Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1978

Volume I. Receptors — Mammals
— Birds

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

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

VOLUME I	RECEPTORS -- MAMMALS
	BIRDS
VOLUME II	RECEPTORS -- BIRDS
VOLUME III	RECEPTORS -- BIRDS
VOLUME IV	RECEPTORS -- FISH, LITTORAL, BENTHOS
VOLUME V	RECEPTORS -- FISH, LITTORAL, BENTHOS
VOLUME VI	RECEPTORS -- MICROBIOLOGY
VOLUME VII	EFFECTS
VOLUME VIII	CONTAMINANT BASELINES
VOLUME IX	TRANSPORT
VOLUME X	TRANSPORT
VOLUME XI	HAZARDS
VOLUME XII	HAZARDS
VOLUME XIII	DATA MANAGEMENT

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Outer Continental Shelf Environmental Assessment Program
Boulder, Colorado

October 1978

U.S. DEPARTMENT OF COMMERCE
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DISCLAIMER

ACKNOWLEDGMENT

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Quarterly Report

Contract No. R7120804
Research Unit 67
1 January - 31 March 1978

Baseline Characterization of Marine Mammals in the Bering Sea: Distribution and Abundance

Principal Investigators

Howard W. Braham

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April 1978

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Date submitted April 7, 1978
Reporter's initials HWB

PI QUARTERLY PROGRESS REPORT - RU67
Reporting Period 1 January - 31 March 1978

Project Title: Baseline characterization of marine mammals in the Bering Sea: distribution and abundance.

I. Abstract

The remaining one-third of all RU67 field data collected since 1975 was logged and submitted to computer card abstract typing during the second quarter of FY 1978. Additionally, most data abstracted onto computer cards during the first quarter were checked for errors. These data are now ready for final checking and editing using the "Quality Control Program" (QCP-2) for aerial survey data.

Final analysis of the northern sea lion (Eumetopias jubatus) data confirmed our earlier diagnosis that a 50% decline in the population has occurred in the eastern Aleutian Islands study area (see appended processed report by Braham, Everitt and Rugh, 1978).

Data on the fall migration of the California gray whale (Eschrichtius robustus) were compiled and the resulting manuscript is in final preparation. Our results show that about 75% of the population leaves the Bering Sea through Unimak Pass during the last two weeks of November and the first week of December.

II. Objectives

The objective of research unit 67 is to summarize important life history information on marine mammals in the Bering Sea to serve as a basis for management decisions related to man's activities. Specifically, a comprehensive literature review coupled with field survey research is used to (1) determine seasonal distribution and abundance; (2) delineate major migration patterns; (3) define traditionally important habitats, such as breeding and feeding areas; and (4) where practical, define species composition and general population condition (sometimes termed "health" - an indicator of present and future viability).

The objectives of this quarter were to further prepare the data for computer analysis; to finalize completed research on the question of a northern sea lion population decline; and to complete the study of fall migration of gray whales.

III. Field and Laboratory Activities

A. Ship or field trip schedule. None

B. Scientific party.

Name	Affiliation	Role
Howard W. Braham	Marine Mammal Div.	PI - data checking, analysis and write-up

Name

David J. Rugh	Marine Mammal Div.	Co-PI - data checking, analysis and write-up
David E. Withrow	Marine Mammal Div.	Data checking

C. Methods.

Laboratory preparation of raw data consisted of computer abstract logging and hand-checking of all abstracts returned (or those available from the previous quarter's work) for mechanical errors. These errors were edited out, but the remaining relational errors must await the QCP-2 computer program check.

D. Sample collection localities.

All data in our files under RUs 67 and 14 were collected over the continental shelf of the Bering and southern Chukchi Seas.

E. Data collected and/or analyzed.

1. Data from all 1977 aerial surveys (n=25) and the remaining 9 of 45 surveys from 1976 were prepared for keypunch abstracting or final QCP-2 editing.

2. All data on northern sea lions in the eastern Aleutian Islands were carefully rechecked and compared to data in the literature. Seventeen different kinds of individual parametric and non-parametric tests were performed. All fall migration data for gray whales were analyzed during this quarter. Eleven parametric and non-parametric tests were performed.

3. The 1976 ice seal data have been plotted, and new estimates of abundance and density begun. Data from RU231 were combined with our 1976 ice seal data for reporting purposes, however the processing for errors is incomplete. The combined data base now consists of 26 surveys for RU67 and approximately 12 surveys for RU231.

IV. Results

As a result of this quarter's data preparation schedule, all RU67 aerial survey data are either computer abstracted or awaiting final quality control checking. The QCP-2 program will be written in April; thus, all RU67 data are expected to be ready for analysis by the beginning of the third quarter (June or July).

Results of data analysis on northern sea lions are reported in the appended processed report titled "Preliminary evidence of a northern sea lion (Eumetopias jubatus) population decline in the eastern Aleutian Islands, Alaska". The population of sea lions in the study area is down to approximately 15,000-20,000 animals from a high of 50,000+ since the late 1950's and early 1960's. Because of the time of year other surveys were flown

(September and October 1975; March 1960; May 1965; and June 1968) our estimate of a 50% decline is considered conservative. On the breeding rookeries in the study area the decline approaches 65%!

Results of the non-OCSEAP fall gray whale migration study show that 2,058 whales were observed during an average 4.9 hours per day of watch between 20 November and 9 December 1977. Assuming that gray whales migrate with equal speed throughout the 24-hour clock, an estimated 11,205 animals passed the shore-based counting station at Cape Sarichef, Unimak Island, Alaska, during the three week watch period (Figure 1). Extrapolating forward and backward in time (area under the curve in Figure 1), we estimate that 11,205 represents about 75% of the total number of gray whales in the population which summer in the Bering Sea. This population estimate is, of course, dependent upon the as yet unverified assumption that no diurnal fluctuation occurs in the number of whales per hour passing the observation point, something we could not measure at the time. The migration route from the northern Bering Sea to Unimak Pass remains unclear, but appears to be a rather direct, i.e. pelagic, route. A processed report concerning the fall migration study will be available to the OCSEAP Juneau office before the next reporting period (June 1978).

The results of the 1976 ice seal data will be presented in the next quarterly report.

V. Preliminary Interpretation of Results

It is significant that a population decline has been identified for the Aleutian Islands sea lions before exploration of the Saint George, Aleutian Shelf and Bristol Bay oil lease tracts has begun. These three areas are important feeding grounds for many pinnipeds and cetaceans but, because of their close proximity to the Aleutian Islands breeding grounds, they are especially important to the northern sea lion. Our results are important for two reasons. First, if in the future the population continues down it may not be attributed to oil development (although in a synergistic manner, additional activities of man may depress the population more). Second, future monitoring programs must take into account a host of interrelated factors (e.g., a westerly shift in population distribution, or the effect of heavy commercial fisheries on sea lion foraging) which have not yet been measured.

If gray whales are vulnerable to man's activities in the near-shore environs, then the movements of whales in mass through Unimak Pass during a rather narrow time frame are of considerable concern. Although the gray whale does not appear to be "endangered" using the definition described in the Endangered Species Act of 1973 (that is, their population appears to have recovered to at least pre-commercial harvest level or greater; Rice and Wolman, 1971), any major segment ofthepopulation subjected to a major perturbation within a short time frame must be considered potentially vulnerable. Because marine mammals are heavily protected by congressional legislation, all activities by man must be carefully researched and closely monitored. Preliminary evidence in California indicate that gray whales change their migration routes when confronted with heavy boat traffic. Since we know little about gray whale

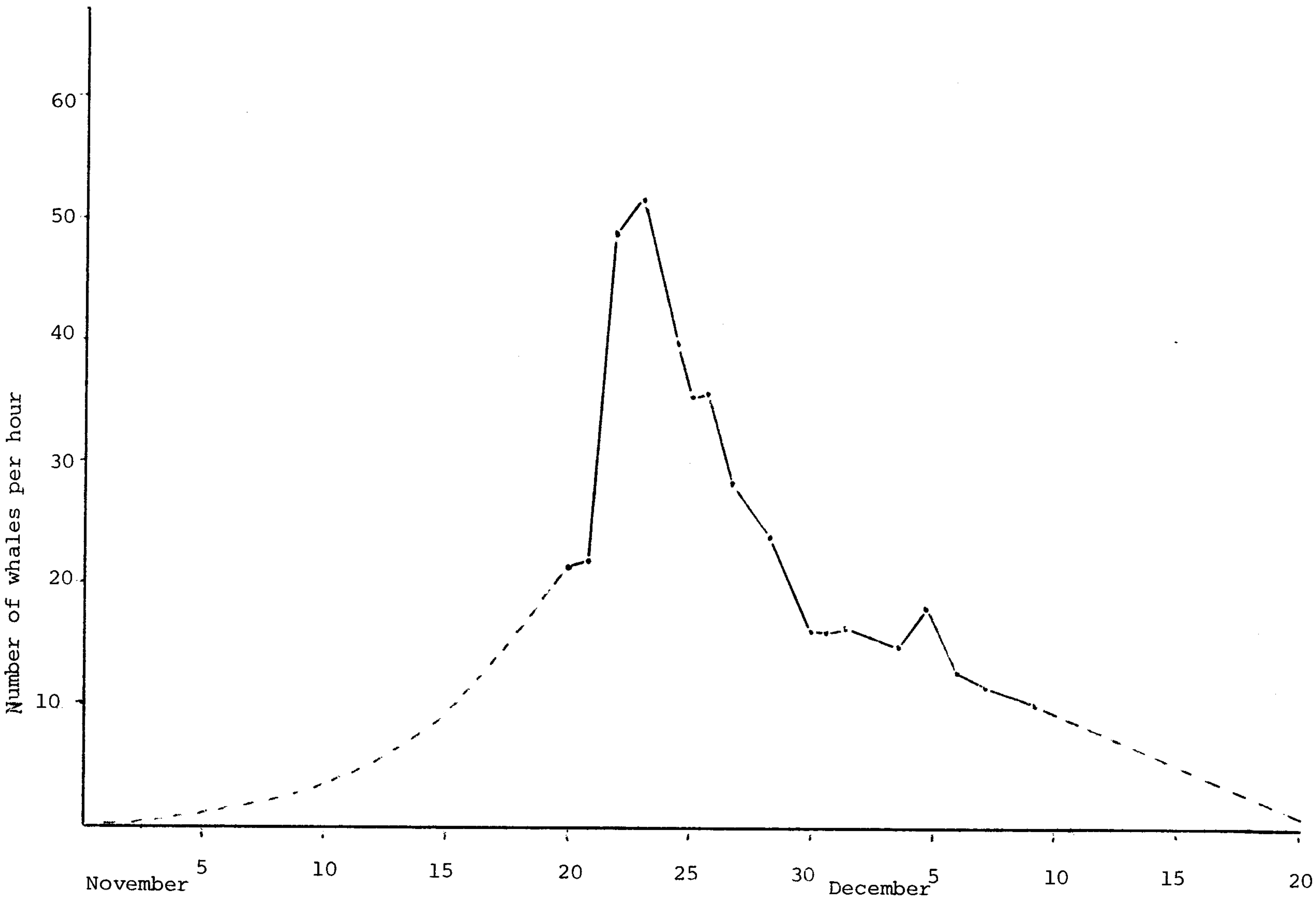

Figure 1. California gray whale counts from Cape Sarichef, Unimak Island, Alaska, 1977.

behavior in Alaska, nor about the possible increase in vessel traffic near gray whale migration routes, it is not clear what effect boat traffic or other oil development activities will have on this species.

VI. Auxiliary Material

A. Literature cited

Braham, H. W., R. D. Everitt and D. J. Rugh. 1977. Preliminary evidence of northern sea lion (Eumetopias jubatus) population decline in the eastern Aleutian Islands. Processed report, NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 30 p.

Rice, D. W., and A. A. Wolman. 1971. The life history and ecology of the gray whale (Eschrichtius robustus). Special Publication No. 3, Amer. Soc. of Mammalogists. 142 p.

B. Papers in preparation or in print

Completed:

Braham, H. W., R. D. Everitt, B. D. Krogman, D. J. Rugh and D. E. Withrow. 1977. Marine mammals of the Bering Sea: a preliminary report on distribution and abundance, 1975-76. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 90 p.

Braham, H. W., R. D. Everitt and D. J. Rugh. 1977. Preliminary evidence of a northern sea lion (Eumetopias jubatus) population decline in the eastern Aleutian Islands. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 30 p. (in review to the Journal of Wildlife Management)

Braham, H. W. 1978. California gray whale (Eschrichtius robustus) spring migration in Alaska (accepted by Técnica Pesquera; revised draft due 1 May 1978). Also submitted under RU68.

Rugh, D. J., and H. W. Braham. 1978. California gray whale (Eschrichtius robustus) fall migration through Unimak Pass, Alaska, 1977. (in review as processed report; to be submitted to the Journal of Mammalogy before 1 June 1978) Also submitted under RU68.

Severinghaus, N. C., and M. K. Nerini. 1977. An annotated bibliography on marine mammals of Alaska. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 125 p.

In preparation:

Braham, H. W., R. D. Everitt, B. D. Krogman, M. K. Nerini, R. G. Punsley, D. J. Rugh, R. M. Sonntag and D. E. Withrow. Marine mammals of the Bering Sea: their seasonal distribution and abundance. (planned final report for RU67; completion date September 1978)

Braham, H. W., G. A. Fedoseev, J. J. Burns and B. D. Krogman. 1978. Distribution and abundance of Phocine seals and walruses in the Bering Sea pack ice in the spring, 1976. (accepted as a book chapter, US-USSR Convention for Environmental Conservation of Marine Mammals; revised draft due 10 June, 1978)

Braham, H. W., B. D. Krogman, R. M. Sonntag and R. G. Punsley. Spring 1976 distribution and abundance of the Pacific walrus, *Odobenus rosmarus*. (in preparation for processed report; final draft due in May 1978)

Everitt, R. D., and H. W. Braham. Harbor seal, *Phoca vitulina richardii*, population on the north side of the Alaska Peninsula and the eastern Aleutian Islands. (in preparation; preliminary draft expected by 1 July 1978)

Krogman, B. D., and H. W. Braham. An estimation of walrus (*Odobenus rosmarus*) abundance, and a review of its distribution. (planned for spring 1979)

Krogman, B. D., and H. W. Braham. Aerial survey methodology applied to the clumped distribution of pinnipeds on ice. (planned for winter 1979)

Sonntag, R. M. A comprehensive World Data Bank computerized mapping and plotting routine. (manuscript in final draft stage)

Withrow, D. E., and H. W. Braham. Ground truth statistics and the bias associated with aerial surveys of pinnipeds. (planned for winter-spring 1979)

C. Oral presentations

1. David Rugh -- 13 January to the Girls Club of South King County, Seattle, WA. OCSEAP research and MMD activities

2. David Withrow -- 23 February to the American Cetacean Society, Seattle, WA. OCSEAP studies, emphasizing the northern sea lion

3. David Rugh -- 28 February to the NW section of the Wildlife Society, Vancouver, B. C. "Preliminary evidence of a northern sea lion population decline in the eastern Aleutian Islands,AK"

4. David Rugh -- 9 March to the Marine Mammal Division. "California gray whale fall migration through Unimak Pass, Alaska"

5. Howard Braham -- 28 March to the Northwest and Alaska Fisheries Center, Seattle, WA. a summary of OCSEAP research at the Marine Mammal Division

D. Updated milestone chart

See attached.

VII. Problems Encountered and Recommended Changes

A delay occurred in the checking and analysis of some data because of a software problem and hardware changes at the computer facility we use. Also, temporary hiring difficulties delayed our timetable, and an emphasis on transferring several OCSEAP personnel on RU68 delayed processing of some data in RU67 and RU69. All of these problems have been resolved.

R.U. #67

Revised 1 April 1978

△ Expected
▲ Completed

MAJOR MILESTONES	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Ice Seal Study (1976-77 data):															
Raw data converted to in-house format				▲ 100%											
Keypunch abstracts coded and checked				▲ 75%		▲ 100%									
Keypunching completed and verified				▲ 25%		▲ 50%	△ 100%								
Final quality check of data (computer check)				▲ 25%				△ 60%	△ 100%						
Convert to 026 format											△ 100%				
Submit to EDS (archival)											△ 100%				
Cetacean Study 1/(1976-77 data):															
Raw data converted to in-house format				▲ 100%											
Keypunch abstracts coded and checked					△ 100%										
Keypunch completed and verified						▲ 75%	▲ 100%								
Final quality check of data (computer check)				▲ 20%			▲ 60%		▲ 100%						
Convert to 026 foramt											▲ 100%				
Submit to EDS (archival)											▲ 100%				
E. Aleutian Islands Pinniped Study (1975-77)															
Raw data converted to in-house format				▲ 100%											
Keypunch abstracts coded and checked					▲ 100%										
Keypunching completed and verified						▲ 75%	▲ 100%								
Final quality check of data (computer check)				▲ 20%		▲ 60%			▲ 100%						
Convert to 026 format											▲ 100%				
Submit to EDS (archival)											▲ 100%				
Quarterly report			▲			▲			▲						
Final report												▲			

1/ Data presentation for the Bering Sea Project (R.U. 67) will be included in the Gulf of Alaska project (R.U. 68) final report, except for one species, the gray whale.

R.U. #67

NARRATIVE REPORTS

Indicate the following for each narrative report/manuscript to be generated under R.U. 67 listed below:

A/In preparation (indicate progress by showing % completion/month)
B/Submit for agency (NMFS) review
C/Final report in printing
D/Submission to OCSEAP

Report	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1. Distribution and abundance of Phocine seals on the Bering Sea pack ice in the spring, 1976-77.				A	—	—	—	—	—	—	B	C/D			
2. Population status of the northern sea lion, *Eumetopias jubatus*, in the eastern Aleutian Islands, Alaska.	A	—	—	B	C	D									
3. Harbor seal, *Phoca vitulina richardii*, populations of the north side of the Alaska peninsula, and the eastern Aleutian Islands.					A	—	—	—	B	C	D				
4. Migration of the California gray whale (*Eschrichtius robustus*) in Alaska.			A	—	—	—	—	—	—	B	C	D			
5. Distribution and abundance of the Pacific walrus (*Odobenus rosmarus*) on the Bering Sea spring pack ice, 1976.	—	—	—	—	—	—	B	C	D						

A comprehensive list of all published or planned manuscripts from research conducted on the Alaskan Outer Continental Shelf Environmental Assessment Program at the Marine Mammal Division for Research Units 14, 67, 68 and 69 (formerly RU 70) under the direction of OCSEAP Principal Investigator Howard W. Braham, Arctic Whales Task Leader.

Braham, H. W. 1978. La ballena California gris (Eschrictius robustus) migración del primavera en Alaska. (Accepted by Tecnicá Pesquera; revised draft due May 1, 1978.)

Braham, H. W. 1978. California gray whale (Eschrictius robustus) in Alaska: Spring migration coupled to feeding behavior. (In preparation to Fisheries Bulletin, due May 1, 1978.)

Braham, H. W., R. D. Everitt, B. D. Krogman, D. J. Rugh and D. E. Withrow. 1977. Marine Mammals of the Bering Sea: A preliminary report on distribution and abundance, 1975-76. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 90 p.

Braham, H. W., R. D. Everitt, B. D. Krogman, M. K. Nerini, R. Punsley, D. J. Rugh, R. M. Sonntag, and D. E. Withrow. Marine mammals of the Bering Sea: Seasonal distribution and abundance. (Planned final report for RU 67; completion date September 1978.)

Braham, H. W., R. D. Everitt and D. J. Rugh. 1977. Preliminary evidence of a northern sea lion (Eumetopias jubatus) population decline in the eastern Aleutian Islands. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 30 p. (Also in review by the Journal of Wildlife Management.)

Braham, H. W., G. A. Fedoseev, J. J. Burns and B. D. Krogman. 1978. Distribution and abundance of Phocine seals and walruses in the Bering Sea pack ice in the spring, 1976. (Accepted as a book chapter, US-USSR Convention for Environmental Conservation of Marine Mammals revised draft due June 10, 1978).

Braham, H. W. and B. D. Krogman. 1977. Population biology of the bowhead, (Balaena mysticetus), and Beluga (Delphinapterus leucas) whales in the Bering, Chukchi and Beaufort Seas. Processed report, U. S. Dept. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 29 p.

Braham, H. W., B. D. Krogman, G. M. Carroll and C. E. Peterson. Population biology of the bowhead whale (Balaena mysticetus) and beluga whale (Delphinapterus leucas) in Alaska I: distribution and abundance. (Planned final report for RU 69).

Braham, H. W., B. D. Krogman, R. M. Sonntag and R. Punsley. 1978. Spring 1976 distribution and abundance of the Pacific walrus (Odobenus rosmarus). Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. (In preparation, final draft due May 1, 1978.)

Braham, H. W. and R. W. Mercer. Cetacean distribution in the Gulf of Alaska. Yakatat Bay to Unimak Island. (In preparation, expected completion date August 1978.)

Braham, H. W. and R. W. Mercer. Marine mammal distribution and relative abundance in the Gulf of Alaska and Southern Bering Sea. (In preparation as final report for RU 68; completion date September 1978.)

Calkins, D. G., K. Pitcher, and K. Schneider. 1975. Distribution and abundance of marine mammals in the Gulf of Alaska. Processed Report, Alaska Dep. Fish Game, Div. Game, Anchorage, AK. 39 p. (sub-contract to Marine Mammal Division.)

Everitt, R. D. and H. W. Braham. Harbor seal (Phoca vitulina richardii) population on the north side of the Alaskan Peninsula and the eastern Aleutian Islands. (In preparation; preliminary draft expected July 1, 1978.)

Fiscus, C. H., H. W. Braham, R. W. Mercer, R. D. Everitt, B. D. Krogman, P. D. McGuire, C. E. Peterson, R. M. Sonntag, and D. E. Withrow. 1976. Seasonal distribution and relative abundance of marine mammals in the Gulf of Alaska. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 238 p.

Krogman, B. D. 1977. Mating bowhead whales. Alaska 63(9):52-53.

Krogman, B. D. and H. W. Braham. Aerial survey methodology applied to the patchy distribution of pinnipeds on ice. (Planned for winter 1979).

Krogman, B. D. and H. W. Braham. An estimation of walrus (Odobenus rosmarus) abundance, and a review of the distribution (Planned for spring 1979).

Krogman, B. D. and R. D. Everitt, Bowhead whale (Balaena mysticetus) copulatory behavior observed off North Coast of Alaska. (In review to the Journal of Mammalogy.)

Mercer, R. W., H. W. Braham, T. Bray, and M. Tillman. Distribution of Dall porpoise (Phocoenoides dalli) in Alaska. (In preparation; completion date September 1978.)

Mercer, R. W., B. D. Krogman and R. M. Sonntag. Marine mammal data documentation for the Platforms of Opportunity Program and Alaskan Outer Continental Shelf Environmental Assessment Program. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA.

Rugh, D. J. and H. W. Braham. 1978. California gray whale (Eschrichtius robustus) fall migration through Unimak Pass, Alaska, 1977. (In review as processed report; to be submitted to the Journal of Mammalogy by June 1978.)

Severinghaus, N. C. An annotated bibliography on Marine Mammals of Alaska emphasizing distribution and abundance. (To be a published NOAA technical report; final draft due late April 1978.)

Severinghaus, N. C. and M. K. Nerini. 1977. An annotated bibliography on Marine Mammals of Alaska. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 125 p.

Sonntag, R. M. A comprehensive World Data Bank computerized mapping and plotting routine. (Manuscript in final edit stage.)

Withrow, D. E. and H. W. Braham. "Ground Truth" statistics and the biases associated with aerial surveys of pinnipeds. (Planned for winter-spring 1979.)

Quarterly Report

Contract No. R7120806
Research Unit 68
1 January - 31 March 1978
12 pages

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

Principal Investigators

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Roger W. Mercer

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April 1978

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Date submitted April 2, 1978
Reporter's initials HWB

PI QUARTERLY PROGRESS REPORT - RU68
Reporting period 1 January - 31 March 1978

Project Title: Seasonal distribution and relative abundance of marine mammals in the Gulf of Alaska

I. Abstract

A total of 132 vessel cruises covering 13,374 individual sighting and/or transit records have been coded and checked since the beginning of FY 1978, including 95 cruises checked and edited during this quarter. Data from a total of 152 vessel cruise logbooks will be used for the RU68 final report. Finalization of the World Data Bank mapping and plotting routine (Sonntag, 1978) and Quality Control Program (QCP-1) data documentation manual (Mercer, Krogman and Sonntag, 1978) has been made. The procedures described in these documents insure that any data compiled using our in-house format will have the greatest chance of being error free, and will be presented by means of a detailed plotting on a Mercator projection.

II. Objectives

The objective of research unit 68 is to summarize all available information on the distribution and relative abundance of marine mammals in the Gulf of Alaska. Marine mammal sightings reported from the Platforms of Opportunity Program, the Marine Mammal Division's pelagic fur seal research program and the OCSEAP Marine Operations and Station Abstracts form our data base. More emphasis is placed on the collection of pelagic than on-shore sighting data because sources of information are primarily observers onboard government and private vessels at sea.

The summarization and analysis of these data will be used as the basis for evaluating the implications of outer continental shelf oil and gas exploration and development with regard to marine mammals and their ecological interaction.

III. Field or Laboratory Activities

A. Ship or field trip schedule. None.

B. Scientific party.

Name	Affiliation	Role
Howard W. Braham	Marine Mammal Div. (MMD)	PI - data analysis and review
Roger W. Mercer	NOAA Corps - MMD	Co-PI - data preparation and analysis

Patrick D. McGuire	MMD	data logging & checking
Ronald M. Sonntag	MMD	programming & data preparation

C. Methods.

Most data are collected by non-Marine Mammal Division scientists participating in the Platforms of Opportunity Program. As such, the variation in data quality is great. In order to reduce the possibility that less than adequate or reliable data enter the data bank, each logbook is carefully scrutinized for logic conformity and accuracy (that is, the information must make scientific sense). Acceptable data are then coded for computer checking, verification, processing and, ultimately, archival for EDS submission. Two manual and two computer checks assure that the highest quality of precision exists.

D. Sample collection localities.

Marine mammal sighting data were collected from southeast Alaska to the eastern Aleutian Islands and the southern Bering Sea north to Nunivak Island.

E. Data collected and/or analyzed.

1. See Table 1.

2. Twelve one-month computer plots were made of Dall porpoise sightings and used (a) to evaluate the effectiveness of the plotting routine and (b) as a model for detailed analysis of all sighting records.

IV. Results

Preliminary results are available on Dall porpoises and gray whales. These two species are being used as models to review the RU 68 data base before any comprehensive analysis takes place.

A. Dall porpoise (Phocoenoides dalli).

1. The frequency of occurrence of Dall porpoises in the Gulf of Alaska appears to be strongly influenced by water temperature (Figure 1).

2. More Dall porpoise sightings occurred per unit effort during the spring and fall months than during the summer in the Gulf of Alaska (Figure 2) and western Gulf (Figure 3).

Table 1. Listing of vessel cruises 1974-77 from which Platforms of Opportunity marine mammal sighting data were obtained for the Gulf of Alaska and related areas of interest.

Record ID	Begin. Date	End. Date	Year	Data Source	Area
174077	Mar. 18	Nov. 9	74	NOAA *MacArthur*	Puget Sound, GOA
174080	Mar. 21	Oct. 31	74	NOAA *Rainier*	GOA
174081	Mar. 22	Aug. 29	74	NOAA *Fairweather*	GOA
174087	Mar. 28	Oct. 31	74	NOAA *Davidson*	PWS
174096	Apr. 6	Jul. 14	74	NOAA *Oregon*	Bering Sea
174102	Apr. 12	Oct. 20	74	USFWS	SE AK
174119	Apr. 29	Aug. 28	74		Pacific, GOA
174180	Jun. 29	Jul. 4	74	AK Trollers	SE AK
174140	May 20	Jun --	74		GOA
174147	May 27	Aug. 16	74	*Tordenskjold*	GOA
174166	Jun. 15	Aug. 24	74	USFS *Matanuska*	SE AK
174179	Jun. 28	Jun. 28	74	USFS *Taku*	SE AK
174209	Jul. 28	Aug. 11	74	USFS *Columbia*	SE AK
174222	Aug. 10	Aug. 27	74	*Resolution*	GOA
174223	Aug. 11	Aug. 14	74	USCG *Midgett*	GOA
174239	Aug. 27	Oct. 20	74	*Resolution*	GOA
174254	Sep. 11	Nov. 7	74	NOAA *Fairweather*	So. California
174255	Sep. 12	Sep. 19	74	*Montague*	GOA, PWS
174279	Oct. 6	Oct. 6	74	USCG *Boutwell*	Bering Sea, GOA
175003	Jan. 3	Dec. 31	75	Foreign Vessel Prgm. - NWAFC	GOA, Bering Sea
175019	Jan. 19	Dec. 9	75	USCG *Modoc*	Bering Sea, GOA
175027	Jan. 27	Oct. 4	75		GOA, West coast
175026	Jan. 28	Mar. 6	75	NOAA *Oceanographer*	GOA
175057	Feb. 26	Apr. 15	75	NOAA *Fairweather*	West coast
175064	Mar. 5	Aug. 15	75	NOAA *MacArthur*	GOA
175070	Mar. 11	Aug. 19	75	USCG *Mellon*	Bering Sea
175087	Mar. 28	Sep. 15	75	USCG *Boutwell*	GOA
175093	Apr. 3	Jul. 13	75	NOAA *Oregon*	GOA, Bering Sea
175112	Apr. 22	Aug. 27	75	NOAA *Rainier*	GOA
175118	Apr. 28	Jun. 11	75	NOAA *Townsend Cromwell*	GOA
175125	May 5	Aug. 21	75	NOAA *Fairweather*	GOA, SE AK
174133	May 13	Jun. 27	74	USCG *Confidence*	Bering Sea
175126	May 6	Oct. 22	75	NOAA *Davidson*	PWS, SE AK
175127	May 7	Nov. 19	75	USFWS	SE AK
175129	May 9	Sep. 20	75	USCG *Midgett*	W. coast, Bering
275129	May 9	Jun. 23	75	NOAA *Discoverer* - MMD	GOA
175137	May 17	Sep. 23	75	USCG *Storis*	GOA, Bering Sea
175142	May 22	Sep. 11	75	*Discovery*	Canada, SE AK
175151	May 31	Aug. 11	75	*Tordenskjold*	Bering, GOA
175153	Jun. 2	Aug. 4	75	USCG *Rush*	Bering Sea
175185	Jun. 12	Aug. 30	75	USFS *El Bartlett*	PWS
175211	Jul. 30	Aug. 8	75	ADF&G *Mr. Divoky*	Bering, Chukchi
175217	Aug. 5	Dec. 6	75	NOAA *Discoverer*	GOA, Bering Sea

Table 1. Cont.

Record ID	Begin. Date	End. Date	Year	Data Source	Area
175254	Sep. 11	Nov. 25	75	NOAA MacArthur	Puget Sound
175272	Sep. 29	Nov. 12	75	USCG Jarvis	GOA, Bering Sea
176005	Jan. 5	Jan. 31	76	Foreign Vessel Prgm. - NWAFC	Bering Sea
176007	Jan. 7	Feb. 21	76	USCG Storis	Bering Sea
176021	Jan. 21	Nov. 9	76	USCG Mellon	GOA
176024	Jan. 24	Nov. 16	76	NOAA Freeman	GOA
176045	Feb. 14	Nov. 28	76	USCG Rush	Bering Sea
276045	Feb. 14	Jun. 18	76	Foreign Vessel Prgm. - NWAFC	Bering Sea, GOA
176049	Feb. 18	Nov. 3	76	NOAA Davidson	N. GOA
276050	Feb. 19	Oct. 27	76	NOAA MacArthur	Lower Cook Inlet,GOA
376050	Feb. 19	Sep. 21	76	NOAA Rainier	W. Coast, GOA
176056	Feb. 25	May 24	76	NOAA Discoverer	GOA
276056	May 25	Jul. 31	76	NOAA Surveyor	GOA
176060	Feb. 29	Sep. 16	76	USCG Midgett	Bering Sea, GOA
176069	Mar. 9	Mar. 13	76	NOAA Surveyor - MMD	GOA
176072	Mar. 12	Mar. 12	76	USCG Jarvis	Aleutians
176075	Mar. 15	Apr. 2	76	NOAA Surveyor - MMD	GOA, Bering Sea
176076	Mar. 16	May 30	76	NOAA Freeman	Bering Sea
176087	Mar. 27	Jul. 19	76	Pribilof	Bering Sea
176090	Mar. 30	Dec. 29	76		W. coast, GOA
176094	Apr. 3	Nov. 18	76	NOAA Oregon	Bering Sea
176097	Apr. 6	Oct. 28	76	Discovery	Puget Sound, SE AK
176098	Apr. 7	Apr. 30	76	NOAA Discoverer - MMD	GOA
176103	Apr. 12	Jun. 24	76	USCG Confidence	Bering Sea
276103	Apr. 12	Apr. 22	76	Resolution	
176104	Apr. 13	Apr. 23	76	NOAA Surveyor - MMD	Bering Sea
176119	Apr. 28	Aug. 7	76	Ole B Troller	SE AK
176120	Apr. 29	Jun. 22	76	USCG Polar Star	GOA, Bering Sea
176133	May 12	Dec. 13	76	NOAA Surveyor	GOA, Bering Sea
175142	May 21	Sep. 21	76	Tordenskjold	GOA
176145	May 24	Sep. 22	76	USCG Resolute	GOA
176149	May 28	Aug. 21	76	Maranatha Troller	SE AK
176154	Jun. 2	Sep. 7	76	USFS Unid. Ferries	SE AK
176160	Jun. 3	Jun. 22	76	NOAA Freeman - MMD	GOA, Bering Sea
176158	Jun. 6	Jun. 25	76	NOAA Surveyor - MMD	GOA, Bering Sea
176164	Jun. 12	Jun. 19	76	Anna Marie	Bering Sea
176178	Jun. 26	Aug. 25	76	Susetta	SE AK
176189	Jul. 7	Jul. 7	76		SE AK
176198	Jul. 16	Jul. 19	76	NOAA Discoverer - MMD	GOA
176217	Aug. 4	Aug. 27	76	Moana Wave - MMD	W. GOA, Bering Sea
276217	May 26	Oct. 24	76	NOAA Surveyor	GOA
176229	Aug. 16	Aug. 27	76	USCG Burton Island	Chukchi, Beaufort
176232	Aug. 19	Sep. 23	76	NOAA Discoverer - MMD	Bering, Chukchi

Table 1. Cont.

Record ID	Begin. Date	End. Date	Year	Data Source	Area
176251	Sep. 7	Sep. 16	76	NOAA Surveyor - MMD	GOA
176256	Sep. 12	Oct. 3	76	Mr. Wahl, Unid. Charters	W. coast
176292	Oct. 18	Oct. 28	76	NOAA Surveyor - MMD	GOA, Bering Sea
177047	Feb. 2	May 24	77	NOAA Freeman	GOA
277047	Feb. 16	Mar. 25	77	NOAA Freeman - MMD	GOA, Bering Sea
177049	Feb. 18	Mar. 8	77	NOAA Discoverer - MMD	Bering Sea
177117	Apr. 27	Jun. 16	77	NOAA Surveyor	GOA
177173	Jun. 22	Jul. 13	77	NOAA Surveyor	GOA, California
177199	Jul. 18	Oct. 14	77	NOAA Surveyor	GOA

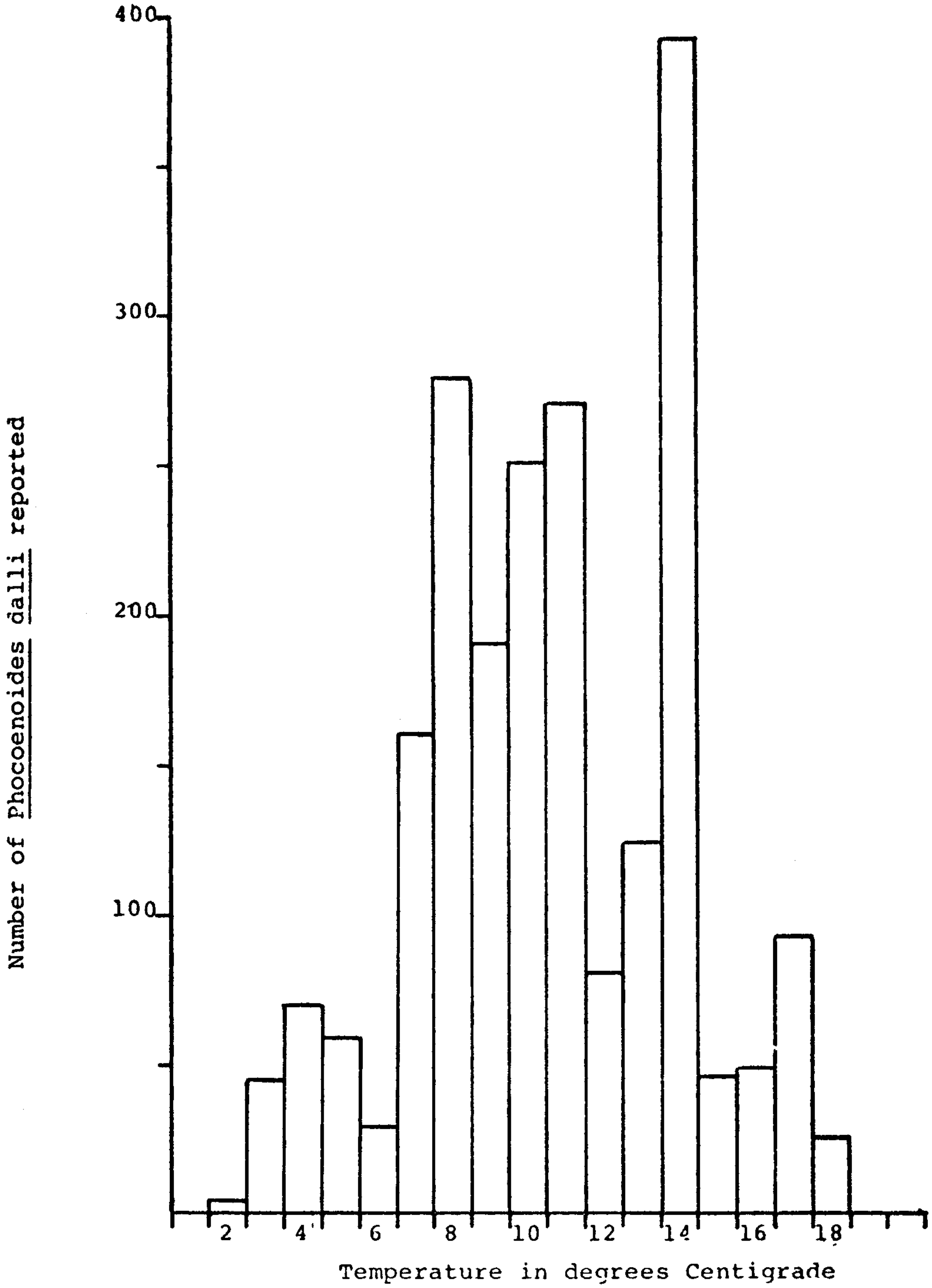

Figure 1. Number of Dall porpoise (Phocoenoides dalli) vs surface temperature in degrees centigrade; taken from Platforms of Opportunity data from the eastern north Pacific Ocean between 1971 and 1977.

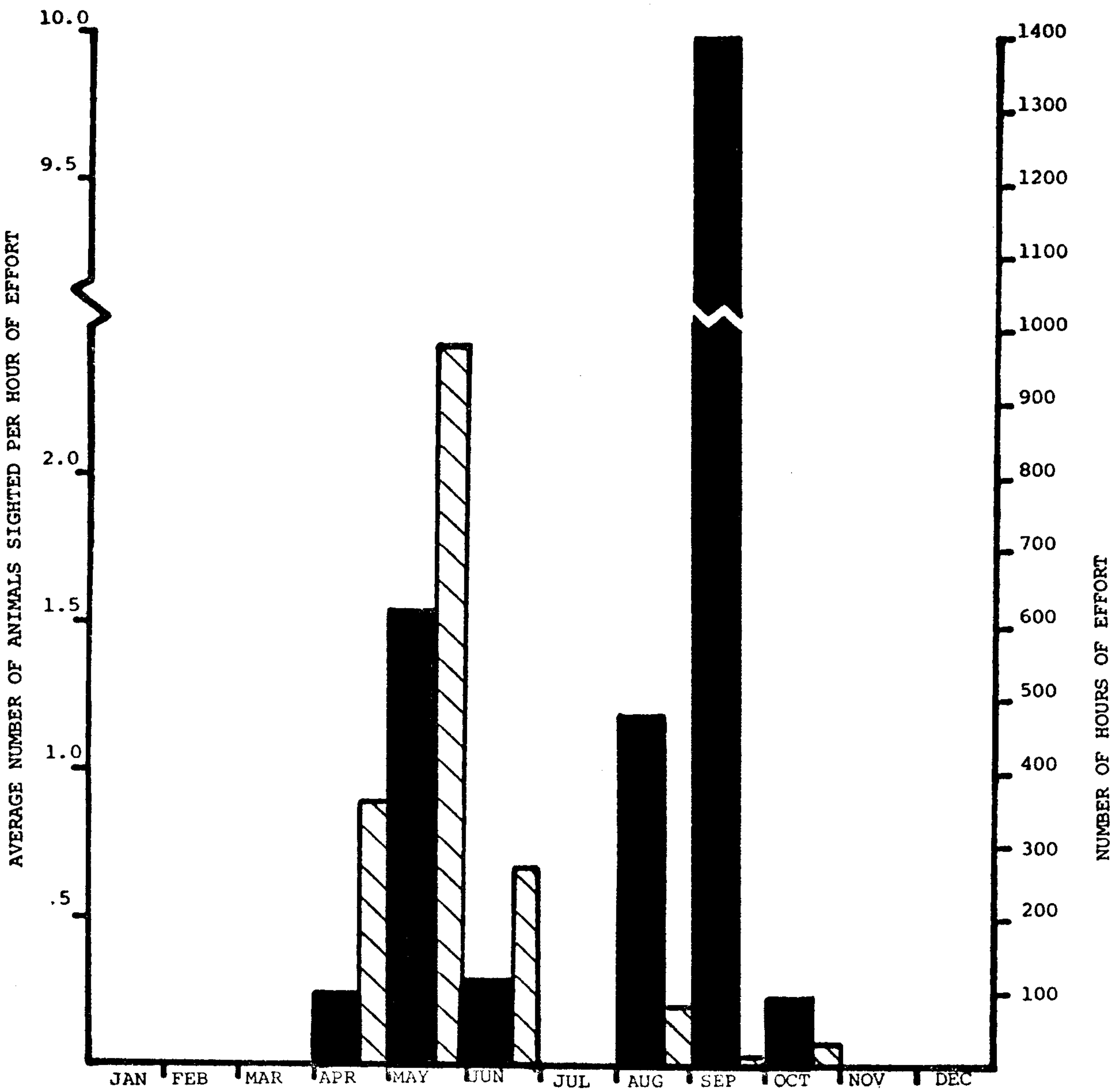

Figure 2. Average number of Dall porpoises sighted per hour or watch (darkened) and hours of effort (cross-hatched) per month. Data collected by National Marine Fisheries Service pelagic sealing crews from 1958-1974 in the Gulf of Alaska area.

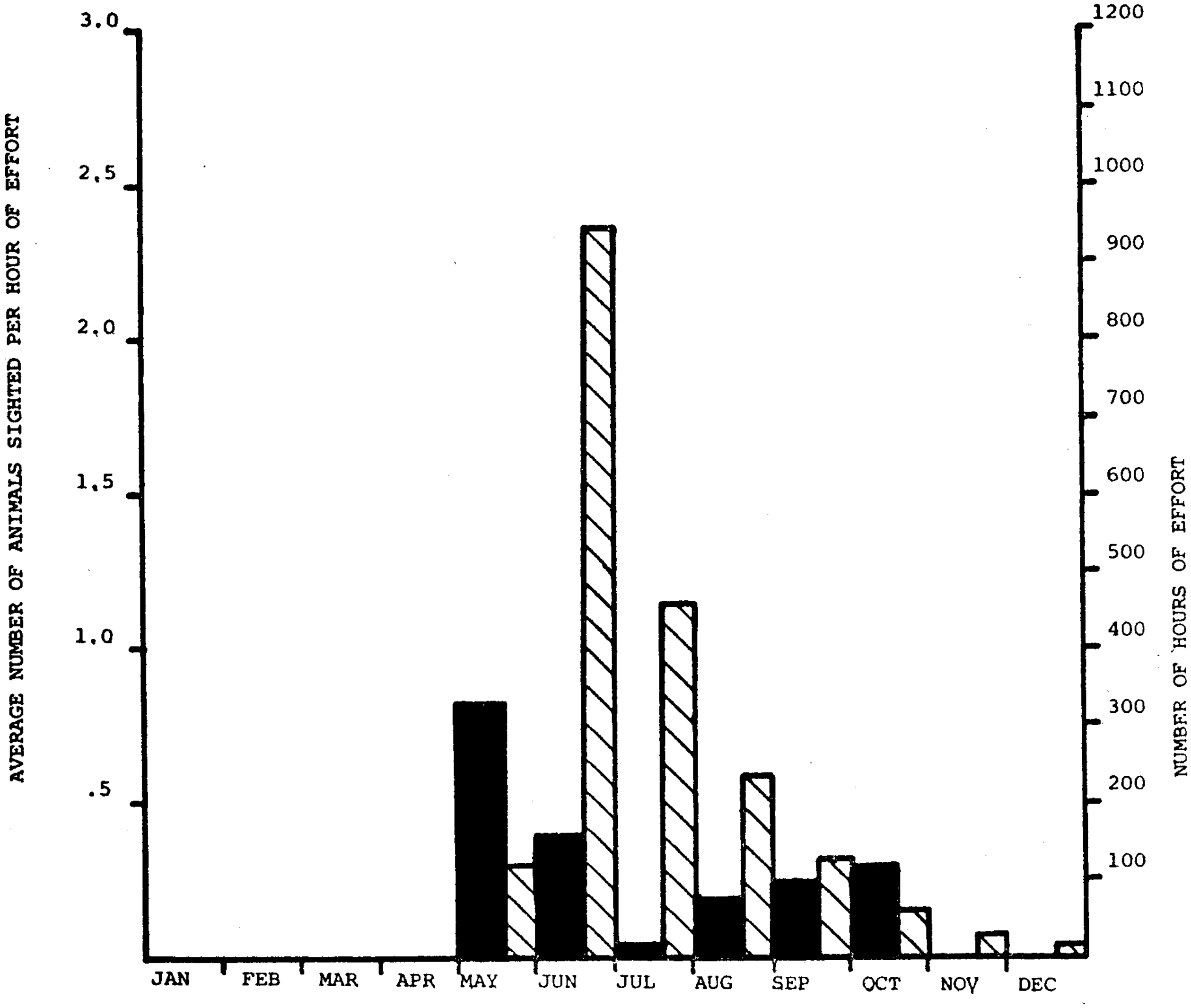

Figure 3. Average number of Dall porpoises sighted per hour of watch (blackened) and hours of effort (cross-hatched) per month. Data collected by National Marine Fisheries Service pelagic sealing crews from 1958-1974 in the Western Gulf of Alaska area.

3. No clear pattern of seasonal movement is evident as yet for animals which migrate from one area of the Gulf to another.

B. California gray whale (<u>Eschrichtius robustus</u>).

1. Gray whales enter the Gulf of Alaska in the spring by mid-March, and perhaps earlier. Early migrants may have wintered along the coast of the Pacific Northwest.

2. The spring migration route into the Gulf of Alaska appears to be coastal. Animals characteristically swim very near shore, many being observed in the surf zone. Preliminary evidence indicates that the availability of food is closely associated with the tendency to stay close to the coastline.

3. In the western Gulf of Alaska gray whales tend to migrate seaward to Kodiak Island, yet remain close to shore.

4. Entrance into the Bering Sea occurs at Unimak Pass coastally along Unimak Island, perhaps by early April. Migration in the Bering Sea is predominantly along the north coast of the Alaska Peninsula into Bristol Bay; however, some animals move northward into the open ocean.

5. The southward fall migration occurs within a 3-5 week period in late November and early December through Unimak Pass and again along the south side of Kodiak Island. After Kodiak Island, the migration route is believed to be offshore across the Gulf of Alaska to southeast Alaska or British Columbia and Washington state.

V. <u>Preliminary Interpretation of Results</u>

A. Dall porpoises migrate across the Kodiak and Northeast GOA oil lease sites, apparently in greatest numbers in the spring (especially May). Preliminary plots indicate that Prince William Sound is an important summering area, however the Kodiak Island oil lease area also appears to be of as yet undetermined importance during the summer. The location of greatest concentration from June through August is Unimak Pass and along the continental edge in the southern Bering Sea. Whether these animals are migrants from the GOA or the western North Pacific Ocean is unknown.

B. California gray whales twice migrate through six oil lease tracts in Alaska each year (NEGOA, Kodiak, St. George Basin, Outer Bristol Bay, Norton and Hope Basins). Preliminary evidence from studies conducted under RU67 indicate that up to 75% of the population moves by Unimak Pass, and perhaps Kodiak Island, during a three week period in the fall. Any adverse effects on gray whales resulting from oil-gas development would be accentuated during this period of animal concentration.

VI. <u>Auxiliary Material</u>

A. List of references.

Mercer, R. W., B. D. Krogman and R. M. Sonntag. 1978. Marine mammal data documentation for the Platforms of Opportunity Program and the Outer Continental Shelf Environmental Assessment Program. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 90 p.

Sonntag, R. M. 1978. A comprehensive World Data Bank computerized mapping and plotting routine. (Manuscr. in review for processed report.)

B. Papers in preparation or in print.

<u>Completed</u>:

Calkins, D. G., K. Pitcher, and K. Schneider. 1975. Distribution and abundance of marine mammals in the Gulf of Alaska. Processed report, Alaska Dep. Fish Game, Div. Game, Anchorage, AK. 39 p. (subcontract to Marine Mammal Division)

Fiscus, C. H., H. W. Braham, R. W. Mercer, R. D. Everitt, B. D. Krogman, P. D. McGuire, C. E. Peterson, R. M. Sonntag and D. E. Withrow. 1976. Seasonal distribution and relative abundance of marine mammals in the Gulf of Alaska. Processed report, U. S. Dep. Commer, NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 238 p.

Mercer, R. W., B. D. Krogman and R. M. Sonntag. Marine mammal data documentation for the Platforms of Opportunity Program and Alaskan Outer Continental Shelf Environmental Assessment Program. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 90 p.

Severinghaus, N. C., and M. K. Nerini. 1977. An annotated bibliography on marine mammals of Alaska. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Marine Mammal Division, Seattle, WA. 125 p.

<u>In preparation</u>:

Braham, H. W. California gray whale (<u>Eschrichtius robustus</u>) spring migration in Alaska. (Accepted by <u>Técnica Pesquera</u>; final draft due 1 May 1978. Also submitted under RU67.)

Braham, H. W., and R. W. Mercer. Cetacean distribution in the Gulf of Alaska: Yakutat Bay to Unimak Island. (Manuscr. in preparation; expected completion date August 1978.)

Braham, H. W., R. W. Mercer, P. D. McGuire, C. E. Peterson and R. M. Sonntag. Marine mammal distribution and relative abundance in the Gulf of Alaska and southern Bering Sea. (Planned final report for RU68; completion date September 1978.)

Mercer, R. W., H. W. Braham and M. Tillman. Distribution of Dall porpoise, Phocoenoides dalli, in Alaska. (In preparation; completion date September 1978.)

Rugh, D. J., and H. W. Braham. California gray whale (Eschrichtius robustus) fall migration through Unimak Pass, Alaska, 1977. (In review as processed report; to be submitted to the Journal of Mammalogy before 1 June 1978; also submitted under RU67.)

Severinghaus, N. C. Annotated bibliography on marine mammals of Alaska -- an update. (in preparation as a processed report)

Sonntag, R. M. A comprehensive World Data Bank computerized mapping and plotting routine. (Manuscr. in review for processed report.)

C. Oral presentations.

From 20-23 March 1978 Roger Mercer gave marine mammal identification briefings to Alaska Trollers Association members in Sitka, Juneau, Petersburg and Ketchikan.

D. Revised milestones. See attached chart.

VII. Problems and Recommended Changes

Data quality control and statistical programming and analysis have been delayed over the past months because of heavy computer usage and replacement of the software system at the University of Washington Computer Center. Also, a new CDC-6400 computer was recently installed replacing the previous less reliable one. This should greatly increase the efficiency of our data analysis.

R. U. #68

MAJOR MILESTONES	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Receipt of all data (raw)			▲ 100%												
Raw data logged and converted to in-house format				▲ 100%											
Keypunch abstract coded and checked				▲ 100%											
Keypunching completed and verified					▲ 100%										
Final quality check of data (computer check)					▲ 80%	▲ 100%									
Convert to 027 OCSEAP format (dependent upon program and manuscript)					▲ 90%		▲ 100%								
Submit to EDS (archival)					▲ 80%		▲ 100%								
Quarterly reports			▲			▲			▲						
Final report												▲			
Progress of all plots, charts, and tables to be submitted under contract				▲ 10%		▲ 30%		▲ 50%		▲ [illegible]					
Completion of data management document			▲ 50%	▲ 90%		▲ [illegible]									
Indicate the following for each narrative report/manuscript to be generated under R.U. 68 listed below:															
A/In preparation (indicate progress by showing % completion/month)															
B/Submit for agency (NMFS) review															
C/Final report in printing															
D/Submission to OCSEAP															
1. Spring migration of the California gray whale, *Eschrichtius robustus* in Alaska (Manuscript)					A	—	—	B	C	—	—	D			
2. Preliminary evaluation of Dall porpoise (*Phocoenoides dalli*) distribution in Alaska		A	—	—	—	—	—	—	—	B	C	D			
3. Cetacea distribution in the Gulf of Alaska and Southern Bering Sea							A	—	—	B	C	D			

Quarterly Report

Contract # R7120807
Research Unit # 69
1 January - 31 March 1978
8 pages

Seasonal Distribution and Abundance of Bowhead and Beluga Whales in the Bering Sea and Arctic Ocean

Principal Investigators

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April 1978

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I. Abstract

II. Objectives

III. Field or Laboratory Activities

IV. Results

V. Preliminary Interpretation

VI. Auxiliary Material

VII. Problems Encountered & Recommended Changes

Date Submitted 4/11/78

Reporter's Initials HWB

PI Quarterly Progress Report

Reporting Period 1 January - 31 March 1978

Project Title: Seasonal distribution and abundance of bowhead and beluga whales in the Bering Sea and Arctic Ocean.

I. Abstract

Field data were analyzed to identify bias in sampling techniques. Poor visibility conditions do not constitute a significant negative bias which must be adjusted. Data are too scant to conclude that lead width greatly influences rates of whale movements by Barrow during the spring sampling period. A computer format is partially presented as a medium for analysis and storage of whale survey data collected from fixed stations. The ice camp index is evaluated as a measure of total population abundance, and components of the bowhead population are categorized as related to the index.

II. Objectives

Objectives for the last quarter were: 1) finish the analysis of data collected during 1976 and 1977 to identify bias in sampling techniques; 2) complete the development of a computer format for storage and analysis of field data collected from a fixed shore (ice) station; and 3) evaluate the ice camp index as a measure of bowhead whale population abundance.

III. Field or Laboratory Activities

A. Ship or field trip schedule.

None

B. Scientific party.

Name	Affiliation	Role
Howard W. Braham	Marine Mammal Division	P.I.
Bruce D. Krogman	Marine Mammal Division	P.I.
Ronald M. Sonntag	Marine Mammal Division	Research Assistant & Computer Programmer
Richard G. Punsley	Marine Mammal Division	Research Assistant & Computer Programmer

C. Methods.

1. Identification of bias in sampling techniques.

A series of tables was prepared showing exact observer schedules, counts of bowhead whales per hour per day, individual bowhead sightings, sightings per hour according to visibility, and counts of bowheads per hour versus lead width. Statistical tests, Student's t, analysis of variance and contingency tests were used where applicable.

2. Development of a computer format for storage and analysis of field data collected from fixed shore (ice) stations.

Several workshops were held within the Marine Mammal Division to discuss and review all of the various methodologies employed for conducting whale counts from fixed points (e.g. California gray whale counts from cliffs, Cape Sarichef gray whale studies, Pt. Hope and Pt. Barrow ice camps and Cape Lisburne cliff station). Workshops were attended by Marine Mammal Division field biologists and computer programmers.

3. Evaluation of the ice camp index as a measure of bowhead whale population abundance.

An attempt was made to separate the bowhead whale population into descrete components and to relate these components to the ice camp index. A mathematical model is being developed to describe both the bowhead whale population and the ice camp index.

D. Sample collection localities.

N/A

E. Data collected and/or analyzed.

1. List number and types of samples or observations. N/A

2. List number and types of analyses.

Data were extracted as subsets and trends (in data) were analyzed using statistical techniques described in Methodology (C).

IV. Results

A. Identification of bias.

No significant differences were found in counts of bowhead whales per hour versus visibility, though a trend toward fewer sightings per hour may yet become apparent if sample sizes are increased.

Variable rates of migration and variable size of sample space are confounding efforts to determine whether or not migration of bowhead whales (at least on a local scale) is influenced by the opening and closure of leads in the flaw zone.

There appears to be a diurnal trend (though not yet mathematically described or statistically treated) in the number of bowheads sighted per hour versus hour of day.

B. Computer format for fixed station survey.

A multiple card format has been developed and a computer file logic has been determined. Basically, each file will constitute an entire season's survey conducted in or near some area of study. The file will consist of records, each record describing a "day's worth of work". Within each record are at present seven card types: 1) record ID card which summarizes contents of record; 2) position card, one for each change in geographic position and altitude of counting station; 3) observer card, one for each change in observer watch; 4) environmental card, one for each change in environmental conditions which may influence animals or the ability of observers to count them; 5) sighting card, for describing each sighting event; 6) theodolite card for mapping movements and dive profiles of whales as they move by counting stations; and 7) comment card.

C. Evaluation of ice camp index as a measure of bowhead whale population abundance.

The population of bowhead whales can be categorized as it relates to the ice camp index as:

$$T = \sum_{i=1}^{n} C_i$$

where: T = total population size
C_i = i^{th} component of the population
n = 5

Letting $C_1 = I$ = ice camp index, the number of bowheads passing by Pt. Barrow during the spring sampling period

then C_2 = number passing by Barrow before the spring sampling period
C_3 = number passing by Barrow after the spring sampling period
C_4 = number passing by Barrow but offshore, out of sight of the observers at the ice camp, and
C_5 = number of bowheads which never pass Barrow, perhaps remaining in the Chukchi Sea.

