribution of zooplankton in May (g/m^3).

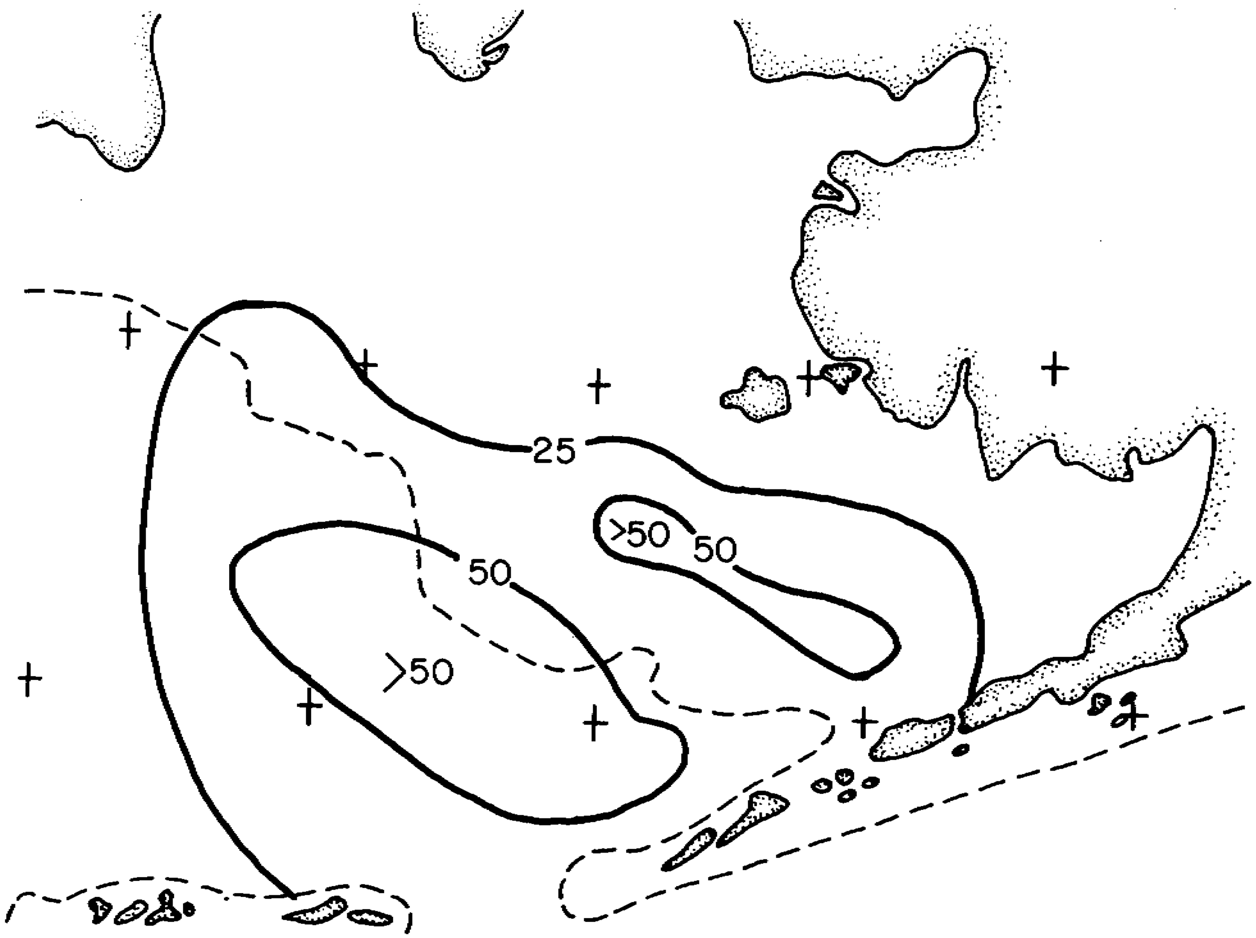

Figure 34.--Percent of mean zooplankton standing stock consumed in May.

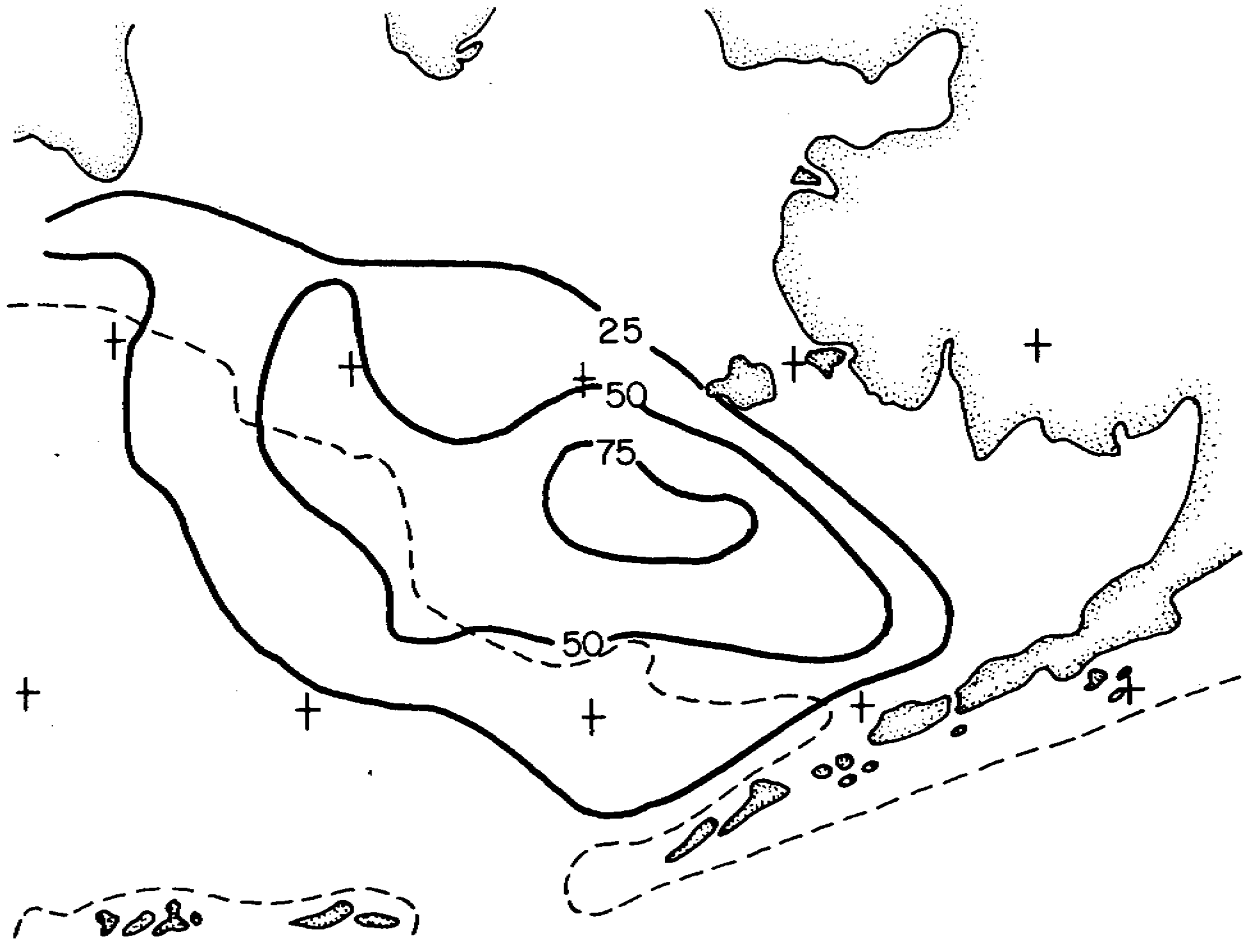

Figure 35.--Percent of mean zooplankton standing stock consumed in August.

G. GENERAL BIOMASS DYNAMICS IN THE EASTERN BERING SEA

The mean standing stocks, annual consumption and annual turnover rates of species and/or groups of species of fish, benthos, and plankton in the eastern Bering Sea are given in Table 7. As pointed out earlier, the inputs into the model are adjusted so that the numbers given in this table should be considered as minimum values (i.e., minimum in the defined ecosystem sustainable biomasses). The mean annual turnover rate of the finfish is slightly less than one (0.89). This means that the mean biomass of the finfish reproduces itself approximately once a year.

Although most of the initial input distributions are prescribed as relatively smooth fields, many of these fields show patchy distributions after a period of computations (six months to two years) (example on Figure 36). This patchiness is mainly brought about by ecosystem internal consumption in species where little or no migrations occur and also causes partial separation of distribution of species. Both patchiness and partial separation of species occur in the sea as normal conditions.

The model runs over several year spans show that marine ecosystems are unstable and sensitive to changes in growth rates, relative distribution and abundance of predators/prey, and changes of composition of food. Detailed quantitative effects of these changes as well as the effects of environment will be investigated with DYNUMES III.

Due to the multiple interactions in the ecosystem, the abundance and distribution of most species show quasi-cyclic variations. The long-term cyclic changes of pollock and herring populations was described in an earlier report (Laevastu and Favorite 1976c). An additional indication of these long-term fluctuations is shown on Figure 37. Further studies of these long-term fluctuations and possible effects of man on these fluctuations will be conducted with DYNUMES III.

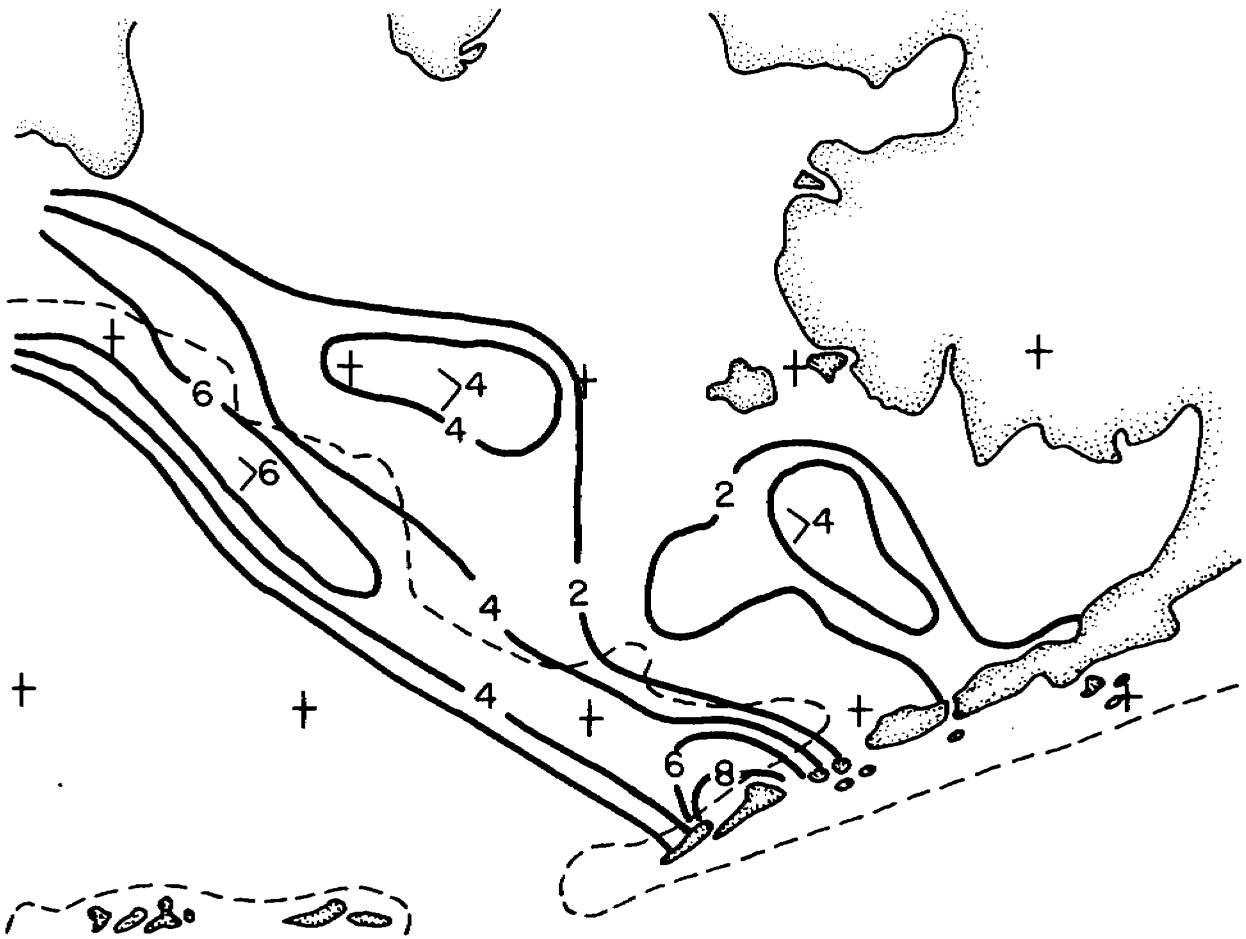

Figure 36.--Distribution of gadids (excluding pollock) in the eastern Bering Sea (in January, third year of computation) in tons per km^2.

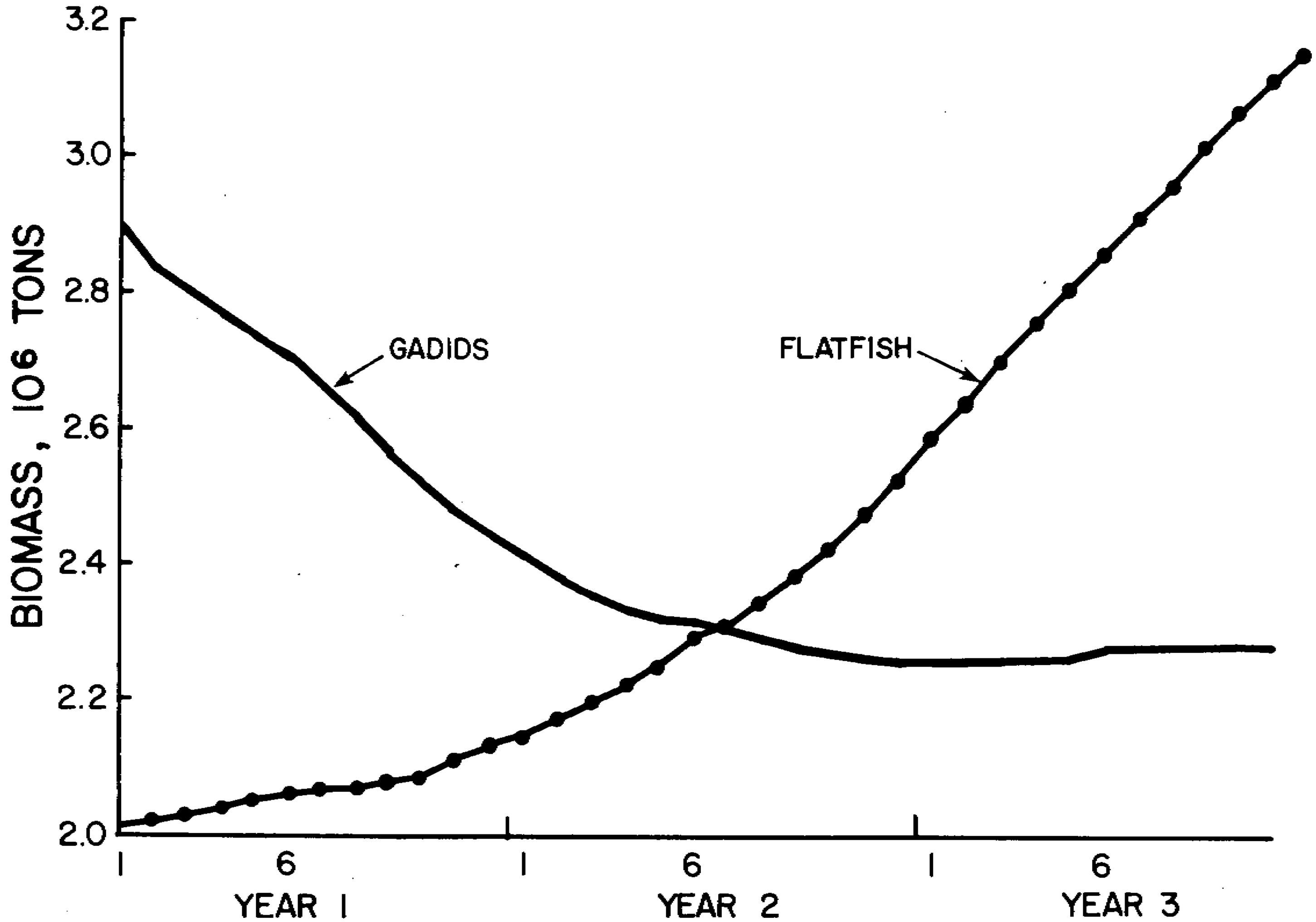

Figure 37.--Examples of changes in biomass of gadids (exluding pollock) and flatfish (excluding yellowfin sole) in the eastern Bering Sea over a three year period, as computed with DYNUMES II with specific inputs.

IV. POSSIBLE EFFECTS OF OIL EXPLORATION AND FISHERY ON MARINE ECOSYSTEM

The possible effects of oil exploration on the marine ecosystem will be studied with the more complete ecosystem model DYNUMES III. Only a few general conclusions on these effects are pointed out below, which have become apparent during the use of the present model.

1) As the marine ecosystem is relatively unstable and as rather extensive fluctuations in abundance and distribution of nearly all species occur in all time scales, it will be extremely difficult, if not impossible, to distinguish between the natural changes in the ecosystem from those caused by oil explorations.

2) All small scale (1 <ca 50 km and t <ca 1 week) disturbances are relatively rapidly smoothed out by the mobility of the ecosystem in offshore areas and there seems to be no effective process which will permit the propogation of small-scale effects within the marine ecosystem.

3) Some exceptions to 2 above are found only along the coastline and in shallow water where one space dimension disappears and where a physical convergence (and convergence line--the beach) exists in the nature. Here the effects are, however, local in nature, although they may be bothersome to limited sectors of local human populations.

4) As the ecosystem internal consumption and consequent turnover rate of the biomass is high (considerably higher than heretofore assumed), and as relatively widespread starvation is expected to occur in the marine ecosystem, it is very difficult to postulate that any essential quantitatively determinable damage can be caused to the marine ecosystem even by relatively extensive temporary accidental damage to part of the ecosystem.

5) The consumption of finfish and other marine resources by mammals is higher than the removal of these resources by man in the intensively fished eastern Bering Sea. Therefore, any attempts to manage marine resources through controlling the fishery by man without managing (controlling) the marine mammal populations, might not achieve the desired effect. It does not seem feasible that any mortalities resulting from oil explorations can reach a noticeable fraction of the removal of resources by mammals and man.

V. SUMMARY

1) The four-dimensional ecosystem model (DYNUMES II) can be used for diagnostic studies on the distribution of the species, for prognostic studies on the effects of environmental anomalies and changing intensity on the marine resources, and for quantitative determination of the possible effects of offshore oil developments on the marine ecosystem in the eastern Bering Sea.

2) The model includes also as inputs the end consumers (mammals, birds, man) whose consumption of other ecological groups is computed in trophodynamic computations within the model.

3) The monthly distribution and abundance of each species (and/or group of species) is computed, using in time and space variable growth coefficients (as influenced by environment and availability of food), fishery and grazing (consumption). Trophodynamic computations within the model give details of the amounts of various food items consumed by different species. The formulas used in the model are given in the text.

4) The ecosystem model requires the knowledge of the biomass distribution with age of the species. A method to compute this distribution is outlined in the paper and examples of Pacific herring biomass distribution is given. The model is found to be sensitive to the growth coefficient. The knowledge of biomass allows the selection of the correct growth coefficient, which is dependent on the mean age of the species biomass.

5) The model shows that the distribution of less migratory species is relatively patchy (as known from the fishery), which is, according to the model results, mainly brought about by grazing. Furthermore, different species/groups of species have rather unique, and in space and time distinct, bulk distribution centers, where only one, or very few, species are predominant. This condition is also known from other higher latitude fisheries.

6) Grazing, which is included in the natural mortality coefficient in conventional, single-species population dynamics approaches, but which is computed separately in the DYNUMES II model, is one of the most important factors in determining the marine ecosystem dynamics (and abundance and distribution of species). Realistic and detailed computation of grazing requires a complete four-dimensional ecosystem model such as the present DYNUMES approach.

7) A number of processes and conditions require additional field studies, before they can be well simulated within ecosystem models, such as the possible distribution and abundance of species under the ice, mortalities caused by subzero temperatures, and principal spawning areas and times of several, more abundant, species.

8) Baleen whales consume a minimum 1.2 million tons of euphausids during the summer in the Bering Sea.

9) Toothed whales consume the same amount of finfish, 1.2 million tons, which is more than half of the total commercial catch.

10) Marine birds consume a minimum of 82 thousand tons of small pelagic fish and fish larvae.

11) Pinnipeds consume about 50 thousand tons of salmon.

12) The model requires that the eastern Bering Sea contain 33 million tons of herring and 6.9 million tons of other pelagic fish (e.g., capelin, Atka mackerel, etc.). Quantitative research on pelagic species in the Bering Sea has been limited in the past and should be accelerated.

13) The model requires also about 8.2 million tons of pollock and more than 2.8 million tons of other gadids in the Bering Sea. Due to their flexible feeding habits and relatively fast growth (i.e., shorter time available for ecosystem internal consumption), the semidemersal species are most abundant species in the area.

14) The biomass of yellowfin sole is about 1.5 million tons, other flatfish about 2 million tons, and other demersal fish (sculpins, eelspouts) about 2.6 million tons. Their distribution is affected by subzero bottom temperatures.

15) Although the availability and production of zooplankton is a limiting factor in fish production in the eastern Bering Sea, the phytoplankton production is not limiting zooplankton or fish production in the area. Only less than one-fourth of the phytoplankton production is consumed directly by the ecosystem.

16) The mean annual turnover rate of the finfish in the eastern Bering Sea is slightly less than one (0.89).

17) Most species seem to have long-term quasi-cyclic variations in abundance.

18) Due to instabilities in the marine ecosystem (e.g., fluctuations of abundance and distributions in all time scales), it is extremely difficult, if not impossible, to distinguish between those changes in the ecosystem that might be caused by oil explorations and those related to the natural fluctuation.

19) All small scale (1 <ca 50 km and t <ca 1 week) disturbances are relatively rapidly smoothed out by the dynamics of the ecosystem in offshore areas and there seems to be no effective process which will permit the propogation of small-scale effects within the marine ecosystem.

20) Some exception to (19) above are found only along the coastline and in shallow water, where one space dimension disappears and where a physical convergence (and convergence line--the beach) exists in nature. Here the effects are, however, local in nature, although they may be bothersome to limited sectors of local human populations.

21) As the ecosystem internal consumption and consequent turnover rate of the biomass is high (considerably higher than heretofore assumed), and as relatively widespread starvation can be expected to occur, it appears that with the existing or expected biological data base that it may be very difficult to quantitatively determine any damage to the marine ecosystem caused even by a relatively extensive but temporary accidental oil spill, with the possible exception of accidents during fish or crustacean spawning activities which may be highly localized.

22) The consumption of finfish and other marine resources by mammals is higher than the removal of these resources by man in the intensively fished eastern Bering Sea. Therefore, any management attempts of marine resources through controlling the fishery by man without managing (controlling) the marine mammal populations, might not achieve the desired effect. It does not seem feasible that any oil exploration effects could reach a noticeable fraction of the removal of resources by the beasts and the man.

23) It is expected that DYNUMES III, a model already well along in development and verification, will considerably advance the accuracy and effectiveness of the present model, DYNUMES II.

VI. REFERENCES

Barton, L.H., I.M. Warner and P. Shafford.

1977. Herring spawning surveys - southern Bering Sea. Alaska Dept. of Fish and Game, OCSEAP RU 19 Rpt.

Laevastu, T. and F. Favorite.

1976a. Summary review of Dynamical Numerical Marine Ecosystem model (DYNUMES). Proc. NMFS/EDS Workshop on Climate and Fisheries. 118-148.

Laevastu, T. and F. Favorite.

1976b. Evaluation of standing stocks of marine resources in the eastern Bering Sea. NWAFC, Proc. Pt., Oct. 1976, 35 p.

Laevastu, T. and F. Favorite.

1976c. Dynamics of pollock and herring biomasses in the eastern Bering Sea. NWAFC, Proc. Rpt., Nov. 1976, 50 p.

Laevastu, T., J. Dunn and F. Favorite.

1976. Consumption of copepods and euphausids in the eastern Bering Sea as revealed by a numerical ecosystem model. ICES, C.M. 1976, Plankton Comm. Paper L34.

Laevastu, T., F. Favorite and W.B. McAlister.

1976. A dynamic numerical marine ecosystem model for evaluation of marine resources in eastern Bering Sea. OCSEAP RU77 Rpt., 69 p + App.

Laevastu, T. and F. Favorite.

1977a. Ecosystem model estimations of the distribution of biomass and predation with age for five species in eastern Bering Sea. NWAFC, Proc. Rpt., Jul. 1977, 39 p.

Laevastu, T. and F. Favorite.

1977b. Minimum sustainable biomasses of marine ecological groups off central and northern California, Oregon, Washington and Vancouver Island coasts. NWAFC, Proc. Rpt., May 1977. 62 p.

McAlister, W.B. and M.A. Perez.

1976. Preliminary estimates of pinniped-finfish relationship in the Bering Sea. NWAFC Proc. Rpt.

Sanger, G.A. and P.A. Baird.

1977. Aspects of the feeding ecology of Bering Sea avifauna. OCSEAP RU77 Rpt., 43 p.

Wiens, J.A. and J.M. Scott.

1975. Model estimation of energy flow in Oregon coastal seabird populations. Condor 77:439-452.

VII. ACKNOWLEDGMENTS

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QUARTERLY REPORT

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REPORTING PERIOD: July 1, 1977 to
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NUMBER OF PAGES: 8

EFFECTS OF PETROLEUM EXPOSURE ON THE BREEDING ECOLOGY OF HERRING AND GLAUCOUS-WINGED GULLS IN THE NORTHEAST GULF OF ALASKA

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October 1, 1977

QUARTERLY REPORT

I. Abstract or Highlights of Quarter's Accomplishments

Very small amounts of petroleum exposure to gull eggs in early stages of incubation lead to high embryonic mortality. Embryonic resistance to petroleum exposure increases with duration of incubation.

We have banded 1206 gulls during the past quarter. Recent band returns range from Cape Hinchinbrook, AK to Olympia, WA, confirming a strongly migratory pattern.

The mixed colony of Herring x Glaucous-winged Gulls at Dry Bay, mouth of the Alsek River, 75 km S. of Yakutat, AK, is reproducing at a high rate, averaging 1.49 chicks produced per nest. The migratory GOA population of interior Herring Gulls breeding at Lake Louise (above Valdez) is reproducing at a lower rate, averaging 0.94 chicks fledged per nest.

II. Task Objectives

A continuing analysis of the effects of petroleum exposure on the reproductive biology of gulls in conjunction with further exploration of the population ecology of large gulls in the Northeast Gulf of Alaska.

III. Field Activities

A. Field Trip Schedule (Summary of 1977 Field Season)

1. Dry Bay: 4 May - 4 June
16 June - 1 July
12 July - 23 July

Lake Louise: 9 June - 10 June
8 July - 10 July
1 Aug - 3 Aug

Cordova: 5 Aug - 1 Sept. Interim in Cordova or transit.

2. Name of Vessel: Alaska State Ferries; private charter boats; Zodiac inflatable Mk III GR.

3. Aircraft: Alaska Airlines, Gulf Air Taxi.

4. Scheduled airlines and Chartered aircraft.

B. Scientific Party

1. Names: Samuel M. Patten Jr. Associate Investigator
Linda Renee Patten Research Technician

We gratefully acknowledge assistance from the U.S. Forest Service, Alaska Department of Fish & Game, Fish & Wildlife Protection, U.S. Fish & Wildlife Service, University of Alaska

B.

1. (cont.) Oregon State University, and the University of Minnesota.

2. Our affiliation is with the Department of Pathobiology, School of Hygiene and Public Health, The Johns Hopkins University, 615 North Wolfe Street, Baltimore, Maryland 21205.

3. Our role is to fulfill contract obligations as Associate Investigator and Research Technician.

C. Methods: Field sampling

Our methods include analysis of reproductive productivity at a series of nest sites marked with survey flags. Petroleum exposure to eggs is by drops from microliter syringes with repeating dispensers. Reproductive success/mortality is compared to controls of 'normal' (unexposed) colonies, and to equivalent amounts of mineral oil (non-toxic). Petroleum used is North Slope Crude Oil provided by NMFS Auke Bay Laboratory.

D. Sample Location:

Dry Bay, mouth of the Alsek River, 75 km S. of Yakutat, AK
59° 10' 00" N. lat. x 138° 35' 00" W. long.

Banding at Dry Bay, Egg Island (Cordova) and Lake Louise (Glenallen). (see figures).

E. Data Collected

Oiling Experiment: conducted in gull colony adjacent to 'A' and 'B' Colony controls. Species: mixed Herring x Glaucous-winged Gulls.

Sample size		Dose	Date of Exposure
10 nests	30 eggs	20 microliters	24 May
20 nests	60 eggs	50 microliters	1 June
20 nests	60 eggs	100 microliters	4 June

Additional data from Mew Gulls, Least Sandpipers and Aleutian Terns.

IV. Results.

A preliminary analysis of petroleum exposure to gull eggs follows:

Dose: 20 ul 30 eggs Date: 24 May

9/30 hatch	=	30%
6/30 "lost" presumed predated	=	20%
15/30 failed to hatch	=	50%

IV. Results (cont.)

Dose: 50 ul	60 eggs	Date: 1 June
16/60 hatch	=	27%
14/60 "lost"	=	23%
30/60 failed to hatch	=	50%
early (1-2 days) chick mortality 3/60 eggs	=	5%

Dose: 100 ul	60 eggs	Date: 4 June
41/60 hatch	=	68.3%
11/60 "lost"	=	18.3%
8/60 failed to hatch	=	13.3%
early (1-2 days) chick mortality 2/60 eggs	=	3%

IV. Results (cont.) 1977 Banding:

We have banded 1206 gulls in the following locations: Dry Bay (Yakutat), Egg Island (Cordova), and Lake Lake Louise (Glenallen). We have banded 72 Herring Gulls, 25 known hybrids, and 1109 Glaucous-winged Gulls. Nine (9) adult Glaucous-winged gulls have been color-dyed yellow with picric acid. We have individually marked 108 gulls with numbered orange 1" lynply tall tarsal bands.

Recently Reported — Band Recoveries (from 1976 and 1976 field seasons): from Egg Island

Cape Hinchinbrook AK	28 July 76
Juneau AK	31 Oct 76
Olympia WA	23 Nov 76
Petersburg AK	10 Dec 76
Harris Harbor AK	15 Jan 77
Prince Rupert BC	23 Jan 77
Rivers Inlet BC	-- Feb 77
Lake Tapps WA	-- Feb 77
Ketchikan AK	3 Mar 77
Valdez Arm AK	24 Aug 77
Cordova AK	31 Aug 77

Recently reported band recoveries from Strawberry Reef, a sandbar barrier island at the east end of the Copper River Delta, 55 km SE of Cordova AK:

IV. Results (cont.)

Vancouver BC	3 Feb 77
Bainbridge Island WA	16 Feb 77

IV. Results (cont.)

1977 Gull Productivity Analysis:

Dry Bay 'A' Colony:300 m x 50 m - a rectangle fronting the Alsek River.
Dry Bay 'B' Colony: 30 m in Ø - a rough circle in the middle of the island.

The colonies are located 4.62 km from the coast on flat gravel bars. Vegetation is Elymus, Epilobium, Achillea, Salix and mosses.

Dry Bay 'A' Colony produced 134 chicks from 90 nest sites: 1.49 chicks/nest.

Dry Bay 'B' Colony produced 28 chicks from 20 nest sites: 1.40 chicks/nest.

Lake Louise 'Bird Island' produced 73 chicks from 77 nest sites: .94 chicks/nest.

V. Preliminary Interpretation of Results:

Very small amounts of North Slope Crude Oil exposure to gull eggs in the field at early stages of incubation lead to high embryonic mortality.
Embryonic resistance to petroleum exposure increases with duration of incubation. Mineral oil doses in equivalent microliter doses caused no significant egg mortality. Resistance to petroleum exposure is perhaps a surface to volume relationship: as the embryo increases in size, exposed membrane surfaces diminish in proportionate size. Eggs are most vulnerable to petroleum exposure in early stages of incubation.

Recent band recoveries confirm a strongly migratory movement of juvenile gulls from Egg Island and Strawberry Reef. The young gulls move slightly north to the Prince William Sound region, and then migrate south, wintering from Ketchikan to Puget Sound.

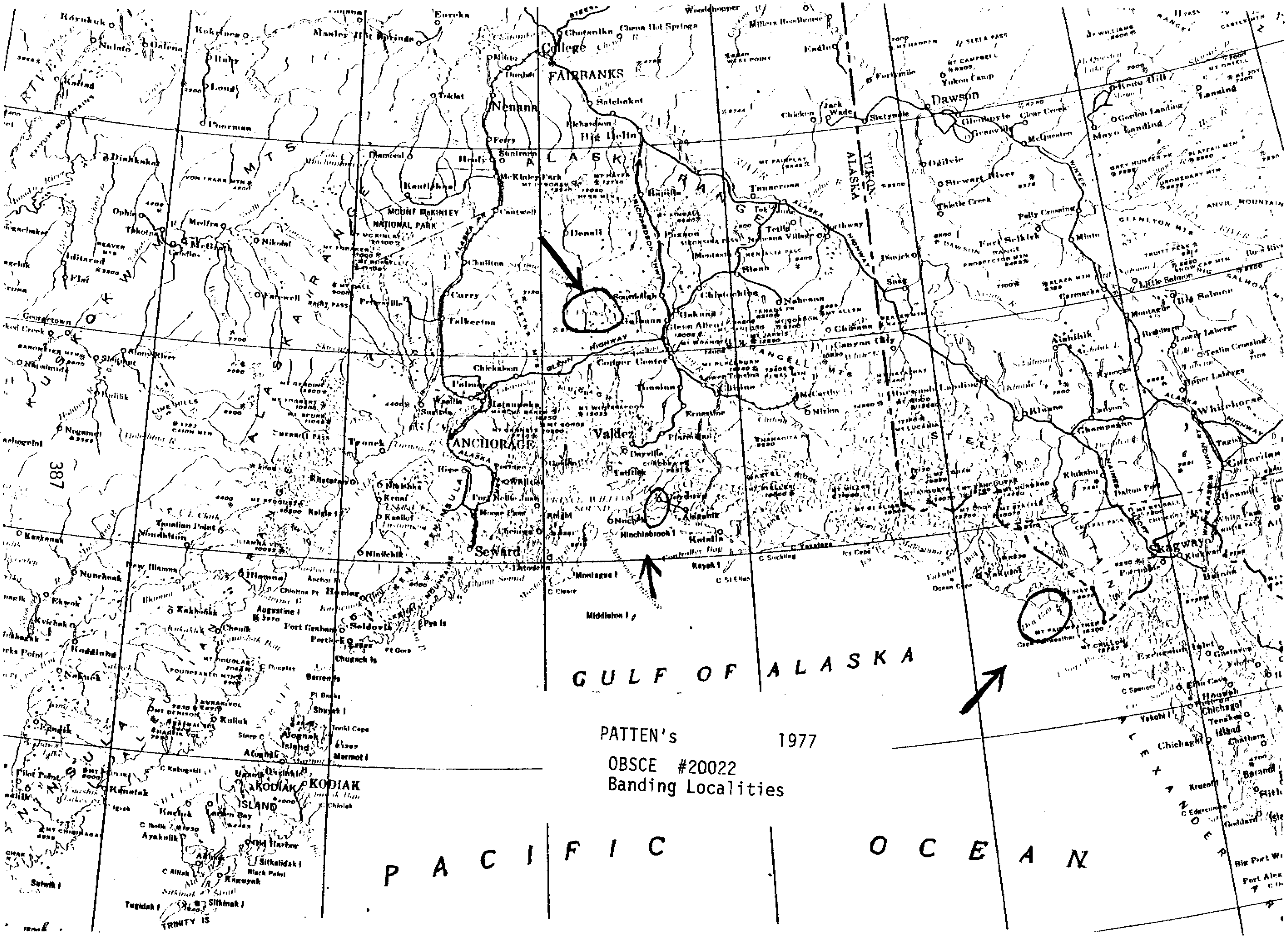
The mixed colony of Herring x Glaucous-winged Gulls at Dry Bay, mouth of the Alsek River, 75 km south of Yakutat, is reproducing at a high rate, averaging 1.49 chicks produced per nest. The migratory GOA population of interior Herring Gulls breeding at Lake Louise (above Valdez, near Glenallen) is reproducing at alower rate, averaging 0.94 chicks produced per nest. The productivity is most likely related to available food supply.

VI. Auxiliary Material: Oral presentation of preliminary research results to Juneau Project Office.

VII. Problems Encountered/Recommended Changes: None.

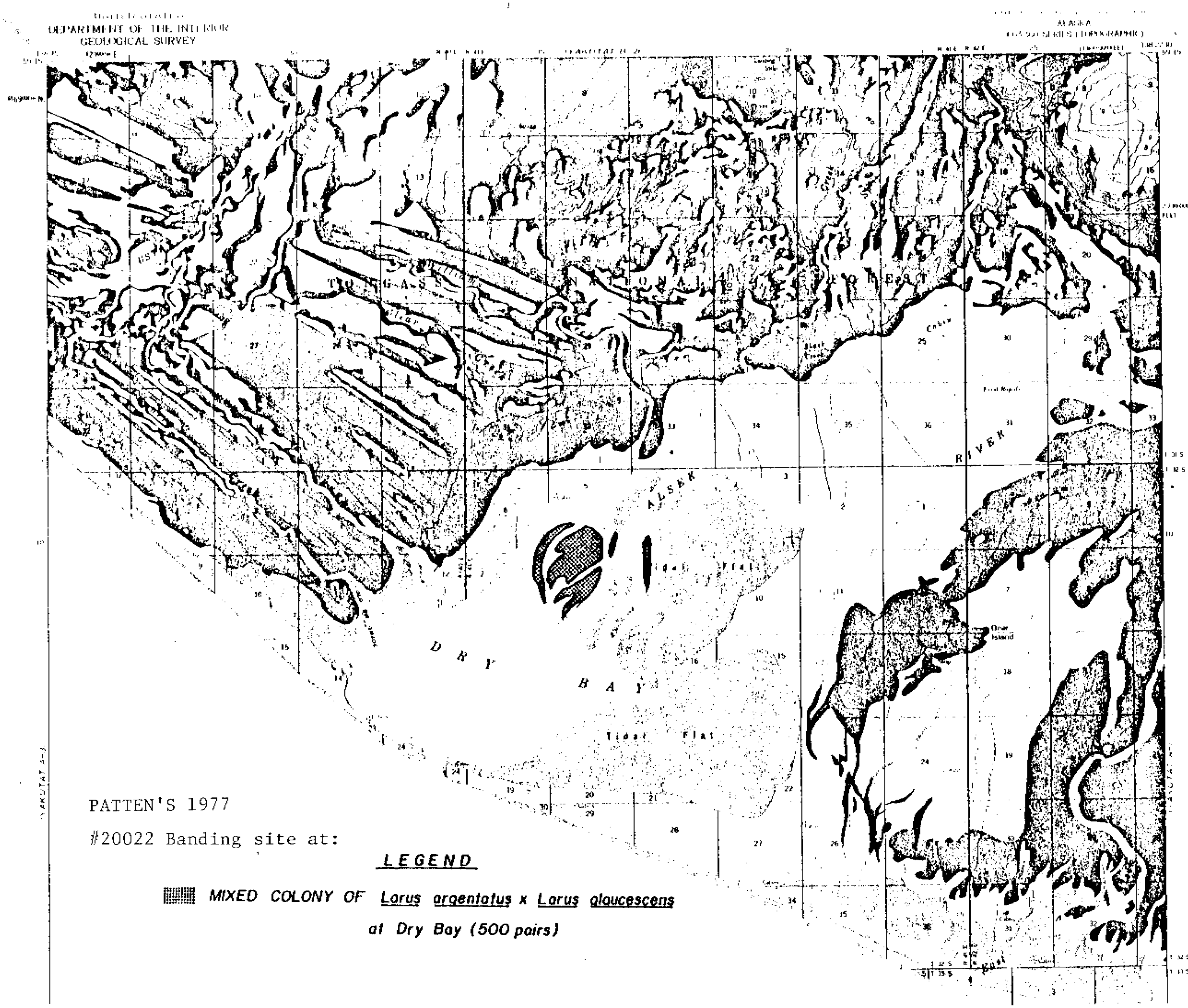
VIII. Estimate of Funds Expended:

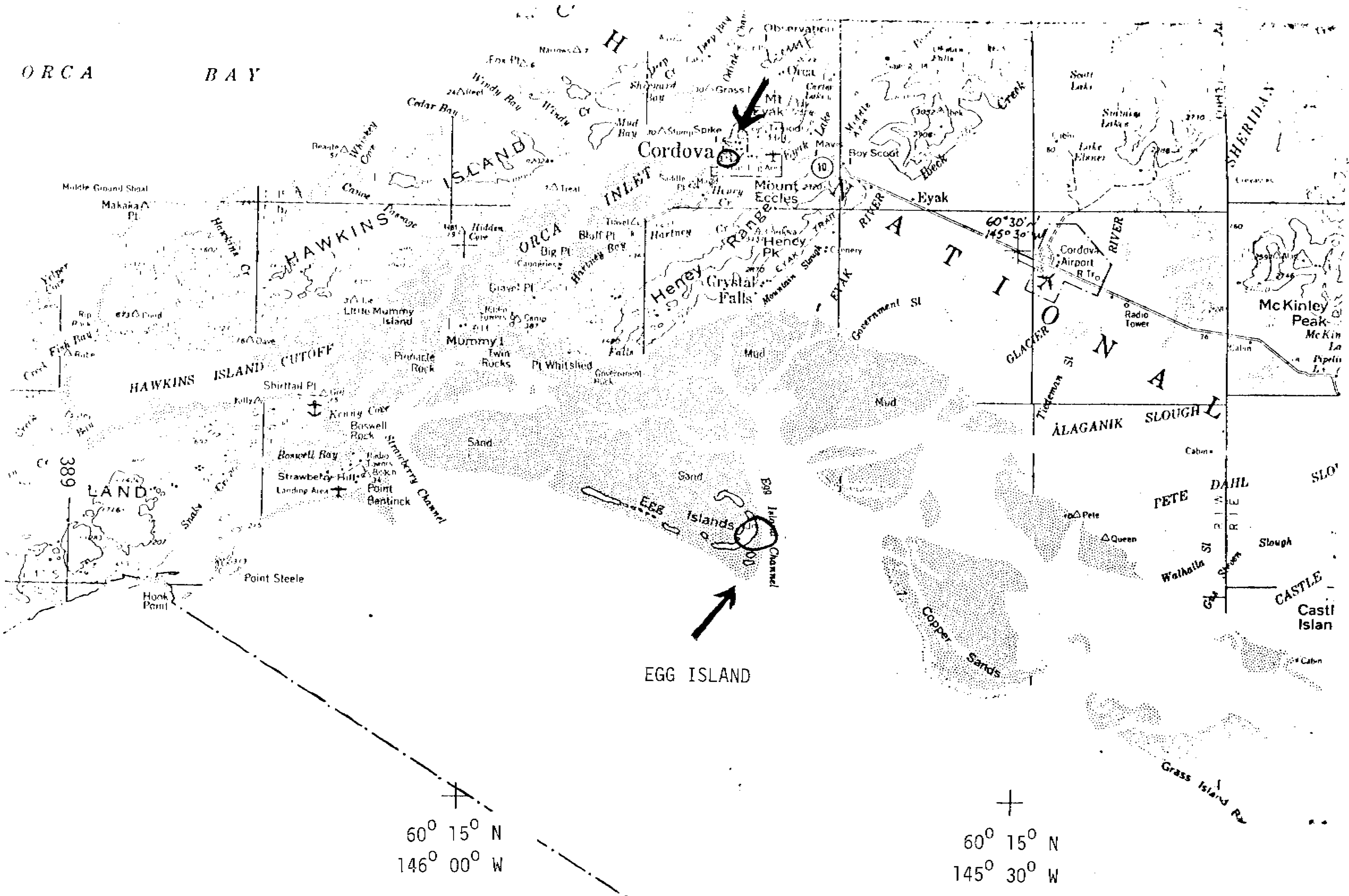
We have utilized most categories with no overruns. Unexpended computer funds will be carried over for use in FY 78 as stipulated in RFP Guidelines and with permission from Juneau Project Office.



PATTEN's 1977

OBSCE #20022
Banding Localities


DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
ALASKA
TONGASS NATIONAL FOREST
ALSEK
RIVER
DRY BAY
Tidal Flat
PATTEN'S 1977
#20022 Banding site at:
LEGEND
MIXED COLONY OF Larus argentatus x Larus glaucescens
at Dry Bay (500 pairs)



PATTEN's OBSCE #20022 1977 banding;

NOTE: Two localities in Cordo a area.

RU # 278

NO REPORT WAS RECEIVED

October 1, 1977

QUARTERLY PROGRESS REPORT

Research Unit #389

Task Title: Transport, retention, and effects of the water-soluble fraction of Cook Inlet Crude oil in experimental food chains

Jeannette A. Whipple
Principal Investigator

Thomas G. Yocom
Task Leader

I. Abstract of Quarter's Accomplishments:

Groups of 30 starry flounder (*Platichthys stellatus*) were exposed continuously for five weeks to water-soluble components of Cook Inlet crude oil in seawater and/or in their food (Japanese littleneck clams, *Tapes semidecussata*). Concentrations of hydrocarbons in exposed seawater averaged 100 ppb; concentrations in exposed clams (exposed for at least 1 week to 100 ppb WSF in seawater) averaged 7.7 ppm.

Uptake and accumulation of low-boiling-point aromatic hydrocarbons were rapid in fish exposed to contaminated seawater. Concentrations of some components in fish livers (after only one week of exposure) were more than 97,000 times higher than the concentrations of those components in the water column.

Concentrations of hydrocarbons in tissues of flounder receiving exposed food but uncontaminated seawater were much lower than those from flounder in contaminated seawater. After a full five weeks of receiving a daily ration of exposed clams (equivalent to 4% of the flounder wet body weight per day), levels of low-boiling-point hydrocarbons (in tissues analyzed) were 1.7 ppm. In all cases the detectable hydrocarbons in livers from these fish were unidentified compounds believed to be metabolites. In contrast, flounder exposed through the water column generally had many of the same petroleum hydrocarbons in their tissues as those identified in the exposed seawater.

High concentrations of the unidentified low-boiling-point compounds were detected in tissues of flounder in all exposure groups; in some liver samples the total concentration of these compounds exceeded 200 ppm (concentrations of higher-boiling-point petroleum hydrocarbons and metabolites have not yet been determined).

Growth rates of flounder in the various exposure groups did not differ significantly from those of controls. No behavioral differences were observed between any of the groups.

II. Task Objectives:

The objectives of this study are to determine the accumulation and passage of petroleum constituents in experimental marine food chains and the effects of petroleum exposure on the test organisms. The specific objectives are:

1. To determine the accumulation, retention and transfer of petroleum constituents in experimental food chains consisting of up to four trophic levels including primary producers, consumers and primary and secondary carnivores. Exposure will be either from water-soluble fractions of petroleum or introduced only in food to distinguish the effectiveness of petroleum accumulation from food and water exposure pathways. Adult and larvae food chains will be studied.

2. To determine mortality of experimental animals under various exposure conditions including mortality in eggs and larvae from exposed adults.

3. To determine morphological and behavioral abnormalities caused by selected exposure conditions.

4. To predict potential effects of crude oil on populations and communities in terms of reproductive success, energy utilization and growth.

5. To recommend maximum allowable levels of petroleum components in the water column and fish food organisms and, if possible, to identify components of crude oil with the greatest potential for adverse biological effects.

III. Research Activities:

A. Field Activities:

Field activities were limited to the collection of Japanese little-neck clams (*Tapes semidecussata*) on those few occasions when no clams could be obtained from our supplier on Puget Sound, Washington. Clams collected locally were taken near Foster City on San Francisco Bay.

B. Laboratory Activities:

1. Scientific Party

a. Jeannette A. Whipple - Chief, Physiology Investigations; Principal Investigator; also in charge of experiments dealing with effects of water-soluble hydrocarbons on spawning clams and floumder and their subsequent offspring.

b. Thomas G. Yocom - Fishery Biologist; Task Leader; planning and supervision of experiments; also in charge of acute and chronic studies with flounder.

c. Pete Benville, Jr. - Research Chemist; development of water and tissue samples for water-soluble hydrocarbons and metabolic by-products.

d. D. Ross Smart - Biological Technician; plans and conducts experiments on the acute and chronic effects of water-soluble hydrocarbons on clams and shrimp; assists in other experiments.

e. Meryl H. Cohen - Biological Aide; assists in development of analytical techniques; assists in studies on phytoplankton, clams, and flounder; in charge of laboratory equipment.

f. Martha E. Ture - Biological Aide; care and maintenance of experimental animals; in charge of experiments on phytoplankton.

C. Methods:

EXPERIMENT 2C: Uptake, retention, and effects of chronic exposure to low levels of the water-soluble fraction of Cook Inlet crude oil to starry flounder.

Starry flounder were exposed continuously to the water-soluble fraction of Cook Inlet crude oil in water, food, or water and food as outlined in the July 1, 1977, Quarterly Progress Report to OCSEAP (see pages 18 and 19). Some minor changes were made, however, most notably that the exposure period was shortened to 5 weeks, and six fish (rather than three) were subsampled on weeks 2 and 5 of the exposure period. In addition, we elected to weigh and measure only fish being sacrificed each week; we were concerned about possible adverse effects of weekly anaesthetization and handling on hydrocarbon uptake.

EXPERIMENT 2B: Uptake, retention, and effects of chronic exposures to low levels of the water-soluble fraction (WSF) of Cook Inlet crude oil to littleneck clams.

The methods for Experiment 2B, previously described in the July 1, 1977, Quarterly Progress Report (pages 16 and 17), have been modified to accommodate the decrease in time available for experimentation. Exposure periods for clams were reduced from 8 weeks to 2 weeks followed by a 1-week depuration period. The decrease in the duration of the experiment alleviated the need for daily feeding of the clams. Morphometric measurements were not taken from the clams, because measurable growth cannot be seen in a 3-week period.

Two species of clams were used for WSF exposure in the 30-gallon aquariums, Protathaca staminea and Tapes japonica. Four pooled samples of

10 grams of clam tissue for each species were taken at 2 or 3-day intervals throughout the experiment. Two of the four samples were analyzed for monoaromatic hydrocarbons and the other two for dicyclic aromatics.

Procedures for exposing clams in the 400-gallon holding tank remain unchanged from the July 1, 1977, Quarterly Report. Two 10-gram samples were taken daily for tissue analysis; one for monoaromatic hydrocarbons and one for dicyclic aromatic hydrocarbons.

Analytical Procedures

Analysis of water samples

Water samples were taken daily from exposure tanks and were analyzed for monocyclic aromatic hydrocarbons by extracting a one-liter sample twice with 10 ml of TF-Freon and injecting 3.2 microliters of each extract into the gas chromatograph (GC) (column packed with Bentone 34 on chromosorb PAW). Every 2 days, samples were taken from solubilizers feeding into the exposure tanks; these 1-liter samples were extracted 3 times with 10 ml of TF-Freon and injected into the GC.

In addition, one-liter solubilizer samples were extracted with 80 ml methylene chloride for analysis of dicyclic aromatic compounds. Extracts were concentrated to about 10 ml and stored in a freezer. Subsequent preparation for analysis followed procedures developed at the National Analytical Laboratory (appended to this report).

Analysis of tissue samples

Tissues dissected from test flounder and clams were split in half and placed in pre-weighed, methylene chloride rinsed culture tubes. Samples to be analyzed for dicyclic aromatic hydrocarbons and aliphatic hydrocarbons were stored in a freezer until they could be processed according to the procedures developed at the National Analytical Laboratory (appended to this report).

Samples to be analyzed for low-boiling-point compounds were digested with 6 ml of 4N NaOH and 4 ml of TF-Freon. Samples were allowed to digest for 18 hours at 30°C during which time they were shaken often. Following this digestion, samples were centrifuged 10 min. (while still warm) at 3000 rpm after which the TF-Freon layer was drawn off into a culture tube. This tube was re-centrifuged and a 3.4 microliter subsample was injected into the GC.

Previous problems with lipid emulsions in the Freon layer were eliminated by slowly freezing the sample overnight (after the first centrifugation) and then thawing it and drawing off the Freon if the emulsion had disappeared. If the emulsion persisted, the sample was cleared with 1-2 ml of 20% H_2SO_4 and re-centrifuged. This clearing procedure did not interfere with any compounds of interest on the GC although we did experience a 10-15% reduction in total detectable concentration of low-boiling-point components when H_2SO_4 was used. (However, we found it superior to a number of alcohols and other drying agents such as sodium sulfate).

Outside analysis of water and tissue samples

(National Analytical Laboratory (NAL) subcontract)

A total of 20 frozen tissue samples has been sent for GC or mass spectrometric (MS) analysis and an additional 15 extracted samples of flounder tissues, clam tissue, and seawater from the solubilizers for GC or GC-MS. Two crude oil samples were sent to NAL for fingerprinting.

D. Sample Localities:

Starry flounder were taken in bottom trawls in Pacific coast waters near Bodega Bay, California (Sonoma County). Japanese littleneck clams (*Tapes semidecussata*) were trucked to San Francisco from Puget Sound, Washington.

E. Data Collected or Analyzed:

1. Number and types of samples/observations

To date this quarter, over 300 water samples and 750 tissue samples were taken during experiments on chronic exposure of starry flounder and littleneck clams to WSF.

2. Number and types of analyses

Approximately 200 water samples have been analyzed for monocyclic aromatic hydrocarbons. Nearly 100 tissue samples have been partially or completely analyzed for low-boiling-point hydrocarbons.

Roughly 10 water samples and 30 tissue samples have been partially analyzed for dicyclic aromatic hydrocarbons, aliphatic hydrocarbons, and phenols.

IV. Results:

A. Uptake and accumulation of low-boiling-point petroleum hydrocarbons from food, water, or food and water in livers of starry flounder.

Analyses of tissue samples from experiments in which starry flounder were chronically exposed to WSF in food, water, or food and water were begun this quarter. Most of the analyses completed to date were of monocyclic aromatic components and low-boiling-point metabolites. No tissues other than liver have been analyzed in sufficient numbers to make a meaningful presentation. It is noteworthy that liver samples had far higher concentrations of hydrocarbons than any other tissue analyzed.

Uptake of hydrocarbons from food

A group of 30 flounder received a daily ration (4% of the wet-body weight of the flounder) of clams that had been exposed for at least 1 week to the water-soluble fraction of Cook Inlet crude oil. Clams so exposed attained average tissue concentrations of 7.7 ppm of low-boiling-point petroleum hydrocarbons and metabolites (Table 1).

Fish sampled after 5 weeks of this diet had accumulated an average 1.72 ppm of low-boiling-point hydrocarbons (Table 2). None of these compounds has yet been identified (Figure 1) although they occurred in livers of flounder in other exposure groups. We suspect they are metabolites.

It is curious that no monocyclic aromatics were detected in livers from this treatment group because these compounds were present in the clam tissue fed to the flounder (Figure 2 and Table 1).

Uptake of hydrocarbons from water

A group of 30 starry flounder was exposed continuously to 100 ppb of the WSF of Cook Inlet crude oil flowing through a test tank at 6 liters/min. Concentrations of six monocyclic aromatic compounds were determined from the solubilizer feeding each test tank and tank concentrations of some of these compounds (most notably p-xylene) were estimated given the amount of water used to dilute the solubilizer outflow to a concentration of 100 ppb (Table 1).

After 2 weeks of exposure, concentrations of monocyclic aromatic compounds reached an average concentration of 22 ppm in flounder livers (Table 2). After 5 weeks exposure, the level had reached an average of 49 ppm. The concentration of unidentified components (those not appearing in chromatograms of livers from control flounder) reached average levels in excess of 130 ppm making a total concentration (low-boiling-point compounds only) of about 180 ppm. In one flounder liver, the total concentration exceeded 300 ppm (Figure 3).

The liver of one flounder exposed for only one week to 100 ppb WSF was found to contain nearly 150 ppm of monocyclic aromatic compounds (Figure 4). The flounder had lost weight and was in poor shape (a condition

TABLE 1. Estimated concentrations of monocyclic aromatic hydrocarbons and other low-boiling-point hydrocarbons.

SAMPLE	CONCENTRATION (PPM)							
	BENZENE	TOLUENE	ETHYL-BENZENE	P-XYLENE	M-XYLENE	O-XYLENE	OTHER	TOTAL
SEAWATER	0.041	0.043	0.002	0.00005	0.007	0.004	<0.01	0.100
CLAM	2.23	1.43	<0.04	<0.04	0.30	<0.04	3.74	7.70

TABLE 2. Concentrations of monocyclic aromatic and other low-boiling-point hydrocarbons in livers of starry flounder exposed to the WSF of Cook Inlet crude oil.

SOURCE OF EXPOSURE	LENGTH OF EXPOSURE (Weeks)	CONCENTRATION (PPM)							
		BENZENE	TOLUENE	ETHYL-BENZENE	P-XYLENE	M-XYLENE	O-XYLENE	OTHER	TOTAL
FOOD	1	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.39	0.39
	3	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.63	0.63
	5	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	1.72	1.72
WATER	2	3.09	9.50	2.15	0.93	4.44	1.94	131.88	153.93
	5	6.11	18.35	6.35	1.81	9.71	6.64	131.11	180.08
FOOD & WATER	1	5.61	17.01	3.95	1.16	7.76	5.50	64.04	105.03
	2	4.11	13.21	3.38	0.83	4.84	1.68	80.53	108.58
	5	6.54	14.28	5.45	1.30	8.85	6.13	198.68	241.23

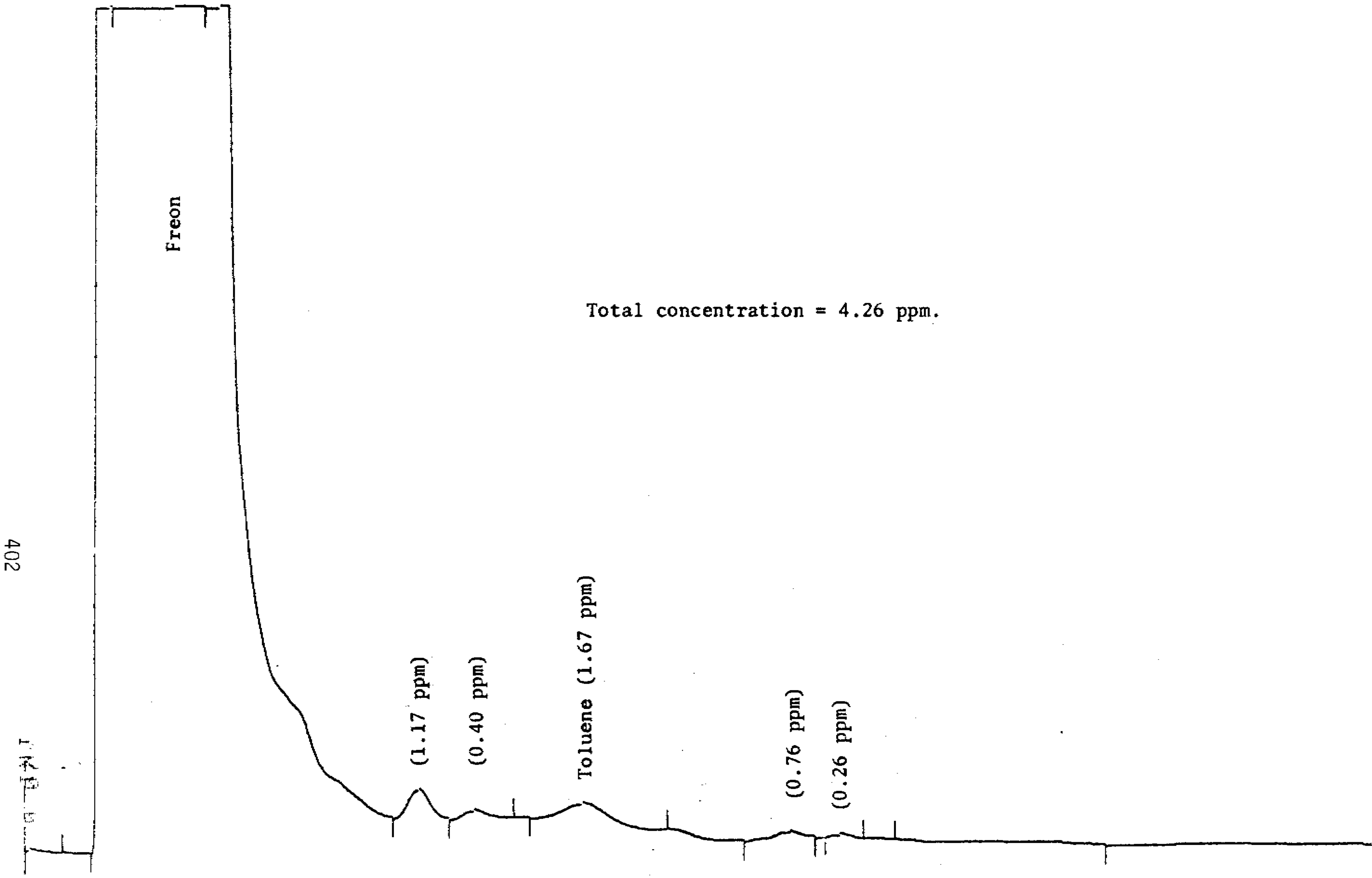


Figure 1. Chromatogram of low-boiling-point hydrocarbons detected in the liver of a starry flounder fed WSF-contaminated clams for 5 weeks. This fish had the highest level of low-boiling-point hydrocarbons of any fish in the food-exposure group. Higher-boiling-point compounds have not yet been analyzed.

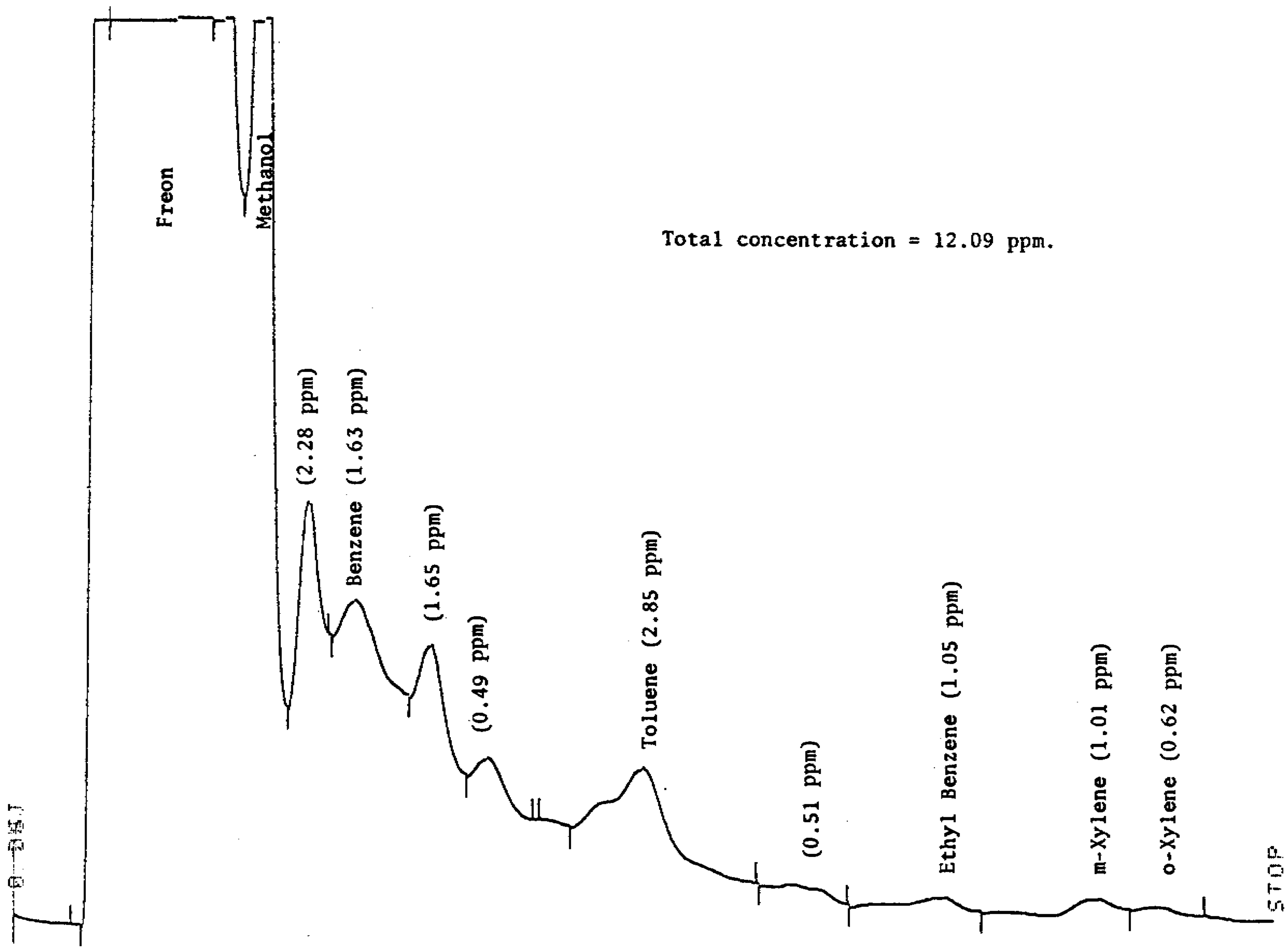


Figure 2. Chromatogram of low-boiling point hydrocarbons in a sample of clams exposed for 1-2 weeks to 100 ppb WSF. This sample had the highest level of hydrocarbons of any clam sample analyzed. Higher-boiling-point compounds have not been analyzed.

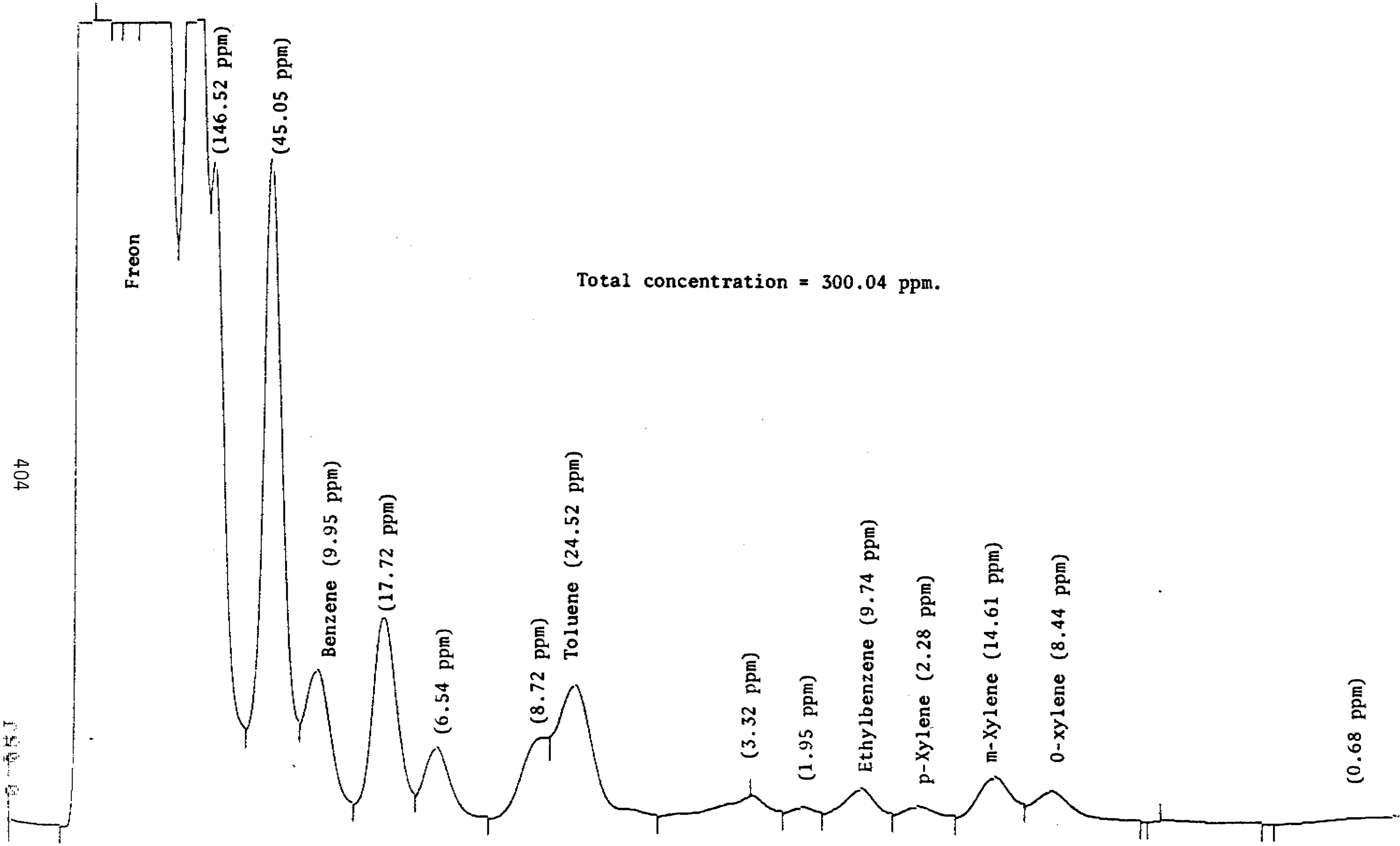


Figure 3. Chromatogram of low-boiling-point hydrocarbons detected in the liver of a starry flounder exposed 5 weeks to 100 ppb WSF in the water column.

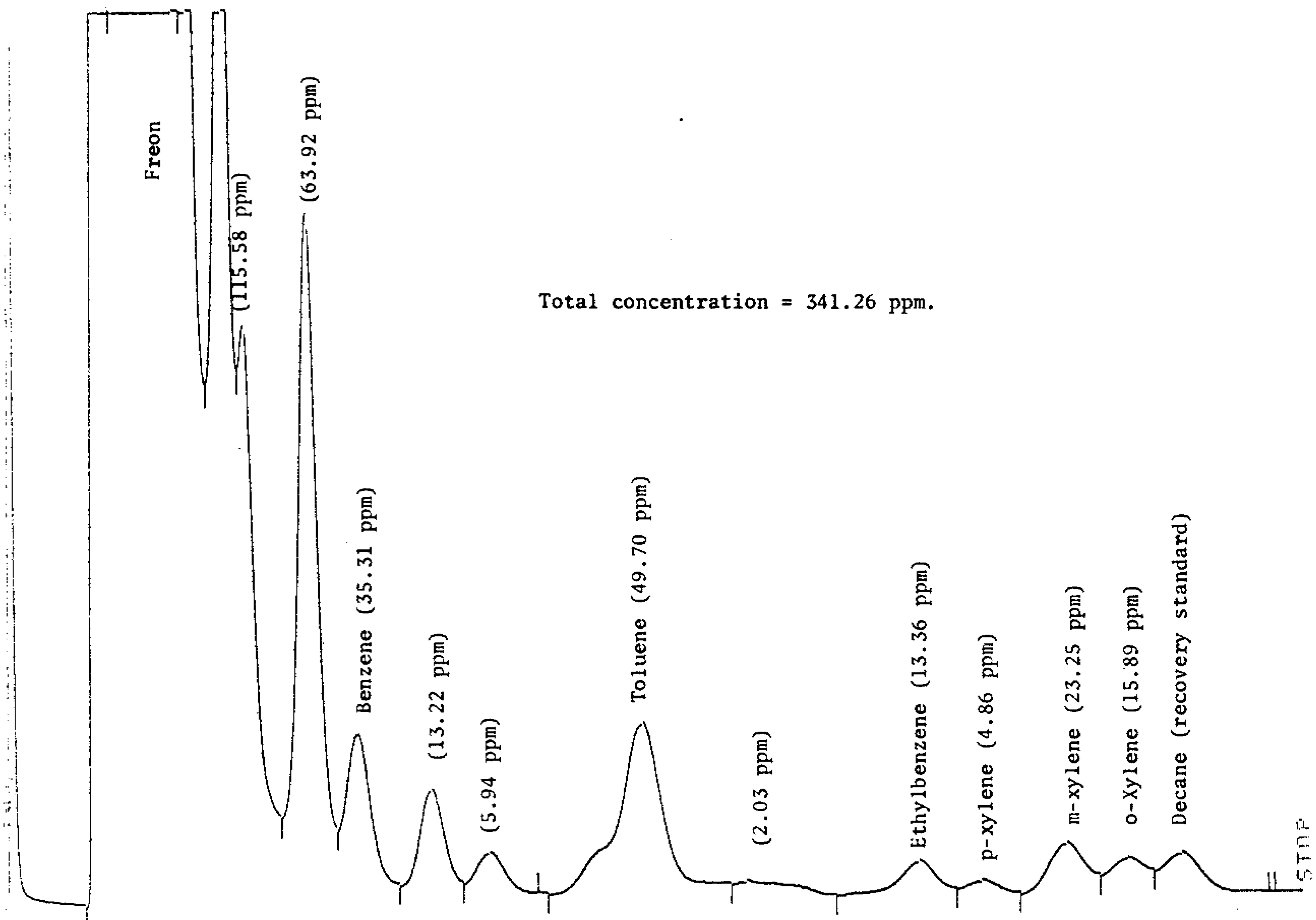


Figure 4. Chromatogram of low-boiling-point hydrocarbons detected in the liver of a starry flounder exposed to 100 ppb WSF for one week.

not attributed to the WSF exposure) and as a result may not have been metabolizing the hydrocarbons as quickly as healthy flounder. However, the tissue concentration was noteworthy because it represented remarkable accumulation of petroleum hydrocarbons. The following list shows how many times higher the concentration of compounds was in the liver than in the water:

Benzene	--- 860 times
Toluene	--- 1,150 times
Ethylbenzene	--- 6,680 times
p-xylene	---97,250 times
m-xylene	--- 3,320 times
o-xylene	--- 3,970 times

Uptake of hydrocarbons from water and food

A group of 30 starry flounder was exposed continuously to 100 ppb WSF flowing through a test tank at 6 liters/min. In addition, these fish received a 4% daily ration of littleneck clams that had been exposed for at least one week to 100 ppb WSF. After 2 weeks of such exposure, concentrations of 6 monocyclic aromatic hydrocarbons in livers of these flounder reached an average concentration of 28 ppm; this concentration is about 280 times higher than the total concentration of these compounds in the water column (Table 2 and Table 1).

After 5 weeks of such exposure, the average concentration of monocyclics increased to over 44 ppm. In addition, there was considerable accumulation of unidentified low-boiling-point petroleum hydrocarbons. Concentrations in one flounder liver of all low-boiling-point petroleum compounds (monocyclics included) was over 300 ppm (Figure 5). None of

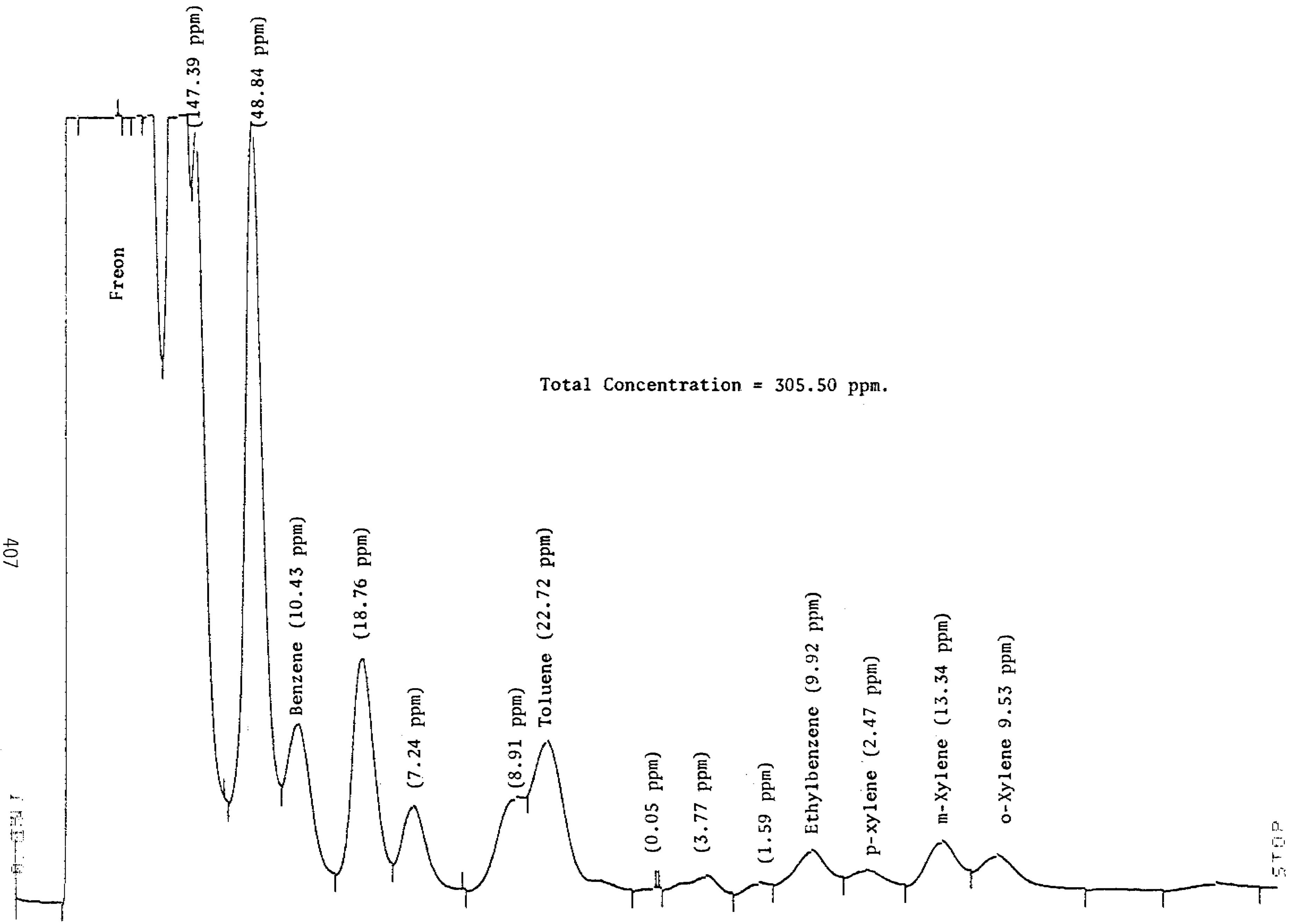


Figure 5. Chromatogram of low-boiling-point hydrocarbons detected in the liver of a starry flounder exposed to 100 ppb WSF in the water column and fed WSF-contaminated clams for 5 weeks.

the unidentified compounds was ever detected in any of the water samples (GC sensitive to about 10 ppb).

Growth of flounder in chronic exposure experiments

Flounder grew under all treatment conditions and no treatment group grew at rates significantly different from any other or from the controls. At the end of the 5-week exposure period flounder had grown an average of 4.6% (length) and were 19.5% heavier than at the start of the experiment.

B. EXPERIMENT 2B: Uptake, retention, and effects of chronic exposures to low levels of WSF of Cook Inlet crude oil to littleneck clams.

Analyses of over 200 clam tissue samples from the 3-week exposure test and flounder food exposure tank are in progress. Three clam samples and 1 shrimp tissue sample were extracted to determine an estimate of tissue concentrations of mono-and dicyclic-aromatic concentrations to be expected after 2 weeks of exposure to water concentrations of 100 ppb WSF. Naphthalene was the only dicyclic detected in the tissue. Concentrations in the clam samples were 59.5 ppb and 87.2 ppb; concentrations in the shrimp sample were 178 ppb. The concentration of naphthalene in the water column was approximately 2.5 ppb. The total monocyclic concentration for the one clam sample examined was 2,518 ppb with 86% of this concentration attributed to toluene.

During the 21-day continuous exposure, water concentrations of the 6 monocyclic aromatics in the test tanks averaged 179.0 ppb ($\pm$67.7) and 132.1 ppb ($\pm$ 46.5).

V. Preliminary Interpretation of Results:

It is clear that flounder accumulate low-boiling-point compounds much more rapidly through the water column than they do through molluscan food items. It is also apparent that monocyclic aromatic hydrocarbons are either metabolized into other compounds during digestive uptake or else they are not taken up through that pathway (radioisotope work is necessary to determine which of these hypotheses is correct--we suspect the former is true).

A number of unidentified compounds was detected in GC analysis of tissue samples. Because these peaks were not detected in water samples or control tissue samples, we suspect that they are metabolic breakdown products of petroleum hydrocarbons. These compounds will be identified during the next quarter either by GC-MS or by determining their Kovat's indices on two or three packed columns.

Flounder were not visibly affected physiologically or behaviorally by the chronic exposures to which they were subjected. However, we would not rule out adverse affects at the cellular or subcellular level as we were not equipped to make those types of measurements.

It was not clear whether flounder had reached maximum accumulation of petroleum hydrocarbons (and metabolites) after 5 weeks of exposure. Further analyses of tissues for monocyclic and dicyclic compounds must be made before any major conclusions can be drawn.

VI. Problems Encountered/Recommended Changes:

Turn-around-time on samples sent to the National Analytical Laboratory (NAL) for analysis has been unsatisfactory. We still have not received complete analyses of any samples even though we began sending samples there in March 1977. We have begun to process samples in-house and now send split samples to NAL, keeping half of each sample to analyze ourselves. However, we still need GC-MS confirmation of the identity of compounds identified in our chromatograms.

Problems encountered earlier with emulsified tissue samples (monocyclic analysis) were eliminated after experimentation with various drying agents (see methods section of this report).

Many compounds were present in water samples and presumably tissues in levels that were below our level of detectability (approximately 10 ppb). Concentrations of these compounds had to be estimated from knowing the concentration of the compound in solubilizer samples and the dilution necessary to produce 100 ppb in tank concentrations. This method is questionable because we could not accurately assess losses of components through volatilization, ionization, or adsorbtion at the tank level. As this report was being written, initial tests were being completed of a photoionization detector on our GC. Preliminary results indicated that all monocyclic components were detectable in exposure tank extracted water samples. This increased sensitivity is about 100-1000 times better than we were able to attain using a conventional flame ionization detector. Water and tissue samples will be re-tested through the new detector and results will be included in the final report.

VII. Estimate of Funds Expended:

All funds have been spent.

APPENDIX

Analytical Methods
National Analytical Laboratory

Water Analysis Procedure:

A. Freon extraction - to be used when determining the concentration of treatment tanks. Good only for the 6 monoaromatic hydrocarbons.

   1. Place 1 liter of water sample in a clean, Freon rinsed separatory funnel.

   2. Extract 1ℓ sample with 10 ml. of Freon, 4 ml of HCl and recovery standard.

   3. Drain off the Freon layer into a glass vial and tightly cap.

   4. Extract the same 1ℓ samples 2 more times following Steps 1 and 2.

   5. Load one or two GC autosampler vials for each extraction.

   6. Load autosample and inject into GC.

B. Seattle's National Analytical Lab's method - to be used for analysis of the diaromatic and larger polynuclear aromatic compounds.

PROCEDURE: EXTRACTION OF HYDROCARBONS FROM WATER

1. Pour sample into clean, solvent-rinsed graduated cylinder and determine volume.[A]

2. Pour sample from graduate into clean, solvent-rinsed separatory funnel.

3. Rinse sample bottle + graduate 2X with $MeCl_2$ and add this to the separatory funnel.

4. Spike sample with recovery standard.

5. Add 4 ml $MeCl_2$ per 100 ml sample and shake vigorously for 2 min.

6. Draw off $MeCl_2$ layer into clean, solvent-rinsed (dry) ehrlenmeyer flask with ground glass mouth.

7. Repeat 5 and 6 twice using 2 ml of $MeCl_2$ per 100 ml of sample.

8. Place snyder column on ehrlenmeyer and evaporate to ∿10 ml and transfer to a clean, solvent-rinsed concentrator tube, rinsing ehrlenmeyer 2X with $MeCl_2$, and concentrate to ∿1 ml.[B]

9. If SiO_2 fractionation is desired: Add 2 ml hexane and concentrate to 1 ml. Now it is ready for SiO_2.

If SiO_2 fractionation is not desired: Add ISTD to give a final concentration of ∿8 ng/μl, read volume, vial and cap. Sample is now ready for analysis.

A. The sample must be taken in a container that is the size of the sample to be analyzed. It must be filled and sealed with a Teflon screwcap. The sample must be preserved with 5 ml HCl (or to a pH of ∿2) and stored in a refrigerator until analyzed.

B. Use special Snyder column, ebullator, and heat sample from tip only.

Tissue Analysis Procedure:

A. Freon extraction method - still in developmental stage.
It will be used to determine monoaromatic concentrations of tissues.
The general format is as follows:

1. Place 10 grams of tissue into a screw-cap centrifuge tube.
Add 6 ml. of 4N NaOH, 4 ml of Freon, and recovery standard.
Cap the tube tightly.

2. Shake vigorously for 1 min. Then digest for 18 hr. at 30°C.

3. Centrifuge at 3000 RPM for 10 min.

4. Transfer Freon layer to another centrifuge tube and repeat Step 3.

5. Remove the Freon without disturbing any water on contaminate layer to a clean screw-cap tube.

6. Place 0.5g. of sodium sulfate in tube to remove any water in the Freon layer.

7. Transfer to a clean screw-cap tube and add internal standard.

8. Inject into a GC column designated for "dirty" tissue samples.

B. MacLeod et al. Seattle extraction method:

To be used for analysis of Dicyclic and larger aromatics, and for all samples sent to Seattle.

Tissue Extraction

Mussels. Pry open the shells with a clean spatula and separate the two halves by severing the adductor muscle. Scrape the tissue from the shell into a tared 100 ml beaker for compositing with other individuals.

Snails. Place specimens between several sheets of clean foil and crack the shells by striking them firmly with a hammer. Remove the shell fragments (with clean forceps or spatulas), peel off the foot and deposit the tissue in a tared 100 ml beaker. The remainder of the procedure is identical for both molluscs.

Transfer the tissue sample to a homogenizer tube and blend with the homogenizer at medium speed for at least 30 seconds. Return the tissue to the original pre-tared beaker and weigh to assure that the sample amount is sufficient for the procedure. Weigh 10 g (to nearest 0.1 g) of sample into a tared 40 ml screw-capped centrifuge tube. Add 6 ml of 4N sodium hydroxide to each sample and to one empty tube for a reagent blank. Cap each tube tightly with a Teflon-lined screw cap, shake vigorously for 1 min, and place each sample tube in an oven at 30°C for 18 hr (overnight). Cool the samples to room temperature and shake to check completeness of digestion. If well digested, add 15 ml of peroxide-free diethyl ether, recap tubes tightly, and shake vigorously for 1 min. Check the caps for tightness, then centrifuge the tubes at 3000 RPM for 10 min. If the upper ether phase is clear, transfer it with a Pasteur pipet to a 1 oz sample bottle equipped with a Teflon-lined screw cap. Avoid any carryover of the lower aqueous plase. If the supernatant ether phase is not transparent, see note 1 below before proceeding. Add approximately 0.5 g of anhydrous sodium sulfate to each bottle without agitation or swirling. Repeat the extraction with 10 ml of ether and combine the extracts. Cap the bottles tightly, swirl briefly and allow to settle for 10-15 min. A persistant turbidity indicates the presence of residual water which must be removed by additional anhydrous sodium sulfate before proceeding (see note 2 below).

Transfer the dried ether extracts to a 25 ml concentrator tube, attach the reflux column, and add a micro-ebullator (boiling tube). Place the apparatus in the tube heater at 80°-85°C (see note 2). Shroud the apparatus with aluminum foil to enhance distillation. Concentrate the solution to 2 ml and remove concentrator tubes from the heater. Add 2 ml of hexane and a second micro-ebullator, and concentrate to 1.8 ml to completely remove the ether. If the extract is turbid or viscous, column flow will be restricted. Such a sample should be dissolved in methylene chloride and filtered through a short (1-2 cm) silica gel column with methylene chloride. A bed of silica gel on a small fritted-glass (coarse) Buchner funnel is suitable. The methylene chloride solvent in the eluate should then be concentrated and displaced by hexane. The sample is now ready for microgravimetry and silica gel chromatography.

Notes:

1. If the emulsion layer is small, remove clear ether layer and proceed to the second extraction. If the emulsion is extensive, add about 1 g anhydrous sodium sulfate to the mixture and shake and centrifuge as before. Transfer the clear supernatant ether phase to the 1 oz bottle and proceed with the second extraction.

2. Care must be taken to avoid bumping during evaporation to avoid loss of the sample. Incomplete removal of water is the principal cause of this bumping, as indicated by the turbidity noted earlier. During evaporation, residual water comes out of solution as a separate phase at the bottom of the concentrator tube. This phase plugs the ebullator and halts boiling, leading to overheating and bumping. The remedy is to dry over more anhydrous sodium sulfate for a longer time and to carefully transfer the ether phase, avoiding any aqueous phase. In extreme cases, a double-ended ebullator may be used.

Silica Gel Chromatography

Column Preparation. Prepare columns immediately prior to use. Fill a column to the flare in the reservoir with methylene chloride. Push a 0.5 cm glass-wool plug to the bottom of the column with a glass rod. Measure 15 ml (7 g) of 100-200 mesh silica gel (activated at 150°C for 24 hr, then cooled in a dessicator) into a 25 ml graduated cylinder and transfer to a 250 ml erlenmeyer flask. Add 25 ml of methylene chloride and swirl vigorously to make a slurry. Place a long-stem funnel into the column such that the tip rests off-center on the bottom of the reservoir just below the surface of the methylene chloride.

Quickly pour the slurry into the funnel and wash the residual slurry into the funnel with methylene cnloride from a Teflon wash bottle. The adsorbent particles should quickly settle to the bottom of the column with little turbulence at the settling front. When the settling front extends upward about 1 cm from the glass-wool plug, slowly open the stopcock to a flow of 1-2 drops per second. Collect the eluate in an erlenmeyer flask to minimize solvent vapor escape. Swirl the column reservoir gently to wash the particles into the column. When the settling front reaches the top of the suspended particles, open the stopcock all the way to complete the settling. Add about a 1 cm layer of clean sand through a funnel to the top of the gel, followed by an equal amount of anhydrous sodium sulfate.

When the methlene chloride surface is just above the top of the sand, add a ml of petroleum ether with a Pasteur pipet and allow to drain. When the liquid level again almost reaches the top of the sand, add 40 ml of petroleum ether and continue to elute. Close the stopcock when the solvent meniscus almost reaches the top of the column. Discard the rinse elutes. Cover the column with aluminum foil until use.

Sample Chromatography. The sample extract should be in 1-2 ml of hexane in the concentrator tube. Crush the ebullator with a glass rod and rinse the rod with a small amount of petroleum ether. Carefully transfer the extract solution with a Pasteur pipet to the top of the column and elute. Never allow the liquid meniscus to go below the upper surface since air will be entrapped, which will disrupt the column. Rinse the concentrator tube with 0.5 ml of petroleum ether and add to the column. Open the stopcock and collect the eluate in a clean 25 ml concentrator tube. When the meniscus just reaches the column top, carefully add 15 ml of petroleum ether. Care must be exercised not to disturb the upper surface of the column during each addition. When the meniscus again just reaches the sand, add 3 ml of 20% (V/V) methylene chloride in petroleum ether. Elute solvent at 2-4 ml/min to separate the saturated from the unsaturated hydrocarbons. When 18 ml has eluted into the concentrator tube receiver, replace it with a second tube. This 18 ml eluate, referred to as fraction 1, contains the saturated hydrocarbons. As the meniscus again just reaches the top, add 25 ml of 40% (V/V) methylene chloride in petroleum ether. This eluate, fraction 2, will contain the unsaturated and aromatic hydrocarbons. A transparent extract, when applied to the column, will elute in less than 30 minutes.

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INFLUENCE OF PETROLEUM ON EGG FORMATION AND EMBRYONIC DEVELOPMENT IN SEABIRDS

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INFLUENCE OF PETROLEUM ON EGG FORMATION AND EMBRYONIC DEVELOPMENT IN SEABIRDS

Project Report for the period 1 March 1977 to 31 October 1977

TO: National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program, Boulder, Colorado 80302

SUBMITTED BY: Point Reyes Bird Observatory, Stinson Beach, California 94970
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PRINCIPAL INVESTIGATORS: D. G. Ainley (PRBO) and C.R. Grau (University of California, Davis, California 95616)

This study is an attempt to appraise the effects that a brief exposure to an oil spill would have on the reproduction of Cassin's Auklets (Ptychoramphus aleutica) and on Western Gulls (Larus occidentalis) nesting on the Farallon Islands of California. These species are representative of many birds breeding along the Pacific Coast that are at risk from oil pollution during the reproductive period.

Females of breeding pairs of auklets were dosed with bunker C oil or empty capsules as controls, and egg production, hatching success, and fledging success were determined. Samples of eggs were compared in regard to yolk structure, presence of oil components, and embryonic development, and were related to observations made previously at UCD with Japanese quail.

Attempts to dose gulls were unsuccessful.

Methods of detecting oil components in egg yolk have been developed in preparation for further field studies of bunker C and Prudhoe Bay crude oil effects on auklets.

Investigators in the field work on the Farallon Islands were Steve Morrell (PRBO), Tom Roudybush (UCD), Ron LeValley (PRBO) and Joan Dobbs (UCD); in the laboratory work, Tom Roudybush and Tom Wootton (UCD).

CASSIN'S AUKLET STUDY

During the 1977 breeding season on Southeast Farallon Island, 251 female Cassin's Auklets (Ptychoramphus aleutica) were force-fed gelatin capsules that were empty or contained 300 mg or 600 mg bunker C oil. These birds and their eggs and chicks were observed throughout the breeding season, as were birds in a control group. No significant differences in laying, hatching or fledging success were observed among the four groups.

Methods.

In January and early February 1977, 300 Cassin's Auklet burrows were selected and altered to allow human access. An additional 80 control burrows, studied since 1972 and in which birds were not given oil or capsules, were used to compare the effects of force feeding. Beginning in mid-March, all burrows were checked every other day until the first egg was found. On the night of 31 March we began our program of dosing at least 30 female auklets per night.

Each study burrow was checked until a pair of birds was found. We sexed the pair by measuring the bills with calipers. This method was proved reliable by analysis of specimens in museums. If the bill lengths were not distinctly different (an uncommon event), the bill depth was also measured. The bird with the smaller bill of each pair was assumed to be the female. She was force fed one of three possible experimental doses -- an empty capsul or a capsule containing 300 mg or 600 mg bunker C. Both members of the pair were then returned to their burrow. The type of dose was alternated in sequence (600 mg, 300 mg, empty capsule) so that equal numbers of each treatment were administered each night. Dosing was completed on 7 April after eight successive nights of work.

All experimental burrows were checked daily for eggs through 14 April, after which they were checked every four days. The control burrows were checked every other day throughout the study. When an egg was found, the burrow was not checked again for 38 days (to determine incubation period and/or hatching weight) or 42 days (to determine hatching success). Hatching weight was measured to the nearest 0.5 gram with a Pesola spring scale which was checked daily for accuracy with an electronic balance. After hatching, at least 10 chicks from each group were weighed daily (when alone) until fledging, others were weighed beginning shortly before fledging and others were checked only to determine fledging success. In all comparisons of times, weights and success, only the first egg laid is considered and only if it was laid on at least the second day after a selected experimental dose was administered.

The following definitions apply to this study:

Incubation period is the first day the egg is found until the day before the chick is found free of its egg shell;

Nestling period is the first day the chick is found until the chick is fledged;

Hatching weight is the weight of a chick on the first day it is found (within 24 hours of hatching);

Fledging weight is the weight of a check on the last day it is in its burrow before fledging;

Maximum number of eggs possible equals the number of females dosed minus the number of burrows that collapsed before an egg was laid;

Maximum number of eggs possible to hatch equals the number of eggs laid minus the number of eggs collected and the number of burrows collapsed, filled in, or where checking was discontinued.

Results.

The data for breeding success in each of the four groups are summarized in Table 1. Chi square tests of the four groups in all possible combinations of two showed no significant differences between any two groups for either hatching or fledging success.

No differences were apparent in timing of egg laying following treatment for any of the three treatment groups (Table 2). However, when date of egg laying is considered (Table 3), there appeared to be a slight delay in onset of laying as the oil dosage was increased. This cannot be considered significant. Egg laying in the group given empty capsules and in control group were similar. The first egg for the control group was laid on 3 April, while the first eggs (after treatment) for the three groups dosed were -- empty capsule, 3 April; 300 mg, 5 April; 600 mg, 2 April (second egg in this group laid 7 April). The discrepancy in onset of egg laying disappeared within the first two weeks.

Discussion.

An examination of Table 1 shows that most of our attention to hatching and fledging success, period and weight was directed to the group of eggs lai 2-7 days after dosing. Since yolk formation in the Cassin's Auklet eggs take eight days (Roudybush and Grau, 1977), we felt that the effects of various treatments would be most apparent in this group. However, no major differences were found. The incubation periods, fledging times and fledging weights are comparable in all groups and are also comparable with the findings of Manuwal (1972) from his studies on S.E. Farallon in 1969-71: Mean incubatior period--37.8 days (range 37-42; n=86); fledging time--41 days; fledging weigh --158 grams. The hatching weight data for the three treatment groups are also comparable with each other and with Manuwal's figure of 21 grams.

Although there appeared to be a slight delay in the onset of egg laying with increased oil dose (Table 3), the effect cannot be considered significar Delayed egg laying can be important to breeding success, however, since late breeders always do very poorly (PRBO unpublished data).

The procedures of bill measurement, dosing and checking for egg laying apparently did not cause birds to abandon their burrows, nor to affect experimental birds in other ways, when done in the manner used by us. All sixty birds (30 pairs) handled the night of 31 March were banded with numbered aluminum leg bands. Seventeen of those 30 burrows were checked on the night of 16 June. Of the 34 adults that could have been present in the 17 burrows, 29 adults were found in 16 burrows; only one burrow was vacant. Of the 29 adults, 28 were birds originally treated and banded. The one unbanded bird was with a banded female that had produced an egg that did not hatch. These data indicate that the auklets can tolerate well the level of disturbance to which we exposed them.

Some burrows in loose soil were destroyed by our activity. We also suspect that we caused some abandonment of eggs when we made repeated checks to determine exact date of hatching and hatching weight.

The incubation periods and hatching weights did not differ significantl among the groups. Samples of eggs that failed to hatch were taken to Davis for examination of egg contents. Most of the embryos were macerated or decomposed. No pattern of causes of death was found.

Definitive chemical analyses of auklet eggs for presence of oil components have been delayed until techniques are developed using quail and other laboratory birds, as detailed later in this report. Preliminary data indicate, however, that no significant amounts were incorporated into auklet eggs.

WESTERN GULL STUDY

The field observation on the effects of the oil on gulls confirmed the 1976 results in which dosing became the principal problem. In the present year, capsules containing oil were coated with hydrogenated vegetable oil to lengthen time of capsule solution, and the capsules were sewn inside small squid. The gulls readily took the squid. As soon as the capsule dissolved and the oil was released, the squid, now covered with oil, was regurgitated, and was eaten by the mate or another bird. Within a few seconds it was regurgitated again. Sometimes this was repeated several times. This study convinced us that dosing gulls by capsule is fruitless. Other small trials with gulls included snaring and smearing with oil on the head and necl and injecting the oil intraperitoneally into two birds. All these gulls abandoned their nexts. Another potentially more useful technique that is still being evaluated was to coat the first egg laid with oil, and after the female incubated it overnight thus coating the brood patch with oil, the egg was removed. Eggs laid subsequently were collected for chemical analysis and observation of yolk structure. Results are not yet complete, but they do not appear to be promising.

FATE OF INGESTED OIL

Following the observations of gull behavior in regurgitating oil, auklets and other birds were also studied. To determine the time which is required for elimination of oil from the guts of auklets, birds were captured at random at night and placed in cardboard boxes covered with netting. The auklets were fed 600 mg of bunker C oil and observed until the oil was passed in their feces. The auklets began eliminating the oil at a mean time of 36 minutes after being fed (Table 4).

Adult Japanese quail reared in cages and adult pen-reared mallards deprived of food for 16 hours (overnight) were compared in their responses to oil with fed birds, with the results shown in Table 4. It will be noted that fed quail took a mean of 177 minutes before eliminating oil while unfed quail took only 29 minutes. Mallards responded differently: feeding did not affect passage time.

Black-footed Albatrosses and Common Murres that were being cared for in preparation for release were also dosed. The numbers are small, and two of the albatrosses were found later to be infected by bacteria, but their responses appeared to be different from the other birds studied. The murres reacted violently to the oil dose.

If the same relationship between oil retention times in fed and unfed quail holds for fed and unfed auklets, fed auklets would be expected to retain oil for three hours before beginning to eliminate it. This would greatly extend the time of the auklet's exposure to oil and would expose the auklet at a time when it is actively absorbing nutrients. This may increase the toxicity of oil to both the auklet and any egg which it is forming at the time of exposure.

STRUCTURAL AND CHEMICAL EXAMINATION OF YOLKS

Auklet eggs collected during the critical period of 2-7 days after dosing with bunker C oil were frozen, fixed in formalin, and examined for structural changes such as those observed in eggs laid by quail after being dosed with bunker C (Grau, et. al., 1977). No characteristic features could be detected. At that time, before hatching data were obtained, we had the first indication that auklet responses were different from those of quail given comparable doses of oil. This lack of effect spurred our interest in developing chemical methods that would detect hydrocarbons or metabolites of petroleum compounds in eggs if they are present, and quantifying the amounts present.

Eggs of quail and chickens that had been given single doses of bunker C oil were treated and extracted, and various techniques were used to detect compounds that might be unique to petroleum-fed birds. The richness of egg yolk in triglycerides, phospholipids, sterols, and pigments complicates the extraction and treatment processes, and makes difficult detection of hydrocarbons and their metabolites in extracts prepared from yolks.

Much of our laboratory work and all of our field work to date has utilized bunker C oil as the potential spill component. This material is recognized as being potentially harmful to birds because of its toxicity, viscosity, adhesiveness, and its ubiquitousness as a fuel oil for ships. It constitues a significant component of the petroleum in commerce.

From experiences in other laboratories (Ehrhardt, 1972; Neff and Anderson, 1975; Warner, 1976), we presumed that ultraviolet absorption and gas chromatographic analyses of saponified, Florisil-treated extracts would be the most likely methods of differentiating between eggs of control and oil-fed birds, but early attempts were not successful. The high lipid content of egg, and the presences of interfering substances thwarted these efforts to find oil components.

Yolks from oil-treated quail and chickens were found to differ from normal yolk in appearance and response to solvents. "Oil" yolks were lighter in color than normal. Denaturation and initial extraction of the thawed yolk with acetone, as part of phospholipid studies, resulted in a stringy texture as compared with the normal crumbly appearance. No major differences were found in phospholipid distribution (by thin-layer chromatography) or by ultraviolet absorption of extracts containing primarily triglycerides or phospholipids.

Our most recent attempts to detect oil components in yolk have been more encouraging. We are now able to detect differences in fluorescence of extracts prepared from "oil" and normal eggs after thin-layer chromatography of yolk extracts that have been cleaned with alumina and silica gel. The present method has not been tested extensively, and will no doubt be modified later. Differences have also been found in gas chromatographic analysis of these extracts, indicating that many petroleum hydrocarbons are incorporated into eggs.

Methods.

A 500 mg sample of frozen yolk was dried in a vacuum oven at 60^{o} for 8 hours, or alternatively, a sample of yolk that has been fixed in 4% formalin after freezing (Grau, 1976) was used without drying. The sample was extracted by agitation in a beaker with 15 ml of petroleum ether, then with 15, 10, and 10 ml portions, and the extract was filtered into a flask. A mixture of 750 mg aluminum oxide G (E. Merck) and 750 mg silica gel (Absorbosil-3) both washed twice with petroleum ether, were added to the extract, shaken several times, filtered into a beaker, the solvent was evaporated, and transferred with isopentane to one spot on an activated silica gel plate scored with vertical grooves to prevent cross contamination. The plate was developed with isopentane: isopropanol: chloroform (100:1:0.2) and observed in ultraviolet light (253 nm).

Results.

Extracts from normal eggs showed some dark orange fluorescence at the front; those from quail or chickens fed bunker C showed a bright, light blue fluorescence. Spectrophotofluorometry of eluates of these spots is now being developed. Gas chromatrographic analyses of extracts show differences between normal and "oil" yolks, but only preliminary results are presently available (GC work in collaboration with W.G. Jennings, Dept. Food Science and Technology, UCD).

In addition to the eggs from quail or chickens fed bunker C, fluorescence differences are apparent from Prudhoe Bay crude oil fed to quail, and Kuwait crude oil and South Louisiana crude oil fed to ducks (Duck eggs kindly submitted by W.N. Holmes, University of California, Santa Barbara, from mallards chronically fed 1% oil).

Several auklet eggs from dosed and control birds have been extracted and examined for fluorescence, but no differences have been found. Because the number of eggs laid during the 2-7 day post-dose period was low, the results cannot be considered as conclusive.

PROBLEMS ENCOUNTERED AND PROPOSED SOLUTIONS

The major problem in the auklet study was related to elimination of oil by the birds before effects could have been caused. Preliminary indications are that Cassin's Auklet do not retain petroleum in their bodies, and so apparently suffer no detrimental effects in terms of breeding success. However seabirds are far more likely to be exposed to petroleum while feeding at sea than while at their terrestrial breeding sites. In 1978, we therefore plan to feed some auklets small amounts of euphausiids (their normal diet) at the same time they are fed petroleum. The petroleum may be retained longer if food is also present in the stomach, as would be the case of birds exposed to oil while feeding at sea. We suspect that Cassin's Auklets coming ashore at night at the start of the breeding season may do so with empty or nearly empty stomachs.

The regurgitation responses of Western Gulls present such major problems that this part of the original plan will be abandoned for the present.

Although it is now possible to detect oil components in eggs, it is not possible to assess the various effects on reproduction to particular components of refinery products or of crude oils. Bunker C adversely affects egg production, shell quality, and embryo survival of quail (Grau, et al., 1977), but Prudhoe Bay crude oil affects only aspects of reproduction other than embryo survival (Engel, et al., 1977). Further studies of the effects of various fractions of bunker C embryos will be pursued, in order to provide baseline information that can be applied to wild birds at risk from potential oil spills.

The encouraging recent results with photofluorimetric and gas chromatographic analyses are expected to be improved by high pressure liquid chromatographic analyses, which will soon be applied to egg extracts with the collaboration of W.G. Jennings.

References

Ehrhardt, M. 1972. Petroleum hydrocarbons in oysters from Galveston Bay. Environ. Pollution 3:257.

Engel, S.W., T.E. Roudybush, J.C. Dobbs, and C.R. Grau. 1977. Depressed food intake and reduced reproduction in Japanese quail following a single dose of Prudhoe Bay crude oil. Presented at the 17th Hanford Biology Symposium, Richland, Washington, Oct. 17-19.

Grau, C.R. 1976. Ring structure of avian egg yolk. Poultry Science 55:1418.

Grau, C.R., T. Roudybush, J. Dobbs, and J. Wathen. 1977. Altered yolk structure and reduced hatchability of eggs from birds fed single dose of petroleum oils. Science 195:779.

Manuwal, D.A. 1972. The population ecology of Cassin's Auklet on Southeast Farallon Island, Calif. Ph.D. Dissertation, UCLA. 298 pages.

Neff, J.M., and J.W. Anderson. 1975. in Proceedings of the 1975 Conference on Prevention and Control of Oil Pollution p. 469. American Petroleum Institute, Washington, D.C.

Roudybush, T., and C.R. Grau. 1977. Yolk formation in some Pacific seabirds and shorebirds. Presented at Pacific Seabird Group meeting, Asilomar, Calif., Jan. 7-9.

Warner, J.S. 1976. Determination of aliphatic and aromatic hydrocarbons in marine organisms. Anal. Chem. 48:578.

Table 1. Breeding success of treated and control Cassin's Auklets - 1977

	Empty gelatin capsule	300 mg Bunker C	600 mg Bunker C	control
# of females dosed before first egg laid	86	84	81	-
maximum # of eggs possible to be laid	82	75	78	79
Total # of eggs laid	80	72	77	75
% eggs laid of possible maximum	98	96	99	95
# eggs laid 2-7 days after dosing	21	27	25	-
% eggs laid 2-7 days after dosing	26	38	32	-
maximum # of eggs possible to hatch	74	68	66	74
total # of eggs hatch	51	57	48	62
% eggs hatch	69	84	73	84
maximum # of 2-7 day eggs possible to hatch	19	26	23	-
# of 2-7 day eggs hatch	13	22	17	-
incubation period (days)	*38.9±1.6 N=10	*38.5±0.8 N=16	*38.9±1.2 N=12	38.4±0.9 N=55
hatching weight (grams)	*18.5±1.4 N=9	*20.0±1.9 N=14	*18.5±2.4 N=10	-
fledging time (days)	*43.0±3.8 N=9	*42.0±2.3 N=11	*44.0±1.9 N=11	41.0±3.1 N=48
fledging weight (grams)	*153.0±10 N=9	*149.0±12 N=12	*150.0±13 N=11	152.0±14 N=48
% fledging success	*90.0 N=10	*78.0 N=18	*85.0 N=13	87.0 N=55

* Data are for eggs laid 2-7 days after dosing only.

Table 2. Timing of egg laying by Cassin's Auklets following treatment

Dose	Total # eggs laid		Number of days between dosing and egg laying							
			2-7	8-13	14-19	20-25	26-31	32-37	38+	Un-known
Empty capsule	80	# of eggs	21	22	19	4	7	1	4	2
		% of total	26	28	24	5	9	1	5	3
		cumulative %	26	54	78	83	92	93	98	
300 mg Bunker C	72	# of eggs	27	18	12	8	1	3	0	3
		% of total	38	25	17	11	1	4	-	4
		cumulative %	38	63	80	91	92	96	96	
600 mg Bunker C	77	# of eggs	25	17	15	8	4	2	2	4
		% of total	32	22	20	11	5	3	3	5
		cumulative %	32	54	74	85	90	93	96	

Table 3. Cumulative percent of total number of first eggs laid by auklets

	Empty capsule (N=80)	300 mg Bunker C (N=72)	600 mg Bunker C (N=77)	Control (N=75)
April 1-2			1	
3-4	3			1
5-6	4	6		8
7-8	8	17	7	11
9-10	14	32	25	18
11-12	27	42	39	34
13-14	38	52	44	45

Table 4. Responses of several bird species to dosing with capsules containing bunker C oil

Species	Number of Birds	Time between dosing and Regurgitation		Time between dosing and Fecal Elimination	
		Mean	Range	Mean	Range
Cassin's Auklet[1] (*Ptychoramphus aleutica*)	10	-	-	36 min	12-82 min
Western Gull[1] (*Larus occidentalis*)	15	*	0-35 min	-	-
Common Murre[2] (*Uria aalge*)	3	10 min	7-13 "	18 min	7-33 min
Black-footed Albatross[2] (*Diomedea nigripes*)	3	-		10 hrs	6-20 hrs
Japanese Quail[3] (*Coturnix coturnix japonica*)	6 fed	-		177 min	143-226 mi
	5 unfed	-		29 "	11-67 "
Mallard[3] (*Anas platyrhynchos*)	6 fed	-		52 "	20-145 "
	6 unfed	-		46 "	31-79 "

*Upon contact with oil. Some oil was hidden in bait.
1) Dosed on S.E. Farallon Island.
2) Dosed at International Bird Rescue Research Center, Berkeley, CA.
3) Dosed at University of California, Davis, CA.

We observed by aspiration that no food was present in auklet stomachs at night. This information, together with data on passage time of oil in fed and unfed quail and mallards indicates that if auklets are similar to quail, then oil may have passed through the auklets too quickly to affect their eggs.

The cooperation of Alice Berkner of the International Bird Rescue Research Center is gratefully acknowledged.

QUARTERLY REPORT

BIOAVAILABILITY OF HYDROCARBONS AND HEAVY METALS TO MARINE DETRITIVORES FROM OIL-IMPACTED SEDIMENTS (RU 454)

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CONDITION INDEX AND FREE AMINO ACIDS OF *MACOMA INQUINATA* EXPOSED TO OIL-CONTAMINATED SEDIMENTS

Our study has shown that both condition index and certain free amino acids in *Macoma inquinata* were significantly altered by exposure to oil-contaminated sediments (Tables 1,2). Adequate sample size was an important factor in demonstrating statistically significant reductions in condition. The reduction in condition index in exposed clams, although small (~10%), provided evidence of a deterioration in nutritional state. A decrease in bivalve condition index is an indication that affected clams may have been in a state of negative-energy balance; in other words, metabolized energy exceeded energy consumed as food. Utilization of endogenous storage products such as tissue protein, lipid, and carbohydrates may have been necessary to provide the balance of the energy for metabolism under such conditions (Gabbott, 1976). Condition index of oysters and mussels have been closely correlated with tissue glycogen content (Walne, 1970; Gabbott and Stephenson, 1974; Gabbott and Bayne, 1973).

Using the criteria proposed by de Wilde (1975) for *Macoma balthica*, a value of > 10 represents good condition, ~8 moderate, and < 6 poor. If these criteria are applicable to *M. inquinata*, the clams in this study possessed mean values for condition index which ranged from good to moderate. Condition in bivalves is known to undergo seasonal variations which are reflective of reproductive and nutritional state (Walne, 1970; Trevallion, 1971; de Wilde, 1975). Periodic sampling of clams from our collection site during the course of this study indicated that condition index of our experimental clams,

Table 1. Condition index of *Macoma inquinata* exposed to oil-contaminated sediment in the second experiment. Exposure was conducted in the field only. (From Roesijadi and Anderson, 1978).

Treatment	Sample size (n)	Condition index
Control	91	8.92 ± 0.18 (S. E.)***
Exposed	50	7.46 ± 0.28

*** Significant at $p<0.001$; Student's t test

Table 2. Free amino acid content of *Macoma inquinata* exposed to oil-contaminated sediment in the second experiment. Conducted in the field only. (From Roesijadi and Anderson, 1978).

Amino acid	Concentration (μ moles/g) Control	Concentration (μ moles/g) Exposed	
Alanine	22.53 ± 1.82 (S.E.)	16.80 ± 2.02 (S.E.)	
Arginine	6.89 ± 0.40	4.56 ± 0.73	*
Aspartate	1.44 ± 0.17	0.90 ± 0.27	
Glutamate	2.72 ± 0.22	2.21 ± 0.19	
Glycine	70.25 ± 4.51	43.56 ± 4.99	**
Histidine	0.28 ± 0.03	0.22 ± 0.04	
Isoleucine	0.37 ± 0.02	0.32 ± 0.04	
Leucine	0.63 ± 0.05	0.48 ± 0.05	
Lysine	0.59 ± 0.04	0.41 ± 0.04	**
Methionine	0.20 ± 0.03	0.13 ± 0.02	
Phenylalanine	0.22 ± 0.02	0.19 ± 0.02	
Proline	0.57 ± 0.04	0.74 ± 0.25	
Serine	4.09 ± 0.41	3.24 ± 0.39	
Threonine	1.16 ± 0.05	0.87 ± 0.07	**
Tyrosine	0.37 ± 0.03	0.33 ± 0.03	
Valine	0.54 ± 0.04	0.44 ± 0.16	
Taurine	37.06 ± 1.94	35.08 ± 2.39	
Total	150.57 ± 8.15	110.48 ± 8.24	**
Taurine:Glycine	0.54 ± 0.04	0.89 ± 0.12	*

* Significant at $p<0.02$, Student's t test

** Significant at $p<0.01$, Student's t test especially those used in field exposures, were out of phase with the natural population. In general, clams in this study possessed lower condition index than those collected freshly at the times of experiment termination (13.79 ± 1.63 and 17.01 ± 0.78 for experiments 1 and 2, respectively). Thus, experimental manipulation also was a factor which influenced condition index of clams in this study. The effect of oil-exposure on condition was, therefore, either additive or synergistic with general experimental conditions.

Since arginine, lysine and threonine are considered to be essential amino acids (Mahler and Cordes, 1971), decreases in these substances in oil-exposed clams were also suggestive of alterations in nutritive state. Increased utilization of these amino acids, possibly in protein synthesis, by oil-exposed clams or a decrease in their ingestion with food may have accounted for our observations. The large decrease in glycine content in our oil-exposed clams was consistent with previous studies which examined free amino acid levels in marine animals subjected to pollutant or natural stresses (Jeffries, 1972; Roesijadi *et al.*, 1976; Bayne *et al.*, 1976). As a consequence of the decrease in glycine, the taurine:glycine ration was elevated in oil-exposed clams. The actual values of 0.54 ± 0.06 (S.E.) for control clams and 0.89 ± 0.19 (S.E.) for exposed clams in this study were not directly comparable to those reported by Jeffries (1972) or Bayne *et al.* (1976) since taurine levels in *Macoma inquinata* were much lower than those in the bivalves *Mercenaria mercenaria* and *Mytilus edulis* used in the other studies. Although taruine: glycine ratios may prove useful in identifying bivalves which have experienced stressful environmental conditions, it is evident that the cause of the change in the ratios is due primarily to alterations in glycine content. This pattern has been consistent in the studies conducted to date. Examination of glycine metabolism would certainly be useful in understanding this apparent stress response.

LITERATURE CITED

Bayne, B.L., D.R. Livingstone, M.N. Moore, J. Widdows. 1976. A cytochemical and biochemical index of stress in *Mytilus edulis* L. *Mar. Pollut. Bull.* *7*:221-224.

de Wilde, P.A.W.J. 1975. Influence of temperature on behavior energy metabolism, and growth of *Macoma balthica* (L). pp 239-256. *In:* Ninth European Marine Biology Symposium. H. Barnes (ed). Aberdeen Univ. Press, Great Britain.

Gabbott, P.A. 1976. Energy metabolism. pp 293-355. *In:* Marine Mussels: Their Ecology and Physiology. B. L. Bayne (ed). Cambridge Univ. Press, Cambridge.

Gabbot, P.A. and B.L. Bayne. 1973. Biochemical effects of temperature and nutritive stress on *Mytilus edulis* L. *J. Mar. Biol. Ass. U.K. 53:*269-286.

Gabbot, P.A. and R.R. Stephenson. 1974. A note on the relationship between the dry weight condition index and the glycogen content of adult oysters (*Ostrea edulis* L.) kept in the laboratory. *J. Cons. Int. Explor. Mer.* *35:*359-361.

Jeffries, H.P. 1972. A stress syndrome in the hard clam, *Mercenaria mercenaria.* *J. Invert. Pathol. 20:*242-287.

Mahler, H.R. and E.H. Cordes. 1971. *Biological Chemistry.* Harper and Row Publications, New York.

Roesijadi, G., J.W. Anderson, and C.S. Giam. 1976. Osmoregulation of the grass shrimp *Palaemonetes pugio exposed to polychlorinated biphenyls* (PCBs). II. Effect on free amino acids of muscle tissue. *Mar. Biol. 38:*357-363.

Trevallion, A. 1971. Studies on *Tellina tenuis* Da Costa III. Aspects of general biology and energy flow. *J. Exp. Mar. Biol. Ecol. 7:*95-122.

Walne, P.R. 1970. The seasonal variations of meat and glycogen content of seven populations of oysters *Ostrea edulis* L. and a review of the literature. Fishery Invest. Land, Ser. 2:35 pp.

QUARTERLY REPORT

Contract No. 03-6-022-35193

Research Unit No. 467

Reporting Period: 1 July 1977 - 30 September 1977

Number of Pages: 9

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October 1, 1977

Publications Resulting From This Work

Roesijadi, G., D.L. Woodruff, J.W. Anderson. 1978. Bioavailability of naphthalenes from marine sediments artifically contaminated with Prudhoe Bay crude oil. *Environmental Pollution (in press).*

Roesijadi, G., J.W. Anderson, J.W. Blaylock. 1978. Uptake of hydrocarbons from marine sediments contaminated with Prudhoe Bay crude oil: Influence of feeding type of test species and availability of polycyclic aromatic hydrocarbons. *J. Fish. Res. Bd. Canada (in press).*

Roesijadi, G., and J.W. Anderson. 1978. Condition index and free amino acid content of *Macoma inquinata* exposed to oil-contaminated marine sediments. *In:* 1977 Symposium on *Pollution and Physiology of Marine Organisms.* Georgetown, S.C., ed by Winoma and F.J. Vernberg, Academic Press, New York (in press)

BEAUFORT SEA BARRIER ISLAND - LAGOON

ECOLOGICAL PROCESS STUDIES

I. Task Objectives

This program's general objective is 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 studies are designed to (1) identify and analyze the importance of selected ecosystem components and processes contributing importantly to the structure and productivity of nearshore ecosystems, (2) evaluate the feasibility of detecting and quantifying temporal change in those ecosystem components and processes identified as important, and (3) identify mechanisms by which those components and processes could be tested for their sensitivity to man-caused change and, therefore, for their utility in predicting and analyzing impacts of OCS petroleum development.

An additional objective is to coordinate this program's design, research efforts, and data products with those of OCS Research Units No. 526, 529, 530, and 531.

II. Activities

A. Field Trip Schedule

Aquatic biology and ornithology field teams have continuously occupied the research camp on Pingok Island, 5 miles off the Beaufort Sea coast, for the duration of this quarter. Daily observations and data collections by these biologists in the vicinity of Simpson Lagoon have constituted the program's key field research efforts.

B. Scientific Party

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

Name	Affiliation	Project Role
Alan Birdsall	LGL Limited*	General Management
Joe Truett	LGL Limited**	Project Director
Tom Wetmore	LGL Limited*	Data Management
Carl J. Walters Ray Hilborn Sandra Buckingham Randall Peterman	Institute of Animal Resource Ecology Univ. of Brit. Columbia Vancouver, B.C.	Systems Analysis Modelling
Peter Craig	LGL Limited***	PI, Aquatic Ecology (Ecology of fishes Nutrient Dynamics)

Name	Affiliation	Project Role
William Griffiths	LGL Limited*	Aquatic Ecology (Ecology of fishes and benthos)
Lewis Haldorson	LGL Limited**	Aquatic Ecology
Stephen Johnson	LGL Limited*	PI, Ornithology
Gary Searing	LGL Limited*	Ornithology
John Richardson	LGL Limited****	Ornithology (Bird migration analysis)

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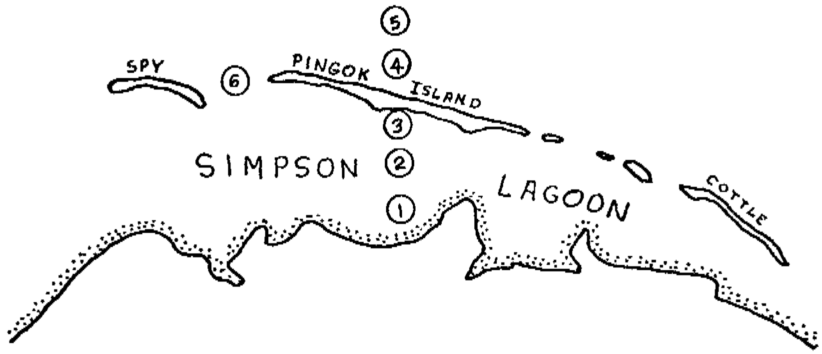
C. Methods

Described herein are methods used during the aquatic biology and ornithology field research portions of the program. General tactics used for program planning and integration were described in the last quarterly report.

Major portions of the field sampling for both aquatic biology and ornithology were accomplished from Zodiac inflatable boats, to a great extent, equipped with short-shaft outboard motors. Helicopter and fixed-wing aircraft were used for aerial bird surveys. Observations of marine mammals were routinely recorded during the course of aerial surveys.

Both aquatic biologists and ornithologists remain in the field as of the submission of this report. They will terminate this year's field research soon after 1 October.

Aquatic Biology. A variety of nearshore habitats were sampled in the Simpson Lagoon study area -- shallow lagoon near mainland, deep lagoon, shallow lagoon near island, shallow marine near island, deep marine ($\gtrsim$ 10 m). Six representative habitats were established as sampling stations (see next page for spatial pattern). The distribution and abundance of fishes (including ichthyoplankton) and important invertebrates were monitored at these stations at approximately 10-day intervals.



Spatial Pattern of Aquatic Sampling Stations

Fish sampling methods included fyke nets, variable-mesh gill nets, seines, and an otter trawl. Field analysis of specimens involved collection of standard life-history data: length, weight, sex, and reproductive condition. Stomach samples and otoliths (for age determination) were retained for laboratory analysis. Live fish were marked (Floy dart tags, opercular tags) and released for movement studies.

Sampling methods for invertebrates included an otter trawl (equipped with a small mesh liner) and zooplankton nets of several kinds (0.25 m zooplankton net, Faber trawl, surface 14 cm net). Collections were preserved in formalin and returned to the laboratory for analysis of numbers, weights and gross taxonomic groupings.

Surveys made by a diver in representative lagoon and nearshore marine habitats provided quantitative information on habitat partitioning by invertebrates, and distribution of benthic detritus and bottom surface sediments.

Digestion-rate experiments were performed, using Four-horned Sculpin, Mysids and Amphipods as test animals. The purpose of these experiments was to estimate food consumption rates of the organisms, and, thus, to evaluate rates of energy flows through the food web.

Ornithology. Observers documented, from positions on mainland beaches and on barrier islands, the use of the Jones Islands-Simpson Lagoon area by migrating and staging birds during spring and late summer. Radar observations of bird migration over the study area and surrounding areas were made in spring (last quarter) using the Oliktok DEW station equipment. Incidental observations of migration during the course of other duties was also recorded. During migration watches, observers recorded numbers, and behavior of, and habitat use, by all birds observed in the area. Information was transferred daily to computer forms developed by LGL, so that data could be readily analyzed with the aid of existing computer programs.

III. Results and Preliminary Interpretations

Results reported herein must be viewed as preliminary, in that supporting data are not yet available. The following presentations, therefore, reflect interpretations made by project biologists on the basis of trends in samplings to date.

General Processes. Several important processes brought to light by the summer's research appear to refute some assumptions of the initial mathematical model. Important differences between the simulation and the system as it now appears are noted below.

- The barrier island - lagoon system was originally viewed as being not greatly different functionally from other types of nearshore environments, e.g., those without barrier islands, etc. However, it appears that the lagoon is a discrete environment, different in several aspects from adjacent marine areas.

- The nature of nearshore water circulation appears to be generally as originally simulated. An assumption was that the frequent water exchange between sea and lagoon would rapidly flush the system of its non-mobile components, such as detritus. Research has revealed the contrary: The benthic detrital layer, seemingly important as a food chain base, apparently resists flushing.

- The detrital material appears to be more active biologically than originally thought (BOD is suprisingly high, for example).

- Some birds (Oldsquaw in particular) and, perhaps fish, as well, appear to prefer the lagoon, as opposed to the seaward side of the islands, for feeding. It was originally thought that the lagoon might afford only "protection" to molting ducks and was probably not unique in terms of bird food availability.

Aquatic Biology. As of 15 September 1977, 8,172 fish were caught, of which 2,799 were tagged and 1,422 were processed in the field laboratory. Twenty-four of the tagged fish have been recaptured. Fish processed in the laboratory were, by species, as follows. Stomach samples were taken from 1,280 of these.

255	Four-horned Sculpin
54	Arctic Flounders
36	Broad Whitefish
16	Humpback Whitefish
212	Arctic Cod
146	Least Cisco
520	Arctic Cisco
158	Arctic Char
25	Miscellaneous
1,422	TOTAL

Several general findings of this quarter's ornithological research are:

- Bird migration through the area appears similar in major respects to that in other areas and years along the southern Beaufort coast, and is, therefore, probably highly traditional and not likely to vary as much annually as does nesting, molting, and feeding distribution of birds.

- Abundant bird species in the area are few. Abundant/ecologically important species include Oldsquaw, Red and Northern Phalaropes, and Glaucous Gulls.

- The Oldsquaw, functionally probably the most important bird species in the ecosystem, appears to depend on the same types and size ranges of epibenthos as do the principal fish species.

- Few birds of any species collected were found to have eaten fish.

More conclusive support for the above observations, as well as additional conclusions based on field research, must await further analysis of data.

IV. Preliminary Interpretation of Results

Interpretation of results are presented in the preceding section.

V. Problems Encountered / Recommended Changes

Major problems centered around communication among disciplines. We anticipate focusing greater attention on integrative and communicative aspects of the program in the future.

Few insurmountable logistics problems arose within the biological research effort. However, some of the associated researchers reported that their efforts were severely hampered by logistics support difficulties.

VI. Estimate of Funds Expended

Estimated funds expended by 30 September are slightly more than half the budget for Phase II of the Barrier Island - Lagoon program.