A preliminary model of how C_1 can be estimated by c_1 is:

$$c_1 = \sum_{i=1,2}^{n} t_i + \sum_{i=2,2}^{n} it + e_1 + e_2 + e_3 + e_4$$

where: n = the number of continuous periods of watch and non-watch

$\sum_{i=1,2}^{n}$ = the summation of all of the periods of watch, i.e. n_1, n_3, n_5, n_n

$\sum_{i=2,2}^{n}$ = the summation of all of the periods of non-watch, i.e. n_2, n_4, n_6, n_n

t_i = estimated total number of "seeable" bowheads which moved by the ice camp during the i^{th} period of watch

it_i = interpolated estimate of the number of bowhead whales which moved by the camp during the i^{th} period of non-watch

e_1 = error term describing whales which were tallied more than once (i.e. duplicate sightings)

e_2 = error term describing whales which were mistaken for duplicate sightings and were not tallied (i.e. separate whales, one mistakenly tallied as a re-sighting)

e_3 = error term describing "seeable" whales which went unobserved

e_4 = error term describing whales which were "unseeable" as they moved by the ice camp (e.g. whales swimming underwater by the camp)

The number of bowheads passing by Barrow near the ice camps during periods of watch can be calculated as:

$$\sum_{i=1,2}^{n} t_i = \sum_{i=1,2}^{n} h_i \times r_i = \sum_{i=1,2}^{n} h_i \times \sum_{i=1,2}^{n} {}^{\chi_i}/h_i$$

where: h_i = number of hours of the i^{th} period of watch

r_i = rate per hour of bowheads moving by Barrow

χ_i = the tally of bowheads during the i^{th} period of watch

The number of bowhead whales passing by Barrow near the ice camps during periods of non-watch can be calculated as:

$$\sum_{i=2,2}^{n} it = \sum_{i=2,2}^{n} \left[\frac{(h_{i-1} \times r_{i-1}) + (h_{i+1} \times r_{i+1})}{(h_{i-1} + h_{i+1})} \times h_i \right]$$

$$= \sum_{i=2,2}^{n} \left[\frac{(h_{i-1} \times {}^{X_{i-1}}/_{h_{i-1}}) + (h_{i+1} \times {}^{X_{i+1}}/_{h_{i+1}})}{(h_i-1 + h_i+1)} \times h_i \right]$$

Based upon field data collected so far under OCSEAP, it is difficult to estimate the error terms (e's) in the equation.

Little information exists which would allow any but the grossest of estimates of the size of remaining components of the population C_2 through C_5.

V. Preliminary Interpretation

A. Identification of bias.

The fact that observers see nearly as many whales during periods of poor visibility as during periods of better visibility suggests that only a small correction factor may be necessary for counts made during poor visibility. Visibility is probably not much of a problem for the Barrow ice camp because (1) leads seldom have large fetches for wave development; (2) the wind seldom blows very hard; and (3) bowhead whales are very easily seen even in rough water.

Braham and Krogman (1977) felt that the intermittent movement of whales past Barrow was in part a result of the opening and closing of the ice lead system, however not enough information is available to confirm this.

Trends in numbers of bowhead whales sighted per hour of day may represent more of a fatigue factor than a real biological phenomenon.

B. Development of a computer format.

The computer format shall continue to be developed as it is tested on raw field data. It is very likely that revisions will be necessary with its first use, and therefore the format is not presented in its entirety here.

C. Evaluation of ice camp index as a measure of bowhead whale population abundance.

Evaluation of the ice camp index as it relates to total population size makes it very clear that further research must be conducted to address the question of bias. The ice camp index must be thought of as a measure of only one component of the bowhead population, and a measurement which at this time has an undefined amount of error associated with it.

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, whales in the Bering, Chukchi and Beaufort Seas. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Seattle, WA. 29 p.

B. Papers in preparation or in print. Completed:

Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead, Balaena mysticetus, and beluga, Delphinapterus leucas, whales in the Bering, Chukchi and Beaufort Seas. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Seattle, WA. 29 p.

Krogman, B. D. 1977. Mating bowhead whales. Alaska 63(9): 52-53.

Krogman, B. D., and R. D. Everitt. Bowhead whale (Balaena mysticetus) copulatory behavior observed off north coast of Alaska. (in review to the Journal of Mammalogy)

Mercer, R. W., B. D. Krogman, R. M. Sonntag. 1978. Marine mammal data documentation for the Platforms of Opportunity Project and Outer Continental Shelf Environmental Assessment Program. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Seattle, WA. 90 p.

Severinghaus, N. C., and M. K. Nerini. 1977. An annotated bibliography on Marine Mammals of Alaska. Processed report, U. S. Dep. Commer., NOAA, NMFS, NWAFC, Seattle, WA. 125 p.

In preparation:

Braham, H. W., B. D. Krogman, and G. M. Carroll. Population biology of the bowhead whale (Balaena mysticetus) and beluga whale (Delphinapterus leucas) in Alaska I: distribution and abundance. (planned final report for RU69; completion date September 1978)

Sonntag, R. M. A comprehensive World Data Bank computerized mapping and plotting routine. (manuscript in final edit stage)

C. Oral presentations.

27 March. Braham addressed the Northwest and Alaska Fisheries Center, Seattle, Washington, on Marine Mammal Division-OCSEAP research in Alaska.

D. Updated milestone chart.

See attached.

VII. Problems Encountered and Recommended Changes

None.

MAJOR MILESTONES RU # 69

	1977			1978											
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Population biology of the bowhead (Balaena mysticetus) and beluga (Delphinapterus leucas) whales in the Bering, Chukchi and Beaufort Seas.				A	—	—	—	—	—	B	C	D			

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1/ Develop 026 ice station format. I am developing a computer format for coding field data collected while making counts of whales moving by fixed points on land or shorefast ice. Since "026" applies to the aerial survey format, I suggest a new number be designated. In my opinion, RU 69 survey information cannot be translated into either 026 or 027 (shipboard) formats.

2/ Convert to OCS format. Requires one computer run, and will be done all at once as part of 3/.

3/ Submit to EDS (archival).

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MORBIDITY AND MORTALITY OF MARINE MAMMALS

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I. SUMMARY

This study is designed to identify the common pathological conditions and their causes in marine mammals of the Bering Sea and Gulf of Alaska - Cook Inlet region. Because they are highly visible and are the main top level consumers in the marine system, marine mammals may provide the best, most easily assessed index of the "health" of the marine system as a whole. Present knowledge of the morbidity/mortality factors affecting species inhabiting the Alaskan shelf waters is summarized. Predation and parasitism seem to be the principal causes of natural illness and death, followed closely by malnutrition. Our investigations in the past year have centered on necropsy of samples drawn from the living populations in the eastern Bering Sea and Gulf of Alaska. The main sources have been specimens collected by projects R.U. #229, 230, 232, and 243. In the 96 collected specimens examined, the most frequently occurring gross pathological conditions were (1) hepatitis, probably of helminthic origin, (2) pneumonitis, also principally caused by helminths, (3) dermatitis, of fungal, bacterial, and possibly viral origin, (4) wounds, from various causes, and (5) gastric ulcers caused by parasitic invasions. Serological analyses indicated frequent exposure of Steller sea lions to leptospirosis and sea lion vesicular disease. Parasites and microbiological infections seem often to be sufficiently debilitating to predispose these animals to predation, which may account in part for the apparent predominance of predation as a cause of mortality. The drift of carcasses from known sources in the northern Bering Sea - Bering Strait region suggests that the rate of drift is very slow (about 5 km/day) and that the larger carcasses may drift for up to two months and for distances of at least 300 km.

II. INTRODUCTION

General Nature and Scope of Study

The Alaskan continental shelf supports some of the largest, most productive marine mammal populations in the world. Several of these populations are the mainstay of the economy for coastal residents of western and northern Alaska and of the northeastern part of the Soviet Union. Others are shared with Canada and Japan. The goal of this study is to determine the normal, pre-OCS-petroleum-development pattern of illness and death from natural causes in those populations. Emphasis is placed on identification of debilitating and mortality factors whose effects might be enhanced synergistically by the stresses brought to bear in connection with exploration and development of offshore petroleum resources.

Specific Objectives

1. To identify and determine the causes and rates of occurrence of pathological conditions in samples drawn from the living populations of marine mammals of the Alaskan continental shelf.
2. To determine the normal spatial distribution and numbers of dead and moribund marine mammals by species, sex, and age on the Alaskan coast and to determine the causes of their death or moribund condition.
3. To identify and describe the drift patterns of dead marine mammals from known sources.

Relevance to Problems of Petroleum Development

Since marine mammals are the top level consumers in the marine ecosystem, wholly dependent on the productivity of all trophic levels below them, their health is one of the best, most visible indicators of the "health" of the system itself (e.g. see Koeman *et al.*, 1973; Stirling *et al.*, 1977). Because they tend to be long-lived and to have special abilities to store environmental contaminants in certain organs and tissues, they can provide a cumulative record of past environmental conditions. Their responses to short-term changes also are readily detectable from their physical condition and reproductive success. Since the frequency of occurrence and effects of pathogens are likely to be enhanced in animals stressed by other factors, monitoring the relative health of these animals can provide nice indications of the functional state of the system that they live in.

III. CURRENT STATE OF KNOWLEDGE

An annotated bibliography containing 252 titles of papers relative to the pathology and mortality of species of marine mammals known to occur in Alaskan waters was presented in the 31 December 1976 quarterly report of this project. The following brief résumé is based on those materials, plus others encountered in the meantime, and on the results of this project in the Bering Sea and Gulf of Alaska up to 31 March 1978. Since most of the information applies to individual species, genera, or families of marine mammals, it is most appropriate to present it in that manner.

Carnivora

The sea otter and eight species of pinnipeds are abundant in the waters of the Alaskan continental shelf, their numbers being at or near the maximum that their environment can sustain. With two exceptions (sea otter and fur seal), their kinds and causes of natural illness and death in Alaska had not been studied in any depth before this project was begun.

Enhydra lutris, Sea Otter - Mortality in sea otters was studied by Barabash-Nikiforov (1947), Rausch (1953), and Estes and Smith (1973) and most extensively by Kenyon (1969). About 70% of the deaths were in immature animals; the remainder were in adults, mainly of old age. Most deaths were due to malnutrition, the primary causes of which seemed to be a combination of dental problems and severe winter storms. Other causes were trauma (mainly due to falling rocks), parasitism (mainly due to stomach nematodes, causing ulcers), infectious diseases, and predation (by eagles, killer whales), in that order. In southern Bristol Bay, a considerable mortality occurs in some years as a result of severe ice conditions that prevent the animals from having access to their food (Schneider and Faro, 1975). Contamination of the fur by oil and other foreign matter is swiftly lethal, since it results in impairment of thermal insulation and loss of positive buoyancy (Kenyon, 1969; D. Siniff, unpublished).

Callorhinus ursinus, Northern Fur Seal - Natural mortality of northern fur seals has been studied principally by Keyes (1965) and co-workers on the Pribilof Islands. The main primary causes of death in pups, which have a mortality rate of from 5 to 20% in the first 5 months of life, were (1) malnutrition, as a result of prolonged separation of mother and pup and/or insufficient milk production by the mother, (2) trauma, mainly from bites inflicted by the adults, (3) parasitism, principally by the hookworm *Uncinaria lucasi*, and (4) infectious diseases. An equally substantial or even greater mortality of the young seals in their first winter at sea may be due in largest measure to their lack of experience and lack of energy reserves

(Miller, 1977). With little insulation other than their fur, and with the extremely high metabolic demands for muscular energy and thermoregulation, these young seals seem to be especially vulnerable to starvation and disease at that time. As in the sea otters, contamination of their insulating fur coat by foreign material such as oil is almost certain to be lethal in a very short time after exposure (Miller, 1977; G. L. Kooyman, unpublished). The mortality of adults appears to be due mainly to predation, parasitism, infectious diseases and, perhaps, ingested toxins (Keyes, 1965). In males, the adult mortality rate is more than three times that in females, probably due to injuries sustained in competition for breeding territories (Johnson, 1968). Infectious diseases, especially leptospirosis and sea lion vesicular disease (SMSV), may be of greater importance than was recognized previously (Smith *et al.*, 1975, 1977). In recent years, entanglement in flotsam (nets, lines, plastic strapping) has increased dramatically and may be having a significant negative impact on the population (G. Y. Harry, pers. comm.).

Eumetopias jubatus, Steller Sea Lion - Annual mortality of pups on the rookeries appears to be very high (Pike, 1961; Thorsteinson and Lensink, 1962), about as in the fur seals, and seems to be due mainly to trauma (from being bitten or crushed by adults), storms (leading to injury or malnutrition), and predation. In adults, impaired ventilation, caused by lungworms (Dougherty and Herman, 1947), and gastric ulcers, caused by nematodes in the stomach (Liu and Edward, 1971), may be important debilitating or even lethal factors. The role of infectious diseases is uncertain; both leptospirosis and sea lion vesicular disease occur commonly (see "Results") and may be linked with a high rate of fetal mortality. Injuries from falls and entanglement in flotsam also may cause some mortality in adults (K. Pitcher, pers. comm.).

Odobenus rosmarus, Walrus - The walruses have not yet been studied in sufficient detail for evaluation of the major causes of natural mortality. Predation by killer whales (*Orcinus orca*) and polar bears (*Ursus maritimus*) has been most often reported (Zenkovich, 1938; Brooks, 1954; Popov, 1958, 1960; G. C. Ray, unpublished), but it is unlikely that this is the most important. Trauma, of unknown etiology, causing mutilation, bone fractures, and internal hemorrhage, was emphasized by Hanna (1920, 1923) and Schiller (1954). Our only substantial findings thus far in this study have been of one case of vertebral fracture (neck), one of umbilical hernia, and one of acute pneumonitis probably resulting from inhalation of purulent material from a dental abcess. Various debilitating conditions, such as dermatomycosis, wounds, fibropapillomas, cystic ovaries, uterine tumors, biliary fibrosis, and renal calculi have been detected in samples from the living population, but their frequency of occurrence and contribution to mortality are not yet adequately known.

Erignathus barbatus, Bearded Seal - The causes of natural mortality in bearded seals, other than predation by polar bears, are largely unknown. In samples from the living population of the Bering Sea, helminthiasis of the liver, with secondary bacterial invasion, has been the only major pathological finding in this study, occurring in 5 out of 96 specimens examined. Various other conditions, such as acute dermatomycosis, focal necrosis of the liver, and trauma of unknown etiology have been found occasionally, but their importance as contributors to mortality is uncertain. Our findings of one stillborn pup and one newborn with injuries resulting in death from internal hemorrhage, plus two seals that had been killed by polar bears (Eley, 1976; L. Bishop, unpublished), are the only records known to us of natural mortality in this species.

Phoca largha, Spotted or Larga Seal - We have records of only two specimens known to have died from natural causes, each of which (1 adult, 1 pup) had suffered injuries leading to death from internal hemorrhage. In 119 specimens drawn from the living populations, four had lesions in the lungs resulting from helminthic invasion, and three had gastric ulcers also caused by helminths; one had ulcerative skin lesions (bacterial?); one had a dental abcess; two showed splenomegaly of unknown cause; two showed lymphadenitis; and two pups showed signs of malnutrition. In 26 of these that were examined critically for evidence of liver disease, 24 showed focal necrosis, probably due to invasion by larval helminths. Popov (1975) found massive infestations of the gut by acanthocephalans to result in a significant amount of necrosis of the intestinal wall.

Phoca vitulina, Harbor Seal - Since the harbor seal occurs in the Temperate Zone in both the North Atlantic and North Pacific Oceans and resides inshore, where it is highly visible, many cases of dead and moribund individuals have been reported. At least 15 different causes of morbidity and death have been diagnosed, most of them attributable to invasion by parasites or microbiological agents of disease (e.g. Ball, 1930; Blessing and Eickhoff, 1967; Blessing and Rummeld, 1969; Hsu *et al.*, 1974; Jacobsen, 1966; Van Pelt and Dieterich, 1973; Wilson *et al.*, 1972), starvation (Bigg and Tarasoff, 1969; Fisher, 1952; Reineck, 1962), or predation (Scheffer and Slipp, 1944). In the western North Atlantic, pre-weaning mortality of pups appears to be high (about 17%, according to Boulva, 1975), mainly due to premature abandonment and subsequent starvation or thiamine deficiency (Geraci, 1970); the same high rate seems to occur also in the Alaskan area (B. Johnson, unpublished). In our samples from the living populations in Alaskan waters, beginning in FY78, we have found dental disease, focal necrosis of the liver, and severe nasal infestations by parasitic mites the most common pathological conditions, followed closely by dermatomycosis and parasite-induced gastric ulcers.

Phoca hispida, Ringed Seal - Ringed seals are known to be preyed on intensively by polar bears and by arctic foxes (*Alopex lagopus*) throughout their circumpolar range (e.g. see Stirling, 1974; Smith, 1976; Eley, 1976); but there is very little other information on their causes of natural morbidity or mortality. In the Bering Sea, we have found only two dead or moribund animals, both of them pups, one of which was suffering simply from malnutrition; the other showed acute dermatomycosis with secondary systemic streptococcal infection. In a sample of 45 specimens from the living population, the only significant pathological findings were one with consolidative pneumonia, one with acute fungal dermatitis, and three with focal necrosis of the liver.

Phoca fasciata, Ribbon Seal - The major causes of mortality in the ribbon seal, according to Shustov (1969), are (1) predation by sharks and killer whales, (2) predation on the newborn young by gulls and eagles, (3) dermatitis, and (4) gastric ulcers caused by anasakid nematodes. Our findings in 56 specimens drawn from the living population of the Bering Sea lend support to this. We had three cases of severe injuries, at least one of which was certainly due to shark bite, and two cases of acute mycotic infection of the skin.

Other conditions of uncertain importance were two cases of bacterial dermatitis and ten of focal necrosis of the liver.

Cetacea: Mysticeti

At least eight species of baleen whales are known to occur in waters on and adjacent to the Alaskan continental shelf, some of them in large numbers. Most of the available information on pathology of these large whales is from examination of specimens of the same or related species taken in commercial whaling operations in the Antarctic region. Since the findings from these may not apply in the Alaskan area, only the materials from North Pacific populations are summarized here.

Balaena mysticetus and *B. glacialis*, Bowhead and Right Whales - Apart from Tomilin's (1957) mention of (a) exostoses of unknown cause on the vertebrae of two bowheads, (b) ectoparasitic and endoparasitic infestations, and (c) presumed predation by killer whales, the kinds and causes of pathological conditions in these two species are unknown.

Balaenoptera spp., Blue, Fin, Sei, and Minke Whales - In recent years, a number of balaenopterid whales taken in both the North Pacific and the Antarctic have been found to have a heretofore unknown pathological loss of baleen plates and "replacement" of these by irregularly formed growths (Rice, 1961, 1963; Tomilin and Smyshlyaev, 1968). The causative agent is unknown. Other than lists of ecto- and endo-parasites, no other pathological agents or conditions of this group of whales has been reported from the North Pacific region. During 1953 to 1973, Fay (unpublished) examined four beached carcasses of minke whales (*B. acutorostrata*), two of which at St. Lawrence Island, Bering Sea, had been killed by killer whales, and two in Turnagain Arm, Cook Inlet, had become stranded by receding tides, evidently while pursuing schools of fishes. Six other records of minke whales were reported to Fay in the same period by reliable observers. Two of these whales had stranded when pursued by killer whales, one other had been killed by that predator, and the cause of death of the other three was unknown. In the same period, confirmed records of one blue whale (*B. musculus*), and three fin whales (*B. physalus*) were received; one of the latter had been killed by killer whales, but the cause of death of the others was not determined. In the course of the present project, we have found five beached carcasses of minke whales and the remains of one fin whale. However, we were not able to diagnose the cause of death in any of these, due to their degenerate condition when found.

Megaptera novaeangliae, Humpback Whale - Though this is a widely distributed whale in Alaskan waters, there seems to be no information on its pathological conditions, other than occurrence of endo- and ectoparasites (See review by Deliamure, 1955).

Eschrichtius robustus, Gray Whale - The gray whale is more heavily infested with ectoparastic cyamid lice and commensal barnacles than any other species, but neither of these seems to have any major pathological effect other than, possibly, local irritation and some reduction of hydrodynamic efficiency (Tomilin, 1957). Predation by killer whales appears to be a mortality factor of major proportions in this species, much more so than in any of the other baleen whales (Andrews, 1914). Of 39 beached carcasses of gray whales that were found on St. Lawrence Island and in Bering Strait by personnel of this project from 1953 to 1976, at least 16 (41%) had been killed by that predator; the cause of death of the others was not determined. One found in the Kodiak area in 1977 also had been killed by killer whales. Rice and Wolman (1971) found certainly identifiable scars from killer whale teeth on 18% of 317 gray whales drawn from the living population, but much less evidence of debilitating disease and parasitism. However, it is conceivable that disease is a common factor, predisposing the animals to predation. In the 35 animals examined by Andrews (1914), one showed massive necrosis of the flesh on one side of the head, one had a large tumor on the ventral side of the caudal peduncle, and in one other, the skin on the snout "was drawn into small circular patches, leaving large sections of the blubber exposed." Rice and Wolman (1971) found evidence of acute inflammation and damage to the liver associated with parasitism in one of their specimens. Evidence of natural exposure of gray whales to vesicular disease of sea lions (SMSV) was detected serologically by Akers *et al.* (1974).

Cetacea: Odontoceti

Much of the information on pathology in species of toothed whales, dolphins, and porpoises found in the North Pacific region has been derived from animals held in captivity for some period of time. The applicability of this information to natural populations is open to some question, since it has seldom been possible to ascertain with certainty whether the conditions or agents of disease were acquired prior to or during the confinement. At the very least, the findings in captive animals are indicative of the ability of various kinds of pathogens to invade these species and the kinds of effects they can have under stressful conditions. Several kinds of toothed whales inhabit only the deeper waters, off the shelf, hence consideration of them is not relevant to the OCSEA Program. The following are résumés of those that regularly occur on the shelf.

Ziphiidae, Beaked Whales - Two of the species of beaked whales found in Alaska (*Ziphius cavirostris* and *Mesoplodon stejnegeri*) are regarded as very rare and are known only from occasional occurrence of beach-dead specimens. We know of no published information on natural causes of illness and death in these whales, other than that they usually have numerous superficial scrapes and scars, presumably made by the teeth of their companions (Hubbs, 1946; Mitchell and Houck, 1967). We have examined only two specimens of *Mesoplodon*, one of which apparently had died as a result of head injuries, probably from collision with a ship; the other was affected by and may have died from massive parasitic invasion of its kidneys.

Delphinidae, Dolphins and Porpoises - The only common delphinids of the Alaskan continental shelf are the killer whale, *Orcinus orca*, the Dall porpoise, *Phocoenoides dalli*, and the harbor porpoise, *Phocoena phocoena*. The natural causes of illness and death are little known in any of these. In old age, killer whales evidently are often afflicted with dental disease, as a consequence of excessive abrasion of their teeth (Tomes, 1873; Colyer, 1938; Tomilin, 1957), and atherosclerosis (Roberts *et al.*, 1964; Hashimoto *et al.*, 1967), but they seem to be otherwise long-lived and little affected by the kinds of disease agents that strike other species. Dall porpoises have some parasitic infections of unknown importance and appear to be very easily stressed (Ridgway, 1966). Tomilin (1957) reported exostoses of unknown cause on skeletons of both killer whales and harbor porpoises, and we found one young harbor propoise that had died as a result of an umbilical hernia.

Delphinapterus leucas, Belukha or White Whale - The belukha is preyed on by both killer whales and polar bears (Sleptsov, 1952; Kleinenberg *et al.*, 1964), and this is certainly an important cause of mortality, though perhaps not the primary cause. Acute inflammatory reactions and mechanical damage due to helminthic parasites at least in the kidneys, stomach, central nervous system, and ears, appear to be severe enough to predispose the animals to predation and other secondary causes of death (Vsevolodov, 1948; Usik and Temirova *in* Kleinenberg *et al.*, 1964; Kenyon and Kenyon, 1977).

IV. STUDY AREA

From FY75 to FY77, the study area of this project was the shelf and shore of the eastern Bering Sea, from Unimak Pass to Bering Strait. In FY78, this has been expanded to include also the Western and Northern Gulf of Alaska, from Kodiak Island to Yakutat Bay, and Lower Cook Inlet.

V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

Rationale

Data on the morbidity and mortality of marine mammals are obtained from two sources:

1. Necropsy of specimens collected non-selectively from the living populations. This provides information on the kinds, causes, and relative severity of pathological conditions currently occurring in those populations and probably contributing to natural mortality. Given that the samples are sufficiently large (i.e. at least 100 specimens of each regional population), the approximate rate of occurrence and relative importance of each condition can be estimated.
2. Necropsy of beach-dead carcasses. This provides information on the actual causes of mortality in the populations, as well as data on the usual frequency of occurrence and aerial distribution of dead animals along the coasts. While it does not provide direct data on rates of mortality, rates may be inferred from the composition by age and sex, provided that the samples are sufficiently large for each species in each region.

Sources

Samples from the living populations are obtained through cooperative interaction with other OCSEAP projects (R.U.#229, 230, 232, 243), in which specimens are collected for information on trophic relations, productivity, and other biological and populational characteristics. The same specimens collected for those projects are utilized by this project.

Data on beach-dead animals are obtained in periodic shoreline surveys by personnel of this project, mainly via aircraft capable of landing on the beach or, less often, via small boats.

Methods

Necropsy procedures for both the collected specimens and beach-dead carcasses are as described in the project's Manual for Postmortem Examination (see Annual Report, R.U.#194, 31 March 76). Basically, these consist of:

1. Collection of blood sample for serum antibody analysis.
2. External examination for ectoparasites, wounds, and cutaneous abnormalities.
3. Internal examination for gross pathological conditions and endoparasites.
4. Collection and preservation of tissues for histopathological study and for heavy metal and hydrocarbon analysis.
5. Isolation and culture of pathogenic agents.

In the past year, pathology in the living populations was investigated during three research cruises in the Bering Sea (*Surveyor* 15 March-8 April, 11 April-3 May; *Discoverer* 19 May-11 June) and during two cruises in the Gulf of Alaska (*Surveyor* 25 October-2 November; *Resolution* 12-19 November). Data on beach-dead carcasses were obtained in southern Bristol Bay (5 April, 10-14 June), at St. Matthew and St. Lawrence Islands (26 June-5 July), on Tugidak Island, Kodiak area (26 May-7 August), and in Lower Cook Inlet (15 November).

Serological analyses were performed in the laboratories of the Naval Biosciences Center, Oakland, California and in the Virology Unit, Alaska Division of Public Health, Fairbanks. Microbiological isolates were cultured and identified in the Virology and Bacteriology Units, Alaska Department of Health, Fairbanks and in the Ames and Plum Island Animal Disease Laboratories of the U.S. Department of Agriculture. Histopathological materials from selected specimens were analyzed by the Department of Pathology, the Johns Hopkins University School of Medicine, Baltimore. All other pathological, parasitological, and other biological materials were processed by personnel of this project at the University of Alaska, Fairbanks.

VI. RESULTS

Pathology in the Living Populations: Bering Sea

Forty-five specimens of pinnipeds collected in the ice front of the Bering Sea were examined during FY77. The gross pathological findings in these are shown in Table I and annotated below.

Wounds

The sea lion had numerous superficial wounds and scars, particularly on the head and neck, probably inflicted by the teeth of other sea lions. In the two spotted seals, lacerations mainly on the hind flippers also appeared to have been made by the teeth of other seals. One ribbon seal had lost part of the distal end of the fifth digit of the left hind foot as a result of a shark bite; the second ribbon seal had a large crescentic scar of unknown origin on the right flank. One ringed seal had a 2 cm puncture wound on the ventral surface, over the sternum, that penetrated through the blubber to the underlying muscle; the wound was abscessed but draining, and a hemolytic beta *Streptococcus* was isolated from it.

Dermatitis

A 5x6 cm depilated area on the belly of the sea lion showed slight swelling and congestion of the skin. In histological section, the epidermis of the lesion was considerably thickened (x2) and hyperkeratotic, with acute inflammatory reaction in and around the hair follicles and sweat glands. The causative agent is unknown but presumed to be bacterial.

The three ribbon seals, the spotted seal, and one of the ringed seals had nodular lesions, 1.5 to 2.4 mm in diameter, in the skin of their hind flippers and ankles. Some of these in one of the ribbon seals and the one spotted seal were ulcerative. Histologically, each case showed acute inflammatory reactions in and around the hair follicles, indicative of

TABLE I

FREQUENCY OF OCCURRENCE OF PATHOLOGICAL CONDITIONS IN PINNIPEDS COLLECTED IN THE EASTERN BERING SEA, SPRING 1977

	Sea lion	Walrus	Bearded seal	Ribbon seal	Spotted seal	Ringed seal
Number examined	1	1	8	14	18	3
Wounds	1	0	0	2	2	1
Dermatitis	1	0	0	3	1	2
Abscessed mammary	0	0	0	1	0	0
Bone disease or fracture	0	0	0	2	0	0
Eye inflammation	0	0	0	0	0	1
Lung disease	1	0	0	3	5	0
Lymphadenitis	0	0	0	1	1	0
Biliary fibrosis	0	0	3	0	0	0
Hepatitis	1	0	2	9	16	1
Gastric-duodenal ulcer	1	0	1	1	2	0
Pancreatic tumor	0	0	0	1	0	0
Trauma	0	0	1	0	1	0

invasion by a microbiological agent. Clumps of unidentified cocci were demonstrated in pockets beneath the stratum corneum of one of the ribbon seals, and hyphae and spores of an unidentified fungus were present in another. The presence of inclusion bodies in hypertrophied epidermal cells of the spotted seal suggested the presence of a viral agent. Since each of these seals was molting at the time of collection, it is conceivable that several kinds of pathogens may gain access through the open hair canals and cause focal infections at that time.

In the second ringed seal, there were broad areas of depilation on the fore and hind flippers, within which were numerous rings of raised, darkly pigmented lesions. A mycotic agent, as yet unidentified, was isolated from these lesions and demonstrated as well in histological sections.

Abscessed Mammary

One adult male ribbon seal had a subcutaneous draining abscess about 2 cm in diameter, beneath the right vestigial mammary teat, possibly as a result of a superficial wound in that area. The thick caseous contents suggested that this was an infection of long standing, as did the relatively low level of inflammation around it. A pure culture of the bacterium *Moraxella lacumate* was isolated from the lesion.

Bone Disease or Fracture

Two adult ribbon seals showed gross evidence of bone displacement, probably the result of fracture, in one distal phalange, one in a fore limb, the other in a hind limb.

Eye Inflammation

The one ringed seal with extensive dermatomycosis of the extremities also showed acute inflammation of the conjunctiva, with associated puffiness of the eyelids. The cause of this condition was not determined.

Lung Disease

Each of the nine animals had one to three grossly apparent nodular lesions in the lungs. Histologically, each case showed strong eosinophilic inflammation indicative of parasitic invasion. The presence of helminths (nematodes) was demonstrated in the one sea lion, and in one each of the spotted and ribbon seals.

Lymphadenitis

One each ribbon and spotted seals had greatly enlarged (x2) lymph nodes, in which mild inflammation was indicated on histological section. The causative agent was not isolated.

Biliary Fibrosis

Three bearded seals had greatly thickened bile ducts, and in two of these the fibrous thickening was so extreme that the ducts were readily palpable. In each case, this condition was associated with the abundant presence of the trematode *Orthosplanchnus fraterculus* and, in two cases, with the presence as well of bacterial agents (*Staphylococcus epidermidis* and *Edwardsiella tarda*). The extreme fibrosis, resulting from severe, chronic inflammation, appears to have been caused by the combined effects of both the parasitic and the microbiological agents. Abundant calculi also were present in the bile ducts of one of the specimens.

Hepatitis

Acute, focal hepatitis, appearing as minute (to 1 mm) whitish spots beneath the liver capsule and, in severe cases, throughout the liver tissue, was noted in the majority of the pinnipeds that were examined. In histological preparations, these lesions appeared as moderately organized, more or less circular sites of inflammation, containing mainly eosinophilic leucocytes. The latter suggests that they were parasite-induced, possibly by larvae of one of the common helminths of these seals. Thus far, in the materials collected in this project, the presence of such larvae has not been demonstrated either in the lesions or elsewhere in the tissues, hence the identity of the causative agent remains uncertain.

Gastric-Duodenal Ulcers

The one sea lion, one ribbon seal, and two spotted seals showed severe helminth-induced damages and local inflammation of the stomach wall, associated with moderate to heavy infestations of nematodes of the genera

Anasakis, *Contracaecum* and *Phocanema*. In the one bearded seal, a dense population of the cestode *Pyramicocephalus phocarum* also had caused severe inflammation of the upper duodenum.

Pancreatic Tumor

A single, isolated nodule about 4 mm in diameter, found in the pancreas of the one ribbon seal was identified histologically as an islet cell adenoma.

Trauma

Two seal pups, one of which was a bearded seal and the other a spotted seal, were found dead on the ice. In each case, death had been caused by a severe blow to the abdomen, which resulted in rupture of the liver (bearded seal) and the pancreas (spotted seal), followed by massive internal hemorrhage. The bearded seal was newborn, but the spotted seal was at least two weeks old. The cause of these injuries is unknown.

Pathology of the Living Populations: Gulf of Alaska

Our work in the Gulf of Alaska-Cook Inlet area was begun in the first month of FY78. To date, we have examined 51 specimens collected in the northern and northeastern part of that area. The gross pathological findings in these are shown in Table II. The histopathological analyses of these have not yet been completed.

Wounds

While each of the sea lions had one or more minor, superficial scrapes and scars, probably caused by the teeth of other sea lions, none of these was of any real pathological significance. However, one specimen showed a severe wound encircling the neck. where a band of fiberglass webbing had cut through the skin and blubber to the level of the muscle surface. The fiberglass band, apparently flotsam from the high seas fishing fleet, evidently had been in place on the animal's neck for some months to have created such a gaping wound. There was some indication of healing along the edges of the lesion and no gross signs of secondary infection.

TABLE II

FREQUENCY OF OCCURRENCE OF GROSS PATHOLOGICAL CONDITIONS
IN PINNIPEDS COLLECTED IN THE GULF OF ALASKA,
AUTUMN 1977

	Sea lion	Harbor seal
Number examined	42	9
Wounds	1	0
Dermatitis (depilatory)	2	0
Dermatitis (nodular)	1	0
Lung disease	0	1
Hepatitis	4	9
Gastric ulcers	0	1

Dermatitis

Large (to 10 cm in diameter), more or less circular depilated lesions were present on the skin of two of the sea lions. These grossly resembled the one lesion on the specimen described above from the Bering Sea. In one of the same animals, numerous cutaneous nodules, resembling pox lesions, were present over the body surface, as well.

Lung Disease

One of the harbor seals had several firm nodules in the lungs, probably attributable to lungworm infection.

Hepatitis

Four of the sea lions and all of the harbor seals showed focal micro-abscesses of the liver, and in some cases these were present in abundance. In gross appearance, this condition appeared to be the same as in the Bering Sea seals. The cause in unknown.

Gastric Ulcers

One of the harbor seals with a moderate burden of stomach nematodes had one parasite-induced ulceration of the stomach wall.

Helminthic Parasites

The findings to date of helminth parasites in pinnipeds of the Bering Sea and Gulf of Alaska, are shown in Table III. As yet, the samples from each species and region are small, and little confidence can be placed in the results. However, they indicate in a general way that the parasite burdens of the different host species tend to be distinctively different, which may be mainly a reflection of their different feeding habits. That is, each species of parasite presumably is found in its larvae stage in a different fish or invertebrate intermediate host, hence the presence of the adult stage in a seal is indicative that the latter has fed on that particular kind of prey sometime within the previous weeks or months. At present, there is insufficient information on the life cycles of these parasites with which to identify the kinds and quantities of prey consumed by the seals, but our efforts to obtain that kind of information by parasitological examination of the different prey

TABLE III

FREQUENCY OF OCCURRENCE OF HELMINTH PARASITES IN ALASKAN PINNIPEDS (PERCENT INFECTED)

Host	Number examined	*Anophryocephalus ochotensis*	*Diplogonoporus tetrapterus*	*Diphyllobothrium cordatum*	*Diphyllobothrium lanceolatum*	*Diphyllobothrium* sp.	*Pyramicocephalus phocarum*	*Orthosplanchnus fraterculus*	*Pricetrema eumetopii*	*Phocitrema fusiforme*	*Anisakis* sp.	*Contracaecum osculatum*	*Phocanema decipiens*	*Dipetalonema spirocauda*	*Corynosoma strumosum*	*Corynosoma semerme*	*Corynosoma villosum*	*Corynosoma validum*	*Corynosoma hadweni*	*Bulbosoma* sp.
Steller sea lion NEGOA	42	95	92	-	-	36	-	-	62	9	47	35	74	-	85	-	100	-	-	7
Steller sea lion Bering Sea	7	71	28	-	-	14	-	-	-	-	57	14	71	-	-	-	100	-	-	-
Walrus	1	-	-	-	-	100	-	100	-	-	-	-	-	-	-	-	-	100	-	-
Bearded seal	8	-	-	100	100	62	100	50	-	-	-	25	62	-	-	-	-	100	-	-
Harbor seal NEGOA	11	18	27	-	-	9	-	-	-	-	-	91	9	-	100	-	64	-	-	9
Harbor seal Bering Sea	2	50	-	-	-	-	-	-	-	-	-	-	50	-	50	-	-	-	-	-
Spotted seal	31	74	13	-	-	13	-	-	-	13	-	58	52	3	94	87	-	-	-	10
Ribbon seal	19	10	-	-	-	20	-	5	-	-	-	85	25	5	90	35	20	10	-	5
Ringed seal	15	6	46	-	-	6	-	-	-	-	-	23	23	-	87	80	-	27	6	-

species are continuing on an opportunistic basis, as materials are made available by other OCSEAP investigators.

Serology

Serum antibodies in significant amounts, indicating previous exposure to infection by two pathogens, the bacterium *Leptospira pomona* and caliciviruses of the group identified as San Miguel Sealion Virus (SMSV) and antigenically identical with the Vesicular Exanthema of Swine Virus (VESV), have been demonstrated by Smith and co-workers (Akers *et al.*, 1974; Smith *et al.*, 1976; Smith *et al.*, 1977) as being common in pinnipeds of the California coast and in northern fur seals at the Pribilof Islands. Therefore, it is appropriate to test for the presence of antibody reponse to these pathogens in other Alaskan pinnipeds. The results of those tests, thus far, are shown in Table IV. Strong positive reactions to SMSV/VESV antigens, indicating serum antibody titres of 1:20 or greater, have been demonstrated in a high proportion of the Steller sea lions and a low proportion of the harbor seals. Strong reactions to antigens of *Leptospira pomona* have been demonstrated only in the Steller sea lions. The results of tests in all other species of Bering Sea pinnipeds have been negative.

Beached Carcasses

Our investigations of marine mammal mortality, based on enumeration and necropsy of beached carcasses were minimal in FY77 and the first half of FY78, and were confined mainly to the Bering Sea.

Bristol Bay

Approximately 105 km of the northern coast of the Alaska Peninsula, in and about Port Moller, were surveyed via helicopter on 5 April, but no carcasses were found.

The southern shore of Bristol Bay from Naknek to Bechevin Bay was surveyed via Supercub aircraft between 10 and 14 June. In the 654 km of shoreline surveyed, only 8 recently beached carcasses and the remains of 11 from previous years were sighted. Four of the recent carcasses were adult male walruses, two of which had died from bullet wounds; the cause of death of the others could not be determined, due mainly to their advanced state of decomposition. Three other of the recent carcasses were harbor seals; one was a minke whale.

TABLE IV

RESULTS OF ANALYSES FOR SERUM ANTIBODIES TO MICROBIOLOGICAL PATHOGENS IN PINNIPEDS OF THE BERING SEA AND GULF OF ALASKA[1]

Pinniped	SMSV/VESV		*Leptospira*	
	No. examined	No. positive[2]	No. examined	No. positive[2]
Bering Sea				
Sea Otter	1	0	1	0
Steller Sea Lion	5	3	6	2
Walrus	55	0	56	0
Bearded Seal	1	0	11	0
Harbor Seal	2	0	2	0
Spotted Seal	29	0	45	0
Ribbon Seal	18	0	32	0
Ringed Seal	1	0	13	0
Gulf of Alaska				
Steller Sea Lion	96	64	-	-
Harbor Seal	150	8	-	-

[1] Sera from Bering Sea pinnipeds collected by personnel of this project; those from Gulf of Alaska collected by personnel of R.U.#229, 243. Analyses for SMSV/SESV antibodies performed by Naval Biosciences Center, Oakland; analyses for *Leptospira* were by the Naval Biosciences Center and the laboratories of the Alaska Department of Health and Welfare, Division of Public Health, Fairbanks.

[2] Serum antibody totres of 1:20 or greater.

St. Matthew Island

Approximately 120 km of shoreline of St. Matthew and Hall islands were surveyed via helicopter on 26 June and resulted in the finding of three marine mammal carcasses. Two of these were adult male walruses that probably had died of natural causes, though they had been scavenged to such a degree that the actual cause of death and length of time since death could not be determined. The third carcass, which appeared to be fresh, was either a walrus or a sea lion, could not be certainly identified or examined due to unfavorable conditions for landing the aircraft.

St. Lawrence Island

The southern coast of St. Lawrence Island, from Puguviliak Bay to East Cape and including the Punuk Islands, was surveyed via helicopter between 28 June and 1 July. Along the 171 km of St. Lawrence Island shoreline surveyed, the remains of 45 beached marine mammal carcasses were sighted. Only seven of these were recent strandings, and of those, three (1 walrus, 1 bearded seal, 1 ringed seal) were pups of the year. The causes of death of the walrus calf and bearded seal pup could not be determined (but they were not gunshot); the ringed seal pup was emaciated but otherwise in excellent condition and apparently was simply a case of starvation. The other four carcasses were of adult walruses.

Twenty-nine of the 45 carcasses were of animals that had washed ashore in the 1976 ice-free season (June-November in this area). Seventeen of these were gray whales, one was a young bowhead whale, and the rest were adult walruses. Fourteen of the 19 older ramains also were of gray whales; one was a young bowhead, and the remainder were walruses.

Punuk Islands

The southwestern end of the largest Punuk island is a regular hauling ground for walruses in autumn, and a substantial number of these animals dies there annually, presumably from natural causes. This site was visited on June 28, at which time the remains of 81 walruses were identified, about two-thirds of which had lain there for more than one year. There were no signs of gunshot wounds in any of these, but their advanced state of decay and dismemberment by scavengers precluded any determination of the actual cause of death. Age and sex were determined for each of these specimens, and an analysis of these data, together with those from two previous large samples, is currently underway.

Tugidak Island (Kodiak area)

The shoreline of Tugidak Island (about 120 km) was surveyed via all-terrain vehicle between May 26 and July 18, with the result that 16 new carcasses and remains of three from previous years were found. Of the recently beached specimens, three were cetaceans (1 gray whale, 1 minke whale, 1 harbor porpoise), five were sea otters, and eight were pinnipeds (4 each sea lions and harbor seals). The cause of death only of the gray whale was determined with certainty (killer whale predation). Nearly all of these carcasses were on the western side of the island.

Miscellaneous

Two specimens of Stejneger's beaked whale, *Mesoplodon stejnegeri*, were examined in the past year, opportunistically. The first, a young male about 5 m long, was at Moffet Point, Izembek Lagoon in southeastern Bering Sea on 24 June. The cause of death was not certainly determined (due to the carcass having been partly scavenged by bears), but a major contributing factor appeared to be severe parasitism of the kidneys by nematodes of the genus *Crassicauda*. The second specimen, an adult male about 7 m long, was at Homer, Lower Cook Inlet on 15 November. This animal appeared to be in excellent condition, with the exception of an open, bleeding wound on the head, associated with several larger areas of contusion and hemorrhage. The primary cause of death in this case probably was collision with a passing ship.

Drift Trajectory of Marine Mammal Carcasses from Known Sources

The bodies of marine mammals during late winter, spring, and early summer tend to be negatively buoyant when divested of air in the lungs. Thus the dead mammal tends to sink to the bottom at first, then to float just to the surface after a sufficient amount of gas is produced in the tissues by putrifaction to make is positively buoyant. The drift of the sunken carcass probably is minimal; the floating carcass presumably is propelled mainly by surface currents, for there is ordinarily too little of it exposed above the sea surface to be affected greatly by winds.

In the northern Bering Sea-Bering Strait region, there are at least three known sources of marine mammal carcasses (principally walruses) from which the drift trajectory can be measured. Each of these is an area where walrus hunting by Eskimos is intensive in the months of May and June, where the water depths are sufficiently shallow (< 50 m) to permit bloating and floating of carcasses, and where large numbers of animals are killed or mortally wounded and not successfully retrieved. Two of these areas are near St. Lawrence Island, the first about 15 to 20 km WNW of Gambell, and the second about 20 to 30 km NE of Savoonga; the third is nearly in the center of Bering Strait, within a radius of about 15 km of Little Diomede Island. The animals in the first area are mainly adult females, while those in the second are mainly adult males; adults of both sexes are found in the third area.

Area #1: 15-20 km WNW of Gambell

The annual subsistence harvest of walruses in this area takes place mainly in the first three weeks of May. Since the surface currents here are mainly from southwest to northeast (Hughes *et al.*, 1974; Coachman *et al.*, 1975), it is to be expected that most of the carcasses of gunshot victimes from this source would drift northeastward toward Bering Strait. However, there are also large eddies north of St. Lawrence Island, in which some proportion of the carcasses might be expected to be caught, eventually to come ashore on the northern coast of the island. In 1975, 13 such carcasses (4 males, 9 females), out of an estimated 100 to 150 from that source, beached along the northern coast of St. Lawrence Island between Akeftapak and Kangee bays (Fig. 1). These were found during a survey in late August and were judged to have lain there for at least a month before they were found. In 1977, the first such carcasses were just arriving in the western part of that area on July 5.

Area #2: 20-30 km NE of Savoonga

The harvest in this area takes place mainly from mid-May to the first week of June. This is an area within the complex system of eddies north of St. Lawrence Island, hence a large proportion of the estimated 2-300

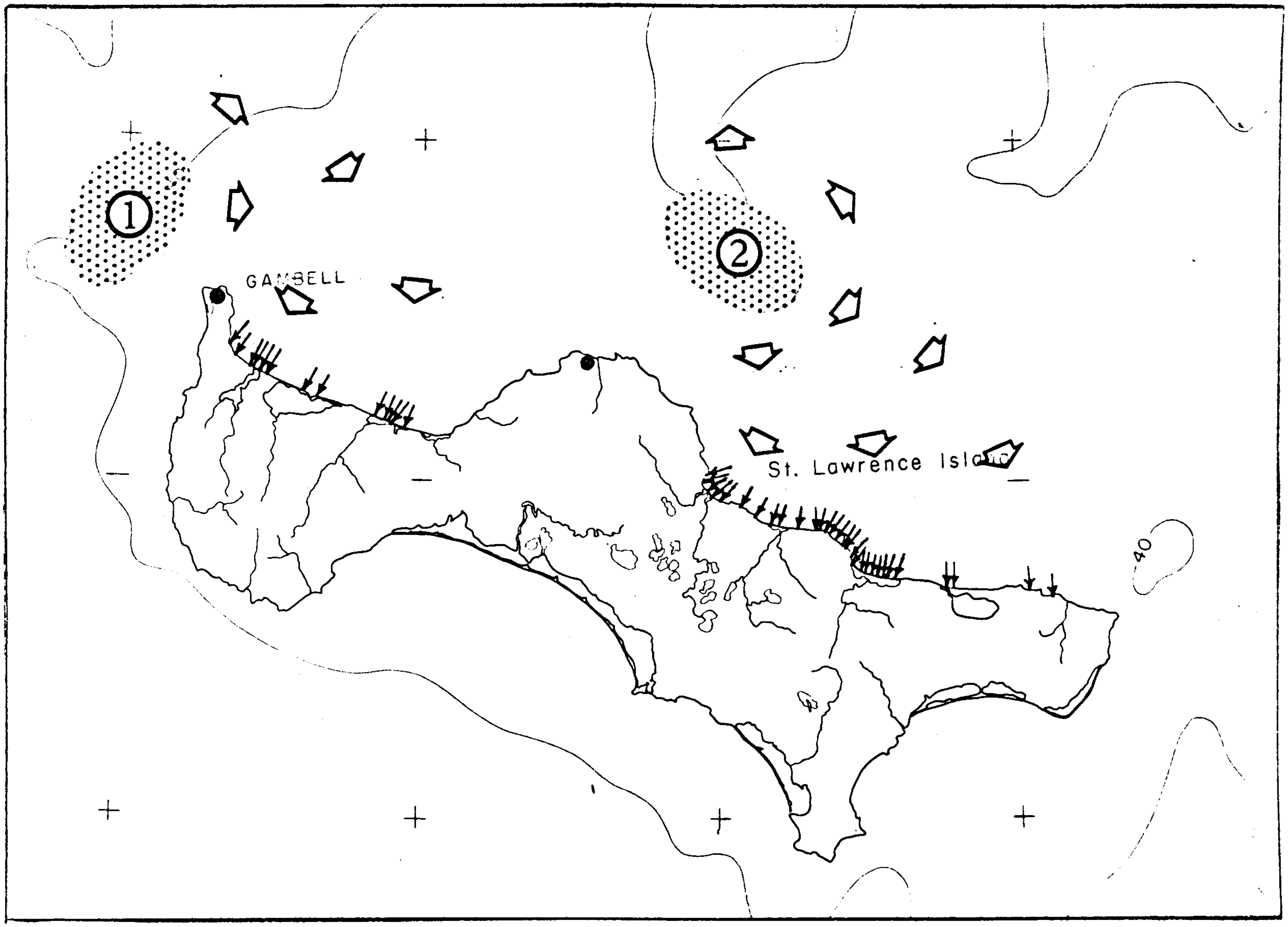

Figure 1. Distribution at St. Lawrence Island, August 1975, of beached walrus carcasses (small arrows) derived from source areas #1 and #2 (stippled). Open arrows show suggested drift routes.

carcasses from this source might be expected to be caught in that circulation and, ultimately, to beach on the northern coast of the island itself. The remainder would be carried north, toward Bering Strait. In mid-August 1975, 30 such carcasses (27 males, 3 females) were found between Ivikhtok and Kitnagak bays (Fig. 1), two of which had recently arrived (within the previous week); the remainder had been *in situ* no more than 3 or 4 weeks. In 1977, this portion of the coast was icebound at least until 1 July, precluding any possibility of the carcasses beaching until after that time.

Area #3: within 15 km radius of Little Diomede Island

Walruses are taken in this area mainly from the last 10 days of May to the middle of June. The surface currents here are mainly from south to north, with strong eddies to the northeast and northwest (Zenkevich, 1963; Coachman *et al.*, 1975), hence many of the gunshot carcasses might be expected to go northward into the central Chukchi Sea, while some proportion would be caught in the eddy systems, ultimately to beach on the Alaskan and Siberian coasts. A survey of the Alaskan coast north of Bering Strait, from Cape Prince of Wales to Point Hope, during 16-25 July 1975 yielded 88 walrus carcasses, at least 90% of which were gunshot victims, and nearly all of these were in the zone from Bering Strait to Cape Espenberg. Judging from their condition, those nearest Cape Prince of Whale had lain *in situ* the longest (3-4 weeks); some were still coming ashore in the vicinity of Cape Espenberg. By 1 August, when observers from the U.S. Fish and Wildlife Service (FWS) flew surveys of the same area, 89 walrus carcasses were found between Wales and Espenberg, and on 8 August, 1 was present also between Kotzebue and Point Hope, where none had been present 2 weeks earlier.

In 1976, we surveyed the Wales to Kotzebue area between 12 and 31 July and found nearly the same distribution of gunshot walrus carcasses as we had found in the previous year (Fig. 2). We counted 48 in all and some were still coming ashore. By 4 August, 6 carcasses from source #3 had reached the coast between Kotzebue and Point Hope, and by 25 August, a survey of the latter area by FWS and ADF&G personnel disclosed 49 additional carcasses that had drifted in during the 3-week interim. Apparently, very few carcasses ever reach the coast farther north than Point Hope; only one was sighted there by the FWS-ADF&G survey team.

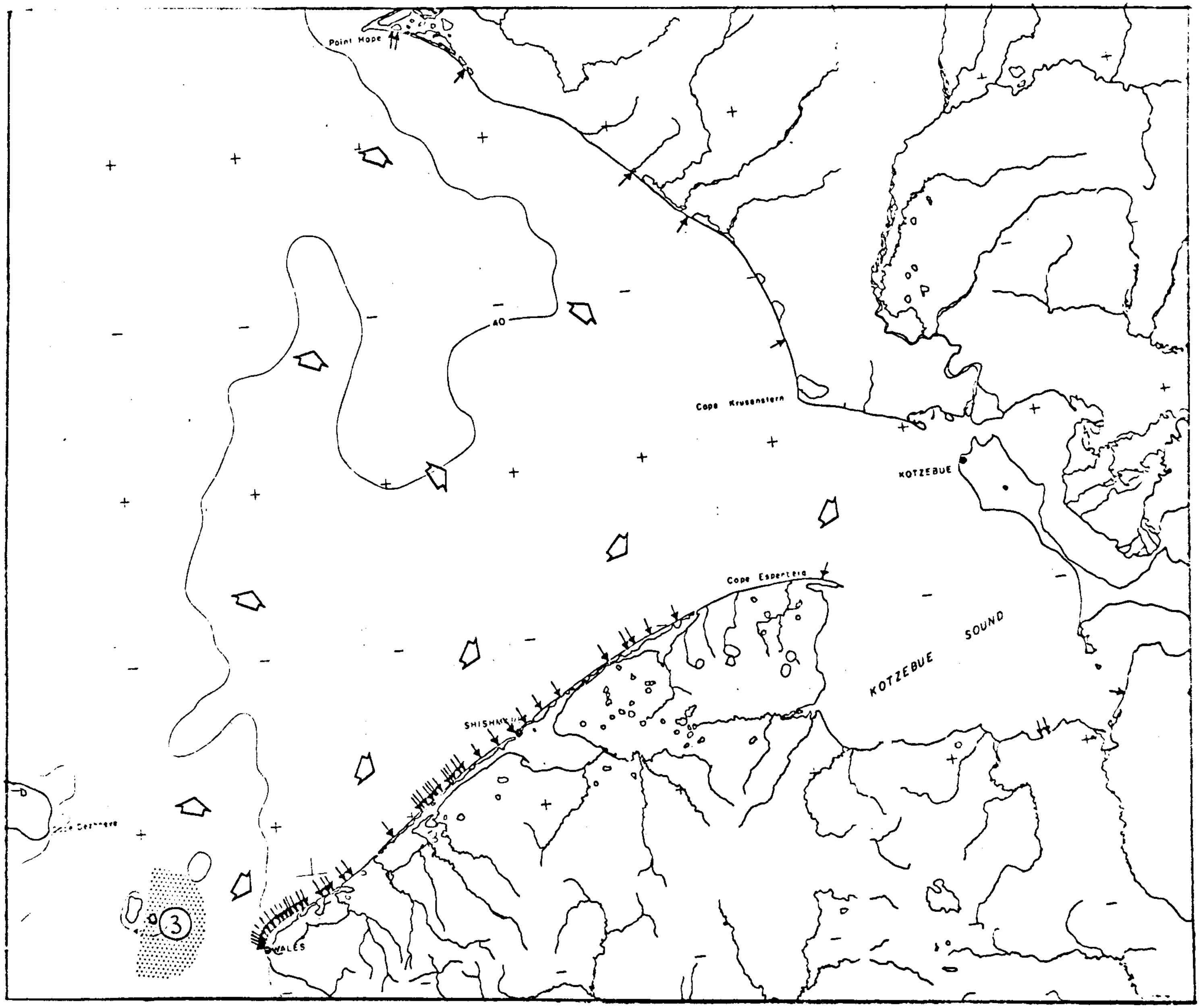

Figure 2. Distribution in southern Chukchi Sea-Bering Strait region, 12 July-4 August 1976, of beached walrus carcasses derived mainly from source #3, showing suggested drift routes.

Meetings

Project personnel attended and participated in six relevant meetings in the past year.

1. Marine Mammal Stranding Workshop, Athens, Georgia, 11-13 August.
2. OCSEAP Bird and Mammal Review, Fairbanks, 25-28 October.
3. LCI Coordination Meeting, Seattle, Washington, 9-11 November.
4. Second Conference on Biology of Marine Mammals, San Diego, California, 12-15 December
5. Kodiak Coordination Meeting, Anchorage, 31 January-1 February.
6. Ocean Pollution Research and Monitoring Workshop, Anchorage, 12-14 March.

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VII. DISCUSSION

The marine mammals of the Bering Sea and Gulf of Alaska, some 3 to 4 million strong, are resources of considerable economic value to the United States and the Soviet Union, and to some extent to Canada and Japan, as well. While the harvests of these for commercial and subsistence purposes certainly comprise an important part of the overall mortality of the populations, man is not the only causative agent of death; a substantial number of marine mammals dies there each year from natural causes, conceivably in as great or greater quantity than those killed directly by man the hunter. Our investigations thus far have shown that at least 6% of the specimens drawn from the living members of those populations had some kind of major pathological condition of non-human origin that was likely to have caused or contributed to their death (Fay *et al.*, 1977). Numerous other conditions, probably of secondary importance, occurred even more commonly.

Parasitic helminths and predators seem to be most frequently incriminated as agents of illness and death of marine mammals, here in Alaska as elsewhere. However, it remains questionable whether they are the most important primary agents of mortality. It is seldom feasible to diagnose adequately the primary and contributing causes of death in beached carcasses, simply because of rapid breakdown and attractiveness to large scavengers. The presence of parasites and of injuries caused by predators, including man, are most easily recognized, which may tend to bias the findings toward inordinately high rates of their occurrence. Conceivably, malnutrition, microbial infections, and toxins may predispose the animals to heavier than normal parasitization and to predation by natural enemies, as well as by man, but these conditions are more difficult and often impossible to assess in weathered, autolyzed, and dismembered carcasses.

Parasitological investigation of these mammals appears to have excellent potential as a monitoring procedure for assessing trophic relations in a changing environment, in addition to providing pathological information. Since nearly all of the helminth parasites are acquired from the vertebrate and invertebrate prey, and since the parasites themselves may persist in the mammals for several months, the parasite burden of a given species should be a nice cumulative index of its feeding habits over long periods of time. Given that the life-cycles and host relationships of the parasites are known, parasitological assessment may provide a more comprehensive view of trophic relations than does the direct examination of stomach contents and may be a more sensitive indicator of environmental change.