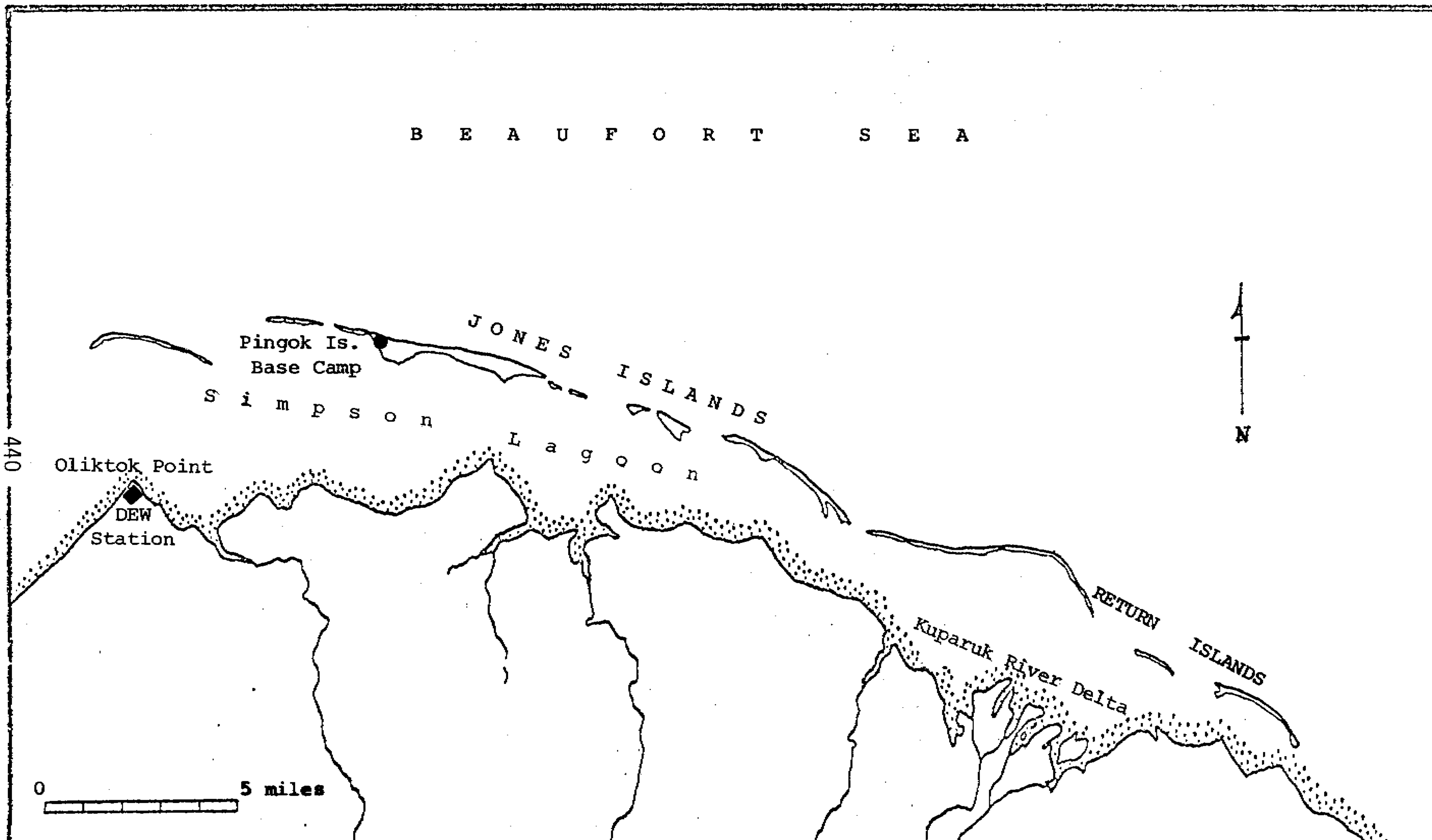


Figure 1. Location map of the Simpson Lagoon - Jones Islands study area.

Several general trends were evident. Sculpins were the most frequently caught fish in fyke nets. Fish catch per unit effort increased as the season progressed. Arctic Cod catches increased dramatically toward the end of the season (after 1 September). Fish movement through the area appeared, in general, to be highly variable; large numbers of fish might be caught one day and only a few the next.

The following observations made by the aquatic biologists appear important at this stage of the research program:

- Temperatures and salinities fluctuate rapidly in the lagoon, apparently because of the effects of wind-induced water mass exchange between the lagoon and ocean.

- Mysids appear to be the most abundant type of epibenthic organism in the lagoon and are the major food item for both fishes and key lagoon-feeding birds (Oldsquaw).

- A diver estimated, based on visual observations, that the number of Mysids per square meter of lagoon bottom ranged from 300-1000.

- Trawl samples indicate that epibenthic organisms in the lagoon abound in deeper waters (more than 2 m deep) early in the season, became more evenly distributed as the season progressed, and appeared to move from the shallow waters near the mainland by mid-September.

- Anadromous fishes (Char, Least and Arctic Cisco, Broad Whitefish) appeared to be more transient in the lagoon system than were Four-horned Sculpin. Arctic Flounder appeared to invade the lagoon area in mid-summer, and Arctic Cod were abundant only after 1 September.

- Fish movement eastward and westward appeared to be concentrated near the mainland shore, at least in early and mid-summer.

Ornithology. Approximately 60 active nests of several bird species were monitored on the islands and on mainland beaches. Nest success was low, primarily because of predation on eggs and young by Arctic Foxes (on some of the islands as well as on the mainland). Lemming abundances were very low; we speculate that rates of nest predation by Foxes might, consequently, have been unusually high.

Birds collected and processed by 15 September in the field laboratory for stomach analysis, condition, sex and age, were as follows.

79 Oldsquaw
27 Glaucous Gulls
56 Red Phalaropes
28 Northern Phalaropes
5 Semipalmated Sandpipers
1 Pectoral Sandpiper

Investigators searched for nesting birds on barrier islands near the end of the last quarter and during the first of this quarter. Several islands, each with different physical features important to nesting birds, were searched for nests. Physical features characterizing nest sites -- island size, distance from mainland and distance from other islands, relationships of nest and colony sites to spring break-up and snow-melt patterns, distance of nests from shore of islands, height above sea level, proximity to driftwood or vegetation, substrate material, nearness of nest to nest of same or other species, etc. -- were described by the ornithologists.

In addition to nesting-bird surveys on islands, censuses of migrating shorebirds using island and mainland beaches were made during August and early September.

Twice-monthly aerial surveys were made during the course of this quarter to characterize the aerial distribution of and habitat use by each species of large bird (ducks, geese, loons, gulls, Arctic Tern, jaegers) and by shorebirds as a group. Surveys were made from helicopter and fixed-wing aircraft. During these surveys two observers, one on each side of the aircraft, recorded all birds seen and distinguished whether they were within 100 m (terrestrial areas) or 200 m (marine areas) of the aircraft flight path. Each bird sighted was classified by species (and sex and age if possible), habitat, location, number, response to aircraft, and apparent activity (nesting, feeding, etc.). Each transect was divided into segments of uniform lengths to facilitate statistical comparisons between transects, and to more precisely position each bird sighted, so that aereal distribution of the birds could be accurately determined.

Stomachs of Oldsquaw, Glaucous Gulls, and shorebirds collected were preserved for food habits analysis. Epibenthic and water-column samples of invertebrates were taken where bird collections were made to correlate bird food habits with food availability.

D. Sample Localities

Sampling stations for the aquatic biology investigation are depicted under "Methods" of this report. Figure 1 depicts the Simpson Lagoon - Jones Islands area where the aquatic and ornithological investigation (as well as associated investigations of RU's 526, 529, 530 and 531) took place. Some of the aquatic and much of the ornithological sampling locations were site-of-opportunity within this general study area.

CONTAMINANT BASELINES

CONTAMINANT BASELINES

CONTENTS

RU #43

Report Not Received

Quarterly Report

Research Unit: #152
Reporting Period: 7/1/77 - 9/30/77
Number of Pages: 36

The Distribution, Composition, Transport and Hydrocarbon Adsorption Characteristics of Suspended Matter in the Gulf of Alaska, Lower Cook Inlet and Shelikof Strait

Principal Investigators: Richard A. Feely, Oceanographer
Joel D. Cline, Oceanographer

Pacific Marine Environmental Laboratory
3711 15th Avenue N.E.
Seattle, Washington 98105

October 1, 1977

I. Task Objectives

The major objectives of the suspended matter program include: (1) determination of the seasonal variability of the distribution and composition of suspended matter in Lower Cook Inlet and Shelikof Strait; (2) an investigation of the processes controlling resuspension and redistribution of bottom sediments; and (3) an investigation of the sorptive characteristics of Cook Inlet suspended matter for crude oil.

II. Field or Laboratory Activities

A. Field Activities

1. Ship Schedule

   ACONA-245 (27 June - 12 July 1977)

2. Participants from PMEL

   a. Dr. Joel Cline, Oceanographer

   b. Mr. Gary Massoth, Oceanographer

   c. Mr. Anthony Young, Oceanographer

   d. Ms. Jane Hannuksela, Oceanographer

   e. Ms. Marilyn Pizzello, Physical Science Aid

   f. Mr. Frank Swoboda, Electronics Technician

   g. Mr. Glenn Greathouse, Technician

   h. Mr. Albert Chapdelaine, Jr., Student, UW

3. Methods

   a. Particulate Matter - Water samples were collected in 10-liter Top-drop Niskin bottles and filtered under vacuum through preweighed 0.4 μm Nuclepore® and Selas® filters. The filters were removed from the filtration apparatus, placed into individually marked petridishes, dried in a desiccator for 24 hours, and stored for shipment to the laboratory.

b. Nephelometry - The vertical distribution of suspended matter was determined with a continuously recording integrating nephelometer. The instrument is interfaced into the ship's CTD system using the sound velocity channel (14-16 KHz). Continuous vertical profiles of forward light scattering were obtained in analog form on a Hewlett Packard 7044A X-Y Recorder. The signals from the CTD-Rosette system and the nephelometer were also simultaneously interfaced into the ship's data acquisition system. This resulted in computer listings of conductivity, temperature, depth, salinity, sigma T and light scattering for all of the stations.

c. Petroleum Hydrocarbon-Suspended Matter Interactions - Gram quantities of suspended matter were extracted from Lower Cook Inlet using a continuous flow centrifuge (operating conditions: 500 ml/min @ 17,000 rpm). The suspended matter was placed into 500 ml glass bottles with aluminum lined plastic caps and returned to the laboratory for subsequent interaction studies with Cook Inlet crude oil.

4. Sample Locations

Figures 1, 2, and 3 show the locations of the suspended matter stations in the northeastern Gulf of Alaska (DISCOVERER Cruise RP-4-Di-77A-III, 14-31 March 1977) and Lower Cook Inlet and Shelikof Strait (DISCOVERER Cruise RP-4-Di-77A-IV, 4-16 April 1977 and ACONA Cruise 245, 27 June - 12 July 1977). In Figure 1 stations B and D are the locations of the arrays which contain the current meters, nephelometers, and sediment traps.

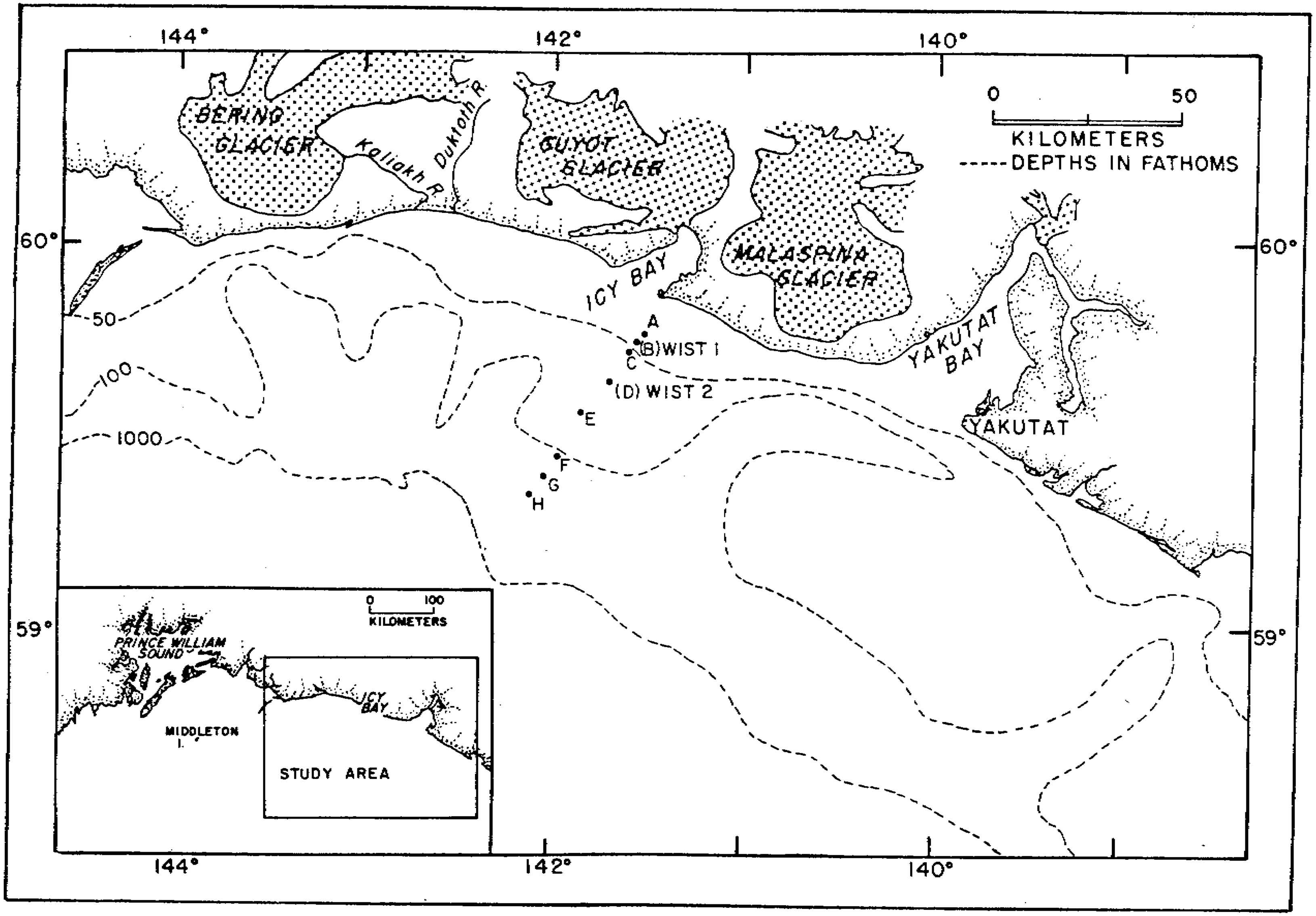


Figure 1. Locations of suspended matter stations in the northeastern Gulf of Alaska (RP-4-Di-77A-III, 14-31 March 1977).

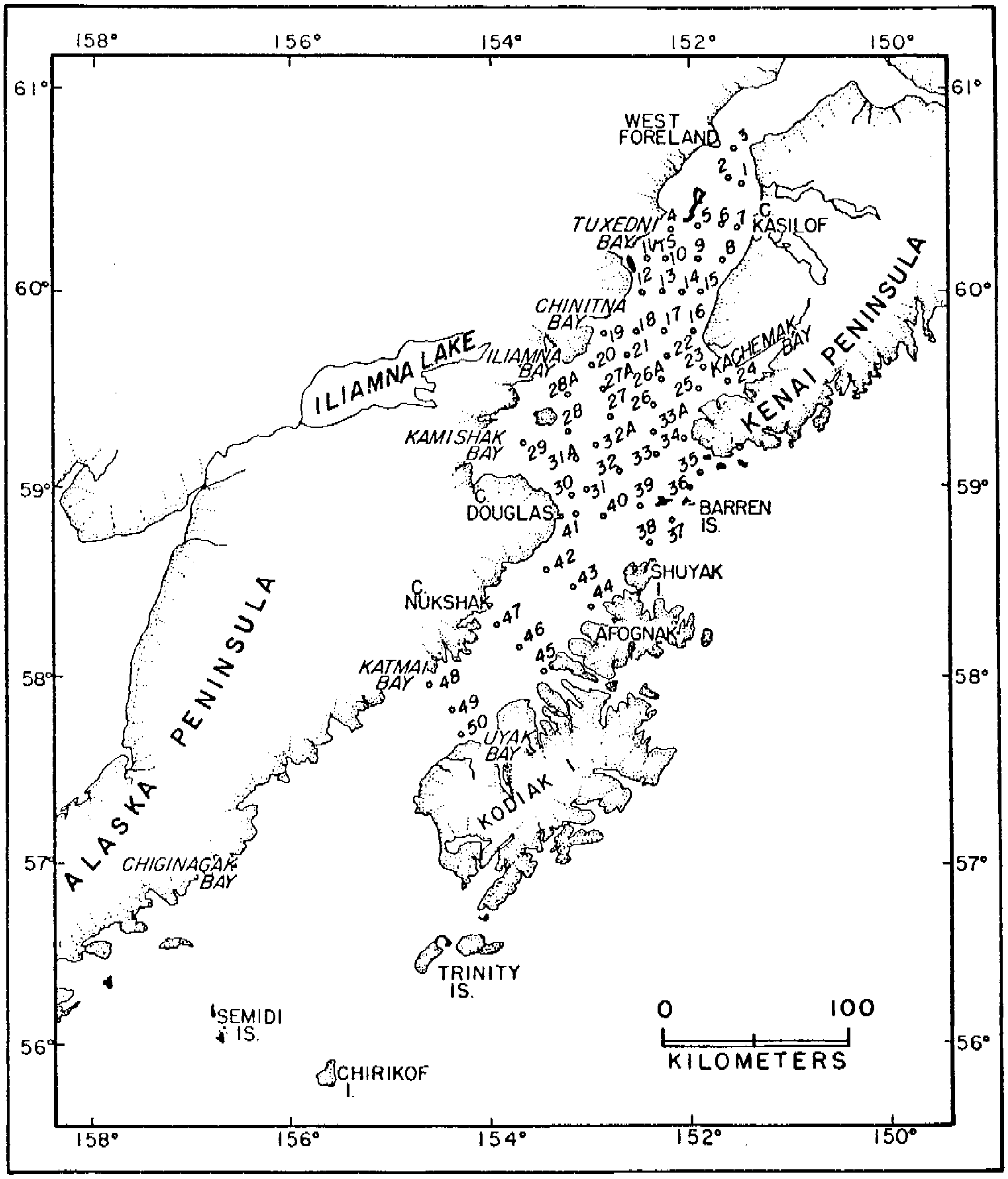


Figure 2. Locations of suspended matter stations in Lower Cook Inlet and Shelikof Strait (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

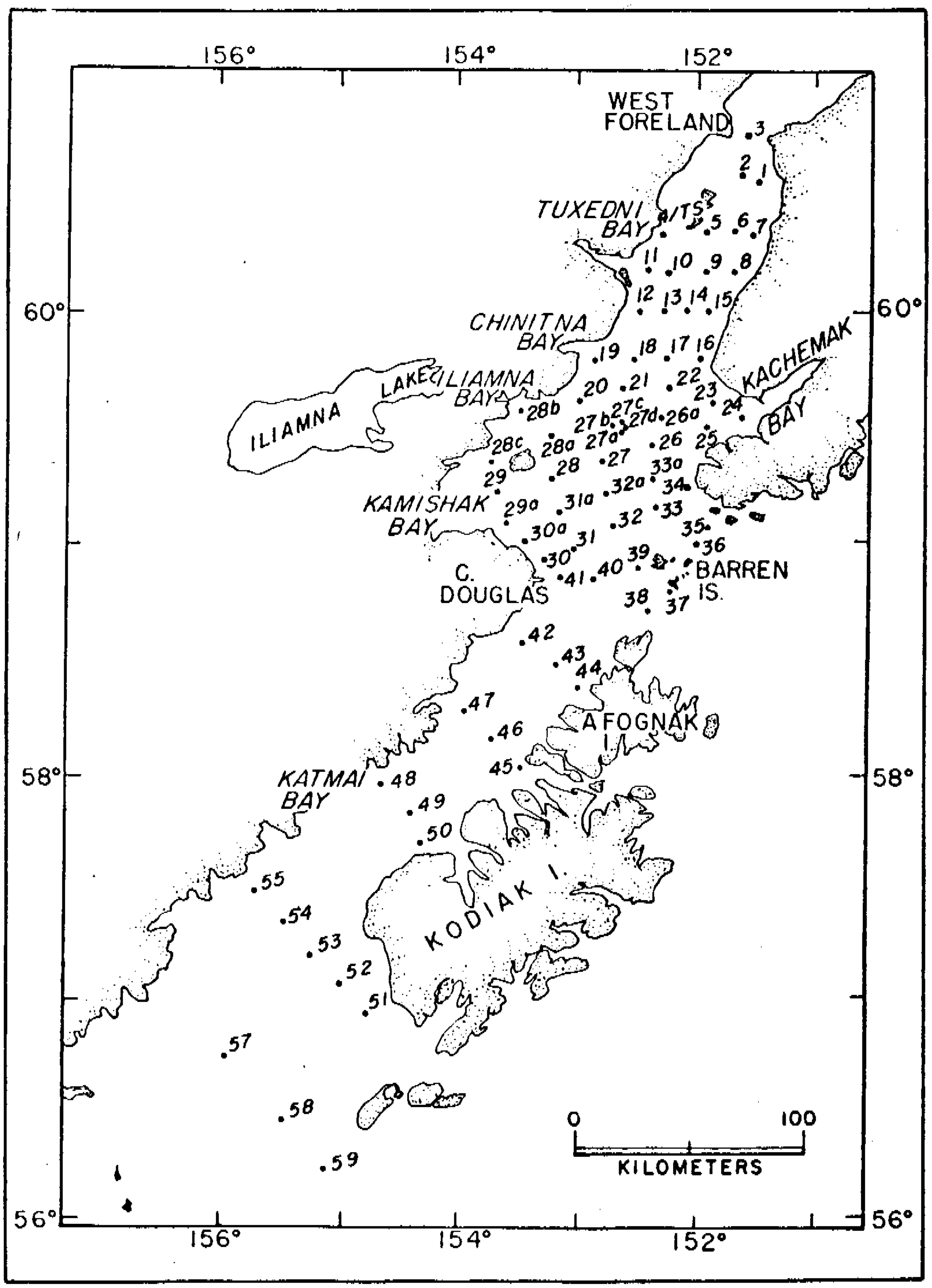


Figure 3. Locations of suspended matter stations in Lower Cook Inlet and Shelikof Strait (Acona-245, 28 June - 12 July 1977).

5. Data Collected

Particulate matter samples were collected from 8 stations in the northeastern Gulf of Alaska and 57 and 71 stations, respectively, during the cruises in April and July in Lower Cook Inlet and Shelikof Strait. Samples were taken from several preselected depths depending on location. Nominally, these depths included: surface, 10 m, 20 m, 40 m, 60 m, 80 m, 100 m, and 5 m above the bottom. At two stations in the northeastern Gulf, WIST I and WIST II (Figures 4 and 5), single arrays consisting of a nephelometer mounted in the weight, two and four Aanderaa current meters, respectively, and one and three sediment traps, respectively, were deployed on 17 March 1977. With the exception of one nephelometer, all of the equipment was successfully recorded on 8 June 1977.

B. Laboratory Activities

1. Methods

The major (Mg, Al, Si, K, Ca, Ti, and Fe) and trace (Cr, Mn, Ni, Cu, Zn, and Pb) element chemistry of the particulate matter is being determined by x-ray secondary emission (fluorescence) spectrometry utilizing a Kevex® Model 0810A-5100 x-ray energy spectrometer and the thin-film technique (Baker and Piper, 1976). The inherent broad band of radiation from an Ag x-ray tube is used to obtain a series of characteristic emission lines from a single element secondary target which then more efficiently excites the thin-film sample. Se and Zr secondary targets are used to analyze the samples for both major and trace elements. Standards are prepared by passing suspensions of finely ground USGS standard rocks (W-1, G-2, GSP-1, AGV-1, BCR-1, PCC-1) and NBS trace element standards through a 37 μm mesh polyethylene screen

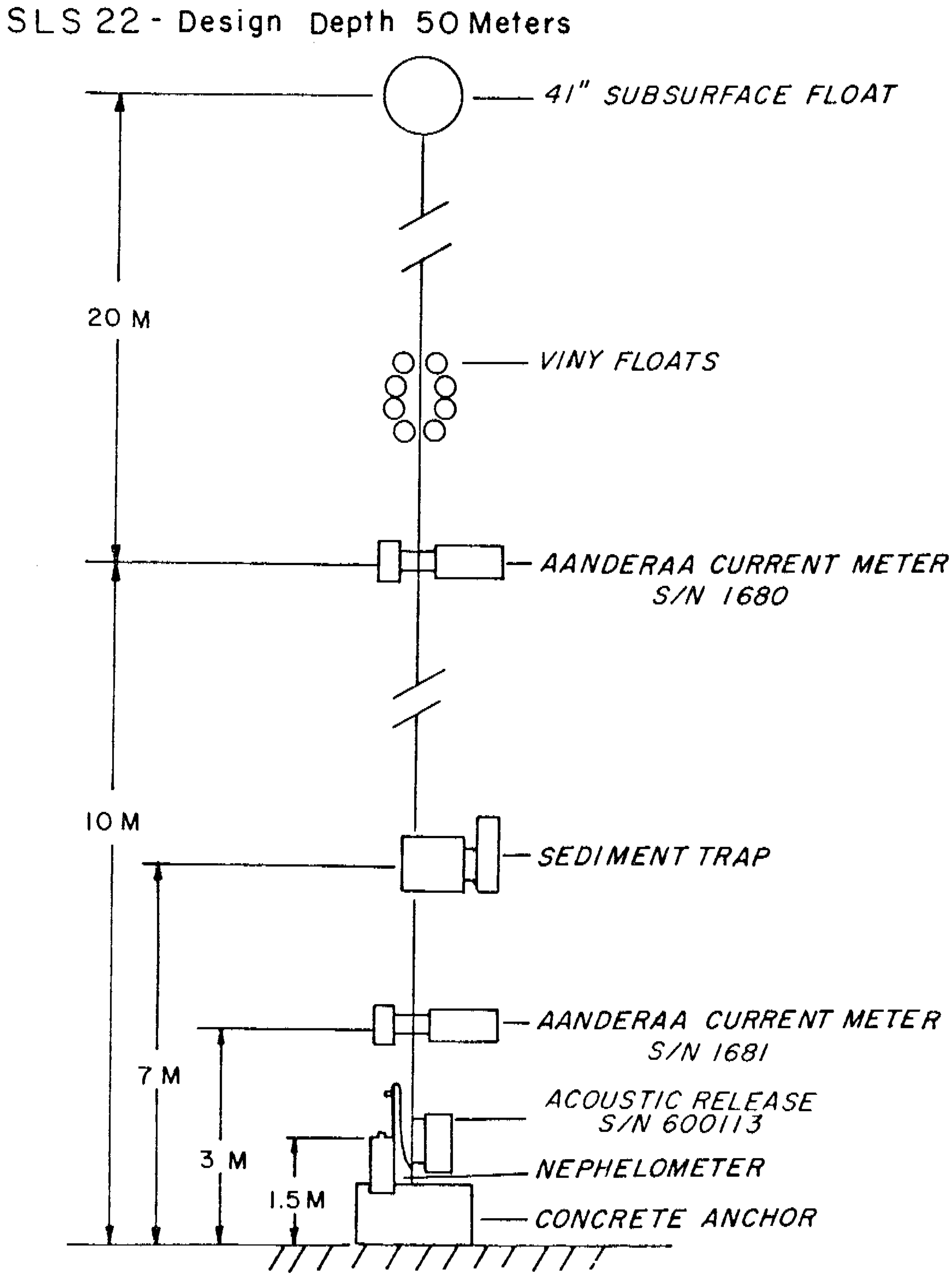


Figure 4. Schematic diagram of the current meter-nephelometer-sediment trap mooring at WIST-I. The mooring was deployed on March 17 and recovered on June 8, 1977.

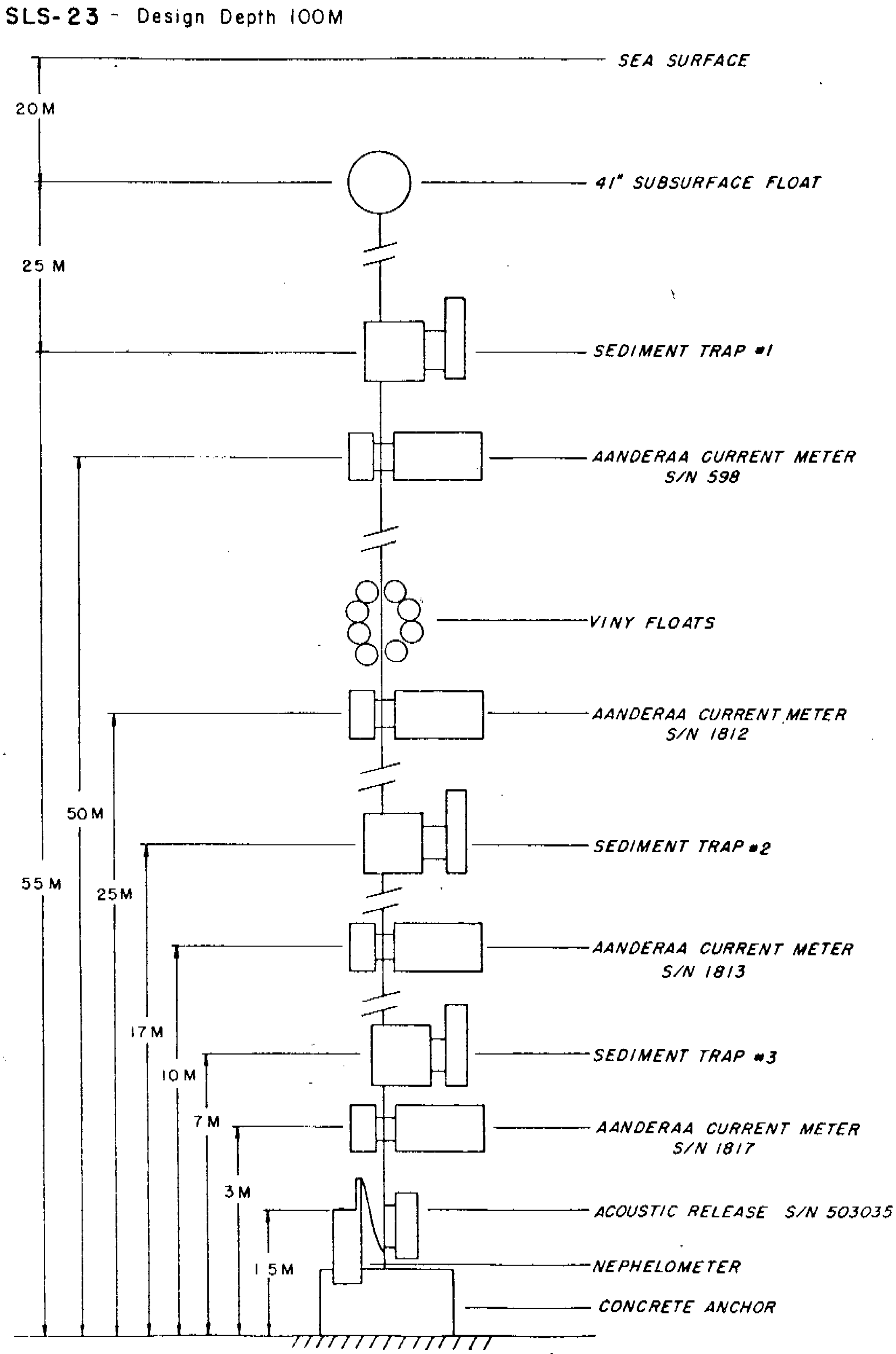


Figure 5. Schematic diagram of the current meter-nephelometer-sediment trap mooring at WIST-II. The mooring was deployed on March 17 and recovered on June 8, 1977.

followed by collection of the size fractionated suspensates on Nuclepore® filters identical to those used for sample acquisition. The coefficient of variation for 10 replicate analyses of a largely inorganic sample of approximately mean mass was less than 3 percent for the major constituents and as high as 5 percent for the trace elements. However, when sampling precision is considered, the coefficients of variation increase, averaging 12 and 24 percent for major and trace elements, respectively.

Analysis of total particulate carbon and nitrogen is carried out with a Hewlett Packard model 185B C-H-N analyzer. In this procedure, particulate carbon and nitrogen compounds are combusted to CO_2 and N_2 (micro Dumas method), chromatographed on Poropak® Q, and detected sequentially with a thermal conductivity detector. NBS acetanilide is used for standardization. Analyses of replicate surface samples yield coefficients of variation ranging from 2 to 10 percent for carbon and 7 to 14 percent for nitrogen.

2. Data Collected

We have completed all four cruises in the Gulf of Alaska and Lower Cook Inlet which were scheduled for the present fiscal year. At this point, approximately 700 samples have been collected and weighed for suspended loads. In addition, approximately 250 samples have been collected for elemental analysis and 40 grams of suspended matter from Lower Cook Inlet have been collected for the crude oil-suspended matter interaction studies.

III. Results

A. Particulate Matter Distributions and Transport

Figures 6 through 9 show particulate matter distribution at the surface and 5 m above the bottom for the April and July cruises in Lower Cook Inlet and Shelikof Strait. As shown in Figures 6 and 8, the surface particulate matter distributions are characterized by unusually high horizontal gradients. On the eastern side particulate concentrations are relatively low, ranging from 0.5 mg/ℓ near Cape Elizabeth to about 5.0 mg/ℓ near Cape Ninilchik. On the western side suspended loads increase rapidly from concentrations around 5.0 mg/ℓ in Kamishak Bay to concentrations greater than 100 mg/ℓ north of Tuxedni Bay. The salinity and temperature data (Figures 10 through 17) for these cruises show very similar horizontal distribution patterns, illustrating the predominance of the inflowing relatively clear saline Gulf of Alaska water on the eastern side and the outflowing turbid low salinity water from Upper Cook Inlet on the western side. The outflowing turbid water is transported past Augustine Island to Kamishak Bay, where a portion of the suspended material settles out and the remaining material is transported around Cape Douglas into Shelikof Strait and is dispersed.

The near bottom suspended matter distributions (Figures 7 and 9) are very similar to the surface distributions, suggesting that Cook Inlet is extremely well mixed with respect to suspended matter. In apparent agreement with this, the vertical cross-sections of the distribution of suspended matter from Kachemak Bay to Kamishak Bay (Figures 18 and 19) show little, if any, vertical gradients. These data are supported by the salinity and temperature distributions (Figures 20 through 23) which are uniform with depth in April and only slightly stratified in July. Apparently, the turbulence which is caused by tidal mixing is sufficient to keep the water column well mixed with respect to suspended matter.

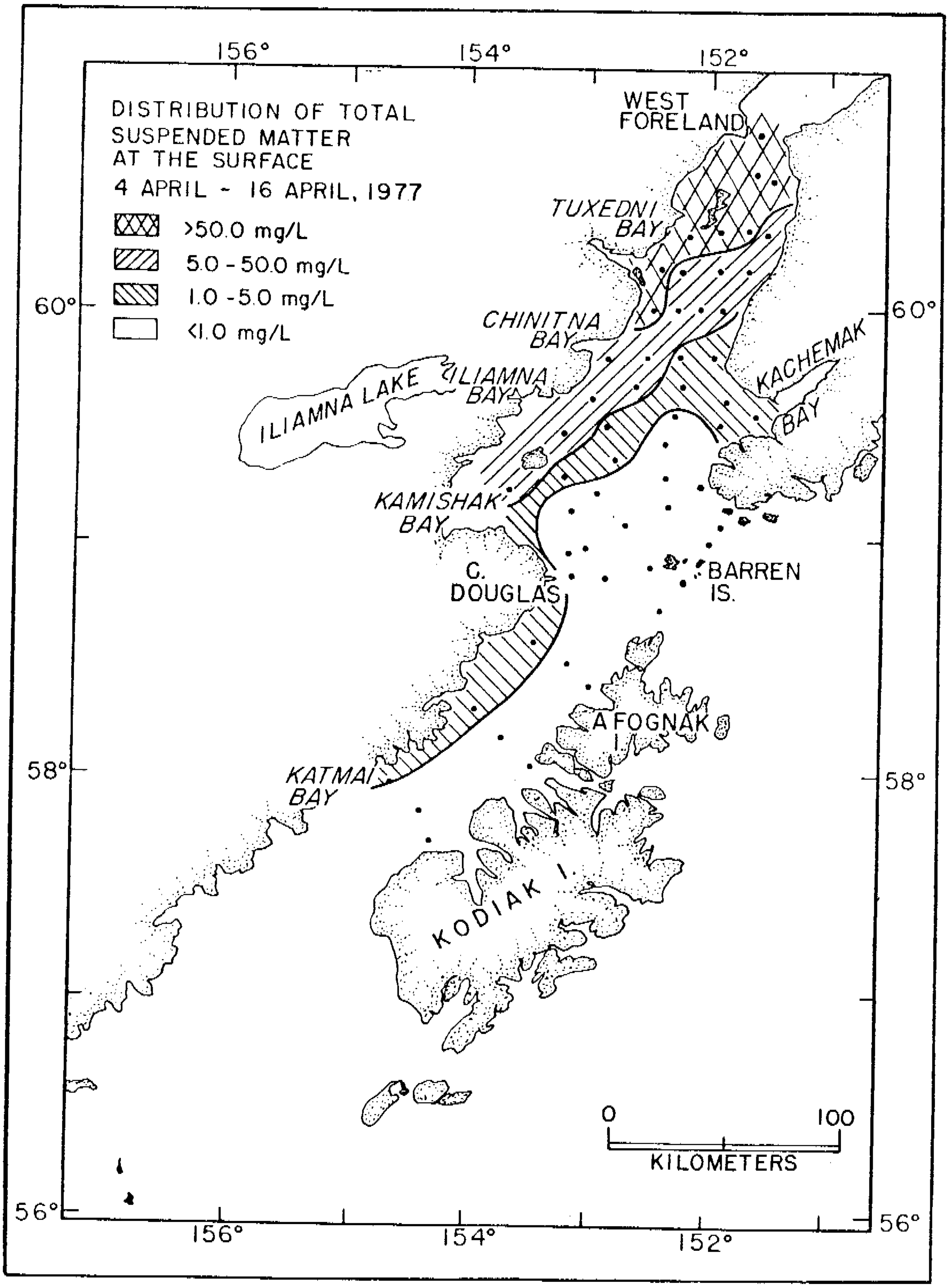


Figure 6. Distribution of total suspended matter at the surface in Lower Cook Inlet and Shelikof Strait (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

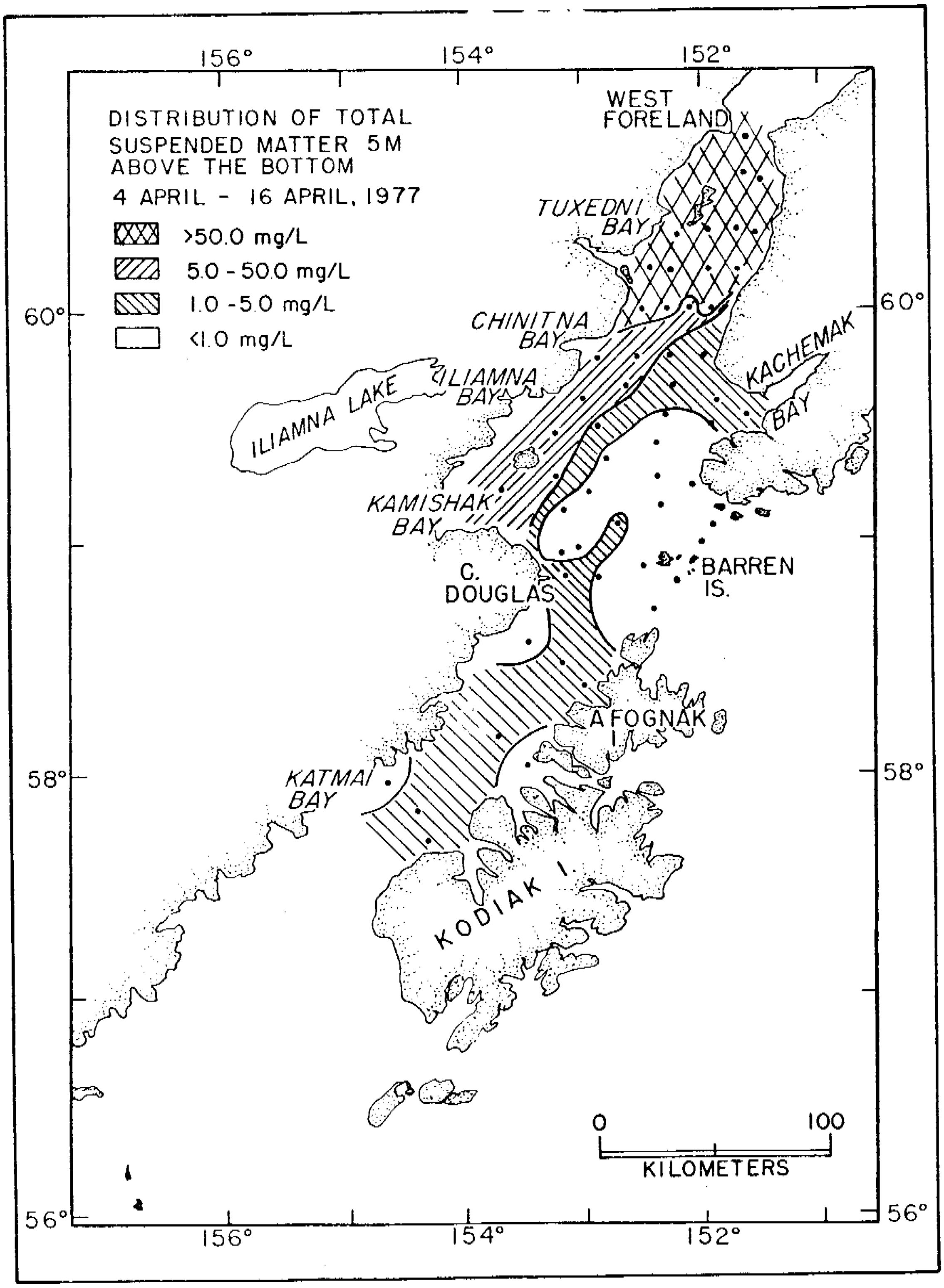


Figure 7. Distribution of total suspended matter 5 m above the bottom in Lower Cook Inlet and Shelikof Strait (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

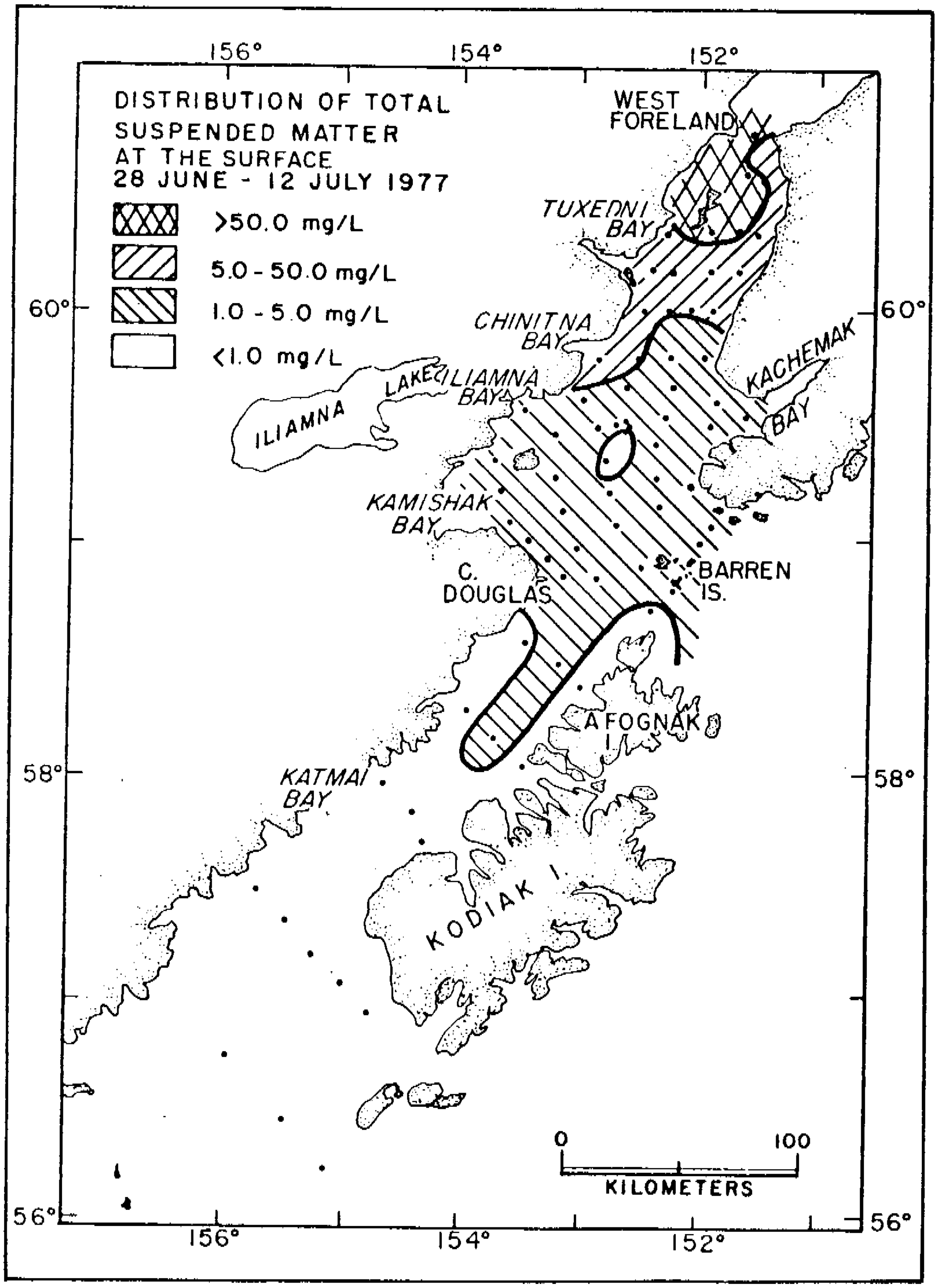


Figure 8. Distribution of total suspended matter at the surface in Lower Cook Inlet and Shelikof Strait (Acona-245, 28 June - 12 July 1977).

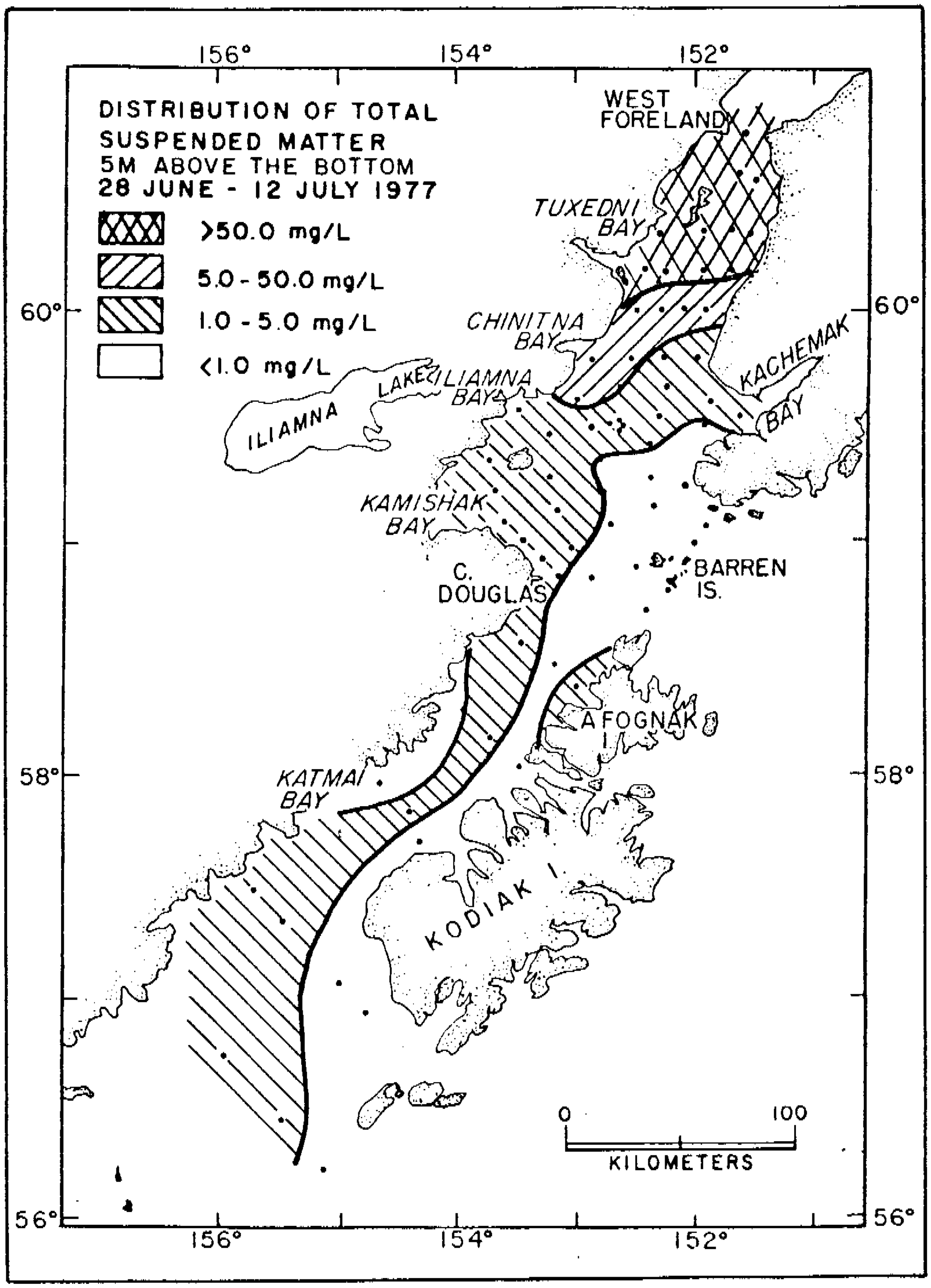


Figure 9. Distribution of total suspended matter 5 m above the bottom in Lower Cook Inlet and Shelikof Strait (Acona-245, 28 June - 12 July 1977).

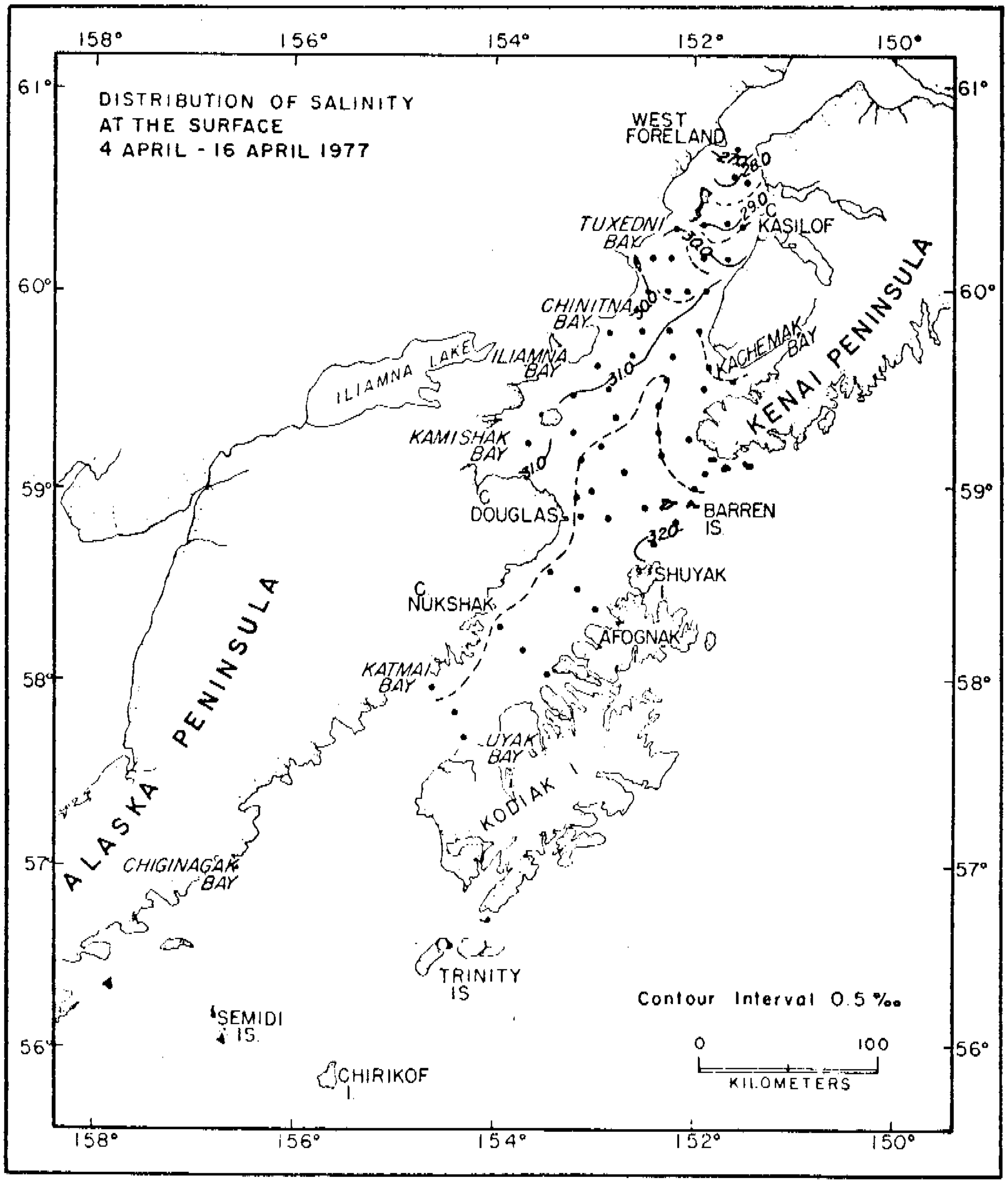


Figure 10. Distribution of salinity (‰) at the surface in Lower Cook Inlet and Shelikof Strait (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

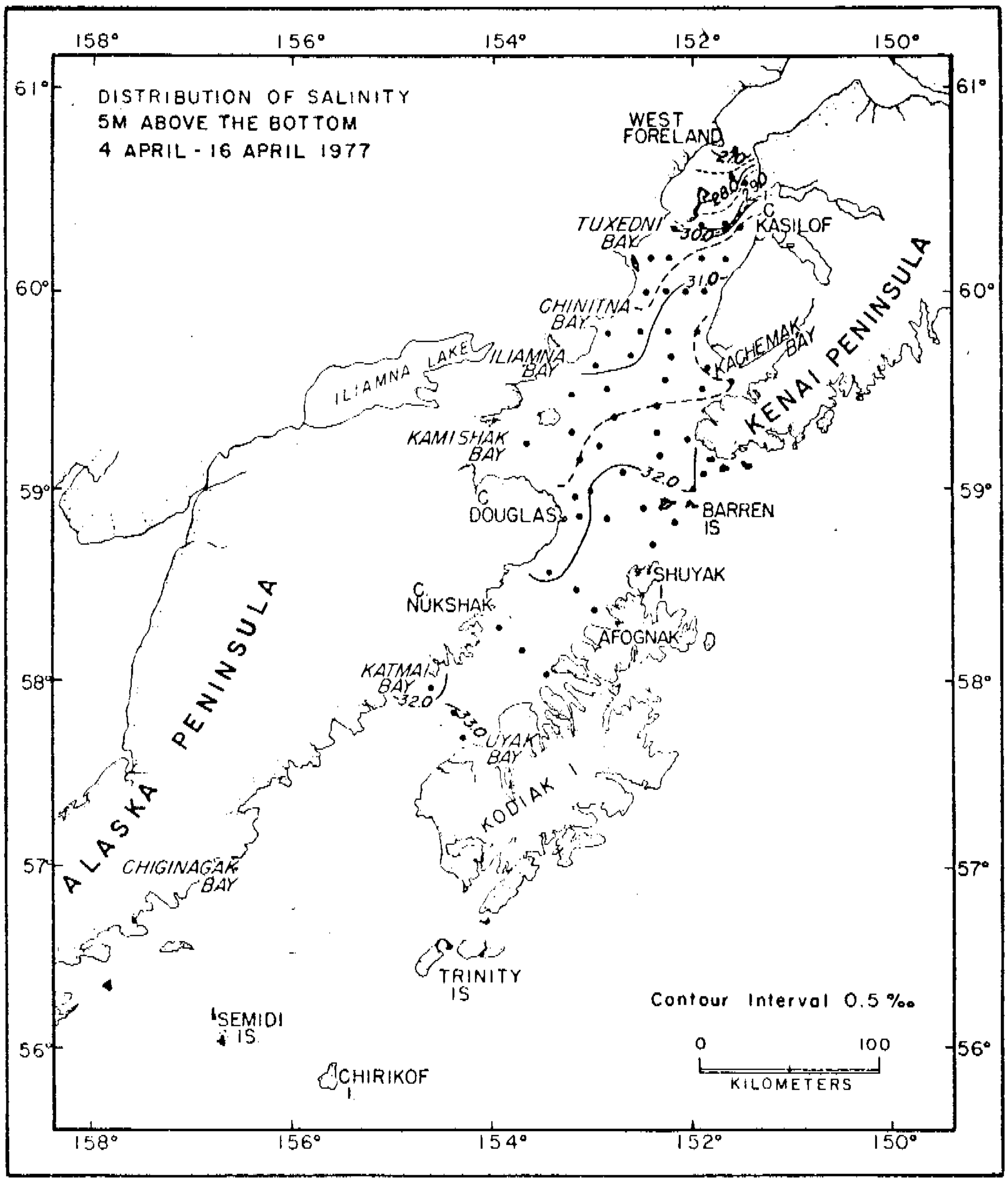


Figure 11. Distribution of salinity (‰) 5 m above the bottom in Lower Cook Inlet Inlet and Shelikof Strait (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

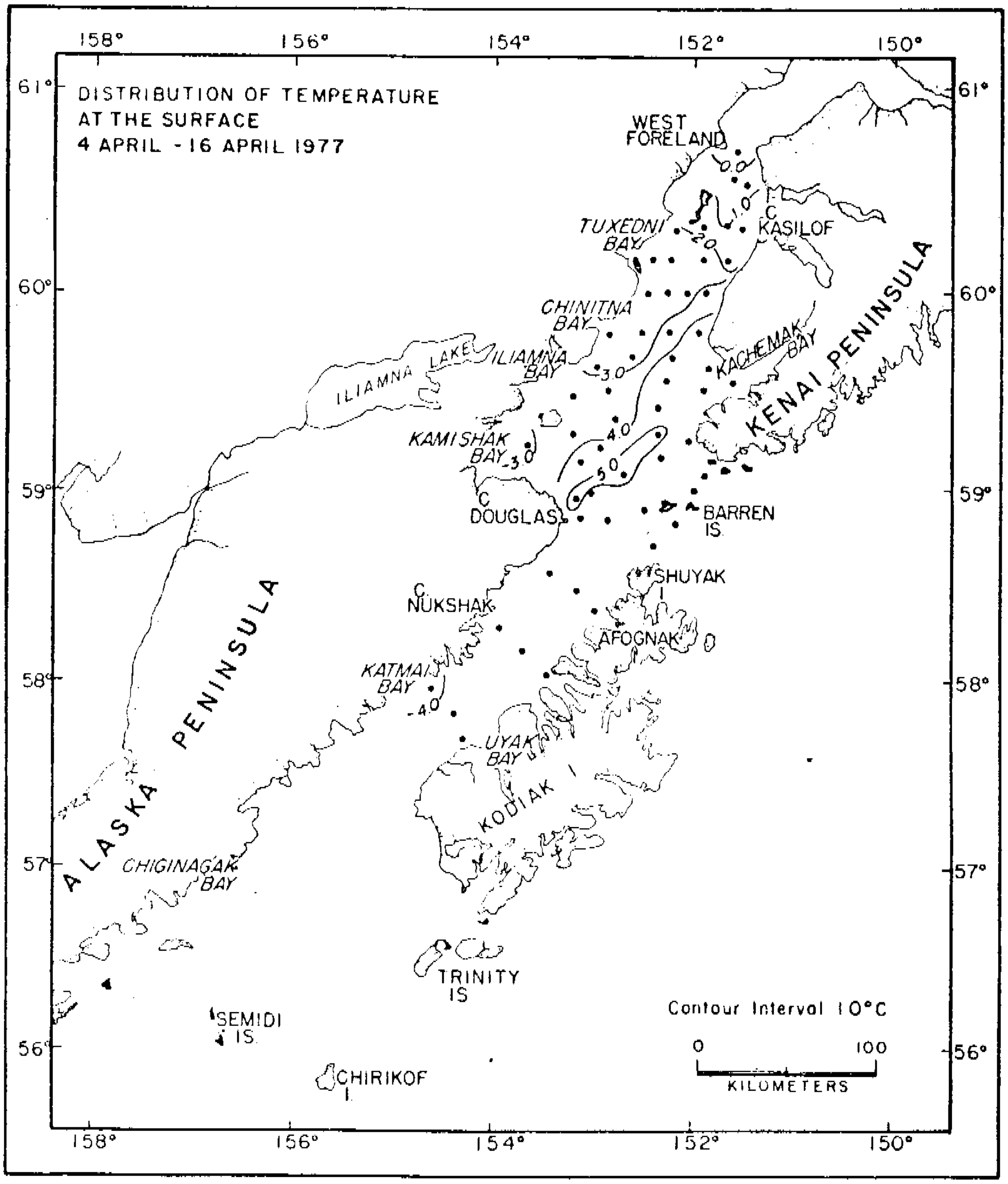


Figure 12. Distribution of temperature (°C) at the surface in Lower Cook Inlet and Shelikof Strait (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

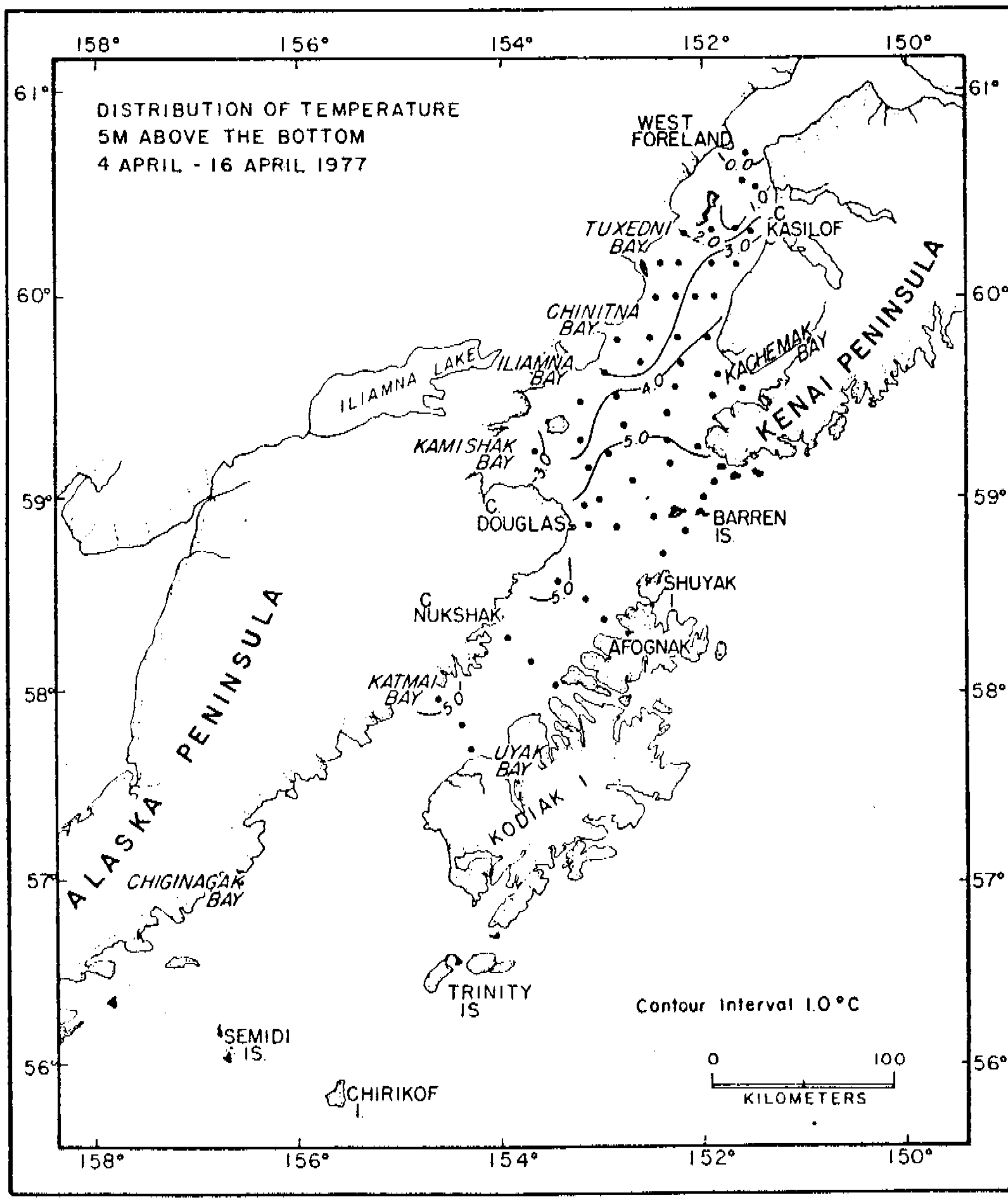


Figure 13. Distribution of temperature (°C) 5 m above the bottom in Lower Cook Inlet and Shelikof Strait (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

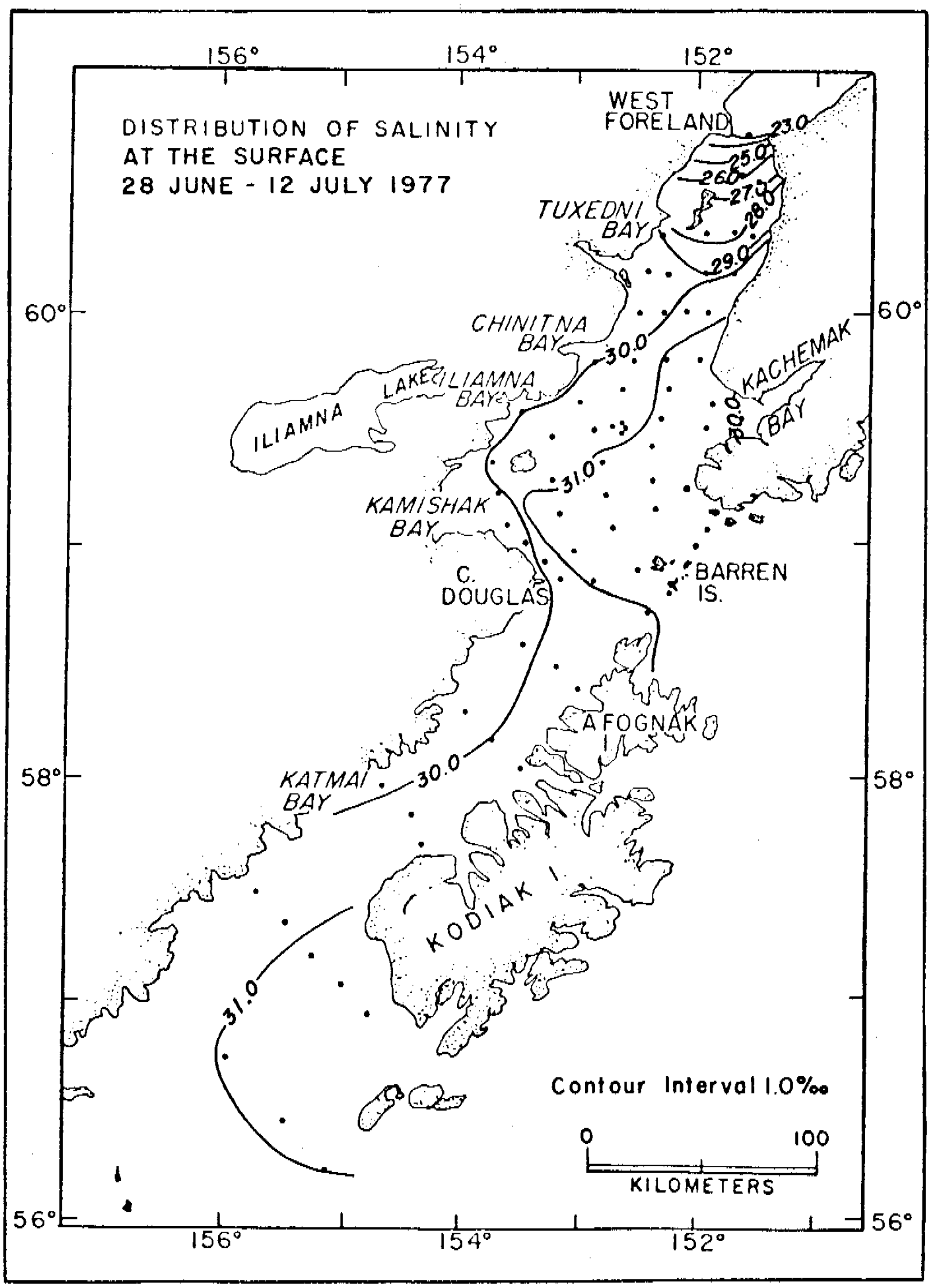


Figure 14. Distribution of salinity (‰) at the surface in Lower Cook Inlet and Shelikof Strait (Acona-245, 28 June - 12 July 1977).

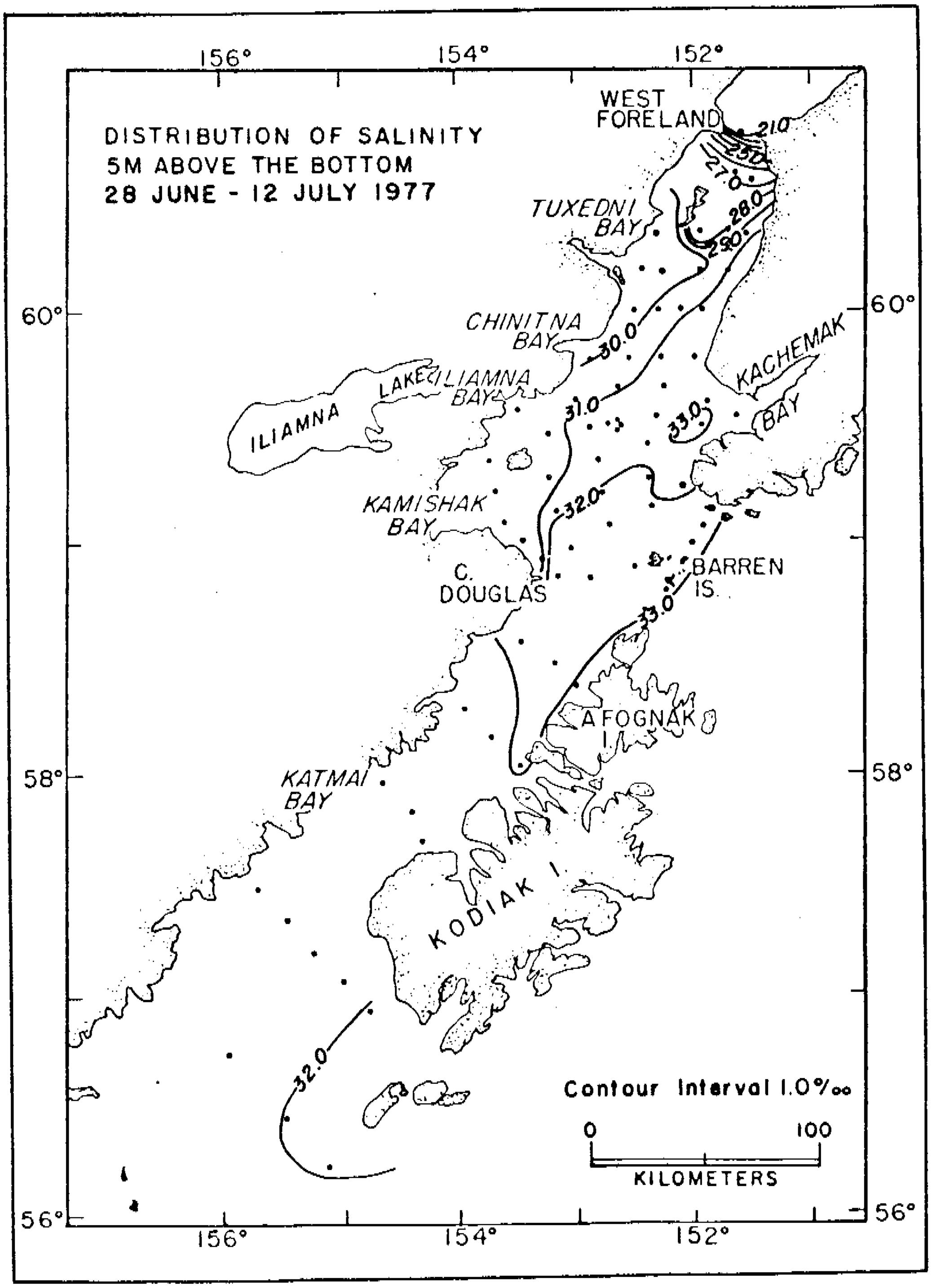


Figure 15. Distribution of salinity (‰) 5 m above the bottom in Lower Cook Inlet and Shelikof Strait (Acona-245, 28 June - 12 July 1977).

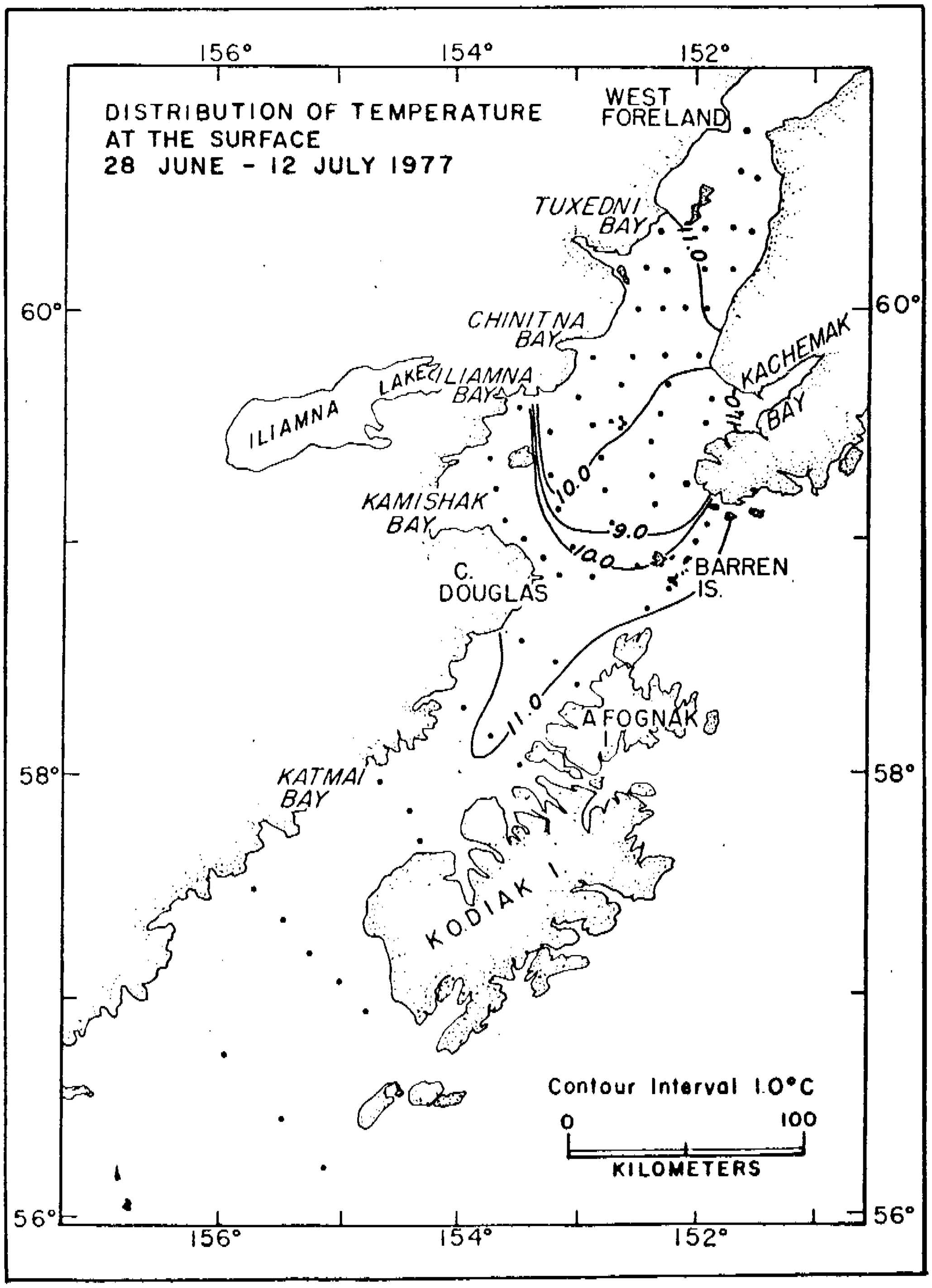


Figure 16. Distribution of temperature (°C) at the surface in Lower Cook Inlet and Shelikof Strait (Acona-245, 28 June - 12 July 1977).

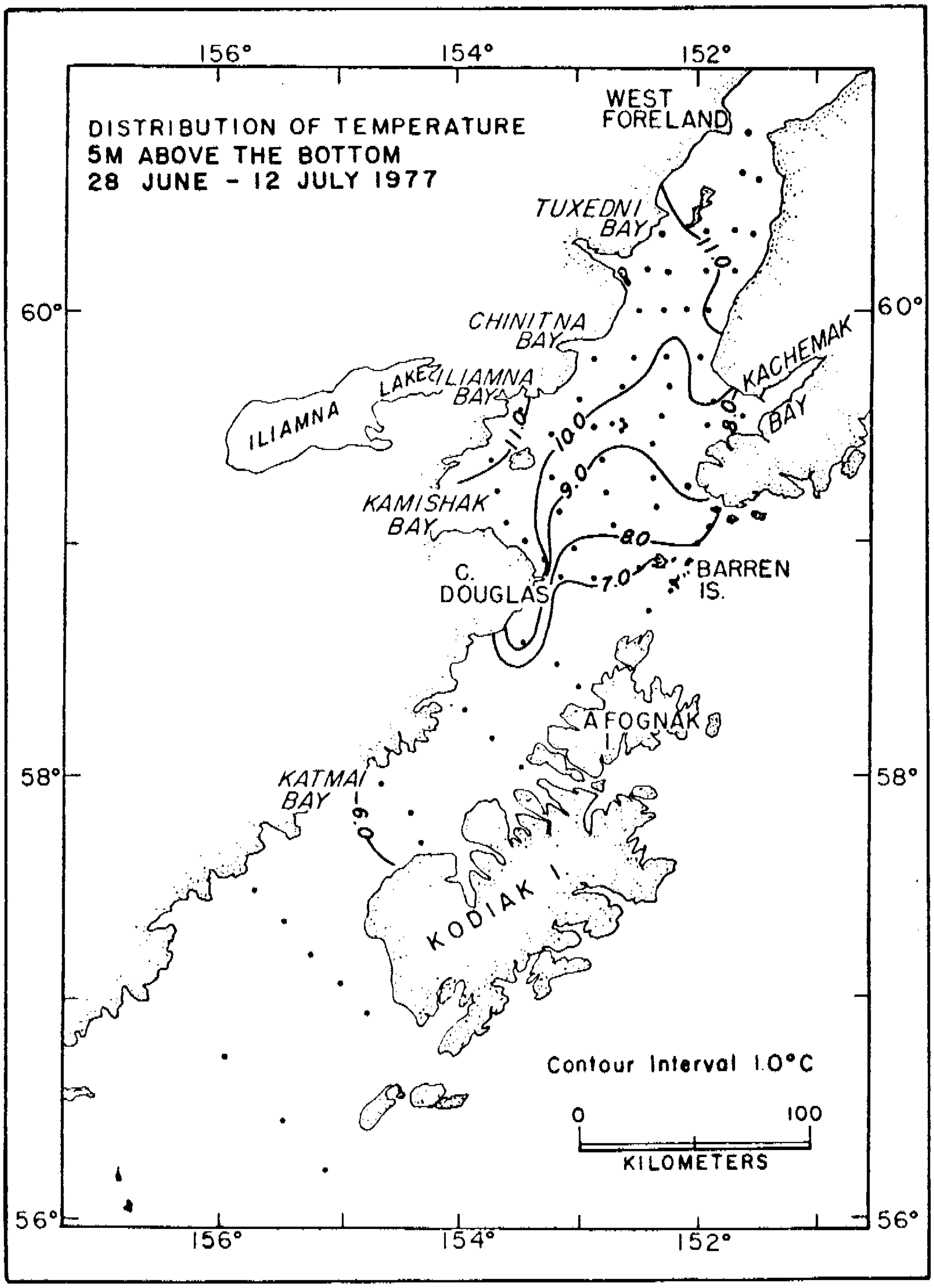


Figure 17. Distribution of temperature (°C) 5 m above the bottom in Lower Cook Inlet and Shelikof Strait (Acona-245, 28 June - 12 July 1977).

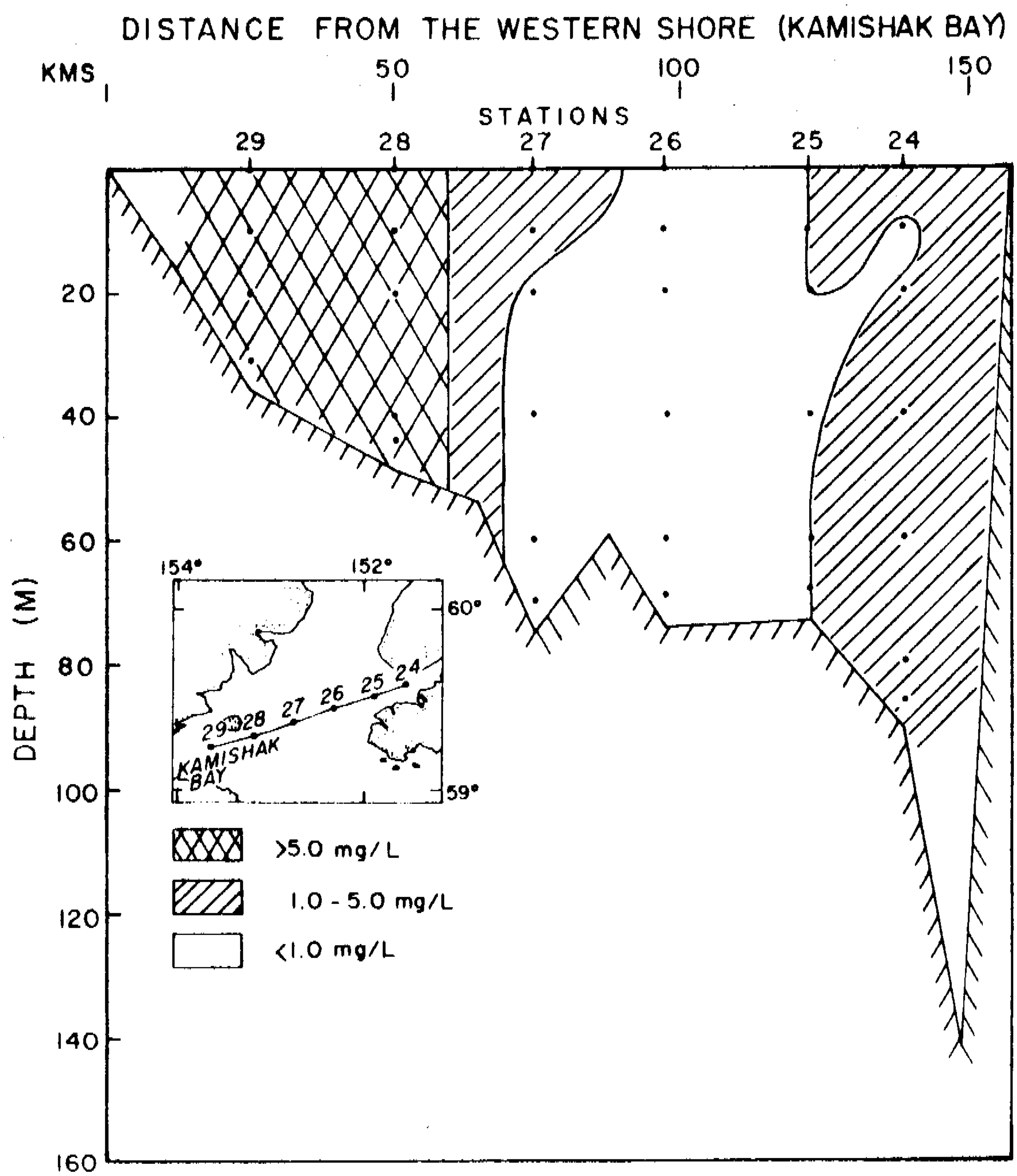


Figure 18. Vertical cross section of the distribution of total suspended matter for stations 24 thru 29 in Lower Cook Inlet (Cruise RP-4-Di-77A-IV, 4-16 April 1977)

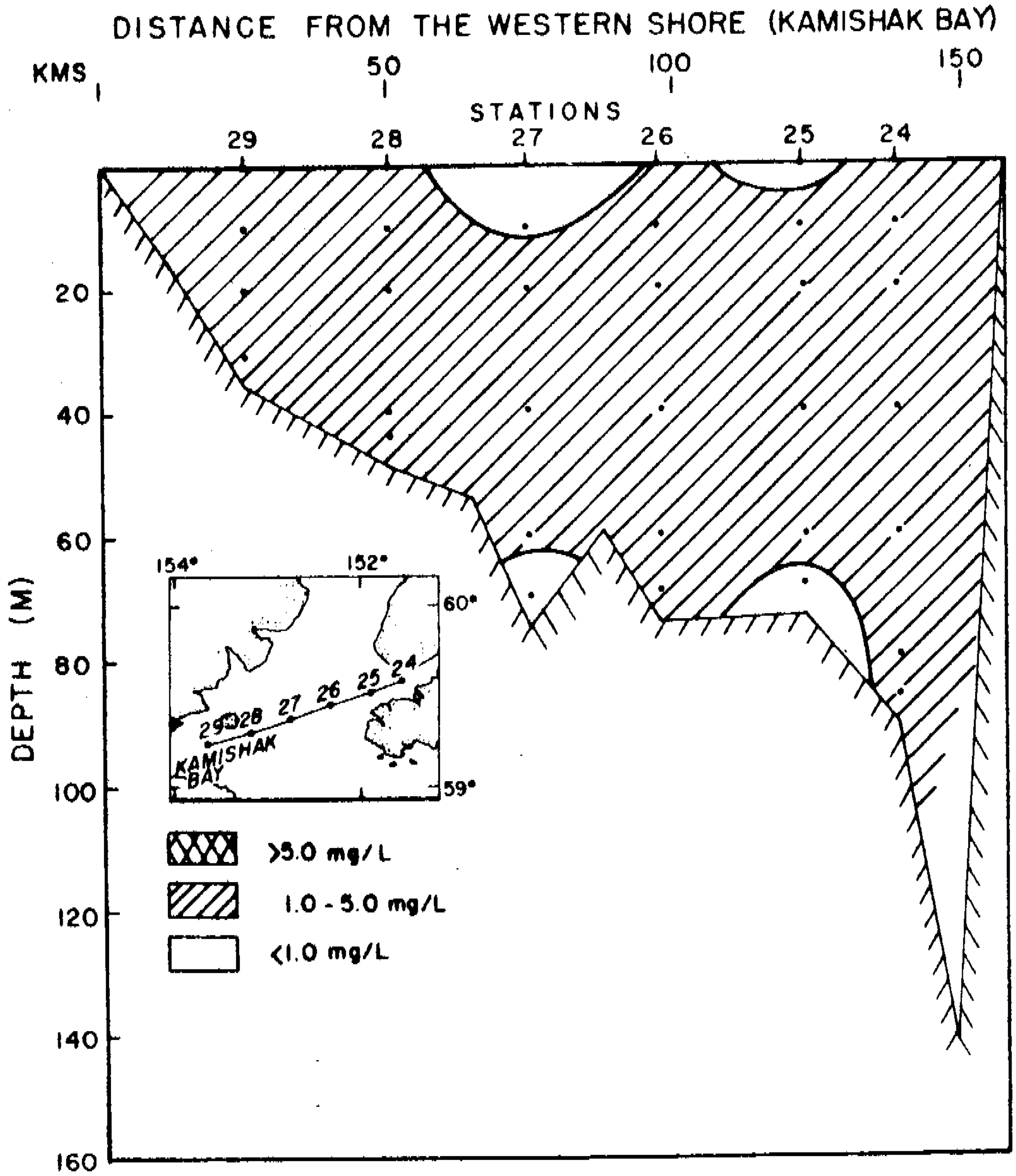


Figure 19. Vertical cross section of the distribution of total suspended matter for stations 24 thru 29 in Lower Cook Inlet (Acona-245, 28 June - 12 July 1977).

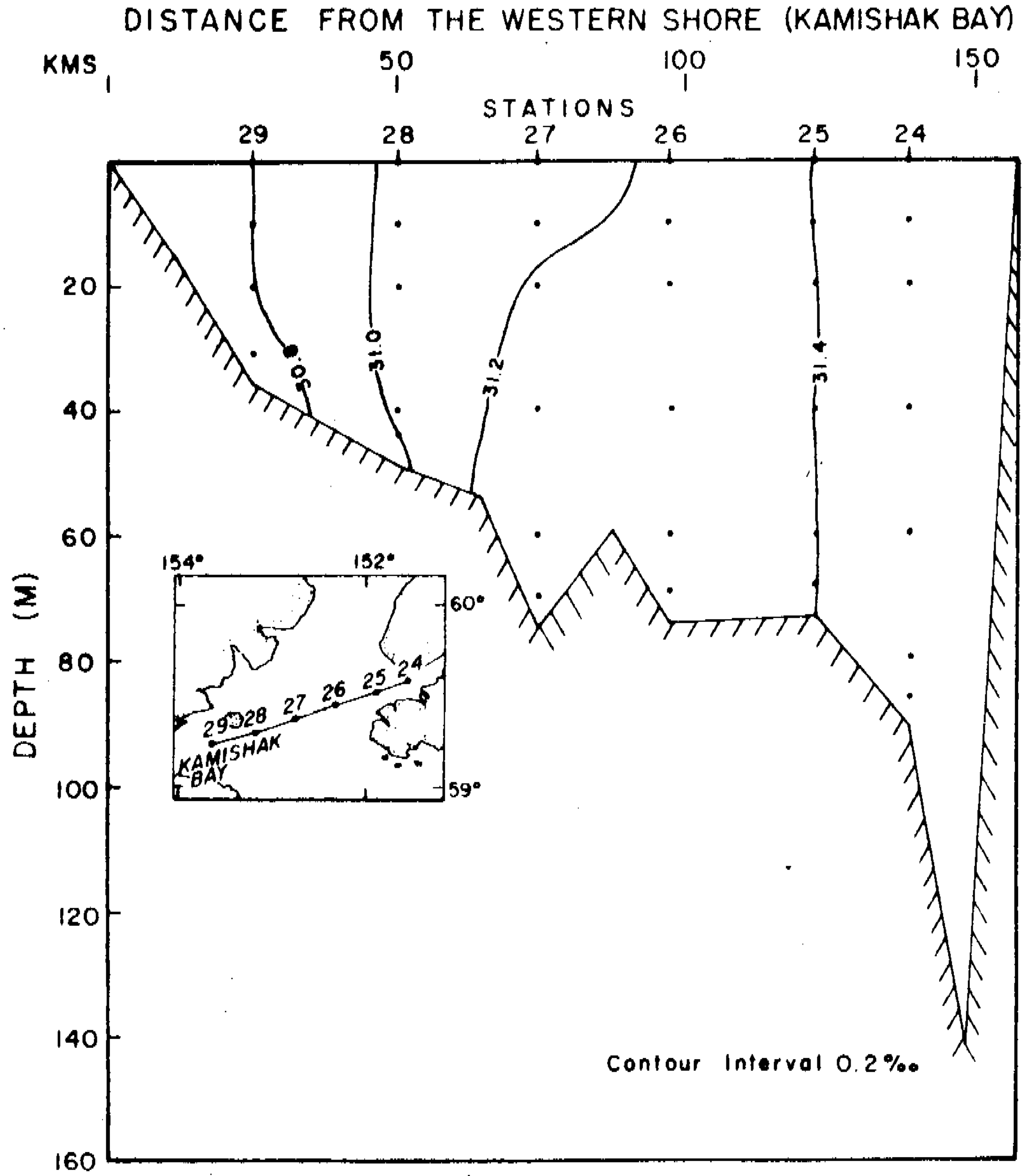


Figure 20. Vertical cross section of the distribution of salinity (‰) for stations 24 thru 29 in Lower Cook Inlet (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

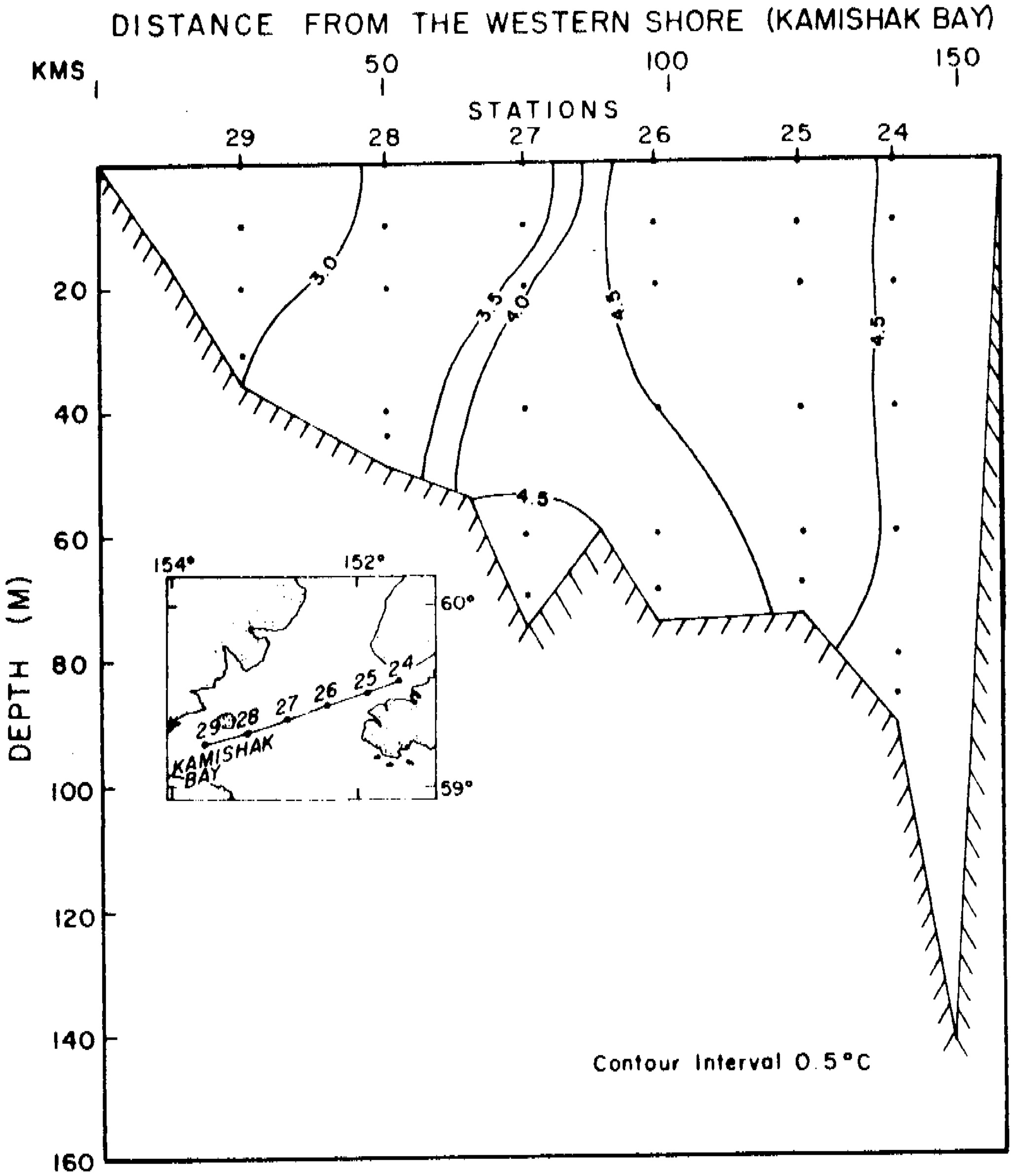


Figure 21. Vertical cross section of the distribution of temperature (°C) for stations 24 thru 29 in Lower Cook Inlet (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

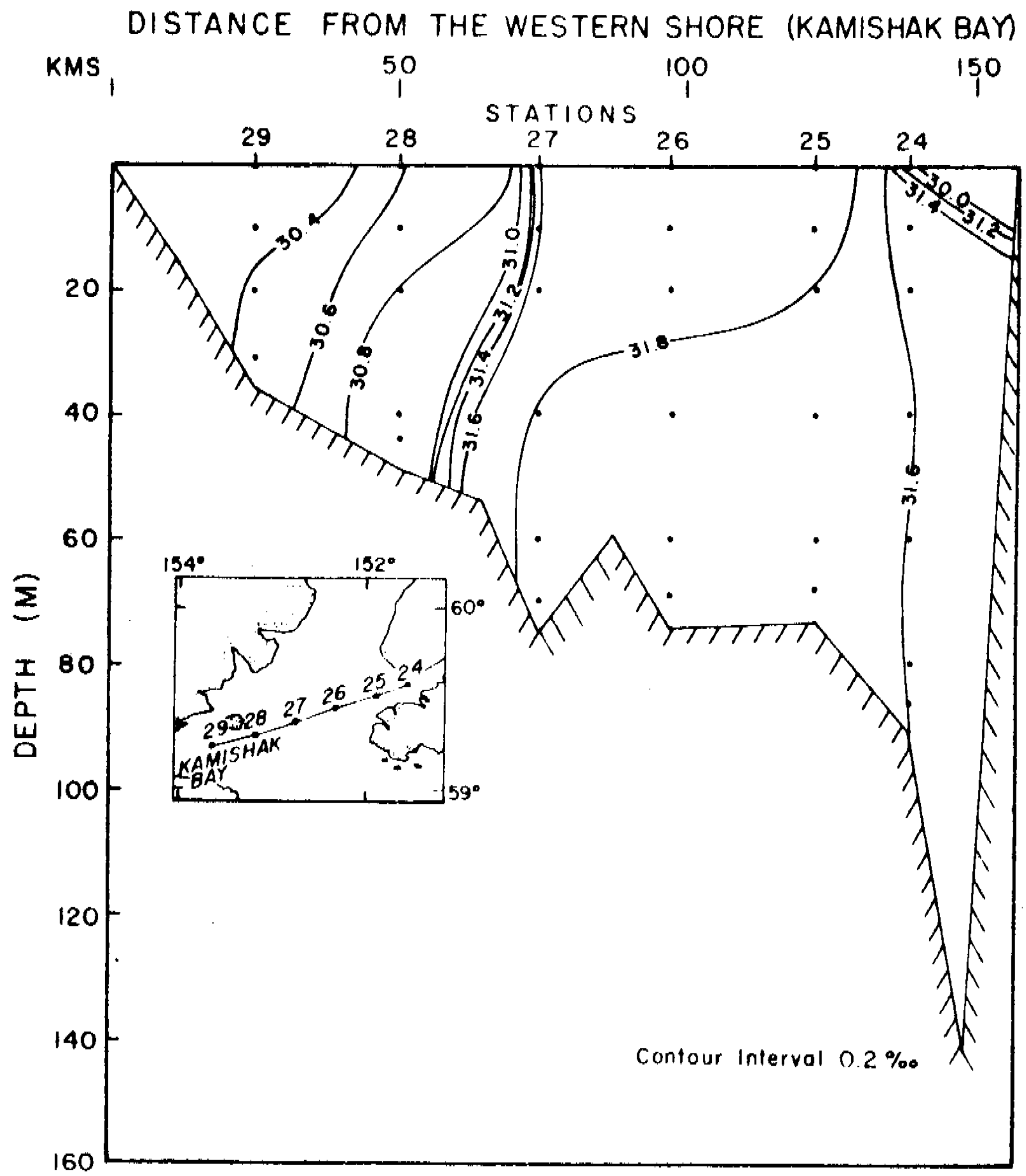


Figure 22. Vertical cross section of the distribution of salinity (‰) for stations 24 thru 29 in Lower Cook Inlet (Acona-245, 28 June - 12 July 1977).

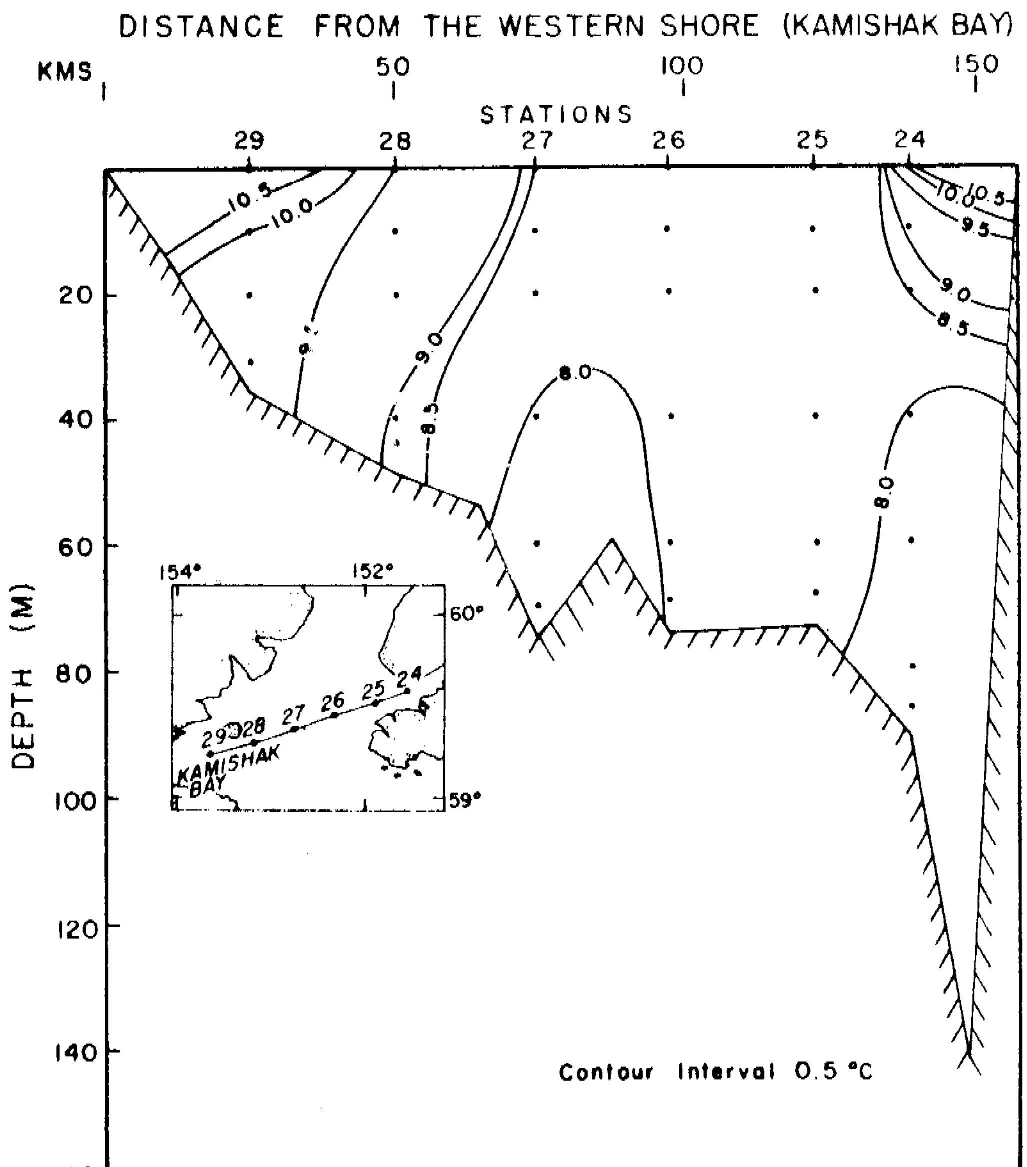


Figure 23. Vertical cross section of the distribution of temperature (°C) for stations 24 thru 29 in Lower Cook Inlet (Acona-245, 28 June - 12 July 1977).

B. Temporal Variability of Suspended Matter

In order to obtain some information about high frequency (hourly) fluctuations of particulate concentrations in Lower Cook Inlet, a 36-hour time series experiment was conducted at station 11 during the April cruise and a 26-hour experiment was conducted at station 4 during the July cruise. Water samples were collected and filtered every two hours from the surface and 5 m above the bottom. The results of these experiments are shown in Figures 24 and 25. As shown in these figures, concentrations of suspended matter are highly variable both at the surface and near the bottom. At the surface, particulate concentrations range from 40-90 mg/ℓ at station 11 and 10-115 mg/ℓ at station 4. The surface maxima have a 12-hour period and appear to reach their peak shortly after the tidal currents have come to maximum velocity. Near the bottom the suspended matter concentrations are more variable and may reach concentrations in excess of 130 mg/ℓ. The near-bottom particulate maxima do not show any consistent periodicity and, most probably, reflect local variations in the amount of material that is resuspended into the water column by bottom currents.

C. Suspended Sediment-Oil Interaction Study

During the April 1977 cruise aboard the R/V DISCOVERER, experiments were conducted to determine the capacity of Cook Inlet suspended sediments to accommodate crude oil. To this end, near surface water was collected near Kalgin Island and stored for subsequent use in the interaction study. Aliquots of this water were mixed with varying amounts of crude oil in both 250 and 1000 ml separatory funnels. The containers then were immersed in a constant temperature bath and shaken gently for a period of one hour at $5^{\circ}C$. At the conclusion of the agitation period, the funnels

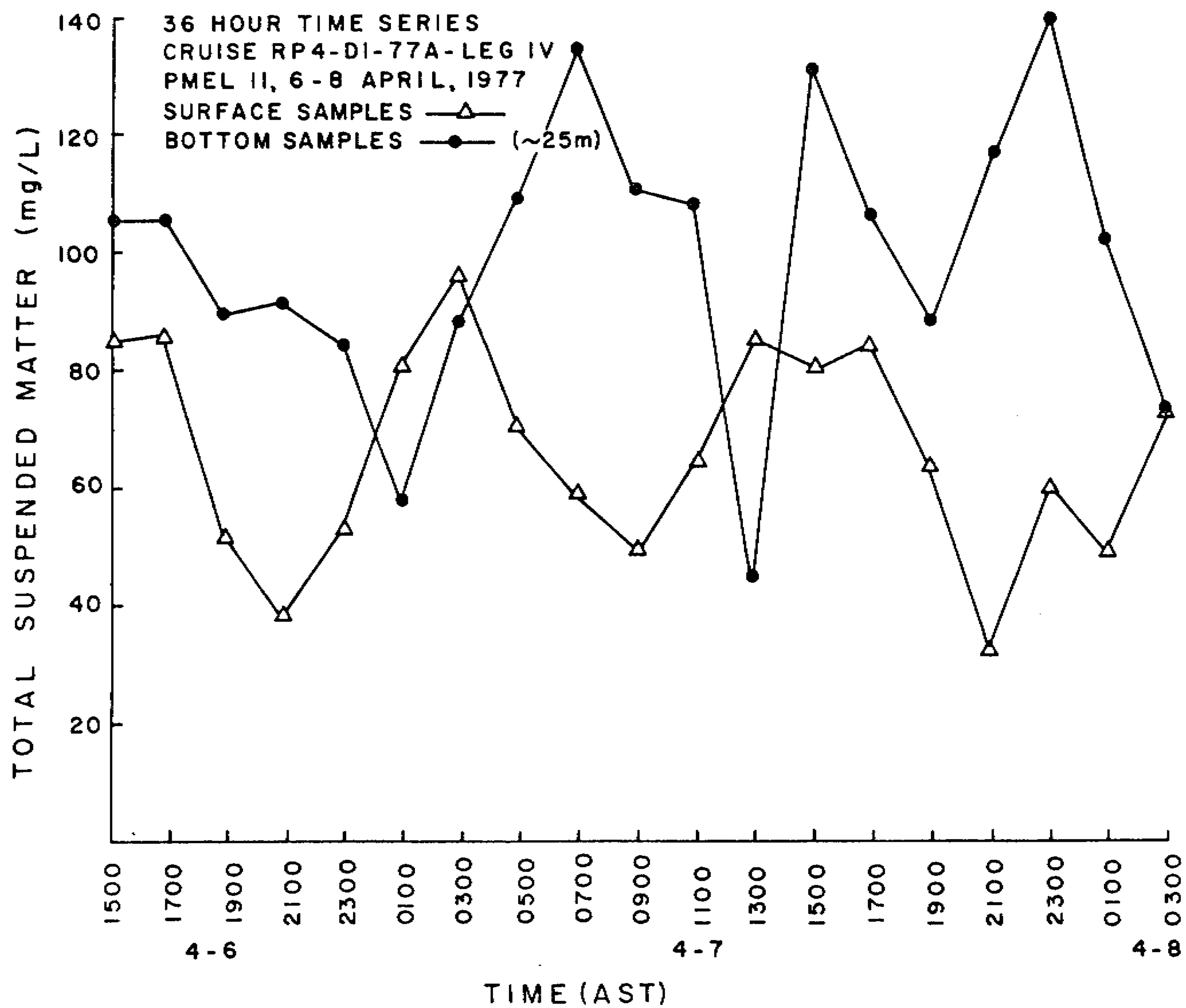


Figure 24. Temporal variability of total suspended matter at the surface and 5 m above the bottom at station 11 in Lower Cook Inlet (Cruise RP-4-Di-77A-IV, 4-16 April 1977).

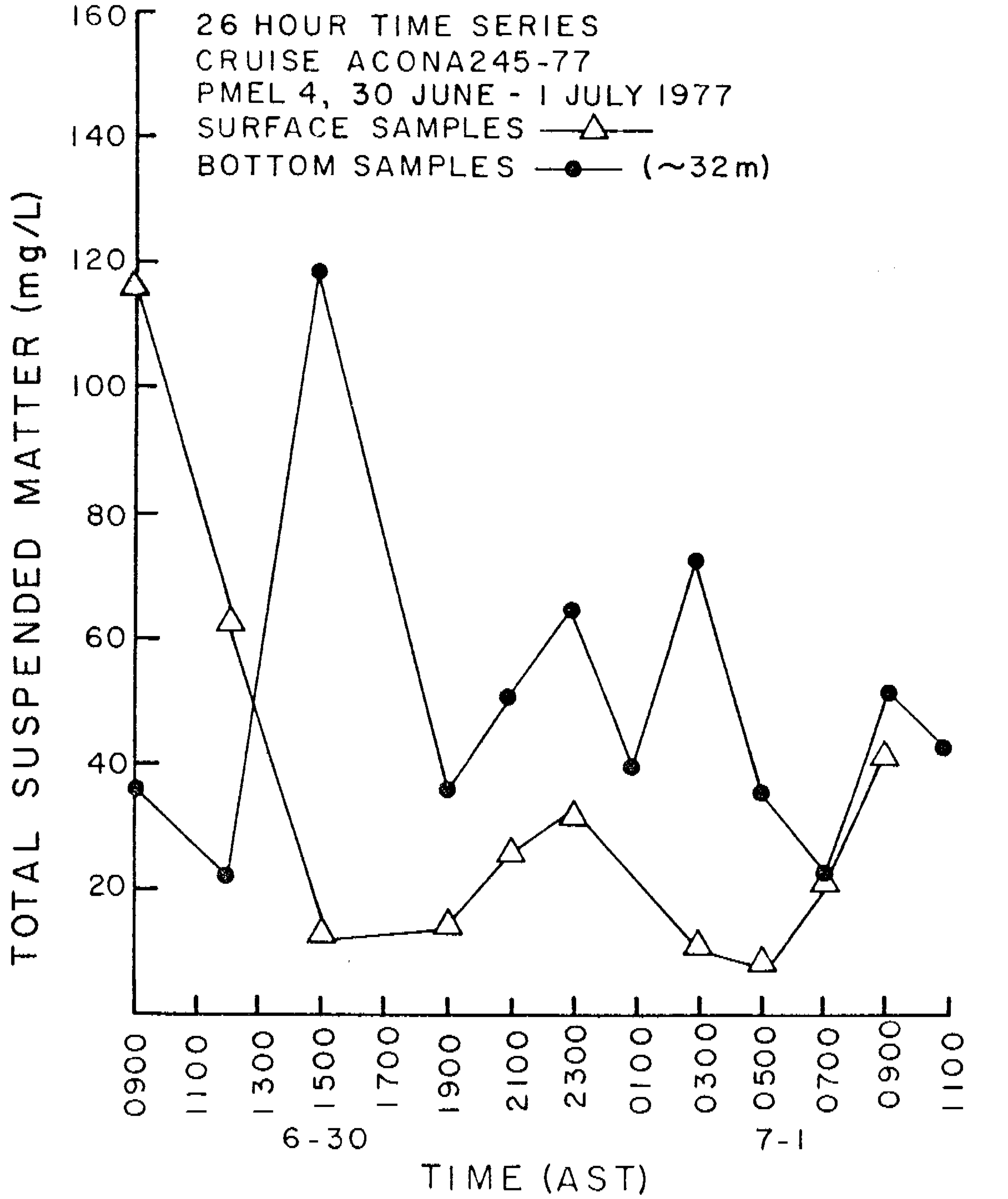


Figure 25. Temporal variability of total suspended matter at the surface and 5 m above the bottom at station 4 in Lower Cook Inlet (Acona-245, 28 June - 12 July 1977).

were removed from the bath and the solid phases allowed to settle (usually one hour). The oiled sediment particles were drawn off through the stopcock and extracted with methylene chloride to recover the oil. Similarily, the remaining water and sediment were extracted to effect a total recovery of the oil. Sediment and water extracts were stored in teflon capped centrifuge tubes and returned to the laboratory for analyses. Unfortunately, of the sixteen experiments performed in the field, only six of the samples survived the journey to the laboratory. Many of the samples had evaporated excessively or the contents were lost altogether.

Those extracts that did arrive intact were reduced to a volume of 2 ml, the solvent exchanged for hexane, and reduced again to 2.0 ml. An aliquot of this extract (25 $\mu\ell$) was evaporated and weighed in a Cahn Microbalance. Studies conducted here have shown that approximately 5 percent of Cook Inlet crude oil is lost by evaporation during the first 10 minutes, presumably the volatile fraction. Recoveries of Cook Inlet crude oil from seawater also were investigated. Approximately 90-100 percent recoveries were obtained when 3-20 ml aliquots of CH_2Cl_2 were employed to extract 600 ml of seawater. The solvent volume reduction step (60 ml $CH_2Cl_2 \rightarrow$ 2 ml CH_2Cl_2) results in approximately a 25 percent loss of the original oil added.

These results should be construed as preliminary in nature, as extreme difficulty was encountered in maintaining environmental control over the experiment. Notwithstanding these difficulties, the results obtained from the field experiments are shown in Table 1.

It is clear that the quantity of oil retained by the sediments generally increased as the concentration of oil increased. Loadings of oil in suspended matter (mg oil/mg sediment recovered) varied from 0.025 to

0.44. This latter figure is suspect and is probably excessive. Quantities of oil added varied from 8 to 42 mg, while the amount of sediment recovered varied from 26-138 mg, depending on the experimental volume and the degree of flocculation that occurred. Ambient suspended sediment concentration at the time of sampling was approximately 150 mg/ℓ.

While these experiments are quite preliminary and need to be confirmed in the laboratory, they point to the fact that suspended matter in Cook Inlet possesses a large capacity for accommodating oil. Ignoring the high value shown in Table 1, it appears that these sediments may accommodate up to 30 percent of their weight in oil or remove up to 40 percent of the total oil added. Similar studies carried out with Prudhoe Bay crude oil and suspended matter from the Skagit River in Washington show analogous results. In these studies, sediments occluded up to 30 percent of their weight in oil, or in terms of the experimental design, approximately 25-30 percent of the added oil was sedimented as flocs.

These results suggest that suspended matter may be an important transport mechanism for spilled oil in Cook Inlet. However, these idealized experiments, which are still in progress, shed little light on the physical interaction between oil and sediment. Studies of this phenomenon should be initiated in order to understand the nature of this interaction with the aim of developing a prediction model applicable to widely varying environmental conditions.

Table 1. Accommodation of crude oil on suspended matter obtained from Cook Inlet. Oil and suspended matter were shaken gently in seawater for one hour at 5°C. The concentration of suspended matter was approximately 150 mg/ℓ. The values in parentheses (column 4) reflect the corrected oil recovery, assuming a 25% loss during the solvent reduction step.

Oil Added mg	Oil Recov.-Water mg	Oil Recov.-Sed.* mg	Σ Oil Recov. %	Sed. Recov. mg	Loading mg Sed./ mg Oil
8.45	4.39	0.73	60 (75)	28.6	0.025
8.45	0.48	4.42	58 (72)	138.3	0.035
16.90	7.29	6.27	80 (100)	26.5	0.24
25.35	4.33	13.15	69 (86)	29.9	0.44
25.35	2.90	10.25	52 (65)	94.9	0.11
42.25	22.21	4.63	64 (80)	88.2	0.30

*Values not corrected for water accommodated oil.

IV. Preliminary Interpretation of the Results

The distribution patterns of suspended matter in Lower Cook Inlet show a direct relationship to water circulation. The inflowing relatively nonturbid Gulf of Alaska water moves along the eastern coastline until it reaches the region just north of Cape Ninilchik where it mixes with the highly turbid brackish water from Upper Cook Inlet. Under the influence of tidal currents and coriolis forces the turbid water moves southwest along the western coast into Shelikof Strait where the particulate matter disperses and settles to the bottom. This counterclockwise circulation pattern gives rise to extremely large horizontal gradients in suspended matter. However, tidal mixing is extensive and rapid; and, therefore, no vertical suspended matter gradients were observed during either of the two cruises in Lower Cook Inlet.

The preliminary results of the hydrocarbon-suspended matter interaction studies indicate that up to 30-40 percent of Cook Inlet crude oil may be accommodated by particles in suspension. These results, which must be considered to be preliminary at best and in need of further verification, suggest that accommodation and subsequent transfer of oil in association with suspended particulate matter may be a major controlling mechanism affecting the distribution of hydrocarbons in Lower Cook Inlet. Further studies involving the physical interactions of oil and particles are required before these preliminary results can be properly interpreted.

V. Problems Encountered

We have no significant problems to report at this time.

VI. Estimate of Funds Expended

	Allocated	Expended	Balance
Salaries and Overhead	$159.2K	$159.2K	0
Travel and Per Diem	9.8K	9.8K	0
Major Equipment	40.0K	40.0K	0
Expendable Supplies	28.8K	28.8K	0
Shipping	2.2K	2.2K	0
Publications	1.0K	1.0K	0
Ranked FY 76 Funds	20.0K	20.0K	0
	$261.0K	$261.0K	0

References

Baker, E. T., and D. F. Piper. Suspended particulate matter: collection by pressure filtration and elemental analysis by thinfilm x-ray fluorescence, Deep Sea Research, 23:181-186, 1976.

Sharp, J. H. Improved analysis for "particulate" organic carbon and nitrogen from seawater, Limnol. and Oceanogr., 19(6):984-989, 1974.

Quarterly Report

Research Unit: 153
Reporting Period: 1 June - 30 Sept. 1977
Number of Pages: 52

Identification of Natural and Anthropogenic Petroleum Sources Utilizing Low Molecular Weight Hydrocarbons, C_1-C_4

Dr. Joel Cline

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7600 Sand Point Way N.E.
Seattle, WA 98115

October 1, 1977

I. Task Objectives

During the past year, regional studies into the distributions of the low molecular weight hydrocarbons (LMWH) were conducted in Bristol Bay and the northeast Gulf of Alaska. The principal focus of the program was to provide baseline information on the temporal and spatial variations as a prelude to the probable development of OCS petroleum resources. Our responsibility to these objectives will be largely met at the close of the current field season, although important seasonal data in some areas will be lacking.

Studies of the abundances and distributions of LMWH this year have focused on lower Cook Inlet, Shelikof Strait, Kodiak Island Shelf, and the Tarr Bank-Kayak Island area. This report focuses on studies just completed in LCI and the Kodiak Shelf.

Objectives of the study in LCI and Kodiak Shelf were to assess the baseline concentrations of LMWH and to identify significant anthropogenic and natural sources of hydrocarbons. These sources might include subsurface natural seepage, spillage or leakage from production platforms, or input from transportation activities. If point sources of petroleum hydrocarbons are identified, the distribution of LMWH provides valuable information about the dispersion characteristics of the dissolved fraction.

II. Field Activities

A. Ship Schedule

The distribution and abundances of LMWH were evaluated in LCI, Shelikof Strait, and the Kodiak Shelf during April and July 1977. Each cruise was divided into two legs, the first being devoted to LMWH and suspended matter studies in LCI and Shelikof Strait, the second focusing on benthic sources of LMWH in the Tarr Bank region (April 1977) and the distribution of LMWH in waters over the southeastern Kodiak Shelf (July 1977).

Vessel:	R/V DISCOVERER	Vessel:	R/V ACONA
Cruise Date:	4-22 April 1977	Cruise Date:	28 June - 16 July 1977
Cruise No.:	RP-4-DI-77A-IV	Cruise No.:	ACONA-245

B. Scientific Compliment

The scientific compliment aboard the R/V DISCOVERER during April included (LMWH only):

Dr. Joel Cline, PMEL, Cruise Leader

Mr. Anthony Young, PMEL, Oceanographer

Ms. Marilyn Pizzello, PMEL, Technician

Mr. Brad Echert, NOS, Electronic Technician

Mr. Rob Martinez, PMEL, Technician

Mr. James Cimato, BLM, Observer

Mr. Varis Grundmanis, UW, Graduate Student

The scientific compliment aboard the R/V ACONA in July included (LMWH only):

Mr. Joel Cline, PMEL, Cruise Leader

Mr. Anthony Young, PMEL, Oceanographer

Mr. Frank Swoboda, PMEL, Electronic Technician

Mr. Glenn Greathouse, PMEL, Marine Technician

Personnel assigned to the suspended matter program during both cruises will be listed in the quarterly report being submitted by Dr. Feely.

C. Methods

Analysis of waters for LMWH: LMWH are stripped from a 1-liter volume of seawater using a modified procedure recommended by Swinnerton and Linnenbom (1967). Hydrocarbon components, methane, ethane, ethene, propane, propene, iso- and n-butanes, are removed in a continuous stream of He and trapped on activated alumina at -196°C. After a nominal 10-minute stripping time, the trap is warmed to 100°C and the components flushed into the gas chromatograph for analysis.

Chromatography of the components is effected on a column of Poropak® Q (8' x 3/16"), 60-80 mesh, in series with a small column of activated alumina (3/16" x 2") impregnated with 1% silver nitrate by weight. This dual column configuration results in sharper peaks, better separation of olefins, and reduced component retention times. Chromatography of LMWH components through C_4 is accomplished in less than six minutes. Detection of the component hydrocarbons as they emerge from the column is performed with a flame ionization detector.

D. Data Collected and Analyzed

1. LCI and Shelikof Strait (April 1977)

   No. Stations: 44

   No. Samples Analyzed: 141

   Trackline Miles: 560 n.m.

2. LCI, Shelikof Strait, and Kodiak Shelf (July 1977)

   No. Stations: 102

   No. Samples Analyzed: approx. 500

   Trackline Miles: 870

III. Results and Discussion

A. Cook Inlet

The distributions of the low molecular weight alkanes and alkenes (C_1-C_4) were observed in LCI during the months of April and July 1977. During the April cruise, numerous analytical difficulties were encountered, resulting in rather poor coverage of the hydrocarbon distributions north of Kachemak Bay. These problems were later resolved, and subsequent observations in July were both complete and reliable. Both observational sets will be discussed in this report.

The sampling grid employed during both cruises is reflected in Figure 1, except that during April no sampling was conducted north of the Forelands. Apparently existing regulations prohibit the use of NOAA Class I vessels (i.e., R/V DISCOVERER) north of Kalgin Island. In July, the R/V ACONA was used and rather extensive sampling in the producing fields north of the Forelands was carried out (stations not shown on Figure 1).

1. Methane

The surface distributions of dissolved methane are shown in Figures 2 and 3 for the months of April and July. General features of the distribution include a tongue of methane deficient waters entering through Kennedy Entrance ($100\ n\ell/\ell < CH_4 < 150\ n\ell/\ell$) and high surface concentrations north of Kachemak Bay. North of the Forelands, concentrations of methane exceeded 600 $n\ell/\ell$ during the month of July (Figure 3). The lateral shelf areas of the Inlet also were characterized by high concentrations of methane (200-900 $n\ell/\ell$), more so during summer than was observed during spring.

Near bottom distributions of dissolved methane are shown in Figures 4 and 5 for the months of April and July. Concentrations were much lower in

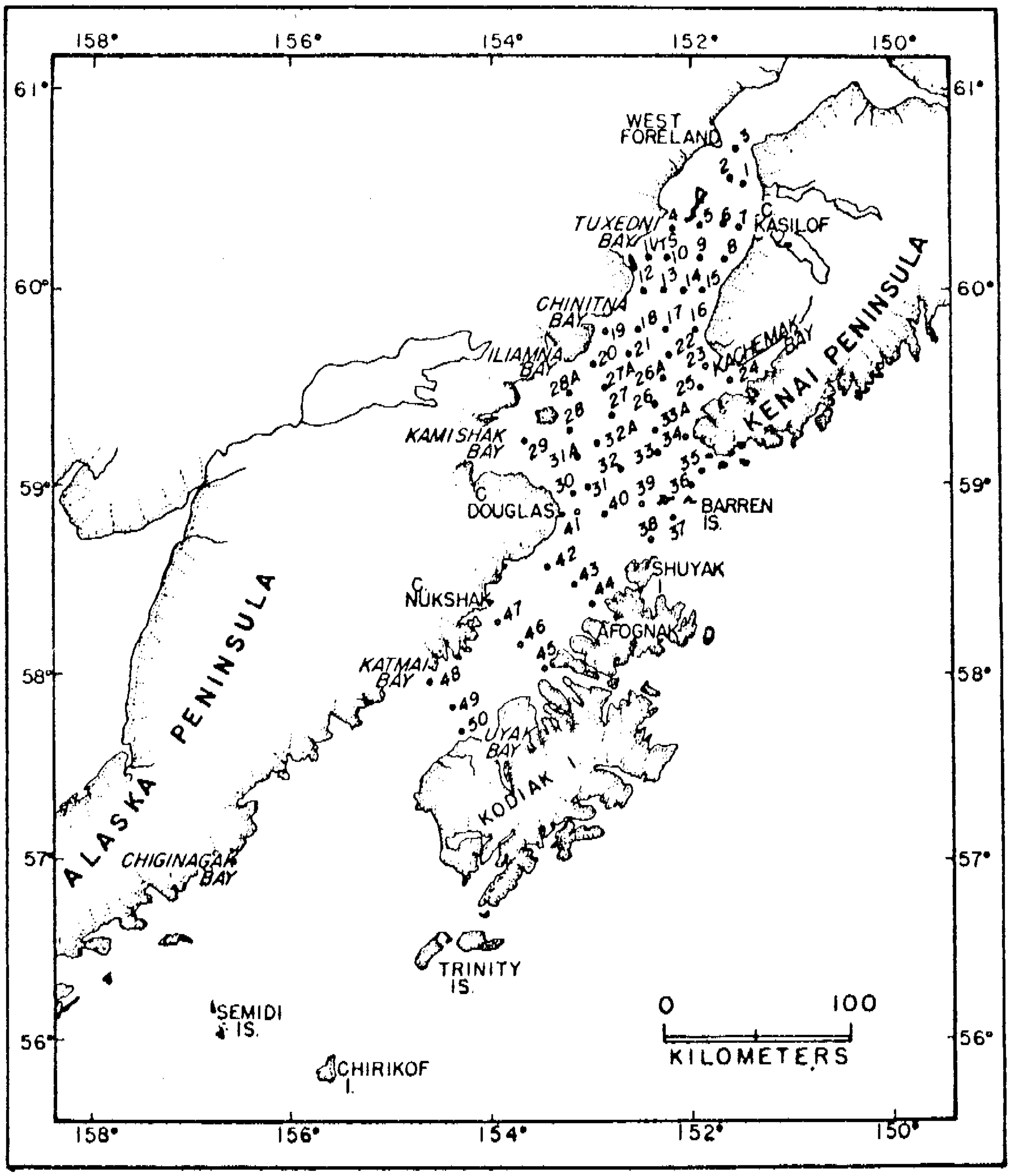

Figure 1. Station locations occupied in April and July 1977 in Cook Inlet and Shelikof Strait. Stations occupied in July above the Forelands not shown.