Judging from the drift of gunshot carcasses from known sources, the larger dead animals, such as walruses and perhaps whales, may persist at sea for some weeks or months and may travel several hundred kilometers before beaching. Their rate of transport by surface currents appears to be very slow (about 5 km/da), though the currents themselves may exceed 1 or 2 km/hr.

VIII. CONCLUSIONS

Until further investigations are completed, no conclusions are possible.

IX. NEEDS FOR FURTHER STUDY

Necropsy of Collected Specimens

This aspect of the work should be continued as long as specimens can be made available by other projects (R.U. #229, 230, 232, 243). Sample sizes for each species are not yet adequate for generalization but, in most cases, are approaching a minimally acceptable level.

Further Investigation of Parasite Life-Cycles

The normal intermediate hosts of helminths parasitizing marine mammals of Alaskan waters are not yet adequately known. Further work is needed to identify all or most of these hosts through autopsy of collected fishes and invertebrates that are the known or presumed prey of the mammals, in order to permit interpretation of parasitological data in terms of trophic relations.

Necropsy of Beached Carcasses

The number of relatively fresh, beached carcasses from which information can be gained on natural causes of death is large, but the problem of gaining timely access to these specimens is not soluble with the present system of annual surveys. A modest stranding alert-response system needs to be developed to make better use of the material available, at least in a few localities where communication and transportation networks are adequate to support it.

Steller Sea Lion Population Declining?

Recent work by investigators from the Marine Mammal Division, National Marine Fisheries Service suggests that there has been a drastic decline in numbers of sea lions in the eastern Aleutians-Bering Sea district, the cause of which is unknown. Our findings of high incidence of serum antibodies to leptospirosis and SMSV in sea lions from that district and the findings of Pitcher/Calkins (R.U. #243) of frequent premature births in sea lions of the Gulf of Alaska suggest a relationship between pathogens and lowered productivity, which should be investigated at once.

X. SUMMARY OF 3RD QUARTER OPERATIONS, APRIL-JUNE 78

Field Activities

1. 30 March-3 April - Charter Aircraft Cordova-Cape St. Elias (Fay)
   Investigation of premature births in Steller sea lions.
2. 6-20 April - *Surveyor* Leg IV Lower Cook-Kodiak (Fay & Shults)
   Necropsy of collected specimens; survey of beached carcasses.
3. 4-15 April - NOAA helicopter Nome area (Dieterich)
   Necropsy of collected specimens.
4. 2-19 May - *Surveyor* Leg V Bering Sea pack ice (Shults & B. P. Kelly)
   Necropsy of collected specimens.
5. 22 May-15 June - *Surveyor* Leg VI Bering Sea pack ice (Fay & Shults)
   Necropsy of collected specimens.
6. 27-31 May - NOAA helicopter southern Bristol Bay (Dieterich & assistant)
   Survey of beached carcasses.
7. 19 June-4 July - *Surveyor* Leg VII Gulf of Alaska (Shults & D. G. Ritter)
   Necropsy of collected specimens.

Revised Milestone Chart

Some activities shown in earlier versions of the FY78 milestone chart have been modified as a result of changes in availability of logistic support:

1. The proposed collections and necropsies via USCG icebreaker in February in southeastern Bering Sea were not carried out, due to non-availability of the platform. No available substitution.
2. The NEGOA collection and necropsy via "Pitcher charter" in March was cancelled. Substituting for it will be a brief trip to C. St. Elias (Calkins charter) for investigation of the cause of premature births in Steller sea lions.
3. An LCI-Kodiak collection and necropsy trip (with Pitcher-Calkins) has been added in April via the *Surveyor* Leg IV.
4. A Bristol Bay stranding survey via NOAA UH1H helo has been added in May.
5. The proposed May-July-September stranding surveys in the Kodiak area have been deleted for lack of personnel to man them and uncertain availability of helicopter support.
6. The proposed LCI stranding survey in September has been re-scheduled in August.

Problems Encountered/Recommended Changes

None

MILESTONE CHART

RU #: 194 PI: Francis H. Fay

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

MAJOR MILESTONES	1977			1978											
	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
NEGOA collections and necropsies (SURVEYOR)	▲														
NGOA/PWS collections and necropsies (RESOLUTION)		▲													
C. St. Elias sea lion study (charter)							△								
Norton Sd. collections and necropsies (NOAA helo)							△								
LCI-KODIAK collections and necropsies (SURVEYOR-IV)							△								
Bering Sea collection and necropsy (SURVEYOR-V)								△							
Bering Sea collection and necropsy (SURVEYOR-VI)									△						
Bristol Bay stranding survey (UH1H)								△							
GOA collections and necropsy (SURVEYOR-VII)									△						
Bristol Bay stranding survey (charter)										△					
Kodiak collection and necropsy (Pitcher charter)										△					
LCI stranding survey (SURVEYOR/helo)											△				
St. Lawrence I. stranding survey (charter)											△				
Kodiak collection and necropsy (SURVEYOR)												△			

△ Planned Completion Date ▲ Actual Completion Date

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ANNUAL REPORT

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Biology of the harbor seal, *Phoca vitulina richardi*, in the Gulf of Alaska

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INTRODUCTION

This research unit is a basic ecological, life history study of the harbor seal in the Gulf of Alaska. Specific objectives include: (1) investigation of food habits and identification of important prey species, (2) examination of growth and physical condition and (3) determination of population productivity with emphasis on establishing age of sexual maturity and age specific pregnancy rates. Peripheral objectives include collection of data concerning distribution, use of critical habitats, effects of disturbance and population composition, and collection of specimen materials for disease and environmental pollutant analyses.

Exploration, development and transportation of petroleum reserves in the Gulf of Alaska have a number of potential harmful effects on harbor seal populations. Some of the more obvious include the following: (1) direct injury to animals through contact with or ingestion of oil (this may result directly in death of the individuals involved or could result in lowered physical condition which in turn might alter long term survival and biological processes such as growth and reproduction), (2) disturbance, particularly during vulnerable stages of their life cycle such as pupping and molting, (3) reduction of productivity of the marine system by contamination, (4) direct mortality of important prey species by contact with oil and (5) increased levels of environmental contaminants.

This project was designed to collect information to aid in the decision making process for gas and oil development in the Gulf of Alaska. Data gathered will enable development of guidelines for all stages of the O.C.S. development program which will reduce harmful effects on harbor seal populations. Predevelopment data are being collected so changes which might occur can be detected.

This year (FY 1979) is the final year of field work for the project. During FY 1980 comprehensive data analyses will be completed and a final report prepared. Annual reports prepared in 1976 and 1977 provided detailed descriptions of the study area, described methods of research and reviewed prior knowledge. This annual report summarizes activities during the past year and presents significant findings.

RESULTS AND DISCUSSION

Four collecting trips were completed during calendar year 1977 resulting in the taking of 125 harbor seals. Animals collected to date total 254. All laboratory procedures relating to food habits, age determination and reproductive biology are completed. Disease studies are being conducted under RU-194.

SEX AND AGE COMPOSITION OF COLLECTED ANIMALS

Age determinations, based on counts of cementum growth rings, were completed. Sex and age composition of collected animals is presented in Tables 1-3.

REPRODUCTION IN FEMALE HARBOR SEALS

Table 1. Sex and age composition of 165 harbor seals collected in the Kodiak Island area.

Age	Number of Females	Number of Males
0-12 months	7	4
1 year	3	2
2	1	3
3	5	2
4	5	8
5	3	2
6	3	1
7	4	2
8	3	2
9	8	4
10	5	3
11	4	5
12	5	5
13	1	4
14	6	6
15	1	5
16	6	8
17	0	3
18	1	1
19	2	4
20	0	1
21	2	1
22	3	1
23	3	0
24	4	0
26	2	0
30	1	0
TOTALS	88	77

Table 2. Sex and age composition of 54 harbor seals collected along the outer Kenai coast.

Age	Number of Females	Number of Males
0-12 months	0	4
1 year	2	0
2	0	1
3	3	2
4	0	2
5	0	1
6	3	0
7	3	2
8	1	2
9	5	1
10	1	4
11	0	3
12	2	1
13	1	0
14	0	1
15	2	0
17	2	0
18	1	1
19	1	0
25	0	1
26	0	1
TOTALS	27	27

Table 3. Sex and age composition of 34 harbor seals collected in the northeastern Gulf of Alaska. Collection locations included Yakutat Bay, Icy Bay, Controller Bay and Middleton Island.

Age	Number of Females	Number of Males
0-12 months	4	1
1 year	1	0
2	1	1
3	1	1
4	2	0
5	3	1
6	2	0
7	1	1
8	1	2
10	4	0
11	0	1
12	3	0
13	0	1
14	1	0
18	1	0
TOTALS	25	9

Productive maturity, or the age at which a female first produces offspring, is an important parameter needed for population dynamics calculations. All females 4-years-old and younger were nulliparous (Table 4). However, it is apparent that occasionally a 4-year-old female will produce a pup. One 5-year-old was pregnant and one of her ovaries contained a corpus albicans suggesting a prior pregnancy. It appears that most females attain productive maturity during their fifth and sixth years although a few may not become mature until as late as 9 years of age.

Age specific pregnancy rates were calculated after examination of reproductive tracts of females collected between implantation and ovulation (Table 5). The pregnancy rate for mature females exceeded 90 percent.

Reproductive failures were noted in 10 females. Five involved initial pregnancies. Of these, two involved animals which ovulated and then did not breed or the blastocyst failed to implant. Two others apparently aborted and it was impossible to clearly determine the cause of the other failure. The five failures of multiparous females all appeared to result from abortions.

REPRODUCTION IN MALE HARBOR SEALS

Only limited data on age of sexual maturity in male harbor seals have been collected (Table 6). Harbor seals have seasonal spermatogenetic activity (Bigg 1969; Pitcher 1977), and because much of our collecting has taken place outside of the active period the available sample size for examining sexual maturity is small. No animals under 7 years old and all but one animal 7 years old or older, that were collected during the active period had abundant epididymal sperm indicating sexual maturity. No sperm were found in the epididymis of a 22-year-old male possibly because of reproductive senility.

Again, the seasonal distribution of collected animals is not adequately complete to deliniate the pattern of seasonal spermatogenetic activity. The data available (Table 7) agree closely with those collected in Prince William Sound (Pitcher 1977) which showed that mature males were in breeding condition from April until September. Individual variability in the seasonal onset of spermatogenesis was apparent.

GROWTH

Postnatal growth of harbor seals collected in the Kodiak Island area is shown in Figures 1 and 2. Growth, both weight and length, appears to be completed by age 10 years and possibly as early as 7 age years. These data basically agree with those presented by Pitcher (1977) and Bigg (1969). A comprehensive analysis of growth data by geographic area will not be completed until next year when the final report is prepared, however, preliminary analysis showed some interesting patterns (Table 8). Adult animals collected in the Kodiak area and along the Kenai Coast appeared to be very similar in length and weight. Seals collected in Prince William Sound (Pitcher unpublished) were shorter and weighed less than the Kodiak and Kenai animals, but these differences were not

Table 4. Proportion of female harbor seals attaining productive maturity by age class.

Age	Number of Females	Number Becoming Sexually Mature	Percent Becoming Sexually Mature
0-12 months	7	0	0
1 year	6	0	0
2	2	0	0
3	9	0	0
4	7	0	0
5	5	2	40
6	7	3	43
7	10	2	20
8	4	1	25
9	12	2	17
10-30	65	0	0

Table 5. Age specific pregnancy rates for 132 female harbor seals collected in the Gulf of Alaska.

Age (Years)	Total Females	Number Pregnant	Pregnancy Rate
0-4	31	0	0%
5	5	4	80%
6	6	6	100%
7	10	9	90%
8	4	4	100%
9	13	11	85%
10-19	49	45	92%
20-30	14	13	93%

Table 6. Age of sexual maturity in 15 male harbor seals collected in the Gulf of Alaska. Based on the presence of abundant epididymal sperm during the period 20-30 May.

Age (Years)	No. of Males	Epididymal Sperm Absent	Trace	Abundant	% Mature
1	1	1			0
2	2	2			0
3	2	2			0
4	3	1	2		0
5	1		1		0
6	1		1		0
7	3			3	100
8	2			2	100
9	1			1	100
10-22	15	1		14	93

Table 7. Seasonal spermatogenetic activity in 77 male harbor seals, 7 years and older, collected in the Gulf of Alaska. Activity based on the presence or absence of abundant epididymal sperm.

Time Period	No. of Males	Epididymal Sperm None	Trace	Abundant
9-12 Oct.	3	3		
5-10 Nov.	6	6		
7-11 Feb.	2	2		
18-25 March	18	11	4	3
15 April - 2 May	27	2	4	21
20-31 May	21	1		20

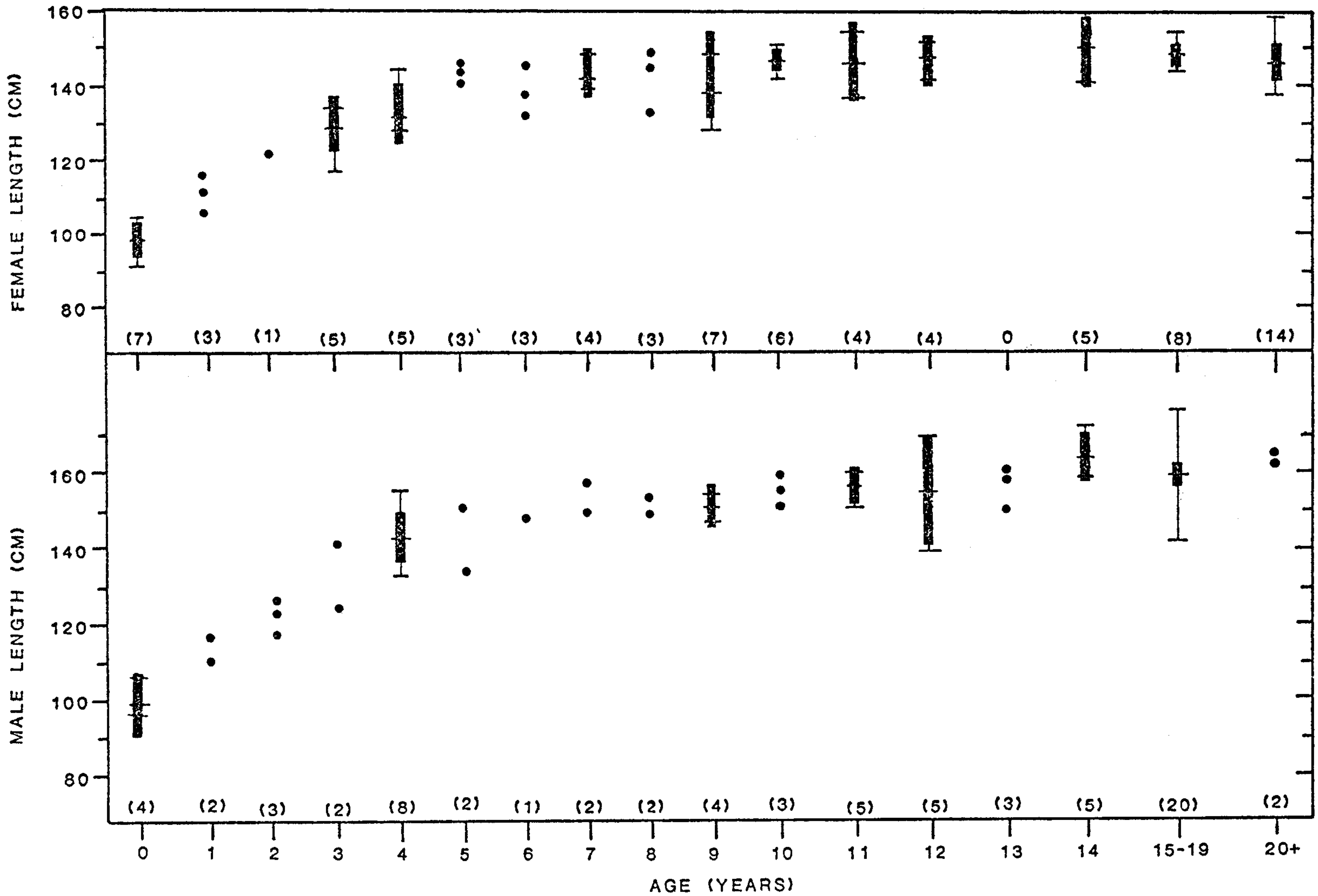

FIG. 1. STANDARD LENGTHS OF MALE AND FEMALE HABOR SEALS COLLECTED IN KODIAK WATERS BY AGE CLASS. VERTICAL LINE, RANGE; BOX, MEAN WITH 95% CONFIDENCE LIMITS; HORIZONTAL LINE IN BOX, MEAN; NUMBER IN PARENTHESIS, SAMPLE SIZE.

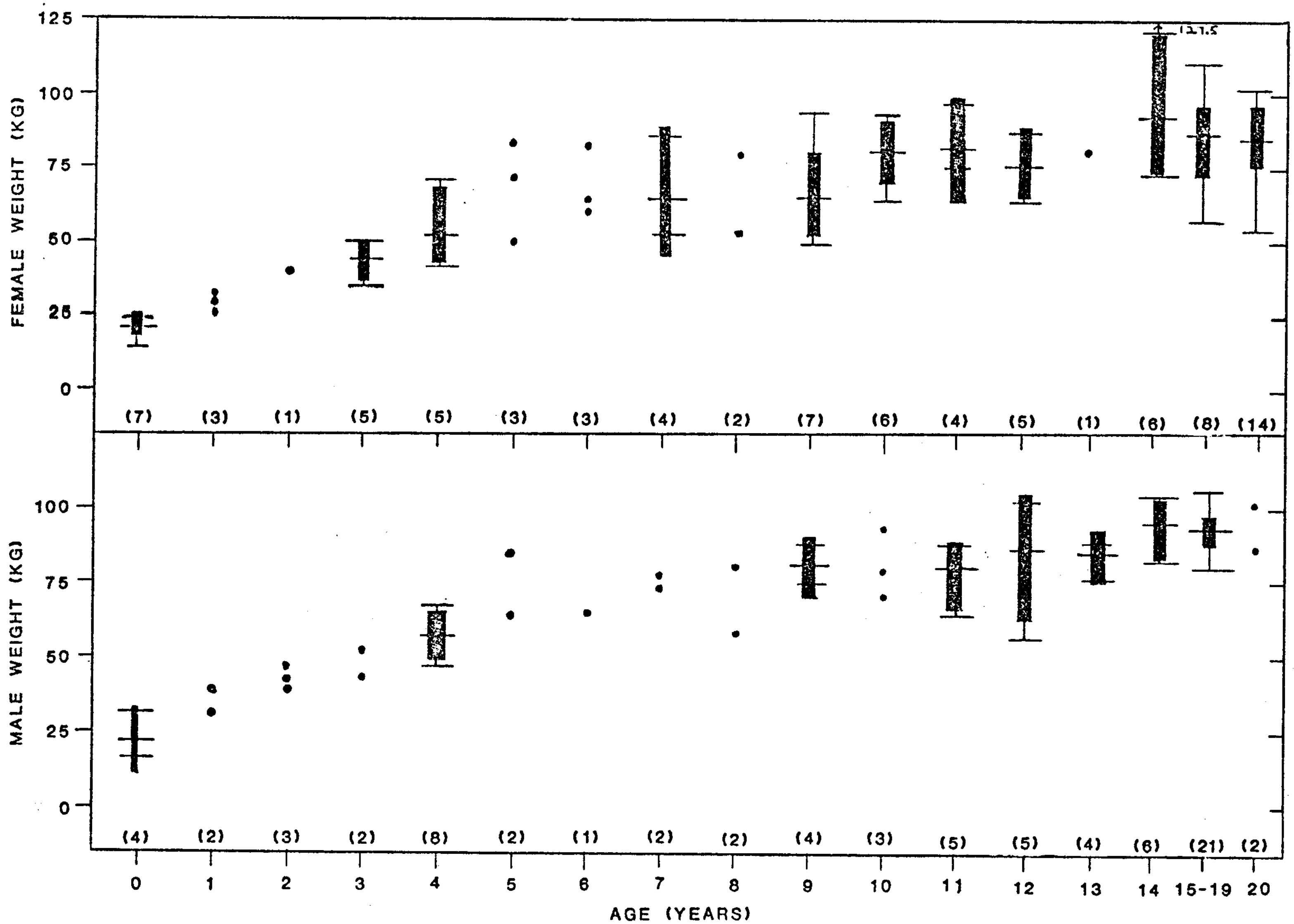

FIG. 2. WEIGHTS OF MALE AND FEMALE HARBOR SEALS COLLECTED IN KODIAK WATERS BY AGE CLASS. VERTICAL LINE, RANGE: BOX, MEAN WITH 95% CONFIDENCE LIMITS: HORIZONTAL LINE IN BOX, MEAN: NUMBER IN PARENTHESIS,SAMPLE SIZE.

Table 8. Comparison of standard lengths and weights of harbor seals, 10 years old and older, collected in the Gulf of Alaska. Data points are means with 95% confidence intervals.

Area	Sample Size		Standard Length (cm)		Weight (kg)	
	F	M	F	M	F	M
Kodiak	40	40	147.7 ± 1.6	155.9 ± 2.4	83.4 ± 3.9	88.4 ± 3.2
Kenai	10	11	149.2 ± 2.5	156.7 ± 2.1	81.7 ± 5.4	79.6 ± 6.5
Prince William Sound	7	7	143.9 ± 4.3	153.7 ± 6.1	70.8 ± 13.4	79.2 ± 8.2
Icy and Yakutat Bays	6	*	139.4 ± 4.9	*	64.4 ± 19.2	*

* N<4

significant at the 0.05 probability level. Standard lengths of females from the Northeastern Gulf (Icy and Yakutat Bays) were significantly less ($P > 0.05$) than females from Kodiak and Kenai. Mean weights of females from the Northeastern Gulf were less than from Kodiak and Kenai, however, the difference was not significant ($P < 0.05$).

CONDITION

Blubber thickness as an index to physical condition has been recorded for all collected animals. Preliminary analysis of condition data is based on reproductively mature females because of their importance to the population and because they comprise the single, largest component of our sample. There appears to be a general seasonal pattern to blubber thickness (Figure 3). Relatively high blubber reserves are present throughout the winter then are apparently reduced by lactation and molting in summer (Pitcher 1977) and then replenished during fall.

Comparison of blubber thickness during late winter and spring by area and years shows one striking difference (Table 9). Adult females from Kodiak in 1977 were significantly thinner ($P < 0.05$) than adult females from all other areas except Icy Bay and from animals collected in the same area during the previous year. The significance of this difference is not known, however, it demonstrates that considerable year to year variation occurs.

FOOD HABITS

Food habits analyses were based on volumes and occurrences of prey items found in stomachs. Biomass measurements such as volume are generally considered the best indicator of prey utilization (Fiscus and Baines 1966). Volume may give a distorted view in cases where different prey species are digested at different rates or when meals are at different stages of digestion when the animals were collected. Frequency of occurrence analysis may suggest greater than actual importance of small prey that are frequently encountered in low numbers. Frequency of occurrence also may exaggerate the importance of items which have persistent skeletal components that remain in the stomach for extended periods.

Food habits data are presented for three geographic regions. These include the Kodiak area, the outer Kenai coast and the Northeastern Gulf of Alaska.

In the Kodiak area (Table 10) octopus (*Octopus* sp.) was the dominant prey item by both volume and occurrence analysis. Capelin (*Mallotus villosus*), pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus macrocephalus*) were major fish species. The families Cottidae and Pleuronectidae were significant components of the harbor seal diet in the Kodiak area.

Along the outer Kenai coast, pollock and herring (*Clupea harengus*) were the dominant prey (Table 11). Other significant items were octopus and Pacific sandfishes (*Trichodon trichodon*).

In the Northeastern Gulf, pollock and two species of Osmerid smelts were the major prey (Table 12). By volume, a shrimp (*Pandalus borealis*) was dominant, however, this was the result of a single occurrence which happened to be an extremely full stomach.

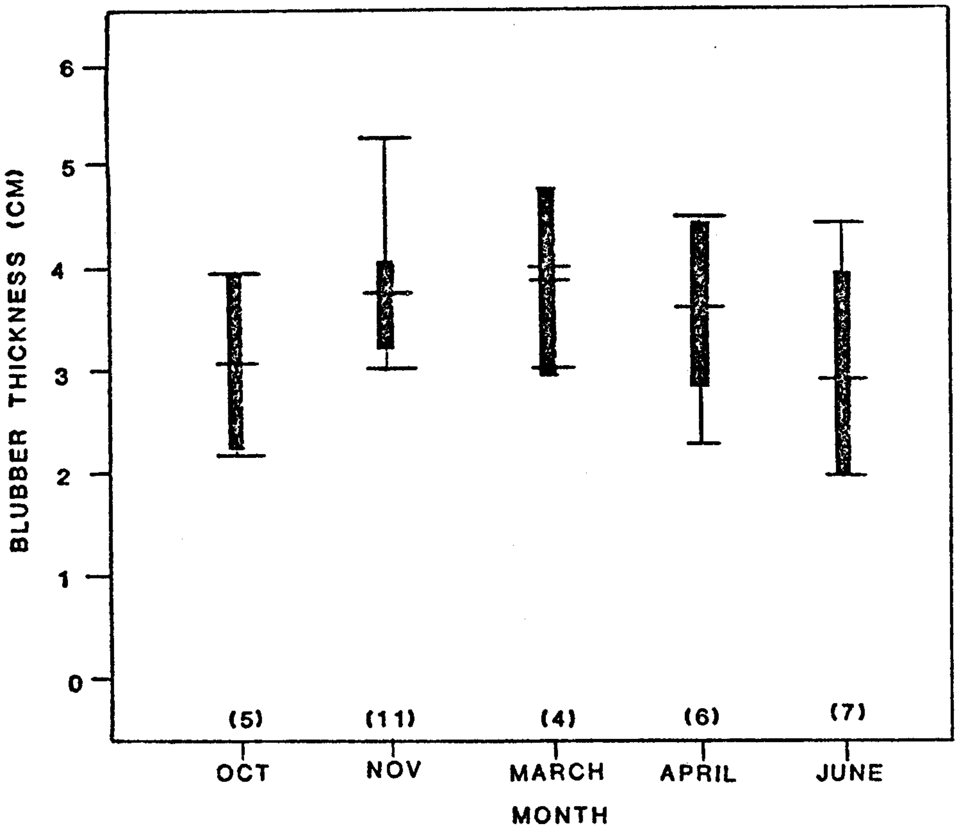

FIG. 3. SEASONAL BLUBBER THICKNESS OF 33 ADULT, FEMALE HARBOR SEALS COLLECTED IN THE GULF OF ALASKA DURING 1976.

Table 9. Comparison of blubber thickness of mature females (7 years old and older) collected during late winter and spring from different areas and during different years in the Gulf of Alaska. Data points are means with 95% confidence intervals.

Area	Sample Size	Year	Blubber Thickness (cm)
Prince William Sound	9	1975	4.0 ± 0.4
Kenai Coast	4	1976	3.8 ± 0.9
Kenai Coast	15	1977	3.7 ± 0.2
Kodiak	6	1976	3.6 ± 0.8
Icy Bay	4	1976	3.3 ± 2.1
Kodiak	33	1977	2.4 ± 0.1

Table 10. Summary of composition of stomach contents from 165 harbor seals collected in the Kodiak Island area, Alaska.

Prey Item	Occurrences Number	Occurrences %	Volume cc	Volume %
Gastropoda	3	1.9	30	0.1
Cephalopoda (Total)	35	21.6	9651	30.3
Decapoda (squids)	1	0.6	10	tr*
Octopoda (*Octopus* sp.)	32	19.8	9521	29.9
Unid. cephalopods	2	1.2	120	0.4
Decapoda (Crustacea) (Total)	11	6.8	1410	4.4
Crangon sp. (shrimps)	1	0.6	10	tr
Pandalidae (shrimps)	3	1.9	940	2.9
Sclerocrangon sp. (shrimps)	1	0.6	10	tr
Spirontocaris sp. (shrimps)	1	0.6	10	tr
Paguridae (hermit crabs)	1	0.6	10	tr
Brachyera (unid. crabs)	4	2.5	430	1.3
Unid. invertebrates	2	1.2	20	tr
Rajidae				
Raja sp. (skates)	1	0.6	1200	3.8
Clupeidae				
Clupea harengus (herring)	2	1.2	20	tr
Osmeridae (Total)	18	11.1	9220	28.9
Mallotus villosus (capelin)	17	10.5	7260	22.8
Thaleicthys pacificus (eulachon)	1	0.6	1960	6.1
Gadidae (Total)	35	21.6	4324	13.6
Eleginus gracilis (saffron cod)	1	0.6	30	0.1
Gadus macrocephalus (Pacific cod)	12	7.4	2004	6.3
Microgadus proximus (tomcod)	2	1.2	20	tr
Theragra chalcogramma (pollock)	20	12.3	2270	7.1
Zoarcidae				
Lycodes spp. (eelpouts)	5	3.1	100	0.3
Scorpanenidae				
Sebastes spp. (rockfishes)	2	1.2	730	2.3

Table 10. Continued.

Prey Item	Occurrences Number	Occurrences %	Volume cc	Volume %
Hexagrammidae				
Hexagrammos sp. (greenling)	1	0.6	40	0.1
Cottidae (Total)	8	4.9	1760	5.5
Dasycottus setiger (sculpin)	2	1.2	20	tr
Enophrys bison (sculpin)	1	0.6	240	0.8
Myxocephalus sp. (sculpin)	2	1.2	1440	4.5
Unid. Cottidae	3	1.9	60	0.2
Trichodontidae				
Trichodon trichodon (Pacific sandfish)	2	1.2	60	0.2
Bathymasteridae				
Bathymaster signatus	3	1.9	50	0.2
Ammodytidae				
Ammodytes hexapterus (Pacific sandlance)	12	7.4	543	1.7
Pleuronectidae (Total)	16	9.9	2560	8.0
Atheresthes stomias (arrowtooth flounder)	2	1.2	20	tr
Eopsetta jordani (petrale sole)	1	0.6	10	tr
Hippoglossoides elassodon (flathead sole)	3	1.9	145	0.5
Lepidopsetta bilineata (rock sole)	1	0.6	10	tr
Limanda aspera (yellowfin sole)	5	3.1	1670	5.2
Lyopsetta exilis (slender sole)	1	0.6	10	tr
Parophrys vetulus (English sole)	2	1.2	75	0.2
Unid. Pleuronectidae	1	0.6	620	1.9
Unid. fish remains	5	3.1	145	0.5
Metal	1	0.6	10	tr
TOTAL	162	99.7	31873	99.4

* Less than 0.1%

Table 11. Summary of composition of stomach contents from 55 harbor seals collected along the outer Kenai coast, Alaska.

Prey Item	Occurrences Number	%	Volume cc	%
Cephalopoda (Total)	7	14.6	115	1.5
Decapoda (squids)	2	4.2	20	0.3
Octopoda (*Octopus* sp.)	5	10.4	95	1.3
Decapoda (Crustacea) (Total)	2	4.2	20	0.3
Pandalus sp. (shrimps)	1	2.1	10	0.1
Pagurus sp. (hermit crab)	1	2.1	10	0.1
Clupeidae				
Clupea harengus (herring)	7	14.6	1595	21.1
Osmeridae				
Mallotus villosus (capelin)	2	4.2	220	2.9
Gadidae (Total)	22	45.8	2888	38.2
Gadus macrocephalus (Pacific cod)	3	6.3	35	0.5
Microgadus proximus (Pacific tomcod)	2	4.2	85	1.1
Theragra chalcogramma (pollock)	17	35.4	2768	36.6
Hexagrammidae				
Hexagrammos decagrammus (greenling)	1	2.1	10	0.1
Trichodontidae				
Trichodon trichodon (Pacific sandfish)	4	8.3	440	5.8
Ammodytidae				
Ammodytes hexapterus (sandlance)	1	2.1	10	0.1
Unidentified fishes	2	4.2	2255	29.9
TOTALS	48	100.2	7553	99.9

Table 12. Summary of composition of stomach contents from 31 harbor seals collected in the northeastern Gulf of Alaska. Collecting areas included Middleton Island, Controller Bay, Icy Bay and Yakutat Bay.

	Occurrences		Volume	
Prey Item	Number	%	cc	%
Cephalopoda				
Octopoda (*Octopus* sp.)	2	4.8	20	0.7
Decapoda (Crustacea)				
Pandalus borealis	1	2.4	1,200	44.9
Clupeidae				
Clupea harengus	1	2.4	50	1.8
Osmeridae (Total)	14	33.3	680	25.0
Hypomesus pretiosus (surf smelt)	4	9.5	460	16.9
Mallotus villosus (capelin)	9	21.4	210	7.7
Thaleicthys pacificus (eulachon)	1	2.4	10	0.4
Gadidae (Total)	13	31.0	620	22.8
Eleginus gracilis (saffron cod)	1	2.4	10	0.4
Gadus macrocephalus (Pacific cod)	1	2.4	10	0.4
Theragra chalcogramma (pollock)	11	26.2	600	22.1
Hexagrammidae (greenling)	1	2.4	10	0.4
Cottidae (sculpins)	1	2.4	10	0.4
Trichodontidae				
Trichodon trichodon (Pacific sandifsh)	4	9.5	55	2.0
Ammodytidae				
Ammodytes hexapterus (sandlance)	1	2.4	10	0.4
Pleuronectidae (Total)	3	7.1	30	1.1
Atheresthes stomias (arrowtooth flounder)	1	2.4	10	0.4
Limanda aspera (yellowfin sole)	1	2.4	10	0.4
Unid. Pleuronectidae	1	2.4	10	0.4
Unid. fish	1	2.4	10	0.4
TOTALS	42	100.2	2715	100.1

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

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I. Summary of objectives, conclusions, and implications with respect to OCS oil and gas development

Ringed seals, Phoca hispida, and bearded seals, Erignathus barbatus, are major components of the marine mammal fauna of the Bering, Chukchi, and Beaufort Seas. They have been chosen as target species for investigation based upon criteria including their significance in the ecosystem, importance to people residing along the coast, and considerations of timeliness, feasibility, and applicability to OCS requirements. This does not overlook the significance of other marine mammal species of the region, some of which are the subjects of other investigations (i.e. walrus, spotted seals, bowhead whales), and some of which suggest a lower probability of successful achievement of important task objectives (i.e. ribbon seals or grey whales). All of the marine mammal species of the area will be included in certain kinds of analyses such as that of distribution.

The broad objectives of this project are to obtain baseline information about the natural history and ecology of ringed and bearded seals. These species occupy vastly different ecological niches within the ice-dominated marine systems in question.

The ringed seal is a small, widely distributed and very abundant species which mainly occurs in areas of extensive, relatively thick and stable sea ice. It is the only species within our study area that occupies the landfast ice. It is the species taken in largest numbers by Eskimo seal hunters. Ringed seals feed mainly on zooplankton, the smaller shrimp, and demersal fishes.

In marked contrast, bearded seals are the largest of our northern seals. They are also widely distributed, but occur in the drifting ice. They feed almost exclusively on benthic organisms. Annual harvests of bearded seals are much lower than those of ringed seals. However, due to the great difference in size, the amount of usable protein is almost the same. Bearded seals are preferred by coastal residents.

Our intent in selecting these species for investigation was to examine simultaneously the biology of two species which are of significant importance to man, and which depend on vastly different habitats within the marine ecosystem.

The implications with respect to oil and gas development are basically that we will be able to recognize how, when, where, and why certain activities may have proximal or ultimate effects on these two important species. As examples, how does seismic exploration in areas of landfast ice affect ringed seals which breed there? What food organisms are these seals utilizing? Are there differences in the susceptibility of prey species to oil pollution--or, which of the seals is most susceptible to significant indirect effects of oil development? How much disturbance will the seals tolerate? Will they avoid areas of intensive human activity? Are there critical migration routes, etc.? Answers to almost all of the questions concerning the potential effects of oil and gas development on these seals depend on an understanding of their natural history and ecology.

II. Introduction

Bearded and ringed seals constitute two of the five pinniped species associated with the ice-dominated habitat of the Bering, Chukchi, and Beaufort Seas. By virtue of numbers and distribution they are of great significance to coastal residents of northern Alaska and Siberia, providing reliable sources of food and usable byproducts. Their importance as significant, functioning elements of the marine environment is not adequately known. Both species occur throughout the seasonally ice-covered regions. However, differences in habitat requirements (including food habits) result in an ecological partitioning of the marine system in question. Proposed OCS lease areas in the Bering, Chukchi, and Beaufort Seas fall directly within the habitat of these two species.

The primary emphasis of our ecological studies responds to OCSEAP tasks A-1, A-2, and A-3. Information required for accomplishment of objectives A-6 and A-31 is being obtained. Our study (as well as many others) is required in order to eventually achieve objective E-1.

Information required to meet the task objectives includes, but is not limited to, such things as natality, mortality, population size, population structure, trophic relationships, detailed understanding of factors determining density, distribution, seasonal movements, critical habitats, behavior, and other biological processes. Historical events indicate that marine mammals, as intelligent, irritible (in the physiological sense) and ecologically specialized organisms have almost always been adversely affected by the activities of man. The proposed exploitation of outer continental shelf resources poses the real threat of habitat alteration. Adverse impacts can be lessened if there is an adequate understanding of the ecosystem and its component parts and types of perturbation that can be anticipated.

Specific objectives of this project are as follows:

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 food habits in these two species.

3. Acquisition of additional data on productivity and growth rates.

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

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

6. Initial assessment of regional differences in density and distribution of ringed and bearded seals in relation to major habitat conditions.

7. Acquisistion of additional information on seasonal migrations.

III. Current state of knowledge

A considerable amount of general background information concerning bearded and ringed seals is presently available and is being summarized under our task objective 1. Almost all of this information relates to general understanding of aspects such as reproduction, age and growth, gross physical characteristics, general seasonal movements, general distribution, and food habits. However, the knowledge presently available remains inadequate for purposes of understanding the dynamic processes of these two species, their impact on and role in the northern environment, and the probable effects of disturbance both to the species themselves and the environment on which they depend.

A. Ringed seals

Ringed seals have a circumpolar distribution in arctic and subarctic seas, and they are the most abundant seal found in the Arctic. Polar bears, arctic foxes, and ringed seals are the only mammals that have been recorded north of 85°N latitude.

In Alaska, ringed seals inhabit the shorefast and moving pack ice of the Bering, Chukchi, and Beaufort Seas. Stragglers have been collected at Unalaska Island in the Aleutian Islands and on the Pribilof Islands.

The general distribution of ringed seals is limited by the distribution and quality of sea ice; however, some ringed seals are seen during ice-free periods in the Bering and Chukchi Seas. Seals appear at various coastal locations with the formation of shorefast ice in the fall and then disappear from these coastal areas in the spring with the ice breakup. Seals which winter in the Bering Sea may appear to move farther and are more widely distributed than adult ringed seals. The density of ringed seals varies greatly with the area and the season, but depends chiefly on the stability of shorefast ice for reproduction.

In addition to man, predators of ringed seals include polar bears (Ursus maritimus) (the chief predator), arctic (Alopex lagopus) and red foxes (Vulpes vulpes), dogs, wolves (Canis lupus), and ravens (Corvus corax).

Females give birth to a single, white-coated pup in ice dens (lairs) on both landfast and drifting pack ice during March and April. The female seals build the lairs on ice pressure ridges or under snow in refrozen leads for protection from predators and severe weather. Lairs are about 10 feet (305cm) long with an entrance from the water located at one end.

There is some evidence that females lacking maternal experience give birth in marginal habitat--drifting pack ice--and may be more subject to polar bear predation. The more experienced females give birth in better habitat, landfast ice, and may have higher reproductive success.

At birth the average weight of pups is 10 pounds (4.5kg) and the average length is about 24 inches (61cm). Females nurse pups for about two months during which the pup doubles its birth weight, to about 20 pounds (9.0kg). This gain is due to an increase in blubber thickness which provides the pup insulation to reduce heat loss to the cold water, air and ice, and provides an energy reserve. Weaning usually takes place at ice breakup.

Most females breed again within a month after the birth of the pup. Implantation of the new fetus is delayed 3-1/2 months and occurs in mid-July or early August. Pregnancy lasts about 11 months. Female ringed seals first ovulate at five or six years of age but successful conception does not appear to take place until the female is seven years old. Males become sexually mature at seven or eight years of age.

Ringed seals have been reported to live to an age of 36 to 40 years in the wild; however, relatively few animals taken in subsistence harvests exceed 10 to 15 years of age.

Until recently the ringed seal has been considered a silent species unlike many of its relatives which produce very melodious and complex "songs." Recent studies have shown that ringed seals do emit several types of vocalization under water and that these vocalizations are not readily audible above water or ice. Although these vocalizations are "heard" all year, if one uses a hydrophone (underwater microphone), the number of vocalizations increases during the breeding season. This may mean that the vocalizations are used to maintain social organization or to defend territories.

The behavior of ringed seals is poorly understood since both males and females spend the greater part of the year beneath the ice in lairs or in the water. From April until ice breakup, ringed seals "haul out" on the shorefast ice on sunny and warm days and undergo a molt (shedding and regrowth of the hairs). Peak of the molt is in May and June. Apparently the warmth and rest are required for rapid regrowth of the hairs.

The primary food of ringed seals in the nearshore western Beaufort Sea during spring and summer is euphausiids. In the Chukchi Sea they appear to feed primarily on shrimps in the summer and fishes (largely arctic cod) in the winter.

B. Bearded seals

Bearded seals are also a circumpolar arctic species. Although they can maintain breathing holes in ice, they appear to do so only rarely and are thus largely excluded from the winter fast ice zone. The winter density of bearded seals in the Beaufort Sea is low (about 0.1 animals/mi^2) with animals found in the flaw zone and nearshore pack ice.

Bearded seal pups are born on top of the ice from late March through May. Pups are capable of swimming shortly after birth and are weaned in 12 to 18 days. Subsequent to pupping, animals breed and molt.

As was the case with ringed seals, a seasonal concentration of animals occurs during summer. However, as they are primarily benthic feeders, few bearded seals remain with the summer pack ice when the southern edge is over deep water. They redistribute south with winter ice formation. The majority of animals winter in the Bering Sea and in the highly fractured ice north of the Bering Strait.

Bearded seals in the Chukchi and Bering Seas feed primarily on shrimps, crabs, and bivalve molluscs. Foods of bearded seals in the Beaufort Sea are presently being investigated (cf. Annual Report RU #232).

IV. Study area

The study area for this project includes the nearshore and offshore waters and ice of Bristol Bay, Bering Sea, Norton Sound, Bering Straits, Kotzebue Sound, Chukchi Sea, Beaufort Sea, and Arctic Ocean. Specific collection localities from which we have attempted to sample during this contract period include Stebbins, Nome, Savoonga, Gambell, Shishmaref, Kotzebue, Point Hope, Cape Lisburne, Point Lay, Wainwright, Barrow, and Barter Island. With the aid of ships and helicopters we have sampled the offshore areas of Bristol Bay, Bering Sea, Norton Sound, Chukchi Sea, Kotzebue Sound, Beaufort Sea, and Arctic Ocean. We have attempted to sample within and adjacent to areas outside the following proposed lease areas: Beaufort Basin, Hope Basin, Norton Basin, Bristol Bay, and Saint George Basin.

V. Sources, methods, and rationale of data collection

A. Ringed and bearded seals are collected as systematically as possible from different geographical areas and habitat types throughout the year. The objective of our sampling program is to detect variations in sex and age distribution, growth rates, reproductive conditions, parasites, and food habits in relation to season, geographic area, and habitat type. Acquisition of the large amounts of specimen material required for an understanding of the natural history and ecology of these two species is continuing at major Eskimo hunting villages. In addition, selective collection by the Principal Investigators is utilized to collect animals under specific environmental, temporal, and behavioral conditions. Selective collection provides additional data that cannot be obtained from the animals taken at the Eskimo hunting sites.

B. Weights and standard measurements are taken, when possible, from animals taken by Eskimo hunters, and from all animals selectively collected. The weights and measurements include: gross weight, hide and blubber weight, curvilinear length, standard length, axillary girth, maximum girth, front and hind flipper lengths and widths, navel to anus length, penis to anus length, tail length, and blubber thickness at the sternum. These data are used to establish fetal, pup, subadult, and adult growth rates, seasonal condition patterns, and to assist in making biomass calculations. In addition to weights and standard measurements, we attempt to obtain: specific location, date and time of collection; habitat and ice type; behavior at time of collection; group size and composition; tidal stage; and water depth.

C. The sex of a specimen is determined by examination of the external genitalia, or reproductive organs in those cases where the intact animal is not presented.

D. The ages of all seals for which claws are available are initially estimated by claw examination. The claw provides a rapid and accurate means of age determination for seals up to six years of age, as growth rings or ridges are formed annually on the claw. After six years the claws are worn such that the initial ring ("constriction of birth") and usually subsequent rings are worn off. For these specimens, a canine tooth is sectioned and stained, using a modification of the Johnson and Lucier (1975) technique. The tooth sections are examined with the aid of a light microscope and the age of the seal is determined by enumerating the dentine or cementum annuli (Smith 1973, Benjaminsen 1973). Age determinations are necessary for development of growth rates, to determine population structure and productivity, and age specific food habits.

E. The analyses of food habits of bearded and ringed seals involve separation and identification of food items and determination of frequency of occurrence and volume of prey species. (See Annual Report for RU #232 for a detailed discussion.)

F. Species productivity is determined through laboratory examination of reproductive tracts and correlation of these data with the age of each specimen.

Testes are weighed to the nearest 0.1 g with and without epididymides. Length and width at the middle of the testes are measured to the nearest millimeter. Testes volume (nearest cc) is determined by water displacement. Bacula are cleaned by boiling, air dried, and then measured (nearest mm) and weighed (nearest 0.1g).

The presence of sperm in the epididymides is used to acertain breeding condition. The epididymides are sliced and a drop of fluid is squeezed onto a slide and examined under 78x or 300x magnification. Sperm presence or absence in the epididymal fluid is quantified as: none found, trace, or abundant.

Ovaries are weighed to the nearest 0.1 g and then cut into 2mm longitudinal sections. The sections are left joined at the base to preserve their relative position. The sections are examined macroscopically for corpora lutea, corpora albicantia, follicles, and ovarian masses or abnormalities. The largest diameter of corpora lutea, corpora albicantia, and largest follicle are measured to the nearest mm. Drawings are made of each ovary for later reference. The presence of absence of a fetus is noted at necropsy.

G. All specimens are examined macroscopically for gross pathological conditions. We attempt to conduct a complete necropsy on each seal selectively collected. Time and conditions do not allow complete necropsies of all the specimens obtained in the various villages but we endeavor to examine, at least partially, as many as possible. The necropsy procedure followed is that outlined in Fay et al. 1976.

H. Samples (about $125 cm^3$) of heart, liver, kidney, skeletal muscle, and skin and blubber are wrapped in aluminum foil, labeled, and frozen. These tissue samples will be provided to other investigators for microbiological, hydrocarbon, pesticide, and heavy metal analyses.

I. Aerial, ship, and ground surveys are being used to determine the distribution and densities of ringed and bearded seals killed by polar bears and arctic foxes. These dead seals are being examined to determine how they were killed, physical condition, and amount consumed by the predator. Specimens are collected for laboratory analyses. In addition, the geographic location, specific habitat (breathing hole, lead, lair, etc.), and ice type are noted. Standard measurements are made on all seals.

Teeth and claws are collected to determine the age of the prey. Reproductive tracts are examined for sex and reproductive condition following standard techniques. Blubber, selected organs and tissues, stomach and digestive tract of prey species are examined for parasites, diseases or pathologic conditions, and food habits, and will be provided to cooperators for analyses for pesticides, heavy metals, and petrochemicals.

Several ecological and behavioral parameters will be investigated to determine factors affecting prey availability and selection and hunting success of predators. For example, polar bears tend to take seals at breathing holes, seals hauled out on the ice, or in lairs; therefore, these factors influence hunting success of bears. The numbers and kinds of seals seen on the ice during surveys will be related to ice conditions, weather, and seal biology data to obtain environmental and natural history correlates to hauling out behavior.

J. Population structure of ringed and bearded seals is assessed through sex and age determination of samples obtained at coastal hunting sites and during the course of selective collection. Eskimo collaborators have been established in various villages, with hopes of obtaining jaws and claws and other specimen material from seals killed by the villagers. The collectors also maintain logs of dates, species, and sexes of kills.

K. Seasonal migration patterns are determined through observations at coastal hunting sites, and from shipboard and aerial surveys.

L. Aerial, shipboard, and ground surveys are used to determine the distribution and densities of pinnipeds in the ice-covered Bering, Chukchi, and Beaufort Seas. These surveys are conducted chiefly in June during the post-reproductive and molting period of ringed and bearded seals, but by the end of this research surveys will have been conducted during every season and will have covered all ice types.

Aerial surveys are flown in both fixed-wing airplanes and helicopters. Aircraft used thus far for surveys have been a Cessna 180, Cessna 195, DeHavilland Twin Otter, and Lockheed P2V (all fixed-wing aircraft) and Bell 205 and 206B helicopters. Survey transects were 0.9 km (0.5 miles) on each side of the aircraft. Transect width was maintained with fixed reference points on the windows and wing struts or floats. Surveys were flown at altitudes of 91.5 meters (300 feet). All seals (by species) and polar bears observed on these flights were enumerated.

Location and distances traveled along flight tracts were determined by standard aerial navigation techniques, by radar fixes from various DEW-Line stations, or with the aid of GNS-500 system (very low frequency, Omega navigation system).

Ground surveys were conducted on shorefast ice near villages or base camps either on foot or on snow machines. Shipboard surveys were conducted from U.S. Coast Guard and N.O.A.A. ships working near the ice edge.

M. Natural history and behavioral observations are obtained from several sources: 1) field observations by the principal investigators, 2) unpublished field observations of other reliable investigators, 3) reports from Eskimos, and 4) observation of captive animals.

The bulk of the natural history and behavioral observations is recorded by the principal or other investigators while they are on the sea ice, or aboard ships, skin boats, or aircraft. These observations are usually made with the aid of field glasses or spotting scopes and are recorded as field notes with appropriate ecological and behavioral conditions.

Because of the amount of time they spend on the ice pursuing marine mammals, Eskimo hunters can provide a wealth of information concerning behavior and natural history. Interview of several hunters may sometimes be required to separate facts from traditional folklore, or information given just to impress or please the interviewer. Rarely has information been given which is intended to mislead the investigators.

VI-VII. Results and Discussion

A. Field activities and specimen collection

Field activities during the reporting year were conducted extensively throughout our study area. These activities included both collection of specimens and surveys of ice habitats and seal densities and distribution. Specimens were obtained at hunting sites in Nome, Savoonga, Gambell, Shishmaref, Point Lay, Wales, Point Hope, Wainwright, and Barrow. Collections offshore, with the aid of ships, boats, or helicopters, were made in Norton Sound and the Bering, Chukchi, and Beaufort Seas. A complete listing of field activities for the reporting year is presented in Table 1.

During reporting year 1977-1978, specimens were obtained from 487 ringed seals and 215 bearded seals (Table 2). Measurements, jaws, claws, stomachs, reproductive tracts, and parasitological material were obtained from most specimens. All specimen material is processed as rapidly as possible.

Of the 487 ringed seals obtained, 246 were males and 235 were females; a 1:1 sex ratio ($P > 0.05$). Similarly 128 bearded seal (90 males and 118 females) were found to have a 1:1 sex ratio ($P > 0.05$).

B. Ringed seal

1. Population characteristics

<u>Sex ratio</u>

A sample of 3,264 postnatal ringed seals obtained by Alaska Department of Fish and Game personnel from 1973 to the present

Table 1. Schedule of field activities, April 1977 - March 1978.

Date	Location	Activity	Personnel
April-March	Fairbanks	Examination of seal specimens and analyses of data	Eley, Burns
April-March	Fairbanks	Data management	Frost, Eley, Burns, Lynn
April	OSS SURVEYOR (southern Bering Sea)	Collection of seal specimens and seal and ice surveys	Burns, Lowry, Frost
April	Barrow	Collection of seal specimens	Eley
May	OSS DISCOVERER (Bering Sea)	Collection of seal specimens	Lowry
May	Point Hope	Collection of seal specimens from native harvest	Seaman
June	Nome	Collection of seal specimens	Frost
June	Wales	Collection of seal specimens from native harvest	Seaman
June	Point Lay to Barter Island	Aerial surveys of seals and ice	Eley, Burns
June	Fairbanks	Preparation of quarterly report	Eley, Burns
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
September	Fairbanks	Preparation of quarterly report	Burns, Eley
October-November	Shishmaref	Collection of seal specimens	Tremaine
October	Fairbanks	Attended OCSEAP seabird and marine mammal meeting	Burns, Eley
November	Prudhoe Bay	Collection of seal specimens	Eley, Lowry
November	Barrow	Collection of seal specimens	Eley, Burns
November	Nome	Collection of seal specimens	Frost

Table 1. continued.

Date	Location	Activity	Personnel
December	San Diego	Attended marine mammal biology conference	Burns, Eley
December	Seattle	Attended marine mammals-fisheries interactions conference	Lowry, Burns
December	Fairbanks	Preparation of quarterly report	Eley, Burns
January	Anchorage	Game Division meeting	Burns, Eley
January	Barrow	Beaufort Sea Synthesis meeting	Burns, Eley, Frost
January-February	Shishmaref	Collection of seal specimens	Seaman
January-February	Nome	Collection of seal specimens	Seaman
February-March	Gambell	Collection of seal specimens	Seaman
February-March	Kotzebue	Collection of seal specimens	Seaman
February-March	Fairbanks	Collection of seal specimens	Eley, Burns

Table 2. Seal specimens obtained from April 1977 to March 1978.

Location	Males	Females	Sex Unknown	Total
Barrow				
Ringed seal	13	14	1	28
Bearded seal	4	3	-	7
OSS DISCOVERER				
Ringed seal	2	-	-	2
USCGC GLACIER				
Ringed seal	8	8	-	16
Bearded seal	2	3	-	5
Nome				
Ringed seal	12	17	-	29
Bearded seal	7	1	1	9
Point Hope				
Ringed seal	23	8	-	31
Prudhoe Bay				
Ringed seal	13	10	-	23
Bearded seal	1	1	-	2
Shishmaref				
Ringed seal (July-Sept)	137	147	4	288
Ringed seal (Oct-Dec)	10	7	-	17
Ringed seal (Jan-Feb)	19	15	-	34
Bearded seal (July-Sept)	63	88	-	151
Bearded seal (Oct-Dec)	7	7	-	14
OSS SURVEYOR				
Ringed seal	-	1	-	1
Bearded seal	3	7	0	10
Wainwright				
Bearded seal	-	4	-	4
Wales				
Ringed seal	9	8	1	18
Bearded seal	3	4	6	13
TOTAL				
Ringed seal	246	235	6	487
Bearded seal	90	118	7	215

consisted of 1,626 (49.8%) males and 1,638 (50.2%) females which was a 1:1 sex ratio ($P > 0.05$). An even sex ratio in postnatal ringed seals also has been reported by other investigators (McLaren 1958, Johnson et al. 1966, Smith 1973). Males and females appear in approximately equal proportion throughout the year except during the spring (March and April) when males are more accessible to subsistence hunters. Females are involved in pupping activities and are apparently unavailable to hunters. A 1:1 sex ratio was also found in most age groups (Table 3). The sex ratio of 73 fetal ringed seals (36 males and 37 females) was essentially 1:1. A 1:1 fetal sex ratio has also been reported for ringed seals by other investigators (Johnson et al. 1966, Smith 1973).

Table 3. Sex and age structure of 3,264 ringed seals collected in the Bering, Chukchi, and Beaufort Seas (1973-1977).[1] Most seals were taken by coastal subsistence hunters.

	Males			Females		
Age	Numbers	Percent of all males	Percent of age cohort	Numbers	Percent of all females	Percent of age cohort
Pup	399	24.5	51.2	381	23.3	48.8
1	245	15.1	51.0	235	14.3	49.0
2	150	9.2	54.0	128	7.8	46.0
3	86	5.3	47.0	97	5.9	53.0
4	82	5.0	42.9	109	6.6	57.1
5	95	5.8	46.8	113	6.9	53.2
6	105	6.4	51.2	100	6.1	48.8
7	99	6.1	51.0	85	5.2	49.0
8+	365	22.6	48.3	390	23.9	51.7
Total	1626	100.0	49.8	1638	100.0	50.2

[1] Older age classes will be subdivided in a subsequent analysis as the laboratory processing of teeth, used for determining age, is not completed.

Longevity and mortality

The oldest ringed seal collected during this study was a 29-year-old male. The maximum age for a female was 28 years. Ringed seals in excess of 30 years have been reported from the Canadian Arctic and it has been suggested that ringed seals may attain an age of 40 years (Smith 1973). The majority (93%) of the Alaskan specimens, almost all taken by subsistence hunters, were 11 years old or younger.

Life tables were prepared, following the techniques of Caughley (1966, 1977) to analyze the mortality rate of male and female seals seven years old and younger (Tables 4 and 5). The behavior of ringed seals when hunted appears to be such that no selectivity is possible by the hunter as all that is generally observed is a head sticking out of the water or a seal hauled out on the ice. Discrimination of sex or age is not readily apparent. A collection of seals from a specific area at a certain season is a good indication of what age or sex groups are present. Additionally, collections of seals from a wide geographic area, taken throughout the year, are a good index of the sex and age structure of the population (Fedoseev 1965, Smith 1973).

Table 4. Life table for 1,626 male ringed seals.

Age	# Killed fx	# Killed/1000 dx	# Survivors/1000 lx	Mortality rate (%)	Survival rate (%)
Pup	399	245	1000	24	76
1	245	151	755	20	80
2	150	92	604	15	85
3	86	53	512	10	90
4	82	50	459	11	89
5	95	58	409	14	86
6	105	64	351	18	82
7	99	61	287	21	79
7+	365	-	226	-	-

Table 5. Life table for 1,638 female ringed seals.

Age	# Killed fx	# Killed/1000 dx	# Survivors/1000 lx	Mortality rate (%)	Survival rate (%)
Pup	381	233	1000	23	77
1	235	143	767	19	81
2	128	78	624	12	88
3	97	59	546	11	89
4	109	66	487	14	86
5	113	69	421	16	84
6	100	61	352	17	83
7	85	52	291	18	82
7+	390	-	239	-	-

The mean annual mortality rates for both male and female ringed seals were 20 percent (Tables 4 and 5). Male and female seals had the same range (0-50%) in mortality rates, and the standard deviation of the rate of males (9.66) was not significantly different ($P > 0.05$) from that of females (9.35). The trends in mortality patterns, as exhibited by the life table, were essentially the same in males and females. The mortality rate is high for pups and the rate lowers during the juvenile years (1-7 years). Our sample of seals older than age seven remains to be completely analyzed.

Pathology and parasitology

A considerable amount of material for pathological and parasitological examination has been collected by this project and Research Unit 232. The bulk of this material has been given to Drs. F. H. Fay and R. A. Dieterich and Mr. L. M. Shults (RU #194 - Morbidity and Mortality of Marine Mammals) for examination, analyses, and reporting.

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 6. A paper on the status and effects of *Dipetalonema spirocauda* on Alaskan marine mammals is in the early stages of preparation, and will be enclosed as part of a future quarterly report.

Table 6. Examinations for marine mammal heartworms (*Dipetalonema* (*Acanthocheilonema*) *spirocauda*).

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

Polar bear predation

Of 71 pinnipeds killed by polar bears examined thus far, 65 (92%) were ringed seals, 5 (7%) were bearded seals, and 1 (1%) was a walrus (Table 7). The 65 ringed seals examined consisted of 34 (52%) males. This bias toward males appears to be due to the fact that most specimens were obtained during March and April when females are involved in birth activities and apparently not readily accessible to bears. The sex composition of ringed seals killed by bears was not significantly different from the sex composition of seals taken by subsistence hunters in nearby villages during the spring (Table 8). Adult ringed seals (older than 6 years of age) were taken most commonly by bears, followed by juveniles (1-6 years old). Pups (less than 1 year old) were the least common age class taken by bears. The five bearded seals killed by bears included two pups and three one-year-olds. The sex ratio approached 1:1. The single walrus was a female calf. It appears that the sex and age composition of seals killed by bears is reflective of availability rather than a selectivity towards an age or sex group. These findings contrast somewhat with those of Stirling and Archibald (1977) who found pups to be important to bears in most years in the western and eastern high Canadian Arctic. Although ringed seals are the most abundant pinniped along the northwestern Alaska coast in spring, and appear as the most abundant seal taken by both bears and Eskimo hunters, it is not known whether bears are selecting ringed seals because of their relative abundance or because of the relative ease of capture as compared to bearded seals and walrus.

Table 8. Comparison of sex and age structure of ringed seals killed by polar bears and native hunters during March - May.

	Sex Composition		Age Composition		
	males(%)	females(%)	adult(%)	juveniles(%)	pups(%)
Bears	24(79)	9(21)	23(56)	16(39)	2(5)
Hunters	60(80)	15(20)	44(54)	30(37)	8(9)

Approximately 210 hours of aircraft surveys have been flown in the polar bear predation study. These cover three major ice types (shorefast ice, flaw zone, and moving pack ice) in approximately equal time proportions. Forty (56%) of the kills have been in the flaw zone ice, 17 (24%) on moving pack ice, and 14 (20%) on shorefast ice. Bears appeared to be more successful in flaw zone ice due to the abundance of newly formed leads which allowed more access to seals via breathing holes. Forty-seven (66%) of 71 seals killed by bears were taken at breathing holes.

Bears were relatively unsuccessful in obtaining ringed seals from lairs. Only 22 seals were killed in 107 lairs excavated (21%) by bears. Sixty seal lairs (56%) were excavated on shorefast ice and 47 (44%) lairs were on pack ice. No excavated lairs were noted in the flaw zone. The densities of ringed seal lairs in the various ice types are unknown; however, the preferred habitat of breeding female ringed seals is the shorefast ice. Stirling and Archibald

Table 7. Species, sex and age composition of 71 pinnipeds killed by polar bears.

Species Composition			Sex Composition			Age Composition		
	number	percent	males(%)	females(%)	unknown(%)	adults(%)	juveniles(%)	pups or calves(%)
Ringed seal	65	92	34(52)	9(14)	22(34)	23(56)	16(39)	2(5)
Bearded seal	5	7	2(40)	2(40)	1(20)	-	3(60)	2(40)
Walrus	1	1	-	1(100)	-	-	-	1(100)
Total	71	100	36(51)	12(17)	23(32)	23(49)	19(40)	5(11)

(1977) found that bears in the eastern and western Canadian Arctic were successful in obtaining seals in only 8 percent of lairs excavated.

The walrus calf and one bearded seal pup were the only pinnipeds killed by bears after being stalked on the ice. No observation of bears killing seals swimming in leads or open water were obtained.

Bears fed predominantly on the hide and blubber and abandoned a considerable amount of meat. In 52 percent of the kills examined, more than 50 percent of the carcass was abandoned. Forty-two (91%) of 46 kills had all of the hide and blubber consumed except that on the head. The four cases (9%) where the hide and blubber were not consumed consisted of pups (2 bearded seals and 2 ringed seals), which do not have a thick layer of blubber. The hide and blubber are preferentially taken, apparently due to the high energy value of these tissues (Stirling and McEwan 1975). The abandoned carcasses are consumed by other bears or more often by arctic foxes. When two or more bears are on a kill the larger bear gets the hide and blubber and the smaller bear gets the rest of the carcass. The division of a carcass between a sow and cubs is unclear, but essentially the whole seal is consumed.

Two (10%) of 20 kills examined at Cape Lisburne during March and April of 1976 were cached by bears apparently for later use. Seals were buried under 1 m of snow and ice and the bears (1 boar, and 1 sow with 2 cubs-of-the-year) were within 0.5 km of the cached seals, resting or sleeping on pressure ridges.

Best (1977) found that a minimum of one ringed seal every 6.4 days was required by bears to meet their energy requirements of free existence. This estimate was derived from nutritional data on captive bears at Churchill, Manitoba. Marking, tracking, and resighting data on bears along the western Alaska coast in spring (Eley, unpubl. data) indicate a seal was killed on the average every 6.5 days. Using the estimates of 6500 bears in the western Alaska population and 2500 bears in the northern Alaska population (Lentfer, pers. comm.) a gross estimate of the number of seals killed by bears is possible. A maximum of 365,000-371,000 seals would be killed per year by 6,500 bears and 140,000-143,000 seals would be killed by 2,500 bears.

These predation figures asssume that the one seal killed every 6.4 days is constant throughout the year and does not take into consideration the fact that during certain seasons of the year larger prey, such as bearded seal and walrus, may be more available than ringed seal. Theoretically fewer of these larger prey would have to be killed to meet the bears' energy requirements if: 1) bears would cache these larger carcasses, and reutilize them at a later date; or 2) bears were able to store the excess energy, available from these large prey, as fat for later energy mobilization. In addition, the predation figures did not take into account pregnant females that would be denning for five to six months and not hunting. The reproductive cycle of Alaskan polar bears averages 4.13 years (Lentfer 1976) and 57.6 percent of the female population are potential breeders (Stirling et al. 1975). The sex ratio of bears appears to be 1:1 (Stirling et al. 1975). During a given year the western Alaska bear population would be comprised of 453 pregnant females and the northern Alaska population of 174 pregnant females. "Correcting" the predation figures to account for denning females results in an estimated 352,000-358,000 seals killed by the western Alaska population per year and 135,000-138,000 seals killed by the northern Alaska bear population.

Indices of ringed seal abundance

Successful feeding and reproduction are tantamount to the survival of all species. Therefore, the goal of seal management should be to protect these critical feeding and reproduction areas from unnecessary disturbance or disruption. These critical areas change temporally and spatially and, considering the dynamic state of the sea ice ecosytem, there can be large spatial changes in the location of critical areas in a short period of time. Habitat selection by ice inhabiting pinnipeds has been aptly discussed by Fay (1974) and Burns (1970), and the reader is referred to those papers for a fuller discussion. Breeding adult ringed seals are found primarily (but not entirely) associated with shorefast ice, while the bearded seal is associated with many ice types and overlaps with all ice-associated pinnipeds in the study area.

Critical areas are ascertained first by determining seal densities in various locations and then by correlations of densities with observed or measured ice, behavioral, ecological, or oceanographic conditions. In June 1970, 1975, 1976, and 1977 ringed seal surveys were conducted by airplane over the shorefast ice from Barter Island to Point Lay. In addition, the 1976 survey was expanded to cover the shorefast ice from Point Hope to Cape Krusenstern and Kotzebue Sound and the pack ice of the Beaufort and Chukchi Seas. The results of these surveys are presented in Table 9.

These densities should not be considered absolute densities as the figures are not corrected for "unseen" animals (Hansen 1968, Enright et al. 1969). The density figures should be used as indices of abundance. We are unsure, at this time, of the relationship of molting seals to breeding seals in an area of fast ice. Burns and Harbo (1972) used counts of dispersed seals as an index of breeding seals since many dispersed seals were seen hauled out in collapsed lairs or were mother-pup pairs. However, substantial numerical data are not available to support this breeding index hypothesis. We hopefully will provide these data during our future survey data analyses.

The areas of highest mean densities (Cape Krusenstern-Point Hope; Cape Lisburne-Point Lay; Wainwright-Barrow; Barrow-Lonely)

Table 9. Ringed seal densities (observed seals/mi^2) calculated from 1970, 1975, 1976, and 1977 surveys.

Location	1970	1975	1976	1977
Kotzebue Sound	-	-	0.7	-
Cape Krusenstern-Pt. Hope	-	-	2.3	-
Pt. Hope-Cape Lisburne	-	-	0.9	-
Cape Lisburne-Pt. Lay	-	-	4.9	-
Pt. Lay-Wainwright	5.4	2.9	1.9	3.3
Wainwright-Barrow	3.7	6.2	3.8	2.6
Barrow-Lonely	2.3	2.8	1.4	1.0
Lonely-Oliktok	1.0	1.4	1.1	0.5
Oliktok-Flaxman Island	1.4	1.0	1.4	0.7
Flaxman Island-Barter Island	2.4	1.8	0.4	1.2
Chukchi Sea-moving pack ice	-	-	0.2	-
Beaufort Sea-moving pack ice	-	-	0.1	-

are normally areas of very stable shorefast ice during late winter and spring. Within these larger areas there are variations in the density of ringed seals which appear to be dependent on the quality of shorefast ice. For example, between Cape Krusenstern and Point Hope the mean density was 2.3 ringed seals per square mile, yet within this larger area the densities varied from 0.2 seals per square mile near Kivalina (early breakup of shorefast ice) to 3.8 seals per square mile near Cape Thompson (stable shorefast ice).

The most stable shorefast ice is found either along complex coasts or along coasts where the 10-fathom line lies far offshore. The edge of the shorefast ice tends to coincide with the 10-fathom curve. The higher densities in the Chukchi Sea are probably reflective of the better ice condition together with higher overall biological productivity of the Chukchi as compared to the Beaufort Sea.

The densities of molting ringed seals in the moving pack ice are considerably less than in the shorefast ice (Table 9). However, circumstantial evidence obtained during our March-April 1978 field work (95 to 140km north of Prudhoe Bay, Alaska) indicates that the stable pack ice may be more important to breeding ringed seals than previously has been assumed. Perhaps ringed seals are responding to the stability of ice combined with available food rather than shorefast ice versus pack ice. The shorefast ice of the Chukchi Sea is much more stable than the Chukchi pack ice during the breeding and molting season, but the pack ice and shorefast ice appear essentially equal in stability during March to June in the Beaufort Sea.

A detailed "population" analysis will be presented in a future report. However, several trends are apparent at this time. Densities of ringed seals throughout the Beaufort Sea have declined approximately 50 percent between 1970 and 1977 and this decline is apparently due to heavy ice during 1975 and 1976 (Stirling et al. 1975, Burns and

Eley 1977). Ringed seal densities in the northern Chukchi Sea have decreased approximately 35 percent from 1970 to 1977. In more southerly areas such as Norton Sound, Bering, and southern Chukchi Seas there appears to have been an increase in ringed seal densities. In March of 1977, we surveyed 177.4 mi^2 of Norton Sound and observed 149 ringed seals. This is a density of 1.27 seals per square mile, and it is a high density for March in Norton Sound. Apparently what has happened is a net western and southwestern displacement of ringed seals from the Beaufort and northern Chukchi Seas into areas of more favorable ice conditions. If ice is the proximate causative factor for the decline, then we should see a gradual increase in ringed seal densities after the better ice years of 1977 and 1978. Based on subjective feelings, more ringed seals were in the Barrow area in March and April of 1978 as compared to March and April of 1977.

Although the densities (indices of abundance) have decreased since 1970, the density figures alone may not indicate the whole story. The density figures are not significant unless they are combined with areal measurements of ice to obtain "population estimates" for the various coastal sectors. For example, a smaller density of seals in a given coastal sector may still yield the same population estimate as a larger density if different areas of ice are involved. The ice data are being prepared at this time by Dr. W. J. Stringer and his group (RU #257) at the University of Alaska and will be presented in our population analyses report.

In our 1978 surveys and subsequent analyses we will be investigating the effects of human disturbance on seal densities and we will be looking specifically at seismic activities. We have seen in previous surveys that densities decrease in the vicinity of coastal villages (Fig. 1) and these decreased densities apparently are due to disturbance by snow machines and general village activities rather than by hunting. The same general trends are seen around villages whether or not much hunting is accomplished by the residents of the village. Oil exploration activities are becoming more and more prevalent on the shorefast ice of the Beaufort Sea and it is imperative that we understand what perturbations these activities may cause.

2. Growth and indices of condition

<u>Growth</u>

The embryonic and fetal development of the ringed seals is one of the parameters that influences fertility. Embryological development is usually considered as a continuous process of growth and differentiation from the formation of the zygote to parturition. Growth and differentiation appear continuous, albeit slow, during the 3-1/2 month delay before implantation, but the factors that affect the rate of growth and differentiation are unknown.

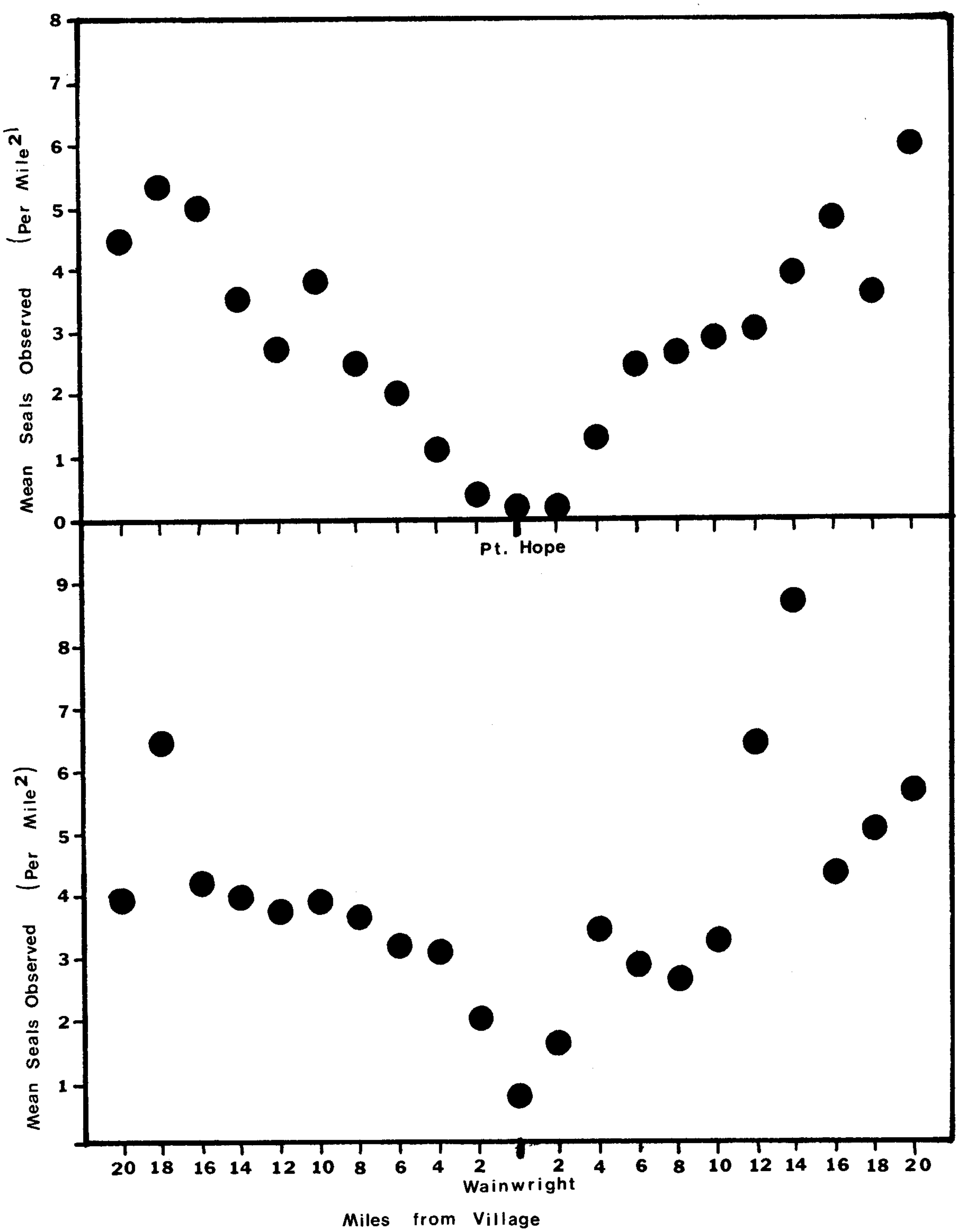

Figure 1. Observed densities of ringed seals in the vicinity of two Alaska villages.

Female ringed seals appear to be impregnated in late April or early May, soon after the birth of the pup. Impregnation is followed by a delay of up to 3-1/2 months before implantation, in late August. Mean implantation date appears to be around 25 August. Implantation appears to occur over a long period extending from early August to mid-September. Prenatal growth in length is essentially linear throughout the fetal period (Fig. 2). Prenatal weight gain is initially linear. It increases rapidly during mid-pregnancy and approaches asymstotic growth during late pregnancy (Fig. 2). The growth curves for ringed seals taken in Alaskan waters are similar to those for ringed seals in Canada (McLaren 1958, Smith 1973).

Seven newborn (less than 4 days old) ringed seals averaged 4.7 kg in weight (range 3.9kg-5.2kg). The mean weight of 10 full-term fetuses was 3.8 kg. The mean weights of male and female pups at birth are not significantly different ($P > 0.05$), although the sample size is small (3 males and 4 females).

Pup weights increase steadily from birth until weaning in late May or early June (Fig. 3). In late June and early July the weights of pups decrease somewhat as the pups adjust to life on their own. In mid- and late July pups' weights increase steadily, leveling off in August and September. The mean weights of male and female pups generally do not differ ($P > 0.05$); however, more variation is evident in the weights of males than of females.

Blubber thickness over the sternum increases from 0.5 cm or less at birth to an average of 2.6 cm in May and early June. During mid- and late June and July, the blubber thickness decreases to a mean of 1.1 cm and this decrease in thickness is probably associated with the loss of weight immediately after weaning. By August mean blubber thickness has increased to 1.9 cm and then levels out at a mean of 3.0 cm from September to February. There appears to be no difference in blubber thickness between male and female pups ($P > 0.05$).

The lengths of pups increased steadily from birth and appeared to begin leveling out in August and September (Fig. 3). The mean lengths of male and female pups did not differ ($P > 0.05$) and variation in length was approximately equal in the two sexes.

Increase in weight (Fig. 4) of ringed seals is most rapid during the first five or six years of life and begins to level off during the seventh to ninth years. In our samples, maximum weights were achieved during the eleventh to fourteenth years of life. From birth through the second year of life the weights of male and female ringed seals are not significantly different ($P > 0.05$). After two years of age male ringed seals are slightly heavier than females (Fig. 4) until the seventh year when females exceed males in mean weight. The majority of females seven years old and older are pregnant and the weight of a fetus and placenta (up to 6kg) results in higher mean weights for females.

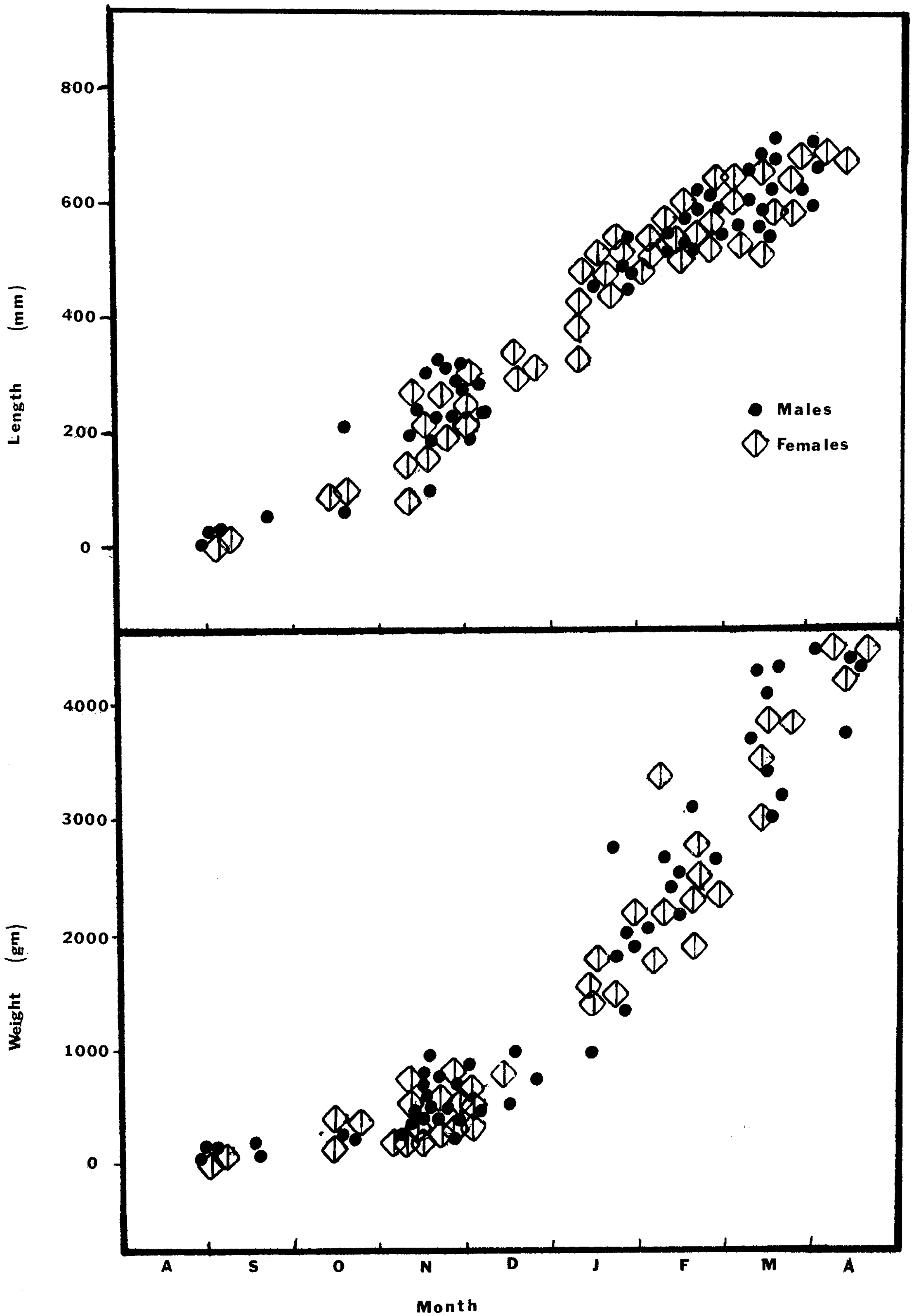

Figure 2. Growth of ringed seal fetuses taken in Alaska (standard length and weight) from implantation to birth.

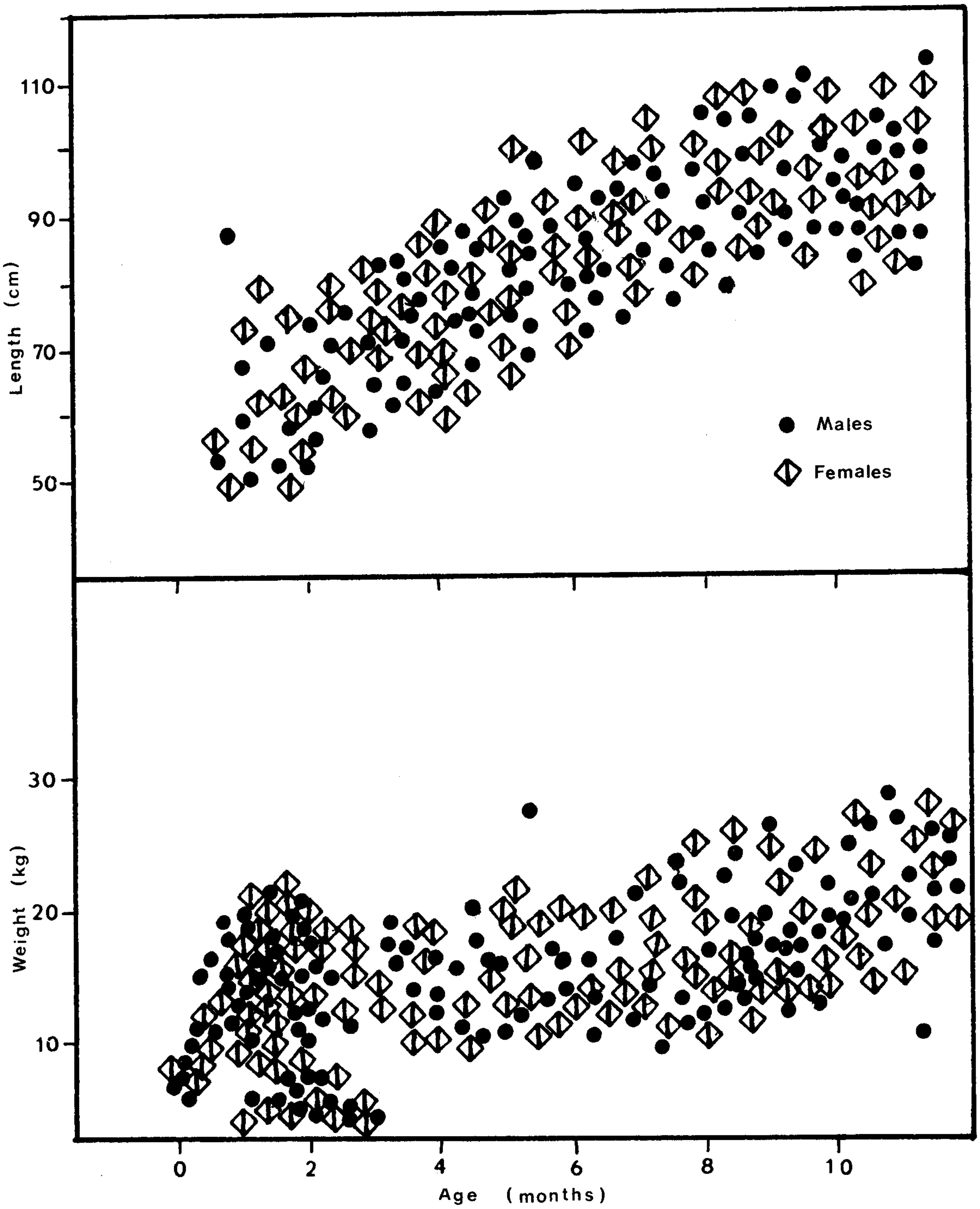

Figure 3. First year growth in standard length and weight of ringed seals.

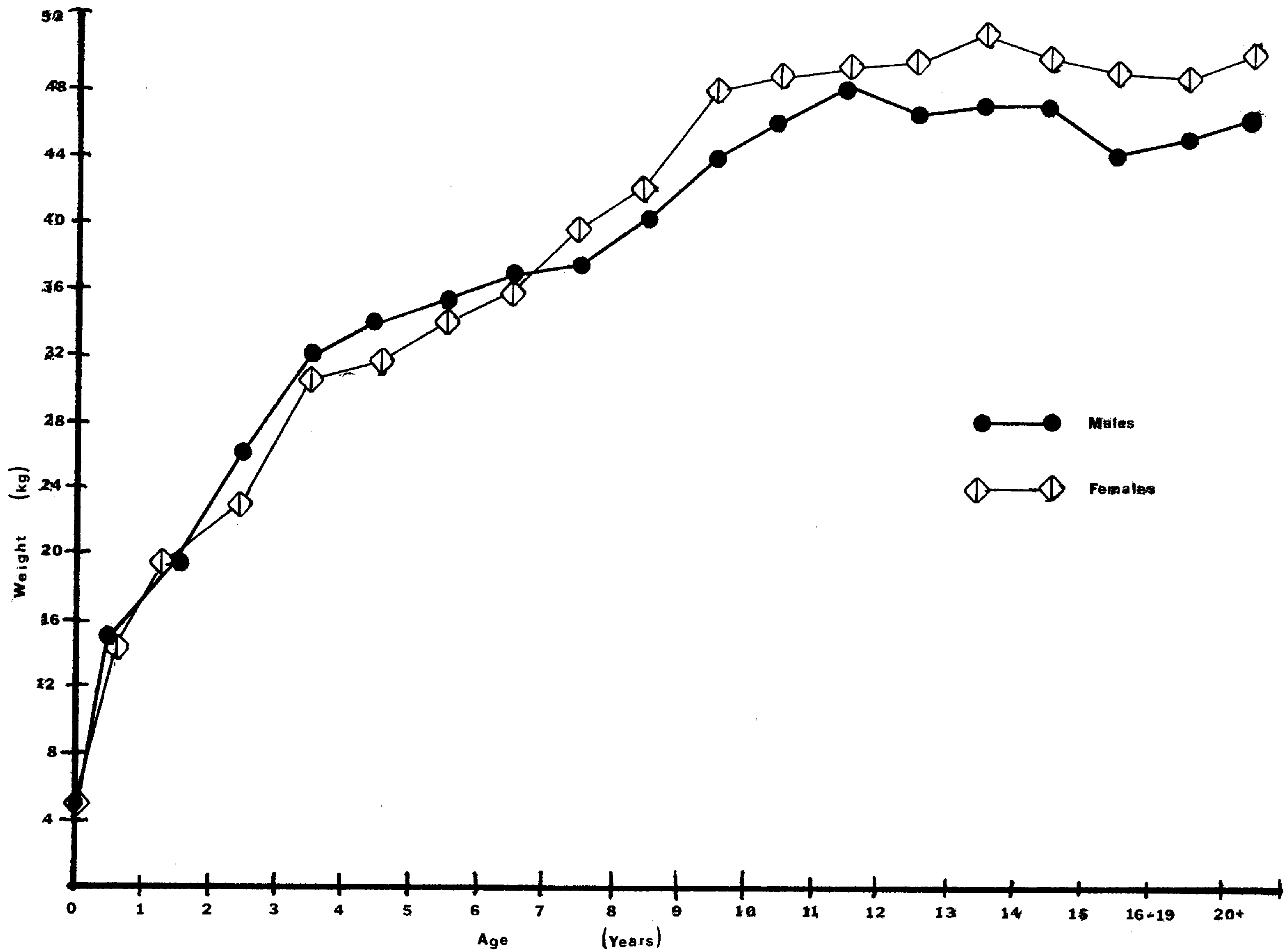

Figure 4. Weights of ringed seals taken in Alaska by age class.

Growth in skeletal size, as measured by standard length, is most rapid during the first six years of life (Fig. 5) and then skeletal growth tends to level out somewhat after the eighth year. Males are generally larger in standard length throughout life but this difference is not significant. The larger difference between males and females between the seventh and twelfth years apppears to be due to sampling bias. Maximum standard lengths are achieved during the eleventh to fifteenth years of life.

Ringed seals are the smallest of all pinnipeds in Alaska. The largest adult female recorded for Alaska was 187 cm in length and the largest male 146 cm. The heaviest ringed seals examined by us thus far were a 111.0 kg pregnant female, taken in March, and a 90.0 kg male, taken in January. However, the weight of an individual varies with age and season. Heaviest weights are achieved by adults in winter and early spring when the seal has a heavy layer of fat or blubber under the skin. This blubber is used for insulation and as an energy source during the breeding and pupping seasons. The weights of ringed seals decline with the decrease in feeding during the reproductive and molting season.

Indices of condition

Three measures of physical condition of Alaskan ringed seals have been analyzed thus far: total weight, blubber thickness, and a physical condition index (axillary girth/standard length x 100). These three indices are direct or indirect measurements of subcutaneous fat, with the assumption that high subcutaneous fat levels are synonymous with good physical condition. A comparison of other methods of determining physical condition, such as blood sera constituents, with fat level indices has not been made but would be quite useful.

The three measures of physical condition are compared in Figure 6. All three indices show the same general trends. There was no difference between sexes. The data for males and females are combined in the figures. Physical condition (amount of depot fat) is highest in January and February. During the birth and breeding periods (March-May) feeding appears to decline; therefore, more fat is metabolized and condition begins dropping to lower levels. Reduced feeding continues into June and early July as the seals molt. Ringed seals spend a considerable amount of time basking on the ice on sunny and warm days during the molt. Apparently the warmth and rest are required for rapid regrowth of hairs (Feltz and Fay 1966). In late July and August feeding intensifies and physical condition steadily increases.

Body size, growth rates, and indices of condition are indicators of a pinniped population's relationship to food resources. If abundant food is available less time and energy are expended in obtaining food. Whereas, if less food is available, more time and energy must be expended in foraging and meeting the body's minimal

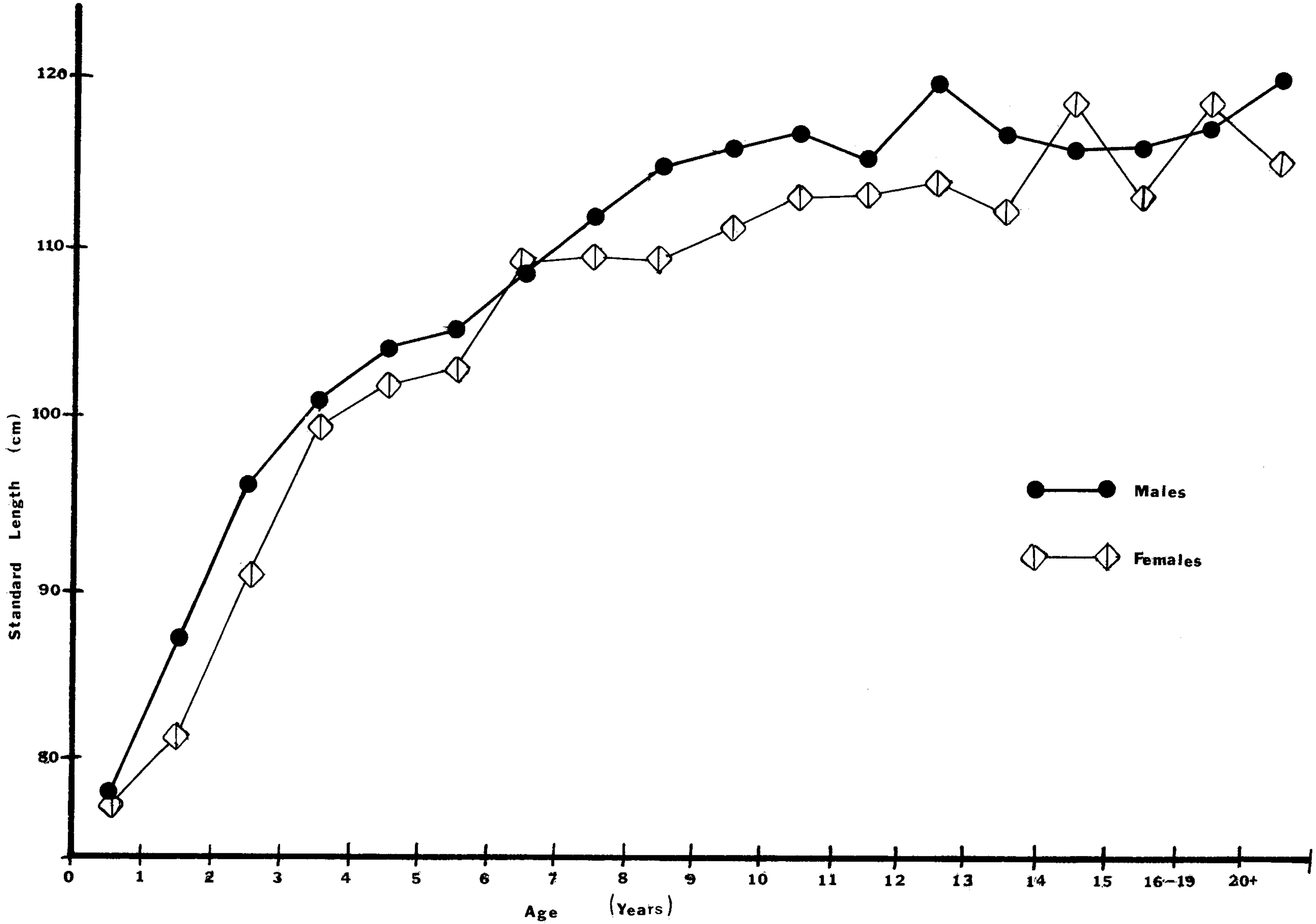

Figure 5. Standard lengths of ringed seals taken in Alaska by age class.

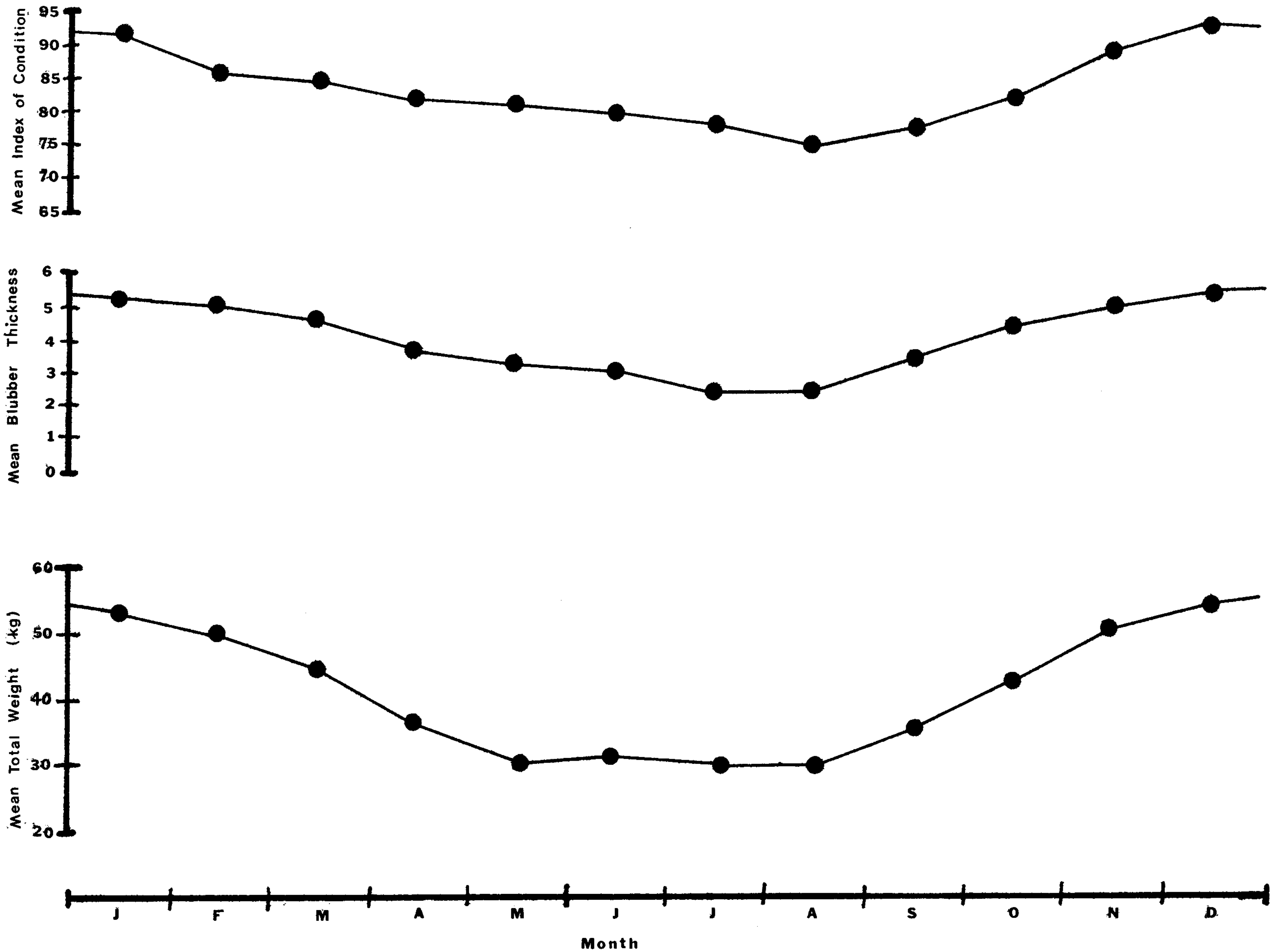

Figure 6. Indices of condition for both sexes and all ages of ringed seals older than pups, taken in Alaska.

energy requirements and less time and energy are available for other functions. Increases in body size, growth rates, and indices of condition by natural improvement, reduction in the number of seals, or artificial enhancement of food resources may result in a reduced age of sexual maturity and increased population productivity. Conversely, a reduction in food resources by natural or artificial perturbations (heavy ice, oil spills, or chronic exposure to toxic pollutants) of ringed seal habitat could result in an increased age of sexual maturity and decreased pregnancy and survival rates thereby resulting in decreased population productivity.

3. Reproduction

Pupping

Detailed observations and data on pupping and related activities have not been obtained. Most of our logistic support has been available either before or after the pupping season. However, some opportunistic data have been gathered. Seven newborn ringed seal pups were obtained between 31 March and 17 April which confirms the mid-March to late April pupping period reported by McLaren (1958). Ringed seals give birth to their pups in subnivean lairs on landfast, flaw zone and moving pack ice; however, landfast ice is the preferred habitat. The structure and function of the birth lair is discussed in detail by Smith and Stirling (1975). The basic function of the lair is protection from weather and predators. Ringed seals mate soon after the birth of the pup.

The young begin to shed their white fetal pelage about two weeks after birth and have grown their first-year pelage by mid- to late May (McLaren 1958). The female apparently stays with the pup until breakup of the ice in early to mid-June when weaning takes place (McLaren 1958). A pup taken on 27 May had milk in its stomach. No milk was noted in stomachs of pups taken in June or July. Pups with adults, in collapsed lairs, were observed during seal surveys as late as 20 June.

Males

The epididymides of 454 male ringed seals (representing all age classes and collected during all seasons) have been examined microscopically for the presence of sperm. The concentration of sperm in an epididymal smear was subjectively quantified as abundant, trace, or none. Males were considered sexually mature if abundant sperm were found in a smear and if the male seal was collected between 1 March and 15 June when ovulation is most likely to occur in females. It was found that males become sexually mature from five to seven years of age (Table 10). Active spermatogenesis was detected in essentially all males seven years old and older. No reproductive senility was noted.

Table 10. Age of sexual maturity in male ringed seals based on the presence of abundant epididymal sperm during the period 1 March - 15 June.

Age (years)	Number examined	Sperm Presence: Abundant (number)	Trace (number)	None (number)	Percent mature
Pup	32	-	-	32	0
1	24	-	-	24	0
2	14	-	-	14	0
3	10	-	-	10	0
4	11	-	-	11	0
5	12	4	1	7	33
6	10	4	2	4	40
7	7	6	1	-	86
8	19	19	-	-	100
9	13	13	-	-	100
10	15	15	-	-	100
11+	24	23	1	-	96

Weight and volume of testes has been used as an indicator of sexual maturity in pinnipeds (Laws 1956, McLaren 1958, Hewer 1964). Plots of testes volumes and weights show exactly the same trends. Only testes volume is illustrated in Figure 7. Testes are enlarged at birth due to the influence of maternal hormones. After birth and throughout the first year of life testicular volume decreases (Fig. 7). The increase in testes volume is slow from ages one to four, when it begins to increase rapidly. Testes volume remains relatively constant after eight years of age. Both testes volume and the presence of sperm in the epididymides indicate that sexual maturity is reached by male ringed seals by age seven or eight, although some are physiologically capable of breeding at an earlier age. However, the relationship between physiological sexual maturity and behavioral sexual (and physical) maturity is unknown. Studies of other pinniped species indicate that physiological maturity is achieved several years before behavioral maturity (Hewer 1964, Orr and Poulter 1967).

The earliest date that sperm was found in male epididymides was mid-December (Table 11) and active spermatogenesis appears to continue until early July. Substantial sperm remains in the epididymides of some males until mid-August. Most adult female ringed seals appear to ovulate in April and May; therefore, the males are physiologically capable of breeding well before and long after most females. A longer season of potential breeding capability also has been reported in other phocid seals (Bigg 1969, Ling 1969). No geographic variation in spermatogenic activity has been detected thus far; however, our sample size from the Beaufort Sea is small.

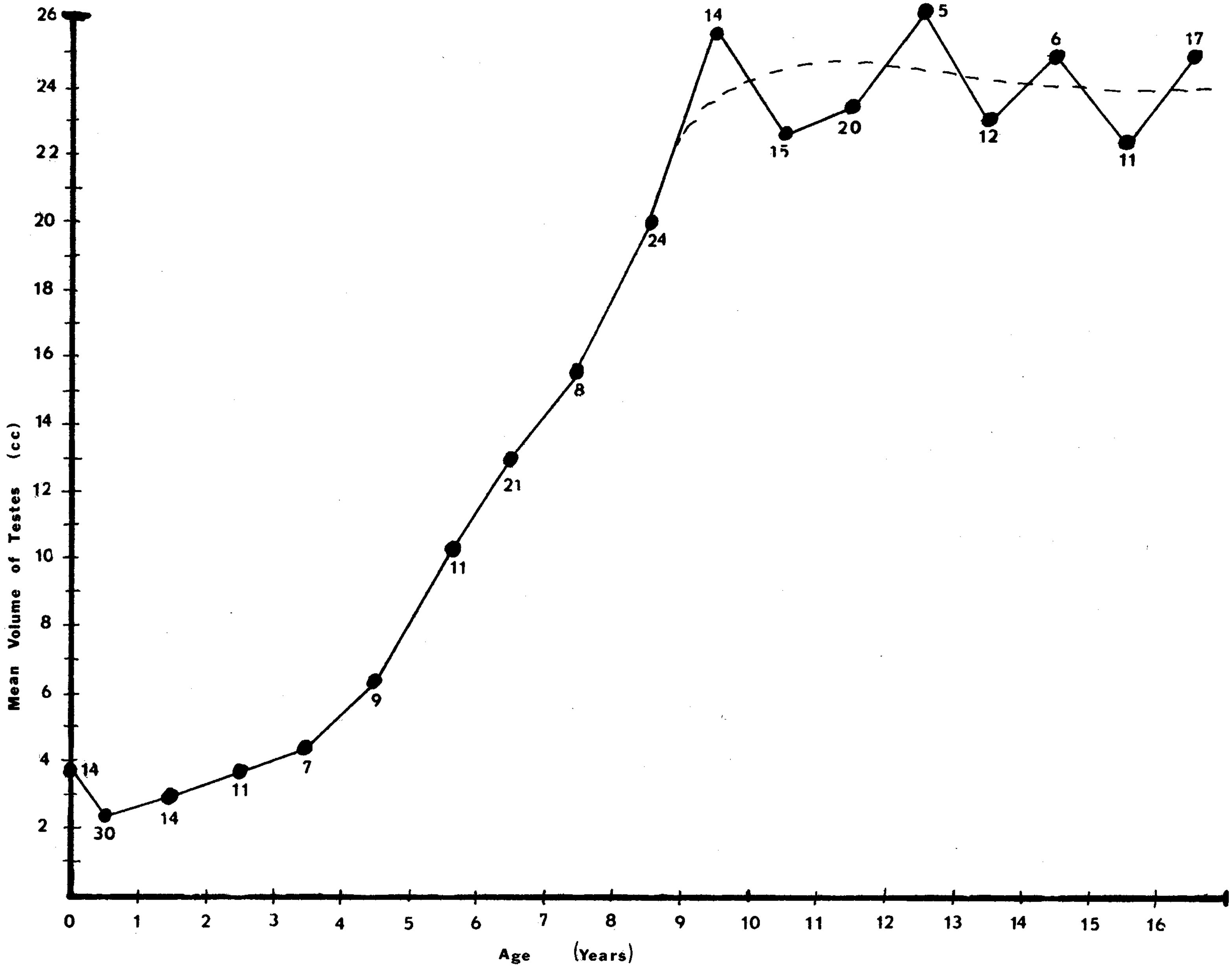

Figure 7. Testes volume of ringed seals taken in Alaska by age class. Sample size indicated near corresponding points.

Table 11. Seasonal variation in sperm presence in the epididymides of male ringed seals seven years old and older.

Month	Number examined	Sperm Presence Abundant (number)	Trace (number)	None (number)
January	17	7	2	8
February	12	5	3	4
March	29	28	1	-
April	20	20	-	-
May	27	27	-	-
June	44	26	8	10
July	32	4	3	25
August	18	1	6	11
September	7	-	-	7
October	2	-	-	2
November	21	-	3	18
December	14	1	1	12

Females

Sexual maturity in the female ringed seal has sometimes been considered as the age at which first ovulation occurs (McLaren 1958, Smith 1973). However, successful pregnancies frequently do not result from these first ovulations. Females may not be behaviorally or physically mature enough to accomplish successful fertilization or implantation. In those cases where fertilization appears to have taken place the blastocyst apparently had failed to implant. In population dynamic and natural history studies, the age at which a female produces her first offspring is a more useful concept, and this age has been termed productive maturity (McLaren 1958). Productive maturity will be the terminology used in this report.

Productive maturity, pregnancy rates, and productivity can only be ascertained with an accurate determination of pregnancy. During the period of delayed implantation, a normal appearing corpus luteum may be found in the ovaries even if a blastocyst is not present (Bigg 1973). In addition, all blastocysts do not necessarily implant, particularly in young females. Only reproductive tracts obtained after the normal period of implantation will be used in calculating reproductive parameters, unless otherwise stated.

Some confusion of meaning has arisen 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.

The examination of 142 females in the ages classes pup to two years of age failed to find any evidence of ovulations. Two (10%) 3-year-old females, three (14%) 4-year-olds, and eight (30%) 5-year-old females had ovulated for the first time but none of these ovulations resulted in a pregnancy. Productive maturity was reached as early as 6 years of age and as late as 10 years of age (Table 12). The majority of females attained reproductive maturity between the seventh and ninth years. All females 11 years of age and older were multiparous. The female that attained reproductive maturity at 10 years of age was collected in 1976 when ringed seal populations were on the decline and pregnancy rates were at a lower level. The female ringed seals attaining reproductive maturity at six years of age were during years (1964, 1967, and 1977) when pregnancy rates and population levels were apparently at higher levels. McLaren (1958) and Smith (1973) found first ovulations in ringed seals as early as four years of age and first pregnancies as early as six years of age in Canada. Pregnancy rates and population levels were high during the years these specimens were obtained. During the recent decline of ringed seals in the Canadian Arctic the same trend was seen: a decline in pregnancy rates and population levels and an increase in the age of reproductive maturity.

Table 12. Reproductive status of female ringed seals.

Age	Nulliparous (%)	Primaparous (%)	Multiparous (%)	Reproductive failures(%)
Pup	54(100)	-	-	-
1	51(100)	-	-	-
2	37(100)	-	-	-
3	20(100)	-	-	-
4	21(100)	-	-	-
5	24(89)	-	-	3(11)
6	23(77)	3(10)	-	4(13)
7	12(54)	9(41)	-	1(5)
8	5(33)	5(33)	3(20)	2(14)
9	1(6)	5(31)	9(57)	1(6)
10	-	1(11)	7(78)	1(11)
11	-	-	8(100)	-
12	-	-	6(100)	-
13	-	-	4(100)	-
14	-	-	4(100)	-
15	-	-	7(100)	-
16	-	-	2(100)	-
17	-	-	4(67)	2(33)
18	-	-	3(100)	-
19	-	-	4(100)	-
20+	-	-	6(67)	3(33)

Ovarian weight can be used as an indirect indicator of sexual and productive maturity. Ovaries are enlarged at birth due to the influence of the maternal hormones. Subsequent to birth and throughout the first year of life ovarian weight decreases (Fig. 8). Growth in ovarian weight is slow but constant from ages one to eight. Ovarian weight remains relatively constant after age eight when most females have attained productive maturity.

Three types of reproductive failures were noted in examinations of female reproductive tracts: 1) failure of the blastocyst to implant or failure in fertilization of ovum, 2) spontaneous abortion of a fetus, and 3) resorption of an embryo. Missed pregnancies resulting from productively mature females failing to ovulate, although a form of reproductive failure, will not be considered in this section (or in Table 12), but will be discussed as part of the section on reproductive rates.

Nine instances of failure of blastocysts to implant or failure of fertilization were noted. All nine cases were in females apparently ovulating for the first time (three 5-year-olds, four 6-year-olds, one 7-year-old, and one 8-year-old). The corpora lutea in the ovaries of these nine females were smaller than normal and were degenerating. No embryos or implantation sites were found in the uterine horns. All nine seals were collected after implantation should have taken place. No corpora albacantia were found in the ovaries of these nine females indicating previous pregnancies. Abortion of a fetus had occurred in one 8-year-old, one 9-year-old, and three females over 20 years of age. The causes of these abortions could not be determined. Three females (two 17-year-olds and one 10-year-old) were found to have fetuses in various stages of resorption. All three females were obtained in Nome. Two females were collected in the spring and one was obtained during the winter. As in the case of abortions, no gross pathological conditions were noted that may have resulted in resorption of the fetus.

In a sample of 33 adult female ringed seals obtained between 1962 and 1973, 30 were or just had been pregnant (Table 13), yielding a pregnancy rate of 91 percent. The reproductive tracts of 44 adult females collected during 1975-1976 have been examined and 31 (70%) were pregnant or recently had given birth. This 70 percent pregnancy rate is undoubtedly high as many females were taken after fertilization and before implantation; therefore, failures in fertilization and implantation are not evident. The pregnancy rate during 1976 and 1977 increased to 81 percent with 13 pregnant females of 16 examined that had been collected after implantation. Specimens examined thus far in 1977-1978 have yielded a 92 percent pregnancy rate, with 12 pregnant females of those 13 examined.

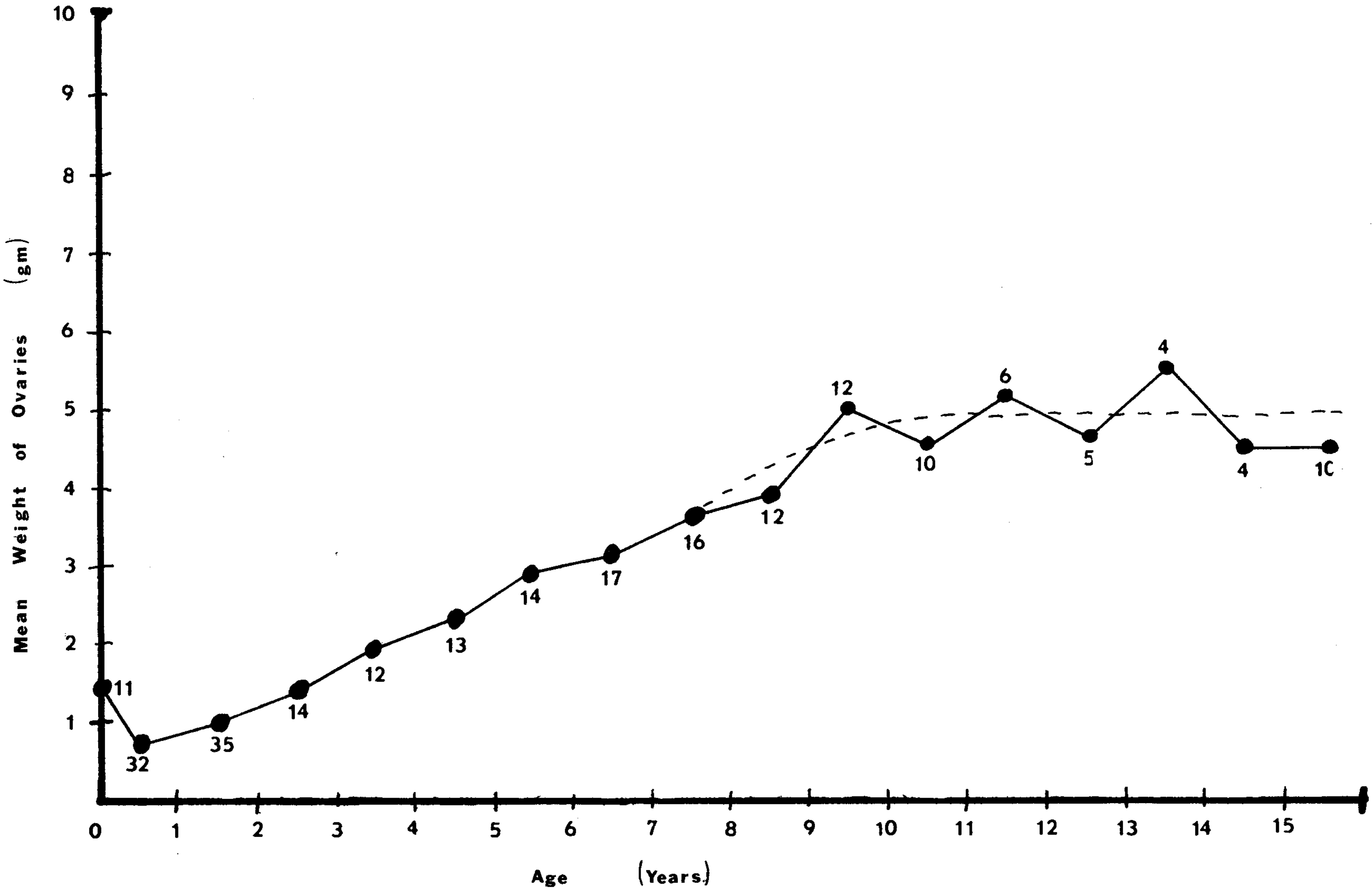

Figure 8. Weights of ringed seal ovaries by age class. Sample size indicated near corresponding points.

Table 13. Pregnancy rates of sexually mature female ringed seals collected by Alaska Department of Fish and Game personnel from 1962 to 1978.