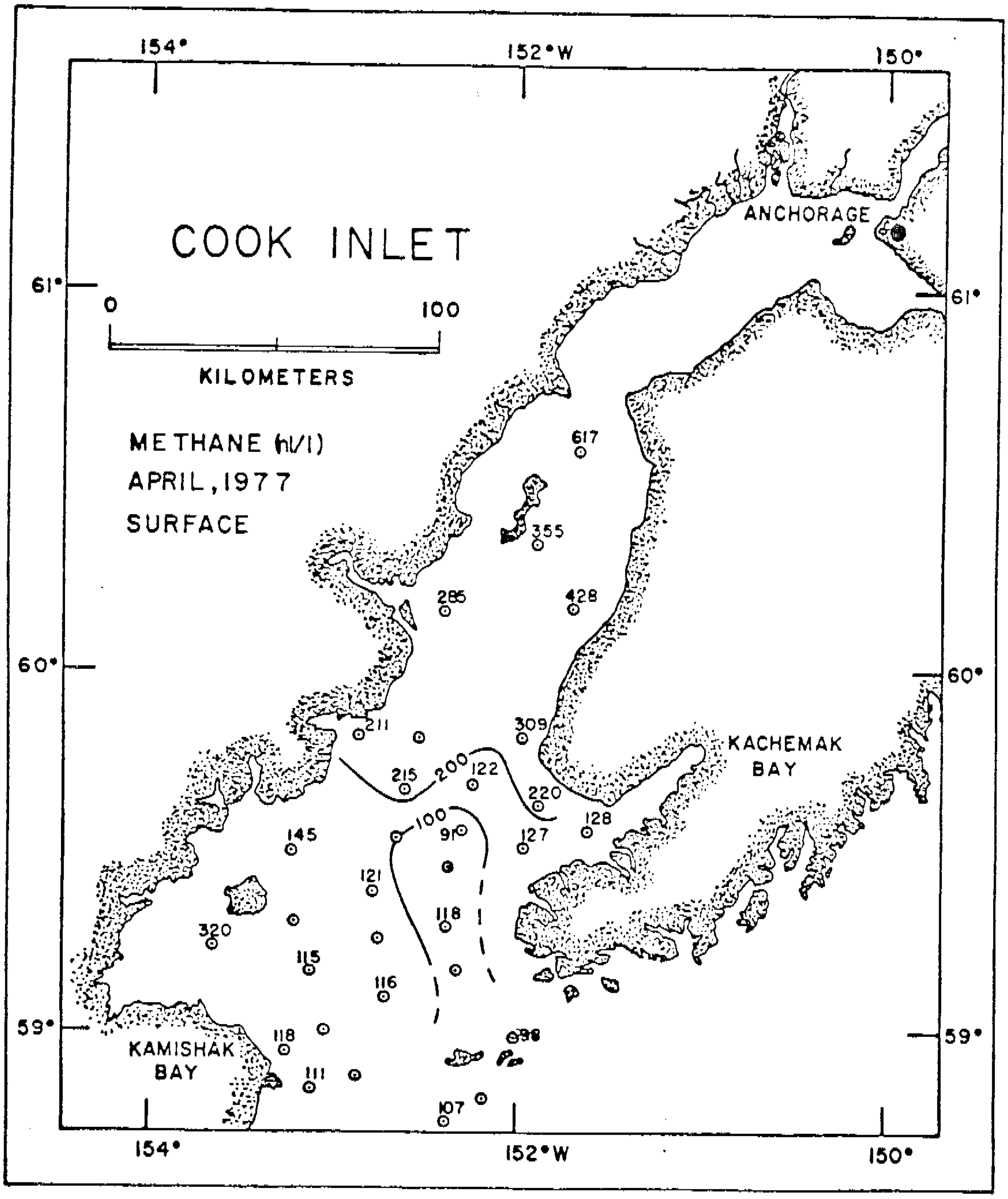

Figure 2. Distribution of methane (nℓ/ℓ, STP) in the surface layers during April 1977. Concentrations not shown at all stations for the purpose of clarity.

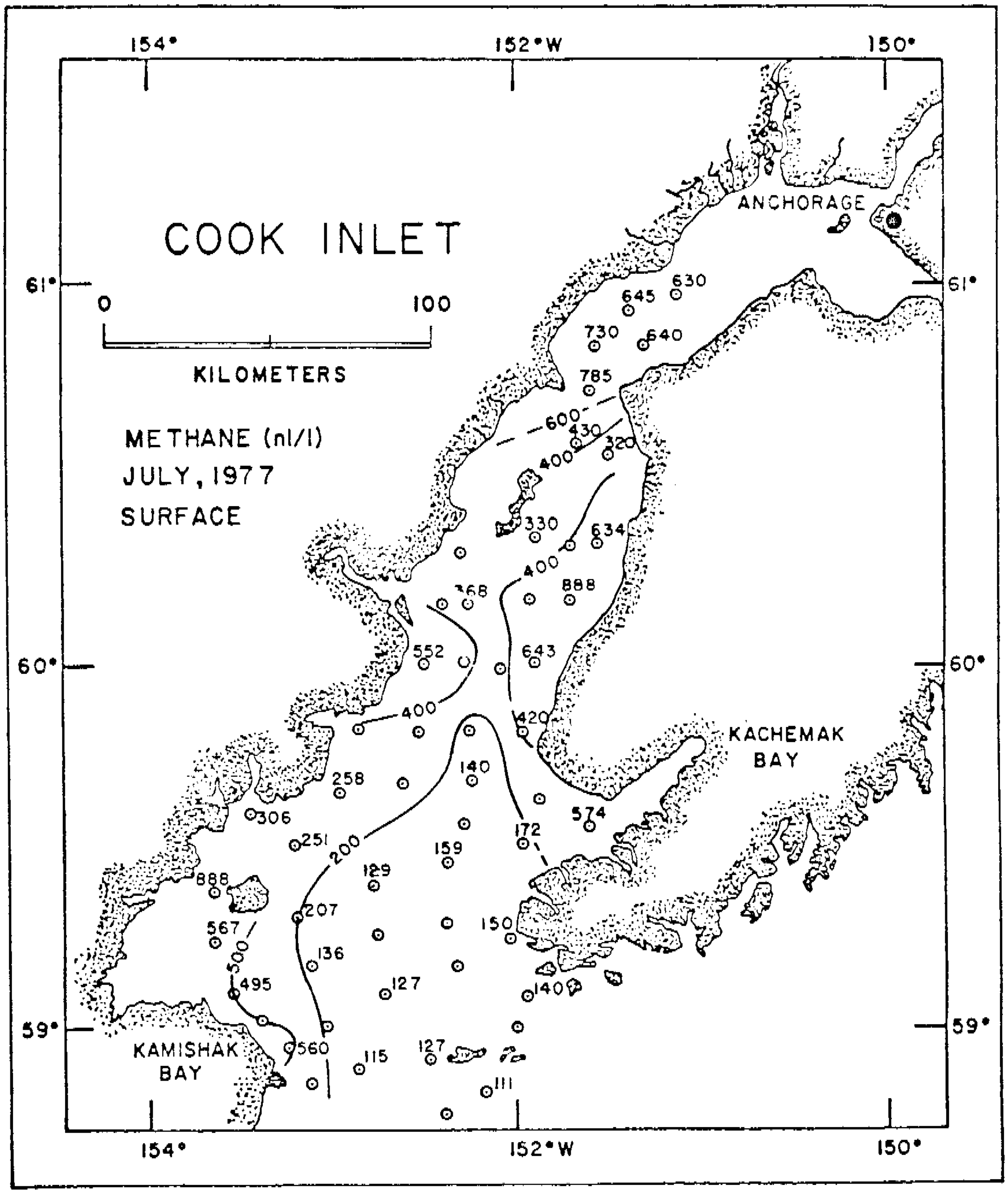

Figure 3. Distribution of methane (nℓ/ℓ, STP) in the surface waters during July 1977. Concentrations not shown at all stations for the purpose of clarity.

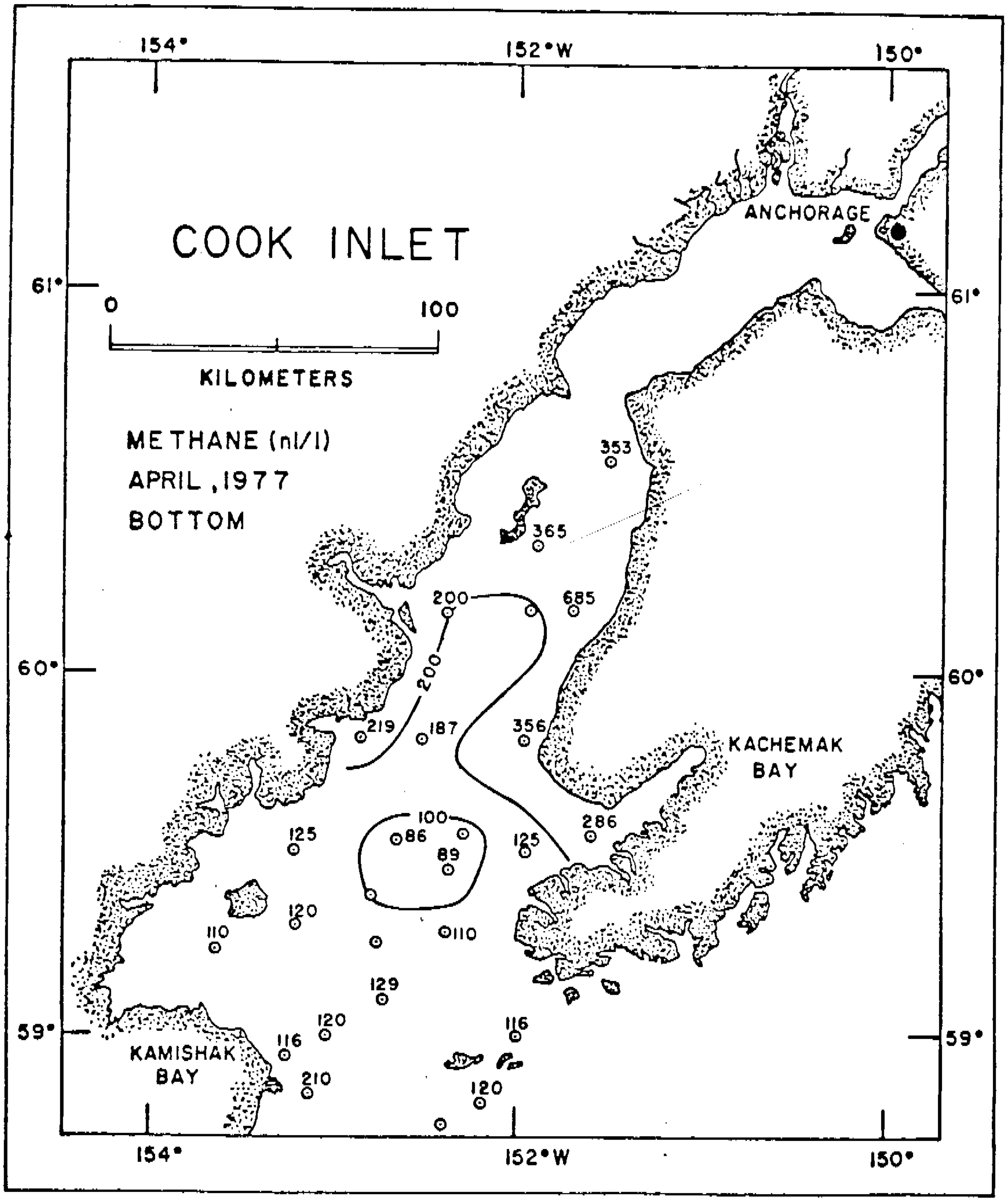

Figure 4. Distribution of methane (nℓ/ℓ, STP) within 5 m of the bottom during April 1977. Concentrations not shown at all stations for the purpose of clarity.

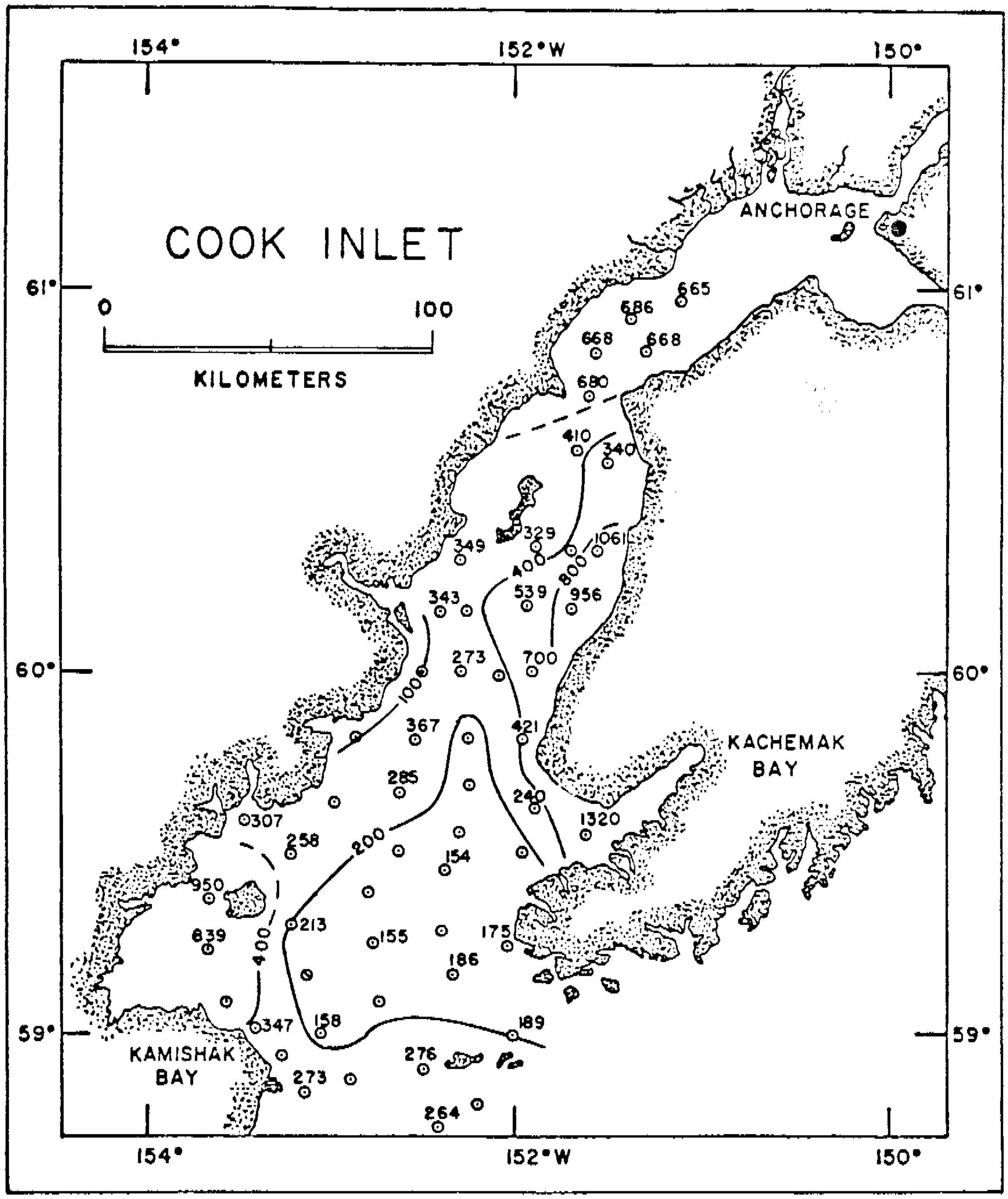

Figure 5. Distribution of methane (nℓ/ℓ, STP) within 5 m of the bottom during July 1977. Concentrations not shown at all stations for the purpose of clarity.

April compared to July measurements, presumably reflecting a reduced biological activity. As was observed in the surface distributions, the incoming water is low in methane (100-150 nℓ/ℓ), although some local effect from the bottom is apparent when the seasonal distributions are compared. In July, high concentrations of methane appear to be emanating from the shelf region north of Kachemak Bay, where concentrations near 1000 nℓ/ℓ were observed (Figure 5). Near bottom concentrations of methane north of the Forelands were uniformly near 675 nℓ/ℓ, quite similar to the concentrations observed in the surface layers (see Figure 3). This is indicative of the large vertical mixing that existed at the time of the observations (see Figures 6-9), resulting in a homogeneous water column with respect to salinity and temperature. The relationship between the distributions of hydrocarbons and the hydrography will be deferred until later in the discussion.

2. Ethane and Ethene

The surface and near-bottom concentrations of ethane are shown in Figures 10-13. In April, concentrations of ethane were rather uniform at 0.2-0.4 nℓ/ℓ with noted exceptions north of Kalgin Island, where concentrations were followed by more extensive sampling in July, particularly north of the Forelands and these results are shown in Figures 12 and 13.

The most striking feature is the elevated concentrations of ethane north of Kalgin Island. The highest concentration observed was 7.7 nℓ/ℓ at station 3 (Figure 1), with lesser amounts to the north. Concentrations appear to be higher on the west side of UCI and presumably diminish toward the north. At the time of the observations, the water column was well mixed so little vertical structure was apparent.

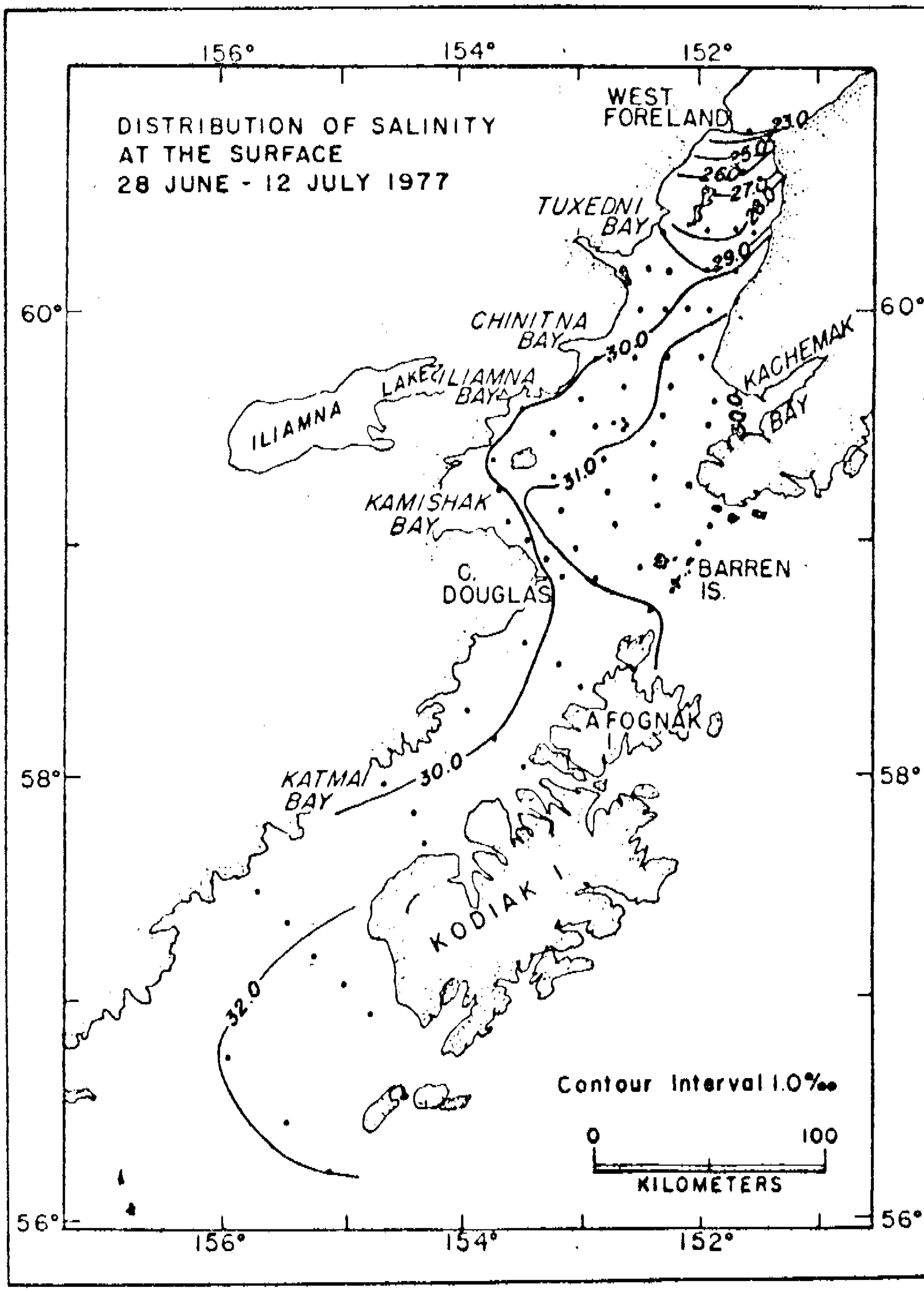

Figure 6. Distribution of salinity (°/oo) at the surface during July 1977.

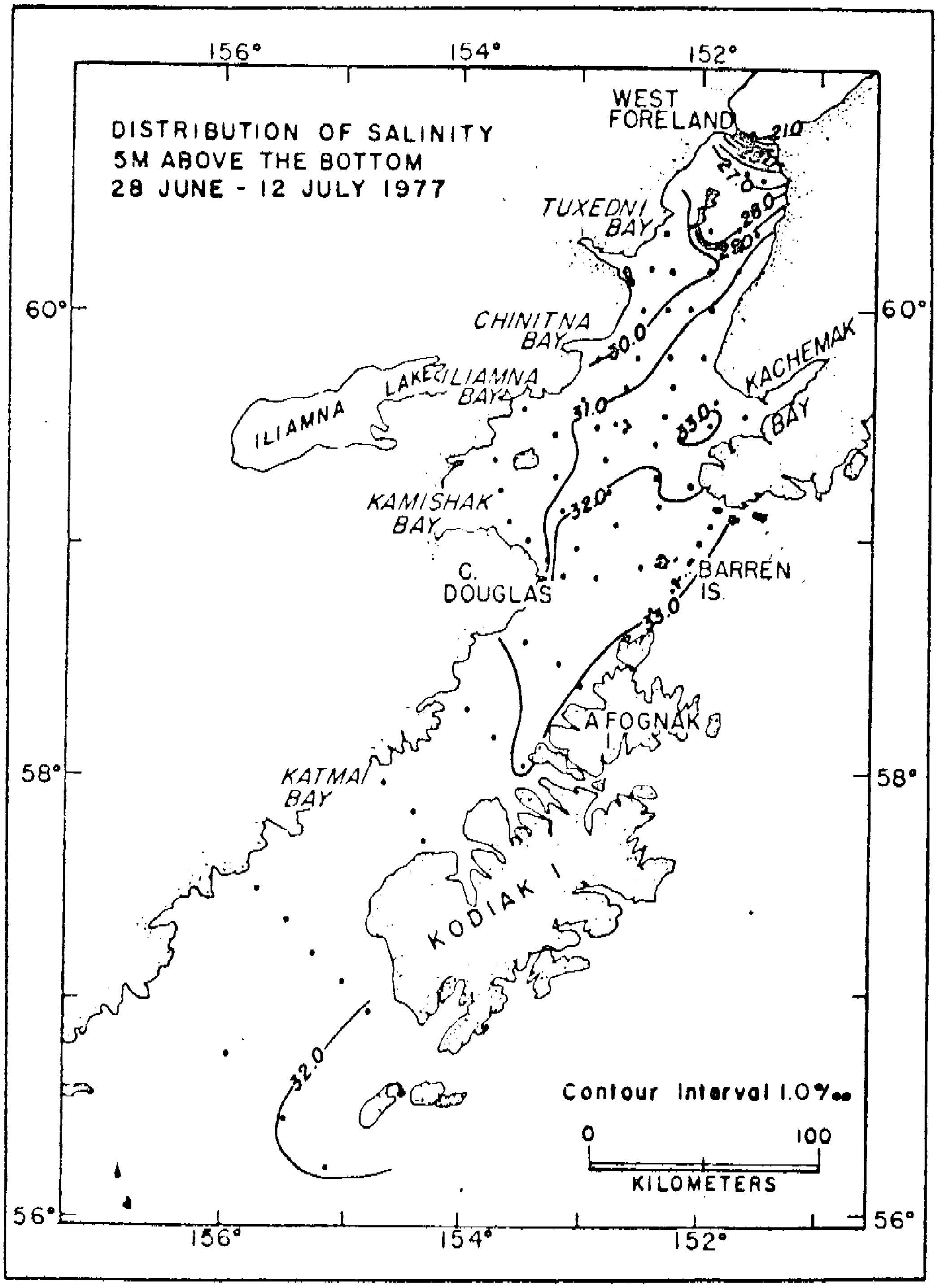

Figure 7. Distribution of salinity (°/oo) within 5 m of the bottom during July 1977.

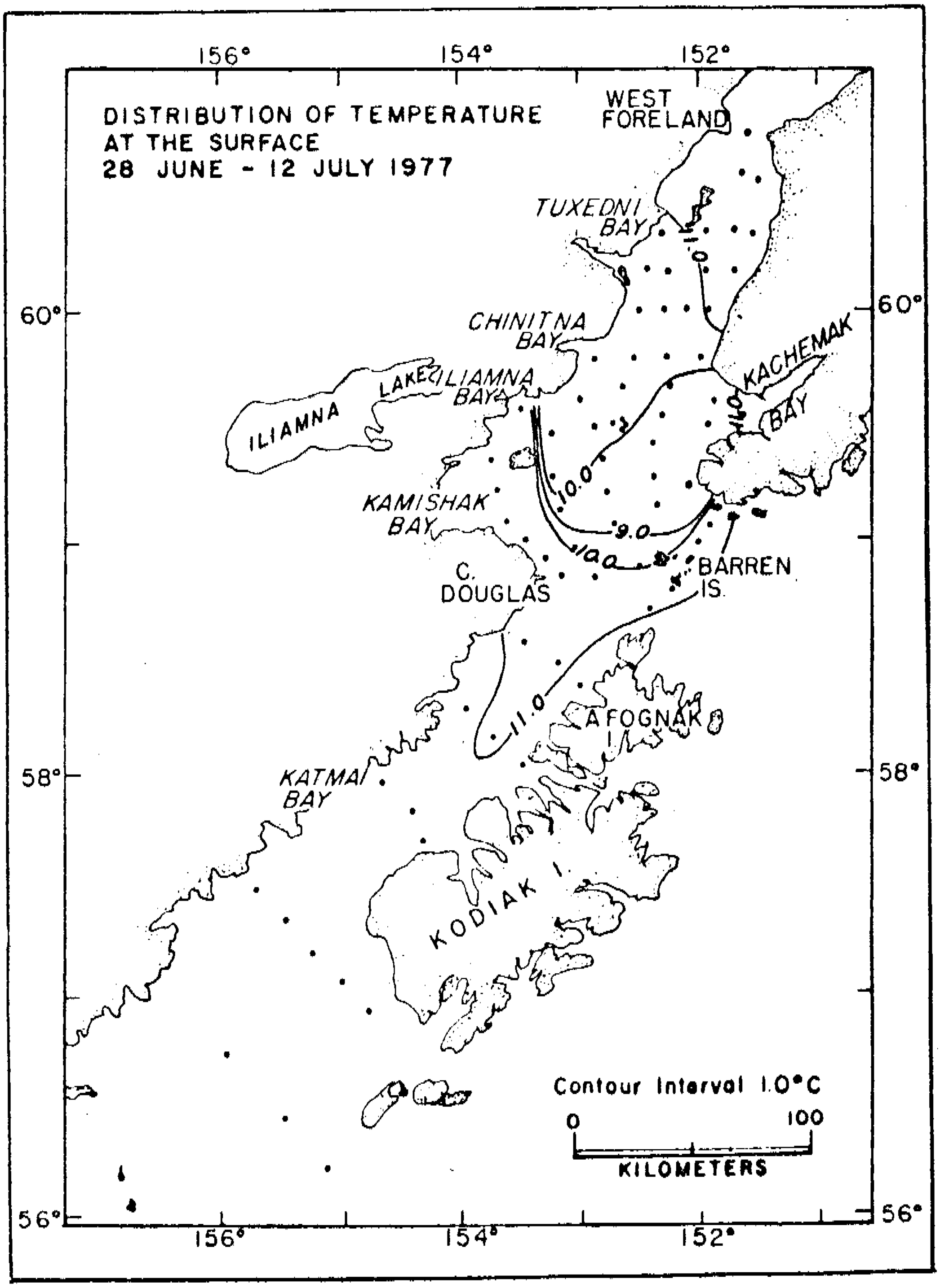

Figure 8. Distribution of temperature (°C) at the surface during July 1977.

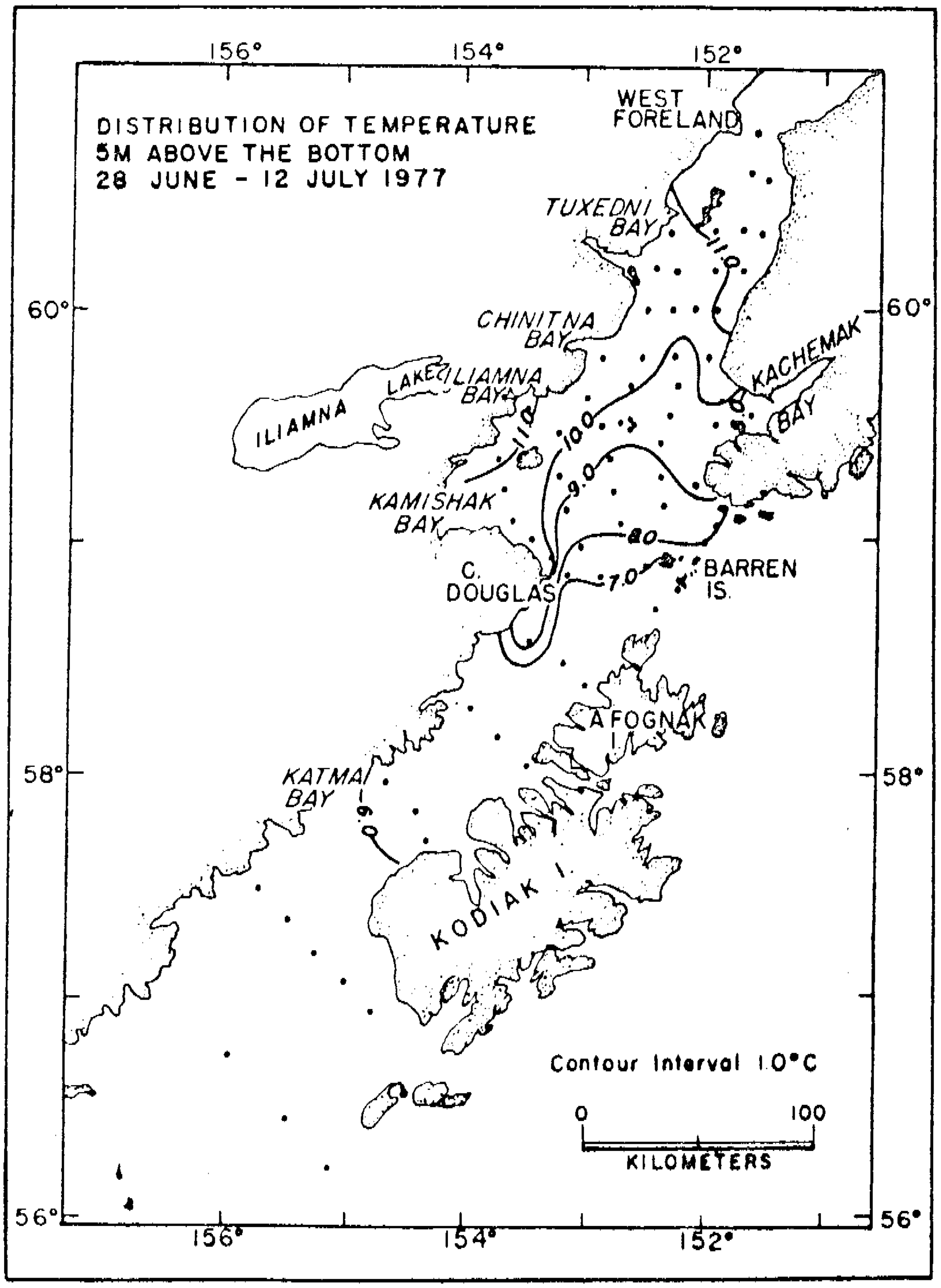

Figure 9. Distribution of temperature (°C) within 5 m of the bottom during July 1977.

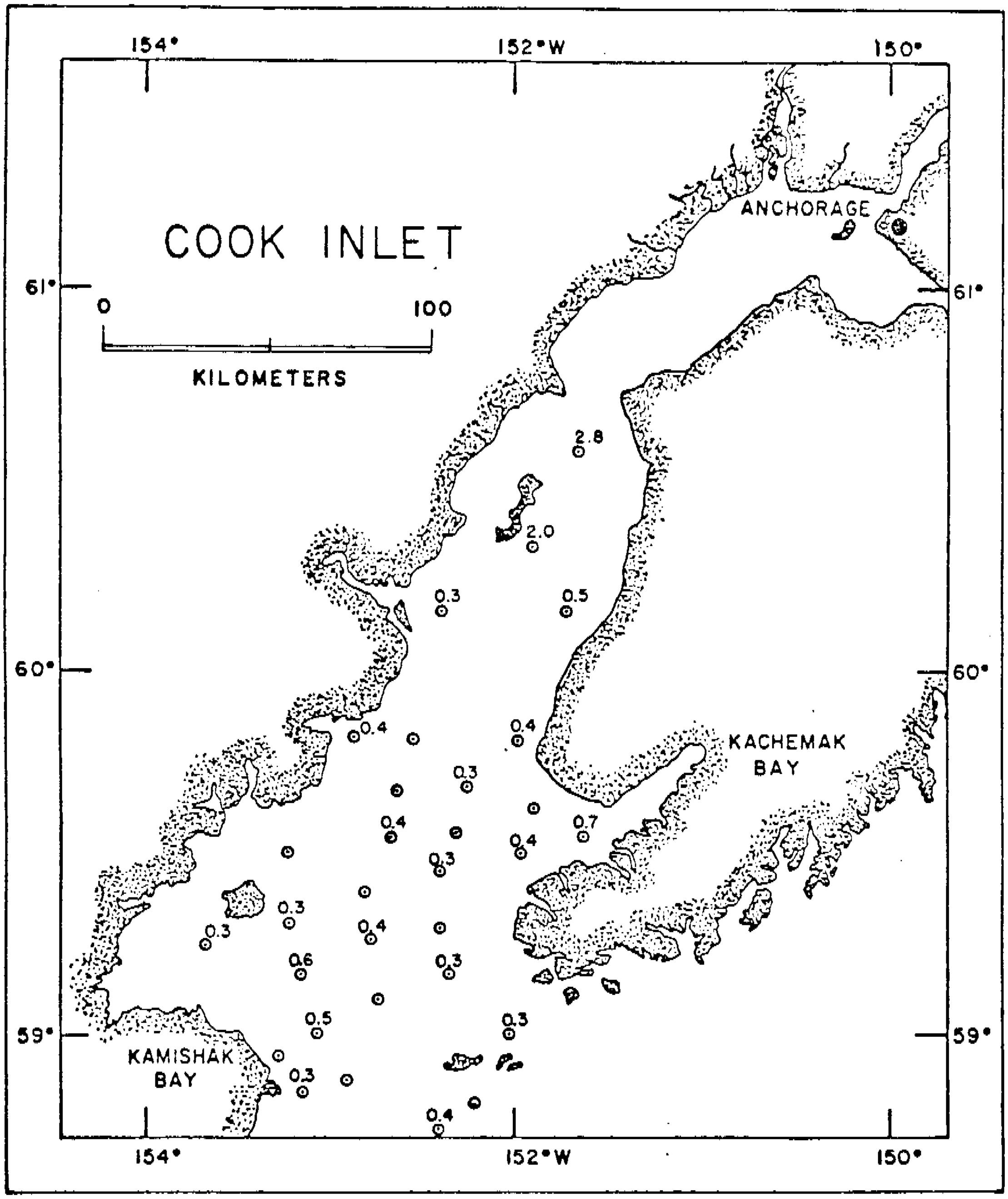

Figure 10. Distribution of ethane (nℓ/ℓ, STP) in the surface layers during April 1977. Concentrations not shown at all stations for the purpose of clarity.

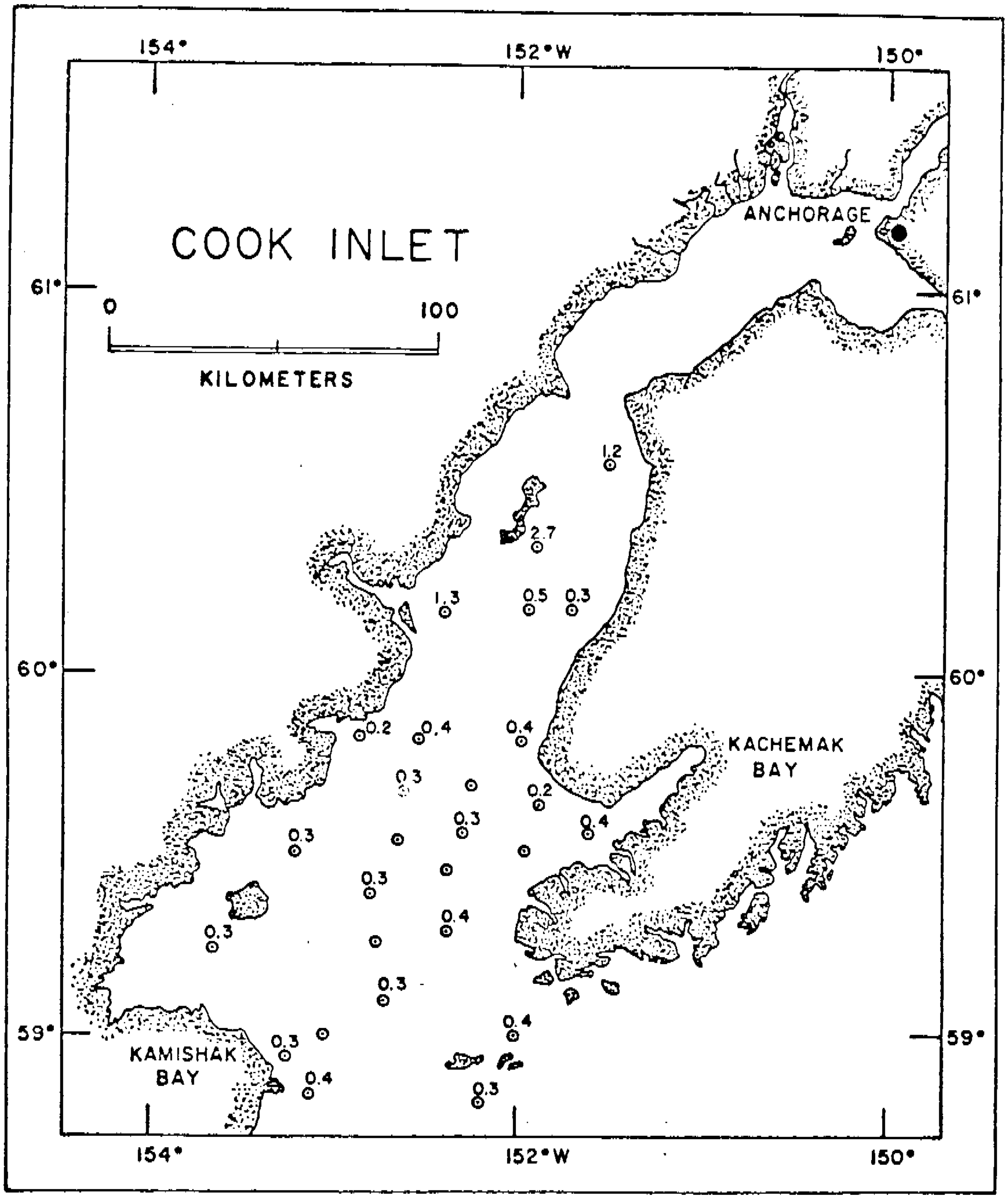

Figure 11. Distribution of ethane (nℓ/ℓ, STP) within 5 m of the bottom during April 1977. Concentrations not shown at all stations for the purpose of clarity.

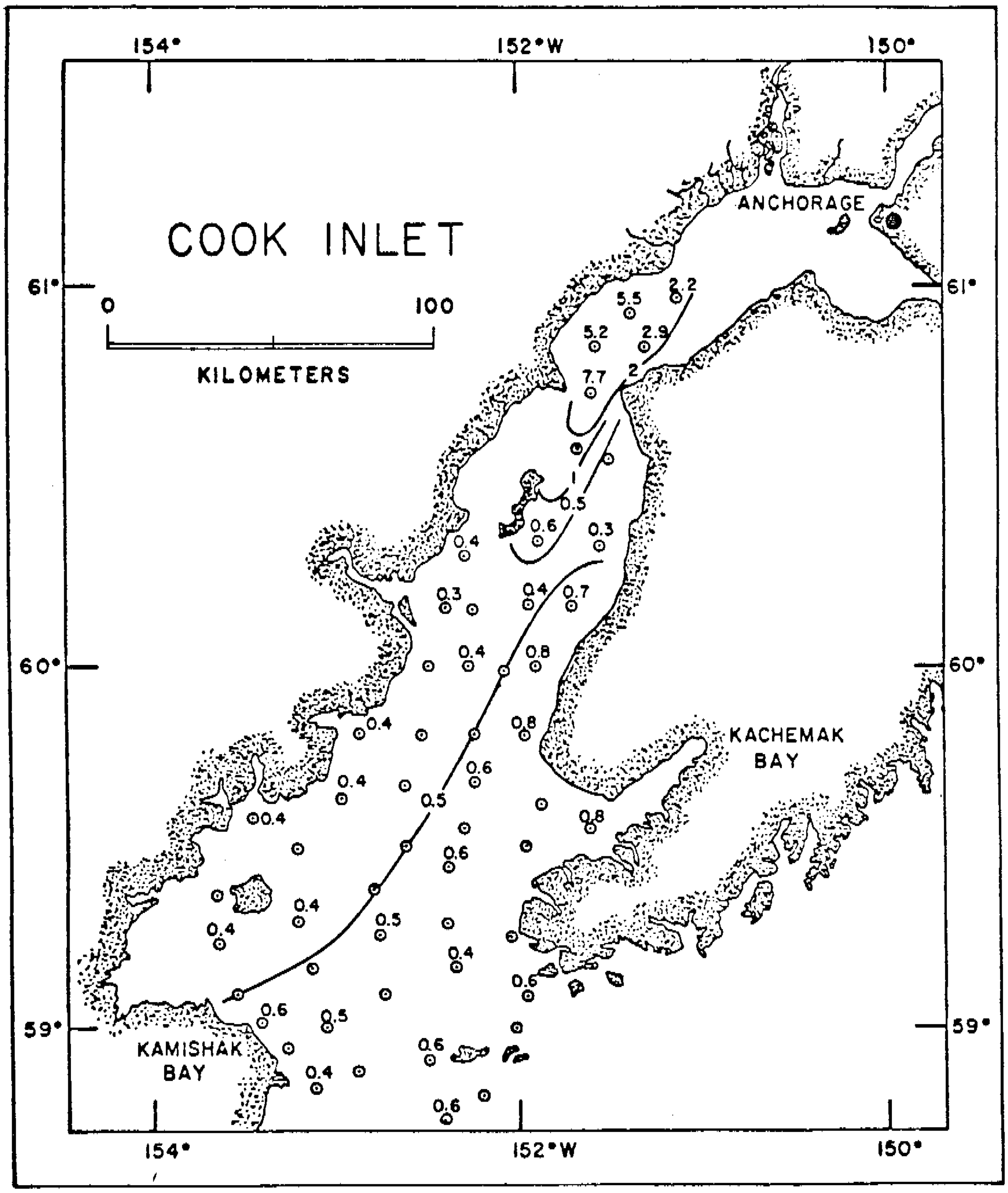

Figure 12. Distribution of ethane (nℓ/ℓ, STP) in the surface layers during July 1977. Concentrations not shown at all stations for the purpose of clarity.

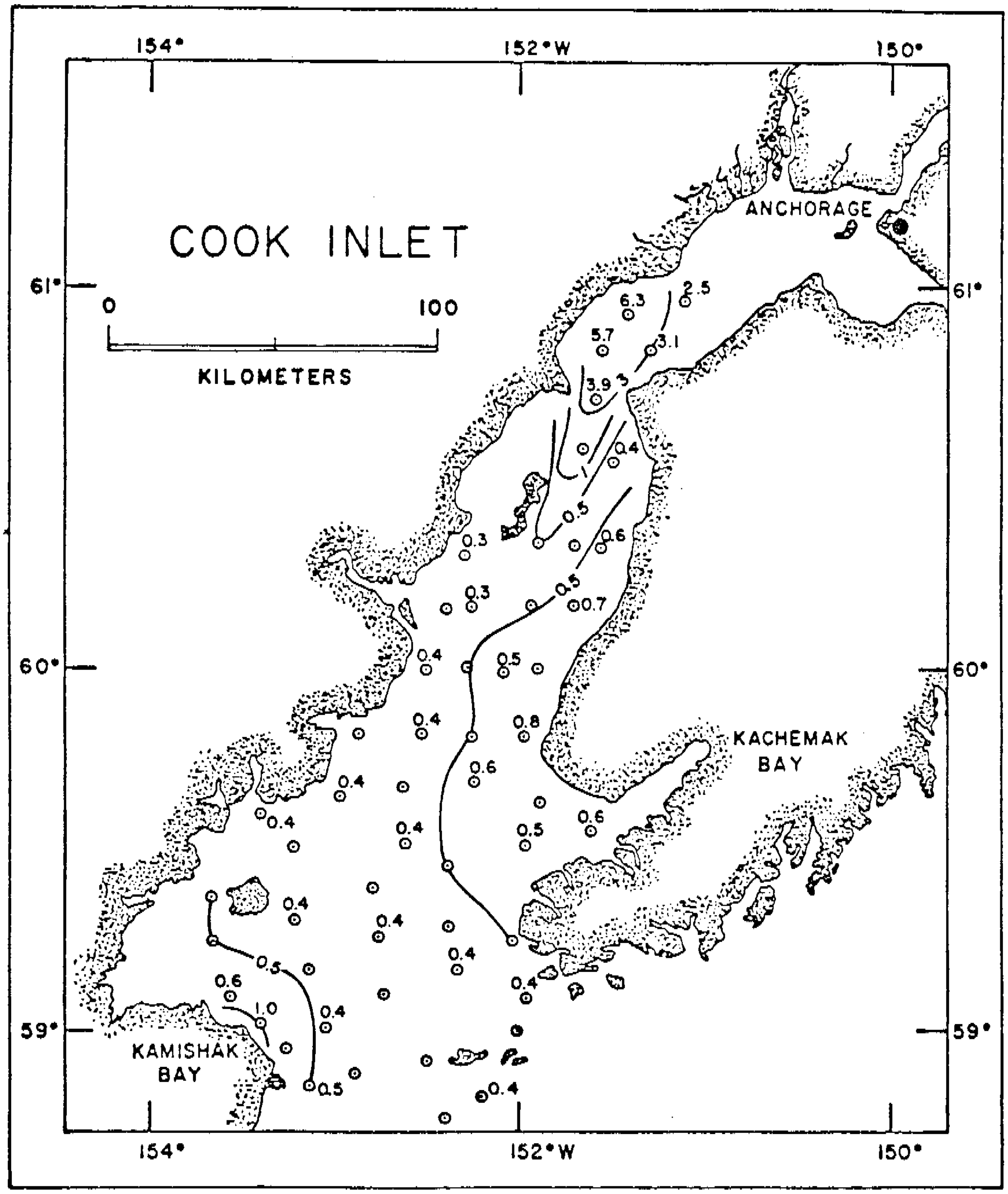

Figure 13. Distribution of ethane (nℓ/ℓ, STP) within 5 m of the bottom during July 1977. Concentrations not shown at all stations for the purpose of clarity.

South of the Forelands, the concentration of ethane diminishes rapidly to values in the range of 0.3-0.6 nℓ/ℓ. A strong horizontal gradient in salinity exists in the region north and east of Kalgin Island representing the zone of mixing between the relatively fresh waters of upper Cook Inlet and the more oceanic waters of LCI (Figures 6 and 9). Similar gradients are evident in the distribution of ethane and represent the strong horizontal salinity stratification that existed. Accumulations of ethane, and other hydrocarbons as well, presumably are related to the degree of ventilation existing north of the Forelands. Surface trajectory of the ethane-rich waters toward the south is passing just east of Kalgin Island in agreement with the salinity distribution shown in Figure 6.

In LCI, the concentration of ethane in the surface layers is slightly higher on the east side as compared to the west. This is due in part to the higher levels of ethene observed (see below) and both are presumably related to the cyclonic circulation in LCI. The marine waters entering LCI on the east are probably more productive than the sediment-laden waters moving south along the western shore.

One last feature needs to be mentioned. There is a small, possibly negligible, increase in the concentration of ethane observed near Cape Douglas (Figure 13). The highest concentration of ethane observed in this area was 1.0 nℓ/ℓ, a value somewhat larger than the amounts found elsewhere in the southern part of the Inlet. The location of these anomalous concentrations of ethane is near alleged seep activity on shore and its occurrence may represent incipient concentrations of hydrocarbons entering Kamishak Bay from that or similar sources.

Concentrations of ethene observed in April 1977 are shown in Figures 14 and 15. With the single exception of station 24 located in Kachemak Bay, where

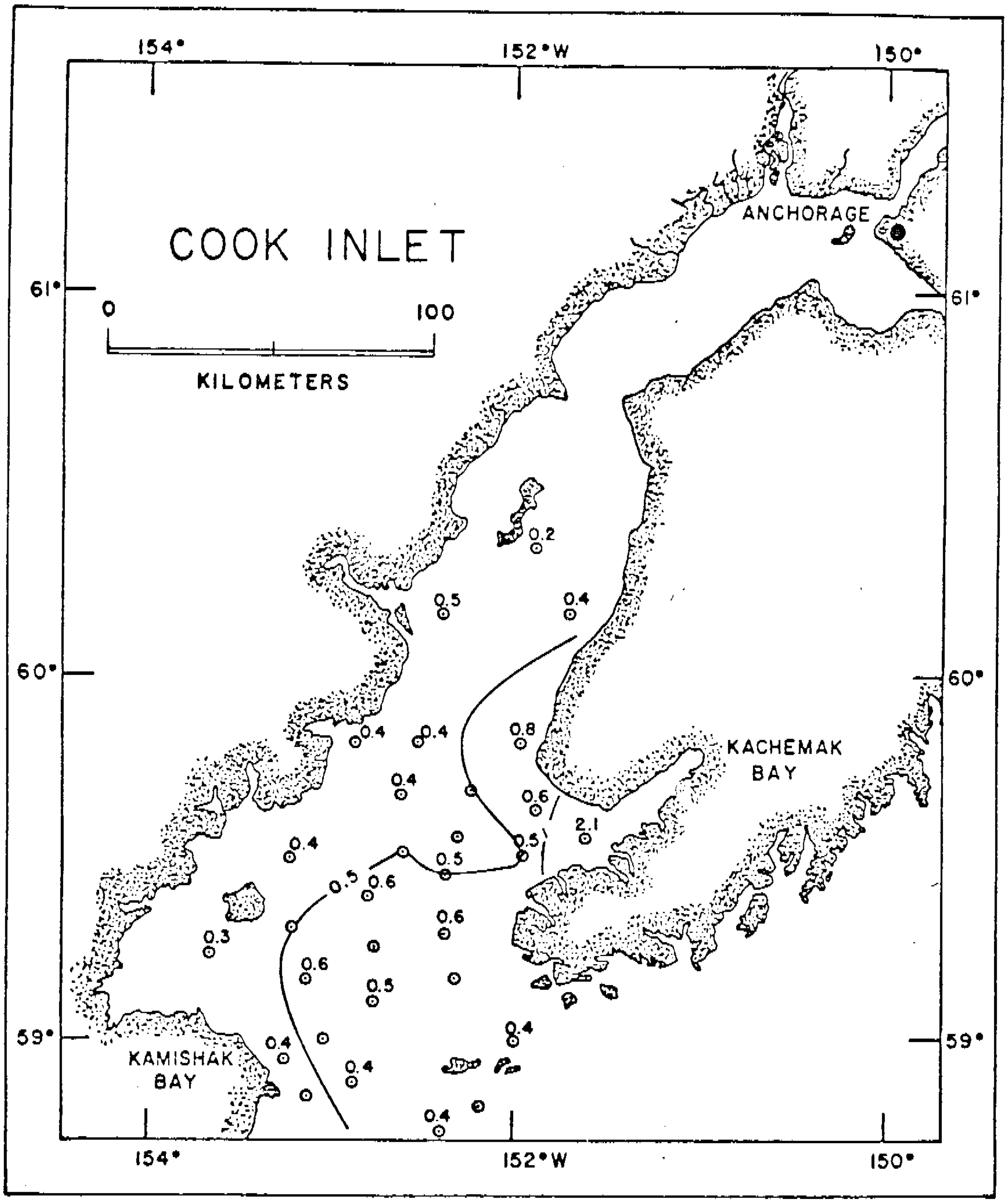

Figure 14. Distribution of ethene (nℓ/ℓ, STP) in the surface layers during April 1977. Concentrations not shown at all stations for the purpose of clarity.

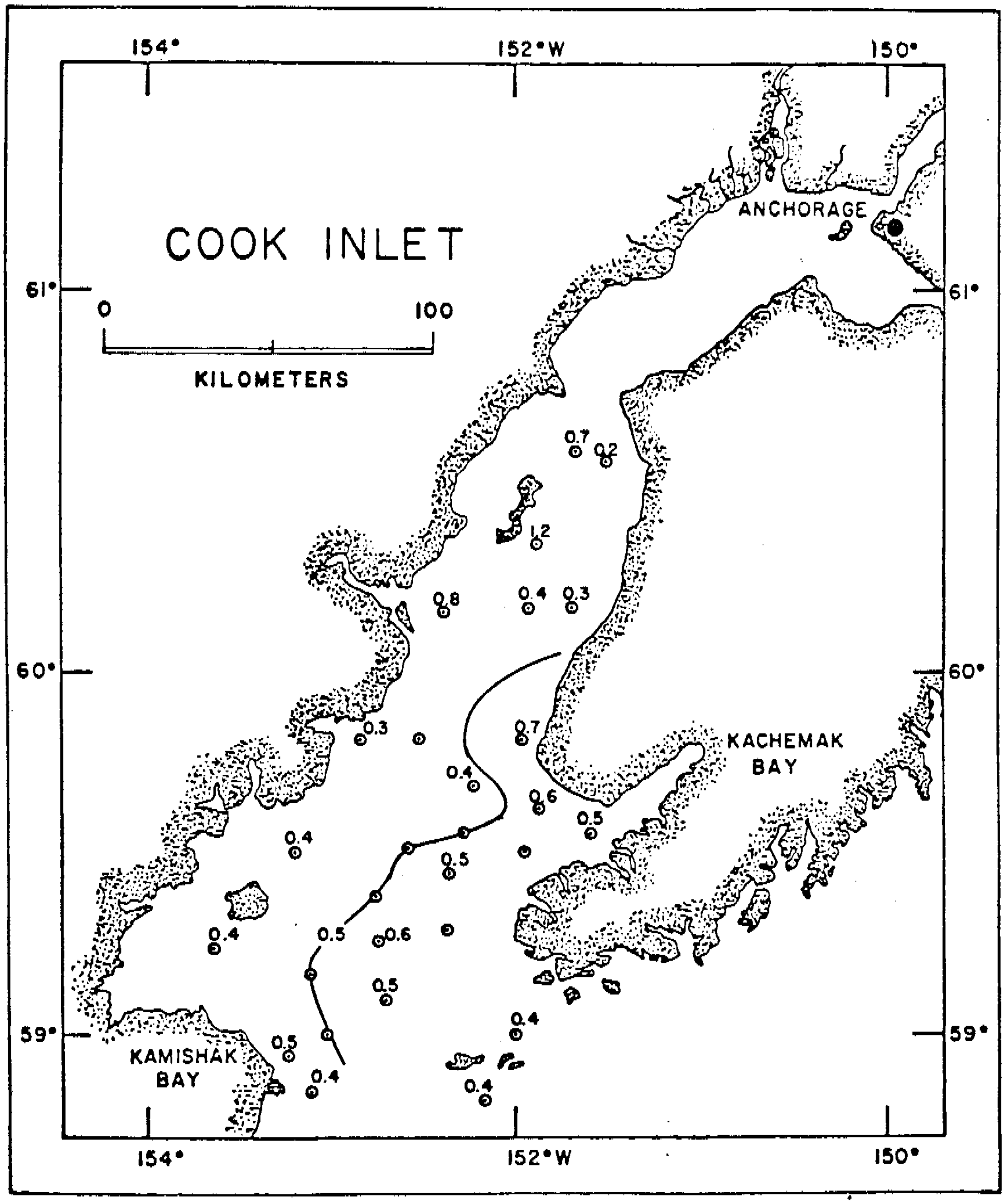

Figure 15. Distribution of ethene (nℓ/ℓ, STP) within 5 m of the bottom during April 1977. Concentrations not shown at all stations for the purpose of clarity.

a surface concentration of 2.1 nℓ/ℓ was measured, the concentrations of ethene ranged from 0.2-0.6 nℓ/ℓ in both the surface and near-bottom waters. Slightly higher values in the near-bottom waters (0.7-1.2 nℓ/ℓ) were observed (Figure 15), but because of analytical difficulties these values may not be reliable. As was shown with the distribution of ethane, the more saline waters along the eastern shore are characterized by higher concentrations of ethene.

Figures 16 and 17 show the distribution of ethene in July 1977. Surface features worthy of note include the near absence of the C_2 olefin north of the Forelands (0.5 nℓ/ℓ) and the strong source emanating from the shore north of Kachemak Bay ($C_{2:1}$ > 4 nℓ/ℓ). The largest concentration of ethene was observed in Kachemak Bay and was probably related to high primary productivity. Interestingly, some of the lowest concentrations of ethene were found in Kamishak Bay ($C_{2:1}$ < 2 nℓ/ℓ). The distribution of ethene in the near-bottom waters is similar to that found in the surface layers. The noted exception is the reduced values found in Kennedy and Stevenson Entrances, which reflect a condition normally found in deeper water. Depths in this region are in excess of 100 m.

The high concentrations of ethene found near the eastern shore are presumably biological in origin, but whether they arise from processes associated with primary productivity or are related to microbial activity in the sediments is not known at this time.

A useful diagnostic tracer of petrogenic hydrocarbons is the ethane/ethene ratio, since olefins are not normally present in crude oil. The $C_{2:0}/C_{2:1}$ ratio for the waters of Cook Inlet is depicted in Figures 18 and 19. These results dramatically show the unusual composition of the hydrocarbon gases originating in upper Cook Inlet, and that they are clearly discernible from the normal biological makeup shown in LCI. Extensive surveys in other OCS

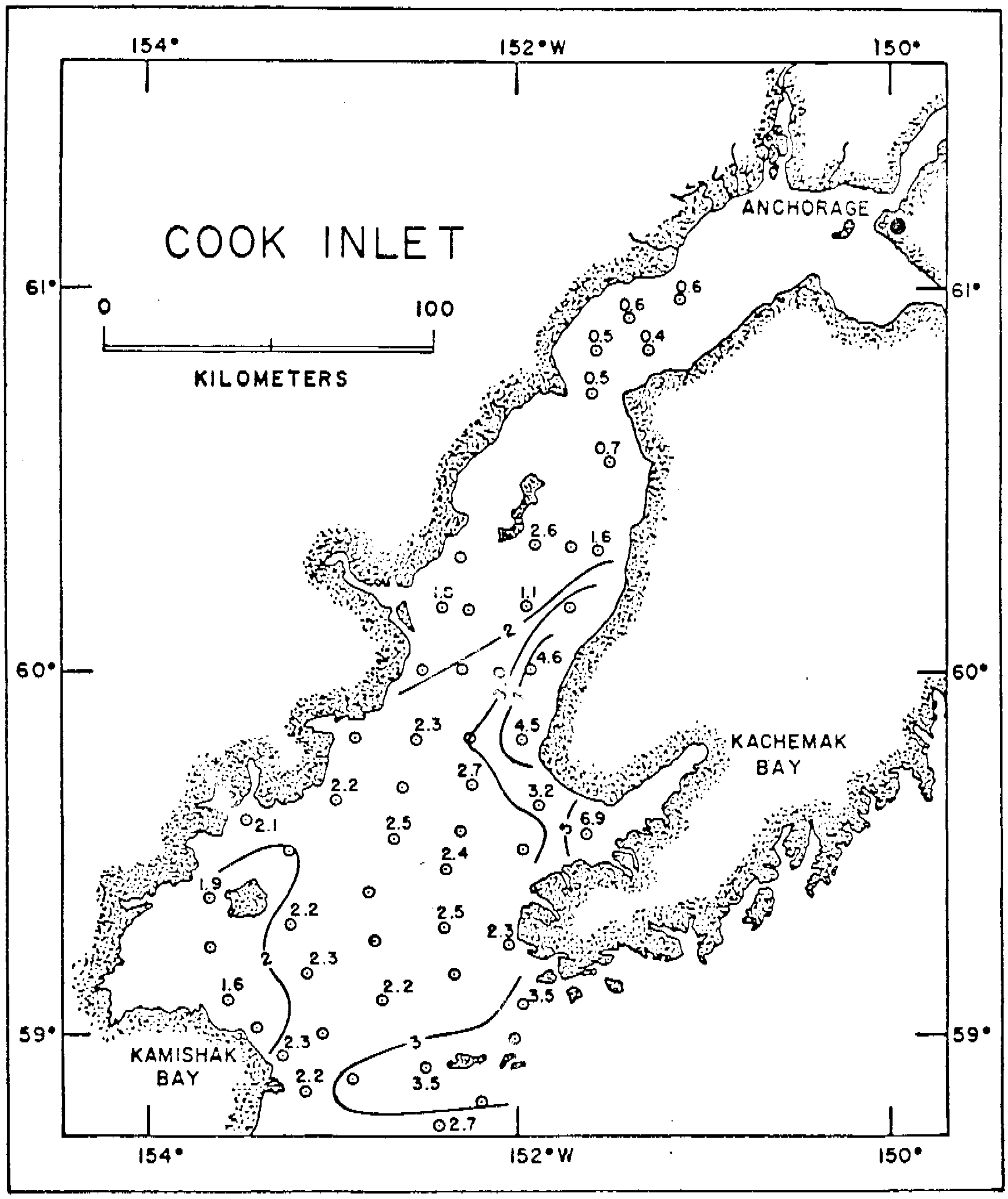

Figure 16. Distribution of ethene (nℓ/ℓ, STP) in the surface layers during July 1977. Concentrations not shown at all stations for the purpose of clarity.

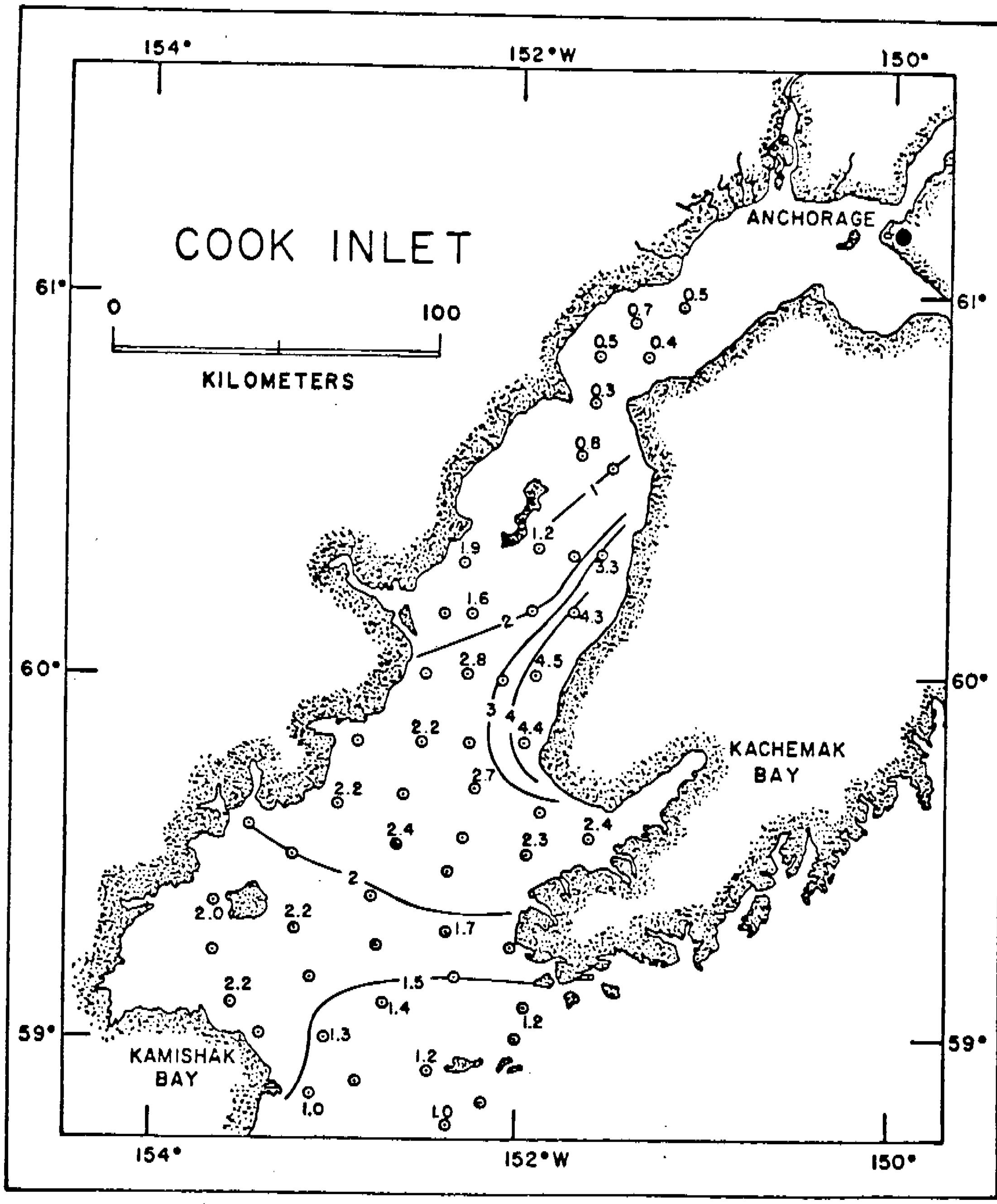

Figure 17. Distribution of ethene (nℓ/ℓ, STP) within 5 m of the bottom during July 1977. Concentrations not shown at all stations for the purpose of clarity.