	1962-1973	1975-1976	1976-1977	1977-1978
Number examined	33	44	16	13
Number pregnant	30	31	13	12
Percent pregnant	91	70	81	92

Johnson et al. (1966) found that 240 of 280 (86%) adult females (collected near Cape Thompson, Alaska during 1960 and 1961) were 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 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 were found, respectively (Stirling et al. 1975).

The reasons for these changes in pregnancy rates of female ringed seals are unknown and they are presently under investigation. During the period of reduced pregnancy rates (January 1975 through April 1977) the majority of nonpregnant females apparently did not ovulate. In addition, absorption and resorption were more prevalent than in years with higher pregnancy rates. 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, total weight, and the index of condition (axillary girth/standard length X 100) are good indicators of physical condition of ringed seals. Blubber thicknesses and total weights were separately compared for sexually mature females collected from 1962 to 1977 during essentially the same season and there was no significant difference ($P > 0.05$) in blubber thickness or total weight. The index of condition is a more sensitive measure of condition, but indices of condition during November to April were not significantly different ($P > 0.05$) from 1962 through 1977. However, sample sizes for many months were less than six and several months of several years had no samples at all. Indices of condition during June through September 1975 and 1976 were higher than in previous years. If females were not involved in reproductive activities perhaps they do not decrease in condition as much as those who are reproductively active.

4. Literature review

Approximately 750 literature citations directly and indirectly concerning ringed seals have been recovered from our searches and those of OASIS and its updates. OASIS searches were not as effective in finding older references as were our own searches because OASIS searches did not extend back past 1972 for Biological Abstracts and 1964 for Oceanic Abstracts and Government Report Announcements. In addition, Zoological Record, the best literature citation source for marine mammals, is not searched by OASIS. OASIS search updates have been timely in providing references.

A summary of the literature as related to Alaskan ringed seals was presented in our Annual Report for 1976 and it is summarized as, III. Current State of Knowledge, in this report. The more important references are listed as, XI. References and Literature Cited. A more complete ringed seal bibliography will be presented in a future report.

5. Food habits and trophic relationships

See Annual Report For Research Unit #232, "Trophic relationships among ice inhabiting pinnipeds."

C. Bearded seals

Distribution and seasonal movements

Surveys from ships and aircraft operating in the ice front of the Bering Sea during March-April 1976 and 1977 have provided information about the distribution and relative density of bearded seals in this ice habitat. Also, changes in density between March and April suggest an important aspect of migration in these seals.

Extensive aerial surveys in the front, utilizing a P2V aircraft, were made between 8 and 23 April 1976. These surveys indicated that during that time bearded seals were distributed throughout the front, although the density was low. Figure 9 shows the general distribution of sightings recorded during these surveys.

Surveys utilizing a Bell 206 helicopter launched from the research vessel SURVEYOR operating in the ice front were also made in April 1976 and in March and April 1977.

From 23 to 25 April 1976 surveys utilizing the helicopter were made by K. Frost and L. Lowry. The general survey area was the ice front in southwestern Bristol Bay, at approximately 56°00'N, 163°22'W. A total of 231 nautical miles of transect lines was covered. Width of the strip transect was 0.5 nm. The observed density of bearded seals hauled out on the ice was low: 0.05 per nm^2.

Similar surveys in the ice front, utilizing the ship-based helicopter, were conducted in March and April 1977. Significantly higher densities of bearded seals were seen in March than in April. A comparison of the results of these surveys is presented in Table 14. The low densities recorded in 1976 and 1977 were similar.

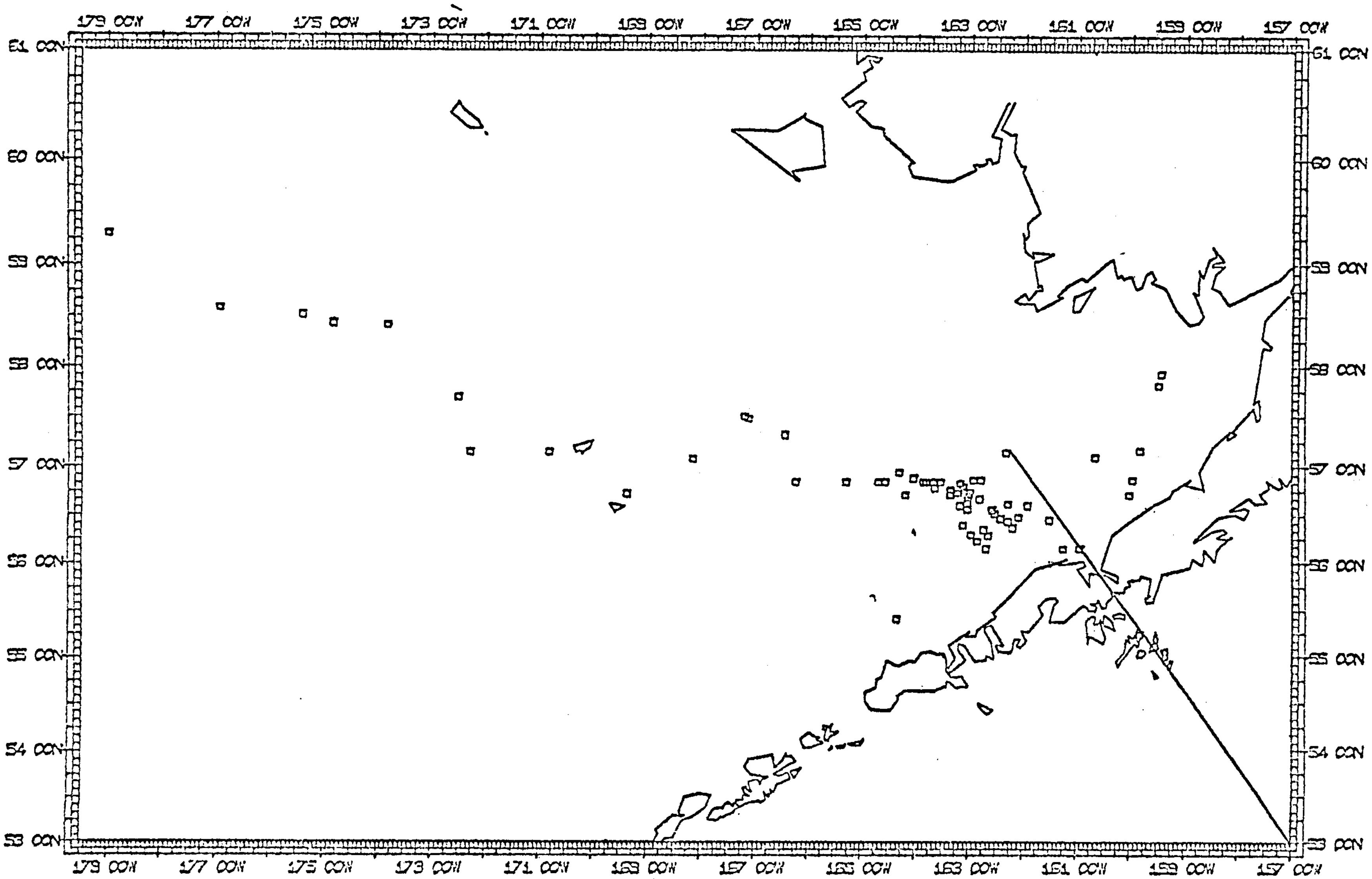

Fig. 9. Combined sightings of all bearded seals observed during surveys within the ice front. Computer map courtesy of H. Braham and B. Krogman, NMFS, Seattle.

Table 14. Results of aerial surveys for bearded seals in the ice front of the Bering Sea during March and April 1977.

Date	Position		General Location	Area Surveyed (nm2)	Bearded Seals observed on the ice	Density/ nm2
March						
27	55°49'	164°25'	SW Bristol Bay	82.7	0	0.0
28	59°08'	169°35'	SW Nunivak Island	103.3	68	0.66
30	58°20'	164°50'	SE Nunivak Island	81.2	16	0.20
April						
21	57°40'	164°55'	SE Nunivak Island	40.6	9	0.22
23	58°30'	169°50'	SW Nunivak Island	199.8	7	0.04
24	58°45'	169°30'	SW Nunivak Island	45.6	1	0.02
25	58°45'	169°30'	SW Nunivak Island	43.9	3	0.07
27	59°40'	174°20'	SW St. Matthew Island	55.9	0	0.00

During 15 days of shipboard operations in the ice front in late May and early June 1977, only one bearded seal was seen.

Surveys in more northerly areas indicate a reverse situation: fewer bearded seals seen in March than in April. In early March 1977 the density of bearded seals hauled out on the ice of Norton Sound, near Nome, was 0.09 per nm^2 during surveys totaling 43.2 nm^2. In comparison, on 20 April 1967, the observed density of these seals on the ice was 0.72 per nm^2 on aerial surveys covering 314 nm^2.

These records support the hypothesis that bearded seals occur throughout the ice-covered regions of Bering Sea, utilize the ice front in comparatively large numbers during winter, and begin an active spring migration which significantly precedes the disappearance of seasonal sea ice. Spotted seals (*Phoca vitulina largha*) and ribbon seals (*Phoca fasciata*) also move seasonally. However, these movements, in the spring-summer period, are correlated more closely to the disintegration of ice.

The shipboard sightings of bearded seals in conjunction with results of aerial surveys have again indicated that, while aerial surveys provide useful information about distribution and *relative* abundance, these surveys underestimate actual abundance because an unknown proportion of seals is not hauled out on the ice. Aerial surveys do, however, provide an accurate count of those seals which are hauled out. A comparison of counts of basking bearded seals, using sightings from the ship as opposed to sightings from the helicopter, indicates that the results are quite similar. On 28 March 1977 aerial surveys indicated a density of 0.66 seals per nm^2. On the following day in the same area the estimated density based on sightings from the ship was 0.64 per nm^2 in an area of 78 nm^2.

Age segregation

In a previous study Johnson et al. (1966) found that at Point Hope there was a "definite preponderance of adults over immature specimens" in the harvests. This was also the situation at Wainwright, in the northern Chukchi Sea, as indicated by the composition of harvests made during July and early August of 1964 and 1965 (Burns 1967).

Circumstantial evidence indicated that the tendency of bearded seals to remain near the ice so long as it occurred over water less than about 150 m was apparently more fixed in adult seals than in the juveniles. Young bearded seals are occasionally taken during the summer months in the ice-free bays, and have been observed several miles up some of the rivers. The periodic occurrence of relatively large numbers of subadult seals in Kotzebue Sound, during the ice-free period, has apparently given rise to the belief that a race of dwarf seals inhabits the area. All of the "dwarfs" we have examined from the area have proven to be sexually immature animals. The reported occurrence of dwarfs was also mentioned by Johnson et al. (1966).

Preliminary information obtained from 1975 through 1977 indicates that pups of the year comprise a substantially higher proportion of bearded seals taken in the Bering Sea than in the Chukchi and Beaufort Seas. Pooled data for these years show that 37.5 percent of 160 seals from the Bering Sea were pups of the year and 13.3 percent of 263 from the Chukchi and Beaufort Seas were pups. Composition of harvests at selected hunting sites is presented in Table 15. Reproductive parameters for sexually mature females from all areas were the same.

It appears that in the course of the northward spring migration adults tend to remain in association with the receding ice while juveniles, particularly pups, occupy more southern, ice-free areas in greater numbers.

Natural mortality of pups also contributes to the lower numbers of this cohort present in the Chukchi Sea during late summer and fall. The magnitude of this mortality is unknown.

Reproduction - female bearded seals

Our sample of female reproductive tracts obtained from 1975 through 1977 includes ovaries from 175 samples. Of these, 64 (37%) were juveniles and 111 (63%) were sexually mature (based on ovulation as indicated by presence of a corpus luteum in either of the ovaries).

Estimation of productivity for the population as a whole has not been accomplished as age determination of all specimens is not yet completed.

One of the important reproductive parameters that has been determined based on this sample is a more precise indication of when implantation of fetuses occurs.

Bearded seals breed from mid-April to mid-May, the period when female seals are in estrous. Males are in breeding condition for a longer period of time than the females. Although the females become impregnated, fetal implantation does not take place until some months after copulation.

Based on a sample of 64 females, which had given birth at least once, and obtained between 26 June and 4 August 1975-1977, fetal implantation begins in early July and occurs, in some females, at least as late as the first part of August. The site in the uterine horn where implantation will occur is obvious at least several days prior to the appearance of a recognizable embryo (one larger than 0.5mm).

Table 15. Proportion of bearded seal pups and animals six years or older in harvests taken at selected locations in Alaska during 1975-1977.

	1975			1976			1977		
Location	N	% Pups	% 6 Yrs. & older	N	% Pups	% 6 Yrs. & older	N	% Pups	% 6 Yrs. & older
Mekoryuk	28	60.7	7.1	0	-	-	0	-	-
Nome	10	10.0	60.0	5	20.0	40.0	14	14.3	50.0
Gambell	9	22.0	77.7	16	56.0	43.7	45	48.9	6.6
Diomede	7	0.0	57.1	14	21.4	71.4	12	25.0	66.0
Shishmaref	3	33.3	66.6	63	14.3	50.8	118	8.4	42.4
Wainwright	33	21.0	39.4	21	14.2	47.6	4	25.0	50.0
Beaufort Sea	0	-	-	5	40.0	20.0	16	18.8	56.2
SURVEYOR Cruise (southern Bering Sea)	0	-	-	1	0.0	0.0	10	30.0	50.0

Table 16 presents a summary of the progression of early implantation. Implantation sites were obvious as early as 26-30 June. However, newly implanted fetuses were not found until 6-10 July.

During the period of implantation almost the entire population of adult bearded seals is in the Chukchi-Beaufort Seas.

Table 16. Stage of implantation in 64 bearded seals obtained between 26 June and 4 August 1975-1977. Included are those females which had given birth at least once.

Dates	Sample Size	Without Obvious Implant Site		Implant Site Without Obvious Fetus		Implanted Fetus	
		N	%	N	%	N	%
June 26-30	14	10	71	4	29	0	0
July 1-5	8	5	63	3	37	0	0
6-10	16	4	25	7	44	5	31
11-15	5	4	80	1	20	0	0
16-20	4	1	25	0	0	3	75
21-25	8	3	38	0	0	5	62
26-30	5	1	20	0	0	4	80
31-Aug.4	4	1	25	0	0	3	75
Totals	64	29		15		20	

VIII. Conclusions

Ringed and bearded seals and associated data have been gathered by the Department of Fish and Game personnel since 1962. However, this annual report covers examinations and analyses conducted between 31 March 1976 and 31 March 1978. Many of our samples and analyses are incomplete at this time and of an ongoing nature. Therefore the results and their preliminary interpretation are considered tentative and are not to be quoted without permission of the Principal Investigators.

Adult ringed seals are mainly associated with the shorefast ice of the Bering, Chukchi, and Beaufort Seas. By virtue of their nearshore habits and numbers, they are important to the coastal residents as a source of food and usable products. Bearded seals are found throughout the pack ice and flaw zone regions. Proposed OCS lease areas in the Bering, Chukchi, and Beaufort Seas are within the habitat of these seal species and pose a real threat to their populations. The objectives of our studies are to develop a baseline of ecological and behavioral data in order to prevent or lessen adverse impacts of outer continental shelf development.

General conclusions are as follows:

1. Ringed seals in Alaskan waters live to be at least 29 years old. Mean annual mortality rates from birth to seven years of age are 20 percent. The mortality rate is higher for pups then decreases slightly. Mortality rates for males and females are similar.

2. Indices of abundance show ringed seals to be more abundant on shorefast than moving ice (in June) and more abundant in the Chukchi Sea than in the Beaufort Sea. Surveys indicate an apparent shift of ringed seals from the Beaufort Sea into the Chukchi Sea during 1976 and 1977.

3. Ringed seals are apparently sensitive to disturbance. The density of ringed seals is low in the vicinity of coastal settlements.

4. Pregnancy lasts approximately 11 months with implantation delayed for about 3-1/2 months after conception. Females appear to be impregated in mid- to late April, soon after the birth of the pup.

5. Pups weigh 4.0 to 5.0 kg at birth and grow rapidly doubling their weight by weaning, two months after birth.

6. Heaviest weights are achieved in winter and early spring when the seal has a heavy, thick layer of blubber. The weights of ringed seals decline with the decrease in feeding during the reproductive and molting season.

7. Active spermatogenesis is found in essentially all seven-year-old and older males collected from March through June. Some five- and six-year-old males also undergo active spermatogenesis.

8. Males are physiologically capable of breeding earlier in the year and long after most females.

9. All female ringed seals seven years old and older appear to be capable of ovulation. Some three- to seven-year-old females are also capable of ovulation. Pregnancy rates have decreased from 91 percent during the period of 1964-1973 to 62 percent for those collected in 1975 and 1976. In 1977 and 1978 pregnancy rates appear to have returned to the 1964-1973 level.

10. In Alaskan waters, polar bears feed primarily on adult, male ringed seals and the bears kill one ringed seal about every 6.5 days during the spring. The hide and blubber are the part of the seal preferred by bears. An estimate of the number of ringed seals killed annually by the Alaskan populations of polar bears is about 500,000.

11. The fetal, pup, and older-than-pup sex ratio is 1:1 and the age composition essentially follows that of other ringed seal populations.

12. A literature review is underway and about 750 citations pertaining to ringed seals have been recovered. Few citations pertain specifically to ringed seals in Alaskan waters.

13. Shipboard and aerial surveys of bearded seals in the Bering Sea have demonstrated active spring migration in this species. Bearded seals that have wintered in the ice front begin moving north in late March, considerably before the disintegration of the ice.

14. Analysis of bearded seal harvest data has confirmed that a substantial proportion of bearded seal pups spends the summer in open waters in the Bering and Chukchi Seas while most adults remain in association with sea ice.

15. Bearded seals breed from mid-April to mid-May when female seals are in estrous. Males are in breeding condition for a longer period of time than females.

16. Bearded seal fetuses implant during July and early August. At this time almost the entire adult population is in the Chukchi and Beaufort Seas.

IX. Needs for further study

There are many needs within the Outer Continental Shelf Environmental Assessment Program which will no doubt be elucidated by many other investigators. Our primary need for further work is the examination of additional specimens, especially from the winter, from far offshore, and from the Beaufort Sea, so that we can fully address our task objectives. Collection of specimens should continue until a sample sufficiently large to determine seasonal, areal, and habitat variation in food habits and population distribution and structure is obtained. This same sample should provide enough reproductive material to calculate population productivity parameters.

The natural histories of important prey species of ringed and bearded seals should be investigated. The life histories and behaviors of prey species appear to have a direct effect on seal distribution, densities, and behavior. Emphasis should be given to potential effects of oil and gas exploration and development on these prey species.

Consideration should be given to developing a radio tracking system for pinnipeds. Once developed, the technique would rapidly provide badly needed information on movements, seasonal distribution, feeding areas, habitat utilization, and behavior. In addition, the use of remote sensing methods such as sonar have great potential for determining actual numbers of seals in an area and obtaining underwater behavioral data. The feasibility of using such equipment should be explored.

X. Summary of Fourth Quarter Operations

A. Field and laboratory activities

1. Schedule

Date	Location	Purpose
January-March 1978	Fairbanks	Routine laboratory and data analyses
January-March 1978	Fairbanks	Data management
January 1978	Anchorage	Game Division meeting
January 1978	Barrow	Beaufort Sea Synthesis Meeting
January-February 1978	Shishmaref	Collection of seal specimens
January-February 1978	Nome	Collection of seal specimens
February-March 1978	Gambell	Collection of seal specimens
February-March 1978	Kotzebue	Collection of seal specimens
March 1978	Prudhoe Bay	Collection of seal specimens
March 1978	Barrow	Collection of seal specimens
March 1978	Cape Thompson-Cape Lisburne	Collection of seal specimens
March 1978	Nome (including Norton Sound)	Collection of seal specimens
February-March 1978	Fairbanks	Preparation of annual report

2. Scientific Party

Name	Affiliation	Role
John J. Burns	ADF&G	Principal Investigator RU#230 and 232
Thomas J. Eley	ADF&G	Principal Investigator RU#230
Kathryn J. Frost	ADF&G	Principal Investigator RU#232
Lloyd F. Lowry	ADF&G	Principal Investigator RU#232
Glenn Seaman	ADF&G	Marine Mammals Technician
Robin Lynn	ADF&G	Marine Mammals Technician
Richard Tremaine	ADF&G	Marine Mammals Technician
Dan Strickland	ADF&G	Marine Mammals Technician
Diane Preston	ADF&G	Laboratory Technician
Paul Strickland	ADF&G	Marine Mammals Technician
Robert Pegau	ADF&G	Regional Supervisor Region V
Edward Muktoyuk	ADF&G	Marine Mammals Technician

3. Methods

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

The ages of seals are determined by evaluation of claw annuli (for animals six years and 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.

Analytical methods are discussed in detail in our Annual Report.

4. Sample localities

Bering (including Norton Sound), Chukchi, and Beaufort Seas.

5. Data collected and other activities

Specimens collected during January, February, and March 1978 are as follows:

	Male	Female	Unknown	Total
Shishmaref				
Ringed seal	19	15	0	34
Nome				
Ringed seal	3	8		11
Bearded seal	8	3		11
Gambell				
Ringed seal	10	5	1	16
Bearded seal	3	1	1	5
Barrow				
Ringed seal	12	6		18

Jaws, claws, reproductive tracts, and stomachs were obtained from most animals and these specimens are being analyzed as rapidly as possible.

Much of this quarter was devoted to meetings and related activities. All permanent personnel (Burns, Eley, Lowry, Frost) were required to attend a Department of Fish and Game, Division of Game, meeting in Anchorage and these persons prepared presentations on their marine mammal research. The OCSEAP-sponsored Beaufort Sea Synthesis Meeting in January required an inordinate amount of time for preparation of the final disciplinary and interdisciplinary reports. Burns, Eley, Frost, and Lowry were chairpersons for either the disciplinary or interdisciplinary groups. The reports for these groups will be published as a separate document.

Project: 230

PI: Burns and Eley

MILESTONE CHART

MAJOR MILESTONES - SPECIMEN COLLECTIONS	1978-1979											
	O	N	D	J	F	M	A	M	J	J	A	S
Beaufort Sea												
Barrow		▲				▲	▲					
Prudhoe Bay		▲				▲	▲					
Icebreaker											△	
Chukchi Sea												
Wainwright										△	△	
Shishmaref	▲	▲	▲	▲	▲				△	△		
Point Hope							△	△				
Norton Sound												
Nome					▲	▲	▲	△	△	△		
Gambell					▲	▲		△	△			
St. George Basin - Bristol Bay												
Ice-reinforced vessel with helicopter								△	△			

△ Planned completion date

▲ Actual completion date

Project: 230

PI: Burns and Eley

MILESTONE CHART

MAJOR MILESTONES--OTHER PROJECT ACTIVITIES	1978-1979											
	O	N	D	J	F	M	A	M	J	J	A	S
Acquisition of specimens	▲						▲	△				△
Processing of specimens for age determination	▲						▲	△				△
Processing of reproductive tracts specimens	▲						▲	△				△
Compilation and analysis of specimen data	▲						▲	△				△
Submission of data	▲			▲			△			△		
Preparation of reports			▲			▲	▲		△			△
Preparation of FY 1979 proposal								△	△			

△ Planned completion date ▲ Actual completion date

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Trophic relationships among ice inhabiting phocid seals

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Appendix I
Offshore Demersal Fishes and Epibenthic Invertebrates of the Northeastern Chukchi and Western Beaufort Seas

Appendix II
Observations on the Food of Ringed Seals and Bowhead Whales in the Region of Point Barrow, Alaska

I. Summary

Ice inhabiting seals are highly visible, numerous, sociologically and economically important species in the Bering-Chukchi, and Beaufort marine ecosystems. A complete understanding of the role of these seals in the trophic structure of these ecosystems is crucial to the evaluation of potential impacts of OCS development. As a first step, the important items in the diet of each species in all areas at all times of year must be determined. Key areas and times of foraging must be determined and will have direct bearing on the suitability of various areas for leasing. When key prey species have been identified and data correlated with information on the distribution, abundance and natural history of these prey species (from other projects), an evaluation of effects of OCS development on the food base of the seals can be made. By understanding the trophic relationships among ice inhabiting seals and other consumers in the system, indirect effects of OCS development (e.g. those favoring population increase of potential food resource competitors) can be predicted.

Previous studies on food habits of ice inhabiting seals have all been geographically and temporally rather limited. From the literature surveyed it appears that ringed seals feed primarily on planktonic crustaceans and fishes, bearded seals eat a variety of benthic invertebrates and fishes, spotted seals eat pelagic and demersal fishes and crustaceans, and ribbon seals consume fishes, cephalopods and shrimp.

A total of 689 specimens are included in this report, approximately double the number reported on in 1977. Stomachs containing food from 447 ringed seals, 161 bearded seals, 72 spotted seals and 9 ribbon seals have been collected and examined. Approximately 450 ringed and bearded seal stomachs are on hand awaiting analysis. The majority of the samples were collected at coastal hunting sites in the Bering and Chukchi Seas during summer. These collections were supplemented by shipboard and helicopter collections made by Alaska Department of Fish and Game personnel in the Bering, Chukchi and Beaufort Seas. Of particular note is the increase in Beaufort Sea samples, as well as the increase in specimens collected during fall and winter months.

Results are presented by locality and time of year within four major geographical areas: southeastern Bering Sea, northern Bering Sea, Chukchi Sea and Beaufort Sea. General feeding patterns are discussed for each species in each area. A brief evaluation of geographical, temporal and age- and sex-related dietary differences is made. Results of our investigations of seal feeding habits are compared to those of previous investigators and to what is known of food availability. Key prey items for each species in each area are identified.

The determination of prey items is only an initial step in this project. In order to attain the goal of ability to predict effects of OCS development, much information will be needed on the functioning of other components of the ecosystem. It is hoped that other OCSEAP projects will provide this information.

II. Introduction

The waters off the coast of Alaska support a tremendous abundance and diversity of marine mammals. Some species occur only during ice-free months while others are more or less dependent on sea ice as a habitat in which to whelp, breed, molt and feed. The relationship between northern marine mammals and sea ice has been well summarized by Burns (1970) and Fay (1974).

In this project, four closely related species of pinnipeds have been chosen for study: the ringed seal, Phoca (Pusa) hispida; the bearded seal, Erignathus barbatus; the spotted seal, Phoca vitulina largha; and the ribbon seal, Phoca (Histriophoca) fasciata. Ringed seals and bearded seals are associated with ice throughout the year, with breeding ringed seals more common on shorefast ice and bearded seals occupying the drifting ice (Burns 1967, 1970; Burns and Harbo 1972). Ribbon seals and spotted seals utilize the ice front of the Bering Sea for whelping and molting in late winter and early spring, then ribbon seals appear to become pelagic while spotted seals move to the coast or north with the retreating ice (Burns 1970, in press, pers. obs.). An estimate of the combined numbers of these four species in the Bering, Chukchi and Beaufort Seas would be 1.5 to 2 million animals.

Marine mammals have a long history of subsistence and commercial utilization (Scammon 1874, Johnson et al. 1966, Reiger 1975). There is great public concern today for their continued well-being. Some indications of this concern and interest are the Marine Mammal Protection Act of 1972, the increased interest in research and management at the international level and the present awareness of the nonconsumptive recreational value of marine mammals (Reiger 1975). Subsistence utilization of certain species is still of considerable economic and cultural importance to coastal Eskimo communities (Johnson et al. 1966). These factors and others make it imperative that the potential effects of outer continental shelf development on ice inhabiting seals be anticipated and minimized to whatever degree possible. Such an evaluation requires a complete understanding of the biology of the species involved as well as how these species affect and are affected by their environment. This project will contribute to such an understanding by examining the trophic relationships of ice inhabiting phocid seals in the Bering, Chukchi and Beaufort Seas.

Specific objectives of this project are as follows:

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 species being studied throughout the geographic range involved and during all times of year that the species occurs in a particular area. The contents of these stomachs are sorted, identified and quantified. This information is 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 is critical in this phase of the project.

5. With the understanding thus obtained of the trophic interrelationships of ice inhabiting phocids in the Bering-Chukchi and Beaufort marine systems, evaluate the probable kinds and magnitude of effects of OCS development on these species of seals. This will entail 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 influences on populations of competitors for food resources.

III. Current state of knowledge

The search for information on distribution, abundance and natural history of potential prey items is essentially complete. Our efforts have been to a large degree aided by the efforts of other projects (e.g. Carey 1977). However, although literature searches have turned up a great many references, it is evident that such information as is presently available (e.g. Stoker 1973, Crane 1974) is not sufficient to satisfy the needs of this study.

The earliest accounts of foods of marine mammals are to be found in the records of early polar expeditions. However, such reports usually involve small samples and are lacking in taxonomic refinement. The discovery that seals are better collectors of some faunal elements, for example swimming crustaceans, than more traditional collecting gear resulted in the analysis of a number of ringed and bearded seal stomachs (e.g. Rathbun 1919, VanWinkle and Schmitt 1936, Dunbar 1954). Most of these studies were concerned with the nature of the contents rather than the feeding biology of the seals, a notable exception being the study of Dunbar (1941). The recognition of seals as potential competitors for commercially important fishes spurred a surge of research on pinniped feeding habits (e.g. Scheffer and Sperry 1931, Spaulding 1964, Briggs and Davis 1972, Rae 1973). Although at least two species (ribbon seals and spotted seals) are known to feed somewhat extensively on commercially important pollock (Arseniev 1941, Burns in press, Wilke 1954), ice inhabiting seals have not been given systematic attention. Some limited information on the food of ice seals in Alaskan waters is available from the reports of interested persons who recorded the stomach contents of specimens they encountered (Kenyon 1962, Burns 1967, unpubl.). The only systematic studies of feeding habits of ice inhabiting phocids were done by Johnson et al. (1966) as part of Project Chariot and the work of several Soviet investigators utilizing material made available by commercial sealing operations. Translations of some of these works have been obtained from various translation services. Several important papers for which translations were apparently not available have been translated for this project. A summary of the results of previous studies of food habits of each of the four species being considered in this project follows.

Ringed seals

By observations and discussions with native hunters in northwest Greenland, Vibe (1950) determined the principal foods of ringed seals in that area to be arctic cod (Boreogadus saida), amphipods, decapod crustaceans and occasionally sculpins. In the spring animals were taken mostly while basking on the ice and always had empty stomachs.

Dunbar (1941) reported on the stomach contents of 47 seals taken in Baffin Island waters during August and September. The pelagic amphipod Parathemisto (=Themisto) libellula was by far the most common food. Mysids were occasionally abundant in the stomachs. Other invertebrates and fishes were found in very small quantities.

McLaren (1958) examined stomachs of ringed seals taken at several localities in the eastern Canadian Arctic. The feeding pattern observed in this area appeared to be largely determined by water depth. In shallow inshore areas the major food items were fishes (mostly arctic cod and sculpins), mysids and shrimps. In deeper offshore waters the primary food was Parathemisto libellula.

No seasonal or age-related differences in food items were noted. A decreased percent of stomachs containing food was noted from late April to the end of June.

Barabash-Nikiforov (1936) reported that the contents of stomachs from two specimens from the Commander Islands contained fishes (Hexagrammidae), crabs and an octopus.

Pikharev (1946) examined the stomachs of 377 seals taken in the spring of 1939 in the Shantar Sea and the Sakhalin Gulf (western Sea of Okhotsk). Only 16 of the stomachs contained food remains, all of these being animals that were in the water or had only recently hauled out on the ice. From this Pikharev concluded that ringed seals do feed during the molt period, and digestion takes place quite rapidly. The most commonly encountered food items were the isopod *Saduria* (=*Mesidotea*) *entomon* and the euphausiid *Thysanoessa raschii*. Two species of gammarid amphipods and one species of hyperiid amphipod were found as well as shrimp (*Pandalus goniurus*), pollock (*Theragra chalcogramma*), smallmouth smelt (*Hypomesus olidus*) and herring (*Clupea harengus pallasi*), each found in one stomach.

Fedoseev (1965) analyzed the stomach contents of 159 ringed seals taken in the northern Sea of Okhotsk. Animals taken in spring (February-April) had fed almost entirely on euphausiids, amphipods, isopods and mysids. Shrimps were also eaten in small quantities. Food was found in 77 percent of the stomachs examined in this period. During the molting period (May-June), remains of food were found in only 21 percent of the animals examined. Shrimps, euphausiids and amphipods were all important in the diet. No stomachs were examined from animals taken in summer but, on the basis of food availability and distribution of the seals, euphausiids were inferred to be the primary food. In the late autumn and early winter (November and December), fishes (saffron cod (*Eleginus navaga*), smelt (*Osmerus* sp.), herring (*Clupea harengus*) and others) were the main food, followed by shrimps, amphipods and euphausiids. Fedoseev noted that pups and yearlings fed largely on small crustaceans (euphausiids and amphipods). Fish and larger crustaceans were found more frequently in adults than in younger animals.

Fedoseev and Bukhtiyarov (1972) reported on the foods of 209 ringed seals taken during spring in the Tamsk and Shantur regions of the Sea of Okhotsk. Euphausiids were the primary food in both areas. Shrimps and fishes were eaten more often in the more southerly (Shantur) region than in the north.

Nikolaev and Skalkin (1975) reported on the stomach contents of 27 ringed seals taken during March and April on the drifting ice in Terpenie Bay (southern Sea of Okhotsk). The primary food was euphausiids followed by shrimps, fishes and crabs.

Kenyon (1962) reported on the stomach contents of 14 seals taken at Little Diomede Island, 11 May-14 June 1958. Shrimp of the genus Pandalus accounted for 96 percent of the food items encountered with mysids, amphipods and fishes present in small amounts.

The intensive study of Johnson et al. (1966) at Point Hope and Kivalina resulted in the examination of 1,923 stomachs from seals taken over the period November 1960 to June 1961. During the months of November, December, January and February, fishes (mostly sculpins, arctic cod and saffron cod (Eleginus gracilus) made up 90 percent or more of the contents. During March, April, May and June, invertebrates, mostly shrimp and amphipods, were the predominant food making up more than half and occasionally more than 80 percent of total stomach contents.

Bearded seals

Vibe (1950) in his report on investigations of the biology of marine mammals in northwest Greenland describes the feeding of the bearded seal as follows: "As regards its food the bearded seal is not particular, it is almost omnivorous; it will, however, mainly stick to the fauna in or just above the sea bottom, where it can get down at it, but if the depths are too great, it will be content with polar cod. It does not select its food elements but seems to feed indiscriminately on all kinds of food which accidentally is found within its habitat." The gastropod mollusc Buccinum and several species of shrimps were the food items most frequently found. Interestingly no clams of the genera Serripes or Clinocardium (listed as Cardium in Vibe) were found in bearded seal stomachs although they were the primary food of walruses in the area. This casts some doubt on the supposition that bearded seals are indiscriminate in their feeding. When taken in water more than 100 meters deep, bearded seals usually had only arctic cod (called polar cod in Vibe and meaning Boreogadus saida) in their stomachs. Arctic cod were also a major food in the heads of fiords in summer.

Dunbar (1941) examined the stomach contents of five bearded seals from the eastern Canadian Arctic. These seals had eaten shrimps, a sculpin and a tubeworm.

Inukai (1942) found shrimps (mostly crangonids), king crabs, sea cucumbers, snails, octopus and echiuroid worms in the stomachs of 11 bearded seals taken off southeast Sakhalin in May.

Kosygin (1966, 1971) reported on the foods of the bearded seal in the Bering Sea in spring and early summer (March to June) 1963 to 1965. Stomachs from 565 animals were examined, 152 of which contained food. The tanner or snow crab (Chionocetes opilio) was the species most commonly eaten making up from 53 to 76 percent of the food. Shrimp (particularly Argis (=Nectocrangon) lar) were the second most important food. Snails were also important. Octopus, priapulids and fishes (particularly pricklebacks and flatfishes) were eaten quite regularly. Kosygin noted considerable constancy in the diet from year to year which he explained by the fact that the animals tend to be found in the same areas each year. Some annular changes were noted (e.g. polychaetes were commonly eaten in 1963 but not in 1964 or 1965) which Kosygin thought were mostly due to heavy ice fields excluding animals from certain feeding areas. No age- or sex-related feeding differences were noted with the exception that it appeared that young bearded seals foraged mostly in the morning while mature animals ate more in the afternoon. The average amount of food in the stomachs decreased from April to June.

Fedoseev and Bukhtiyarov (1972) examined 72 stomachs of bearded seals taken in the Sea of Okhotsk in spring. In the northern (Tamsk) region decapod crustaceans made up 87 percent of the food. Molluscs accounted for less than 6 percent and fishes 3.7 percent. In the Sakhalin Bay (eastcentral) area, clams and snails (found in 40 and 27 percent of the stomachs, respectively) were the main food. Worms of an unspecified type were also commonly eaten.

Nikolaev and Skalkin (1975) reported on the foods of 31 bearded seals taken in the southern Sea of Okhotsk (Terpenie Bay) in March and April. Crabs (Chionocetes and Hyas), molluscs (particularly octopus) and shrimps were the primary foods. Several types of benthic fishes (poachers, flatfishes and sand lance) were also eaten. Twenty-nine of the bearded seals taken were molting, 22 of these had food in their stomachs.

Kenyon (1962) reported on the stomach contents of 17 specimens taken at Little Diomede Island, 11 May-6 June 1958. Shrimps (Pandalus sp. and Sclerocrangon sp.), crabs (Hyas coarctatus alutaceus and Pagurus sp.) and clams (Serripes groenlandicus) comprised the bulk of the contents. Other benthic invertebrates (sponges, annelids and snails) and several species of fish were present in small amounts.

Johnson et al. (1966) examined the stomach contents of 164 bearded seals taken at Point Hope and Kivalina from November 1960 through June 1961. The only month in which a large sample (129) was obtained was June. Shrimp, crabs and clams were the most common food items with other benthic invertebrates found in small quantities and fishes (sculpins and arctic cod) usually comprising less than 10 percent of the total volume.

In his summary of the biology of the bearded seal, Burns (1967) reported on his examination of stomachs from seals collected at Nome, Gambell and Wainwright. In May he found that crabs (Hyas coarctatus alutaceus and Pagurus sp.) accounted for 57 percent of the contents with shrimp, fishes (saffron cod, arctic cod and sculpins) and sponges comprising most of the remainder. In July and August, clams (*Serripes groenlandicus*, *Spisula* sp. and *Clinocardium* sp.) were the most abundant food item, with shrimp, crabs and isopods also quite commonly found.

Spotted seals

Many studies have been done on the food of *Phoca vitulina*; however, most of these have been done on the land-breeding subspecies (*P. v. richardsi*). Only five reports have been found dealing with the feeding habits of the ice-breeding form (*P. v. largha*).

Barabash-Nikiforov (1936) reported on the stomach contents of animals taken on the Commander Islands. He found that during the winter and early spring the principal foods were small octopus, crabs and sipunculids (*Phascolosoma* sp.). Amphipods (*Gammarus* sp.), algae and fishes were present but in small quantities. Later in the year benthic fishes (sculpins and greenlings) became important in the diet.

Wilke (1954) examined the stomach contents of 21 spotted seals killed on the pack ice of the southern Okhotsk Sea during April of 1949. In the 19 stomachs containing food, pollock made up 83 percent of the total volume, herring 10 percent and traces of octopus, squid and other fishes the remainder.

Fedoseev and Bukhtiyarov (1972) examined the stomachs of 23 spotted seals taken in spring in the northern and eastern Okhotsk Sea. Pollock was the main food, being found in 65 percent of the stomachs examined. Saffron cod, sand lance, euphausiids and decapod crustaceans were also eaten.

Nikolaev and Skalkin (1975) found food in three of the seven spotted seal stomachs they examined from Terpenie Bay. Most of the contents were fragments of fishes. Shrimp, crab and octopus had been eaten in lesser amounts.

Gol'tsev (1971) examined 319 stomachs from seals collected primarily in the northwest Bering Sea during the 1966-68 hunting seasons (April-June). From his collections he concluded that spotted seals feed in the morning and in the evening and digest their food quite rapidly. The food of newly weaned young (5 weeks old) was entirely amphipods (*Nototropis* sp. and *Anonyx nugax*) and some algae. At seven to eight weeks old they begin to feed on shrimps (*Spirontocaris macarovi*, *Eualus fabricii* and *E. gaimardii*) and sand lance. When 12 weeks old, larger fish (flatfish and saffron cod) begin to be eaten. Juveniles (age 1 to 4 years) fed mostly on fish (arctic cod, sand lance, saffron cod) and shrimp (*Pandalus* sp.). Adults appear to feed more on benthic forms with octopus, crabs, flounders, sculpins and other bottom fishes prevalent.

Ribbon seals

Arseniev (1941) examined stomachs of 398 ribbon seals taken in the spring off the eastern coast of Sakhalin. The incidence of empty stomachs was very high and increased from 71 percent empty in April to 100 percent empty in July. Pollock was the primary food throughout the sampling period. Cephalopods were eaten commonly from 30 April to 20 May but much less frequently from 25 May to the end of the sample. Shrimp (*Pandalus goniurus*) occurred only occasionally in the stomachs.

The results of Arseniev were confirmed by Wilke (1954) who found 60 percent pollock and 40 percent squid in 2 stomachs he examined from animals taken in the Okhotsk Sea in April.

Fedoseev and Bukhtiyarov (1972) examined the stomach contents of 48 ribbon seals taken in the Sea of Okhotsk in spring. Forty-two of these animals had eaten pollock. Saffron cod were found in two animals, octopus in eight and shrimps in one.

Shustov (1965) examined 1,207 stomachs from seals taken at the ice front of the Bering Sea from March through July. Only 32 of these stomachs contained recognizable food. Shrimps (*Pandalopsis* sp., *Argis lar*, *Pandalus borealis*, *Eualus gaimardii* and others), amphipods (*Parathemisto* sp.), mysids and cephalopods were frequently found. Many types of fishes, especially arctic cod, saffron cod and herring were encountered but were not very common. In interesting contrast to the findings in the Sea of Okhotsk (Arseniev 1941, Wilke 1954, Fedoseev and Bukhtiyarov 1972), no pollock were found in the Bering Sea sample. This can perhaps be explained by the fact that the seals examined by Shustov were taken in the northern Bering Sea, somewhat north of the main concentrations of pollock.

Burns (in press) reports on the food remains found in the stomachs of six specimens collected in the Bering Sea. Four animals were taken in April and May; one contained fish (*Pholis* sp.), two contained shrimp (*Pandalus* and *Sclerocrangon* sp.) and one contained only milk. The stomachs of two specimens collected in February contained large volumes of pollock and arctic cod.

IV. Study area

The area involved in this study includes the Beaufort, Chukchi and Bering Seas. Since some of the species being studied show extensive seasonal movement in relation to changes in ice conditions, the geographic focus of the study also varies seasonally. For convenience and to facilitate application of our results to specific OCS lease areas, we have broken down the study area into four sub-areas. We will present and discuss our results for these sub-areas separately. However, it should be remembered that the species involved are highly mobile animals and could occupy any and all areas at different times of the year. A map of the entire study area showing proposed lease sale areas is shown in Figure 1.

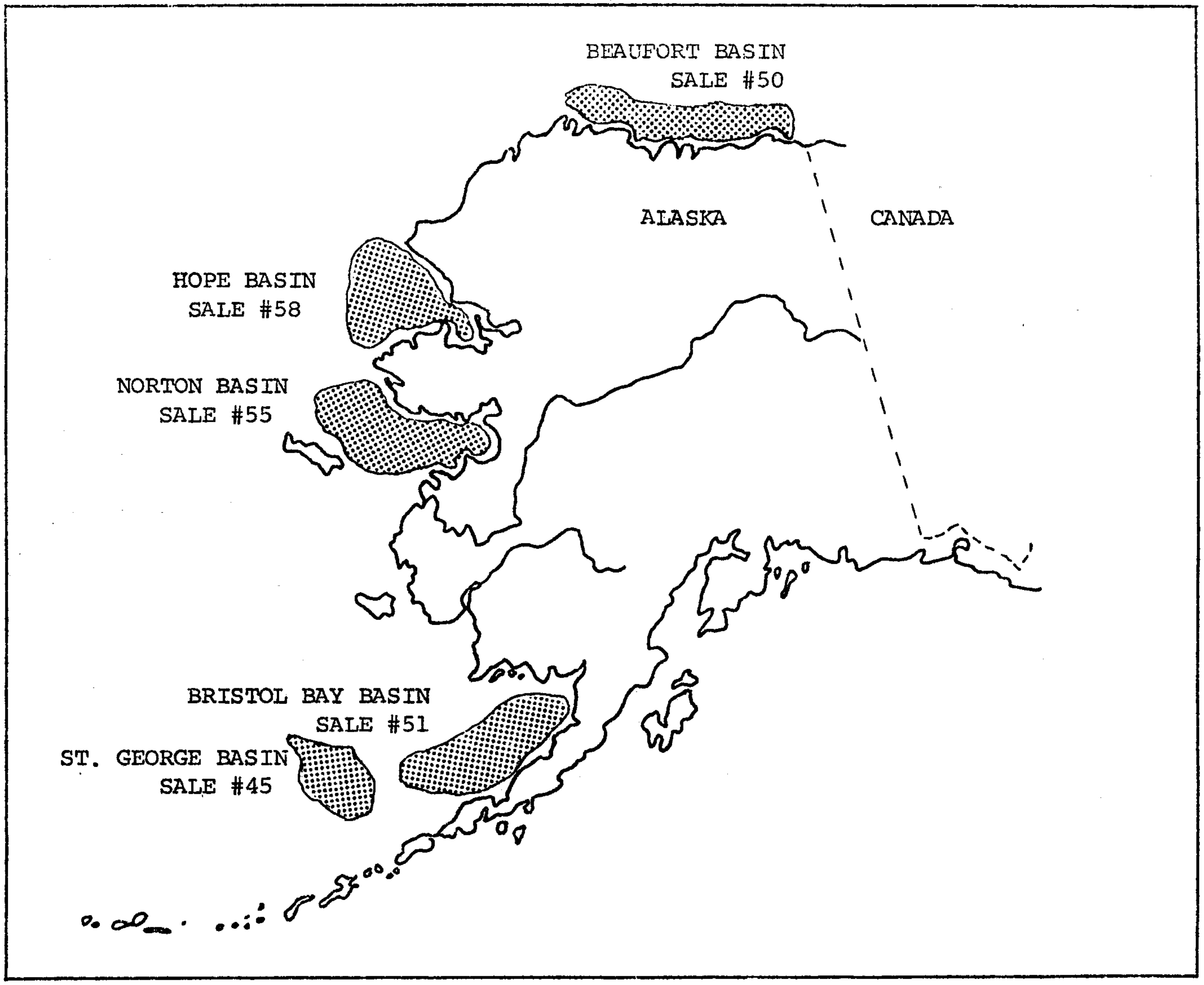

Figure 1. Map of Alaska showing proposed OCS lease sale areas which are included in the study area of this project.

V. Sources, methods and rationale of data collection

Literature

Compilation of existing literature and unpublished data on the food habits and trophic interactions of ice inhabiting seals is essentially complete. Available information on the distribution, abundance and natural history of potentially important prey species has also been compiled. Pertinent literature has been obtained through an OASIS literature search for information about food habits of seals, discussion and consultation with personnel from the University of Alaska Marine Museum/Sorting Center, use of various translation services (Israel Program for Scientific Translations and Fisheries Research Board of Canada) for access to Russian literature, search of Alaska Department of Fish and Game reprint files, library and other literature collections, use of University of Alaska library facilities and inter-library loan services.

Field collection of specimen material

Collectors were sent to coastal hunting villages on the Bering, Chukchi and Beaufort Seas during predictably good hunting periods. Specimen material, including jaws and claws for age determination, reproductive tracts, and stomachs were purchased directly from hunters. Sampling was done by the principal investigators and other ADF&G employees. Some specimens from Point Barrow were provided by Harry Reynolds, ADF&G Area Biologist, who had access to intact seals purchased from local hunters by the Naval Arctic Research lab, as food for the animal colony. Other specimens from Barrow were provided by Bob Everitt, National Marine Fisheries Service, and by Jack Lentfer, U.S. Fish and Wildlife Service (now ADF&G).

Shipboard collections of seals were made by project personnel in areas inaccessible to coastal hunters. Collection in the Bering Sea ice front, where the ice was often impenetrable by small boats, was aided by a Bell 206 helicopter. Other shipboard collection efforts were conducted from small boats. Animals were shot either on the ice or in the water, taken to the ship and processed as described below. Fall, winter and early spring collections in the Beaufort Sea and Norton Sound were made from Bell 206 and UH1H helicopters.

Seals from which specimen material was taken were weighed, sex was determined, and, whenever possible, a series of standard measurements were made for use in this and other ongoing studies on ice inhabiting seals. Tissue and blood samples were collected in some cases and made available to other investigators for heavy metal, hydrocarbon, PCB and pathogen analysis. (See methods section in RU #230, annual report, for detailed description of standard measurements and collection of additional specimen material.)

Only stomachs containing food were collected. Stomachs were tied at the cardiac and pyloric sphincters and severed from the remainder of the alimentary canal near these ties. They were then either injected with 10 percent formalin, labeled and placed intact in plastic bags containing 10 percent formalin, or placed in bags and frozen. All stomachs were shipped to the ADF&G Fairbanks office. In addition, in some of the animals collected by project personnel, the contents of the small intestine were retained and examined for food remains. In cases where the stomach was empty this often provided some information on recent diet. Some of the stomachs not collected by us were opened in the field and the contents preserved or frozen.

When possible, in addition to collection of stomach specimen material, bottom sampling for fishes and invertebrates was conducted with a 19 foot Marinovich otter trawl (1/4 inch stretch mesh body, 1/4 inch mesh cod end liner). Trawls were of 15-20 minutes duration at a ship speed of 2-4 knots. Contents of each trawl were identified, enumerated and representative specimens of organisms retained. Fishes were measured and weighed and the otoliths removed and measured to determine the correlation of otolith size to fish size. Stomach contents of some fishes were examined. Examples of selected invertebrate species were measured and weighed to provide an index of length/weight ratios that could be applied to partially digested food items found in seal stomachs.

Laboratory procedures and identification

Laboratory analysis of stomach contents began 15 October 1975 and has continued intermittently to date. Procedures for processing the stomachs, determining volumes of stomach contents, rough sorting, fine sorting and identification of species have been developed and refined. Necessary taxonomic keys and references have been accumulated, a voucher specimen collection established, and personnel trained for sorting activities. Data sheets have been designed and modified to be compatible with NODC data formats.

Stomachs examined early in the project were trimmed of excess esophageal and small intestinal tissue and weighed full and intact. This process has been discontinued, as has the weighing of empty stomachs. Stomachs were then cut open and the contents transferred onto a standard 1.0 mm Tyler screen where they were thoroughly washed. Empty stomachs were reweighed, returned to 10 percent formalin and stored for future pathological examination. The volume of the total stomach contents of each seal was then determined by water displacement. Those contents that had been removed from the stomachs in the field were simply washed and a total volume determined as above.

The washed contents were either transferred to finger bowls and petri dishes for immediate rough sorting, or placed in jars and stored in 10 percent formalin until sorting could be done. If the latter took place, otoliths were first sorted out and stored separately in 70 percent ethyl alcohol to avoid degradation by the formalin. Rough sorting entailed separation of parasites from food items, and separation of food items into major taxonomic groups. Some parasites were examined by other ADF&G personnel as part of natural history studies on ringed and bearded seals. Recently parasites have been provided to RU #194.

Fine sorting and identification consisted of further refinement of the initial sorting procedure. Sorted fractions were broken down to the lowest possible taxonomic levels permitted by the condition of the material. All sorting and identification required recognition of small bits and pieces of organisms. Seldom were intact organisms present. Shrimp, crabs and amphipods were frequently identified only by the presence of claws, carapaces, or abdomens. Clams were recognized by feet, gastropods by operculae, fish by individual bones or otoliths, etc. Individuals of a group or species were counted, size range was measured (mm) and the volume of the fraction determined by water displacement (ml). Some fractions were also weighed (g) to obtain volume to weight ratios for different groups or species.

Virtually all identifications were done by project personnel. Necessary taxonomic keys and references have been accumulated through library facilities, contact with personnel at the University of Alaska Marine Museum/Sorting Center and correspondence with people presently working in related fields. Much use was made of the Marine Museum/Sorting Center reference collection and of the expertise of sorting center personnel. A reference and voucher specimen collection including bits and pieces of individuals from stomachs, as well as intact specimens from trawls, has been established at ADF&G for use in future identifications and in training of personnel.

In addition, an otolith reference collection has also been compiled. Otoliths were taken from fish recovered by otter trawls, as well as from existing ADF&G fish collections. Considerable interchange of specimen material and ideas occurred between personnel of this project and J. Morrow, RU #285.

Data

Design of formats to handle data and design of compatible data sheets to facilitate keypunching was completed. Data are keypunched, recorded on magnetic tape and submitted to NODC to meet data archiving requirements. To date, data have been manually compiled for all reports. There have been repeated efforts to initiate computer manipulation of data. At present a basic program to tabularize and analyze data is nearing completion. Further effort will be devoted to obtaining more sophisticated programming and computer analyses.

VI and VII. Results and Discussion

The search for background literature and unpublished data is nearly complete. Much information about the feeding of pinnipeds has been accumulated. However, little of this is pertinent to the species and areas presently being investigated. The most relevant articles are summarized under section III of this report. Most of the unpublished data on feeding of ice inhabiting phocids has been gathered by one of the Principal Investigators in this project (John J. Burns) and has been incorporated into this study as appropriate. As pointed out in section III, information on distribution, abundance and life history of potential prey items is not commonly available. Such information as is considered relevant will be included in the discussion.

As mentioned in section IV, our presentation and discussion of results will be broken down into several sub-areas. Detailed presentation of results has been presented in quarterly reports and the annual reports for 1976 and 1977. In the following presentation and discussion, we will deal with results in more general terms in order to elucidate patterns and to increase the potential use of our findings.

In the following presentation and discussion of results, feeding patterns will usually be described in terms of groups of similar organisms, for example shrimps, crabs or clams. This is done for simplification and to make the results more understandable to those not familiar with the numerous species of animals involved in this study. The specific identity of prey items is in some instances of great importance and these species will be pointed out where appropriate such as in identification of key prey species. In such cases common names will be used where available and equivalent scientific names given. However, confusion can easily result from use of common names. For example, a species of major importance in this study, *Boreogadus saida*, is called either arctic or polar cod. The same is true of another genus of fishes, *Arctogadus*. All previous references to arctic or polar cod in reports by this RU have meant *Boreogadus*. Recently *Arctogadus* has been found in ringed seal stomachs providing an opportunity for considerable confusion. In this and all future reports of this RU, arctic cod will refer to *Boreogadus* and polar cod will refer to *Arctogadus* following the convention of the American Fisheries Society (Bailey et al. 1970). The reader should be aware of this potential problem when reading other reports dealing with arctic fauna.

In this report, data from all specimens collected and analyzed since spring of 1975 will be reported. In addition, information from specimens collected prior to the beginning of OCSEAP is included where it will significantly add to the understanding of the trophic relationships of the species being studied. Table 1 summarizes the number of specimens included in this report as compared to the

1977 annual report of RU #232. A total of 689 specimens are included in this report, approximately double the number reported on in 1977. Of particular note is the large increase in the number of ringed and bearded seals from the Beaufort Sea, and the increase in the number of ringed seals from the northern Bering Sea (mostly Norton Sound).

Numbers in Table 1 refer only to processed specimens which contained food. Emphasis has been put on processing of material from the Beaufort Sea and Norton Sound. Approximately 300 ringed seal and 150 bearded seal specimens are on hand awaiting processing. These are mostly from Shishmaref in the early summer of 1977.

Table 1. Breakdown by species and geographical area of stomach contents data included in this report and in the 1977 Annual Report of this RU (1977 specimens in parentheses). Numbers include only stomachs which contained food.

	Species			
Location	Ringed	Bearded	Spotted	Ribbon
SE Bering	6(6)	16(12)	23(15)	9(5)
N Bering	143(29)	61(29)	19(6)	-
Chukchi	223(161)	67(40)	30(5)	-
Beaufort	75(21)	17(3)	-	-
Total	447(217)	161(84)	72(26)	9(5)

Tables of field activities include only operations conducted since the 1977 annual report.

Southeastern Bering Sea

A map of the southeastern Bering Sea is shown in Figure 2. Included in this region are the Bristol Bay, St. George Basin and Navarin Basin lease sale areas. The southern edge of seasonal sea ice occurs in this region. Large numbers of spotted and ribbon seals are found in the ice front zone during late winter and early spring. Bearded seals are most common north of the ice front and ringed seals are found mostly near the coast. Ringed, bearded and spotted seals are taken by coastal hunters mostly during spring migrations.

Table 2 gives a schedule of field activities conducted in the southeastern Bering Sea. Locations are shown in Figure 2. Results of stomach contents analysis are given in Tables 3, 4, 5 and 6.

Table 2. Schedule of field activities - southeastern Bering Sea.

Location/Platform	Dates	Personnel
OSS SURVEYOR	15 March - 3 May 1977	L. Lowry, K. Frost, J. Burns, E. Muktoyuk
OSS DISCOVERER	18 May - 13 June 1977	L. Lowry

Spotted seals collected in the eastern portion of this region (outer Bristol Bay) in March of 1976 and April of 1977 had eaten almost entirely capelin (*Mallotus villosus*). An animal collected further west had eaten entirely pollock (*Theragra chalcogramma*). One collected near St. Matthew Island had beaks of more than 50 octopus in the stomach. Two animals collected west of Nunivak Island in late May 1977 had eaten capelin and herring (*Clupea harengus*). Specimens from village hunters at Mekoryuk contained fishes and shrimps.

In essentially all ribbon seals that have been collected stomachs have either been empty or have contained only persistent hard parts of prey, mostly fish otoliths. Most of the otoliths were from pollock. Capelin and eelpout (*Lycodes* sp.) were also eaten in fairly large numbers. All animals with food remains in the stomachs were collected south of St. Matthew Island (Figure 2). Food remains found in 1976 and 1977 were similar (Table 4).