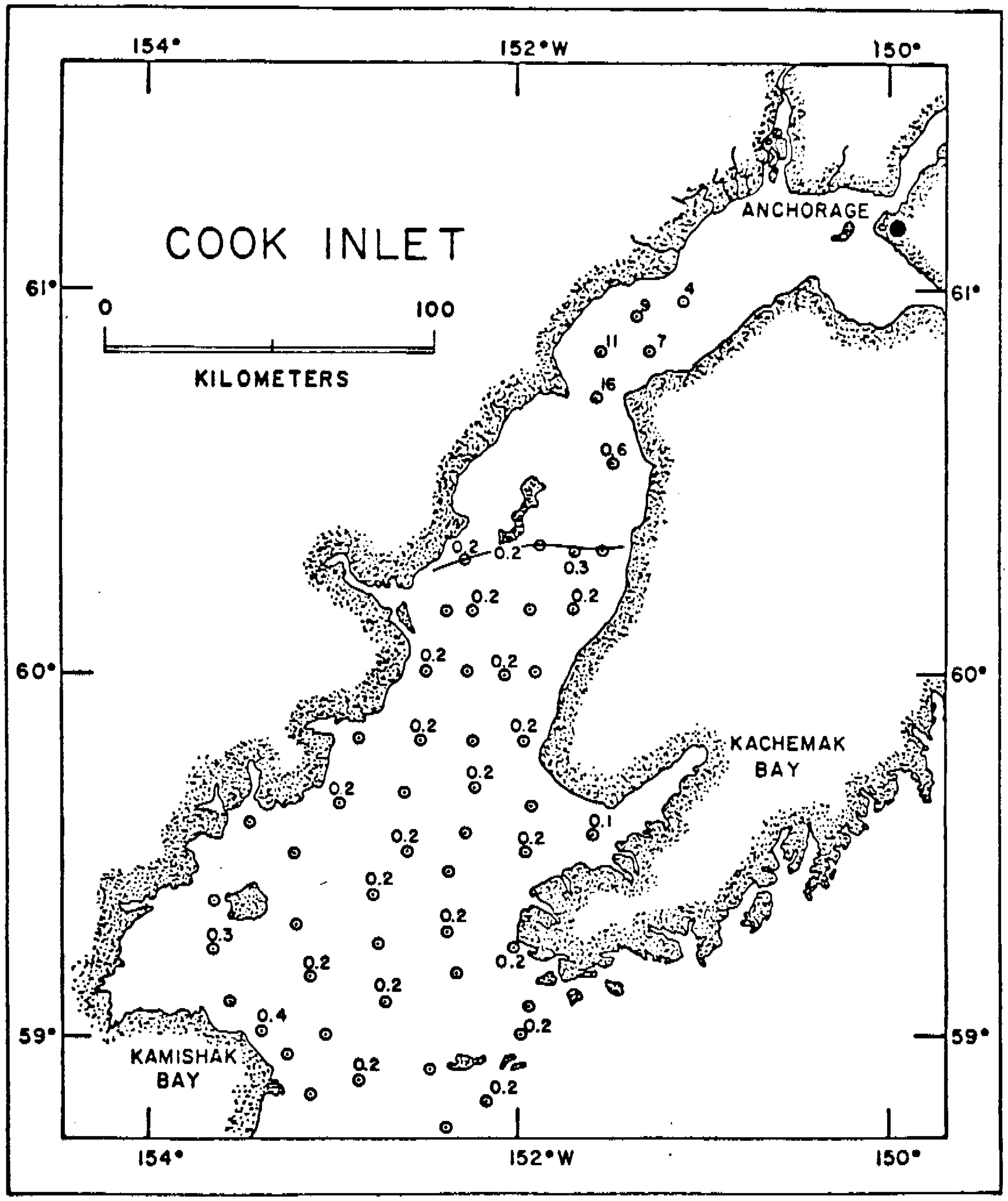

Figure 18. Ethane/ethene ratio in the surface layers during July 1977. Some ratios were not included for the purpose of clarity.

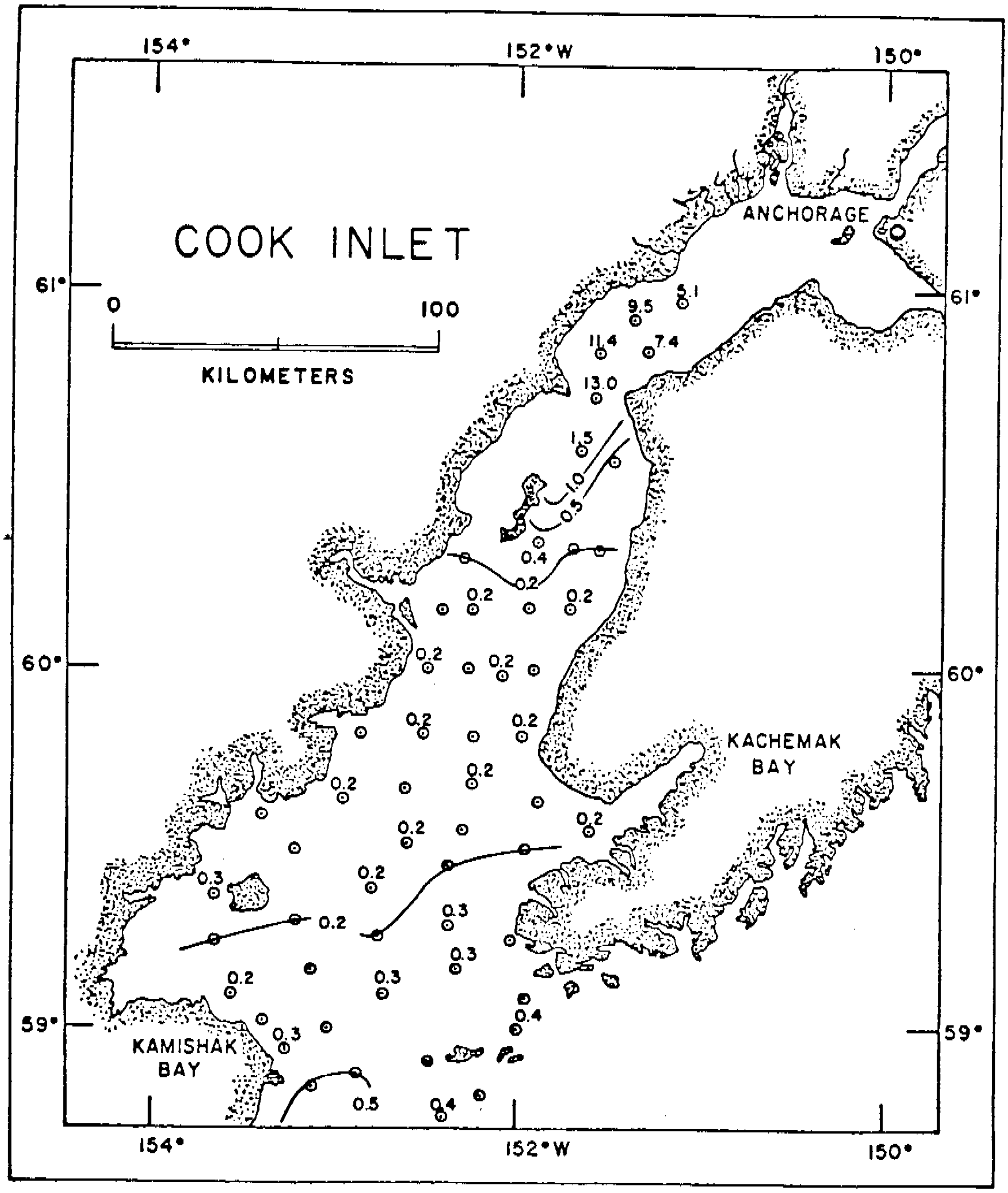

Figure 19. Ethane/ethene ratio within 5 m of the bottom during July 1977. Some ratios were not included for the purpose of clarity.

areas of Alaska have shown that rarely does this ratio exceed 0.5, and clearly that it is closer to 0.2 for the waters of LCI. The hydrocarbon composition of the waters north of Kalgin Island are analogous to the conditions found in Norton Sound. In that investigation, $C_{2:0}/C_{2:1}$ ratios approaching 20 were observed near the locus of the seep.

In Figure 19 is shown the ethane/ethene ratio near the bottom. The ratios in excess of 1 are restricted to the area north of Kalgin Island and reach a maximum value of 13 in the region of the Forelands. In the region just south of Kachemak-Kamishak Bay, the ratios rise slightly to 0.5, again reflecting the deeper water environment. In the general case, the deeper waters are a poor source of both ethane and ethene. As the concentration of these C_2 hydrocarbons approaches zero, the ratio rises to around unity. An explanation for this phenomenon is that the production of ethane is linked to that of ethene. In the case of high production rates of ethene, such as that commonly found during intense phytoplankton blooms, conversion to ethane is slow and not linearly dependent on the concentration of ethene. Conversely, under less favorable conditions, the rate of production of ethane more nearly matches that of ethene and the ratio subsequently increases.

3. Propane

During the April cruise, concentrations of propane varied little between the surface and near-bottom waters. The results are shown in Figures 20 and 21. With the exception of upper Cook Inlet, in which little useful data were taken, the concentration of propane varied from 0.1-0.4 nℓ/ℓ. A single surface value at station 2 shows a significant concentration of 1 nℓ/ℓ (Figure 20), presumably reflecting the relatively large input of this component north of the Forelands.

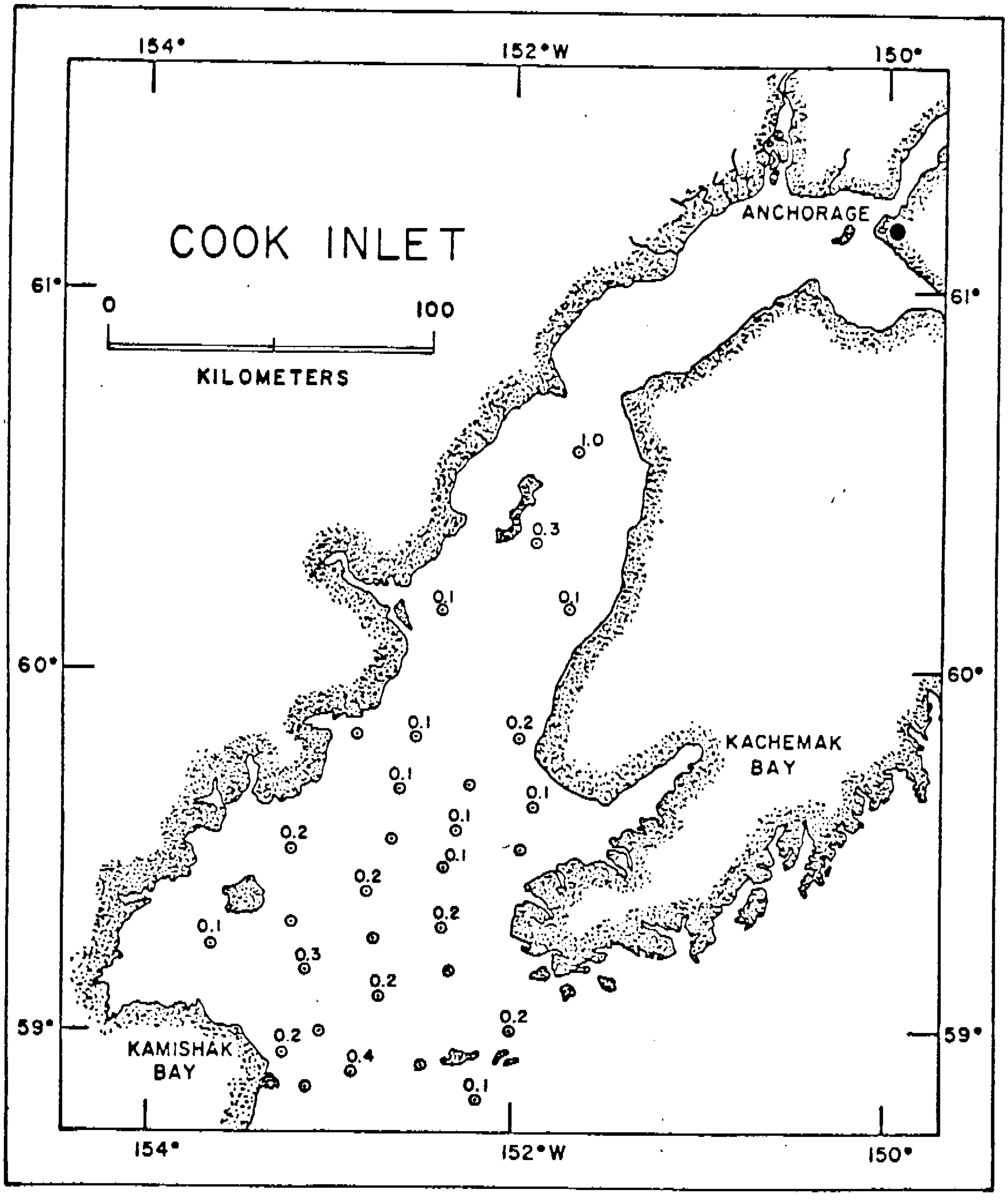

Figure 20. Distribution of propane (nℓ/ℓ, STP) in the surface layers during April 1977. Concentrations not shown at all stations for the purpose of clarity.

The distributions observed in July show this to be the case (Figures 22 and 23). Concentrations of propane north of the Forelands were greater than 1 nℓ/ℓ with a maximum of 4.4 nℓ/ℓ observed in the surface layers at station 3 (see Figure 1). The western side of the Inlet revealed concentrations less than 0.3 nℓ/ℓ, whereas the eastern side was generally characterized by concentrations in excess of 0.4 nℓ/ℓ. The distribution in the surface layers is analogous to that observed for the C_2 hydrocarbons and is presumably regulated by both circulation and biological activity. Concentrations of propane generally increased south of Cook Inlet to values near 0.5 nℓ/ℓ. Distributions of propane near the bottom were little different than the above generalizations (Figure

4. Petroleum Hydrocarbon Source

The data shown previously reveals an unusual assemblage of hydrocarbons emanating from the region just north of the Forelands. The major characteristic of these dissolved gases is the relatively high percentage of ethane, propane, and butanes to that of methane. Because this region is actively producing both petroleum and natural gas, the source is most likely thermogenic rather than biogenic. Seasonal data show that the occurrence of the hydrocarbon components is persistent, rather than episodic. Although the precise nature of the source is not known, characteristics of the probable source may be gleaned from an analysis of the composition of the gases.

A useful parameter relationship delineating thermogenic gases from biogenic components is the ethane/ethene ratio ($C_{2:0}/C_{2:1}$). In Figures 24 and 25 are shown these relationships for the months of April and July. Solid symbols represent data taken north of Kalgin Island only. In April, the biogenic C_2 hydrocarbon assemblage is represented by a preponderance of ethene relative to ethane. The normal biogenic relationship has been regressed and is

$$(C_{2:0})_B = 0.24\ (C_{2:1})_B + 0.22. \quad (n = 54)$$

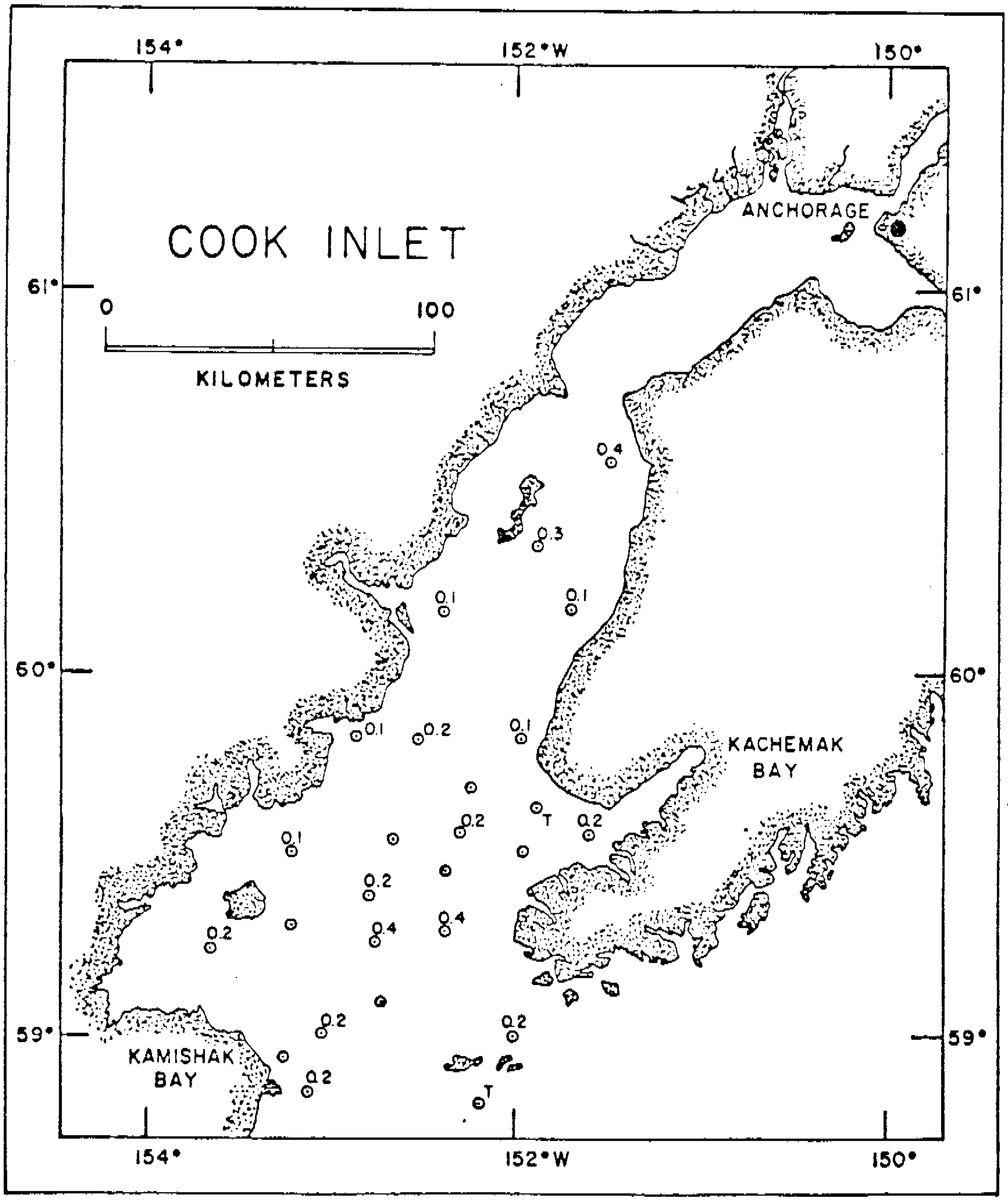

Figure 21. Distribution of propane (nℓ/ℓ, STP) within 5 m of the bottom during April 1977. Concentrations not shown at all the stations for the purpose of clarity.

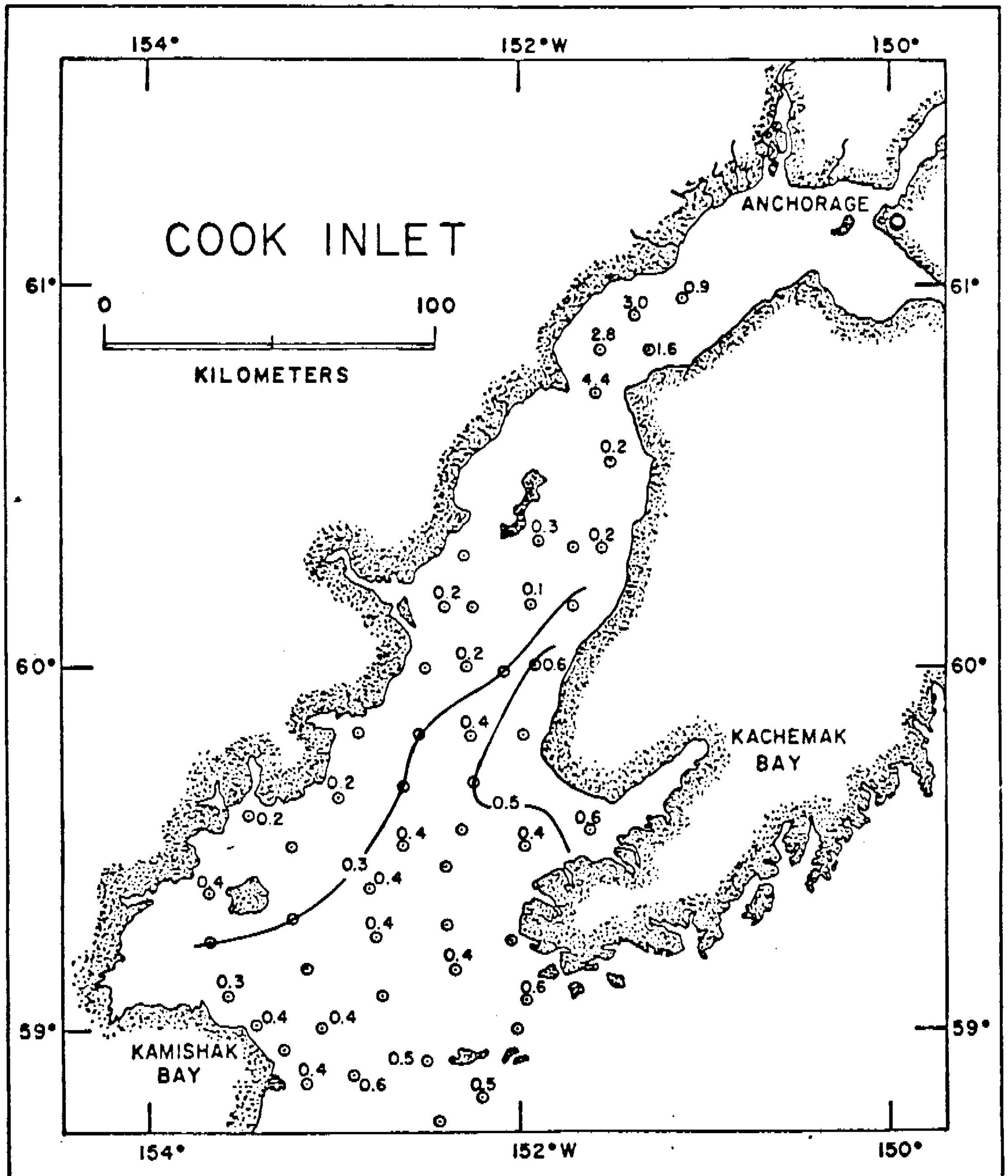

Figure 22. Distribution of propane (nℓ/ℓ, STP) in the surface layers during July 1977. Concentrations not shown at all the stations for the purpose of clarity.

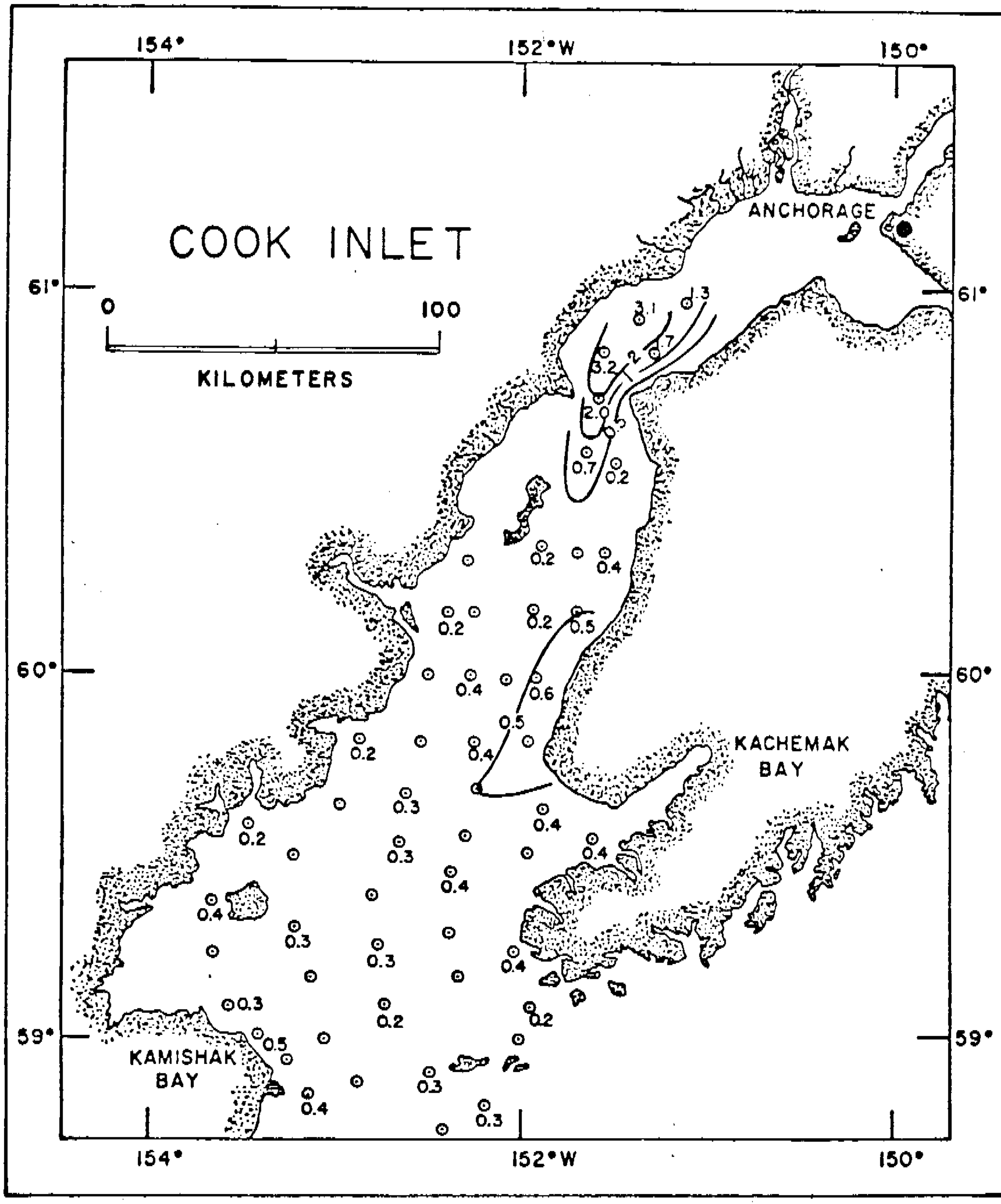

Figure 23. Distribution of propane (nℓ/ℓ, STP) within 5 m of the bottom during July 1977. Concentrations not shown at all the stations for the purpose of clarity.

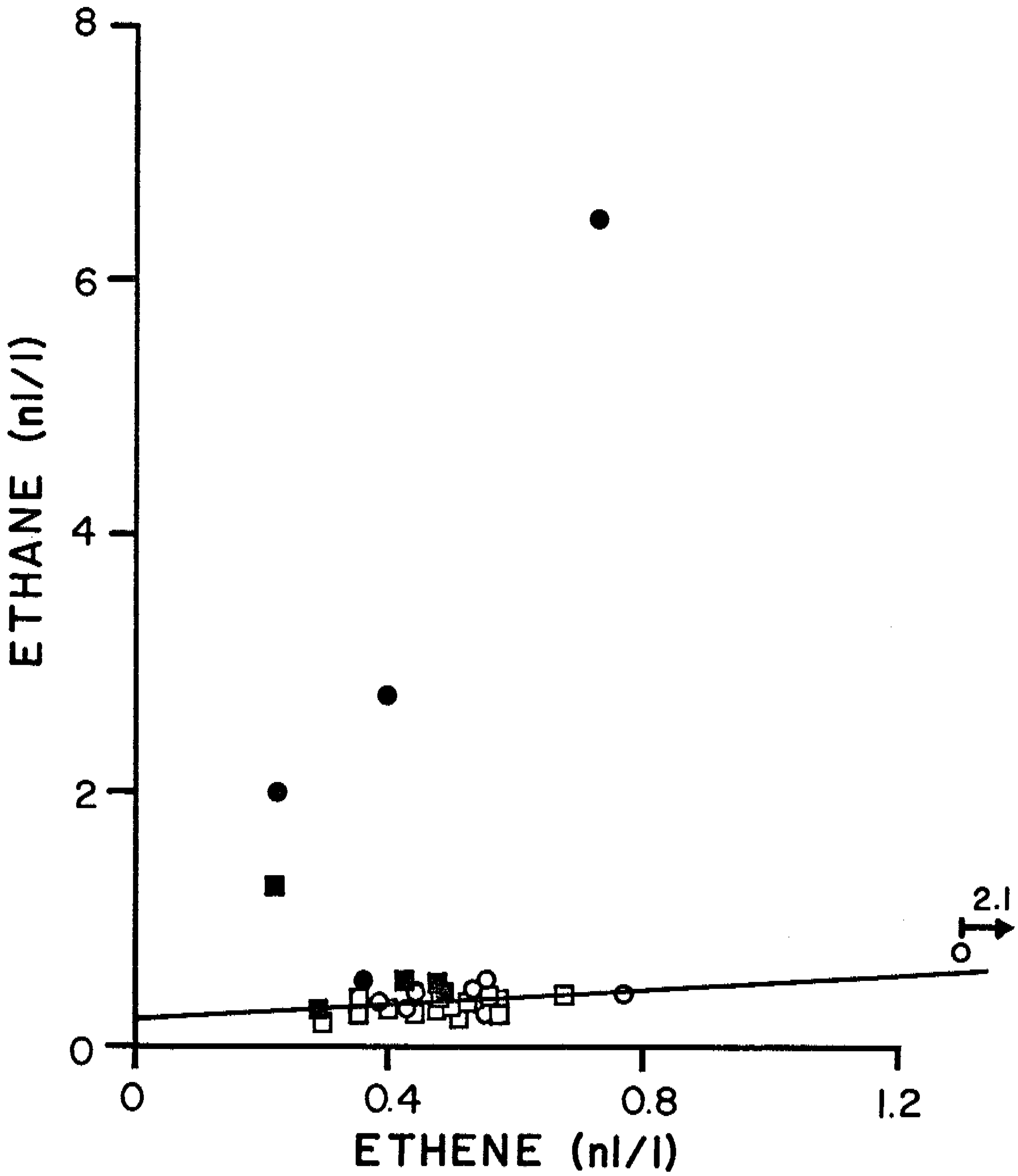

Figure 24. Ethane versus ethene (nℓ/ℓ, STP) for the surface (O) and near-bottom waters (□) in April 1977. The solid symbols represent stations north of Kalgin Island. The regression dependence of ethane on ethene for all samples south of Kalgin Island is: $C_{2:0} = 0.24\ C_{2:1} + 0.22$ (n = 54). Less than one-half of the regressed values are actually shown.

This presumable represents conditions of low biological activity. In July, the amounts of ethene have increased relative to ethane and the regression is

$$(C_{2:0})_B = 0.11\ (C_{2:1})_B + 0.23. \quad (n = 100)$$

The hydrocarbon gases believed to be of thermogenic origin are rich in ethane relative to ethene as dramatically shown in both figures. Our investigations in other OCS areas of Alaska have shown that rarely (< 1%) does the $C_{2:0}/C_{2:1}$ ratio exceed 1, except in areas suspected of either petroleum or natural gas input. Because upper Cook Inlet is characterized by low biological activity, the distinction between thermogenic and biogenic hydrocarbon sources may be more clearly observable than in other areas.

Another diagnostic feature of the hydrocarbon assemblage is the high percentage of propane. This relationship is shown in Figure 26, in which the April data are shown in squares, the July data in circles. The linear regression of the latter set of data is

$$C_{2:0} = 1.73\ C_{3:0} + 0.26. \quad (n = 22)$$

In April, the hydrocarbons being released apparently were richer in ethane than observed in July. If it is assumed that these hydrocarbons are the result of bubble injection, the composition of the source can be tentatively assessed. Using a modified form of the stagnant film boundary layer model as applied to bubbles, the concentration ratio of gaseous hydrocarbons is related to their respective partial pressures in the source bubble. The equation is

$$\Delta C_1/\Delta C_2 = (\alpha_1/\alpha_2)(D_1/D_2)(p_1/p_2),$$

where α_i is the component solubility, D_i is the molecular diffusivities, and p_i is the respective component partial pressures, the quantity of interest here. The ratio of the solubilities of ethane to propane is approximately 1.41; the molecular diffusivities is 1.24, and from the equation above, $C_2/C_3 = 1.73$.

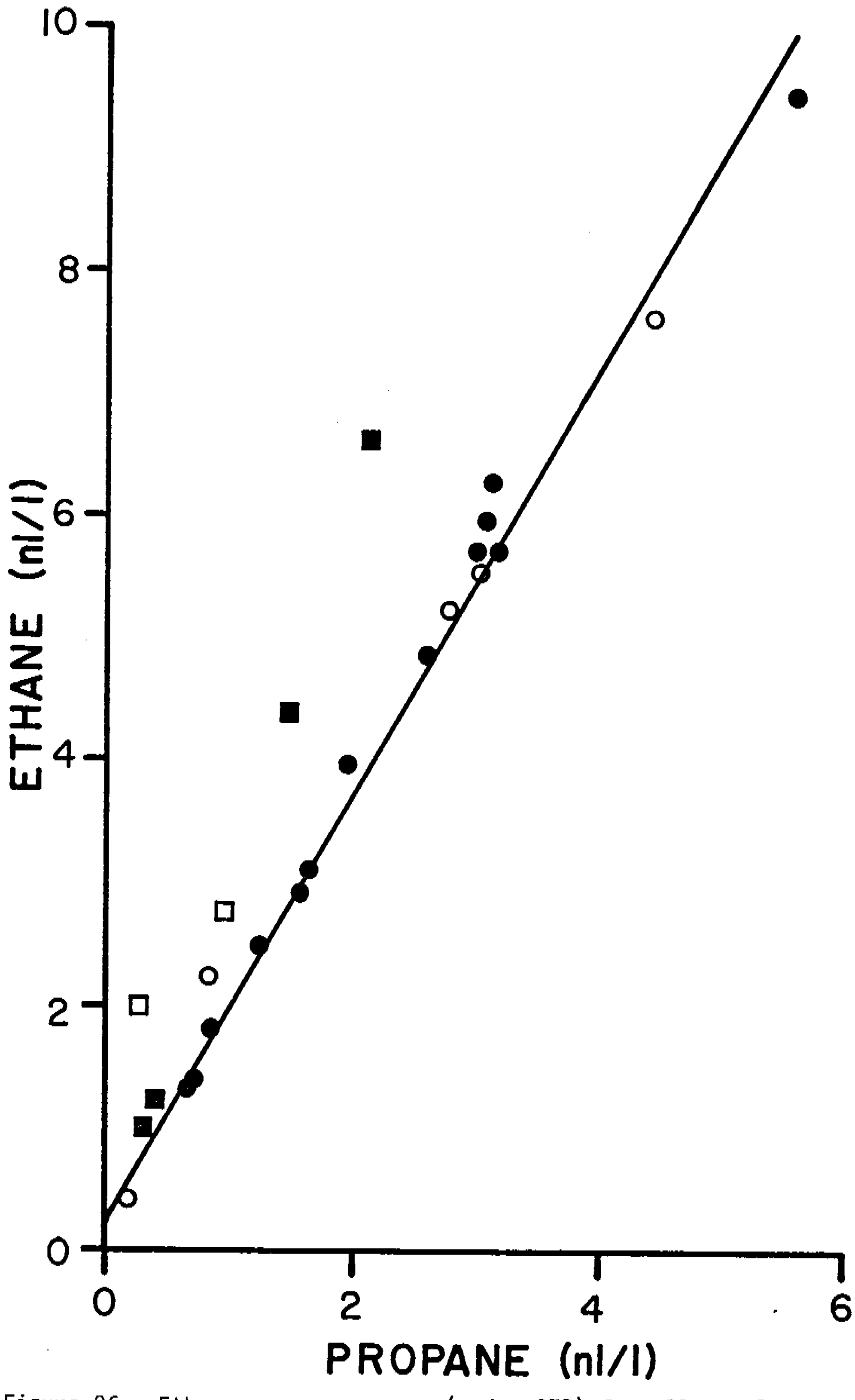

Figure 26. Ethane versus propane (nℓ/ℓ, STP) for all samples north of Kalgin Island. The squares represent observations taken in April 1977; the circles represent observations in July 1977. Open symbols represent surface values. The regression dependence of ethane on propane is: $C_{2:0} = 1.73\ C_{3:0} + 0.26$ (n = 22) for the observations taken in July 1977.

Substituting these quantities into the above equation, $p_{C_2}/p_{C_3} = 1$. A C_2/C_3 ratio less than 2 is highly indicative of a petroleum source rather than natural gas where the ratio is usually 5 or greater.

These factors, taken in concert, suggest that the gaseous hydrocarbons observed in upper Cook Inlet are:

1. thermogenic in origin,
2. associated with petroleum,
3. chronically introduced, and
4. arise from a common original source, although multiple marine vents may occur in the basin.

What is not known, however, is the flux of this material and from what source. Two possible loci that come to mind include submarine seepage and leaking capped wells. It is assumed that any actively producing well system would be monitored for such losses, although as pointed out above, the quantities actually being released may be small. Future research endeavors should include a survey for LMW aromatics and possible cycloalkanes to further define the source of the petroleum hydrocarbons.

B. Kodiak Shelf

A single cruise to the southeastern Kodiak Shelf was conducted during July 1977. The purpose of the cruise was to initiate baseline studies into the distributions and abundances of LMWH. Observations were carried out aboard the R/V ACONA and some of the stations were not occupied because of inclement weather and excessive ship motion. Of the original 21 stations planned, only 17 were occupied. The 4 stations not visited were on the southern shelf. The sampling grid is shown in Figure 27.

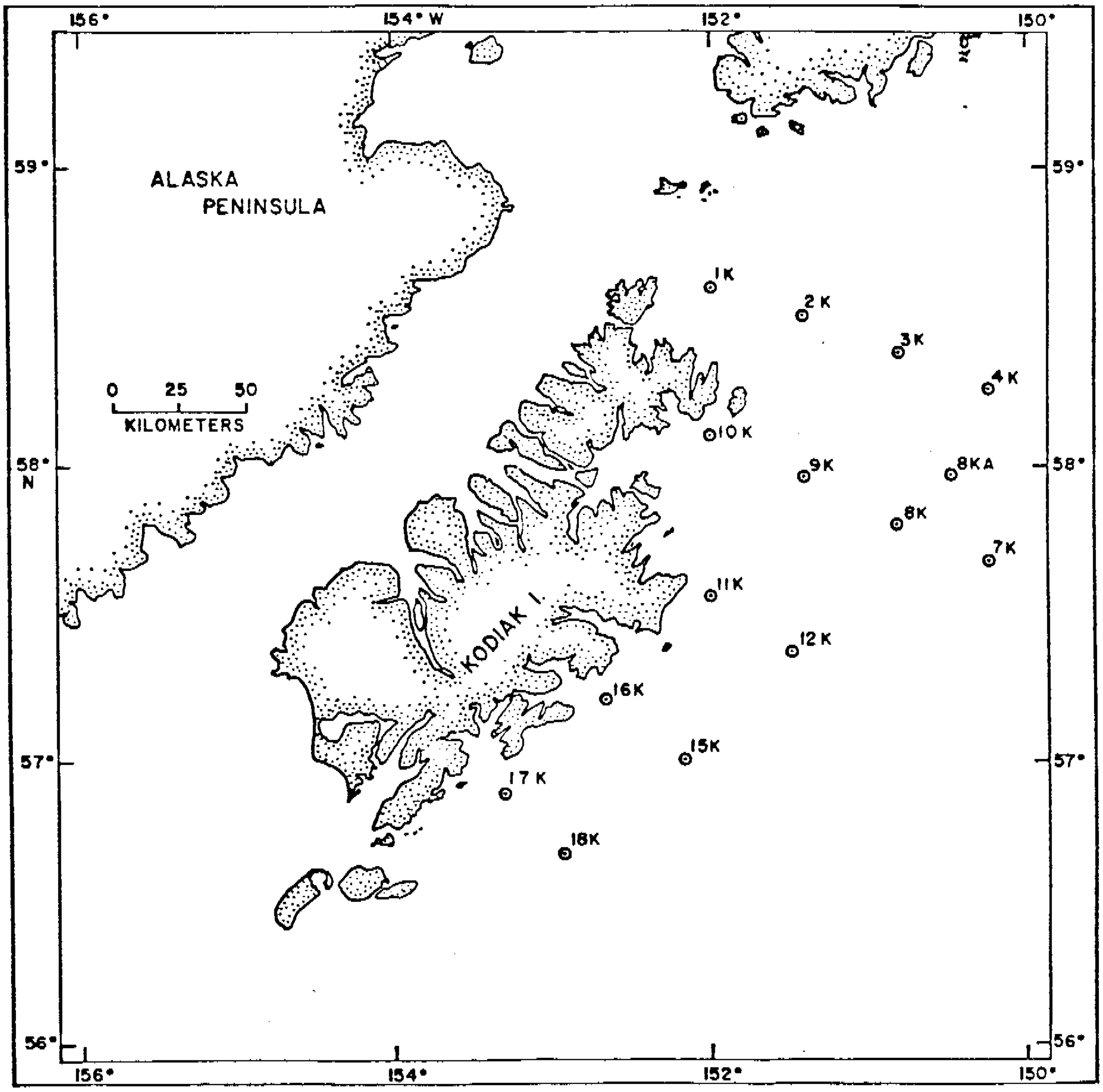

Figure 27. Station locations occupied in July 1977 on the southeastern Kodiak Shelf, Station 8KA was located near a test drilling platform.

1. Methane

The distribution of dissolved methane in the surface and near-bottom waters is revealed in Figures 28 and 29. Surface concentrations were the highest along the southern coast (200-300 nℓ/ℓ) with an elongate distribution extending northward. This feature may be related to biological activity or the result of a countercurrent along the inner shelf. We have not investigated the hydrography to confirm these speculations. Range of values encountered was approximately 100 to 350 nℓ, lowest values being observed over Portlock Bank.

Abundances of methane found in near-bottom waters are some of the largest measured to date anywhere in the OCS of Alaska. As was the case in the surface layers (Figure 28), the highest concentrations were found along the southern coast, forming an elongate distribution toward the north. The highest value (188 nℓ/ℓ) was observed at station 12 located over the Chinick Trough. The sediment texture is apparently sand-silt (75%/25%) at this location. Concentrations of methane this high over a high energy shelf environment are highly unusual and presumably represent strong biological activity. The high concentrations observed farther to the south occur over Kiliuda Trough, whose sediments are characterized by a relatively high concentration of clay-size material. In general, the finer-grained material would be expected to harbor higher concentrations of organic matter through which microbial methane production could occur. As noted above, the lowest methane concentrations (150-300 nℓ/ℓ) were found in the region of Portlock Bank, where coarse sands and gravels prevail. Minimal methane production would be expected under these conditions.

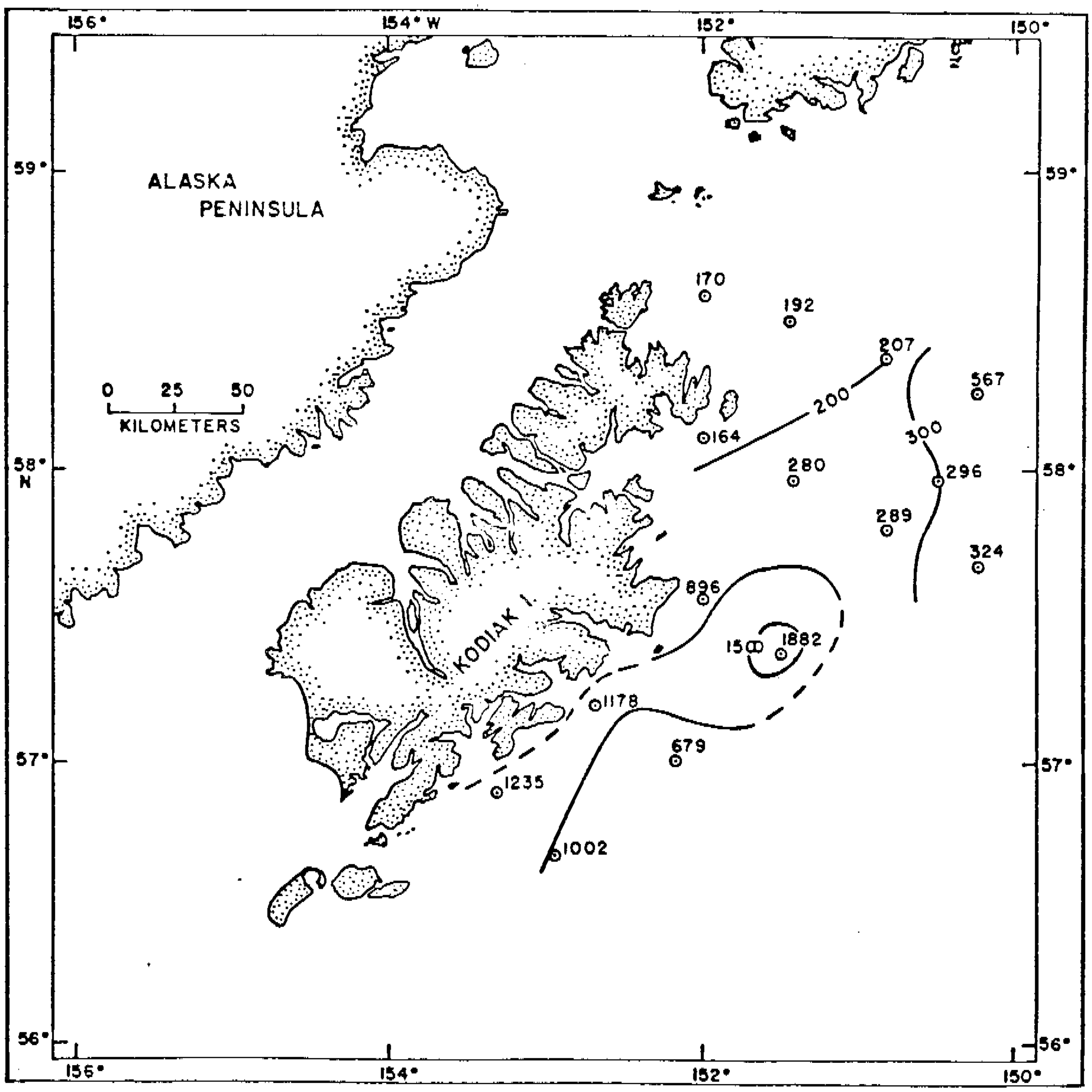

Figure 29. Distribution of methane (nℓ/ℓ, STP) within 5 m of the bottom during July 1977.

2. Ethane and Ethene

The surface and bottom distributions of ethane are shown in Figures 30 and 31. The pattern in the surface layers is similar to that observed for methane, although the range is much smaller. Concentrations of ethane in the waters along the southern coast reach a maximum of 0.9 nℓ/ℓ. These relatively large values are probably related to the concomitant release of ethene (see below). Lowest values occur in the north, where minimum concentrations observed were 0.4 nℓ/ℓ.

Near-bottom concentrations of ethane are shown in Figure 31. Again the highest concentrations are observed near the coast (0.6-0.8 nℓ/ℓ) with a general decrease offshore. The concentration range for the deeper shelf waters is 0.2-0.8 nℓ/ℓ. Note that at station 12, the concentration of ethane near the bottom was only 0.7 nℓ/ℓ. This suggests that the high methane value observed at this station was of biogenic origin.

The concentration of ethene was uniformly high in the surface shelf waters as indicated in Figure 32. Ethene concentrations ranged from lows of 3.2 nℓ/ℓ in the north to a high of 5 nℓ/ℓ off Marmot Bay. As shown earlier, the high concentrations extend south along the coast to Sitkalidak Island. The distribution of ethene appears to be controlled by primary productivity or processes related to it. The aforementioned elevated concentrations of ethane observed in the surface layers near the coast are presumably related oxidatively to the production rate of ethene. This has yet to be shown however.

The near-bottom concentrations of ethene are shown in Figure 33. Highest concentrations are seen near the coast (2.0-2.4 nℓ/ℓ) with lesser values observed offshore (< 1.5 nℓ/ℓ). The largest concentration of ethene was found over Portlock Bank (3.4 nℓ/ℓ) and correlates well with the 567 nℓ/ℓ of methane that was observed at the same location. The bottom texture in this region is

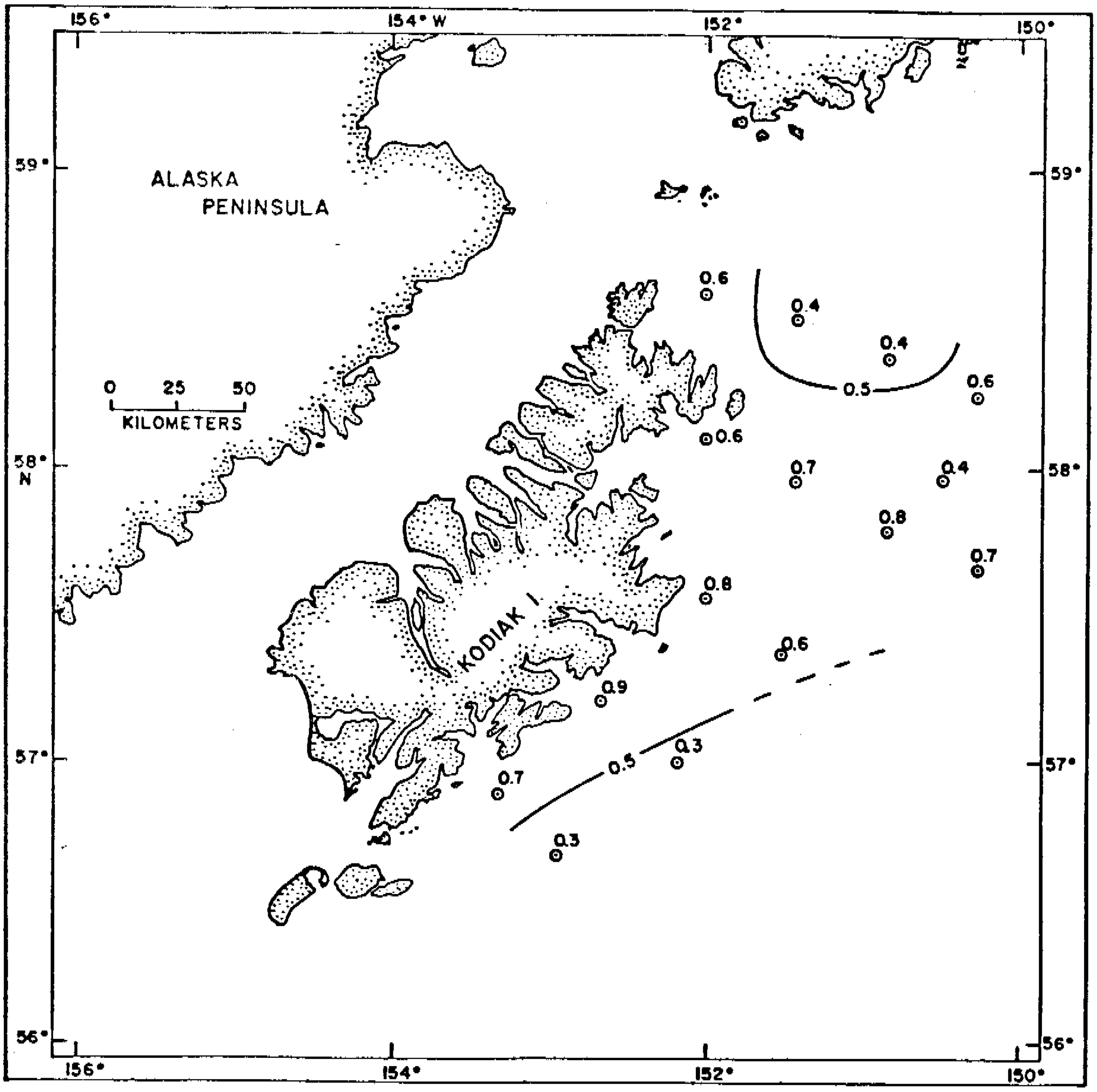

Figure 30. Distribution of ethane (nℓ/ℓ, STP) in the surface layers during July 1977.

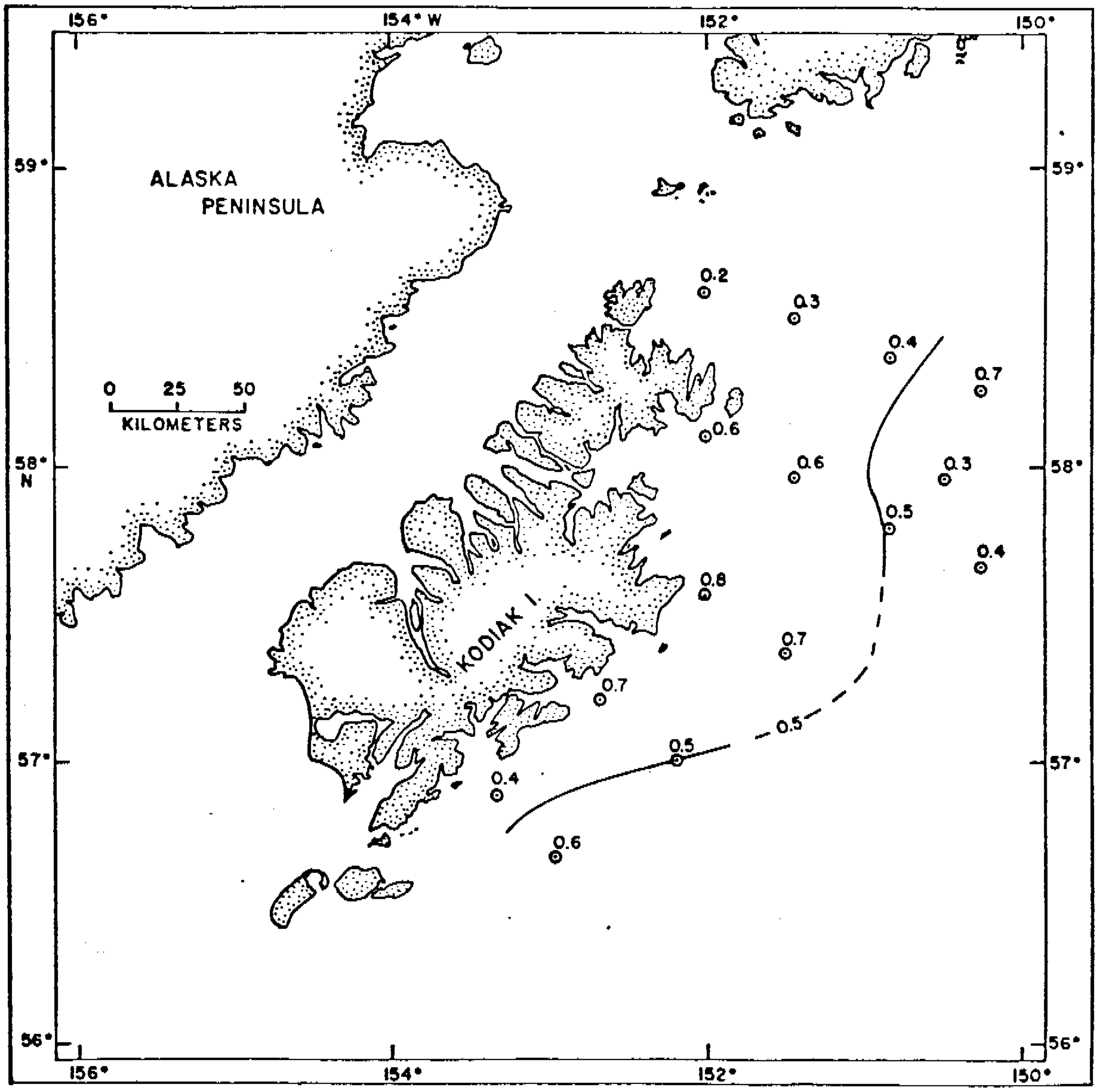

Figure 31. Distribution of ethane (nℓ/ℓ, STP) within 5 m of the bottom during July 1977.

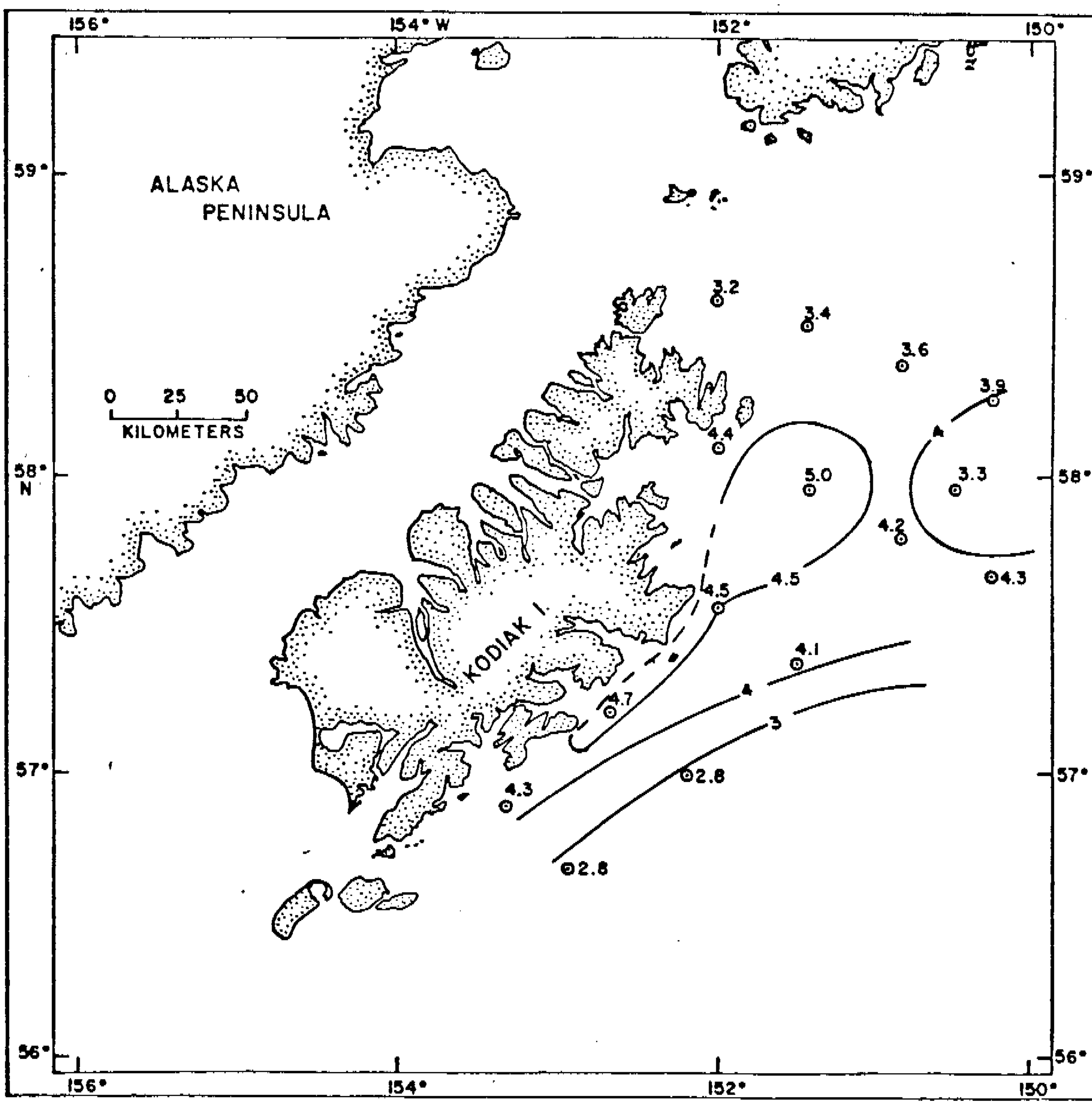

Figure 32. Distribution of ethene (nℓ/ℓ, STP) in the surface layers during July 1977.

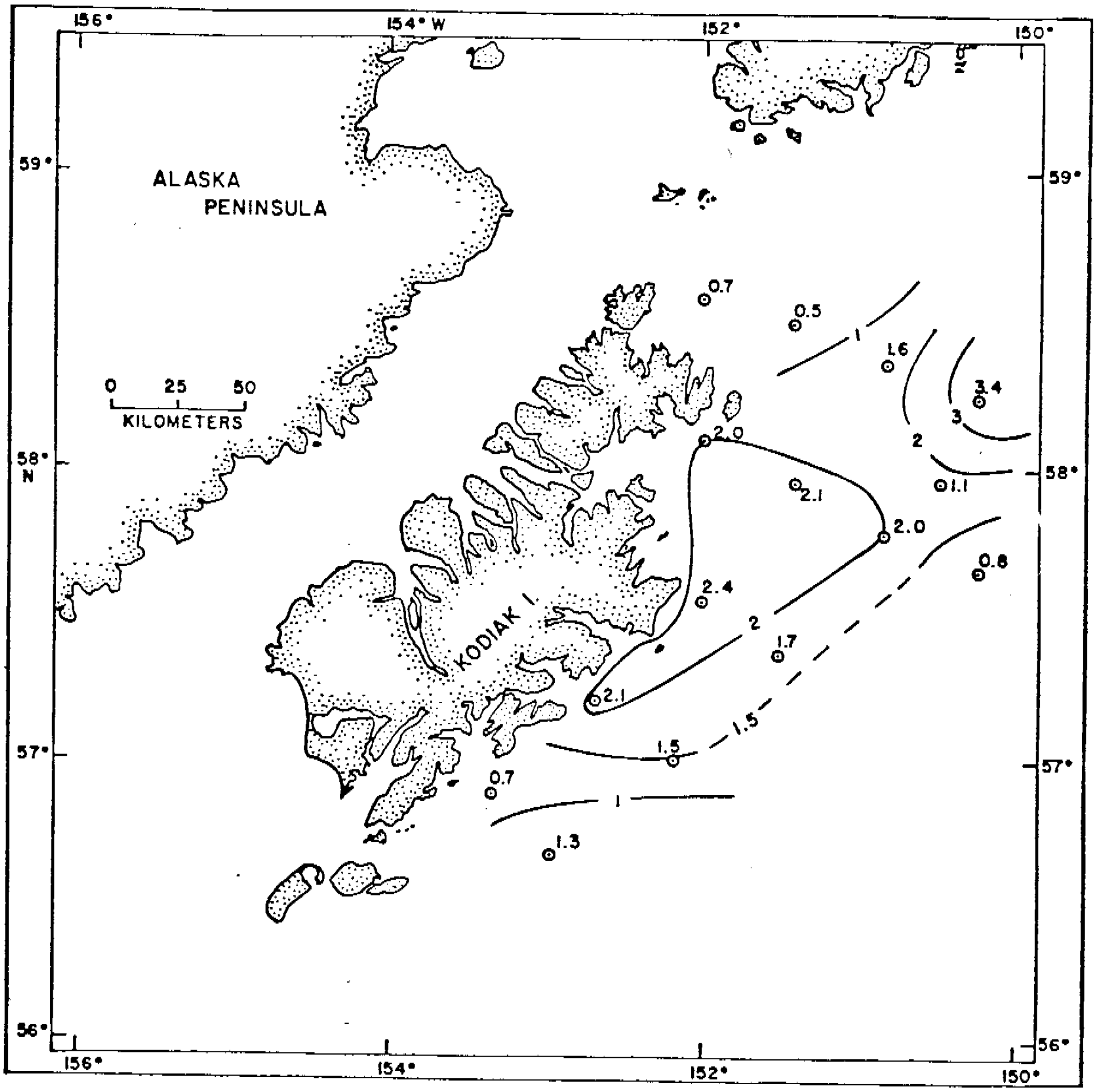

Figure 33. Distribution of ethene (nℓ/ℓ, STP) within 5 m of the bottom during July 1977.

characterized by sand and cobble-size material, not the fine-grained material usually associated with high methane production, and possibly with the production of the higher homologs of methane as well.