In some instances aboard the SURVEYOR, bottom trawls were made in the vicinity of spotted and ribbon seal collections. These trawls usually indicated that both pollock and capelin were present as were flatfishes, sculpins, poachers and eelpouts. Strong selectivity for capelin by spotted seals is indicated in the Bristol Bay region as they were essentially the only food found in stomachs, yet pollock were numerous in all trawls. Pollock and sculpin otoliths occurred occasionally in intestines of these animals. At the time of year these animals were taken (March and April) capelin appear to be most abundant in waters east of the Pribilof Islands (Lowry and Frost, unpubl.). The area north and west of the Pribilofs is known to be the region of greatest abundance of year class 1 pollock (Pereyra et al. 1976), the size most frequently eaten by seals. Not surprisingly, pollock was the major food of the spotted seals and ribbon seals collected there. Ribbon seals ate other demersal fishes in addition to pollock. When the species composition of the ribbon seal diet is compared to that in otter trawl catches,

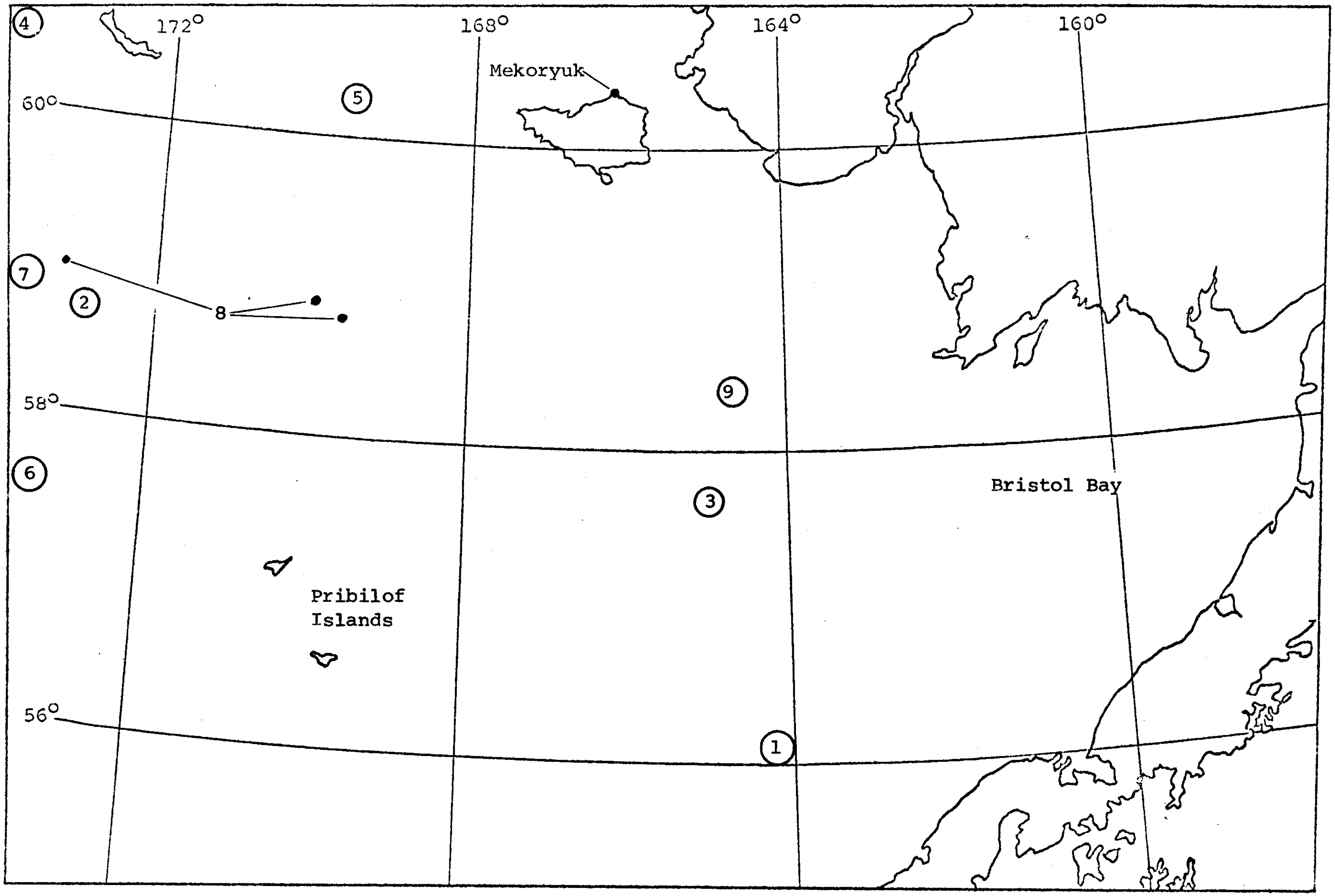

Figure 2. Map of the southeastern Bering Sea showing locations of specimen collections. Numbers correspond to samples shown in Tables 3, 4, and 5.

Table 3a Spotted Seal STOMACH CONTENTS DATA FROM Southeastern Bering Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA		1	2	3	4	5
DATES		25-27 March 1976	22 March 1977	20 April 1977	26 May 1977	30 May 1977
SAMPLE SIZE		7	1	4	1	2
Mean Volume (ml)		506.3	336.8	144.5	6.0	1134.0
FOOD ITEMS	1	Fish 100 Capelin 100	Fish 100 Pollock 100	Fish 100 Capelin 96 Pollock 4	Octopus 100	Fish 100 Capelin 51 Herring 49
	2					
	3					
	4					
	5					

Table 3b — Spotted Seal STOMACH CONTENTS DATA FROM Southeastern Bering Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Mekoryuk 17-30 May 1975 8				
Mean Volume (ml)						
FOOD ITEMS	1	*Fish 87				
	2	Shrimp 13				
	3					
	4					
	5					

* Accurate specific identification of fishes was not possible due to otoliths degraded by formalin. Several fishes were greenling (Hexagrammidae)

Table 4. RIBBON SEAL STOMACH AND INTESTINAL CONTENTS DATA

Southeastern Bering Sea

location	6		7	
dates	19-20 April 1976		21-22 March 1977	
sample size	5		4	
Food Item	#occurrences	% of total fishes	#occurrences	% of total fishes
Invertebrates				
Clams	4*		1	
Snails	1			
Octopus	1		2	
Shrimp	2		1	
Fishes				
Pollock	5	89.4	4	73.5
Capelin	2	1.1	3	12.4
Eelpout	5	8.9	2	5.3
Pricklebacks	1	0.4	2	1.8
Sculpins			1	0.9
Flatfish			2	3.5
Poachers	1	0.4		
Liparids			2	2.7

* small clams very likely from stomachs of eelpout

Table 5 — Bearded Seal STOMACH CONTENTS DATA FROM Southeastern Bering Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA / DATES / SAMPLE SIZE		8 22 March – 23 April 1977 3	9 29 March 1977 1	Mekoryuk 6-30 May 1975 12		
Mean Volume (ml)		1011.5	342.0	137.9		
FOOD ITEMS	1	[1] Brachyuran Crabs 92	Shrimp 64	Shrimp 39		
	2	Polychaetes 4	Crabs 22	**Fish** 19 Sculpins 85 Pollock 7 Saffron Cod 5		
	3	Snails 2	[2] Anomuran Crabs 5	Brachyuran Crabs 18		
	4	**Fish** 2 Eelpout 84 Flatfish 10 Pollock 5		Isopods 10		
	5			Gammarid Amphipods 1		

1. Species such as tanner crabs and spider crabs
2. Species such as hermit crabs and king crabs

Table 6 Ringed Seal STOMACH CONTENTS DATA FROM Southeastern Bering Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Mekoryuk 22 April - 12 June 1975 6				
Mean Volume (ml)		67.0				
FOOD ITEMS	1	Fishes 58 Saffron Cod 65 Sculpins 32				
	2	Mysids 18				
	3	Hyperiid Amphipods 13				
	4	Shrimp 4				
	5	Gammarid Amphipods 1				

it apppears that ribbon seals select for eelpout and against flatfishes. The causes and mechanisms for such selectivity are completely unknown.

As the ice front deteriorates and recedes in May and June some spotted seals move north with the ice while others move to the coast where they are frequently found at the mouths of estuaries. The exact distribution of these coastal groups of spotted seal is poorly known. These seals undoubtedly forage primarily on fishes such as herring and capelin (see Barton et al. 1977 for data on nearshore forage fish distribution). Most ribbon seals remain with the deteriorating ice edge and continue to feed very little. Stomachs of six ribbon seals collected in May and June 1977 were all entirely empty and only one otolith was recovered from the intestines. The distribution of ribbon seals during the ice-free period is poorly known. Available data suggest that most of the animals summer along the Bering Sea shelf and slope (Burns, in press). It is probable that ribbon seals in that area would eat primarily pollock and lesser amounts of other demersal fishes.

Four bearded seals collected at several locations across the ice front ate primarily brachyuran crabs. In the three specimens taken west of 169°W tanner crabs (Chionocetes spp.), mostly recently molted females carrying eggs, were almost the sole food item. The bearded seal taken at the most easterly and nearshore location (164°50'W, 58°25'N) had eaten mostly crangonid shrimps (Argis sp. and Crangon sp.) and spider crabs (Hyas coarctatus). Crangonid shrimps and Hyas spp. were also major food items of bearded seals taken at Mekoryuk in May of 1975. These differences in food species probably reflect the distribution of areas of high tanner crab biomass. The importance of tanner crabs to bearded seals is indicated by the large stomach contents volumes found in seals which had eaten primarily that species. Tanner crabs are the most abundant epifaunal invertebrate in the offshore waters of the southeastern Bering Sea (Feder 1977, Lowry and Frost unpubl.). The two next most abundant groups reported by Feder (1977), king crabs and sea stars, were not eaten at all by bearded seals in our samples from this area. The low stomach contents volumes at Mekoryuk could indicate either poor food availability or that animals had not been feeding actively prior to collection.

Only very limited information is available on foods of ringed seals in the southeastern Bering Sea. This area is at the southern limit of the normal ringed seal range, and ringed seals are very uncommon in the usual area of operations (ice front zone). Six seals taken in spring of 1975 at Mekoryuk had fed on fishes and small crustaceans in relatively small amounts. Three ringed seals taken in the ice front have all had empty stomachs.

The most important food species of spotted, ribbon and bearded seals in the southeastern Bering Sea are pollock, capelin, herring and tanner crabs. There is good evidence to suggest that pandalid shrimps (Pandalus spp.) are sometimes of importance to ribbon and spotted seals (Shustov 1965, Gol'tsev 1971, Burns pers. obs.) perhaps in areas where concentrations of fishes are not available. Shrimp, pollock and herring in the Bering Sea have been commercially harvested at levels higher than sustained yield (Pruter 1973). The magnitude of the tanner crab fishery in the Bering Sea is likely to increase considerably in the near future. The commercial potential of Bering Sea capelin stocks is now being realized (Barton et al. 1977). Thus, all major food items of ribbon, spotted and bearded seals in the southeastern Bering Sea have, are or will soon be harvested by commercial fisheries. Some of these same forage species form the bulk of the diet of fur seals (Scheffer 1950), sea lions and harbor seals (Lowry, Frost and Burns, unpubl.) in this area. Wise resource management will be required to maintain proper food availability for marine mammals in the face of increasing human harvest of marine resources in this area.

Northern Bering Sea

A map of the northern Bering Sea is shown in Figure 3. The Norton Basin lease sale area covers much of this region. Seasonal sea ice is present here from late fall until late spring. Large numbers of ringed and bearded seals winter in this area. Ringed, bearded and spotted seals pass through the area during spring and fall migrations. Spotted seals and occasionally ringed and bearded seals summer in some parts of Norton Sound and around St. Lawrence Island. Residents of Gambell, Savoonga, Diomede, Wales, Nome and Stebbins actively engage in seal hunting. The peak of hunting activity occurs in the spring, with fall and winter hunting occurring sporadically at some localities.

Table 7 gives a schedule of field activities conducted in the northern Bering Sea. Locations are shown in Figure 3. Results of stomach content analysis are given in Tables 8, 9 and 10.

Table 7. Schedule of field activities - northern Bering Sea.

Location/Platform	Dates	Personnel
Nome	25-29 Jan 1977	L. Lowry, E. Muktoyuk
	8-20 March 1977	J. Burns, T. Eley, E. Muktoyuk
	28 May - 4 July 1977	K. Frost, E. Muktoyuk
	16-19 Nov 1977	K. Frost
St. Lawrence Island	20 May - 24 June	D. Strickland
Diomede	20 May - 24 June	J. Matthews
Wales	28 May - 2 July	G. Seaman, D. Strickland

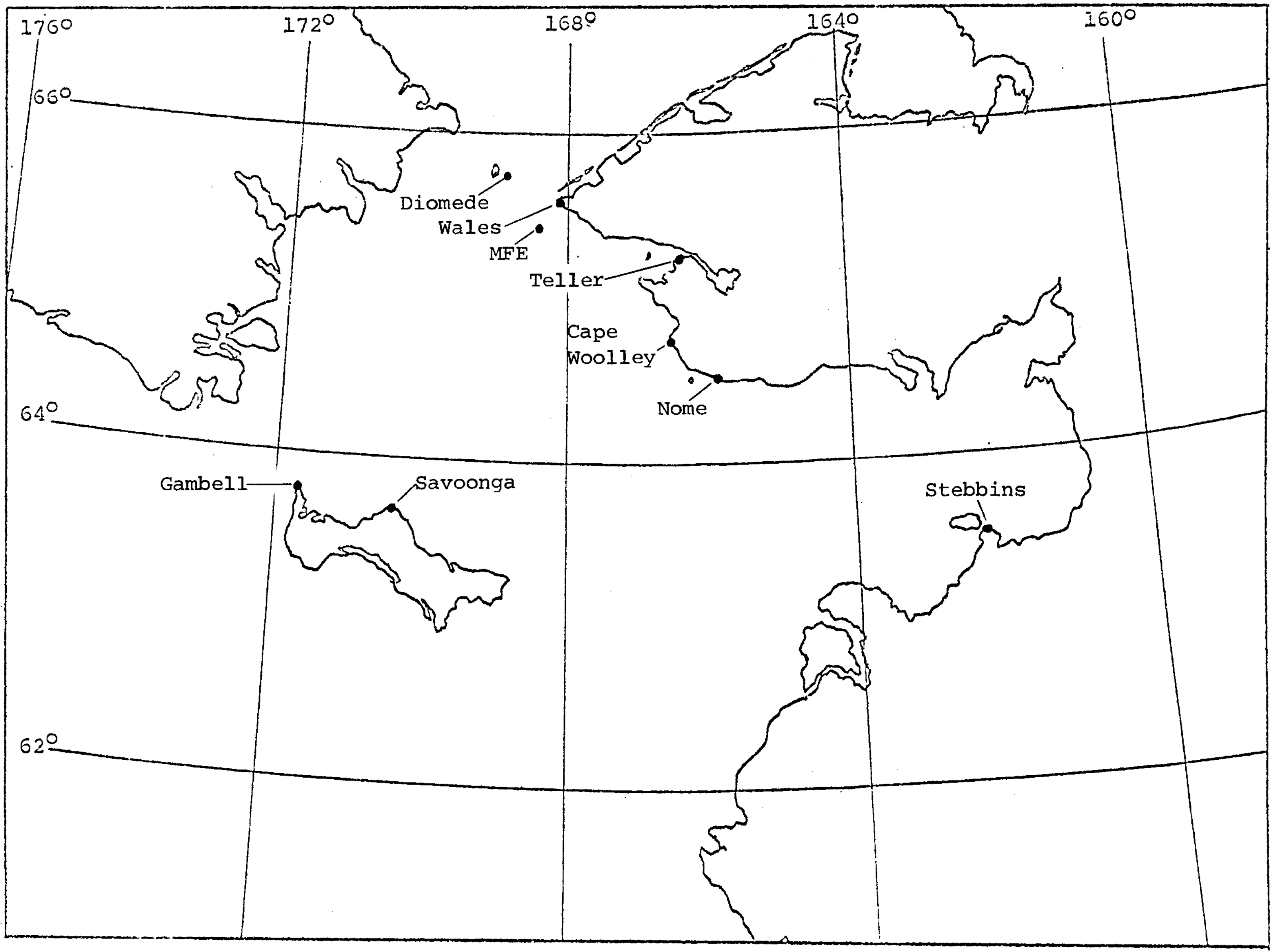

Figure 3. Map of the northern Bering Sea showing locations of specimen collections.

Table 8a Spotted Seal STOMACH CONTENTS DATA FROM Northern Bering Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Cape Woolley 14 Aug - Sept 20 1971&1972 2	Teller 12 Sept - 15 Oct 1970&1972 5	Teller 8-21 Nov. 1972 2	Nome 21 Nov. 1976 1	
Mean Volume (ml)		50.1	1480.0	965.0	867.0	
FOOD ITEMS	1	<u>Fish</u> 97 Saffron Cod 97 Sand Lance 2	<u>Fish</u> 100 Herring 70 Smelt 20 Capelin 10	<u>Fish</u> 100 Smelt 76 Saffron Cod 24	<u>Fish</u> 100 Sand Lance 99 Saffron Cod 1	
	2	Gammarid Amphipods 2				
	3					
	4					
	5					

Table 8b Spotted Seal STOMACH CONTENTS DATA FROM Northern Bering Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Gambell 12-16 June 1977 2	Savoonga 5-29 May 1975& 76 5	Wales 28 June 1977 2		
Mean Volume (ml)		407.1	104.7	27.0		
FOOD ITEMS	1	**Fish** 93 Sculpins 100	Shrimp 90	Shrimp 94		
	2	Shrimp 5	Hyperiid Amphipods 5	Gammarid Amphipod 3		
	3		Euphausiids 5			
	4					
	5					

Table 9a Ringed Seal STOMACH CONTENTS DATA FROM Northern Bering Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE	Stebbins 18 Nov. 1976 2	Gambell 25 May - 15 June 1977 30	Savoonga 29 Feb. - 27 Mar 1976 4	Savoonga 6-13 June 1974-77 3	Wales 28 May - 2 July 1977 10
Mean Volume (ml)	416.5	95.8	71.8	70.3	268.6
FOOD ITEMS 1	<u>Fish</u> 100 Saffron Cod 92 Smelt 6	Shrimp 41	Mysids 79	Shrimp 49	<u>Fish</u> 91 Saffron Cod 100
FOOD ITEMS 2		<u>Fish</u> 36 Saffron Cod 47 Arctic Cod 23 Sculpins 3	Hyperiid Amphipods 11	Mysids 21	Shrimp 8
FOOD ITEMS 3		Mysids 13	Shrimp 8	Euphausiids 15	
FOOD ITEMS 4		Hyperiid Amphipods 6	Gammarid Amphipods 2	Gammarid Amphipods 3	
FOOD ITEMS 5		Gammarid Amphipods 3		<u>Fish</u> 2 Sculpins 100	

Table 9b Ringed Seal STOMACH CONTENTS DATA FROM Northern Bering Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Nome 18-23 Nov. 1976 5	Nome 23-28 Jan. 1976-1977 5	Nome 9-22 Feb. 1971-1978 5	Nome 9-18 Mar. 1977 21	Nome 1-26 June 1977 13
Mean Volume (ml)		178.2	71.6	88.0	246.5	427.1
FOOD ITEMS	1	<u>Fish</u> 93 Saffron Cod 79 Sand Lance 8 Arctic Cod 8	<u>Fish</u> 100 Arctic Cod 87 Saffron Cod 13	<u>Fish</u> 100 Arctic Cod 100	<u>Fish</u> 69 Arctic Cod 86 Saffron Cod 11	<u>Fish</u> 99 Saffron Cod 100
	2	Shrimp 6			Shrimp 30	Shrimp 1
	3					
	4					
	5					

Table 9c Ringed Seal STOMACH CONTENTS DATA FROM Northern Bering Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Diomede 17 May-14June 1958 14 Kenyon(1962)	Diomede 20 May-3 June 1970 12	Diomede 23 May - 11 June 1971 14	Diomede 28 May - 1 June 1975 12	Diomede 27 May - 3 June 1977 7
Mean Volume (ml)		86.0	118.3	255.7	54.9	50.8
FOOD ITEMS	1	Shrimp	Fish 99 Arctic Cod 81	Fish 99 Arctic Cod 100	Gammarid Amphipods 58	Shrimp 44
	2	Gammarid Amphipods		Shrimp 1	Shrimp 18	Fish 40 Arctic Cod 86 Saffron Cod 12
	3	Fish			Fish 14 Sculpins 54 Arctic Cod 43	Gammarid Amphipod 15
	4	Mysids				
	5					

Table 10a Bearded Seal STOMACH CONTENTS DATA FROM Northern Bering Sea

INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		MF (see map) 28 Sept. 1976 1	Gambell 12-28 May 1975& 1976 6	Savoonga 7 May - 19 June 1974 - 1977 8	Wales 25 June - 1 July 1977 6	
Mean Volume (ml)		524.1	253.3	213.5	354.3	
FOOD ITEMS	1	Fish 66 Sculpins 65 Liparids 31	Brachyuran Crabs 29	Shrimp 51	Brachyuran Crabs 54	
	2	Shrimp 26	Shrimp 29	Brachyuran Crabs 13	Shrimp 32	
	3	Brachyuran Crabs 5	Fish 19 Sculpins 98 Wrymouth 2	Fish 13 Sculpins 78 Pollock 11	Clams 6	
	4	Gammarid Amphipods 1	Anomuran Crabs 3	Clams 10	Fish 5 Saffron Cod 57 Flatfish 21 Sculpins 14	
	5		Gammarid Amphipods 1	Anomuran Crabs 3		

Table 10b — Bearded Seal STOMACH CONTENTS DATA FROM Northern Bering Sea

INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Nome 15-24 Nov. 1969 2	Nome 14-18 Mar. 1977 4	Nome 7-26 May 1974& 1975 2	Nome 3-20 June 1976 5	Nome 6-27 June 1977 8
Mean Volume (ml)		216.4	855.9	296.8	852.5	340.0
FOOD ITEMS	1	Shrimp 85	Shrimp 87	Clams 42	Clams 87	Shrimp 45
	2	Anomuran Crabs 13	<u>Fish</u> 9 Sculpins 70 Arctic Cod 15 Saffron Cod 10	Anemones 32	Shrimp 10	Clams 44
	3	Brachyuran Crabs 1	Anomuran Crabs 2	Shrimp 13	<u>Fish</u> 1 Sculpins 71 Saffron Cod 28	Brachyuran Crabs 6
	4		Brachyuran Crabs 1	<u>Fish</u> 6 Sculpins 100		
	5					

Table 10c Bearded Seal STOMACH CONTENTS DATA FROM Northern Bering Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Diomede 11 May-6 June 1958 17 Kenyon (1962)	Diomede 24 April-30 May 1967 5	Diomede 28 May-10 June 1975 6	Diomede 25 May-7 June 1976 4	Diomede 6-23 June 1977 4
Mean Volume (ml)		850.0	2578.0	596.6	410.2	416.8
FOOD ITEMS	1	Brachyuran Crabs	Clams	Brachyuran Crabs 34	Brachyuran Crabs 71	Brachyuran Crabs 48
	2	Clams	Brachyuran Crabs	Fish 31 Sculpins 93 Sand Lance 4 Arctic Cod 3	Anomuran Crabs 11	Shrimp 22
	3	Shrimp	Snails	Clams 8	Shrimp 8	Polychaetes 10
	4	Fish Saffron Cod Sculpins	Shrimp	Octopus 6	Fish 6 Sculpins 89 Eelpout 11	Fish 5 Arctic Cod 50 Sculpins 25 Eelpout 25
	5	Sponge	Sponge	Snails 6	Clams 2	Octopus 4

Few spotted seal specimens have been obtained from the northern Bering Sea. Animals taken at Gambell, Savoonga and Wales in May and June had all eaten small amounts of shrimp. The two specimens from Gambell had also eaten a considerable quantity of sculpins. Spotted seals collected at various locations on the Seward Peninsula in the fall had eaten a variety of fishes. The primary species eaten varies both with time and place of collection. Largest quantities of food were found when herring and smelt (*Osmerus esperlanus*) were eaten.

Ringed seal specimens from the northern Bering Sea have been obtained from a number of locations, years and times of year. Shrimp, mysids, amphipods, saffron cod (*Eleginus gracilus*) and arctic cod (*Boreogadus saida*) and sculpins were eaten by seals taken at Gambell and Savoonga in spring. Saffron cod was the primary food of seals taken in Wales and Nome in the spring and at Nome and Stebbins in the fall. Ringed seals from Nome also fed on arctic cod and pandalid shrimps. Arctic cod are most important in the winter diet while saffron cod are most important in spring and fall. This feeding pattern could probably be explained by seasonal changes in availability of prey. Unfortunately no data are available on seasonal abundance of the prey species except for the summer open water period. Data on spring foods of ringed seals at Diomede are available for a number of years prior to the beginning of OCSEAP (Kenyon 1962, ADF&G unpubl.). All available information is summarized in Table 9. Shrimp, amphipods and arctic cod are the major prey items. The most important prey species is not the same in all years. Shrimp were the most important food in 1958 and 1977, arctic cod in 1970 and 1971 and gammarid amphipods in 1975. The volume of stomach contents was largest when arctic cod were the primary food.

Bearded seal specimens from the northern Bering Sea are also available from a number of locations, years and times of year. Bearded seals taken in spring at Gambell, Savoonga and Wales all ate primarily spider and tanner crabs and crangonid shrimps and lesser amounts of fishes, clams, anomuran (hermit and king) crabs and amphipods. A bearded seal collected south of Wales in September had eaten mostly fish. This somewhat anomalous specimen may be explained by the fact that the seal had been caught in an otter trawl and may have fed on some of the contents of the trawl. Specimens collected at Nome show shrimp, crabs and fishes to be the major foods in November and March while clams are of major importance in the diet in May and June. A similar lack of clams in the winter diet was noted by Burns (1972).

Food items of bearded seals taken at Diomede during five spring hunting seasons are shown in Table 10. Brachyuran crabs were major food items in all years. Shrimp and clams were each major foods in four of five years. The data strongly suggest a decrease in the amount of clams eaten in recent years and a corresponding decline in stomach contents volume. A possible explanation for this could be that clam beds in the vicinity of Diomede have declined as a result of heavy predation by the large population of walruses that forage in the area during spring and fall migrations. Such competition for food could have a direct influence on the health and productivity of the species involved.

Chukchi Sea

A map of the Chukchi Sea is shown in Figure 4. The Hope Basin lease sale area occupies a large portion of the southern Chukchi Sea. Many ringed, bearded and spotted seals pass through the Chukchi Sea as they follow the seasonal advance and retreat of sea ice. Spotted seals summer along the coast in certain areas. Bearded and ringed seals summer in the northern Chukchi in the pack ice. In winter and spring bearded and ringed seals are common in the region with breeding ringed seals mostly on shorefast ice and bearded seals most common in the flaw zone. Seal hunting occurs regularly at the villages of Shishmaref, Point Hope and Wainwright. Hunting activity occurs primarily in the spring and early summer.

Table 11 presents the schedule of field activities conducted in the Chukchi Sea. Locations are shown in Figure 4. Results of stomach contents analyses are presented in Tables 12, 13 and 14.

Table 11. Schedule of field activities - Chukchi Sea.

Location	Dates	Personnel
Shishmaref	24 June - 21 July 1977	G. Seaman, D. Tremaine, D. Strickland
	15-31 Oct 1977	D. Tremaine
	5-11 Nov 1977	D. Tremaine
Point Hope	15 April - 2 June 1977	G. Seaman
Wainwright	22-24 July 1977	G. Seaman

Most spotted seal specimens from the Chukchi Sea have come from Shishmaref. Seals taken there in early July 1976 ate mostly shrimp while seals taken slightly later in July 1977 ate almost entirely herring. Since breakup occurs at this time it is likely that spawning concentrations of herring were just arriving. Barton et al. (1977) report schools of herring off Shishmaref on 25 July 1976. Spotted seals taken at Shishmaref in October had also eaten mostly herring. A seal taken in early November had eaten entirely arctic cod. Two spotted seals taken at Wainwright in summer 1975 had eaten small amounts of sculpins.

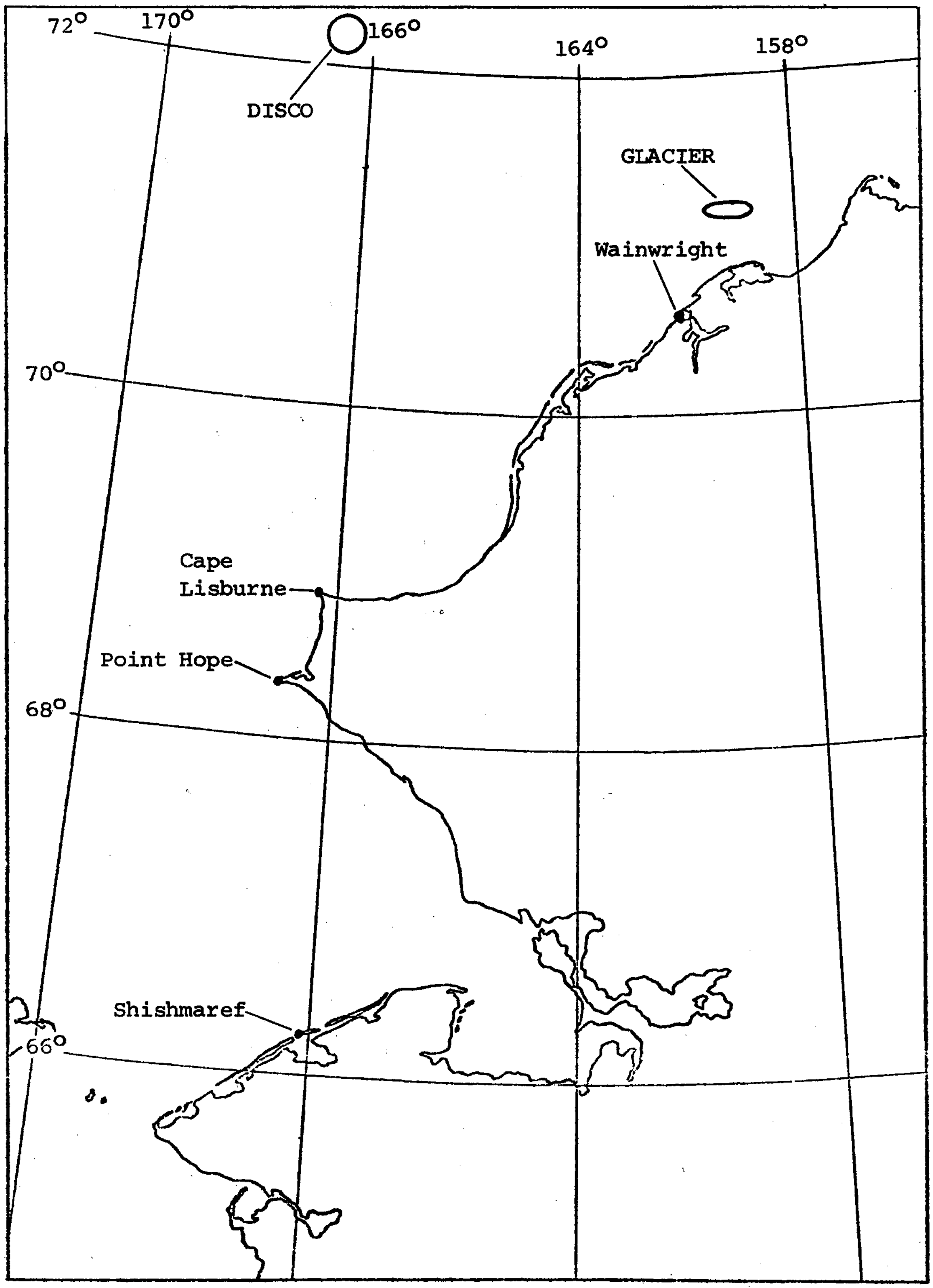

Figure 4. Map of the Chukchi Sea showing locations of specimen collections.

Table 12 Spotted Seal STOMACH CONTENTS DATA FROM Chukchi Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA / DATES / SAMPLE SIZE		Shishmaref 4 - 6 July 1976 3	Shishmaref 8 - 19 July 1977 10	Shishmaref 10 - 24 Oct. 1977 14	Shishmaref 4 Nov. 1977 1	Wainwright 29 July - 4 Aug 1975 2
Mean Volume (ml)		402.9	632.0	432.9	751.0	91.2
FOOD ITEMS	1	Shrimp 87	<u>Fish</u> 99 Herring 96 Saffron Cod 4	<u>Fish</u> 99 Herring 83 Saffron Cod 17	<u>Fish</u> 100 Arctic Cod 100	<u>Fish</u> 97 Sculpins 100
	2	<u>Fish</u> 13 Flatfish 62 Saffron cod 38	Shrimp 1			Isopods 1
	3					Shrimp 1
	4					
	5					

Table 13a Ringed Seal STOMACH CONTENTS DATA FROM Chukchi Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Shishmaref 4 June - 11 July 1976 86 NON-PUPS (ALL SEXES)	Shishmaref 4 June - 11 July 1976 19 PUPS	Shishmaref 4 June - 11 July 1976 36 MALE NON-PUPS	Shishmaref 4 June - 11 July 1976 49 FEMALE NON-PUPS	
Mean Volume (ml)		110.2	39.9	110.9	109.9	
FOOD ITEMS	1	Shrimp 48	Fish 68 Saffron Cod 100	Shrimp 57	Fish 45 Saffron Cod 92 Flatfish 6 Herring 2	
	2	Fish 40 Saffron Cod 87 Flatfish 8 Herring 2	Shrimp 29	Fish 33 Saffron Cod 78 Flatfish 17 Herring 2	Shrimp 42	
	3	Mysids 5	Isopods 2	Isopods 3	Mysids 4	
	4	Isopods 4		Mysids 3	Isopods 4	
	5	Gammarid Amphipods 2		Gammarid Amphipods 2	Gammarid Amphipods 2	

Table 13b Ringed Seal STOMACH CONTENTS DATA FROM Chukchi Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Shishmaref 23-28 Oct. 1977 6	Shishmaref 4-5 Nov. 1977 7	Shishmaref 6 Jan-2 Feb 1978 24		
Mean Volume (ml)		122.0	272.7	314.9		
FOOD ITEMS	1	Hyperiid Amphipods 88	<u>Fish</u> 100 Arctic Cod 86 Saffron Cod 14	<u>Fish</u> 99 Arctic Cod 83 Saffron Cod 10 Sculpins 3		
	2	<u>Fish</u> 7 Saffron Cod 100				
	3	Shrimp 5				
	4					
	5					

Table 13c — Ringed Seal — STOMACH CONTENTS DATA FROM — Chukchi Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE	Wainwright 28 July-11 Aug 1975 20	Point Hope April 1976&1977 29	Point Hope May 1976&1977 27	Cape Lisburne 24 March-1 April 1976 3	DISCOVERER 27-28 Aug 1976 2
Mean Volume (ml)	23.6	71.1	35.1	36.6	75.9
FOOD ITEMS 1	Shrimp 45	<u>Fish</u> 52 Arctic Cod 76 Sculpins 9 Sand Lance 8	Shrimp 38	<u>Fish</u> 31 Arctic Cod 96 Sculpins 4	Shrimp 84
2	<u>Fish</u> 25 Sculpins 43 Cod 28 Capelin 14	Amphipods 28	Amphipods 27	Shrimp 29	<u>Fish</u> Arctic Cod 100
3	Gammarid Amphipods 8	Shrimp 16	Mysids 11	Gammarid Amphipods 20	Gammarid Amphipods 2
4	Isopods 5	Echiuroid Worms 2	<u>Fish</u> 10 Saffron Cod 42 Sand lance 37 Arctic Cod 16	Mysids 1	
5	Hyperiid Amphipods 2	Euphausiids 2	Euphausiids 7		

Table 14a Bearded Seal STOMACH CONTENTS DATA FROM Chukchi Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Shishmaref 4 June - 11 July 1976 25 Non-Pups	Shishmaref 4 June - 11 July 1976 10 Pups	Shishmaref 4 June - 11 July 1976 15 Males	Shishmaref 4 June - 11 July 1976 20 Females	
Mean Volume (ml)		429.8	375.4	304.0	497.0	
FOOD ITEMS	1	Shrimp 42	Shrimp 82	Shrimp 58	Shrimp 50	
	2	Brachyuran Crabs 24	<u>Fish</u> 4 Arctic Cod 66 Saffron Cod 12 Flatfish 8	Brachyuran Crabs 16	Clams 7	
	3	Clams 19	Brachyuran Crabs 4	Clams 7	Brachyuran Crabs 20	
	4	Isopods 3	Isopods 4	Isopods 6	Isopods 2	
	5	<u>Fish</u> 2 Flatfish 56 Sculpins 14 Saffron Cod 12	Clams 2	<u>Fish</u> 5 Flatfish 61 Saffron Cod 19 Sculpins 17	<u>Fish</u> 2 Flatfish 59 Sculpins 12 Saffron Cod 10	

Table 14b Bearded Seal STOMACH CONTENTS DATA FROM Chukchi Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Wainwright 24 July - 7 Aug. 1975 22	Wainwright 28 - 29 July 1976 7	DISCOVERER 27 Aug. 1976 1976 1	GLACIER 1 - 5 Aug. 1977 2	
Mean Volume (ml)		531.1	848.3	655.5	454.5	
FOOD ITEMS	1	Clams 54	Clams 66	Fish 29 Eelpout 91 Sculpins 9	Snails 48	
	2	Shrimp 16	Shrimp 25	Brachyuran Crabs 26	Shrimp 9	
	3	Fish 10 Sculpins 96 Cod 4	Brachyuran Crabs 5	Shrimp 6	Priapulids 6	
	4	Brachyuran Crabs 4	Isopods 2	Priapulids 3	Amphipods 4	
	5	Snails 4	Fish 1 Sculpins 60 Sand Lance 26 Arctic Cod 14		Brachyuran Crabs 3	

Large collections of ringed seals have been made at Shishmaref in late spring and early summer. Comparisons of food of pups versus non-pups and males versus females are shown in Table 13. Shrimp and saffron cod were the main foods of all ages and sexes. Non-pups ate more shrimp than fish and ate flatfish and herring in addition to saffron cod. Pups ate considerably more fish than shrimp and all fish eaten were saffron cod. Diets of male and female ringed seals were similar except that males ate more shrimp than fish while the reverse was true for females. Ringed seals taken at Shishmaref in late October ate mostly hyperiid amphipods (Parathemisto libellula). Seals collected a few days later in early November ate entirely fishes, most of which were arctic cod. Foods of seals collected at Shishmaref in January and early February were almost identical to the November sample. Highest volumes of contents occurred in November and January when arctic cod were the primary prey. Ringed seal specimens collected at other locations in the Chukchi Sea during spring and summer all had little food in the stomachs. Shrimp, arctic cod, sculpins, amphipods, mysids and euphausiids were the most commonly eaten foods. At Point Hope a switch from primarily fishes to primarily crustaceans occurred between the months of April and May. A similar shift in diet was noted by Johnson et al. (1966).

Shrimps were the most common food of all ages and sexes of bearded seals collected at Shishmaref in June and July 1976. Shrimp made up a larger proportion of the diet of pups than of older animals. Non-pups ate considerably more crabs and clams than did pups. Diet of males and females was similar. Females had a larger mean volume of stomach contents than did males. Bearded seals collected at Wainwright in summer of 1975 and 1976 ate mostly clams and shrimp. Components of the diet were very similar between the two years. Two seals collected northeast of Wainwright in August 1977 (GLACIER) ate primarily snails and lesser amounts of several other types of invertebrates. Clams were an insignificant portion of the diet which suggests that the abundant clam resource near Wainwright may be quite limited in extent. A bearded seal collected in the far northern Chukchi Sea (DISCOVERER) had eaten mostly fishes and brachyuran crabs.

Beaufort Sea

A map of the Beaufort Sea is shown in Figure 5. Due to the fact that the first OCS lease sale to be held in northern Alaskan waters will involve the nearshore area of the Beaufort Sea, more effort has been devoted to this region than to other areas. The Beaufort Sea is covered by sea ice from about October through June. The open water period is short and very variable in the extent of ice-free areas. Ringed seals are found in this area throughout the year with largest numbers occurring in summer when ice cover to the south has disappeared. Bearded seals are also present year-round in low numbers. Spotted seals are occasionally found along the coast in summer. Seal hunting occurs sporadically at the villages of Barrow and Kaktovik (Barter Island). The majority of specimens have been collected by Alaska Department of Fish and Game personnel using ships, small boats and helicopters.

Table 15 presents the schedule of field activities conducted in the Beaufort Sea. Locations are shown in Figure 5. Results of specimen collections are shown in Tables 16 and 17.

Table 15. Schedule of field activities - Beaufort Sea.

Location/Platform	Dates	Personnel
Barrow/helicopter	4-14 April 1977	T. Eley
Barrow	10-20 June 1977	T. Eley, J. Burns
Beaufort Sea/GLACIER	1 Aug - 6 Sept 1977	K. Frost, J. Burns
Prudhoe Bay/helicopter	5-11 Nov 1977	L. Lowry, T. Eley
Barrow/helicopter	12-17 Nov 1977	T. Eley, J. Burns

The food of ringed seals taken near Point Barrow shows seasonal variation. In late winter and early spring, gammarid amphipods and mysids were the main food items. In May and June euphausiids were eaten regularly in small amounts. Gammarid amphipods and isopods were also major foods at this time. Three seals taken near Barrow and off Pitt Point in August 1976 had eaten large numbers of euphausiids. Seals taken near Barrow in November had eaten large volumes of arctic cod and small amounts of hyperiid amphipods. Ringed seals taken 50 to 100 km offshore from Barrow had eaten small volumes of arctic cod, shrimp, amphipods and mysids.

Thirteen ringed seals taken north of Prudhoe Bay in early September had all fed extensively on hyperiid amphipods. Two seals taken east of Prudhoe in summer both had eaten very small amounts of crustaceans. Seals taken north of Prudhoe in November had eaten arctic cod and hyperiid amphipods.

Crustaceans are the most important foods of ringed seals in the nearshore Beaufort Sea in summer. It appears that certain areas have concentrations of appropriate food items while food is more scarce at other areas. Areas of high summer food abundance were near Barrow in 1976 (euphausiids, *Thysanoessa* spp.) and off Prudhoe Bay in 1977 (hyperiid amphipods, *Parathemisto libellula*). In fall the importance of zooplankton in the diet diminishes and arctic cod become the main food item. There was considerable variation in the amount of food in the stomachs of seals taken off Prudhoe in November which may indicate that arctic cod were not uniformly abundant in that area. Our samples of ringed seals from offshore areas in summer and all areas in winter are too small to interpret in a meaningful fashion.

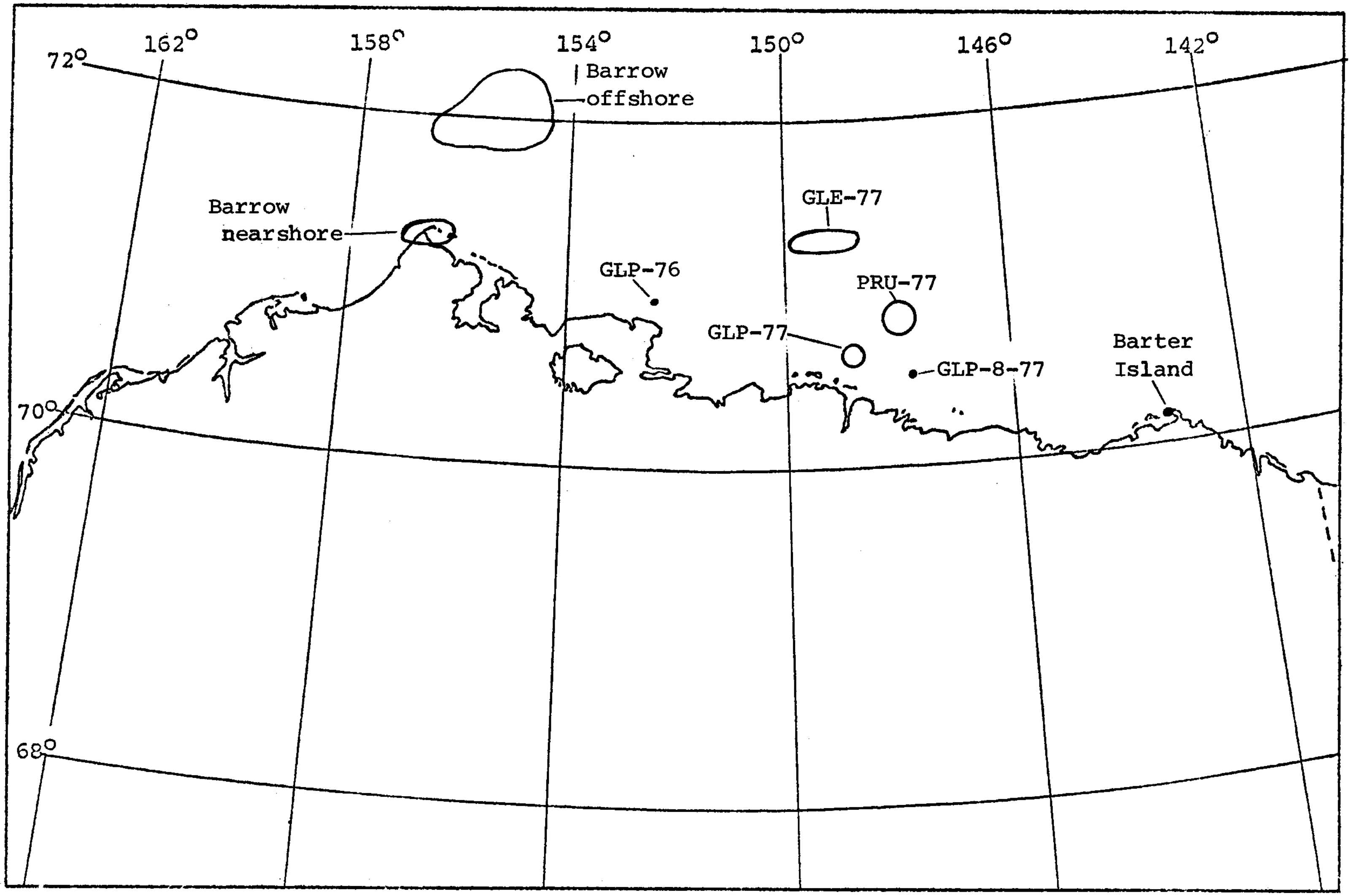

Figure 5. Map of the Beaufort Sea showing locations of specimen collections.

Table 16a — Ringed Seal STOMACH CONTENTS DATA FROM Beaufort Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Barrow 1 Feb-26 April 1975-1977 4 Nearshore	Barrow May-June 1975 9 Nearshore	Barrow 11 May-13 June 1976 4 Nearshore	Barrow&GLP-76 7-20 Aug 1976 3 Nearshore	Barrow 14-17 Nov 1977 14 Nearshore
Mean Volume (ml)		136.5	19.2	88.5	270.7	369.0
FOOD ITEMS	1	Gammarid Amphipods 53	Euphausiids 72	Isopods 56	Euphausiids 96	Fish 94 Arctic Cod 96 Polar Cod 3
	2	Mysids 42	Gammarid Amphipods 23	Euphausiids 36	Mysids 1	Hyperiid Amphipods 5
	3	Fish 2 Arctic Cod 99 Sculpins 1	Fish 2 Capelin 50 Arctic Cod 25 Saffron Cod 25	Gammarid Amphipods 6	Fish 1 Arctic Cod 100	
	4		Shrimp 1	Squid 1		
	5					

Table 16b — Ringed Seal STOMACH CONTENTS DATA FROM Beaufort Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		Barrow 23 March - 1 May 1972-1977 5 Offshore	Barrow 7-9 Aug 1977 2 Offshore			
Mean Volume (ml)		14.0	27.6			
FOOD ITEMS	1	<u>Fish</u> 47 Arctic Cod 83	<u>Fish</u> 49 Arctic cod 82 Polar Cod 10			
	2	Shrimp 42	Shrimp 42			
	3	Gammarid Amphipod 4	Hyperiid Amphipod 7			
	4	Mysids 3	Gammarid Amphipod 1			
	5					

Table 16c Ringed Seal STOMACH CONTENTS DATA FROM Beaufort Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES SAMPLE SIZE		GLP - 8 - 77 17 Aug 1977 1	Barter Island 29 July 1976 1	GLP - 77 1-2 Sept. 1977 13	PRU - 77 7-10 Nov. 1977 19	
Mean Volume (ml)		18.7	23.3	216.0	167.9	
FOOD ITEMS	1	Mysids 78	Gammarid Amphipods 91	Hyperiid Amphipods 92	Fish 87 Arctic Cod 99	
	2	Gammarid Amphipods 12	Shrimp 9	Mysids 4	Hyperiid Amphipods 12	
	3	Shrimp 10		Fish 2 Arctic Cod 91 Liparids 5		
	4			Gammarid Amphipods 1		
	5					

Table 17a Bearded Seal STOMACH CONTENTS DATA FROM Beaufort Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES		Barrow 4-13 April 1977	Barrow 7 August 1976&77	Barrow 1-2 Sept 1973	Barrow 15 Nov. 1976&77	
SAMPLE SIZE		2	2	7	2	
Mean Volume (ml)		139.7	841.3	94.6	457.3	
FOOD ITEMS	1	Hermit Crabs 37	Clams 65	Shrimp 50	Shrimp 48	
	2	Brachyuran Crabs 30	Isopods 29	Brachyuran Crabs 31	Brachyuran Crabs 45	
	3	Octopus 19	Fish 5 Arctic Cod 56 Sculpins 38	Sponge 11	Fish 3 Saffron Cod 76 Sculpins 10	
	4	Amphipods 7		Fish 2 Arctic Cod 96 Eelpout 3	Amphipods 3	
	5	Shrimp 4				

Table 17b Bearded Seal STOMACH CONTENTS DATA FROM Beaufort Sea

NUMBERS INDICATE PERCENT OF THE TOTAL STOMACH CONTENTS VOLUME MADE UP BY THAT TAXON EXCEPT FOR FISH TAXA WHICH ARE PERCENT OF THE TOTAL NUMBER OF FISHES IDENTIFIED WHICH BELONGED TO THAT TAXON.

AREA DATES		GLE - 77 14-17 Aug 1977	PRU - 77 7-8 Nov. 1977			
SAMPLE SIZE		2	2			
Mean Volume (ml)		662.6	594.8			
FOOD ITEMS	1	Brachyuran Crabs 48	Shrimp 66			
	2	Shrimp 40	Amphipod 16			
	3	Priapulids 4	Octopus 8			
	4	Amphipods 3	<u>Fish</u> 3 Sculpins 54 Arctic Cod 41			
	5		Brachyuran Crabs 2			

Few bearded seal stomachs have been examined from the Beaufort Sea. Major food items identified have been similar to those in other areas. Shrimp, crabs and amphipods appear to be the most important foods.

VIII. Conclusions

Foods and feeding of seals

To date we have examined the stomach contents of more than 600 seals. Specimen material is on hand from approximately 400 more animals. The majority of this material has come from coastal hunting villages in the Bering and Chukchi Seas. Most of these seals were taken in the spring and early summer. During the past contract year we have made a particular effort to balance the geographical and temporal distribution of our samples. Specimens from the fall have been collected from the Prudhoe Bay area, Barrow, Shishmaref and Nome. Winter specimens have been collected at Shishmaref, Nome and Gambell and we are anticipating specimens from Prudhoe Bay and Barrow. Geographical coverage has been increased in the ice front of the Bering Sea, the Bering Strait region and the Beaufort Sea. These samples have considerably refined our evaluation of feeding patterns of ice inhabiting seals, particularly ringed seals.

Ribbon seals that have been collected by this project have all been taken in the period of March to June. This is a time of reduced feeding activity due to pupping, breeding and molting and therefore few animals have had recognizable food remains in their stomachs. We have tried to get some indication of recent foods by examining intestinal contents as well as stomach contents. In the area northwest of the Pribilof Islands pollock was the most commonly eaten fish followed by capelin and eelpout. This is an area of high juvenile pollock abundance (Pereyra et al. 1976). Food items in other areas at this time of year include fishes (mainly pollock), shrimps and cephalopods. Foods and feeding areas of ribbon seals during fall and winter, presumably periods of intense feeding, are totally unknown. To investigate this would require a dedicated vessel operating in the Bering Sea for an extended time period. Although the value of such specimens would be great, the success of such an operation cannot be guaranteed.

Spotted seals in all areas sampled fed primarily on fishes. Herring are important foods in all areas in summer. Capelin and pollock are important foods in the southeastern Bering Sea in spring. Saffron cod, smelt and sand lance are eaten in the northern Bering Sea. Saffron and arctic cod are sometimes eaten in the Chukchi Sea. Our samples from Shishmaref and Teller suggest seasonal changes in primary prey species which are probably caused by fluctuating availability of prey. Foods of spotted seals in winter are not known.

Table 18. Key prey species of ribbon, spotted and bearded seals in the Bering, Chukchi and Beaufort Seas.

	Southeastern Bering Sea	Northern Bering Sea	Chukchi Sea	Beaufort Sea
Ribbon seals	Theragra chalcogramma Lycodes spp. Mallotus villosus Pandalus spp.	Theragra chalcogramma Boreogadus saida Pandalus goniurus		
Spotted seals	Mallotus villosus Theragra chalcogramma Clupea harengus Pandalus spp.	Eleginus gracilus Clupea harengus Osmerus esperlanus Ammodytes hexapterus Pandalus goniurus	Clupea harengus Eleginus gracilus Boreogadus saida Crangon septemspinosa	
Ringed seals	Eleginus gracilus Neomysis rayi Parathemisto libellula	Boreogadus saida Eleginus gracilus Pandalus spp.	Boreogadus saida Eleginus gracilus Crangon septemspinosa Ampelisca spp.	Boreogadus saida Parathemisto libellula Thysanoessa spp. Mysis littoralis
Bearded seals	Chionocetes opilio Hyas spp. Argis lar Crangon dalli	Hyas coarctatus Chionocetes opilio Serripes groenlandicus Argis lar	Hyas coarctatus Serripes groenlandicus Crangon septemspinosa Argis lar	Hyas coarctatus Sabinea septemcarinata Boreogadus saida

In the Bering Sea ringed seals feed primarily on fishes and pandalid shrimps. Data from Nome indicate that saffron cod are the primary food in fall and spring while arctic cod are the major food in winter. Similar seasonal shifts in diet occur at Shishmaref and probably at other localities as well. Samples from Diomede indicate that the primary foods eaten can change from year to year. Foods of ringed seals in the Chukchi Sea are similar to those in the Bering Sea. Crustaceans (shrimp, mysids, amphipods and isopods) are more important in the diet of seals taken in the Chukchi Sea. In the Beaufort Sea arctic cod are the most important food in fall and winter. In spring euphausiids, isopods, amphipods and shrimp begin to increase in importance in the diet. In summer zooplankton (hyperiid amphipods and euphausiids) are by far the most important food. It appears that particularly in the Beaufort Sea food resources of ringed seals are very patchy. When foraging in these patches ringed seals consume large quantities of primary food items while seals foraging outside of the patches have eaten small amounts of less appropriate prey.

Crabs and crangonid shrimps are important food items of bearded seals at all areas. At Nome and Wainwright in summer clams are major foods. It appears that clams are not eaten in the winter. At Diomede in 1958 and 1967 clams were major food items. In recent years the importance of clams in the diet of bearded seals at Diomede has decreased considerably. This may be due to a long-term decrease in abundance of clams in the vicinity of Diomede perhaps due to foraging activities of walruses. A number of other food items occur in bearded seal stomachs, occasionally in substantial quantities. This is a reflection of the patchy and diverse nature of benthic communities.

Key prey species of each species of seal in each area are shown in Table 18. These are general patterns and it should be remembered that the exact foods will vary with time and location.

Potential effects of petroleum development

The potential effects of petroleum development on seal populations are multiple. This project is primarily concerned with effects which might be mediated through the trophic structure of the areas under consideration. The following general considerations are involved:

1. Incorporation and potential accumulation of petrochemicals in food webs and the direct effects of ingestion of the compounds by seals.

2. Effects of petrochemicals on the availability and suitability of various food items in light of observed importance in the diet.

3. Resultant effects of 1 and 2 above on the physiological conditions of animals and their ability to respond to normal and abnormal environmental stresses.

Pertinent results of some recent hydrocarbon studies are mentioned below. Other studies are mentioned in the 1977 Annual Report of RU #232.

Almost any discussion of the impacts of petroleum development includes mention of incorporation of hydrocarbons into the food chain and concentration of those hydrocarbons by higher trophic levels. Such incorporation and biomagnification are highly contested by some. Not all organisms do incorporate or accumulate hydrocarbons. However, the possibility exists.

Post-larval pandalid shrimps concentrate benzenes and napthalene. These aromatic functions are depurated quite rapidly but the metabolites are retained for several days. There is evidence that these metabolites cause genetic damage (Malins et al. 1977).

Some bacteria sequester pools of hydrocarbons (Atlas, pers. comm.). In Lower Cook Inlet incorporation of hydrocarbons from detritus by clams has been shown (Shaw, pers. comm.). An arctic species of amphipod, Onisimus glacialis, is known to clean rocks of asphaltics (Atlas, pers. comm.). To our knowledge asphaltics do not transform and their fate once ingested by amphipods is unknown. Gammarid amphipods are a regular food of numerous birds, fishes and ringed seals.

The shrimp Crangon crangon ingests sunken oil. Those shrimp containing oil are more susceptible to fish predation (Blackman 1974 cited in Johnson 1977). This species does not occur in Alaskan waters but other very similar Crangon species do and are important foods of ringed and bearded seals.

Fish are important prey items of fur seals, harbor seals, sea lions, belukha whales, a multitude of seabirds and three of the four species of ice associated seals dealt with in this report. Several of these fish species are key species in the systems of which they are a part. The Bering Sea supports some of the largest commercial fisheries in the world. Numerous local subsistence fisheries by coastal residents exist along the coast. For these reasons the potential effects of petroleum contaminants on fishes are of great concern.

A report by the Council on Environmental Quality (CEQ 1974, cited in Pimlott et al. 1976) lists five ways in which fish populations can be damaged by oil:

1. Eggs and larvae die in spawning and nursery areas from coating and from exposure to concentrations of hydrocarbons in excess of 0.1 parts per million.

2. Adults die or fail to reach the spawning grounds if the spill occurs in a critical, narrow or shallow waterway. Anadromous fish are particularly vulnerable to this situation.

3. A local breeding population is lost due to contaminated spawning grounds or nursery areas.

4. Fecundity and spawning behavior are changed.

5. Local food species of adults, juveniles, fry or larvae are affected.

Fish species of importance to Alaskan marine mammals are pollock, saffron cod, arctic cod, herring, capelin and, to a lesser degree, sculpins. Toxicity tests with petroleum products have been conducted on only a few of these species. Pertinent findings are discussed below.