3. Propane and Propene

Surface and near-bottom distributions of propane are shown in Figures 34 and 35. The same pattern is repeated in the surface layers with higher concentrations found near the coast, decreasing offshore. Near-shore values range from 0.5 to 0.8 nℓ/ℓ; offshore typically range from 0.3 to 0.5 nℓ/ℓ.

Less horizontal structure in the distribution of propane is evident in the near-bottom waters (Figure 35). Concentrations north of Afognak Island are 0.1 to 0.3 nℓ/ℓ; along the coast toward the south the maximum concentration of propane observed was 0.5 nℓ/ℓ.

Distributions of propene are not shown at this time because they are quite similar to those found for ethene. This is not surprising since their production is presumably generically related. Surface concentrations ranged from 2 nℓ/ℓ to a low of 0.8 nℓ/ℓ. Near-bottom concentrations were significantly lower, ranging from trace amounts (< .05 nℓ/ℓ) to levels near 1 nℓ/ℓ.

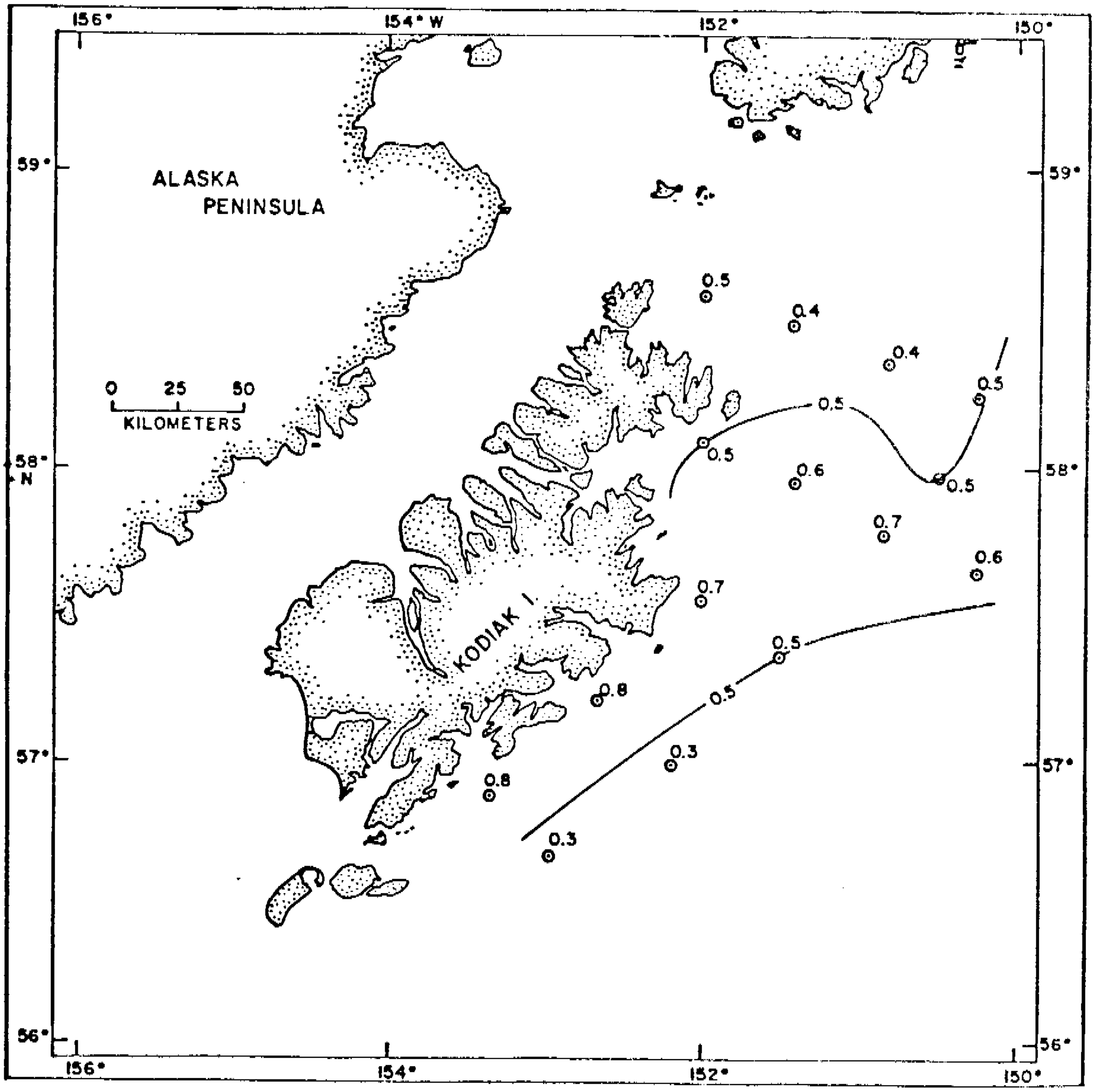

Figure 34. Distribution of propane (nℓ/ℓ, STP) in the surface layers during July 1977.

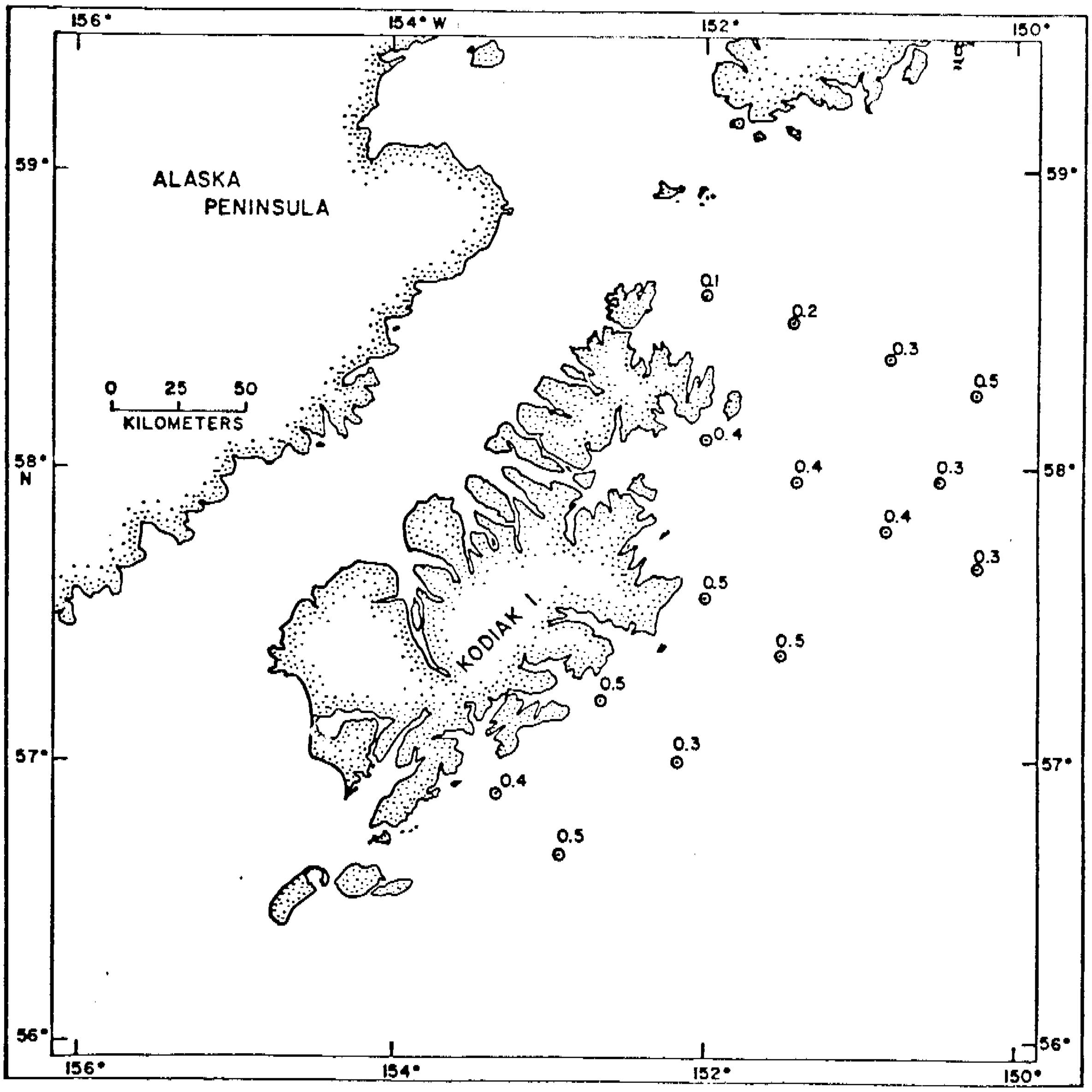

Figure 35. Distribution of propane (nℓ/ℓ, STP) within 5 m of the bottom during July 1977.

IV. Summaries

A. Cook Inlet

The horizontal and vertical distributions of the dissolved low molecular weight hydrocarbons, methane, ethane, ethene, propane, propene, iso- and n-butanes, have been determined in lower Cook Inlet for the periods April and July 1977. The purpose of this investigation is to identify the seasonal abundances and distributions of these hydrocarbons as indicators of petroleum input.

Seasonal measurements conducted reveal a strong biogenic input of LMWH, particularly in LCI. In the Kamishak-Kachemak Bay area, methane concentrations were in the range of 100-150 nℓ/ℓ during April, increasing significantly to above 200 nℓ/ℓ during July. The increases in the concentrations of methane are largely due to microbial degradation of organic matter, either in the surficial sediments or from the overlying water column. Ethane, a good indicator of gas or oil input, was generally less than 0.5 nℓ/ℓ in the lower portion of the Inlet. This fact, together with the strong seasonal dependence on concentrations of ethene and propene, would indicate a predominant biological source. For example, ethene concentrations in the surface layers ranged from an April mean of 0.5 nℓ/ℓ to values greater than 2 nℓ/ℓ in July. Concordant with this noted increase in ethene was a modest elevation in the concentrations of ethane; presumably they are either chemically or biologically related.

In upper Cook Inlet, north of the Forelands, the concentration of alkenes was minimal with a strong predominance of alkanes, notably ethane and propane. This fact alone would suggest a thermogenic rather than a biogenic source. Chromatographic evidence indicates that higher alkanes also were present, including butanes and unresolved pentanes. Maximum concentrations of ethane and propane observed were 7.7 nℓ/ℓ and 4.4 nℓ/ℓ, respectively. Corresponding levels of ethene and propene were less than 0.5 nℓ/ℓ. Throughout the region north of Kalgin Island, the $C_{2:0}/C_{2:1}$ was greater than 1 and generally less than 0.2 elsewhere in the Inlet. Preliminary analysis of the probable gas phase, using a dynamic bubble model, suggests that the $C_{2:0}/C_{3:0}$ ratio is near 1. This would imply that the original source is petroleum and not dry gas. The highest concentrations of ethane and propane were noted above the Forelands on the west side of the Inlet. This area encompasses the McArthur oil field. Precise source of the hydrocarbons is as yet undetermined.

These studies have shown that the concentrations of the low molecular weight alkanes are extremely low throughout most of Cook Inlet and even small increases in the input rate would be easily detected. Also, the ratio of ethane to ethene is a reliable parameter by which thermogenic and biogenic hydrocarbon sources may be distinguished. Our studies have also shown that this particular test parameter will be useful in other OCS areas as well.

B. Kodiak Shelf

During July of 1977, the vertical and horizontal concentrations of the LMWH were determined over the southeastern shelf of Kodiak Island. Hydrocarbon assemblages indicated biological sources rather than thermogenic.

Methane concentrations were highly variable, both in the surface layers (80-369 nℓ/ℓ) and at depth (160-1880 nℓ/ℓ). Variability is presumed related to biological activity in both the water column and underlying sediments.

Concentrations of ethane were everywhere less than 1 nℓ/ℓ, although these levels are considered to be significantly higher than those observed for this season in other OCS areas. Ethene concentrations in the surface layers were relatively high (3-5 nℓ/ℓ), reflecting significant levels of biological activity. It is assumed that the aforementioned levels of ethane are related to these concentrations of ethene. Ethane/ethene ratios have been calculated (although not shown) for the Kodiak Shelf. Values are everywhere less than 0.5 nℓ/ℓ, indicating a predominant biogenic hydrocarbon source.

The concentrations of propane, both in the surface layers and at depth, never exceeded 0.8 nℓ/ℓ. The range in the surface layers was 0.3 nℓ/ℓ to 0.8 nℓ/ℓ; at depth it was 0.1 nℓ/ℓ to 0.5 nℓ/ℓ. Again, the source is believed to be biogenic rather than thermogenic.

The concentrations of iso- and n-butanes were everywhere at or below the detection limit of .05 nℓ/ℓ.

V. Estimate of Funds Expended

	Allocated	Expended to Date	Balance
Salaries and Overhead	$41,238	$41,238	0
Travel and Per Diem	4,140	4,140	0
Major Equipment	8,400	8,400	0
Expendable Supplies	5,100	5,300	-200
Shipping	1,000	1,000	0
Publications	1,000	1,000	0
Banked FY 76 Funds	4,000	4,000*	0
Totals	$64,878	$65,078	-200

*The FY 76 banked monies have been redistributed within the salary and expendable supply categories.

QUARTERLY REPORT

Contract #03-5-022-56
Task Order #12
R.U. #162
Reporting Period: 7/1/77-
8/30/77
Number of Pages: 50

NATURAL DISTRIBUTION AND ENVIRONMENTAL BACKGROUND OF TRACE HEAVY METALS IN ALASKAN SHELF AND ESTUARINE AREAS

Dr. David C. Burrell

Professor of Marine Sciences
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

October 1, 1977

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I. TASK OBJECTIVES

The primary objective of this program is to characterize the trace metal contents of seawater, sediment, and selected indigenous biota in the three originally specified study areas (Gulf of Alaska, S. Bering Sea, Beaufort Sea) plus those regions added through later contract modifications (Lower Cook Inlet, Norton Sound). This program also incorporates sediment grain-size analysis, clay mineralogy analysis and "previous work" literature searches as described in the original Work Statement.

II. FIELD AND LABORATORY ACTIVITIES

A. Field Work

1. S. Bering Sea

OSS *Discoverer* 25 May - 5 June 1977

Personnel: None for this R.V.

Marine mammal samples were collected for us by Dr. Fay. See cruise report for that R.V.

2. Lower Cook Inlet

R/V *Acona* 21-26 June, 1977

Personnel: T. Manson

Intertidal sampling trip to collect *Macoma*, *Mytilus* and *Fucus* (and contiguous sediment) from number of sites in Lower Cook Inlet including the FY 77 designated specific study site (Kachemak Bay), station locations shown below.

3. NEGOA

NEGOA specific study site

R/V *Acona* 25-30 July 1977

Personnel: D. C. Burrell, H. V. Weiss, T. Manson, T. Owens, M. Robb

3. NEGOA (cont'd)

Hydrographic, suspended sediment, nutrient, dissolved and particulate organic carbon, water for heavy metal analysis and interstitial water from cores was taken at a number of stations in Yakutat Bay. Time limitations prevented any stations being occupied in Icy Bay.

4. S. Bering Sea

U.S.S.R. hydromet vessel *Volna* 23 July - 21 August 1977

Personnel: D. T. Heggie

We were requested to participate on this cruise in order to carry out cooperative pollution studies with Soviet scientists. We contracted to do a series of high precision measurements of copper in the euphotic zone. The original objective of this exercise was to do shipboard comparative studies with our Soviet counterparts, but in the event no other heavy metal work of any consequence was carried out. Nevertheless, this was a most useful opportunity to sample from areas of the Bering Sea previously closed to us and we hope that further joint cruises will result.

B. Scientific Parties

As noted above.

C. Field Collection Methods

1. Marine mammals - individuals dissected shipboard and separate tissue samples stored frozen in polyethylene bags.
2. Intertidal benthos - hand collected and stored frozen in polyethylene.
3. Core samples - taken using Haps corer as described in Annual Report. Core samples for interstitial water analysis were collected directly

in plastic core liners in a Benthos corer (using a stainless steel core cutter but no metal barrel). The cores were extended in the usual way but within a glove bag under a nitrogen atmosphere and directly into a series of Reeburgh-type non-metallic squeezers.

4. Water samples - the new water sampling system first used on the G-14 April R/V *Acona* cruise was used also on the 25-30 July R/V *Acona* cruise reported in this report. Water *via* this non-metallic system was used for samples for Cd, Cu, Mn and V analyses, also for suspended load and dissolved and particulate organic carbon determinations.

   Another water sampling system was employed on the *Volna* cruise since these samples were to be collected from the upper water layers. This consisted of a peristarltec pump and associated acid washed polyethylene hose. This water was passed through an in-line nucleopore filter in the usual fashion.

D. Sample Localities

1. Marine mammal samples - the localities for the marine mammal samples and specimen details for the initial two cruises are given in Tables I and II, and in Figure 1.
2. NEGOA specific study site - Figure 2 shows the locations of the standard hydrographic stations occupied on *Acona* cruise number 246.
3. Lower Cook Inlet - intertidal sample localities for both the 4-7 May and 21-26 June sampling trips are shown in Figure 3, and sample details are listed in Tables III and IV.
4. Norton Sound - localities of sediment samples collected in September 1976 and discussed below are shown in Figure 4. Open circles are sites of Haps cores; closed circles of grab samples only.

TABLE I

BERING SEA

OSS *Surveyor* 31 March - 27 April 1977

Seal samples collected for heavy metal analysis

Sample #	Latitude (N)	Longitude (W)	Species	Sex	Weight (kg)	Age (yrs)
1	58°51.0	173°08.0	Ribbon	F	39.5	1
2	58°51.0	173°08.0	Ribbon	M	102.0	-
3	58°56.0	172°40.0	Ribbon	M	81.8	4
4	58°45.6	172°55.4	Spotted	M	35.0	1
5	59°00.6	173°15.0	Bearded	F	--	10+
6	58°53.0	173°07.0	Ribbon	M	107.3	15+
7	58°43.9	169°32.9	Bearded	M	--	12+
8	58°48.5	169°41.0	Bearded	F	--	12+
10	59°06.3	169°41.3	Spotted	F	41.8	1
11	58°24.7	164°52.3	Ribbon	F	98.6	3
14	58°25.3	164°50.1	Bearded	F	32.3	fetus
16	58°21.3	164°49.7	Bearded	F	204.5	2
28	58°54.2	169°13.6	Spotted	M	89.9	6+
29	58°40.1	169°40.3	Ribbon	M	59.9	3
30	58°34.8	169°28.8	Spotted	M	84.0	6+
32	59°22.5	173°43.0	Spotted	M	118.0	6+

TABLE II

BERING SEA

OSS *Discoverer* 25 May - 5 June 1977

Seal samples collected for heavy metal analysis

Sample #	Latitude (N)	Longitude (W)	Species	Sex	Weight (kg)	Age (yrs)
1	60°37.7	174°27.2	Ribbon	M	80.0	10
2	60°36.3	174°37.5	Spotted	F	57.7	6+
3	60°36.3	174°37.5	Spotted	M	45.5	0.3
5	60°36.3	174°37.5	Spotted	M	49.1	2
8	60°26.5	168°55.8	Spotted	F	55.0	4
10	60°24.2	169°49.8	Spotted	M	68.6	5
13	60°35.9	168°10.1	Ringed	M	8.7	pup
15	60°56.6	170°48.3	Spotted	F	37.7	<1

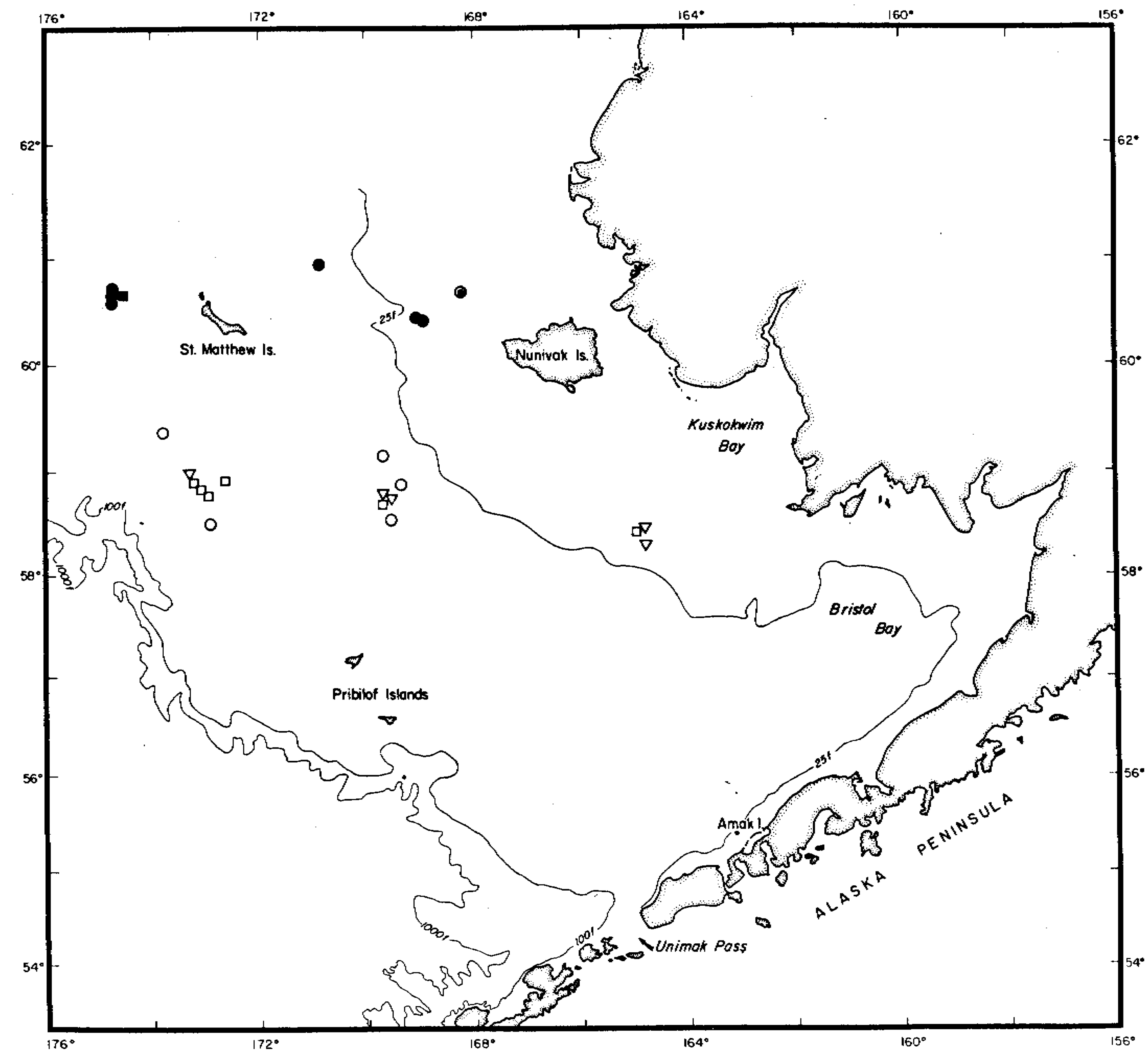

176°
172°
168°
164°
160°
156°
62°
60°
58°
56°
54°
St. Matthew Is.
Nunivak Is.
Kuskokwim Bay
Bristol Bay
Pribilof Islands
Amak I.
Unimak Pass
ALASKA PENINSULA
25f
100f
1000f

Figure 1.

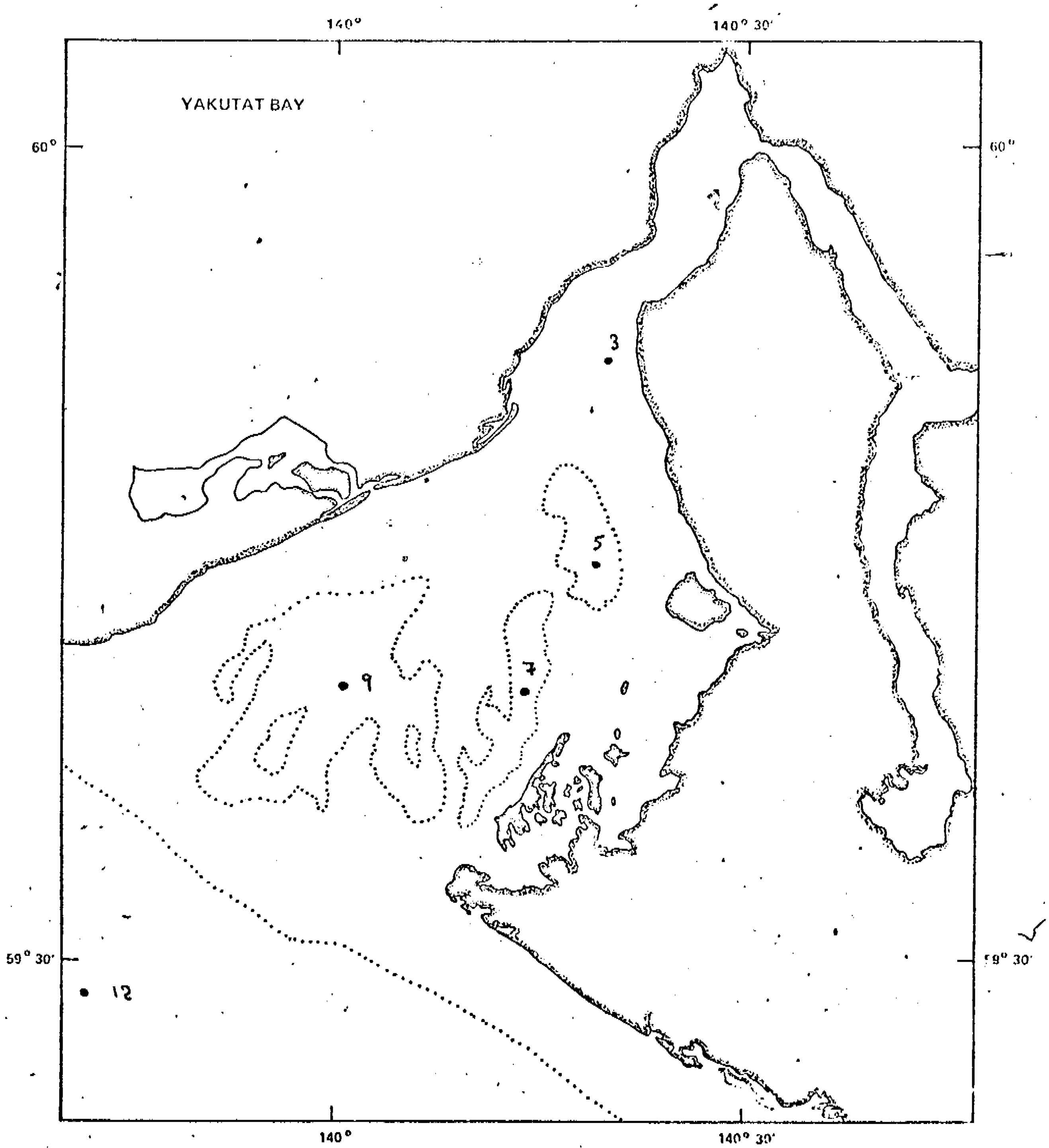


Figure 2.

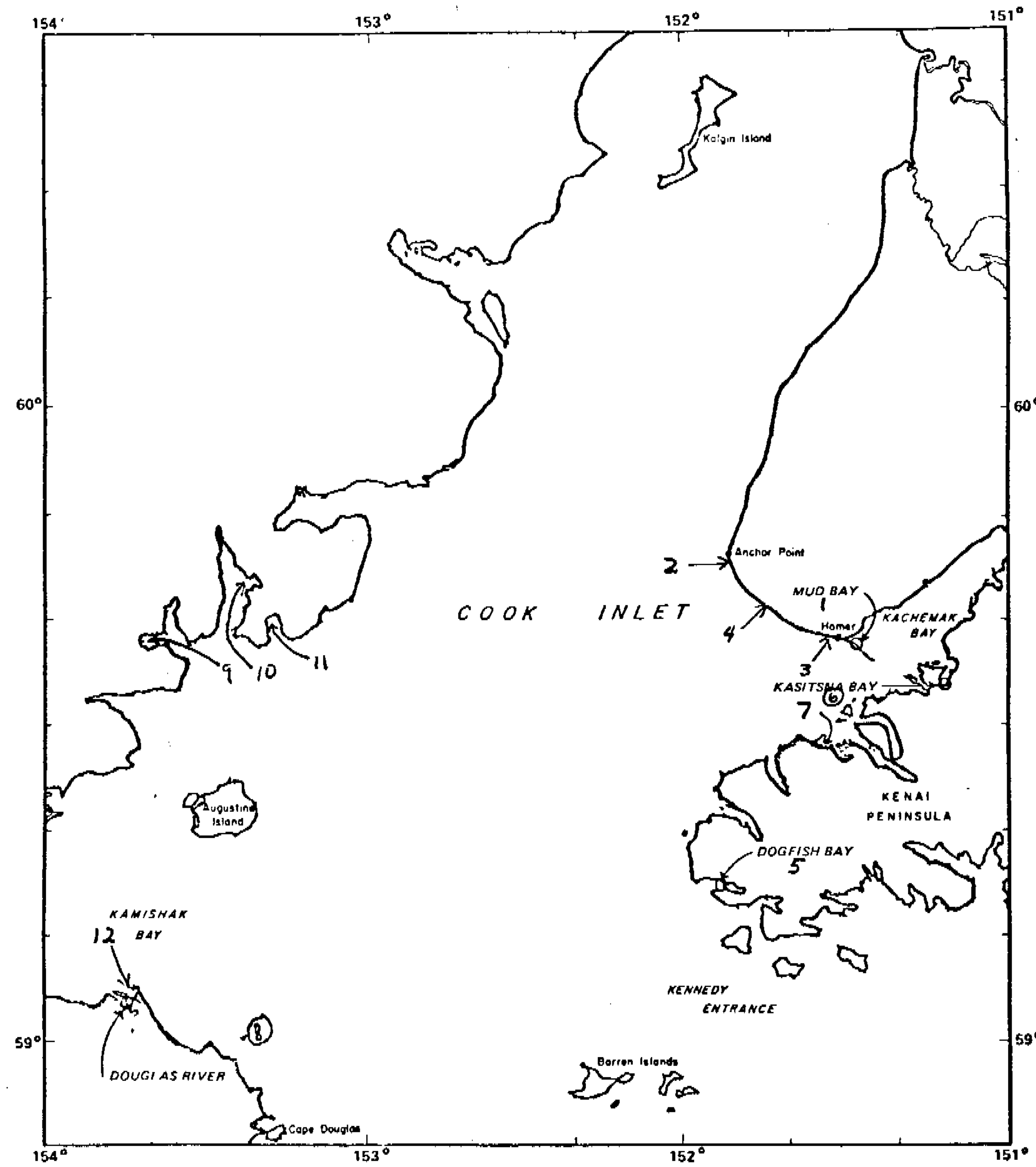


Figure 3. Map of lower Cook Inlet, Alaska showing sampling locations used in this study.

TABLE III

LOWER COOK INLET

R/V *Acona* 4-7 MAY 1977

Intertidal Benthos Collected

Station No.	Locality	Position	Type
1	Kachemak Bay - Mud Bay	59°40 N 151°26 W	*Macoma, Mytilus* *Fucus*, sediment
2	Anchor Point	59°40 N 151°52 W	*Mytilus, Fucus* sediment
3	Outer Bay	59°38 N 151°30 W	*Mytilus, Fucus* sediment
4	Bluff Point - Diamond Creek	59°40 N 151°42 W	*Mytilus, Fucus* sediment

TABLE IV

LOWER COOK INLET

R/V *Acona* June 21-26, 1977

Intertidal Benthos Samples

Station No.	Locality	Position	Type
5	Koyuktulik (Dogfish) Bay	59°14.5 N 151°52.5 W	*Mytilus*, *Fucus*, sediment
6		59°33.2 N 151°36.4 W	Haps core
7	Kasitsna Bay	59°28.8 N 151°34.5 W	*Macoma*, *Mytilus*, *Fucus*, sediment
8		59°03.1 N 153°23.4 W	Haps core
9	Cottonwood Bay	59°38.0 N 153°38.7 W	*Macoma*, *Fucus*, sediment
10	Iniskin Bay	59°43.4 N 153°22.7 W	*Macoma*, *Fucus*, sediment
11	Oil Bay	59°39.1 N 153°18.5 W	*Mytilus*, *Fucus*, sediment
12	Douglas River	59°06.3 N 153°42.2 W	*Mytilus*, *Fucus*, sediment

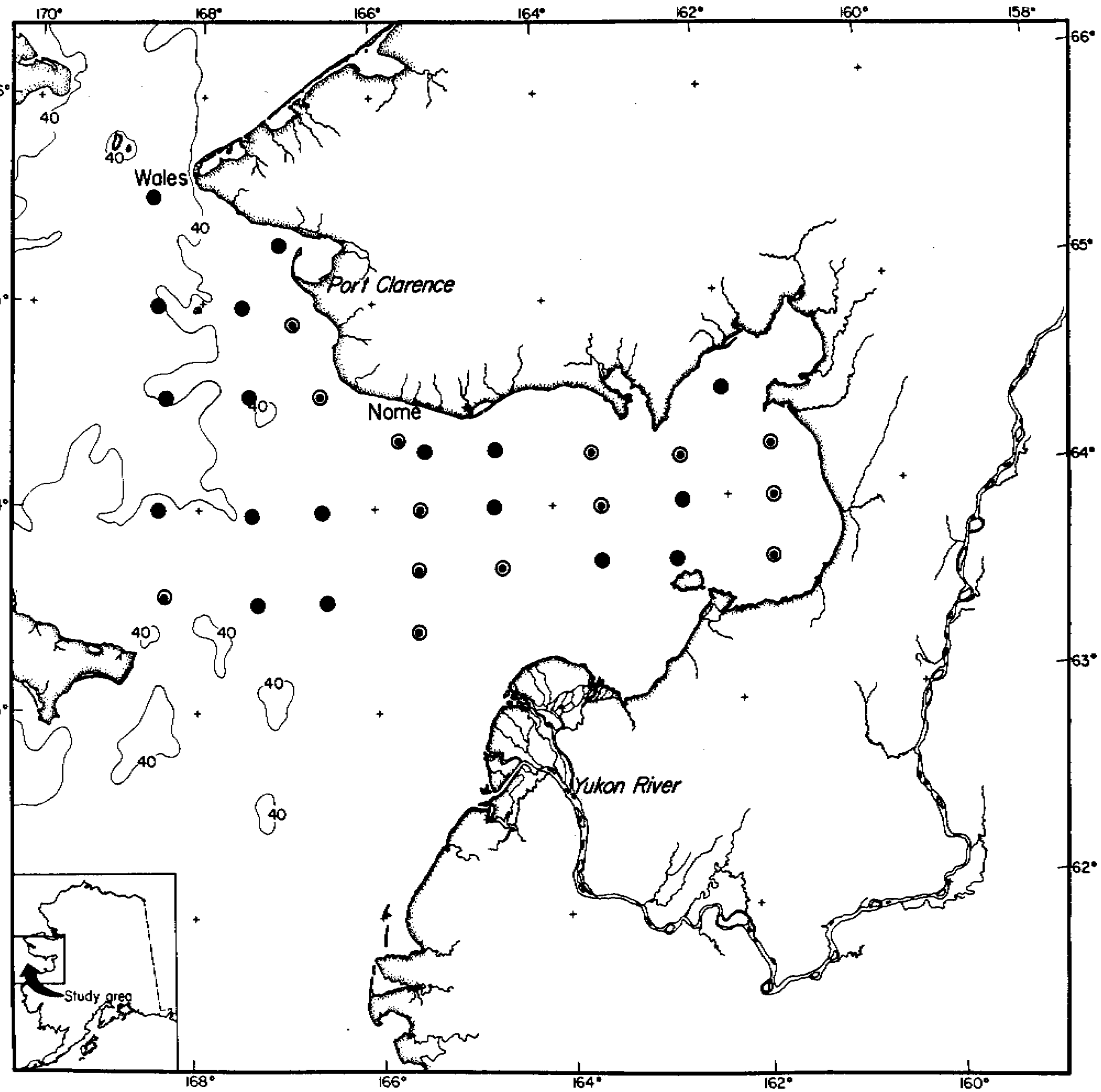

170°
168°
166°
164°
162°
160°
158°
66°
65°
64°
63°
62°
Wales
Port Clarence
Nome
Yukon River
Study area
40

Figure 4.

5. Chukchi Sea - locations of sediment samples collected from the Chukchi Sea in September 1976 are shown in Figure 5. Symbols used are as for (4) above.

6. S. Bering Sea - the cruise track for the *Volna* cruise of 23 July - 21 August is shown as Figure 6. The vessel progressed twice around this box grid.

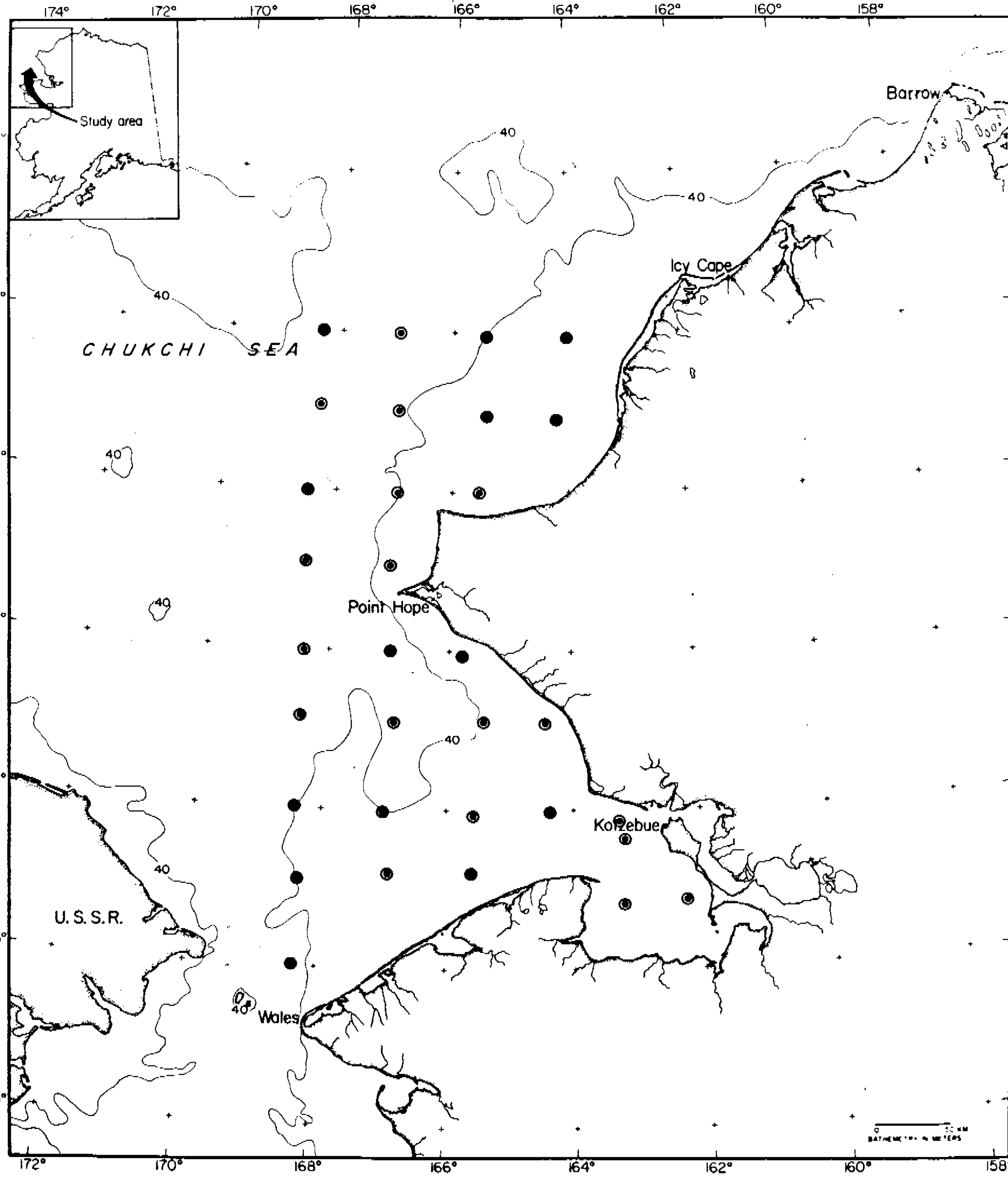
E. Laboratory Analysis Program

1. Dissolved and particulate organic carbon - these parameters are required as essential ancillary data for coastal specific study site research as described in the annual report. The instrumentation has now been instilled and calibrated. We have experienced some difficulties with precision at the lower range but expect this to be overcome very soon. Samples from the NEGOA specific study site are currently awaiting analysis.

2. Nutrient analyses - samples for the NEGOA specific study site profiles have been run.

3. Sediment size analysis - size fractionation analysis has now been completed on all Norton Sound and Chukchi Sea samples. A fairly simple scheme has been adopted for these: clay, sand and gravel with divisions at 4 and -1 ϕ respectively. The S. Bering Sea samples collected on the June 1975 *Discoverer* cruise have been fractionated into 1/4 ϕ sizes from -0.75 to 10. These data are given by Dr. C. M. Hoskin in a concurrent report. Correlations with heavy metal contents will be given later.

4. INAA of biota (Dr. D. E. Robertson) - in practice, the instrumental neutron activation analysis (INAA) of biological tissue samples consists of encapsulating a 10-1000 mg sample of dried tissue (fresh to dry weight ratios



Study area
Barrow
Icy Cape
CHUKCHI SEA
Point Hope
Kotzebue
U.S.S.R.
Wales

Figure 5.

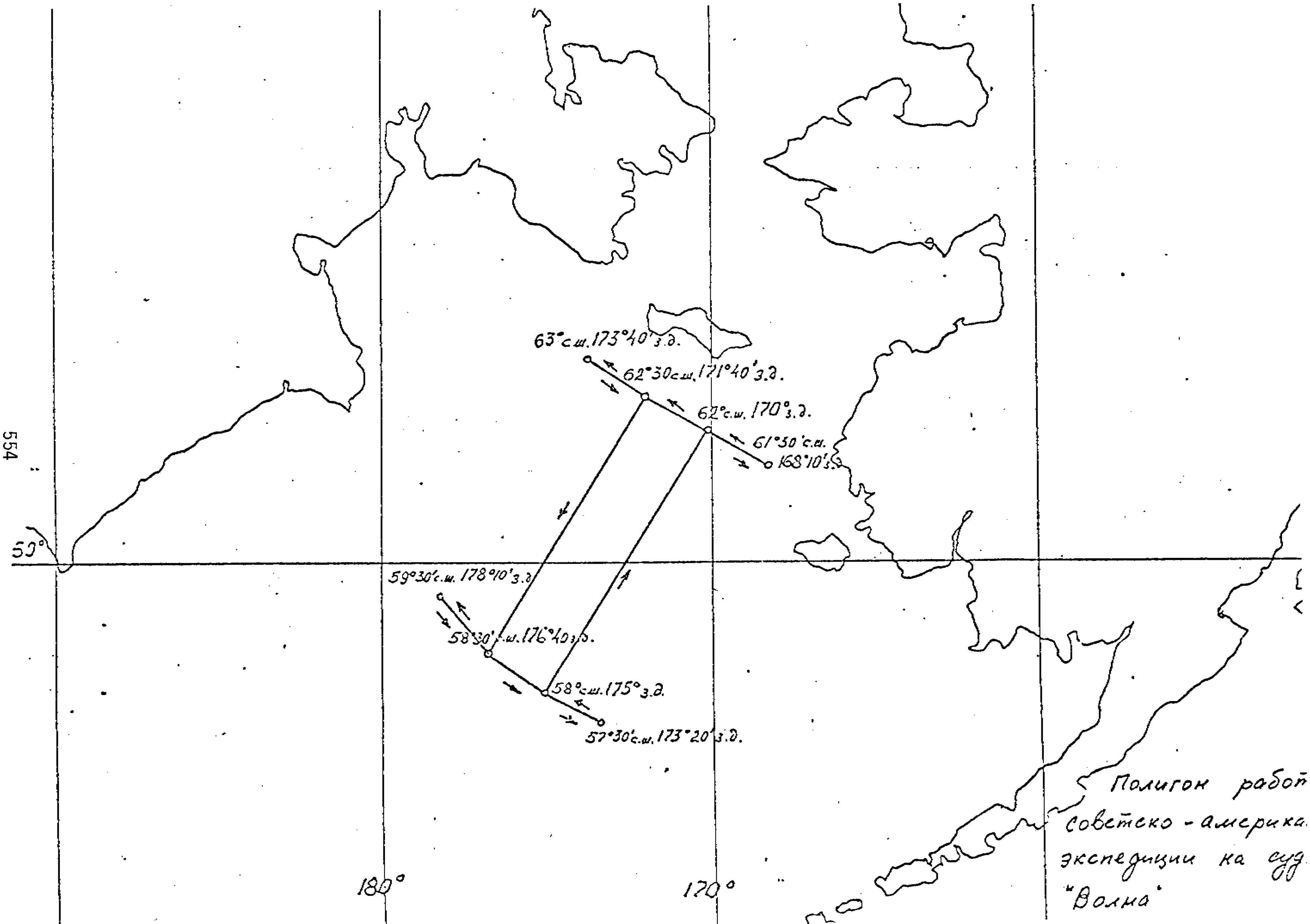

63°с.ш. 173°40' з.д.
62°30 с.ш. 171°40' з.д.
62°с.ш. 170° з.д.
61°30' с.ш.
168°10' з.
59°30' с.ш. 178°10' з.д.
58°30' с.ш. 176°40' з.д.
58°с.ш. 175° з.д.
57°30' с.ш. 173°20' з.д.
59°
180°
170°
Полигон работ
советско-америка
экспедиции на суд
"Волна"

Figure 6.

should be obtained) in a cleaned plastic irradiation vial, and neutron irradiating the sample and appropriate standards to an integral thermal neutron exposure of about 10^{17} n/cm^2. After the irradiation, the samples and standards are transferred into standard counting geometries and counted on a Ge(Li) detector at optimum times following the irradiation to measure both short- and long-lived neutron activation products. Two to four days out of the reactor the major neutron activation products are ^{24}Na and ^{82}Br, but normally high enough concentrations of ^{42}K and ^{76}As are present for accurate measurements. Some of the data for As, Br, Na and K are included in this report.

After the samples have been out of the reactor for about two weeks, most of the ^{24}Na and much of the ^{82}Br have decayed to tolerable levels, and a new suite of long-lived neutron activation products can be instrumentally measured including Rb, Cs, Fe, Zn, Ag, Co, Cr, Hg, Se, Sb and Sc.

We are presently working on a radiochemical separation procedure to measure vanadium in biological tissue by neutron activation analysis.

5. NAA of water (Dr. D. E. Robertson) - we are in the middle of the sea-water neutron activation analyses. Because of the tremendous amounts of ^{24}Na (15.4 hrs) which are produced during neutron irradiation of sea water, INNA of sea water is applicable only for those elements in sea water which have relatively long half-life activation products. None of the short-lived neutron activation products of interest could possibly be measured instrumentally, since the ^{24}Na, ^{38}Cl, ^{42}K and ^{82}Br are orders of magnitude more abundant and completely mask the gamma-ray contributions of the activation products of interest. We have developed radiochemical separation schemes for analyses of short-lived activation

products of interest and have already, or are presently employing them for the determination of V, As and Ag. For the INAA of sea salts, the neutron irradiated samples are stored for about one month to allow these relatively short-lived interfering radionuclides to decay to tolerable concentrations.

The month-old activated sea salts are then transferred into a constant counting geometry (small polyethylene vials or stainless steel planchets) and counted directly on a Ge(Li) diode detector or a dual coincidence gamma-ray spectrometer. The following elements are then measured: Zn, Co, Sb, U, Cs, Rb, Sr, Fe and Sc.

6. Marine mammal tissue samples - work on this program as described in the April-June Quarterly Report has progressed in the current quarter. We have still not received our low temperature plasma asher and hence there has been no change in methodology.

7. Soluble metal by NAA (H. V. Weiss) - Dr. H. V. Weiss has now completed analysis of soluble Cu, V and Mn for the NEGOA specific study site profiles.

Details of methods used will be given in a later report.

III. RESULTS

A. Size distribution of surficial sediment from Norton Sound and Chukchi Sea

These data are listed in Tables V and VI and the distribution of surface fine grained sediment within Norton Sound (as % clay/silt content) is shown in Figure 7.

TABLE V

NORTON SOUND

OSS *Discoverer* September 1976

Sediment Size Fractionation Data (%)

Station #	Clay	Sand	Gravel
N 1	22.11	77.83	.05
2	8.69	91.03	.28
3	44.46	55.17	.37
4	87.04	12.96	0.
5	64.30	35.70	0.
6	86.42	13.58	0.
7	17.14	82.51	.35
8	64.29	34.91	.79
9	89.03	10.41	.56
10	16.26	83.70	.03
11	19.35	80.63	.02
12	56.79	43.21	0.
12D	59.52	39.56	.92
13	81.87	18.12	.02
14	94.64	4.98	.37
15	81.89	18.09	.01
16	19.35	80.63	.02
17	85.61	13.08	1.31
18	91.39	8.59	.01
19	40.79	58.96	.24
20	35.18	63.92	.90
21	21.52	78.48	0.
22	94.53	5.43	0.03
23	43.75	54.95	1.29
24	16.83	83.09	.07
25	13.05	71.40	15.55
26	17.56	67.29	15.15
27	14.08	85.21	.71
28	7.04	82.65	10.31
28A	14.84	71.28	13.88
29	60.97	38.86	.17
30	34.60	56.21	9.18

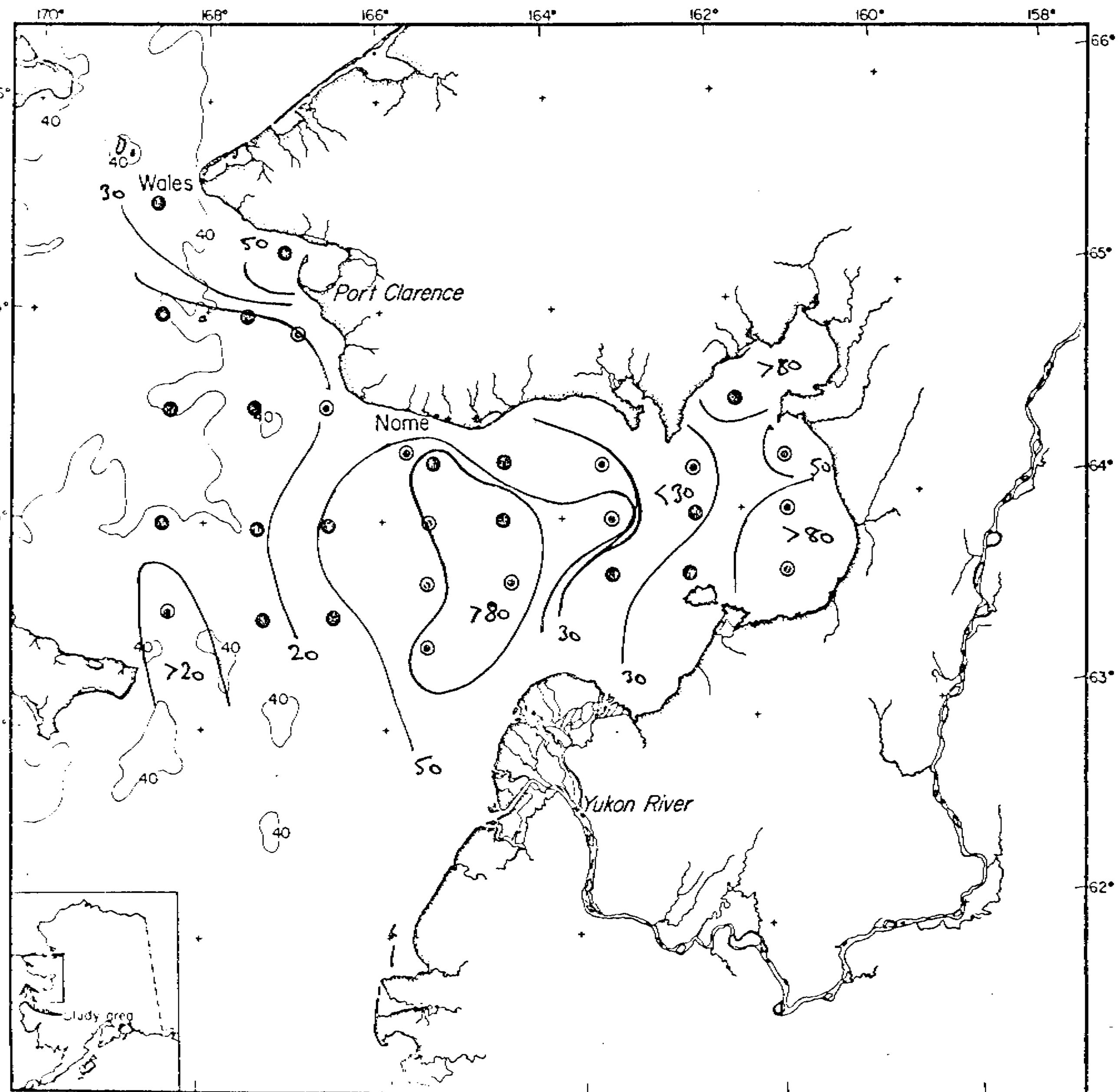
TABLE VI

CHUKCHI SEA

OSS *Discoverer* September 1976

Sediment Size Fractionation Data (%)

Station #	Clay	Sand	Gravel
C 1	2.82	9.31	87.87
2	27.71	54.62	17.67
3	50.97	49.02	.01
4	6.66	93.33	.01
5	85.71	14.21	.08
6	96.05	3.64	.31
7	11.39	85.06	3.54
7A	69.21	30.73	.06
8	78.47	21.53	0
9	68.89	31.02	.09
10	5.89	94.11	0
#2	9.19	90.79	.01
11	86.93	12.99	.08
12	88.12	11.88	0
13	98.98	0.84	0.18
14	92.78	7.13	.09
15	34.52	65.29	.19
16	46.75	52.37	.88
17	20.51	62.52	16.97
18	32.69	22.44	44.86
19	71.27	28.59	0.14
20	6.62	92.94	.44
21	92.72	7.26	.02
22	81.70	18.15	.15
23	3.83	95.74	.43
24	58.42	40.75	.83
25	74.49	25.44	.07
26	25.30	74.47	.23
27	7.38	91.35	1.27
28	24.01	14.39	61.59
29	28.41	58.60	12.99
30	44.87	55.10	.03
31	8.01	91.53	.46



170°
168°
166°
164°
162°
160°
158°
66°
65°
64°
63°
62°
Wales
Port Clarence
Nome
Yukon River
Study area
30
50
40
20
>20
>80
<30

Figure 7.

B. Extractable contents of Norton Sound and Chukchi Sea sediments

These data have been given previously (Tables IV and V of the April-June Quarterly Report) but are relisted here (Tables VII and VIII) with the size fractionation data (from Tables V and VI) added for ease of comparison. Correlation coefficient data for these parameters are given in Table IX.

C. Intertidal *Mytilus* and *Fucus*

The broad survey part of this program is now complete although specific study site samples (e.g. for lower Cook Inlet; Figure 3 and Tables III and IV) will continue to be run. The final sample localities for the N.W. Gulf, Kodiak Island and the Bering Sea are given in Tables X and XII. Sampling sites in the N.E. Gulf are as given in the 1976-77 Annual Report (Table II and Figure 3). An update of the N.E. Gulf heavy metal data for *Fucus* is given as Table XIII.

D. Major and minor elemental composition of biota by NAA

(D. E. Robertson)

The concentrations of As, Br, K and Na in rock sole, neptunea, pollock and crab for the Bering Sea are shown in Tables XIV and XV.

E. Marine mammal tissue samples

We have all but completed this program for the Bering Sea. However, a few replicate determinations and determinations of accuracy and precision need to be completed. These data will be given all together in the next quarterly report.

TABLE VII

NORTON SOUND

OSS *Discoverer* September 1976

Heavy metal contents of sediment extracts (μg/g) and clay + silt %

#	Clay/silt (%)	Cd	Cu	Ni	Zn	Fe	Mn
1	22.1	<0.1	<0.3	<1.3	6.2	746	8
4	87.0	<0.1	0.5	2.5	5.0	3050	48
5	64.3	<0.1	0.5	2.9	5.0	2843	86
6	86.4	<0.1	2.0	3.3	5.7	3084	121
9	89.0	<0.1	1.1	4.3	8.0	4250	79
12D	59.5	<0.1	0.6	1.4	5.1	1609	230
13	81.9	<0.1	0.5	1.8	6.0	2086	283
15	81.9	<0.1	<0.3	<1.3	5.1	1779	75
17	85.6	0.1	2.2	4.2	9.1	2961	193
20	35.2	<0.1	<0.3	<1.3	3.5	966	58
21	21.5	<0.1	0.3	<1.3	3.5	1219	52
23	43.8	<0.1	0.6	1.8	6.6	2066	70
26	17.6	<0.1	<0.3	<1.3	2.5	565	60
28A	14.8	<0.1	<0.3	<1.3	2.5	745	20

TABLE VIII

CHUKCHI SEA

OSS *Discoverer* September 1976

Heavy metal contents of sediment extracts (μg/g) and clay + silt contents (%)

#	Clay/silt (%)	Cd	Cu	Ni	Zn	Fe	Mn
3	51.0	<0.1	<0.3	1.6	3.8	1275	11
5	85.7	<0.1	0.6	1.8	3.7	1489	20
6	96.1	<0.1	<0.3	1.4	6.0	2134	134
7	11.4	<0.1	0.4	1.4	3.5	912	12
7A	69.2	<0.1	0.6	1.8	4.6	2283	54
9	68.9	<0.1	<0.3	1.3	2.6	948	24
10	5.9	<0.1	<0.3	<1.3	2.6	620	25
12	88.1	<0.1	<0.3	1.8	3.4	1197	6
13	99.0	<0.1	0.4	1.8	3.7	1589	10
14	92.8	<0.1	0.3	1.8	3.9	1490	13
15	34.5	<0.1	0.3	<1.3	3.3	1223	29
16	46.8	<0.1	<0.3	1.3	3.4	967	5
19	71.3	<0.1	<0.3	1.3	3.5	1272	22
20	6.6	<0.1	0.3	<1.3	2.8	825	29
22	81.7	<0.1	0.3	1.4	4.3	1560	16
23	3.8	<0.1	0.3	<1.3	0.9	298	2
24	58.4	<0.1	0.3	1.9	3.9	1514	10
25	74.5	<0.1	0.3	1.3	3.7	1343	17
29	28.4	<0.1	0.3	<1.3	3.8	1015	10

TABLE IX

NORTON SOUND

Discoverer September 1976

Heavy metal extract data and grain size correlation coefficients

	S + C	Fe	Mn	Zn	Ni	Cu
Silt and Clay		0.86	0.53	0.67	0.73	0.62
Fe			0.27	0.71	0.98	0.84
Zn					0.76	0.84
Ni						0.85

CHUKCHI SEA

Discoverer September 1976

Heavy metal extract data and grain size correlation coefficients

	S + C	Fe	Mn	Zn	Ni	Cu
Silt and Clay		0.75	0.27	0.63	0.80	-
Fe			0.58	0.89	-	-

TABLE X

N.W. GULF OF ALASKA

Localities of Intertidal Benthos Samples

Name	Locality	
Spectacle Island	55°07.2	159°44.6
Chirikof Island	55°49.6	156°44.1
Cape Nukchak	58°23.4	153°59.4
Low Cape (Trinity Islands)	57°00.0	154°31.5

TABLE XI

KODIAK ISLAND

Localities of Intertidal Benthos Samples

Name	Locality	
Sundstrom Island	56°41.5	154°08.6
Three Saints Bay	57°07.8	153°28.7
Sud Island	58°54.3	152°12.4
Lagoon Point (Sitlakidak Island)	57°11.3	153°03.4
Pasagshak Point	57°26.8	152°27.2

TABLE XII

S. BERING SEA

Localities of Intertidal Benthos Samples

Name	Locality	
Akun Island	54°08.5	165°38.7
Amak Island	55°24.1	163°09.3
Crooked Island	58°39.5	160°16.5
Cape Pierce	58°34.4	161°45.5
Point Edward	55°59.5	160°51.6
Cape Mordvinof	54°55.8	164°26.8
Makushin Bay	53°44.0	166°45.8
Zapadai Bay	56°34.1	159°39.8
Otter Island	57°03.0	170°23.8
Cape Lupin (Unimak Is.)	54°56.7	164°08.0
Sennett Point (Unimak Is.)	54°29.1	164°54.4
Eider Point (Unalaska Is.)	53°57.5	166°35.1

TABLE XIII

N.E. GULF OF ALASKA

FUCUS

μg/g dry weight

	Cd	Cu	Ni	Zn	Hg
Port Dick	3.5	8.0	9.5	16	-
(Gore Point)	2.9	2.5	8.3	10	-
Anchor Cove	1.5	9.5	<10.0	17	0.30
(Day Harbor)	3.5	27.0	15.5	22	-
	3.0	7.0	14.5	13	-
Squirrel Bay	1.5	3.5	<10.0	12	0.25
La Touche Point	3.0	6.0	5.5	-	-
(Latouche Island)	2.9	2.0	9.2	7	-
Macleod Harbor (Montague Island)	4.0	17.0	8.0	22	-
Zaikof Bay	1.5	2.5	<10.0	5	0.45
(Montague Island)	4.0	17.0	9.0	16	-
Port Etches (Cape Hinchinbrook)	2.5	10.5	7.5	15	-
Boswell Bay	1.5	13.0	<10.0	9	0.70
(Hinchinbrook Island)	2.9	13.2	13.2	13	-
Katalla	2.0	17.0	10.0	16	-
(Copper River)	1.9	9.2	18.3	13	-
Kayak Island (Cape St. Elias)	4.0	6.0	15.0	17	-
Middleton Island	1.5	7.0	<10.0	12	0.05
Cape Yakataga	2.0	37.5	<10.0	25	0.10

TABLE XIV

S. BERING SEA

Miller Freeman
D. E. Robertson, Analyst

Elemental Contents of Biota (μg/g Wet Weight)

Rock Sole	As	Br	K	Na
Miller Freeman # 5	1.50 ± 0.05	3.38 ± 0.07	1840 ± 90	620 ± 80
13	2.25 ± 0.03	1.26 ± 0.03	1130 ± 50	300 ± 30
23	0.99 ± 0.03	1.85 ± 0.04	970 ± 50	320 ± 40
27	1.02 ± 0.02	1.58 ± 0.03	900 ± 40	310 ± 40
34	0.68 ± 0.02	1.48 ± 0.03	900 ± 40	260 ± 30
41	1.34 ± 0.02	1.74 ± 0.04	950 ± 50	320 ± 40
43	0.45 ± 0.02	1.17 ± 0.03	790 ± 40	200 ± 30
44	0.27 ± 0.01	0.98 ± 0.02	630 ± 30	180 ± 30
47	0.36 ± 0.02	1.12 ± 0.03	660 ± 40	180 ± 30

Neptunia	As	Br	K	Na
Miller Freeman #15	11.0 ± 0.1	20.6 ± 0.1	810 ±120	1490 ±120
19	9.44 ± 0.09	34.7 ± 0.1	790 ±150	1820 ±150
22	7.70 ± 0.04	17.7 ± 0.1	300 ± 90	850 ± 60
31	0.85 ± 0.02	7.47 ± 0.03	340 ± 30	510 ± 30
50A	25.2 ± 0.2	74.6 ± 0.2	<220	4300 ±500
50B	2.70 ± 0.01	4.98 ± 0.01	240 ± 30	280 ± 20
50C	7.85 ± 0.21	20.9 ± 0.2	-	1200 ±500

A - Dissected anterior tissue sub-section
B - Dissected anterior tissue sub-section
C - Composite calculated from dissected parts

TABLE XV

S. BERING SEA

Miller Freeman
D. E. Robertson, Analyst

Elemental Contents of Biota (μg/g wet weight)

Pollock		As	Br	K	Na
Miller Freeman # 4	Fish 1	0.25 ± 0.02	2.78 ± 0.03	1240 ± 40	420 ± 30
4	Fish 2	0.21 ± 0.02	2.29 ± 0.03	1090 ± 30	350 ± 30
6		0.086± 0.012	1.22 ± 0.02	690 ± 20	200 ± 20
11		0.18 ± 0.02	2.08 ± 0.03	1100 ± 30	300 ± 30
17		0.18 ± 0.01	1.55 ± 0.02	780 ± 20	200 ± 20
21		0.24 ± 0.01	1.58 ± 0.02	860 ± 30	240 ± 20
25		0.45 ± 0.01	1.22 ± 0.01	700 ± 20	180 ± 20
28		0.23 ± 0.01	1.63 ± 0.02	810 ± 20	240 ± 10
36		0.13 ± 0.01	1.86 ± 0.02	1000 ± 30	280 ± 30
39		0.34 ± 0.02	2.78 ± 0.03	1220 ± 30	430 ± 30
42		0.35 ± 0.01	1.63 ± 0.02	940 ± 20	270 ± 20
45		0.18 ± 0.01	1.57 ± 0.01	740 ± 20	240 ± 20
46		0.11 ± 0.01	1.76 ± 0.01	610 ± 20	310 ± 30
49		1.53 ± 0.04	8.46 ± 0.06	3190 ± 80	1380 ±150

Alaska Crab	As	Br	K	Na
Station 7	3.39 ± 0.07	11.5 ± 0.1	2230 ±280	2230 ±170
12	2.65 ± 0.03	5.95 ± 0.05	820 ± 80	980 ± 60
14	2.23 ± 0.03	6.98 ± 0.05	690 ±130	1230 ± 70
20	4.14 ± 0.04	10.8 ± 0.1	1330 ±140	1810 ±100
26	2.34 ± 0.03	5.29 ± 0.05	630 ±120	960 ± 60
29	1.39 ± 0.02	4.34 ± 0.04	590 ± 70	770 ± 50

F. Mercury speciation in NEGOA sediments (H. V. Weiss)

These data were given in the previous report. Subsequently, we have obtained more ancillary organic carbon and size analysis data and a preliminary interpretation is given in the following section.