Herring and capelin both spawn in very shallow water shortly after shore ice breakup. Capelin spawn primarily on gravel beaches while herring utilize mostly seaweed-covered rocks. Major spawning areas in the southeastern Bering Sea have been delineated by Barton et al. (1977). Herring eggs and larvae have been shown to be sensitive to crude oil (Kuhnhold 1970). Mironov (1970) reported death of fish eggs at 10^{-3} and 10^{-4} ml/1, and survival reduced by 11-45 percent at 10^{-4} and 10^{-5} ml/1. Surviving eggs showed delayed hatching with many of the larvae inactive and abnormal. Smith (1977) reports that hydrocarbon concentrations of 1 ppm WSF produced significant reduction in hatching success and gross morphological abnormalities in larvae of herring. In the natural environment only 5-10 percent of the herring are estimated to survive beyond the larval stage. The presence of hydrocarbons may aggravate a natural tendency toward embryonic mortality.

Cods are an important part of the trophic structure of all study areas. Pollock are eaten by all species of seals in the southern Bering Sea. They are also consumed by sea lions, numerous species of birds and other fishes. They are the main target of the second largest commercial fishery in the world. Saffron cod and polar cod are seasonally important to spotted, ringed and bearded seals throughout the northern Bering, Chukchi and Beaufort Seas. The effects of hydrocarbon pollution on these three species are largely unknown. However, acute toxicity tests using water-soluble fractions of Cook Inlet oil have been done on saffron cod from Norton Sound (DeVries 1976). He found that at lower temperatures (3°C) the water-soluble fractions have much less effect than at higher temperatures (8°C). Concentrations of 1.83 ppm paraffins at 3°C and 2.48 ppm at 8°C produced 50 percent mortality within 24 hours.

Almost nothing is known about the sensitivity of Alaska pollock. DeVries (1977) in reporting results of preliminary tests stated that Alaska pollock and Pacific cod died within two hours of exposure to 4 ppm naphthalene at +1°C. At 3 ppm they lost equilibrium after 3 hours and ceased to ventilate at 13 hours, with no recovery upon return to clean sea water. In contrast, sculpins and flatfish tested at 4 ppm lived 20 hours, and at 3 ppm suffered only 10 percent mortality after 48 hours.

Grose (1977, cited in Clark and Finley 1977) reported that 70 percent of the Atlantic pollock eggs (Pollachius virens) within the Argo Merchant slick area were moribund and had adhering oil globules. In adjacent areas a greater percent of the eggs were viable but 64 percent showed evidence of oil contamination. Cytogenetic studies indicated a high incidence of abnormal development.

Kuhnhold (1970), working with another cod species, Gadus morhua, found water extracts of crude oils to be highly toxic to eggs tested 5-30 hours after fertilization. Mortality was lower in older eggs, but many of the hatched larvae were abnormal and died within a few days. Mironov (1967) also working on cod found that crude oil killed all eggs within two days at 100 ppm and within three days at 10 ppm.

Sculpins of several genera (Myoxocephalus, Gymnocanthus, Enophrys) are important food species to bearded and spotted seals and are also eaten by ringed seals. Little is known of their sensitivity to petrochemicals. However, Percy and Mullin (1975) found fry of Myoxocephalus quadricornis, an important prey species in the Beaufort Sea, to be the most sensitive organism they tested. All fry died after 24 hours in a heavy dispersal of oil. DeVries (1977) found adult Myoxocephalus sp. to be more resistant to naphthalene than were cods.

Spider crabs, Chionocetes and Hyas, are major food items of bearded seals in all areas. Their susceptibility to petrochemicals is suggested by the work of Karinen and Rice (1974) and Parker and Menzel (1974). Karinen and Rice found that oil emulsions at 1 ml/l and less caused autonomizing of limbs in newly molted animals. They also found delay of molt with lower rates of molt success. Parker and Menzel working on crab larvae (hermit, spider and stone) found them sensitive to No. 2 fuel oil. High concentrations retarded growth and inhibited molting at concentrations of 0.5 ppm in hermit and spider crab larvae. Smith (1976) found that exposure to Gulf of Alaska crude oil caused alteration of gill ultrastructure in Alaska king crabs. Mironov (1970) states that crabs which have highly resistant adult forms often have sensitive larvae.

Rice et al. (1976) did acute toxicity tests on tanner crab larvae with Prudhoe Bay and Cook Inlet crude oils and found that, although actual death occurred quite slowly and at relatively high concentrations, moribundity happened at concentrations as low as 1-2 ppm.

Shrimps are important food items of bearded, ringed and spotted seals. Pandalid shrimps have been shown to be very sensitive to the water-soluble fractions of Prudhoe Bay and Cook Inlet crude (Craddock 1977). Malins et al. (1977) reported a 50 percent reduction in feeding-associated behavior for two species of pandalid shrimps at 20 ppb WSF of Prudhoe Bay crude oil. At 8-12 ppb naphthalene he found 100 percent mortality of newly hatched Dungeness crab zoea and stage I and V spot shrimp (Pandalus) within 24-36 hours of exposure. Post-larval pandalids concentrated benzene and naphthalene and although they metabolized these compounds they retained the metabolites for several days. These metabolites are known to cause genetic damage in developing larvae.

Brodersen et al. (1977) reported on acute toxicities of four species of shrimps (Eualus fabricii, E. suckleyi, Pandalus goniurus, P. hypsinotus) and king and tanner crabs. Each of those species is a prey species of seals. In all cases larvae were more sensitive than adults. Concentrations as low as 1-2 ppm caused 50 percent moribundity in larvae. Larvae weakened by oil, even though not killed outright, may be more susceptible to predation and the effects of contamination thus magnified.

Percy and Mullin (1975) found the arctic amphipod Onisimus affinus was the most sensitive to oil of all invertebrates tested. They were killed by high concentrations (30-140ppm) in water and also by oil in the sediment. Oil tainted food and sediment were avoided. Anonyx nugax and Ampelisca sp., also arctic forms, are important food items in the northern Bering and Chukchi Seas. They too may be affected in the same manner.

Bivalve molluscs are major food items of bearded seals at a number of locations. In addition, they are the major food of the Pacific walrus and an important food of Alaska king crabs and some fish. Scarratt and Zitko (1972) reported that scallops and clams (Mya) assimilate hydrocarbons. Renzoni (1975) found that water-soluble fractions of crude oil cause reduction in gamete fertilization at 1 ml/l. Decreased survival of eggs, sperm and larvae, and abnormal embryos were caused in Mulinea and Crossostrea. Dow (1975) reported 20 percent reduction in clam populations and reduced growth on oil contaminated mudflats. Mironov (1970) reported that molluscs in the Black Sea were sensitive to oil and oil products.

Copepods, though not a prey species of ice seals, are a main food source of arctic cod. At least one species, Calanus hyperboreas, has been found to be very resistant to oil (Percy and Mullin 1975).

In predicting or assessing the effects of petroleum exploration and development on trophic interactions among species one must consider a multitude of questions. Not only is it important to know the direct effects of hydrocarbons on critical prey species, but one must also evaluate temporal variations in prey sensitivity, critical times or areas for particular prey species and critical feeding period for predator species. Some examples of these sorts of considerations follow.

1. Ringed seals in the Beaufort Sea seem to feed extensively in late summer on zooplankton. This feeding period may be disproportionately important to the general well-being of the seals throughout the year. Food reserves built up during this time may enable animals to make it through ice covered winter months. They may also be important to pregnant females with newly implanted fetuses. An event affecting zooplankton availability at this time might have far greater ramifications than if it occurred at another time.

2. Adult populations of herring and capelin are widely dispersed and significant portions of these populations would probably not be affected by a single oil spill. However, spawning areas are far more localized and occur in coastal areas where the probability of oil coming onto the beach and destroying spawning grounds is great.

3. Arctic cod and saffron cod spawn in nearshore areas under the ice. While the adults are widespread and might not be affected on a large scale by an oil spill, eggs, larvae and juveniles may be localized in areas where environmental perturbation is apt to occur.

4. Many of the prey species utilized by seals in the Bering Sea are also commercially harvested. The effects of oil pollution could be magnified if populations of fishes and invertebrates are already stressed by heavy predation and harvesting.

IX. Summary of Fourth Quarter Operations

A. Ship or laboratory activities

1. Ship or field trip schedule

A schedule of field and laboratory activities conducted during the fourth quarter is given in Table 19. One person was stationed in the field during the entire quarter in an attempt to obtain winter specimen material which until now has been very limited.

Two of the principal investigators involved with this project participated in the Beaufort Sea Synthesis Meeting in Barrow. K. Frost chaired an interdisciplinary session on trophic interactions and J. Burns chaired the interdisciplinary session on OCS impact scenarios.

Analysis of fish and invertebrate trawl data collected during the August 1977 GLACIER cruise was completed. Length, weight, age, reproductive status and food habits were determined for the fishes. Crustaceans were measured and reproductive status noted.

2. Scientific party

See Table 19.

Table 19. Schedule of field and laboratory activities during the fourth quarter. All personnel are employees of Alaska Department of Fish and Game.

Activity	Dates	Personnel
Beaufort Sea Synthesis Meeting	23-27 Jan 1978	K. Frost, J. Burns
Specimen collection - Nome	25 Jan - 15 Mar 1978	G. Seaman, E. Muktoyuk
Specimen collection - Shishmaref	28 Jan - 10 Feb 1978	G. Seaman
Specimen collection - Beaufort Sea	commenced 24 Mar 1978	J. Burns, T. Eley
Analysis of Beaufort Sea trawl data	Jan - Feb 1978	L. Lowry, K. Frost, R. Lynn
Analyses of specimen material	intermittent	L. Lowry, D. Strickland, R. Lynn
Preparation of annual report	1-31 Mar 1978	L. Lowry, K. Frost, J. Burns

3. Methods

Methods of field sampling and laboratory analysis were as described in section V of this annual report.

4. Sample localities

Sample localities are shown in Figures 3-5.

5. Data collected or analyzed

Fifty-three ringed seals were collected, 7 from Nome, 16 from Gambell and 30 from Shishmaref. Only six bearded seal specimens were obtained, five from Gambell and one from Nome.

Table 20. Food items identified from 70 stomachs of ringed seals taken at Prudhoe Bay, Barrow and Shishmaref. Data are expressed in part A as the percent of the total volume of contents comprised by each species or group. Part B indicates the species composition of fishes expressed as percent of the total number of fishes identified.

	Barrow	Prudhoe Bay	Shishmaref		
	Nov 1977 n=14	Nov 1977 n=19	Oct 1977 n=6	Nov 1977 n=7	Jan 1977 n=24
Food Item	% vol/#	% vol/#	% vol/#	% vol/#	% vol/#
A. Amphipods Total	5.4	12.2	88.2	*	*
Parathemisto libellula	5.3	12.0	88.2	*	*
Gammarid amphipods	*	*			*
Shrimp Total	*		4.8	*	*
Crangon septemspinosa			4.8		
Other Invertebrates	*	*	*	*	*
Invertebrates Total	6.4	13.0	93.0	*	*
Fishes Total	93.6	87.0	7.0	99.9	99.4
B. *Boreogadus saida*	96.4	99.5		5.7	82.9
Arctogadus glacialis	3.3	*			
Eleginus gracilus			100.0	13.6	9.8
Lycodes sp.	*	*			
F. Cottidae	*				2.6
Liparis sp.	*	*			
Osmerus esperlanus				0.6	*
Clupea harengus					4.0
Total number of fishes identified	923	1667	2	154	1095
Mean volume of contents (ml)	369.0	167.9	122.0	272.7	314.9

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

Fall and winter specimens from Shishmaref, Prudhoe Bay and Barrow were analyzed. The results are presented in Table 20 and analyzed in our annual report.

6. Milestone charts and data submission schedules

Milestone charts are given on the following pages. The chart of specimen collection milestones has been revised to more accurately reflect anticipated activities. The winter collecting effort at Wainwright was cancelled due to lack of seal hunting activity in that village. Additional collecting efforts were made at Shishmaref and Gambell to fill in data gaps on winter food habits. Shipboard collections in Norton Sound and St. George Basin - Bristol Bay did not take place because ice-reinforced vessels and icebreakers were not available. Additional collecting efforts have been scheduled at Gambell and Point Hope for spring 1978.

Submission of data to NODC has been somewhat delayed. Extensive time was devoted to preparation of Beaufort Sea Synthesis disciplinary and interdisciplinary summary reports by K. Frost who is also in charge of data management. All 1975 data, record types 1-9, have been completed and resubmitted. Reproductive data have been added to 1976 025 specimen data and 1977 specimen data, record types 1-9, have been keypunched and are in the process of final verification. These data should be submitted by May 1978.

B. Problems encountered/recommended changes

None.

Project: 232

PI: Lowry, Burns and Frost

MILESTONE CHART

MAJOR MILESTONES - Specimen Collections	O	N	D	J	F	M	A	M	J	J	A	S
						1978-79						
Beaufort Sea												
Barrow		▲				▲					△	
Prudhoe Bay		▲				▲						
Icebreaker											△	
Chukchi Sea												
Wainwright										△ - -	△	
Shishmaref	▲	▲		▲ —	▲				△ - -	△		
Point Hope							△ -	△				
Norton Sound												
Nome		▲			▲ —	▲ - -	- -	- -	△			
Gambell					▲ —	▲		△ -	△			
St. George Basin - Bristol Bay												
Ice reinforced vessel with helicopter								△ -	△			

Project: 232

PI: Lowry, Burns, Frost

MILESTONE CHART

MAJOR MILESTONES - Other project activities	1978-79 O	N	D	J	F	M	A	M	J	J	A	S
Acquisition and archival of reference specimens	▲	—	—	—	—	▲	—	—	—	—	—	△
Processing of stomach contents	▲	—	—	—	—	▲	—	—	—	—	—	△
Submission of data						▲	△			△		
Preparation of reports			▲		▲	▲			△			△
Attendance at synthesis meetings				▲								
Preparation of FY 79 proposal								△				

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APPENDIX I

Offshore Demersal Fishes and Epibenthic Invertebrates of the Northeastern Chukchi and Western Beaufort Seas

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I. Summary

In response to the almost total lack of information on abundance, distribution and life history characteristics of offshore demersal fishes and epibenthic invertebrates of the Alaskan Beaufort Sea, a limited otter trawl survey was conducted in the summer of 1977. The investigation was focused primarily on species which are known to be of trophic importance to other animals (particularly marine mammals) in the area.

Thirty-three successful otter trawls were done in the northeastern Chukchi and Beaufort Seas at depths ranging from 40 to 400 m. Seventeen species (or species groups) of fishes and 238 species (or groups) of invertebrates were recorded. Two additional species of fishes were found in trawls done in the area in 1976.

The abundance of fishes was very low. Sixty-eight percent of all fishes caught were arctic cod (Boreogadus saida), Canadian eelpout (Lycodes polaris) and twohorn sculpin (Icelus bicornis). Data on distribution, size-frequency, age and growth, reproductive condition, and stomach contents are given for those and other relatively common species.

The epifaunal invertebrate community was found to be diverse and to represent a substantial biomass. Most of the biomass was made up by echinoderms. Most of the species were crustaceans and molluscs. A brief treatment of abundance and distribution of major groups and associations among species is given. A more detailed discussion is given of shrimps, crabs and molluscs which are known to be important food species of bearded seals.

II. Introduction

During the course of the 1977 OCSEAP Beaufort Sea synthesis meeting (Weller et al. 1977), it became evident that information on the distribution, abundance and life history characteristics of offshore epibenthic invertebrates and fishes was almost totally lacking. Certain of these species are known to be important food items of marine mammals in the area (Lowry et al. 1977a,b; 1978). It was decided that during the interdisciplinary trophics cruise aboard the USCG icebreaker GLACIER in the summer of 1978, OCSEAP RU #232 (Trophic relationships among ice inhabiting phocid seals) would conduct limited investigations of the distribution, abundance and life history parameters of certain invertebrate and fish species which are important in the diet of marine mammals of the Beaufort Sea. Species or groups known to be of particular trophic importance include arctic cod, eelpouts, sculpins, shrimps, crabs and molluscs.

III. Current state of knowledge

A. Demersal fishes

Research conducted on Beaufort Sea fishes up to 1955 has been summarized by Walters (1955). An extensive survey of literature on

Beaufort Sea fishes has been recently provided by OCSEAP (Pfeifer 1977). By far the bulk of available literature deals with freshwater and nearshore species. References to offshore demersal fishes are all distributional records, taxonomic studies or anecdotal accounts. We know of no published surveys of distribution and abundance of offshore demersal fishes of the Alaskan sector of the Beaufort Sea. Some limited life history information for widely distributed species can be found in studies from coastal arctic Alaska (e.g. Bendock 1977) and Soviet and Canadian waters (Andriyashev 1954, McAllister 1962).

B. Epifaunal invertebrates

The excellent report of MacGinitie (1955) provides a considerable amount of information on epifaunal distribution, abundance and life history in the vicinity of Point Barrow. MacGinitie (1959) dealt with details of snail distribution and taxonomy in the area and Hulsemann (1962) gave a similar treatment of bivalve molluscs. Shoemaker (1955) reported on distribution of amphipods and Menzies and Mohr (1962) examined collections of isopods and tanaids. Hedgpeth (1963) reported on American arctic pycnogonids and Hulsemann and Soule (1962) listed some bryozoans found along the Alaskan arctic coast. Studies conducted by Squires (1969) in the Canadian Arctic contain a considerable amount of valuable life history and distributional information on shrimps and crabs. Extensive OCSEAP supported benthic sampling in the Beaufort Sea has dealt primarily with distribution and abundance of infaunal organisms (Carey 1977). Also included in this work is a valuable compilation of distributional information and an exhaustive literature survey.

IV. Study area

The study area occupied the northeastern Chukchi and western Beaufort Seas from 164°W longitude to the Canadian-U.S. demarcation line at 141°W and from 70° to 72°N latitude. The water depth in the study area ranged from 40 to 400 m. During the sampling period (2 August to 3 September) the area was mostly open water with only scattered patches of sea ice. Many of the samples were collected near the southern edge of pack ice. From November through early June this area is covered by ice.

V. Methods

Samples of demersal fishes and epifaunal invertebrates examined in this study were collected using semi-balloon otter trawls. Trawls used had 16 and 19 foot (4.9 and 5.8m) openings and were constructed with 1-1/4 inch (3.2cm) stretch mesh webbing in the body and a 1/4 inch (0.6cm) stretch mesh liner in the cod end. Tows were made on the bottom and were of 5 to 10 minutes duration (bottom time) at a ship speed of 3 to 5 knots. Organisms were sorted from debris and readily identified species were counted and weighed. Occurrence of rocks, pebbles or mud in the net was noted. Stomachs of fishes were immediately injected with a 10 percent formalin solution. All organisms were preserved in 10 percent formalin for later detailed examination in the laboratory.

Subsequent analysis of specimens involved determination of fork length, weight and age and stomach contents when possible for all fishes caught. Specimens were measured to the nearest 0.1 cm and weighed to the nearest 0.1 g. Ages were determined by counting otolith annuli after polishing and clearing in xylene. Stomach contents were classified by major groups (e.g. copepods, amphipods, polychaete worms) and the abundance of each group in each stomach was assigned a ranked value. Determination of specific identity of prey items was done in some instances. Degree of stomach fullness was noted. Invertebrates were identified to species and enumerated where possible. Weight of each species or taxon was determined. Identification of all invertebrates with the exception of decapod crustaceans (crabs and shrimps) was done by personnel at the University of Alaska Marine Museum/Sorting Center. Identification of fishes and decapod crustaceans was done by Alaska Department of Fish and Game personnel (Frost and Lowry). Carapace lengths of decapod crustaceans were measured to the nearest 0.1 cm. The number of ovigerous crabs and shrimp in each sample was noted.

Two additional tows were conducted from the GLACIER in August 1976. In these samples, major organisms were identified, counted and measured. Invertebrates were treated in considerably less taxonomic detail than in 1977. Results presented below refer only to the 1977 trawls unless otherwise noted.

VI. and VII. Results and Discussion

A. General

A total of 33 successful tows were conducted during the period 2 August to 3 September 1977. Locations of those tows and the two conducted in 1976 are shown in Figure 1. Ten of the 1977 tows were west of Point Barrow, 10 were between Barrow and Prudhoe Bay and 15 were between Prudhoe Bay and the U.S.-Canada demarcation line. Depth distribution of tows was as follows: 40-50 m depth, 14 tows; 51-100 m depth, 11 tows; 101-150 m depth, 9 tows; 400 m depth, 1 tow.

Nineteen species or species groups of fishes and 238 species or species groups of invertebrates were identified. A taxonomic listing of all species is given in Appendix A. Trawl data sheets for the 1977 survey, included as Appendix B, give the number and weight of all species of fishes in each tow and the weight and number (where appropriate) of the 40 species of invertebrates which occurred in 10 or more tows. Other information pertinent to each tow is included.

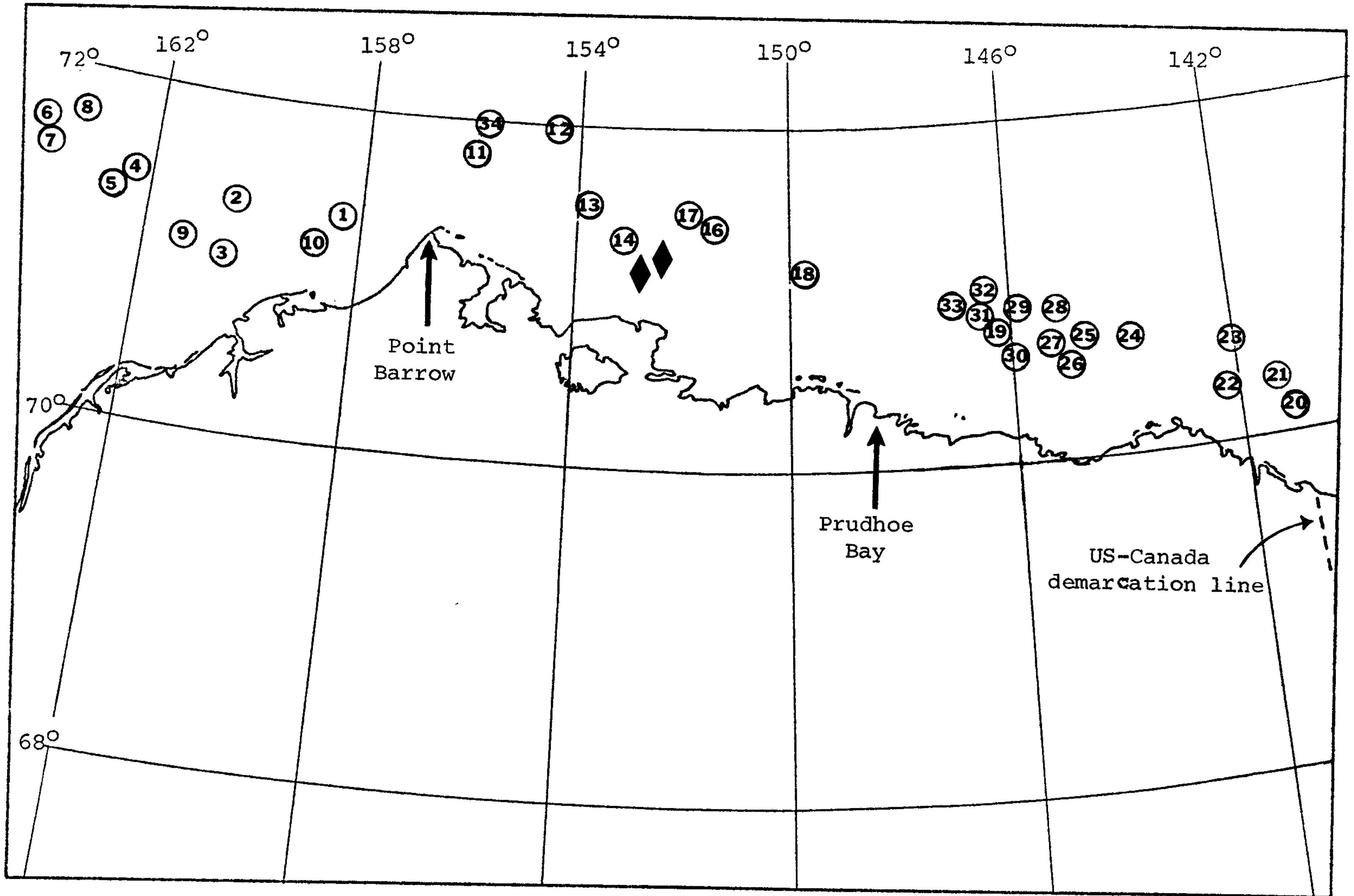

Figure 1. Locations of otter trawl stations in the northeastern Chukchi and Beaufort Seas. Numbers refer to stations trawled in 1977. Stations trawled in 1976 are indicated by ♦.

Although this study was not designed to provide a quantitative estimate of biomass of demersal fishes and epibenthic invertebrates in the area, the area swept by each tow can be estimated. The area swept by an otter trawl depends on effective fishing width of the net (estimated to be between 1/2 and 3/4 of headrope length), bottom time (5 to 10 minutes) and ship's speed (3 to 5 knots). A minimum estimate for area swept by a tow in this study would be 994 m^2 (5 minutes at 3 knots with a 4.9 m net fishing at 1/2 of the headrope length). An estimate of the maximum area swept would be 6,036m^2 (10 minutes at 5 knots with a 5.8 m net fishing at 3/4 of headrope length). It is therefore reasonable to assume that each tow sampled between 1000 and 6000 m^2 of the bottom. It is possible that some species such as arctic cod may have been caught in midwater. However the amount of fishing involved in setting and retrieving the net is small compared to fishing while on the bottom.

B. Fishes

1. General characteristics of the fauna

A total of 17 species (or species groups, e.g. Liparis spp.) were caught during the 1977 trawl survey (Table 1). Two additional species (Lycodes rossi and Lumpenus fabricii) were found in the 2 tows conducted in 1976, making a total of 19 species recorded from offshore waters of the Alaskan Beaufort Sea in 1976 and 1977. Thirty-four species are known to occur in nearshore waters of this area. Of the 50 total species recorded, only 3 (Boreogadus saida, Lumpenus medius and Liparis spp.) were found both nearshore and offshore. The fish faunas of these two zones are obviously quite distinct.

Walters (1955) reviewed the zoogeography of Beaufort Sea fishes. Eight of the 19 species listed in Table 1 had not been positively reported from the Alaskan Beaufort Sea at that time. We know of no surveys of fishes in the offshore Alaskan Beaufort Sea published in the 23 years between Walter's study and this report.

The species found in this study are mostly arctic forms. Six (Lycodes raridens, Gymnocanthus tricuspis, Triglops pingeli and Lumpenus spp.) are primarily Bering Sea species while one (Eumesogrammus praecisus) is found in both the North Atlantic and the Bering Sea (Walters 1955).

The species shown in Table 1 are ranked in order of overall abundance. This ranking for each species is based on the mean of its rank in terms of number of individuals caught, biomass caught and number of tows in which the species occurred. A total of 496 fishes were caught and examined in 1977. Three species, B. saida, L. polaris and I. bicornis, accounted for 68 percent of the fishes caught. This proportion is influenced somewhat by the geographical and depth distribution of the tows (for example, I. bicornis was

Table 1. Species of fishes caught in offshore waters of the northeastern Chukchi and Alaskan Beaufort Sea during 1976 and 1977. Species indicated by an asterisk were found in 1976 only. Other species are ranked in order of decreasing abundance as indicated by the 1977 trawl survey.

Scientific Name[2]	Common Name[2]	# Individuals	# Stations	Depth Range
Boreogadus saida	Arctic cod	194	28	40-400
Lycodes polaris	Canadian eelpout	74	13	40-150
Liparis spp.	Snailfish	27	18	40-400
Icelus bicornis	Twohorn sculpin	68	13	50-130
Eumicrotremus derjugini[1]	Leatherfin lumpsucker	29	11	50-110
Artediellus scaber[1]	Hamecon	30	10	40-70
Gymnelis viridis	Fish doctor	23	11	43-130
Icelus spatula	Spatulate sculpin	14	3	56-64
Lycodes raridens[1]	Eelpout	7	2	64-105
Aspidophoroides olriki[1]	Arctic alligatorfish	19	4	64-400
Gymnocanthus tricuspis	Arctic staghorn sculpin	2	2	50-58
Triglops pingeli	Ribbed sculpin	2	2	105-110
Eumesogrammus praecisus[1]	Fourline snakeblenny	2	2	50-62
Arctogadus glacialis	Polar cod	1	1	150
Lumpenus medius[1]	Stout eelblenny	1	1	40
Lycodes mucosus	Eelpout	2	2	50-105
Lumpenus maculatus[1]	Daubed shanny	1	1	44
Lumpenus fabricii*	Slender eelblenny			
Lycodes rossi*[1]	Eelpout			

[1] Not positively recorded for the Alaskan Beaufort Sea in Walters (1955).

[2] From Bailey et al. 1970.

particularly common east of Prudhoe Bay where many of the tows were made). Thirty-nine percent of all fishes caught were arctic cod which occurred in 85 percent of the tows. The mean number of species per tow was four (range 1-9) with in general more species per tow in the eastern Beaufort Sea than in the Point Barrow and northeastern Chukchi Sea regions. As would be expected, the offshore fauna of the eastern Alaskan Beaufort Sea bears a very close resemblance to that reported for waters offshore from Herschel Island in the Canadian Beaufort (McAllister 1962).

2. Species accounts

In this section a more detailed discussion is given of distribution, food habits and life history features of each species of fish for which 10 or more individuals were caught during the 1977 trawl survey.

<u>Boreogadus saida</u>

Arctic cod are what might be called semi-pelagic. Adults are found both pelagic and near the bottom while age class 0 fish are always found near the surface (Hognestad 1968). In this study the near bottom component of the population was the group primarily sampled. Some fish from midwater or surface may have been caught while setting and retrieving the trawl.

Arctic cod was the most abundant and ubiquitous species found at 28 of the 33 stations sampled (Stations #1-14, 16-22, 26-29, 31) in 1977 and both stations sampled in 1976. This species occurred in every tow west of Prudhoe Bay but only 10 out of 15 tows east of Prudhoe. In addition, fewer individuals were caught in tows taken east of Prudhoe (Table 2). Arctic cod were caught throughout the entire depth range sampled. There was no obvious relationship between abundance and depth of tow.

Table 2. Occurrence and relative abundance of arctic cod in the 1977 survey.

Area	Percent of tows	Mean # individuals/tow	Range # individuals/tow
Western	100	10.3	1-26
Central	100	7.8	2-24
Eastern	66.7	1.9	0-11

In the Barents Sea in August and September arctic cod are most abundant in the coldest regions, usually near the ice (Hognestad 1968). Such a temperature relationship may be responsible for the lower numbers of arctic cod found in the eastern portion of the study area. Temperature also affects vertical distribution (Ponomarenko 1968) and could thus have influenced the results obtained in this study.

Figure 2 shows the size distribution of arctic cod caught in 1976 and 1977. Size of individuals ranged from 4.5 to 18.0 cm fork length. A distinct mode can be seen at about 8.0 cm. Table 3 gives some characteristics of the size distribution of arctic cod in waters less than and greater than 100 m depth. Fishes caught in water greater than 100 m deep were considerably larger than those caught in shallower water. By far the majority of specimens caught in water less than 100 m deep were less than 10.5 cm long. Similar size (or age) segregation has been observed in the Barents Sea (Hognestad 1968). The overall size-frequency distribution observed is thus influenced by the depth distribution of the tows.

Table 3. Size distribution of arctic cod in relation to depth. Number in parentheses is the number of tows in the indicated depth range. Data are presented as percent of total animals found in a depth range which belonged to each of three size groups. Mean size and size range are also given.

			Size Group		
Depth Range	Size Range(cm)	Mean Size	Less than 10.5 cm	10.5-14.0 cm	Greater than 14.0 cm
40-100(15)	4.5-16.3	8.1	89.1	9.0	1.9
101-400(10)	6.7-18.0	11.4	45.1	31.0	23.9

Figure 3 shows the length-weight relationship for arctic cod based on specimens preserved in formalin. A comparison of length and weight of fresh versus formalinized specimens showed a 4.8 percent loss in length and a 13.4 percent loss in weight following preservation. Data for fresh specimens plot very close to the curve indicated in Figure 3 due to the combined shrinkage in length and weight experienced during preservation.

Sizes of the various age classes of arctic cod determined in this study are shown in Table 4 and compared with results of other similar studies. Values given in this study are for formalinized specimens. It is not known whether results in other studies were for fresh or preserved specimens; however, it seems likely that they were preserved in some way. Arctic cod examined in this study grew about 5 cm the first year and 3-4 cm in the following two years. These growth rates are similar to but slightly less than those found by other investigators (see Table 4). Arctic cod show a wide range of sizes in each age class, particularly age 1+. This

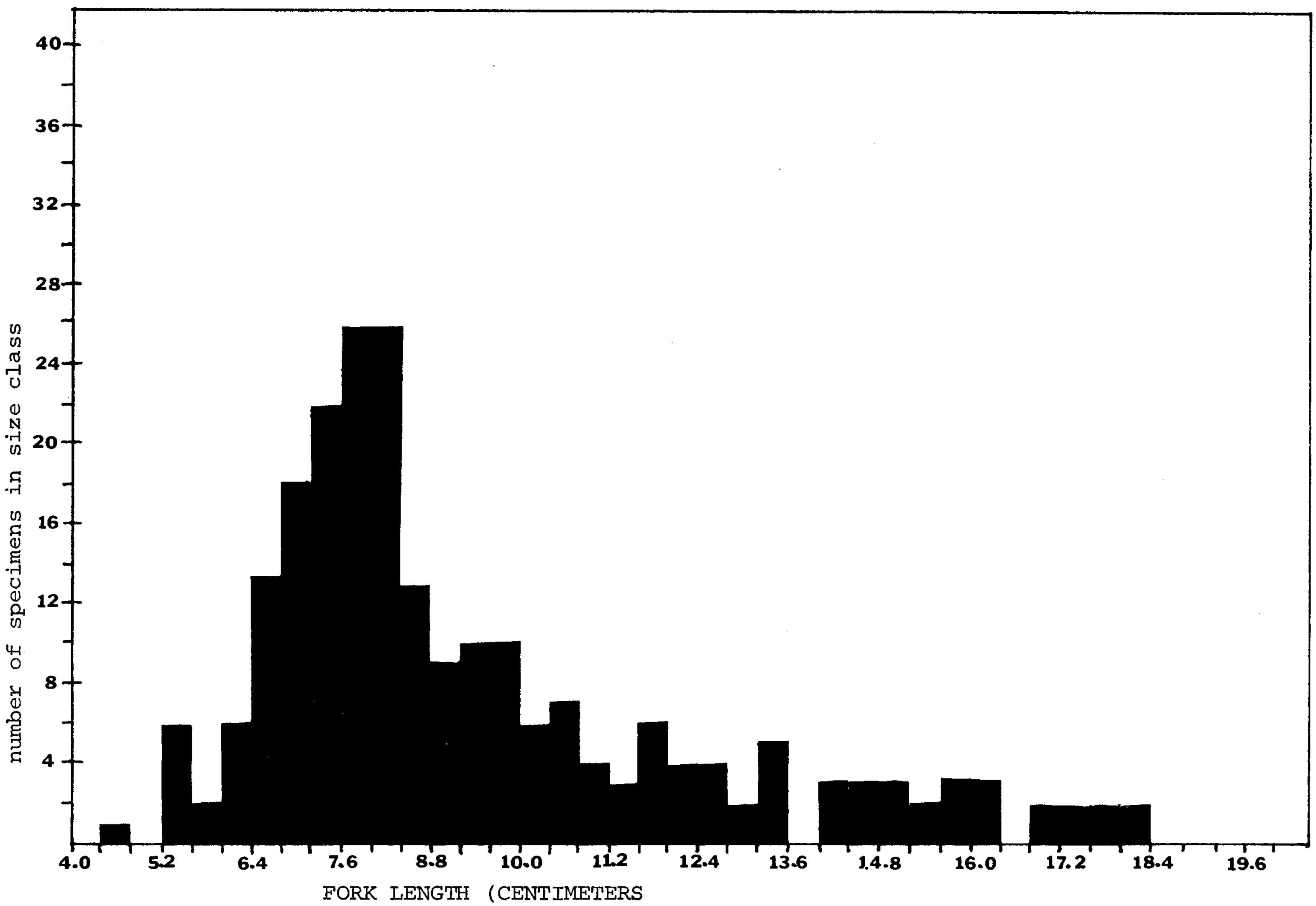

Figure 2. Size-frequency distribution of arctic cod caught in the northeastern Chukchi and western Beaufort Seas, August-September 1976 and 1977.

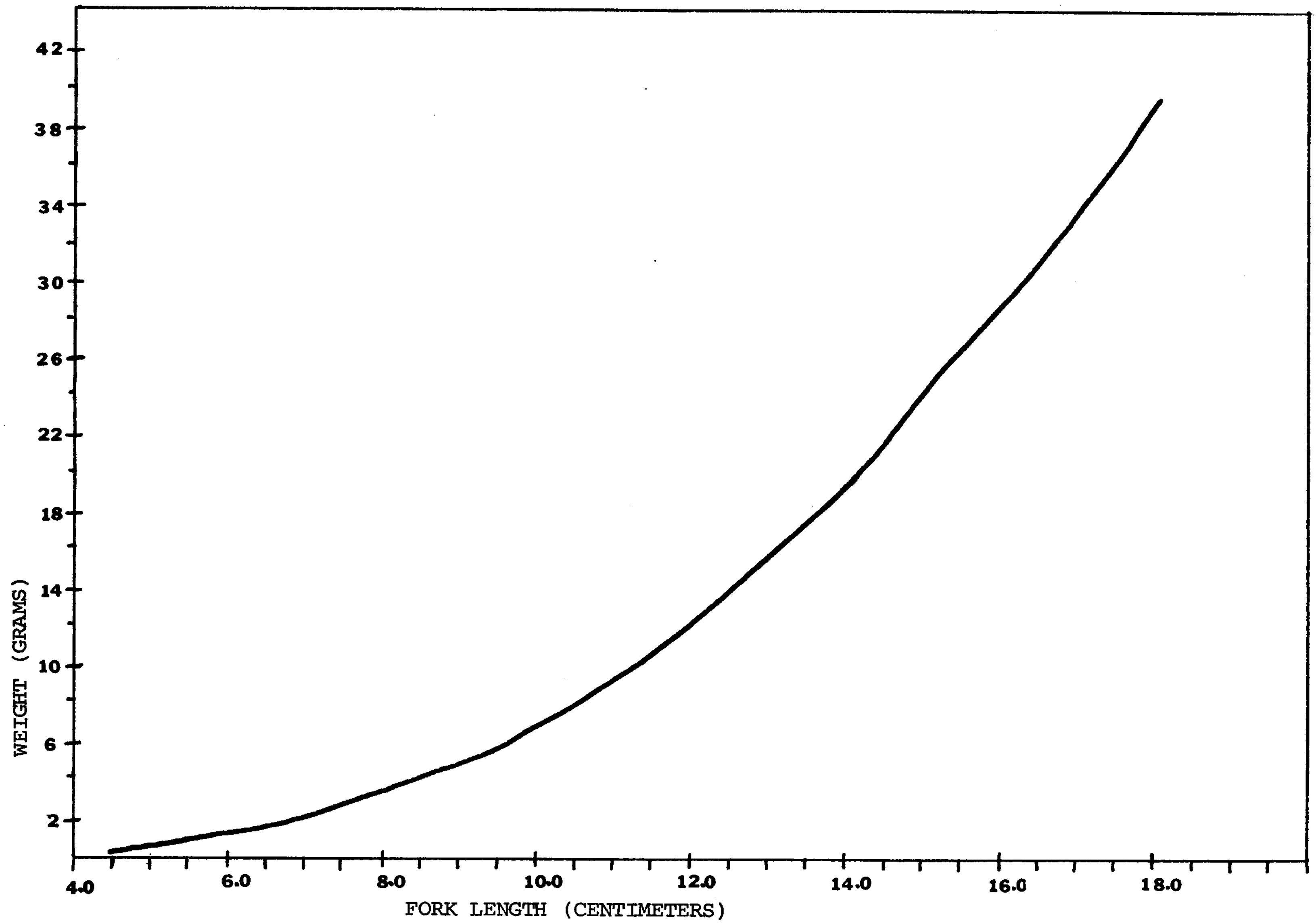

Figure 3. Length-weight relationship for arctic cod.

Table 4. Mean and range of size at various ages for arctic cod in this and other studies.

	This Study x̄	This Study range	Bendock 1977 x̄	Bendock 1977 range	Hognestad 1968 x̄	Hognestad 1968 range	Gjosaeter 1973 x̄	Gjosaeter 1973 range	Andriyashev 1937 x̄	Andriyashev 1937 range
Age class 0+			2.4		4.2	2.0-6.2			3.1	
Age class 1+	7.2	4.5-11.7	9.9		9.3	5.0-13.1	9.3		8.8	7.5-10.0
Age class 2+	11.6	9.7-14.4	13.1		14.9	8.0-22.0	13.4		15.1	14.4-15.8
Age class 3+	14.1	12.9-16.0	16.1		17.8	13.0-24.8	16.6		19.5	19.0-20.0
Age class 4+	17.1	16.1-18.0			19.8	15.5-27.0	19.1		22.5	22.0-23.0
Age class 5+					22.7	17.3-25.2	21.2			
Age class 6+					24.3	19.0-28.8	22.9			
Time of year	August		August		?		July-August-September		summer?	
Location	NE Chukchi & offshore Beaufort Seas		Prudhoe Bay		Barents Sea		Barents Sea		Bering and Chukchi Seas	

could result from an extended spawning period (Rass 1968), patchy food resources resulting in variable growth, or a combination of these two factors. Hognestad (1968) noted different first year growth between areas and years.

According to the literature, arctic cod mature at an age of three to four years corresponding to a size of about 14 to 19 cm (Gjosaeter 1973, Andriyashev 1954). In this study, specimens smaller than 11 cm showed no gamete development and had gonads which weighed about one percent of the body weight. In specimens larger than 11.5 cm eggs were clearly visible in the ovaries and gonads accounted for 2 to 2.5 percent of the body weight. Most arctic cod in the Beaufort Sea probably spawn at an age of three years and a length of 12.5 or more cm. Spawning occurs in the winter months under the ice (Hognestad 1968, Rass 1968).

Stomach contents of 187 arctic cod were examined. Of these, 13 were empty and 17 contained only unidentifiable food remains resulting in 157 stomachs with identifiable contents. Results are compiled and presented in Table 5. Copepods (mostly Calanus hyperboreas, C. glacialis and Euchaeta glacialis) and the pelagic amphipod Aperusa glacialis were by far the most important food items. No size-related dietary differences such as found by Bohn and McElroy (1976) were noted in this study. Mysids, the primary food of arctic cod in nearshore waters (Bendock 1977, Craig pers. comm.), were a very minor item in the diet of offshore specimens.

Table 5. Food items identified from 157 stomachs of arctic cod.

Food Item	# Occurrences in Rank 1	2	3	4	Total # occurrences	Frequency of occurrence
Copepods	86	22	2		110	70.1
Apherusa glacialis (gammarid amphipod)	44	31	7		82	52.2
Other gammarid amphipods	3	9	3		15	10.2
Parathemisto sp. (hyperiid amphipod)	2	7	4	3	16	10.2
Mysids	4	9	1		14	8.9
Euphausiids	2	2	1		5	3.2
Shrimp	1	2			3	1.9
Chaetognath	4	3			7	4.5
Medusae	1				1	0.6

Lycodes polaris

Canadian eelpout are benthic forms common on muddy bottoms where they are thought to burrow tailfirst into the substrate (Andriyashev 1954). It was the second most common species in this study, found at 13 of the stations sampled (Stations #1, 4, 11, 14, 18-20, 22, 26, 29, 31, 32, 34) in 1977 and both stations sampled in 1976. Forty-one of the 74 total individuals caught in 1977 were in Tow #1 which was unusual in that the trawl was on the bottom for about one hour while the ship drifted and made mechanical repairs. It is possible that eelpout swam into the net to feed on the contents and were caught when the net was retrieved. Eighteen were caught in Tow #34 which combined with results from Tow #1 indicate a possible center of abundance near Point Barrow. They were found at depths of 40 to 150 m and showed no obvious relationship between abundance and depth.

The length-frequency distribution of Canadian eelpout is shown in Figure 4. Individuals ranged from 3.8 to 24.5 cm in length with the majority of specimens less than 15 cm long. A mode is present at about 8.0 cm. The length-weight relationship of Canadian eelpout is given in Figure 5.

Due to the small size and opaque nature of the otoliths, this species was poorly suited for age determinations. The mode at about 8 cm in Figure 4 represents individuals 2+ years old. The largest individual caught (24.5cm) was probably 5+ years old.

Ovaries of specimens smaller than 15 cm contained only small eggs while those of individuals 15.5 cm and longer contained eggs of two or three size classes. Eggs of the largest size class ranged from 2.7 to 4.5 mm diameter and numbered 66 in an individual 15.5 cm long and 135 in an 18.9 cm specimen. The gonad accounted for 8.2 and 19.2 percent of the body weight in the 15.5 cm and 18.9 cm specimens, respectively. These observations correspond closely with those of Andriyashev (1954). This species probably spawns in fall or early winter.

Of 74 stomachs examined, 9 were empty and 12 contained only unidentifiable food remains. Of the stomachs containing identifiable food, gammarid amphipods occurred in 27, polychaete worms in 12, cumaceans and caprellids each in 4 and isopods, mysids, shrimp, brittle stars and arctic cod in 1 stomach each.

Liparis spp.

Snailfish were caught at 17 of the stations occupied in 1977 (Stations #1, 2, 6, 12, 16-19, 21-24, 28-33) and at both stations trawled in 1976. Twenty-seven specimens were caught in 1977 with no more than three individuals from any single tow.

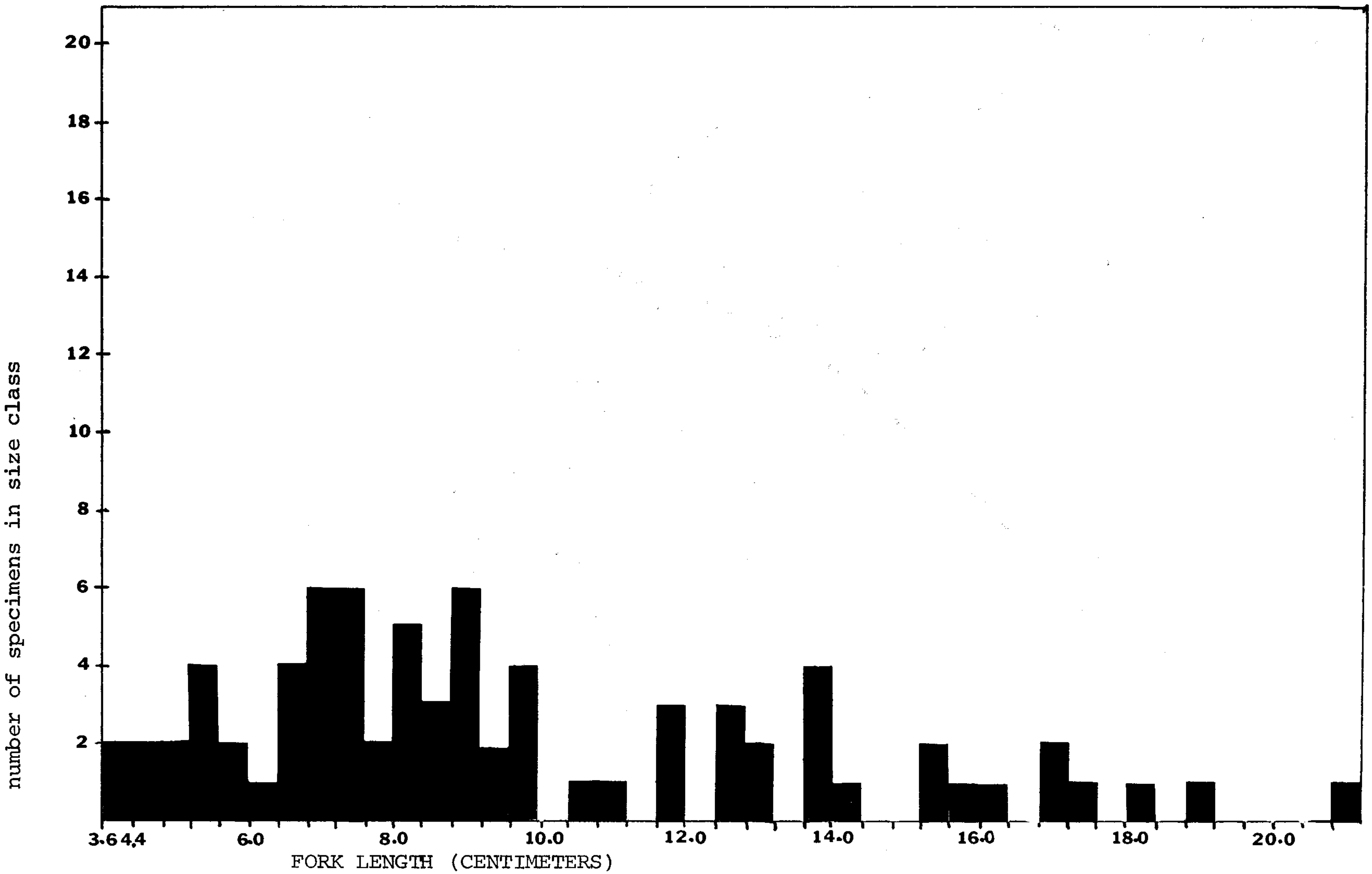

Figure 4. Size-frequency distribution of Canadian eelpout caught in the northeastern Chukchi and western Beaufort Seas in August-September 1977.

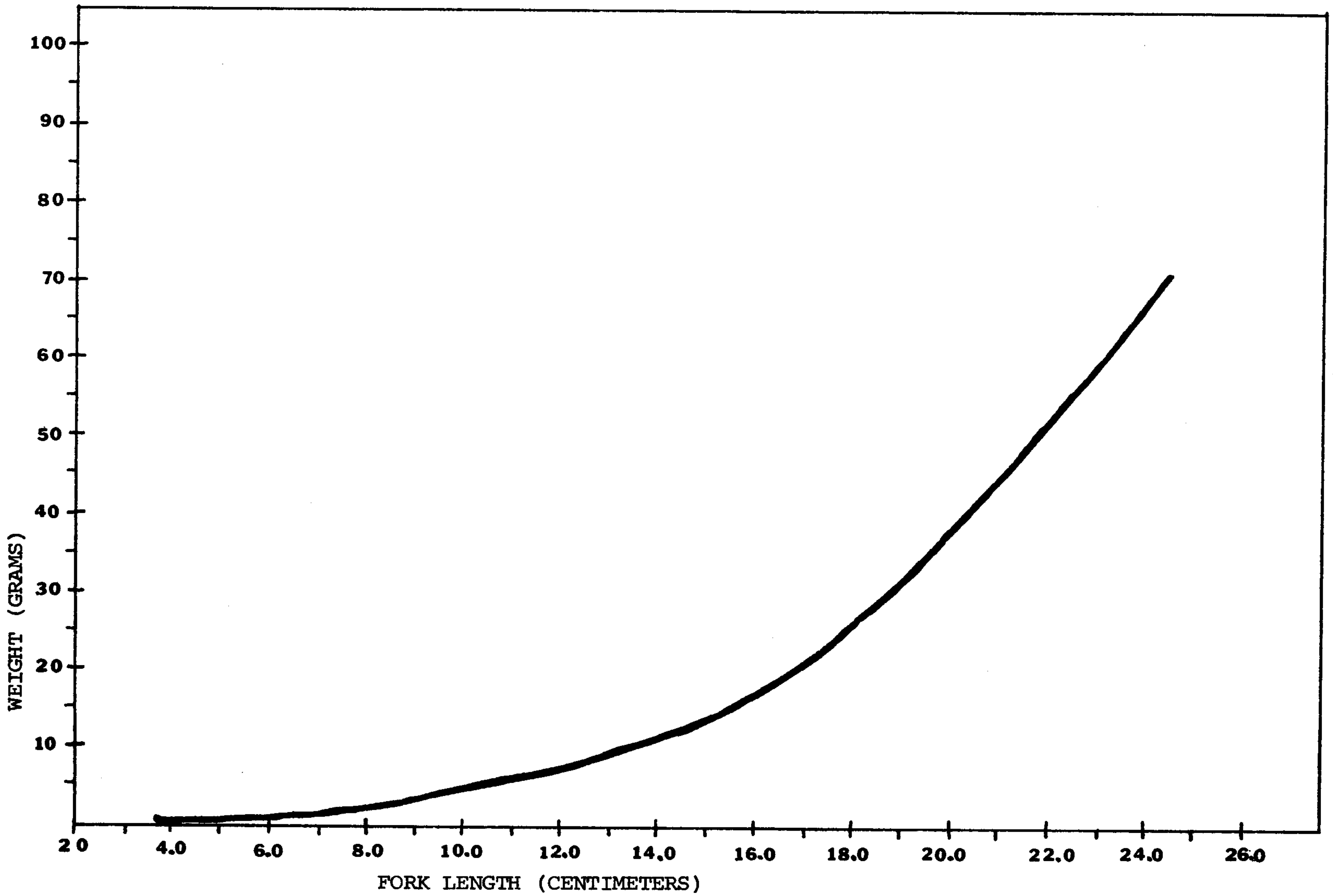

Figure 5. Length-weight relationship of Canadian eelpout

It was impossible to accurately assign most of the specimens to species due to damaged condition resulting from the net and preservation. At least three specimens were L. herschelinus and at least four were L. koefoedi. One specimen appeared to be L. bristolense; however, this specimen was quite damaged. This would represent a major range extension.

Since this group includes at least two species, size frequency and length-weight relationships would not be meaningful. Specimens ranged in size from 3.8 cm (0.4g) to 12.2 cm (34.5g). Age determination was not possible due to minute, opaque otoliths. Two specimens (8.5 and 9.7cm fork length) had numerous large (up to 2mm) eggs which appeared nearly ripe. Of 16 stomachs containing identifiable food, gammarid amphipods occurred in 12, caprellids, hyperiid amphipods, isopods and polychaetes each in 2 and copepods and euphausiids were found in 1 stomach each.

Icelus bicornis

Sixty-eight specimens of the twohorn sculpin were caught during the 1977 survey. They occurred much more frequently east of Prudhoe Bay with 66 individuals found at 11 out of 15 stations in that area (Stations #20-22, 24, 25, 27-32). Only 2 specimens were found in the 18 tows west of Prudhoe (Stations #14 and 17). Forty-eight of the specimens were caught at three stations (#24, 25, 28) suggesting patchy areas of high abundance. They were found at stations ranging in depth from 50 to 130 m. The three stations where large numbers were caught were at 105 to 110 m depth.

Twohorn sculpins caught ranged in length from 3.0 to 7.0 cm. The length-frequency distribution is shown in Figure 6. There was a marked tendency for larger specimens to be female and smaller specimens male. Sex breakdown for animals less than 6 cm long was 33 males and 14 females while of animals 6 cm or longer 3 were males and 20 females. Such sexual dimorphism in size is not uncommon in sculpins.

The length-weight curve for twohorn sculpin is shown in Figure 7. The relationship is similar for both males and females although there is a tendency for females with well developed ovaries to fall somewhat above the indicated line.

The age-length relationship for twohorn sculpin is shown in Figure 8. The size at a given age shows a fairly wide range. This is at least partially due to females being slightly larger than males of the same age. Twohorn sculpin appear to grow about 2 mm per year from the age of two to about six years old. The differences in size of the sexes seen in Figure 6 are probably due to a faster growth rate in females although the sample size is too small to confirm this at present. However, since 9 out of 11 animals 5 years old or older were females, some other factor such as differentiated survival may be involved.

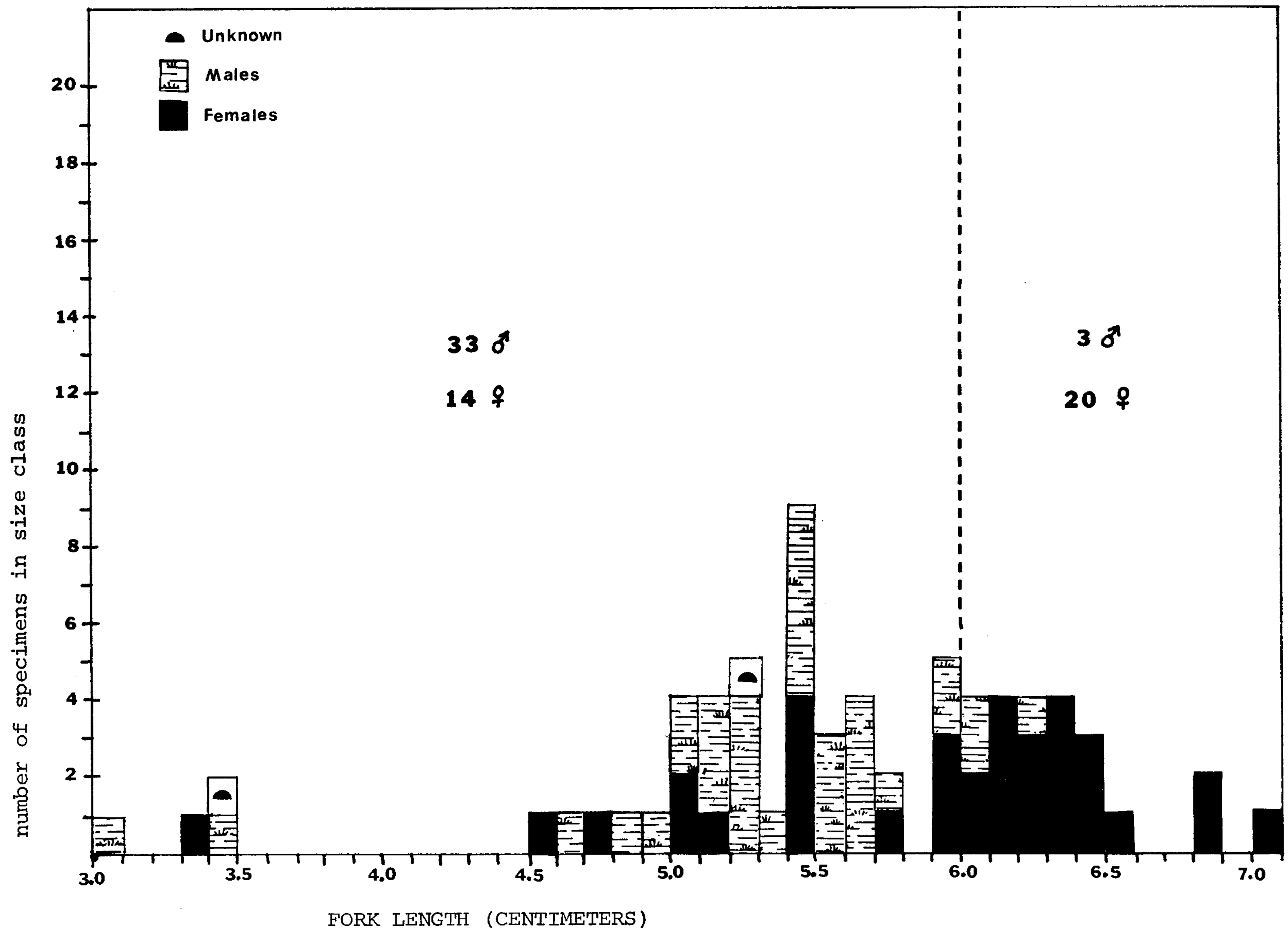

Figure 6. Size frequency distribution of twohorn sculpins caught in the northeastern Chukchi and Beaufort Seas in August-September 1977.