G. Ba and As contents of suspended sediment (D. E. Robertson)

These data for standard stations in the N.W. Gulf of Alaska and from the S. Bering Sea are given in Tables XVI and XVII.

H. V, Mn and Cu profiles at NEGOA specific study site (H. V. Weiss)

These data will be presented in tabular form in the next report. Preliminary findings are noted below.

I. Hydrographic data for NEGOA specific study site

Standard station data for the September (R/V *Acona*, No. 234) and April (R/V *Acona*, No. 240) are given in Figures 8-18.

J. Selenium and chromium data for all shelf areas: Summary of results (T. Gosink)

1. Selenium

Water - The average open ocean concentration of seawater is about 100 ppb. We have observed in the study areas the concentration is usually below a detection limit of $\sim$0.05 ppb. When the values are higher it is usually for surface waters, and seemingly for those rich in biota.

TABLE XVI

N.W. GULF OF ALASKA

Discoverer Leg IV 8-16 October 1975
D. E. Robertson, Analyst

Barium and Arsenic Concentratons in Suspended Sediment (> 0.4 μm)

		ppm in Particulate Matter		μg/l of Seawater	ng/l of Seawater
		Ba	As	Ba	As
101	S	<2800	6.19	<0.76	0.51
	B	1670	8.44	0.67	3.37
104	S	1310	9.56	0.64	4.66
	B	<1320	5.36	<0.56	2.28
108	S	<300	<0.58	<0.84	<1.80
	B	<240	<0.52	<0.69	<1.51
GASSW-119	S	1640	5.01	2.44	7.45
	B	1130	13.8	1.03	12.57
121	S	990	7.39	1.11	8.32
	B	--	--	--	--
122	S	--	--	--	--
	B	660	0.51	0.69	0.53
124	S	<1000	<4.25	<1.16	<4.95
	B	752	<0.46	0.86	<0.52
133	S	<1030	<2.67	<1.26	<3.28
	B	<1160	<1.65	<1.03	<1.46
135	S	<1010	4.34	<1.31	5.64
	B	<520	<1.15	<1.13	<2.45
137	S	<1100	<2.78	<1.44	<3.61
		<600	<1.33	<1.10	<2.45
145	S	<710	<1.8	<1.77	<4.46
	B	--	--	--	--
148	S	1160	<2.68	1.45	<3.35
	B	--	--	--	--
157	S	<340	<0.79	<0.51	<1.19
		<780	<0.86	<1.07	<1.18

TABLE XVI

Continued

	ppm in Particulate Matter		µg/l of Seawater	ng/l of Seawater
	Ba	As	Ba	As
160 S	<2100	<4.85	<3.42	<8.00
B	3100	<3.77	2.28	<2.78
				apparent concentration
Alaska Blank	<0.61	<0.01	0.22	0.37
	<4.17	0.02	<0.11	0.43
	<4.07	0.02	<0.11	0.54
Lab Blank	2.38	0.003	0.06	0.07
	<2.98	0.001	<0.08	0.25

TABLE XVII

S. BERING SEA

Discoverer 2-19 June 1975
D. E. Robertson, Analyst

Barium and Arsenic Concentrations in Suspended Particulate Material
(> 0.4 μ)

		ppm in Particulate Matter		μg/1 of Seawater	ng/1 of Seawater
		Ba	As	Ba	As
MB- 2	S	<1620	11.19	<1.07	7.38
	B	<970	5.18	<1.19	6.31
MB- 8	S	1600	19.42	1.89	22.91
	B	<790	10.45	<1.23	16.30
MB-14	S	<2200	5.66	<2.92	7.47
	B	<6000	11.17	<1.41	2.68
MB-24	S	--	--	--	--
	B	<1110	17.64	<1.21	23.64
MB-37	S	--	--	--	--
	B	<850	14.11	<0.77	12.64
MB-41	S	--	--	--	--
	B	<1150	12.46	<0.80	8.72
MB-43	S	--	--	--	--
	B	<1150	11.3	<1.05	11.30
MB-53	S	<1420	8.64	<1.05	6.40
	B	<1830	26.5	<0.73	10.61
MB-59	S	--	--	--	--
	B	<1000	11.61	<1.31	13.01
MB-64	S	--	--	--	--
	B	<1410	21.17	<0.90	13.55

AC CRUISE 234 CONSECUTIVE STATION NO. 38, YAK012 12/ 9/76
20.7 HOURS GMT

LATITUDE = 59 27.2N LONGITUDE = 140 12.9W SONIC DEPTH = 223 M

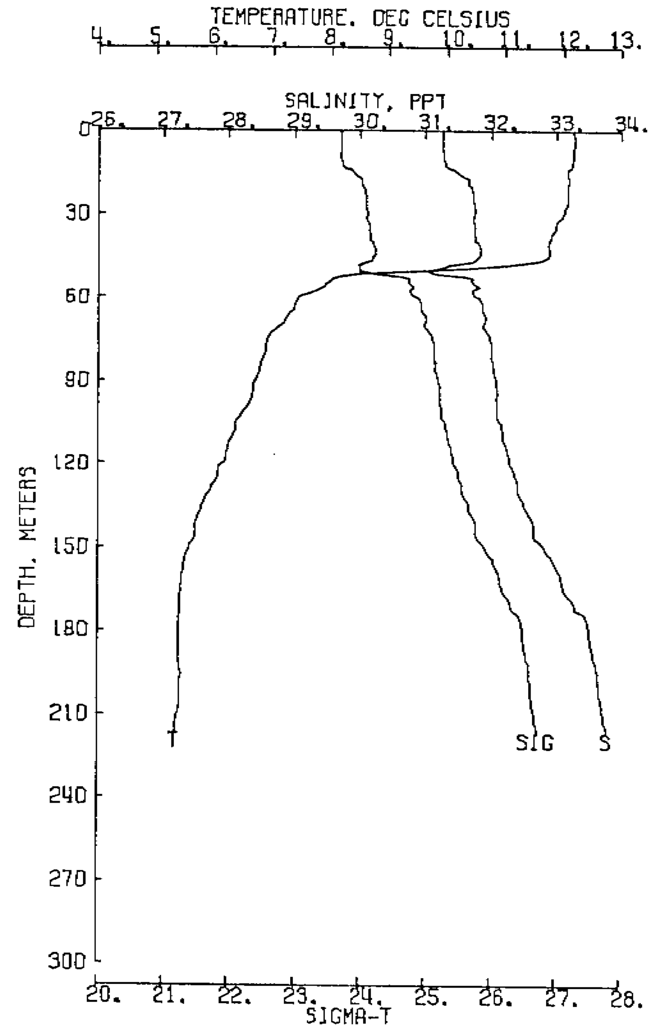
1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (6) ---STRATOCUMULUS ,
CLOUD AMOUNT --- (8) ---8/8 TOTAL ,
VISIBILITY --- (8) ---20-50 KM

	DIRECTION	SPEED	
WIND	85 - 94 DEGR	20 KNOTS	

	DIRECTION	HEIGHT	PERIOD
SEA	85 - 94 DEGR	2.0 M.	SECS
SWELL	- DEGR	M.	SECS

TEMPERATURES -DRY =	12.7 DEGR C.	BAROMETRIC PR. =	1003.4 MB
-WET =	DEGR C.	TRANSPARENCY =	M

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	12.18	31.257	23.69	0.
1.0	12.18	31.257	23.69	0.004
5.0	12.18	31.257	23.69	0.021
10.0	12.15	31.271	23.71	0.042
15.0	12.05	31.510	23.91	0.063
20.0	12.07	31.702	24.06	0.082
25.0	12.06	31.745	24.09	0.102
30.0	11.98	31.747	24.11	0.121
35.0	11.84	31.761	24.15	0.140
40.0	11.72	31.806	24.20	0.159
45.0	11.72	31.796	24.20	0.178
50.0	9.45	31.050	24.00	0.197
75.0	6.89	31.995	25.11	0.274
100.0	6.55	32.105	25.24	0.345
150.0	5.56	32.818	25.92	0.468
200.0	5.42	33.662	26.61	0.554



CRUISE 234 STATION 38

Figure 8.

AC CRUISE 234 CONSECUTIVE STATION NO. 39. YAK009 12/ 9/76
22.7 HOURS GMT

LATITUDE = 59 40.0N LONGITUDE = 139 59.5W SONIC DEPTH = 157 M

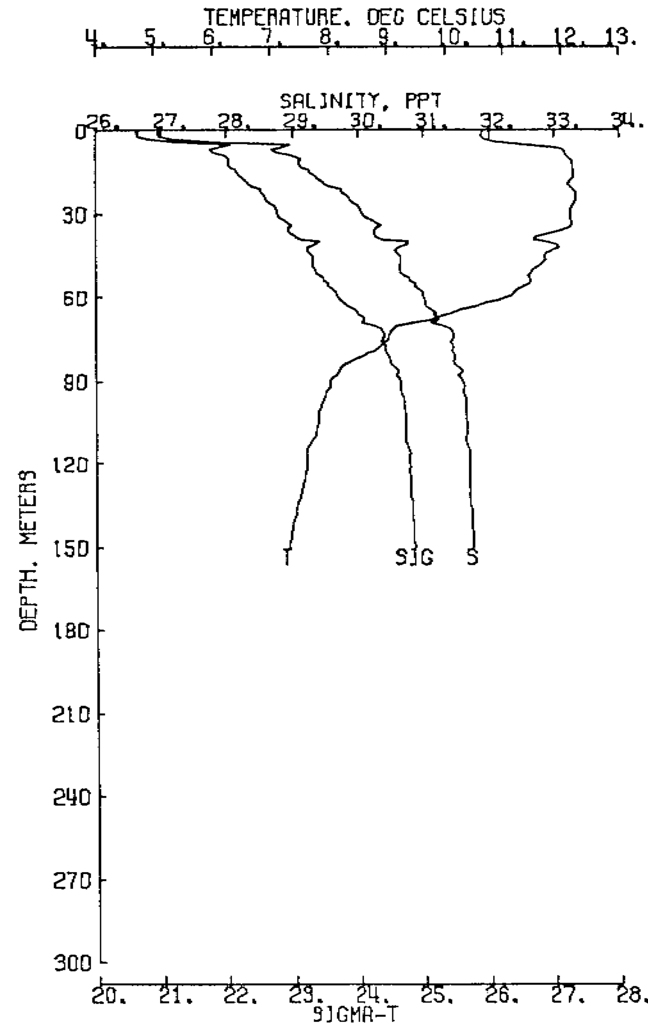
1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (6) ---STRATOCUMULUS
CLOUD AMOUNT --- (8) ---8/8 TOTAL
VISIBILITY --- (8) ---20-50 KM

	DIRECTION	SPEED
WIND	135 - 144 DEGR	12 KNOTS

	DIRECTION	HEIGHT	PERIOD
SEA	135 - 144 DEGR	1.0 M.	SECS
SWELL	- DEGR	M.	SECS

TEMPERATURES -DRY =	12.2 DEGR C.	BAROMETRIC PR. =	1003.5 MB
-WET =	DEGR C.	TRANSPARENCY =	M

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	10.62	26.951	20.63	0.
1.0	10.62	26.951	20.63	0.007
5.0	11.34	28.963	22.07	0.034
10.0	12.15	29.119	22.05	0.064
15.0	12.21	29.264	22.15	0.093
20.0	12.11	29.557	22.39	0.121
25.0	12.24	29.887	22.62	0.148
30.0	12.15	30.080	22.79	0.173
35.0	12.13	30.272	22.94	0.198
40.0	11.71	30.769	23.40	0.222
45.0	11.71	30.649	23.31	0.245
50.0	11.50	30.659	23.36	0.268
75.0	9.01	31.446	24.38	0.370
100.0	7.82	31.640	24.71	0.455
150.0	7.30	31.740	24.86	0.615



CRUISE 234 STATION 39.

Figure 9.

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AC   CRUISE 234 CONSECUTIVE STATION NO.  40.   YAK003    13/ 9/76
                                                         1.0 HOURS GMT

 LATITUDE = 59  52.5N   LONGITUDE = 139  40.0W   SONIC DEPTH =  256 M

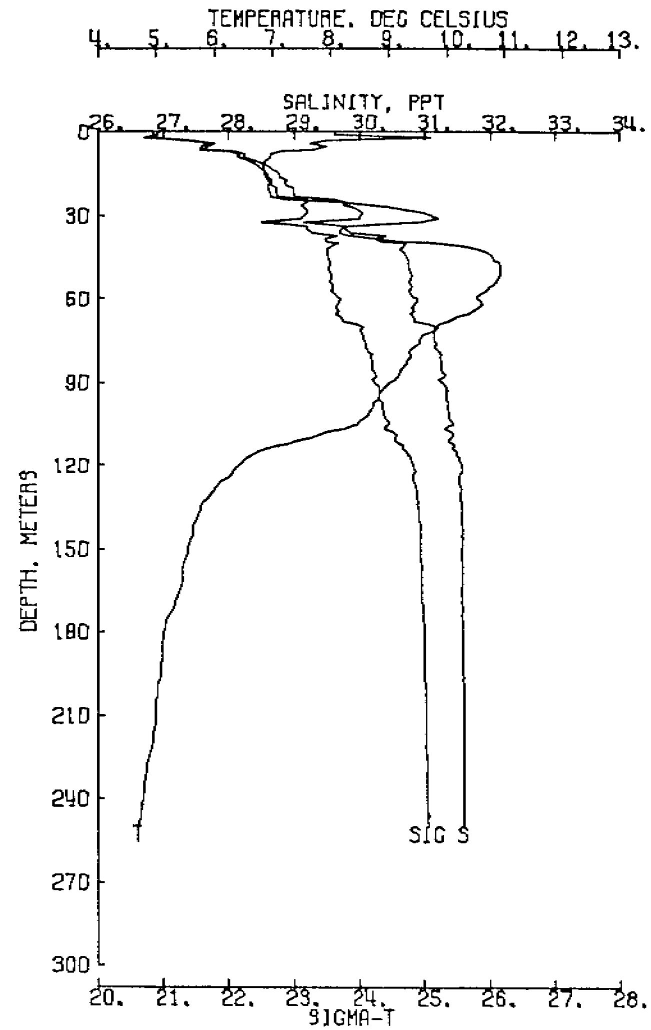
 1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
 CLOUD TYPE --- (6) ---STRATOCUMULUS     .
 CLOUD AMOUNT --- (8) ---8/8 TOTAL    .
 VISIBILITY --- (7) ---10-20 KM
```

	DIRECTION	SPEED
WIND	25 - 34 DEGR	14 KNOTS

	DIRECTION	HEIGHT	PERIOD
SEA	25 - 34 DEGR	0.2 M.	SECS
SWELL	- DEGR	M.	SECS

TEMPERATURES -DRY =	9.4 DEGR C.	BAROMETRIC PR. =	1002.1 MB
-WET =	DEGR C.	TRANSPARENCY =	M

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	8.07	26.843	20.92	0.
1.0	8.07	26.843	20.92	0.007
5.0	7.94	27.665	21.58	0.033
10.0	6.89	28.400	22.29	0.062
15.0	6.88	28.777	22.58	0.089
20.0	6.93	28.981	22.74	0.116
25.0	8.21	29.769	23.19	0.140
30.0	9.75	30.014	23.15	0.164
35.0	8.16	29.780	23.20	0.189
40.0	9.74	30.696	23.68	0.211
45.0	10.79	30.719	23.53	0.233
50.0	10.91	30.773	23.55	0.255
75.0	9.52	31.142	24.06	0.359
100.0	8.70	31.352	24.35	0.452
150.0	5.55	31.561	24.93	0.613
200.0	5.02	31.585	25.01	0.764



CRUISE 234 STATION 40

Figure 10.

AC CRUISE 234 CONSECUTIVE STATION NO. 41. YAK005 13/ 9/76
2.6 HOURS GMT

LATITUDE = 59 44.0N LONGITUDE = 139 40.5W SONIC DEPTH = 179 M

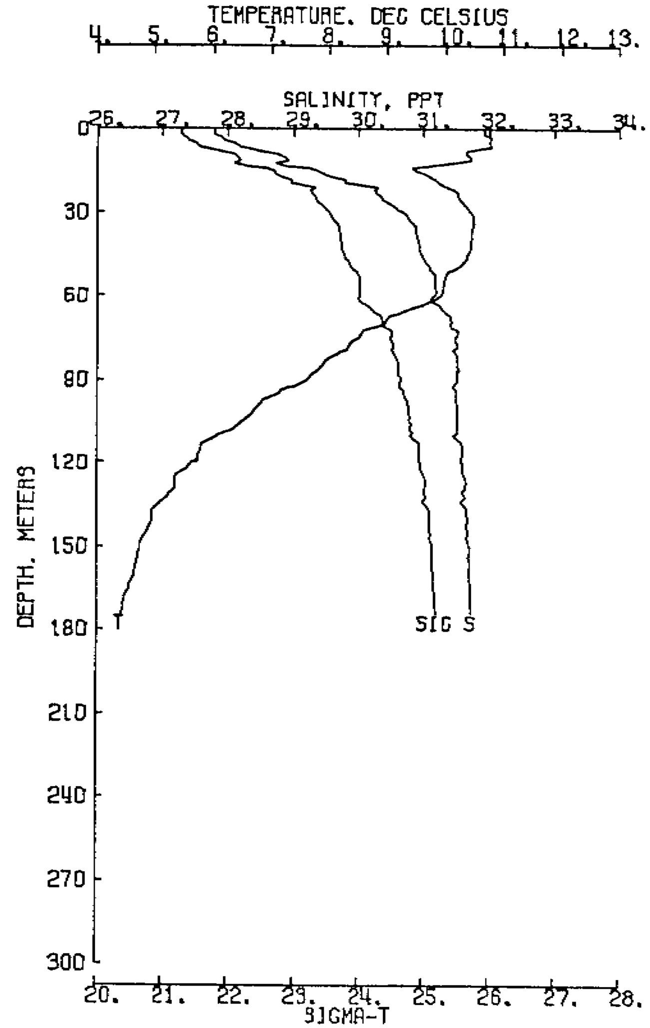
1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (0) ---CIRRUS
CLOUD AMOUNT --- (8) ---8/8 TOTAL
VISIBILITY --- (8) ---20-50 KM

	DIRECTION	SPEED	
WIND	95 - 104 DEGR	10 KNOTS	

	DIRECTION	HEIGHT	PERIOD
SEA	0 - 0 DEGR	0.7 M.	SECS
SWELL	- DEGR	M.	SECS

TEMPERATURES -DRY = 11.1 DEGR C. BAROMETRIC PR. =1001.6 MB
-WET = DEGR C. TRANSPARENCY = M

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	10.65	27.799	21.28	0.
1.0	10.65	27.799	21.28	0.007
5.0	10.76	28.108	21.51	0.032
10.0	10.43	28.883	22.16	0.063
15.0	9.49	29.392	22.71	0.090
20.0	9.93	29.995	23.11	0.115
25.0	10.25	30.378	23.35	0.138
30.0	10.45	30.702	23.57	0.161
35.0	10.48	30.871	23.70	0.182
40.0	10.44	30.911	23.74	0.203
45.0	10.38	30.972	23.79	0.224
50.0	10.17	31.091	23.92	0.244
75.0	8.50	31.487	24.49	0.338
100.0	6.74	31.509	24.75	0.422
150.0	4.73	31.700	25.13	0.572



CRUISE 234 STATION 41

Figure 11.

AC CRUISE 234 CONSECUTIVE STATION NO. 42, YAK007 13/ 9/76
3.6 HOURS GMT

LATITUDE = 59 39.5N LONGITUDE = 139 46.0W SONIC DEPTH = 170 M

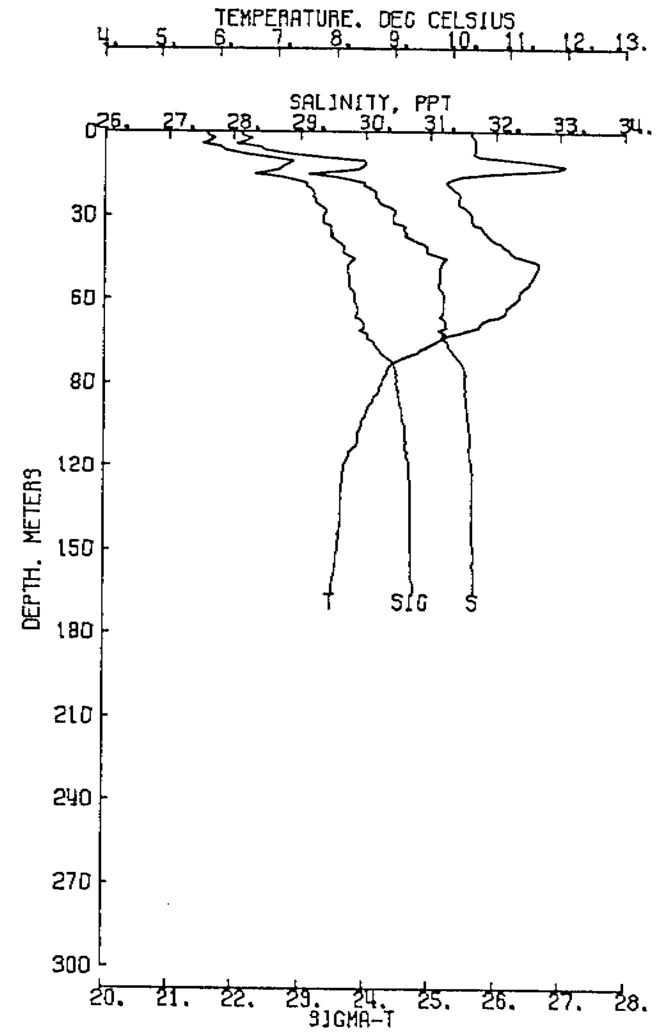
1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (0) ---CIRRUS
CLOUD AMOUNT --- (8) ---8/8 TOTAL
VISIBILITY --- (8) ---20-50 KM

	DIRECTION	SPEED	
WIND	95 - 104 DEGR	5 KNOTS	

	DIRECTION	HEIGHT	PERIOD
SEA	205 - 214 DEGR	0.5 M.	SECS
SWELL	- DEGR	M.	SECS

TEMPERATURES -DRY =	11.1 DEGR C.	BAROMETRIC PR. =	1001.3 MB
-WET =	DEGR C.	TRANSPARENCY =	M

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	10.33	28.113	21.58	0.
1.0	10.33	28.113	21.58	0.006
5.0	10.40	28.385	21.78	0.031
10.0	11.12	29.988	22.90	0.059
15.0	10.68	29.136	22.32	0.085
20.0	9.98	30.055	23.15	0.110
25.0	10.11	30.222	23.25	0.134
30.0	10.34	30.420	23.37	0.156
35.0	10.54	30.584	23.46	0.179
40.0	10.84	30.855	23.62	0.201
45.0	11.29	31.241	23.85	0.222
50.0	11.46	31.130	23.73	0.243
75.0	9.72	31.252	24.12	0.344
100.0	8.52	31.575	24.56	0.433
150.0	8.03	31.675	24.70	0.599



CRUISE 234 STATION 42

Figure 12.

AC CRUISE 234 CONSECUTIVE STATION NO. 43. ICY005 14/ 9/76
15.5 HOURS GMT

LATITUDE = 59 56.0N LONGITUDE = 141 32.5W SONIC DEPTH = 65 M

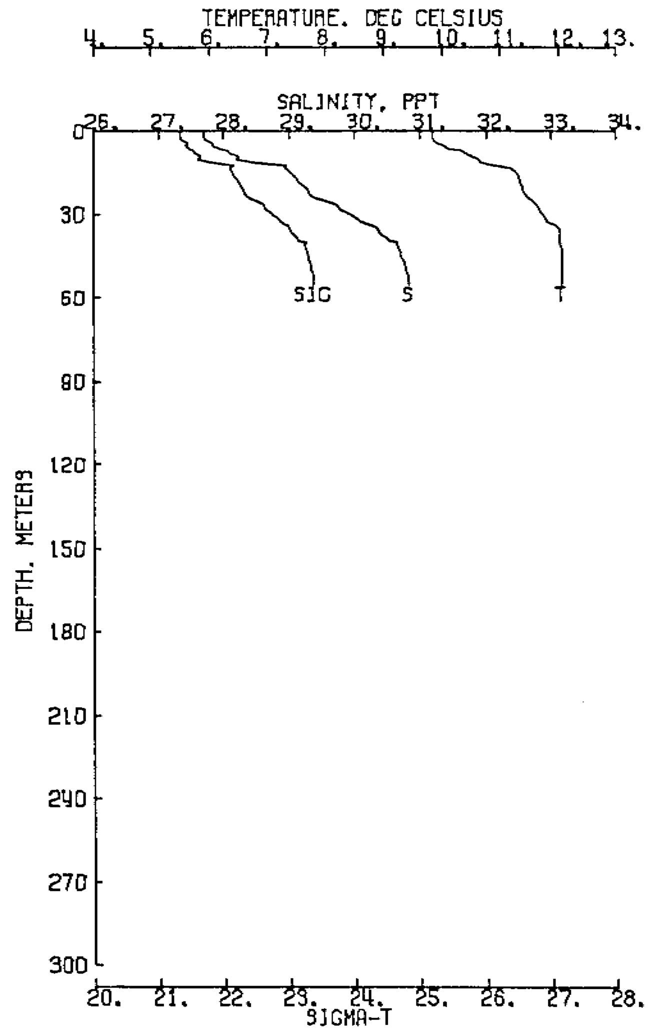
1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (7) ---STRATUS
CLOUD AMOUNT --- (8) ---8/8 TOTAL
VISIBILITY --- (7) ---10-20 KM

	DIRECTION	SPEED	
WIND	55 - 64 DEGR	28 KNOTS	

	DIRECTION	HEIGHT	PERIOD
SEA	0 - 0 DEGR	3.0 M.	SECS
SWELL	- DEGR	M.	SECS

TEMPERATURES -DRY =	7.2 DEGR C.	BAROMETRIC PR. =	998.0 MB
-WET =	DEGR C.	TRANSPARENCY =	M

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	9.83	27.689	21.33	0.
1.0	9.83	27.689	21.33	0.006
5.0	10.04	27.844	21.42	0.032
10.0	10.64	28.198	21.60	0.064
15.0	11.27	29.028	22.13	0.093
20.0	11.38	29.234	22.27	0.121
25.0	11.56	29.597	22.52	0.149
30.0	11.74	29.956	22.77	0.175
35.0	12.01	30.340	23.02	0.200
40.0	12.04	30.654	23.25	0.223
45.0	12.05	30.717	23.30	0.247
50.0	12.05	30.784	23.35	0.270



CRUISE 234 STATION 43

Figure 13.

AC CRUISE 234 CONSECUTIVE STATION NO. 44. ICY010 14/ 9/76
17.8 HOURS GMT

LATITUDE = 59 45.0N LONGITUDE = 141 44.0W SONIC DEPTH = 90 M

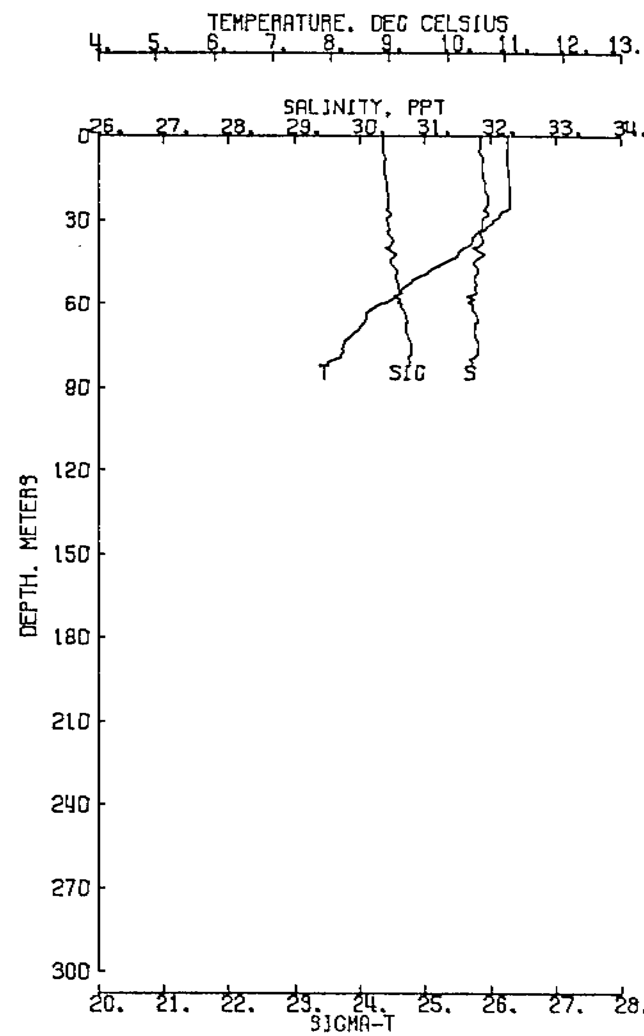
1-DIGIT WEATHER CODE IS (X2) AND INDICATES CONTINUOUS LAYER
CLOUD TYPE --- (6) ---STRATOCUMULUS
CLOUD AMOUNT --- (7) ---7/8
VISIBILITY --- (6) ---4-10 KM

	DIRECTION	SPEED
WIND	895 - 544 DEGR	35 KNOTS

	DIRECTION	HEIGHT	PERIOD
SEA	85 - 94 DEGR	M.	SECS
SWELL	- DEGR	M.	SECS

TEMPERATURES -DRY = 9.4 DEGR C.	BAROMETRIC PR. = 997.3 MB
-WET = DEGR C.	TRANSPARENCY = M

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	11.06	31.853	24.36	0.
1.0	11.06	31.853	24.36	0.004
5.0	11.06	31.831	24.34	0.018
10.0	11.06	31.874	24.38	0.036
15.0	11.07	31.900	24.39	0.054
20.0	11.09	31.925	24.41	0.071
25.0	11.09	31.953	24.43	0.089
30.0	10.80	31.879	24.42	0.106
35.0	10.50	31.848	24.45	0.124
40.0	10.29	31.738	24.40	0.141
45.0	9.92	31.743	24.47	0.159
50.0	9.53	31.759	24.54	0.176
75.0	8.21	31.818	24.79	0.258



CRUISE 234 STATION 44

Figure 14.

AC CRUISE 240 CONSECUTIVE STATION NO. 1. YAK007 9/ 4/77
6.3 HOURS GMT

LATITUDE = 59 39.5N LONGITUDE = 139 46.0W SONIC DEPTH = 172 M

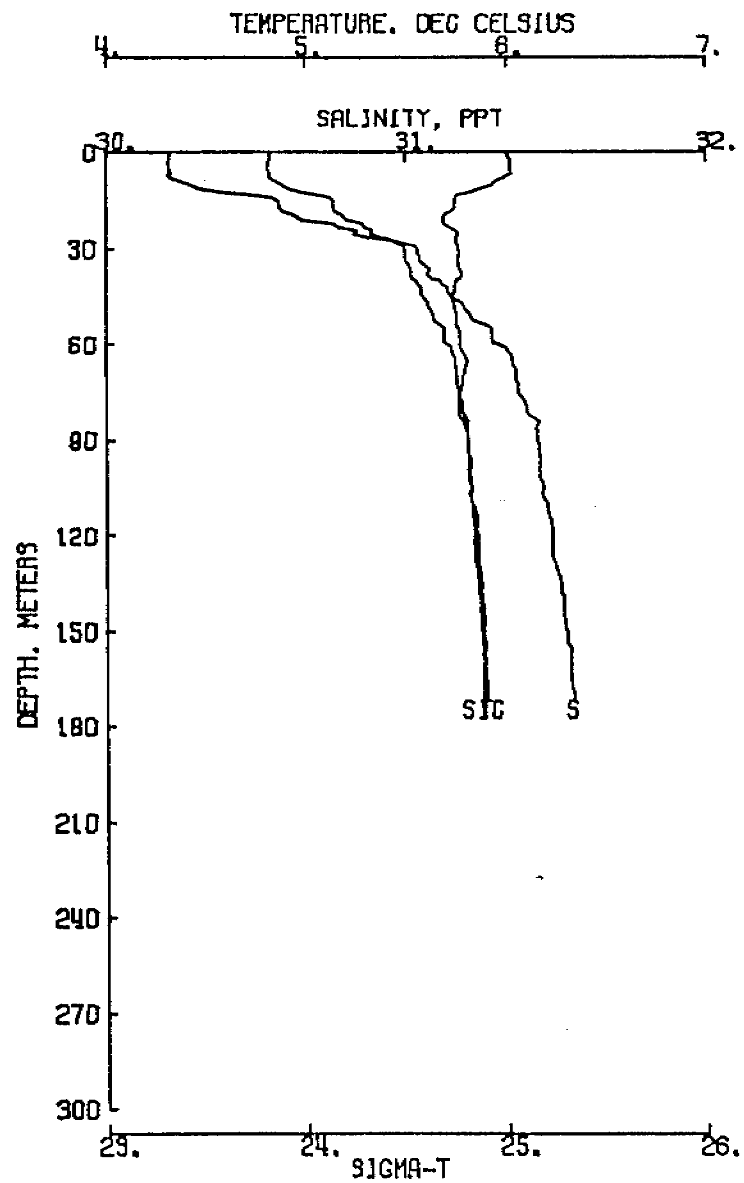
1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- ( ) ---NOT RECORDED,
VISIBILITY --- ( ) ---NOT RECORDED

	DIRECTION	SPEED
WIND	- DEGR	KNOTS

	DIRECTION	HEIGHT	PERIOD
SEA	0 - 0 DEGR	M.	SECS
SWELL	- DEGR	M.	SECS

TEMPERATURES -DRY =	5.0 DEGR C.	BAROMETRIC PR. =1005.2 MB
-WET =	DEGR C.	TRANSPARENCY = M

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	6.00	30.210	23.82	0.
1.0	6.00	30.210	23.82	0.004
5.0	6.02	30.210	23.81	0.021
10.0	5.92	30.287	23.89	0.041
15.0	5.74	30.577	24.13	0.061
20.0	5.69	30.635	24.19	0.079
25.0	5.76	30.826	24.33	0.098
30.0	5.76	31.041	24.50	0.115
35.0	5.76	31.064	24.52	0.133
40.0	5.75	31.114	24.56	0.150
45.0	5.74	31.153	24.59	0.167
50.0	5.75	31.207	24.63	0.183
60.0	5.76	31.397	24.71	0.216
70.0	5.79	31.364	24.75	0.249
75.0	5.77	31.372	24.76	0.265
80.0	5.76	31.400	24.78	0.281
90.0	5.80	31.436	24.81	0.312
100.0	5.82	31.444	24.81	0.344
125.0	5.85	31.467	24.84	0.423
150.0	5.89	31.531	24.87	0.501



CRUISE 240 STATION 1

Figure 15.

AC CRUISE 240 CONSECUTIVE STATION NO. 2. YAK003 9/ 4/77
9.7 HOURS GMT

LATITUDE = 59 52.5N LONGITUDE = 139 40.0W SONIC DEPTH = 260 M

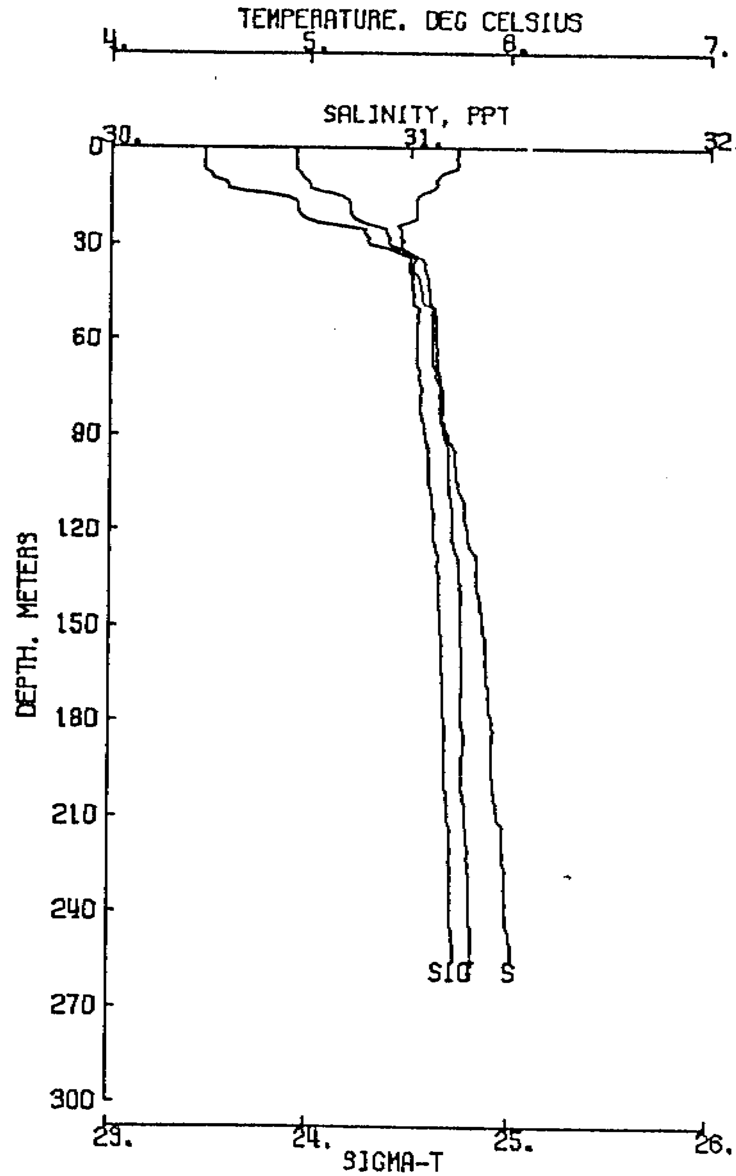
1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- ( ) ---NOT RECORDED,
VISIBILITY --- ( ) ---NOT RECORDED

	DIRECTION	SPEED
WIND	15 - 24 DEGR	KNOTS

	DIRECTION	HEIGHT	PERIOD
SEA	0 - 0 DEGR	M.	SECS
SWELL	- DEGR	M.	SECS

TEMPERATURES -DRY =	5.0 DEGR C.	BAROMETRIC PR. =1005.0 MB
-WET =	DEGR C.	TRANSPARENCY = M

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	5.73	30.312	23.93	0.
1.0	5.73	30.312	23.93	0.004
5.0	5.73	30.315	23.93	0.020
10.0	5.62	30.383	23.99	0.040
15.0	5.54	30.590	24.17	0.059
20.0	5.53	30.631	24.20	0.078
25.0	5.45	30.852	24.38	0.096
30.0	5.45	30.868	24.40	0.114
35.0	5.56	31.017	24.50	0.132
40.0	5.58	31.026	24.51	0.149
45.0	5.60	31.039	24.52	0.166
50.0	5.61	31.079	24.55	0.183
60.0	5.63	31.072	24.54	0.217
70.0	5.64	31.092	24.55	0.252
75.0	5.66	31.104	24.56	0.269
80.0	5.66	31.100	24.56	0.286
90.0	5.67	31.128	24.58	0.320
100.0	5.69	31.154	24.60	0.353
125.0	5.72	31.203	24.63	0.437
150.0	5.76	31.246	24.66	0.520
175.0	5.77	31.268	24.68	0.603
200.0	5.77	31.281	24.69	0.685
250.0	5.82	31.346	24.73	0.849



CRUISE 240 STATION 2

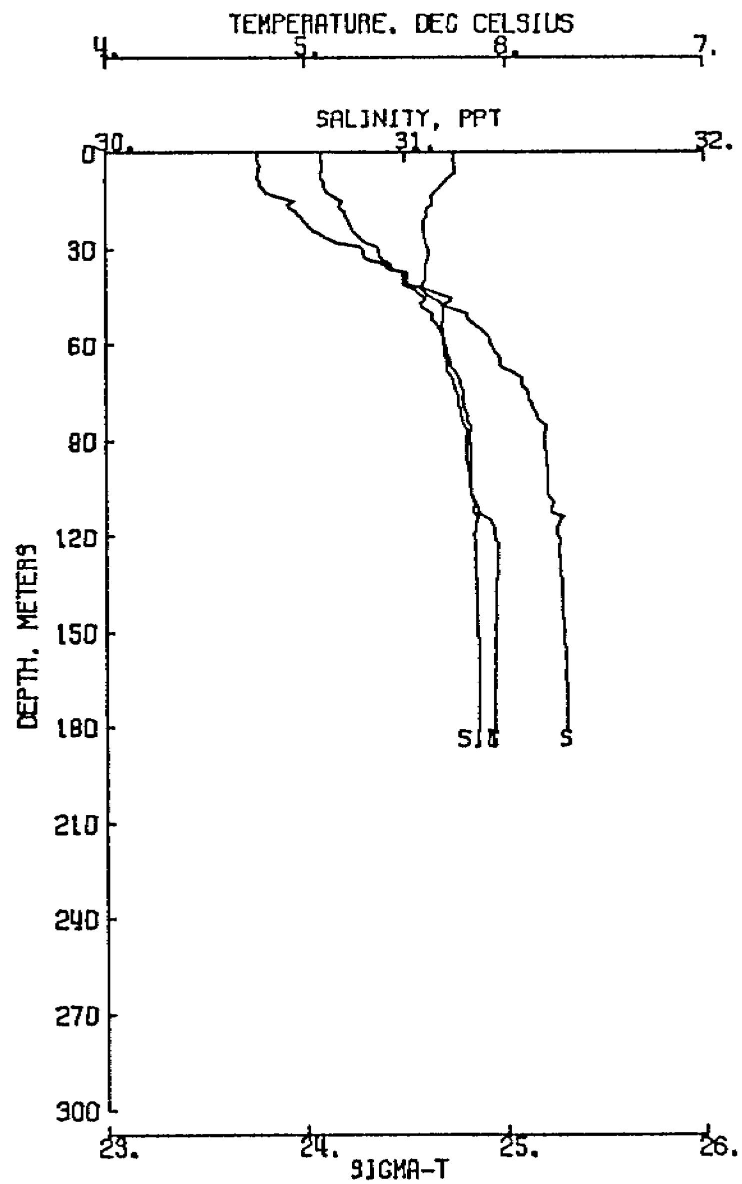
Figure 16.

```
AC   CRUISE 240 CONSECUTIVE STATION NO.    3.   YAK005      9/ 4/77
----------------------------                                12.3 HOURS GMT

 LATITUDE = 59  44.5N   LONGITUDE = 139  40.5W   SONIC DEPTH =  182 M

 1-DIGIT WEATHER CODE IS (X1) AND INDICATES PARTLY CLOUDY
 CLOUD TYPE --- ( ) ---NOT RECORDED
 CLOUD AMOUNT --- ( ) ---NOT RECORDED.
 VISIBILITY --- ( ) ---NOT RECORDED
-------------------------------------------------------------------------
I            DIRECTION          SPEED                                  I
I WIND      15 -  24 DEGR     5 KNOTS                                  I
-------------------------------------------------------------------------
I            DIRECTION          HEIGHT       PERIOD                    I
I SEA        0 -    0 DEGR         M.          SECS                    I
I SWELL        -      DEGR         M.          SECS                    I
-------------------------------------------------------------------------
I TEMPERATURES -DRY =    5.0 DEGR C.   BAROMETRIC PR. =1003.2 MB      I
I              -WET =        DEGR C.   TRANSPARENCY   =         M.    I
-------------------------------------------------------------------------
```

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	5.74	30.504	24.08	0.
1.0	5.74	30.504	24.08	0.004
5.0	5.75	30.513	24.08	0.019
10.0	5.69	30.519	24.09	0.038
15.0	5.64	30.630	24.19	0.058
20.0	5.61	30.652	24.21	0.076
25.0	5.60	30.720	24.26	0.095
30.0	5.62	30.860	24.37	0.113
35.0	5.61	30.936	24.43	0.131
40.0	5.60	31.007	24.49	0.148
45.0	5.64	31.159	24.61	0.165
50.0	5.69	31.206	24.64	0.182
60.0	5.69	31.292	24.70	0.215
70.0	5.73	31.386	24.77	0.247
75.0	5.76	31.413	24.79	0.263
80.0	5.78	31.423	24.80	0.279
90.0	5.81	31.463	24.83	0.311
100.0	5.82	31.473	24.83	0.342
125.0	5.96	31.511	24.85	0.421
150.0	5.95	31.528	24.86	0.499
175.0	5.94	31.537	24.87	0.577



CRUISE 240 STATION 3

Figure 17.

AC CRUISE 240 CONSECUTIVE STATION NO. 5. YAK009 10/ 4/77
4.8 HOURS GMT

LATITUDE = 57 40.0N LONGITUDE = 139 59.5W SONIC DEPTH = 159 M

1-DIGIT WEATHER CODE IS (X6) AND INDICATES RAIN
CLOUD TYPE --- ( ) ---NOT RECORDED
CLOUD AMOUNT --- ( ) ---NOT RECORDED
VISIBILITY --- ( ) ---NOT RECORDED

	DIRECTION	SPEED
WIND	165 - 174 DEGR	10 KNOTS

	DIRECTION	HEIGHT	PERIOD
SEA	165 - 174 DEGR	0.5 M.	SECS
SWELL	- DEGR	M.	SECS

TEMPERATURES -DRY =	5.0 DEGR C.	BAROMETRIC PR. =	994.9 MB
-WET =	DEGR C.	TRANSPARENCY =	M

DEPTH METERS	TEMPERATURE DEG C	SALINITY PPT	SIGMA-T	DELTA-D DYN M
0.	5.64	30.588	24.16	0.
1.0	5.64	30.588	24.16	0.004
5.0	5.64	30.591	24.16	0.019
10.0	5.65	30.606	24.17	0.038
15.0	5.67	30.631	24.19	0.057
20.0	5.69	30.665	24.21	0.075
25.0	5.73	30.749	24.27	0.094
30.0	5.81	31.060	24.51	0.112
35.0	5.84	31.122	24.55	0.129
40.0	5.84	31.167	24.59	0.146
45.0	5.86	31.196	24.60	0.163
50.0	5.88	31.219	24.63	0.179
60.0	5.89	31.427	24.79	0.212
70.0	5.89	31.497	24.84	0.243
75.0	5.87	31.503	24.85	0.259
80.0	5.87	31.522	24.86	0.275
90.0	5.93	31.595	24.92	0.305
100.0	5.94	31.602	24.92	0.336
125.0	5.96	31.634	24.94	0.412
150.0	6.07	31.692	24.98	0.488

CRUISE 240 STATION 5

Figure 18.

Sediment - Only surface oxygenated sediments have been studied. Again in keeping with expectations, the majority of samples are below the detection limit of about 10 ppb. Most detectable quantities are between 15 and 30 ppb with a few highs up to 200 ppb.

Biota - Selenium in this material is highly variable from the normal average of a few tenths of a ppm to more than 10 ppm for specific organs. Gelatinous material in Beaufort Sea water was observed to contain the equivalent of 4 ppb of selenium per liter of seawater.

2. Chromium

Water - Most samples contained about 0.3 ppb of chromium. A fair number were near or below the detection limit of about 0.02 ppb. High values were <2 ppb. Raw water values were slightly higher (factors of 1 to 4) with samples nearer coastal influence showing the highest values.

Sediments - Numerous surface sediment analyses have been reported in the range of 0.2 to 6 ppm. Most analyses are around 1-2 ppm. A few are below the 0.2 ppm level.

Biota - Samples have not as yet been recorded.

IV. PRELIMINARY INTERPRETATION

A. Extractable heavy metal contents of sediments

The final summary of data for all the cruises over the NEGOA grid is given in Table XVIII. We have explained our reasons for determining the extractable, i.e. non-lithogenous or "available" fraction at length elsewhere. It is not possible to summarize the relationships between total heavy metal contents and these extraction values for this area because

TABLE XVIII

N.E. GULF OF ALASKA SEDIMENTS

Station Number	Cruise	Sediment Size (%)			Extractable Metals (mg/kg)					
		Clay	Silt	Sand & Gravel	Cd	Cu	Ni	Zn	Fe	Mn
01	y	62	38	--	tr	14	12	37	6380	125
02	z				tr	6	5	31		
03	y	68	32	--	tr	9	9	27	6350	115
04	y	69	31	--	tr	9	10	30	6740	105
05	y	60	20	20	tr	8	5	14	1880	53
	z				tr	7	6	21		
06	y	33	23	44	tr	7	4	17	2210	65
07	y	42	22	36	tr	6	4	23	2270	50
53A	x				tr	31	12	26		
53	x				tr	12	8	13		
	z				tr	11	8	22		
54	z				tr	13	8	22		
55	x				tr	15	9	15		
	y				tr	17	5	22	3770	99
56	x				tr	8	8	9		
57	x				tr	14	7	13		
	y	27	33	40	tr	13	3	12	2000	91
58	x				tr	13	5	17		
	y	50	47	3	tr	18	5	16	3400	81
52	x				tr	31	12	25		
	y				tr	24	4	23	4020	116
	z				tr	17	13	39		
51	x				tr	20	9	16		
	z				tr	19	11	33		
50	y	62	38	--	tr	14	9	27	7250	130
49	x				tr	26	6	18		
	z				tr	12	11	37		
48	x				tr	14	7	16		
	y	31	34	35	tr	10	6	19	3470	85
42	x				tr	19	6	16		
	y	30	60	10	tr	15	10	24	6780	115
43	x				tr	24	6	17		
	y	60	36	4	tr	12	11	22	6660	90
44	x				tr	17	6	16		
	z				tr	11	4	13		
41	x				tr	23	7	17		
	y	50	50	--	tr	19	7	30	4420	100
40	x				tr	23	6	17		
	y	55	45	--	tr	20	7	21	3640	101
39	y	39	61	--	tr	14	7	29	4000	80
37	x				tr	9	7	16		

TABLE XVIII

Continued

Station Number	Cruise	Sediment Size (%) Clay	Silt	Sand & Gravel	Extractable Metals (mg/kg) Cd	Cu	Ni	Zn	Fe	Mn
30	x				tr	8	4	10		
31	x				tr	30	3	6		
	y	36	62	2	tr	15	9	23	6375	110
32	x				tr	19	3	12		
	y	48	52	--	tr	14	8	22	5105	90
33	z				tr	7	2	12		
34	x				tr	21	4	15		
28	y	40	53	7	tr	13	7	19	2590	105
27	y				tr	8	5	21	2260	115
25	y	20	34	46	tr	4	3	13	1200	50

x - *Oceanographer* February 1975
y - *Silas Bent* 31 August-17 September 1975
z - *Discoverer* 23 November-2 December 1975

separate sample sets (and mostly different elements) have been determined. The overall relationships are, however, well known from other areas; for example, that of a metal such as Cd is largely loosely bound whereas a majority of the copper is likely to be structural. It is fairly clear that the extractable contents correlate with sediment grain size - again as would be expected - but we were unable to obtain sufficient sediment size analyses to quantify the relationship in this area. There is also possibly an increase of copper shorewards. Overall it appears unnecessary to obtain more such data for the Gulf. As in the case of soluble contents we have demonstrated that Alaskan shelf regions are clean and correspond to other such environment elsewhere.

A representative set of core samples suitable for trace metal analysis was collected in Norton Sound in Sepbember 1976. For these samples, and for additional grab samples, we have also determined sediment size fractions (Table V). Figure 6, for example, shows % clay-silt distribution of the surficial sediments. Close correlations of the sediment extract heavy metal data (Table VII) with grain size fineness are evident for Fe and Ni (in particular), Zu and Cu, but not for Mn (Table IX). This relationship would be expected; that with the organic carbon content is an urgent but currently unfunded need. Although no water or biota values are available for this lease area, it is considered that, with the possible exception of the latter type of sample, further baseline work is unjustified. The potential use of this region as a natural oil seep laboratory would be inferior to Cook Inlet which can be sampled easily on a seasonal basis.

Similarly, only sediment analyses are available for the Chukchi Sea. In this region the mean grain size (Table VI) is much coarser than in Norton Sound and correlations (Table IX) between the metal contents and grain size are less meaningful (because many metals are close to detection limit). Nevertheless, the same trends are observed.

B. NEGOA benthos

Pelagic and sub-tidal benthic biota analysis has been very poorly covered in the Gulf. We have published a few values for, for example, crab and *Neptunea* which indicate the overall importance of the benthic communities. Our most comprehensive data set is for the intertidal samples collected by Zimmerman's group, notably *Fucus* and *Mytilus*, both species which have been extensively used as environmental indicator of heavy metal impingement elsewhere. A summary of the *Fucus* data is given as Table XIII. Some beach stations were occupied several times over but in the absence of the usual controls, and since these collections were not made primarily for chemical analysis, nothing definitive can be said about variations with season, life cycle, age, etc. There appears, however, to be no particular geographic region of anomalously high trace metal contents.

C. As, Br, K and Na in biota (D. E. Robertson)

The concentrations of As, Br, K and Na in rock sole, *Neptunea*, pollock and crab are given in Tables XIV and XV. Crab and *Neptunea* contain relatively elevated arsenic and bromine concentrations and show considerable variation from animal to animal.

D. Se and Cr in Alaskan shelf environment (T. A. Gosink)

The only unusual character to these analyses are the water samples which are lower than average values for both selenium and chromium, particularly the former. Surface sediment and biological materials appear normal.

Chromium shows a completely normal clean environment picture, with the water on the low side of average. Coastal sediment has some influence on raising the water column values slightly.

Selenium also shows a clean environment. The water column is particularly devoid of selenium except surface waters when copious biological material is present.

E. Hg speciation in NEGOA sediments (H. V. Weiss)

The total mercury content of surface and bottom seawater and sediments from the N.E. Gulf of Alaska ranged between 2-33 ng/l for seawater and 10.8-67.1 ng/g dry weight of sediment. The range of concentrations for the Chukchi-Beaufort Seas was 8-32 ng/l for seawater and 10.0-106.6 ng/g of dry sediment. These values are comparable to levels found elsewhere in the Alaskan coastal environment. No significant amount of organic mercury could be detected in the seawater samples. The amount of elemental and readily reducible mercury in the sediments was less than 2% of the total for all samples. Mercury (reducible and organic) released from the sediments to seawater with mixing ranged between non-detectable and 54.2% of the total mercury.

F. Ba and As contents of suspended sediment (D. E. Robertson)

These data are shown in Tables XVI and XVII for the N.W. Gulf and S. Bering Sea respectively from both bottom (B) and surface (S) waters. Ba concentrations were often below detection limit. The arsenic concentrations were highly variable and depended upon the suspended load of the seawater samples.

G. NEGOA specific study site

Only preliminary data (e.g. hydrography, TM profiles) are presently available. This sub-program will be summarized in a later report.

V. PROBLEMS ENCOUNTERED

No major problems were encountered during this quarter.

Quarterly Report

Contract #03-5-022-56
Research Unit #275
Task Order #5
Reporting Period 7/1 - 9/30/77

HYDROCARBONS: NATURAL DISTRIBUTION AND DYNAMICS ON THE ALASKAN OUTER CONTINENTAL SHELF

Dr. David G. Shaw
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

October 1, 1977

Quarterly Activity Summary
Contract 03-5-022-56
Task Order Number 275
Quarter Ending 30 September 1977

I. Project Name: Hydrocarbons: Natural Distribution and Dynamics on the Alaskan Outer Continental Shelf; D. G. Shaw, principal investigator.

II. Field and Laboratory Activities

A. Field

One field collection was accomplished during this quarter. Samples (20) of sediment were collected in the nearshore Beaufort Sea at locations from Barrow to Barter Island. This gives much better geographical coverage of the area than previous collections and should help to clarify the distribution and source of aromatics in that area. This collection was at one point shortly before it was scheduled to begin summarily cancelled by the Arctic Project Office. Only the timely return to Fairbanks of the P.I. and his personal intervention reinstated the work. This episode was particularly troublesome because it was contrary to previous understandings and its reasons were never explained.

B. Laboratory

Considerable time has been allocated methodology verification, particularly to implementing BLM's draft performance criteria. Performance has been both good and improving. This is particularly encouraging in view of the low laboratory morale during much of the period caused by uncertainty in future funding levels.

III. Program Development

A considerable fraction of the P.I.'s time was taken up by proposal preparation, planning and coordination with other investigators. This work now appears to have been largely non-productive because of last minute changes in program emphasis and funding.

Research Unit 278

NO REPORT RECEIVED THIS QUARTER

Research Unit 413

NO REPORT RECEIVED THIS QUARTER

QUARTERLY REPORT

RESEARCH UNIT #: 480
CONTRACT #: 03-6-022-35250
REPORTING PERIOD: July 1, 1977 to
September 1, 1977
NUMBER OF PAGES: 2

CHARACTERIZATION OF ORGANIC MATTER IN SEDIMENTS FROM GULF OF ALASKA, BERING AND BEAUFORT SEAS

I. R. Kaplan
W. E. Reed
M. W. Sandstrom
M. I. Venkatesan

Institute of Geophysics and Planetary Physics
University of California
Los Angeles, California 90024

October 1, 1977

Field Activities

Cruise Sea 5-77-BS: Norton Sound, Northern Bering Sea

During July 19 to August 2, 1977, we participated in cruise Sea 5-77-BS of the R/V SEA SOUNDER in Norton Sound. The purpose of this cruise (in terms of hydrocarbon studies) was to extend our sample grid to the western portions of Norton Sound and to sample the sediments south of Nome in an area identified by Cline (RU No. 153) as a potential petrogenic seep. In addition, we performed shipboard analysis of low molecular weight hydrocarbons (LMWH) in sediments of interest to Nelson's (RU No. 413/429) effort to identify geologic hazards in Norton Sound sediments.

A total of eight stations were occupied in which samples were collected with the "Soutar" Van Veem grab sampler. Subsamples were collected for high molecular weight hydrocarbons (HMWH), LMWH, and carbon, nitrogen, and sulfur analysis to be conducted at UCLA. In addition, 12 samples were collected by Kvenvolden for UCLA from vibracores and box cores in stations located near the potential petrogenic seep south of Nome. These samples will be analyzed for HMWH at UCLA.

Laboratory Activities

Analysis of LMWH in sediment samples collected during 1976 summer season from Cook Inlet, Kodiak Shelf, Norton Sound, and Beaufort Sea (see Quarterly Report, September 30, 1976) has been completed. Work remaining involves measurement of $\delta^{13}C$ of methane in selected samples. A final report of the results will be submitted as soon as this analysis is completed. Preliminary results indicate low levels of methane, ethane, ethylene, propane, propylene, *iso*- and *n*-butane, and in many cases pentane and hexane isomers, in all sediment samples. No anomalously high levels of ethane or propane were encountered, indicating that the gases are derived from diagenetic processes and are not related to petrogenic seeps. Confirmation of this interpretation awaits $\delta^{13}C$ analysis of methane in selected samples.

Analysis of HMWH in sediments from Norton Sound, Cook Inlet, Kodiak Shelf, and Beaufort Sea is in progress. A total of 72 samples will be analyzed.

Dr. Reed participated in the chemistry review meeting in Seattle, September 15-16, 1977. At this meeting, it was agreed that UCLA would analyze high molecular weight hydrocarbons in the sediments, although we would not be able to participate in the cruise. It was proposed that approximately 20 samples would be collected from Kamishak Bay and Shelikof Strait, and will be analyzed at UCLA as soon as possible.

QUARTERLY REPORT

RESEARCH UNIT: #500
REPORTING PERIOD: 1 July to
September 1977
NUMBER OF PAGES: 3

"Activity-Directed Fractionation of Petroleum Samples"

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November 22, 1977

Dr. Herbert E. Bruce
ERL/OCSEAP
National Oceanic and Atmospheric Administration
P. O. Box 1808
Juneau, Alaska 99802

Dear Dr. Bruce:

Reference: Research Unit 500

This letter will serve as our Second Quarterly Report on "Activity-Directed Fractionation of Petroleum Samples" covering the period of July 1 to September 30, 1977.

Several changes are being made in the petroleum fractionation scheme in an effort to obtain a better material balance. As reported previously, significant losses occur because of evaporation of the more volatile components during the determination of residue weights. To avoid such losses, the volatiles were removed at reduced pressure prior to fractionation. Fresh Prudhoe Bay crude oil was placed in a flask on a rotating evaporator and heated at 90 C for 10 hr. The volatile fraction, which accounted for 17 percent of the original crude oil, was collected in a trap maintained at -75 C. The residue will be fractionated by silica gel column chromatography.

The silica gel fractionation scheme reported previously for whole crude oil gave relatively small amounts of material in the polar fractions eluted with acetonitrile. We have found that acetonitrile is not a very good solvent for these petroleum fractions and seems to decrease rather than increase the elution rate relative to that achieved by methylene chloride. Tetrahydrofuran (THF) is a much better solvent and even dissolves the asphaltenes (pentane insolubles) very well. Subsequent fractionations will be carried out using THF and THF containing aqueous acid as the most polar eluting solvents.

Efforts to assay petroleum fractions by mammalian cell toxicity assays and Ames Salmonella mutagenicity assays have been hampered by difficulties in dispersing the fractions in the aqueous assay media. Dimethyl sulfoxide (DMSO) is the solvent of choice for dissolving organic components prior to their addition to the assay media as far as minimizing the solvent effect in the assay is concerned. Unfortunately many of the petroleum fractions are not soluble in DMSO. Methylene chloride and THF dissolve the petroleum fractions much better but the solvents themselves show significant toxicity at the highest dosage normally used. Regardless of the solvent used as soon as the petroleum fractions contained in a solvent are added to the aqueous media the insoluble components separate out.

Because of the above problems an effort has been made to find a solvent-dispersant combination that is effective and does not exhibit excessive toxicity in the bioassay systems. Glyceryl monooleate was found to be an effective solvent for the petroleum fractions but was not very effective as a dispersant when added to water. A series of polyethoxylated nonionic dispersants were tried. The most effective dispersant was polyethoxylated (n=6) nonylphenol. When the dispersant was added to a THF solution of crude oil and the mixture shaken with water, a rather stable dispersion was formed.

Bioassays showed that a moderate dosage of the THF-dispersant mixture can be tolerated in the Ames mutagenicity assays. However, the mixture cannot be used in the mammalian cell toxicity assay currently in use at Battelle. The latter assay requires cells that have become attached to the assay container. Small amounts of dispersants cause the cells to become detached and thus interfere with the assay.

Although dispersed mammalian cell toxicity assays can be run if the appropriate culture-shaking equipment is obtained, alternative assays should be considered. Discussions with Jack Anderson at Battelle's Pacific Northwest Marine Biology Laboratory have indicated that a toxicity assay utilizing brine shrimp should be very practical as a screening assay. Such an assay would be inexpensive and would require only small amounts of material. It would also be more indicative of the effect of a petroleum fraction on the marine environment than would a mammalian cell assay. If a suitable solvent-dispersant system can be found for the brine shrimp assay it will be used instead of the mammalian cell toxicity assay originally proposed.

Work planned for the next quarter includes the fractionation of fresh oil and weathered oil by a modified scheme and the *in vitro* bioassay of the fractions using the Ames mutagenicity assay. The modified scheme will combine vacuum stripping of volatiles, silica gel fractionation employing THF as the polar organic eluent, and high-pressure liquid chromatography using μ-Styragel columns. Approximately 50 fractions will be generated from each oil sample instead of the seven fractions described in the last quarterly report.

If you have any questions concerning this work and the proposed use of a brine shrimp screening assay, please do not hesitate to contact me.

Sincerely yours,

J. S. Warner

J. S. Warner
Senior Research Scientist
Organic, Analytical, and
Environmental Chemistry

JSW:jeb

xc: Dr. Rudolf J. Engelman