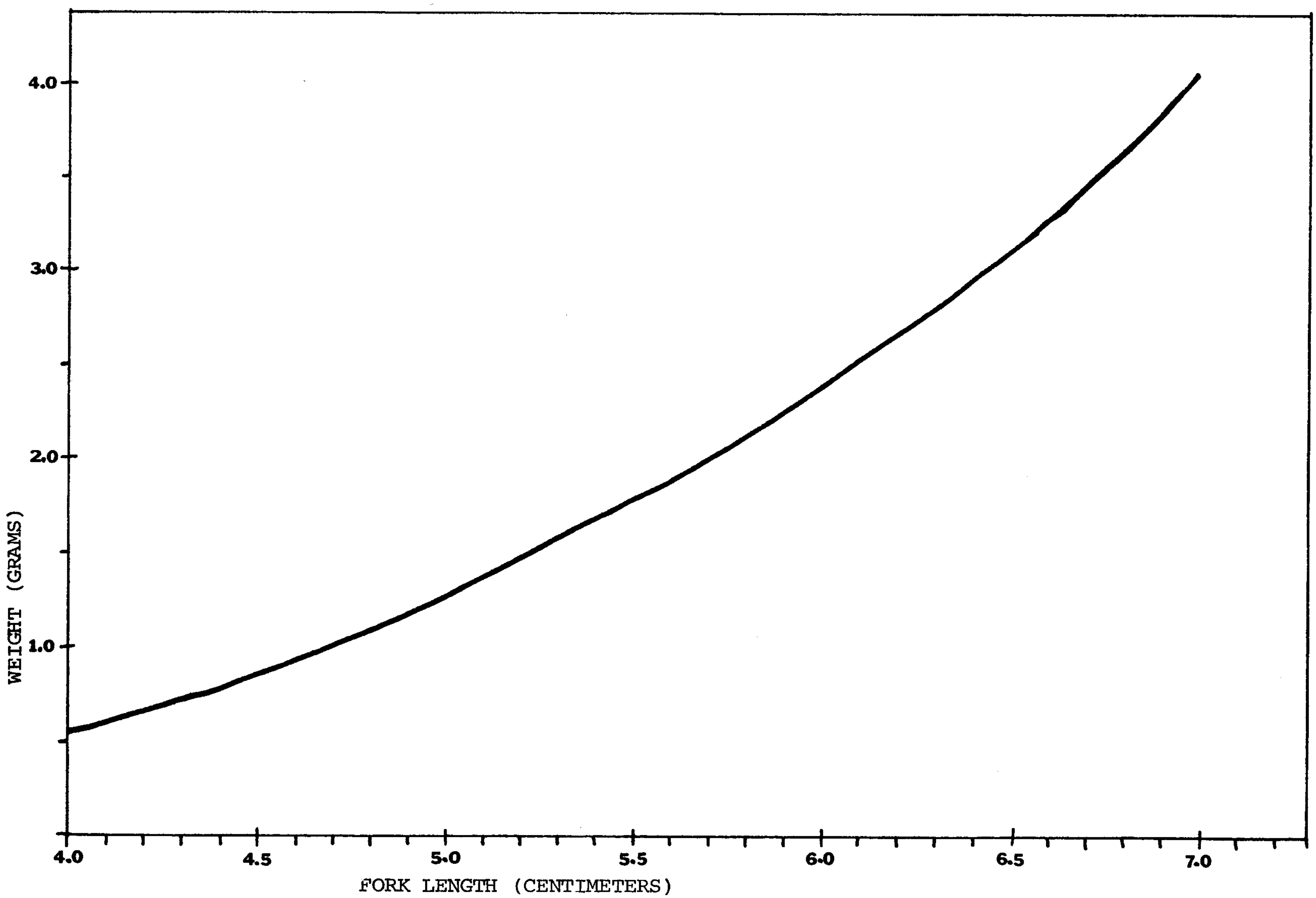

Figure 7. Length-weight relationship for twohorn sculpin.

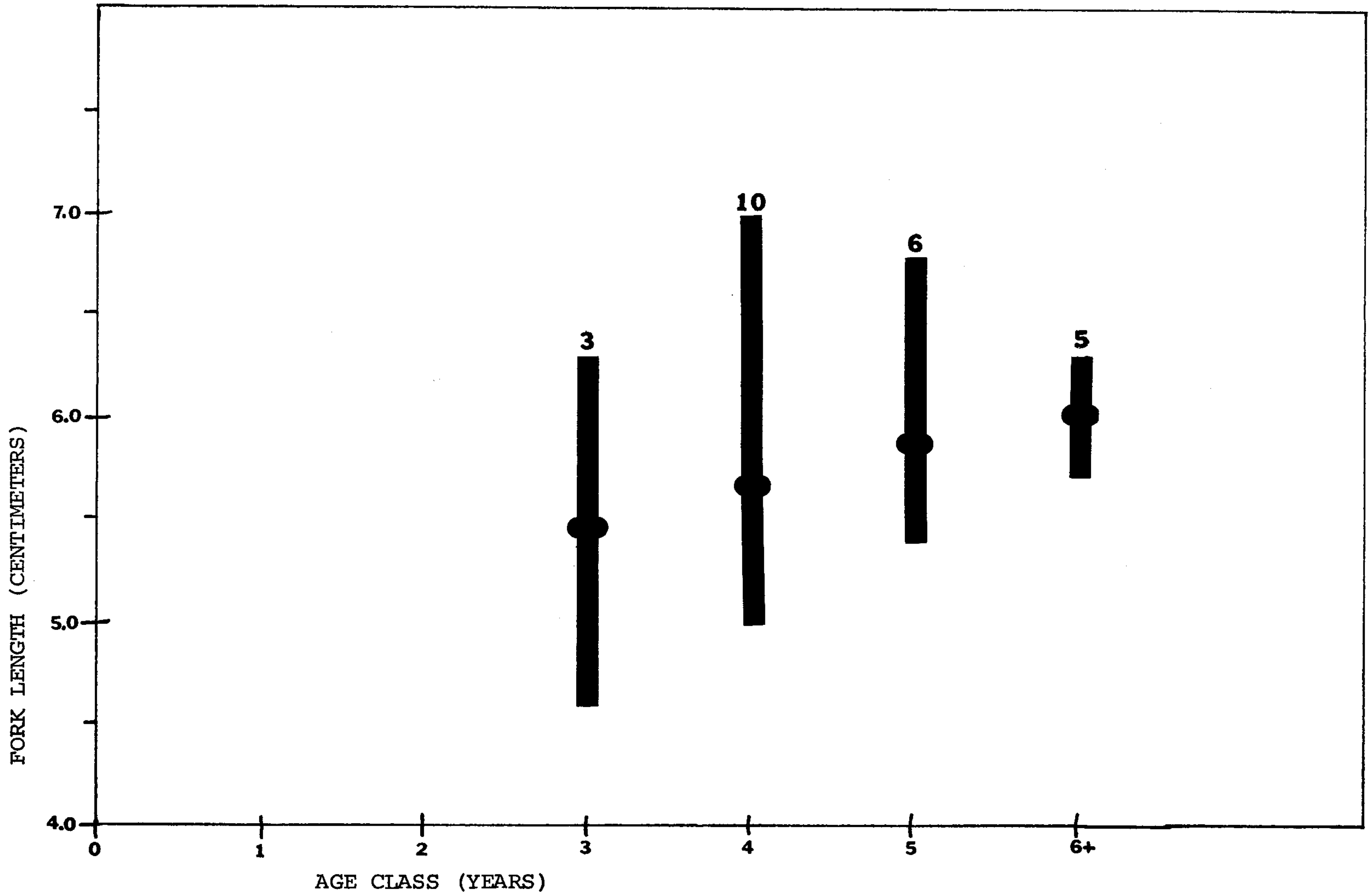

Figure 8. Age-length relationship for twohorn sculpins. Mean values are represented by dots, ranges by vertical bars. Numbers above range bars indicate sample size in that age class.

Female twohorn sculpin mature at about four years of age and a size of about 6 cm. In August the eggs of mature females were 1.4 to 1.9 mm in diameter. The number of eggs in the ovaries ranged from 79 to 180. Andriyashev (1954) reports that this species spawns in August to October and at that time the ovaries contain 147 to 340 eggs up to 3.1 mm in diameter.

Thirty-eight of the stomachs examined contained identifiable food. Gammarid amphipods occurred in 23, polychaetes in 11, mysids and isopods each in 3, euphausiids and hyperiid amphipods each in 2 and shrimp and cumaceans each in 1.

Icelus spatula

Fourteen specimens of the spatulate sculpin were caught at three stations (#1, 20, 31). Eight were females with a mean length of 8.3 cm (range 5.5 to 11.0). Six were males with a mean length of 6.6 cm (range 5.6 to 7.5). Specimens ranged in weight from 1.6 to 14.1 g. No ages could be determined due to degraded otoliths. Eggs in the ovaries ranged from 0.2 to 1.2 mm and numbered 110 to 1000. Eggs were more numerous and smaller than in *I. bicornis*.

Of 10 stomachs containing identifiable food, 4 contained mysids, 3 gammarid amphipods, 2 shrimp and 1 polychaetes.

Eumicrotemus derjugini

Twenty-nine leatherfin lumpsuckers were caught in the 1977 trawl survey. Three were caught in 2 of the 18 tows made west of Prudhoe Bay (Stations #16 and 17) while 26 were caught at 9 of 15 stations trawled east of Prudhoe (#20, 24-28, 30, 31, 33). They were caught at water depths of 50 to 110 m. This species has not been previously reported from the Beaufort Sea.

Specimens ranged in size from 2.5 cm (0.7g) to 8.5 cm (35.8g). Only four specimens were larger than 5.0 cm; those were all females. Of 21 animals for which sex was determined, 15 were females, 6 were males. Females over 6.5 cm long appeared to be reproductively mature and had eggs of two size classes, 0.4 to 0.8 mm and 3.0 to 4.0 mm diameter. No age determinations were made for this species.

The primary food item of leatherfin lumpsuckers was the hyperiid amphipod (*Parathemisto libellula*) which occurred in 23 of 25 stomachs containing identifiable food. Gammarid amphipods occurred in six stomachs and mysids and polychaetes each in one.

Artediellus scaber

Thirty hamecon were caught at nine stations: five west of Point Barrow (#4, 7, 9), three between Barrow and Prudhoe (#16-18), and two east of Prudhoe (#31, 33). They apparently prefer shallow water since all stations at which this species occurred were 70 m or less deep. Specimens ranged in size from 2.7 cm (0.3g) to 7.6 cm (6.6g). Females longer than 5.6 cm appeared reproductively mature and had 50 to 100 eggs ranging in size from 0.6 to 1.6 mm.

The oldest specimen for which age was determined was seven years old. Hamecon probably reach sexual maturity at three to four years old. Growth from the age of one to five years was about 0.8 cm/year.

Twenty-four of the stomachs examined contained identifiable food. Polychaete worms and gammarid amphipods each occurred in 15 stomachs, mysids in 6, cumaceans in 2 and euphausiids, hyperiid amphipods and isopods occurred in 1 stomach each.

Gymnelis viridis

Twenty-three specimens of the fish doctor were caught at 11 stations spread throughout the 1977 survey area (Stations #1, 4, 8, 9, 16, 25, 27, 28, 30-32). These stations ranged in depth from 43 to 130 m. Specimens ranged in size from 7.0 cm (1.2g) to 11.4 cm (5.3g). Three females over 9.0 cm long were reproductively mature and contained about 60 eggs each. Eggs ranged in size from 0.6 to 4.0 mm diameter. No ages were determined for this species.

Of the 13 stomachs which contained identifiable food, gammarid amphipods occurred in 9, caprellids in 2 and mysids, polychaetes and copepods in 1 stomach each.

Aspidophoroides olriki

Nineteen arctic alligatorfish were caught in the 1977 trawl survey. They were found primarily at stations in the vicinity of Point Barrow (#1, 11, 12, 34). They occurred at both stations occupied in 1976. There are no previously published records of this species from the Alaskan Beaufort Sea.

Specimens collected ranged in size from 4.0 cm (0.3g) to 6.7 cm (2.3g). A 6.3 cm female had 260 eggs ranging in size from 0.8 to 1.2 mm.

Six stomachs contained identifiable food. Gammarid amphipods occurred in four stomachs and polychaete worms in two.

C. Epifaunal invertebrates

1. General characteristics of the fauna

A total of 238 species or species groups of invertebrates was identified from 33 trawls. The distribution of species was as follows: 49 gastropods, 34 amphipods, 28 polychaetes, 27 echinoderms, 25 bivalves, 16 ectoprocts and 14 shrimps. Only 14 species occurred in more than 20 trawls. With the exception of the scallop Delectopecten greenlandicus, which occurs only east of 154°, those species are cosmopolitan in the study area. Forty-one species occurred in 10 or more trawls and almost half of the 238 species were found in less than 5 trawls. At 26 of 33 stations echinoderms, primarily brittle stars and crinoids, were the most abundant invertebrate group. In most cases they comprised more than 75 percent of the total trawl biomass.

At least two major community types seem to exist. West of 154°, brittle star communities are predominant with Ophiura sarsi usually the overwhelmingly dominant organism. Associated species vary within a wide range; however, soft corals, Eunephthya spp., and sea cucumbers, Psolus sp. and Cucumaria sp., are characteristic. At all stations where this brittle star community was found the bottom type was mud.

East of Harrison Bay (150°W) a very different community exists. This community seems to be characterized not by a single species, but by a group of abundant species. The most abundant and widespread are the scallop Delectopecten greenlandicus and the crinoid Heliometra glacialis. In addition, sea cucumbers, Psolus sp., sea urchins, Strongylocentrotus droebachiensis, several species of brittle stars (not Ophiura sarsi) and the shrimp Sabinea septemcarinata are usually among the most abundant species. Most trawls in which this species assemblage occurred were in rocky areas.

Some trawls fell into neither of the above patterns. Those trawls were generally in rocky areas between 158° and 162° and between 150° and 154°.

A summary of the abundance of each major group in each trawl is given in Table 6.

Brachyuran crabs

The spider crabs Chionocetes opilio and Hyas coarctatus are probably the two single most important forage species of bearded seals in Alaskan waters. They are the most common food items of bearded seals in the Beaufort Sea (Lowry et al. 1978). Chionocetes opilio is found from the Aleutian Peninsula north to the Beaufort Sea, across the Canadian Arctic and into the North Atlantic as far south as Maine. Hyas coarctatus alutaceus occurs from the Shumagin Islands south of the Alaska Peninsula north to the Beaufort Sea, throughout the Canadian Arctic, and off Newfoundland, Labrador and Greenland (Garth 1958).

Forty-nine Chionocetes were caught in 8 of the 33 trawls done in 1977. They occurred only west of 155°W. Maximum carapace length was 7.5 cm. The largest male was 7.5 cm and the largest

Table 6. Summary data for GLACIER 1977 trawl series. Bottom types are mud (m), gravel (gr) or rock (r). Data for invertebrates are the total weight for that group in grams. Number and weight (in grams) for all fishes are given for comparison.

Trawl #	1*	2	3	4	5	6	7	8	9	10	11
Depth (meters)	64	45	62	42	40	48	44	44	50	102	110
Bottom type	m,gr	m	r	m			m			gr,r	m
Duration (mins.)	?	10	10	10	10	10	10	10	10	10	10
Fishes-number	20	7	2	30	16	30	20	12	8	3	16
Fishes-weight	762	26	12	124	60	149	73	47	35	69	56
Total Invertebrates	34,146	625	3736	14,094	7753	8109	3872	16,234	25,190	6582	12,528
Sponges	10,000									107	
Coelenterates	960		2664	129	178	71	136	395	481	469	13
Polychaetes	130	6	14	10	11	11	28	31	122	15	37
Nemerteans				3							
Sipunculids	32		3	10						2	
Gastropods	340	123	4	40	20	60	9	45	36	221	106
Bivalves	114	114	2	76	12	49	31	28	69	43	16
Octopus	241										
Pycnogonids											
Cumaceans											
Amphipods	42	167	4	13	8	9	5	27	22	31	29
Shrimps	167	112	75	18	80	56	72	109	29	834	247
Anomurans	12	19	7	9		3		6	8	19	19
Crabs	1190	62	73	91	18	159	18	53	308	112	90
Asteroids	485	9	2	20	113		3		428	3	3539
Ophiuroids	10,000			13,600	7300	7500	3400	14,000	1800		8300
Echinoids	304		95							154	
Holothuroids	88	13		66	13	191	164	1540	21,562	700	10
Crinoids											117
Ascidians	41		800						199	3712	
Bryozoans	10,000			9			6		26	160	5

Table 6. Continued.

Trawl #	12	13	14	16	17	18	19	20	21	22	23
Depth (meters)	400	55	50	50	50	40	55	56	80	50	75
Bottom type	m	m	r	r	r	r,m		r	r	r	gr,r
Duration (mins.)	10	10	2-5	10	10	10	10	10	10	10	5
Fishes-number	35	3	16	17	18	13	4	22	7	7	1
Fishes-weight	373	43	77	57	61	41	10	109	37	45	4
Total Invertebrates	5572	4454	1505	3627	5369	2345	633	4962	2034	3188	2073
Sponges											
Coelenterates	25	34	52	135	19	80	24	80	7	73	61
Polychaetes	565	2	3	3	6	1	3	22		16	
Nemerteans											
Sipunculids											
Gastropods	392	64	14	25	106	77	15	251	2	122	56
Bivalves	205	16	7	6	115	705	117	619	48	172	339
Octopus	103		6						74	63	
Pycnogonids											
Cumaceans											
Amphipods	2	25	28	59	81	20		55	30	27	30
Shrimps	169	42	64	131	187	101	7	385	151	61	8
Anomurans	13	37	31	105	13	39			2		
Crabs	2	43	32	152	126	126	25	39	54	33	41
Asteroids	96	2135	81	72	19	996	266	370	273	88	50
Ophiuroids	4000	2050	1	200	100	200	141	49	89	100	21
Echinoids					150				101		61
Holothuroids			86	164	1908			723	3	2187	
Crinoids							22	2199	1200	216	1400
Ascidians				228	2539						
Bryozoans		6	1100	2300		Lots	13				

Table 6. Continued.

Trawl #	24	25	26	27	28	29	30	31	32*	33*	34
Depth (meters)	105	110	50	54	110	130	54	56	100	70	150
Bottom type		r	r				r			r	
Duration (mins.)	10	5	5	10	10	10	10	10	10	10	10
Fishes-number	40	13	7	9	21	6	9	21	10	3	20
Fishes-weight	197	57	80	33	149	53	33	71	30	45	44
Total Invertebrates	6556	1979	1280	2151	6351	2725	4460	4717	2572	2029	7523
Sponges								7			63
Coelenterates	72	10		94	51	212	24	138	3	5	53
Polychaetes	12	16		35	4	12	9	12	9		
Nemerteans		9							8		
Sipunculids	5										
Gastropods	199	24	22	168	180	70	89	87	7	1	441
Bivalves	1666	186	24	1193	660	1505	149	546	1001	762	6
Octopus	79				23						
Pycnogonids											
Cumaceans											
Amphipods	17	20	27	55	89	22	51	67	10	22	17
Shrimps	416	233	47	45	227	42	118	203	208	38	127
Anomurans	11				4		6	16	2		16
Crabs	8	20	21	45	129		81	60			50
Asteroids	465	186	29	120	310	228	298	688	10	295	3005
Ophiuroids	1800	66	8	50	1150	560	30	138	122	Lots	3741
Echinoids	152	199	60		720		305	155	81	40	
Holothuroids	10		431	159			2200	1600		66	1
Crinoids	1300	1000	600	69	2800	9	1100	1100	1111	800	
Ascidians	122	10		45	4						3
Bryozoans											

* Only a portion of the invertebrates from these trawls was sorted: Trawl #1-1/2, Trawl #32-1/5, Trawl #33-1/3. Data represent only the portion sorted.

female was 6.8 cm. That female was the only ovigerous animal. The next largest female was 3.8 cm. MacGinitie (1955) reports catching no ovigerous females off Point Barrow. According to Watson (1970) 50 percent of males are mature at 5.7 cm and 50 percent of females at 5.0 cm. If maturation sizes are similar in the Chukchi and Beaufort Seas, the number of reproductively mature specimens is very low. The ratio of males to females was about 2:1.

One hundred and ninety-two *Hyas* were caught in 28 trawls. Maximum carapace length was 7.3 cm but average maximum length was only 4.9 cm. The largest female was 4.6 cm, the largest male was 7.3 cm. MacGinitie (1955) reported similar maximum lengths of 4.9 cm for females and 7.5 cm for males. Approximately equal numbers of males and females were caught. Twenty-eight percent of all females were ovigerous with the smallest ovigerous female measuring 3.2 cm carapace length. Percent of ovigerous females varied from west to east. West of Point Barrow 50 percent of the females were ovigerous, whereas east of there only 18 percent carried eggs.

Shrimps

Shrimps are one of the primary prey items of bearded seals in the Beaufort and Chukchi Seas. They are also a component of ringed seal diets, although of lesser importance. Fourteen species belonging to the families Hippolytidae (8 species), Crangonidae (5 species) and Pandalidae (1 species) were identified. All 14 species were also reported by MacGinitie (1955) from the Point Barrow region and by Carey (1977). MacGinitie and Carey together list an additional five species from the Beaufort Sea which were not found in this study. Shrimp were present in all trawls with an average of four species per trawl. In 22 trawls shrimp biomass was greater than fish biomass. This was especially true east of Point Barrow. The distribution of shrimps in the 1977 trawl survey is shown graphically in Table 7. A summary of distribution, abundance and biological data for each species is given in Table 8.

Family Hippolytidae

Eualus gaimardii belcheri

E. g. belcheri was the most numerous shrimp in our trawls. It was collected at depths of 40-150 m on both muddy and rocky bottoms. It was the dominant shrimp species (by number and biomass) at 10 stations, all of which were west of Prudhoe Bay. Although this shrimp was present throughout the study area, numbers decreased noticeably east of Prudhoe Bay.

Minimum carapace length recorded was 5 mm and maximum carapace length was 14 mm. This last is considerably smaller than the maximum size (22mm) reported by Squires (1970) for the eastern Canadian Arctic. Twenty-nine percent of the total number of *E. g. belcheri* were ovigerous. The smallest ovigerous female measured 8 mm.

Table 7. Species of shrimps present in 33 August 1977 Beaufort Sea otter trawls. EG = Eualus gaimardii, EM = E. macilenta, EF = E. fabricii, SS = Spirontocaris spina, SP = S. phippsi, LP = Lebbeus polaris, LG = L. groenlandicus, AL = Argis lar, CC = Crangon communis, SB = Sclerocrangon boreas, S = Sabinia septemcarinata. *

	Trawl #	Shrimp Species												# Spp/Trawl
West of Barrow	1	SS	EG	EM	LP			SP		S	SB			7
	2		EG	EM					PG	S				4
	3		EG				EF	SP	PG		SB			5
	4			EM									CC	2
	5		EG	EM					PG	S		AL	CC	6
	6		EG	EM					PG			AL		4
	7	SS	EG	EM					PG	S		AL		6
	8	SS		EM				SP	PG	S	SB			6
	9	SS	EG	EM								AL		4
	10	SS	EG	EM					PG		SB			5
Barrow to Prudhoe	11		EG	EM					PG	S				4
	12	SS		EM					PG	S				4
	13			EM						S				2
	14	SS	EG						PG	S				4
	16		EG	EM	LP	LG		SP		S				6
	17		EG	EM			EF	SP		S			CC	6
	18		EG	EM	LP			SP		S				4
	34		EG	EM	LP					S				4
East of Prudhoe Bay	19			EM						S				2
	20		EG	EM						S				3
	21	SS	EG		LP	LG		SP		S				6
	22		EG	EM	LP			SP		S				5
	23	SS								S				2
	24	SS		EM	LP					S				4
	25	SS	EG	EM						S				4
	26	SS	EG	EM						S				4
	27			EM	LP			SP		S				4
	28		EG	EM	LP					S				4
	29			EM						S				2
	30		EG	EM	LP	LG		SP		S				6
	31	SS	EG	EM	LP	LG		SP		S				7
	32	SS		EM	LP				PG	S				5
	33				LP				PG	S				3

* Late identifications were made of Eualus suckleyi and Argis dentata. E. suckleyi was present in Trawls 10, 16, 31 and 32. A. dentata occurred in Trawls 6 and 32.

Table 8. Offshore Beaufort Sea shrimps collected in August 1977 with numbers, size ranges, frequency of occurrence and percent ovigerous.

Species Name	Depth(m)	Numbers	Size range(mm)	Size modes(s)	% Ovig.	Sm. Ovig.	Number of occurrences	Comments
Eualus gaimardii	40-150	1302	5-14	9	29.4	8	23	less numerous east of Prudhoe
Sabinea septemcarinata	40-400	912	6-19	10,16	7.1	16	28	most numerous east of Barrow
Eualus macilenta	40-400	542	6-12	9	Ø		28	most numerous in water deeper than 100 m
Spirontocaris spina	45-400	80	5-16	9	35.7	7	14	
Sclerocrangon boreas	44-102	67	13-25	15,20	Ø		4	only west of Barrow
Pandalus goniurus	40-400	59	7-25	9,13,19	6.8	16	12	mainly west of Prudhoe
Lebbeus polaris	50-150	37	4-16	6,10	2.7	12	12	mainly east of Barrow
L. groenlandicus	50-80	6	13-22		16.6	22	3	
Argis lar	40-50	5	12-20		Ø		4	east of Barrow
Eualus fabricii	50-60	4	7-10		Ø		2	
Crangon communis	40-50	3	10-13		Ø		3	west of Prudhoe
Spirontocaris phippsi	40-80	50	5-16				11	
Eualus suckleyi	50-110						4	only presence or absence information available
Argis dentata	48-110	2			Ø		2	

E. g. belcheri is widely distributed. It has been reported in Canada from Newfoundland, the Gulf of St. Lawrence, as far north as Ungava and Frobisher Bays (Squires 1970), in the northern Pacific from Sitka northward to the Arctic coast of Alaska and Siberia (Rathbun 1904). MacGinitie (1955) reported it as the shrimp taken in greatest numbers at Point Barrow.

Eualus macilenta

E. macilenta occurred at 28 of 33 stations in water depths from 40-400 m and was the third most numerous shrimp in our trawls. It was the dominant shrimp species at only two of the 1977 trawl stations, and one of the 1976 stations. In all three instances water depths were greater than 100 m. *E. macilenta* and *E. g. belcheri* frequently co-occurred in trawls. *E. g. belcheri* was the most numerous of the two in water less than 100 m and *E. macilenta* usually the most numerous in water greater than 100 m. *E. macilenta* was present in all the deeper trawls whereas *E. gaimardii* was often absent.

Carapace lengths ranged from 6-12 mm with a mode at 9 mm. There were no ovigerous females; however, many females carried large, visible eggs under the carapace.

E. macilenta ranges in the west Atlantic from Greenland to Nova Scotia and in the North Pacific from the Okhotsk and Bering Seas to the Arctic Ocean at depths of 55-540 m. It is more abundant in deeper, colder waters (Squires 1970).

Eualus fabricii

E. fabricii was caught in only two trawls at depths of 50-60 m. Size range was 7-10 mm. None were ovigerous.

Elsewhere they are reported from the Japan Sea and the east Siberian coast to Alaska, the Arctic Ocean off Alaska, and the northwest Atlantic, at depths of 4-200 m (Squires 1970).

Eualus suckleyi

E. suckleyi was identified from four trawls at depths of 50-110 m. No further information was noted for these specimens.

Lebbeus polaris

L. polaris was present in 12 of 33 trawls at depths of 50-150 m. Size range was 4-16 mm carapace length with modal sizes at 6 and 10 mm. Three percent of all individuals were ovigerous with the smallest ovigerous female measuring 12 mm. Squires (1970) in the Canadian Arctic reported the smallest ovigerous female to be 10 mm. In this trawl series *L. polaris* was found mainly east of Barrow.

Squires (1970) summarizes distributional information for L. polaris as follows: in the North Atlantic from the polar regions to Skaggerak and the Hebrides in Europe, to Cape Cod in America, in the North Pacific from the Aleutians, and Bering and Okhotsk Seas, at depths of 0-930 m. MacGinitie (1955) caught three specimens off Barrow.

Lebbeus groenlandicus

Six specimens of L. groenlandicus were caught at three stations at depths of 50-80 m. Carapace length ranged from 13-22 mm. Seventeen percent of all individuals were ovigerous with the smallest ovigerous female measuring 22 mm. L. groenlandicus is present in the North Atlantic from east and west Greenland and from the Canadian Arctic to Cape Cod, in the North Pacific from Arctic Alaska, the Bering Sea to Puget Sound and the Sea of Okhotsk at depths less than 200 m (Squires 1970).

Spirontocaris spina

S. spina was caught in 21 trawls at depths of 45-400 m. It was the fourth most numerous species of shrimp. Carapace lengths ranged from 5-16 mm with the main size mode at 9 mm. Thirty-six percent of all individuals were ovigerous and the smallest ovigerous female had a carapace length of 7 mm. This species seemed to prefer rocky bottoms although it occurred at least once on a hard mud bottom.

S. spina is circumpolar. It is widespread in the North Atlantic, in the North Pacific from Arctic Alaska, Bering Strait, Bering Sea, the Siberian east coast to the Alaska Peninsula and Vancouver, B.C. (Squires 1970, Rathbun 1904).

Spirontocaris phippsi

A single specimen of S. phippsi was caught in 1977 in 50 m of water in the eastern part of the study area. Twenty-four individuals were caught in a single trawl off Pitt Point in 1976. Water depth was 40 m.

Distribution is circumpolar. It occurs from Arctic Alaska to the Shumagins, the Atlantic coast of America southward to Cape Cod, off northern Europe, in 10-250 m (Rathbun 1904).

Family Pandalidae

A single species of pandalid shrimp, P. goniurus, was caught in the eastern Chukchi/Beaufort Sea trawls. P. borealis was also reported from this area by MacGinitie (1955) but we identified no specimens of that species.

Pandalus goniurus

P. goniurus occurred in 12 of 33 trawls at depths of 40-400 m. Only three percent of the individuals were caught east of Prudhoe Bay. Individuals ranged from 7-25 mm carapace length. Although total sample size was relatively small (59) there appeared to be three size modes at 9, 13, and 19 mm. Seven percent of all individuals were ovigerous. The smallest ovigerous female measured 16 mm carapace length.

According to Rathbun (1904) P. goniurus ranges from the arctic coast of Alaska southward to the Okhotsk Sea and Puget Sound, in 5-250 m. Occurrence in water greater than 100 m is unusual.

Family Crangonidae

Five species of crangonid shrimps were identified from the August 1977 trawl series. Of these five only one, Sabinea septemcarinata, was widespread and abundant.

Sabinea septemcarinata

S. septemcarinata, the second most numerous shrimp in our samples, was collected in 28 trawls at depths of 40-400 m. It was the dominant shrimp species in 15 trawls, all of which were east of Barrow. Sabinea occurred west of Barrow, but only in very low numbers (less than 3% of the total).

Carapace lengths ranged from 6-19 mm, with modes at 10 and 16. Only seven percent of all individuals were ovigerous and the smallest ovigerous female was 16 mm, considerably larger than the smallest ovigerous female (10mm) reported by Squires (1970) for the eastern Canadian Arctic.

S. septemcarinata is widely distributed throughout the North Atlantic. It occurs in the Beaufort Sea and the east Siberian Sea at depths of 45-345 m (Squires 1970).

Sclerocrangon boreas

S. boreas was present in only four trawls, all west of Point Barrow, in depths of 44-102 m. Only two rocky bottom stations occurred west of Barrow and S. boreas was the dominant shrimp at both of those stations.

Carapace lengths ranged from 13-25 mm with modes at 15 and 20 mm. No ovigerous females were present. Leech egg cases were present on the pleopods of several individuals. MacGinitie (1955) reported these to be the species Crangonobdella murmanica.

S. boreas is primarily an arctic species. It is present throughout the North Atlantic, in the North Pacific from Bering Strait and Kilesnov to the Straits of Georgia, B.C., in the Arctic Ocean from Siberia to Point Barrow, at 0-400 m (Squires 1970). Squires (1969) reported this species from one shallow water station in the western Canadian Arctic (Franklin Bay).

Argis lar

A. lar was present in four trawls west of Barrow, in 40-50 m of water. Carapace lengths were 12-20 mm. No ovigerous females were present.

Carey (1977) reports *A. lar* from north of Camden Bay. It occurs from the arctic coast of Alaska and Siberia southward to Sitka and the Kurile Islands, off Greenland, in 0-90 m (Rathbun 1904).

Argis dentata

Only two specimens of *A. dentata* were identified. No further information is available on these specimens.

Crangon communis

C. communis was identified from only three trawls, all west of Prudhoe Bay, in 40-50 m of water. Range of carapace lengths was 10-13 mm. No ovigerous individuals were present. A single specimen of *C. communis* was taken by MacGinitie in 1949. That was the first report of this species north of Bering Strait. Rathbun (1904) reports *C. communis* from the Bering Sea to San Diego, California, at 40-600 m.

Amphipods

Gammarid amphipods are the predominant food of many demersal fishes, and regular prey items of seabirds, arctic cod, ringed and bearded seals and bowhead whales.

Gammarid amphipods occurred in every trawl except one. They seldom made up more than two percent of the total trawl biomass. Fifteen families and 34 species were present. The families Lysianassidae and Ampeliscidae were represented by the greatest number of species, eight and five, respectively.

Most species occurred at only one to three stations. Seven species occurred in more than 10 trawls each. Of those seven species all were distributed throughout the study area. Those species were *Ampelisca eschrichti*, *Acanthostepheia behringiensis*, *Rhacotropis aculeata*, *Anonyx nugax*, *Socarnes bidentata*, *Stegocephala inflatus* and *Stegocephalopsis ampulla*. Only one, *Rhacotropis* aculeata, showed any obvious variation in abundance. That species was by far most abundant between Point Barrow and Prudhoe Bay.

Gastropods

Snails are a regular prey item of bearded seals and walruses. They are probably consumed in substantial numbers by sea stars. Thirteen families and 49 species were identified from our trawls. The families Buccinidae and Neptunidae were represented by the greatest number of species.

Margarites costalis was present at all but six stations. It was the most numerous snail in the trawl survey.

Seven species of Buccinum occurred in the trawls. B. polare and B. scaliforme were most numerous. Buccinid snails were in general more abundant west of Prudhoe Bay. This snail genus is often a major component of bearded seal diets.

Ten species of the family Neptunidae occurred in the trawls. Snails of the genus Colus were most common, especially east of Prudhoe Bay. The genera Plicifusus and Neptunea were present mainly west of Prudhoe.

East-west distributional patterns were indicated for several other species and genera. Natica clausa was found only west of Prudhoe, and 9 of 10 tows in which Polinices pallida occurred were west of Prudhoe. Admete couthouyi and two species of the genus Trichotropsis were also present only west of Barrow.

Three species of the genus Trophonopsis (Boreotrophon) were represented in the trawls. Although these species occurred both east and west of Point Barrow, most specimens were caught east of Prudhoe Bay.

Gastropod eggs were found at only one station west of Point Barrow.

Bivalves

Bivalve molluscs are generally abundant and diverse in the benthos. Carey (1977) listed 85 species in his arctic species list. Bivalves are a major food of walruses and bearded seals. They are also eaten by asteroids, crabs and some demersal fishes.

Twenty-five species belonging to 12 families were identified from our trawls. Only seven species occurred in more than five trawls. The small transparent scallop Delectopecten greenlandicus was by far the most abundant species, although it was found only east of 150°W. It occurred in great numbers when it was present.

A small, chalky, heavy-shelled species, Bathyarca glacialis, was the second most numerous bivalve. It was caught only east of Prudhoe Bay and seemed to be very patchy in occurrence.

Nuculana pernula was present only east of the Prudhoe area. Its occurrence coincided closely with that of Bathyarca and Delectopecten.

Cyclocardia crassidens was present throughout the area sampled, as was Nucula tenuis. Two species of Astarte were common. A. montegui was present in greatest number west of Prudhoe whereas A. crenata was most numerous east of Prudhoe.

Polychaetes

Polychaetes are a major component of Beaufort Sea infauna (Carey 1977). They are also a regular component of the epifauna. Most specimens were fragmented and in very poor condition. Nonetheless, 15 families and 27 species were identified. The scaleworms, family Polynoidae, were the most widespread and numerous, occurring in 24 trawls. Three species, Åntinoella sarsi, Eunoe nodosa and Gattyana cirrosa were most common.

Only two other species occurred at more than five stations. Those were Nereis zonata, most numerous west of Prudhoe Bay, and Brada granulata, present in all areas.

Echinoderms

Echinoderms were the overwhelmingly dominant phylum in the Beaufort and northeastern Chukchi Seas. All five orders were represented. In total there were 27 species, 15 of which were asteroids, 7 ophiuroids, 1 echinoid, 1 crinoid and 3 holothuroids.

Ophiuroids were most abundant but least diverse west of 154°W. Ophiura sarsi was the only species identified. East of 154°W numbers of ophiuroids decreased but species diversity increased. Not only was O. sarsi present, but also at least five other species. Ophiacantha bidentata was the most common of those species.

The sea urchin Stronglyocentrotus droebachiensis was present at rocky stations and absent from all muddy stations. It occurred in 14 of 33 trawls in relatively low numbers (usually less than 10 per trawl).

Heliametra glacialis, a crinoid or sea lily, was the dominant organism at 8 of 15 stations east of Prudhoe. It was abundant at most of the other eastern stations, but did not occur at all west of Barrow.

Sea cucumbers were extremely numerous and widespread. Cucumaria sp. was present at 17 stations and Psolus sp. at 16 stations. The two species often co-occurred.

Sea stars were the most diverse of the echinoderms, though never so abundant as other groups. Crossaster papposus and Leptasterias groenlandicus were the most common, each one occurring in more than 20 trawls. The average number of species per trawl increased from 1.4 in the west to 3.7 in the east. The maximum number of species per trawl west of Barrow was three whereas east of Prudhoe it was seven. This difference may be related to the increased number of small bivalves in the eastern area.

Miscellaneous groups

Sponges, anemones, flatworms, nemerteans, bryozoans and tunicates were present in many trawls. The taxonomy of many of these groups is poorly worked out for arctic waters and thus the species lists presented in this report are incomplete. These groups are generally not considered "food benthos" and thus have not been dealt with in any detail in this report. Total biomass for each group at each station is presented in Table 6.

VIII. Conclusions

The number of trawls made during this initial survey is far too small to allow definitive conclusions. However, considering the almost total lack of information available prior to this study, our understanding of offshore demersal fishes and epibenthic invertebrates of the Beaufort and northeastern Chukchi Seas has been significantly increased. Some general conclusions can be made at this time.

The demersal fish fauna is comprised of few species which amount to a small biomass. Compared to species from temperate and boreal regions they are generally small in size, few in number, grow slowly and produce few eggs. Arctic cod and leatherfin lumpsuckers fed primarily on plankton. All other species fed on benthos, mostly gammarid amphipods and polychaetes. The offshore fish fauna is very distinct from that found in nearshore areas. The paucity of information available on the offshore fauna is indicated by the several new records for the Alaskan Beaufort Sea which are included in this report.

Arctic cod was the most abundant species in the study area both in terms of number of individuals and biomass. This is the species of greatest trophic importance to marine mammals and seabirds in the area. They were more common in the western and central portions of the study area. Larger individuals tended to be found in deeper water. Growth rates of arctic cod collected in this study appear to be considerably slower than those reported from other areas. Few individuals of mature size were caught. Food items were primarily copepods and pelagic amphipods.

Epifaunal invertebrates are important components of offshore ecosystems. Identification of epifaunal communities and species interactions is necessary before larger scale system interactions can be understood. Benthic food webs and key species are poorly delineated at present, and cannot be traced until interactions between major infaunal and epifaunal species are known. Some fishes feed on epifaunal species and several species of marine mammals, especially bearded seals, feed almost exclusively on epifaunal invertebrates. The August 1977 GLACIER trawl series provided preliminary data on distribution and abundance of the epifauna. When supplemented by additional sampling these data should provide a basis for study of community interactions.

The invertebrate fauna of the Beaufort and Chukchi Seas is diverse. Two hundred and thirty-eight species, more than have been reported from recent OCS Bering and Chukchi Sea studies, were identified from the 1977 trawl series. Trawl biomass on the average was as great or greater than that of trawls conducted by our group with similar gear in the Bering Sea. However, although the total number of species and the biomass per trawl was relatively great, not many species were found in more than a few trawls, and most trawl biomass was contributed by a very few species.

Echinoderms, primarily brittle stars, sea cucumbers and crinoids, were the most abundant epifaunal group. In most cases they comprised more than 75 percent of the total trawl biomass. Molluscs and crustaceans were the most diverse groups although in general they contributed only a small fraction of the total biomass. What is sometimes termed food benthos, i.e. crustaceans, polychaetes and molluscs, is much less abundant in the Beaufort Sea than are such groups as echinoderms, coelenterates and ectoprocts which are of little or no food value to most organisms.

At least two major community types seem to exist. West of 154°W Ophiura sarsi (brittle star) communities are predominant. Associated organisms include soft corals and sea cucumbers. This community seems to be present only on mud bottoms. East of Harrison Bay (150°W) a very different community characterized by scallops and crinoids exists. In addition, sea urchins, brittle stars (not Ophiura) and crangonid shrimps are usually among the most abundant species. Most trawls in which this species assemblage occurred were in rocky areas.

IX. Needs for further study

One trawl series is certainly only a beginning in delineation of distribution and abundance and key species interactions of Beaufort Sea epifauna. However, even an exhaustive trawl series will not provide answers unless questions are carefully thought out in advance and sampling programs and data analysis designed specifically to answer these questions.

Knowledge which will enable evaluation of the effects of perturbation is the desired end product of OCSEAP investigations. To make such evaluations or predictions one needs to know what key species are within a system, how those key species interact with themselves and other species, what "normal" distribution and abundance as well as annual fluctuations are for those key species and what the determining parameters are for their presence or absence within an area.

Some needs for the epifauna are:

1) Additional trawl data to provide distribution and abundance information.

2) From distribution and abundance information, determination of species associations or communities and within those communities key species, either because they structure that community or because of their use by higher trophic levels.

3) Delineation of determining factors, i.e. temperature, salinity, sediment types, etc. for key species. If critical habitat needs are determined, it should be possible to evaluate potential effects of at least some kinds of habitat alteration.

4) Examination of food habits of key species and their interaction with the infauna. Also determination of the importance of key species to demersal fishes, birds and marine mammals.

5) Sensitivity to hydrocarbon contamination should be determined for key species.

Needs for demersal fish are:

1) A considerably larger number of tows are required to delineate geographical and depth distribution of offshore demersal fishes. Major gaps are in the region from the barrier islands to 40 m water depth and in waters over 110 m deep.

2) Food utilization in relation to availability should be investigated for major species (B. saida, L. polaris, I. bicornis).

3) Seasonal changes in distribution, feeding and reproductive status of B. saida should be investigated. This species is a major trophic link between zooplankton and other vertebrate consumers.

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Appendix A. Taxonomic listing of species found in 1977 GLACIER trawl survey.

TAXONOMIC CODE		SPECIES NAME - TRAWLS IN WHICH PRESENT
		PHYLUM PORIFERA
36		Unidentified sponge - 1, 16, 23, 26, 27, 31, 33, 34
		FAM. AXINELLIDAE
3665010301		Phakettia cribosa - 22
		FAM. POLYMASTIIDAE
36660401		Polymastia mammilaris - 16, 20, 21, 24, 29
		FAM. CRANIELLIDAE
3668040101		Craniella crania - 17, 20
		PHYLUM CNIDARIA
37040505		Thuiaria sp. - 3, 4
373101		Lucernosa sp. - 3
37		Eunephthya sp. - 4-6, 8, 9, 13, 34
37	*	Eunephthya rubiformes - 1, 3, 10, 28
37	*	Eunephthya fruticosa - 1, 3, 7, 10, 22, 27
3740		Unidentified anemone - 1, 3-6, 10-12, 14, 16-25, 27-34
		PHYLUM PLATYHELMINTHES
3901		Turbellaria - 22, 24, 27
		PHYLUM RHYNCHOCOELIA
43		Nemertean - 4, 11, 24, 25, 27, 32
43030202		Cerebratulus sp. - 24, 25, 32
		PHYLUM ANNELIDA
		CLASS POLYCHAETA
		FAM. POLYNOIDAE
5001020202		Antinoella sarsi - 2, 6, 8, 19, 25, 27, 29-31
5001020503		Eunoe nodosa - 1, 4-7, 9, 10, 14, 16, 20, 22, 24, 25, 27, 28, 32
5001020603		Gattyana cirrosa - 1, 2, 4-9, 12, 17, 27, 29, 31
5001020806		Harmothoe imbricata - 2
		FAM. SPINTHERIDAE
50011201		Spinther sp. - 10
		FAM. PHYLLODOCIDAE
5001130104		Anaitides mucosa - 27
5001130106		Anaitides maculata - 7
50011301		Phyllodoce groenlandica - 6, 12
5001130701		Genetyllis castanea - 20
		FAM. SYLLIDAE
5001230507		Typosyllis fasciata - 10
		FAM. NERIDAE
5001240403		Nereis pelagica - 3
5001240406		Nereis zonata - 1, 14, 16, 17, 20, 22, 24, 27, 28
		FAM. NEPHTYIDAE
50012501	*	Nephtys sp. - 10

Appendix A. Continued.

TAXONOMIC CODE	SPECIES NAME - TRAWLS IN WHICH PRESENT
5001250102	Nephtys ciliata - 17
5001250301	Aglaophomus malmgreni - 19, 20, 22, 27
	FAM. ONUPHIDAE
50012901	Onuphis sp. - 29
	FAM. LUMBRINERIDAE
50013101	Lumbrinereis sp. - 7, 19
5001310102	* Lumbrinereis fragilis - 29
	FAM. SPIONIDAE
5001430201	Laonice cirrata - 31
	FAM. FLABELLIGERIDAE
5001540101	* Brada granulata - 1, 2, 4-9, 11, 12, 20, 22, 30, 31
5001540103	* Brada inhabilis - 9, 12
5001540202	Flabelligera affinis - 1, 6, 9
	FAM. SCALIBREGMIDAE
5001570101	Scalibregma inflatum - 27, 29
	FAM. STERNASPIDAE
5001590101	Sternapsis scutata - 18, 29
	FAM. PECTINARIIDAE
5001660202	Cistenides granulata - 1
5001660203	Cistenides hyperborea - 5, 6, 8
	FAM. AMPHARETIDAE
50016703	Amphicteis sp. - 22
	FAM. TEREBELLIDAE
5001680101	Amphitrite cirrata - 12
	PHYLUM MOLLUSCA
	CLASS GASTROPODA
	ORDER ARCHAEOGASTROPODA
	FAM. LEPETIDAE - 28
5102070201	Lepeta caeca - 20, 25
	FAM. TROCHIDAE
5102100315	Margarites costalis - 1, 2, 4-12, 14, 16-20, 22-32, 34
5102100402	Solariella obscura - 4, 6
5102100403	Solariella varicosa - 2, 16, 17
	ORDER MESOGASTEROPODA
	FAM. TURRITELLIDAE
5103330101	Tachyrynchus erosus - 4, 18, 19
5103330102	Tachyrynchus reticulatis - 12, 18, 20, 30, 33
	FAM. TRICHOTROPIDIDAE
5103620203	Trichotropis borealis - 4, 5, 7, 8
5103620206	Trichotropis kroyeri - 8, 9, 27
	FAM. LAMELLARIIDAE
5103660201	Onchidiopsis glacialis - 10, 26
5103660301	Piliscus commondum - 10
51036604	Velutina sp. - 1, 10
5103660408	Velutina undata - 3, 6, 8, 10, 34
510366	Marsenina glabra - 1

Appendix A. Continued.

TAXONOMIC CODE	SPECIES NAME - TRAWLS IN WHICH PRESENT
	FAM. NATICIDAE
5103760201	Natica clausa - 1, 2, 4-8, 10-13, 34
5103760402	Polinices pallida - 2, 4, 6-8, 11, 16, 18, 22, 22, 34
	ORDER NEOGASTROPODA
	FAM. MURICIDAE
5105010401	Trophonopsis (Boreotrophon) clathratus - 10, 22, 31
5105010405	Trophonopsis (Boreotrophon) muriciformis - 2, 5, 18
5105010409	Trophonopsis (Boreotrophon) beringi - 8-10, 13, 16, 17, 19, 20, 22-32
	FAM. BUCCINIDAE
51050401	Buccinum sp. - 1, 10, 11, 23, 24, 28, 34
5105040101	Buccinum angulosum - 1, 12, 19, 22, 29
5105040104	Buccinum scalariforme - 1, 2, 8, 9, 12, 16, 18, 19, 28, 29, 31
5105040116	Buccinum glaciale - 10
5105040123	Buccinum solenům - 8, 9, 22
5105040126	Buccinum polare - 1, 2, 5-8, 12, 22, 24, 25
5105040127	Buccinum ciliatum - 2, 10, 17
5105040128	Buccinum plectrum - 10, 16
	FAM. NEPTUNIDAE
5105050204	Beringius beringi - 17, 27
51050503	Colus sp. - 4, 20, 23, 24, 27, 28, 31, 34
5105050301	Colus spitzbergensis - 34
5105050310	Colus roseus - 4, 5, 9, 12, 20, 22, 28
5105050318	Colus trombinus - 2
51050508	Neptunea sp. - 5, 13
51050508	Neptunea sp. c.f. borealis - 2, 4
5105050810	Neptunea heros - 10, 12, 18, 20
5105050901	Plicifusus kroyeri - 9, 10, 14, 17, 18, 27, 28
5105051002	Pyrulofusus deformis - 18, 22
51050512	Volutopsius fragilus - 12, 24
	FAM. CANCELLARIIDAE
51051401	Admete sp. - 6
51051401	Admete couthouyi (or middeandorffiana) - 4, 5, 7, 10, 12, 34
5105140102	Admete regina - 29
	FAM. TURRIDAE
51060203	Mangelia sp. - 12
51060204	Oenopota sp. - 4, 6, 7, 17
5106020401	Oenopota turricula - 34
5106020414	Oenopota harpa - 4, 8, 17, 20
51060204	Oenopata tenuicostata - 8
	ORDER CEPHALASPIDEA
	FAM. SCAPHANDRIDAE
5110040203	Cylichna alba - 2, 5, 6

Appendix A. Continued.

TAXONOMIC CODE	SPECIES NAME - TRAWLS IN WHICH PRESENT
	ORDER NUDIBRANCHIA
5127	Unidentified nudibranch - 6, 8, 10, 25, 26
51340601	Dendronotus sp. - 3, 13
5134060102	Dendronotus dalli - 17
	CLASS POLYPLACOPHORA
5303020302	Ischnochiton albus - 3, 10
5303070103	Amicula vestita - 3, 10
	CLASS BIVALVIA
	ORDER NUCULOIDA
	FAM. NUCULIDAE
5502020201	Nucula tenuis - 2, 4, 5, 11, 15, 17, 31
	FAM. NUCULANIDAE
5502040201	Nuculana pernula - 18-20, 22, 24, 25-31, 33
5502040202	Nuculana minuta - 4, 15, 17
55020405	Yoldia sp. - 7, 28, 29
5502040502	Yoldia hyperborea - 2, 6, 18, 26
5502040503	Yoldia myalis - 15, 17, 31
	ORDER ARCOIDA
	FAM. ARCIDAE
5506010101	Bathyarca glacialis - 19, 20, 22-29, 31, 33
	ORDER MYTILOIDA
	FAM. MYTILIDAE
5507010403	Musculus corrugatus - 10
	ORDER PTERIOIDA
	FAM. PECTINIDAE
55090501	Chlamys sp. - 1, 11, 17
5509050604	Delectopecten greenlandicus - 14, 16-33
	ORDER VENEROIDA
	FAM. CARDITIDAE
55151701	Cyclocardia sp. - 9, 10
55151701	Cyclocardia c.f. rajabiminae - 4, 6, 7
5515170105	Cyclocardia crassidens - 1, 2, 10, 12, 17, 20, 22
	FAM. ASTARTIDAE
55151901	Astarte sp. - 5, 8, 9, 10
5515190101	Astarte borealis - 1, 2, 12, 22
5515190103	Astarte montegui - 2, 4,65, 11, 12, 17, 19, 22, 27, 31, 34
55151901	Astarte crenata - 10, 14, 16, 18-20, 23-25, 27-29, 32, 33
	FAM. CARDIIDAE
5515220101	Clinocardium ciliatum - 2, 4, 7, 8, 13
5515220201	Serripes groenlandicus - 4, 13
	FAM. TELLINIDAE
5515310101	Macoma calcarea - 4, 12
5515310107	Macoma moesta - 7, 11, 15, 22, 31
5515310109	Macoma loveni - 2
	FAM. VENERIDAE
5515470401	Liocyma fluctuosa - 17

Appendix A. Continued.

TAXONOMIC CODE	SPECIES NAME - TRAWLS IN WHICH PRESENT
	ORDER MYOIDA
	FAM. HIATELLIDAE
5517060201	Hiatella arctica - 8, 9
	ORDER PHOLADOMYOIDA
	FAM. LYONSIIDAE
55200502	Lyonsia sp. - 5, 6
	FAM. CUSPIDARIIDAE
5520100201	Cuspidaria glacialis - 25
	CLASS CEPHALOPODA
	FAM. SEPIOLIDAE
5704020101	Rossia pacifica - 28
	FAM. OCTOPODIDAE
57080102	Octopus sp. - 1, 12, 14, 21, 22, 24, 28
	PHYLUM ARTHROPODA
	CLASS PYCNOGONIDA
6001010102	Nymphon longitarse - 1
6001010104	Nymphon brevitarse - 3, 20, 21, 24, 30
	CLASS CRUSTACEA
	SUBCLASS CIRRIPEDIA
6134020104	Balanus crenatus - 10
	SUBCLASS MALACOSTRACA
	ORDER CUMACEA
6154050103	Diastylis bidentata - 10, 27
6154050108	Diastylis goodsiri - 19, 20, 29
6154050119	Diastylis spinulosa - 19
	ORDER ISOPODA
6162020103	Saduria sabini - 29
6162020201	Synidotea bicuspida - 2, 9-11, 20-22, 27
6162020205	Synidotea nodulosa - 11
	ORDER AMPHIPODA
	FAM. ACANTHONOTOZOMATIDAE
6169010101	Acanthonotozoma inflatum - 2, 7, 8, 11, 34
6169010103	Acanthonotozoma serratum - 10
	FAM. AMPELISCIDAE
6169020101	Ampelisca macrocephala - 30
6169020102	Ampelisca birulai - 27
6169020105	Ampelisca eschrichti - 1, 2, 8, 11, 13, 14, 18, 20, 27-29
6169020202	Byblis gaimardi (eschrichti) - 2
61690203	Haploops sp. - 2, 11, 16, 27
	FAM. ATYLIDAE
6169090107	Atylus smitti - 20, 21, 24, 27, 29, 32, 33
	FAM. CALLIOPIIDAE
6169120405	Halirages nilssoni - 2, 17
	FAM. COROPHIIDAE
6169150305	Ericthonius tolli - 10

Appendix A. Continued.

TAXONOMIC CODE	SPECIES NAME - TRAWLS IN WHICH PRESENT
	FAM. EUSIRIDAE
61692008	Eusirus sp. - 14
6169200802	Eusirus cuspidatus - 2, 10, 20
6169201305	Rhacotropis aculeata - 1-4, 6-9, 11, 13, 14, 16, 17, 22, 32
6169201401	Rozinante fragilis - 2
	FAM. GAMMARIDAE
61692108	Maera sp. - 10
61692110	Melita sp. - 10
	FAM. ISAEIDAE
6169260206	Photis vinogradovi - 2
	FAM. ISCHYROCERIDAE
6169270201	Ischyrocerus latipes - 2, 10
	FAM. LYSIANASSIDAE
616934	Unidentified Lysianassid - 10
61693403	Anonyx sp. - 2
6169340302	Anonyx nugax - 1, 2, 4, 6-11, 14, 18-22, 24, 25-31, 34
6169340312	Anonyx laticoxae - 2, 22, 26, 27
61693414	Hippomedon sp. - 20
61693429	Orchomene sp. - 17
6169344001	Socarnes bidenticulatus - 1-4, 8-10, 14, 22, 27, 30-32
61693444	Tryphosella (tmetonyx) sp. - 20, 22, 27, 30
	FAM. MELPHIDIPPIDAE
6169350101	Melphidippa goesi - 2
	FAM. OEDICEROTIDAE
6169370101	Acanthostepheia behringiensis - 2, 4, 6-9, 13, 17-20, 22, 24, 25, 27-31, 33, 34
6169371202	Paroediceros lynceus - 2, 11, 34
	FAM. PARAMPHITHOIDAE
6169390302	Paramphithoe polycantha - 6-8, 11, 34
61693903	Paramphithoe cuspidata - 29
	FAM. PLEUSTIDAE
6169430405	Pleustes panoplus - 2, 7-9
	FAM. STEGOCEPHALIDAE
6169470601	Stegocephalopsis ampulla - 1, 8, 10, 11, 16, 21, 23, 24, 25-28, 30-33
6169470701	Stegocephala inflatus - 1-3, 6, 8-11, 16-34
	ORDER DECAPODA
	SUBORDER NATANTIA
	FAM. HIPPOLYTIDAE
61791602	Spirontocaris sp. - 7, 26, 31, 32
6179160205	Spirontocaris phippsi - 1, 3, 8, 16-18, 21, 22, 27, 30, 31
6179160211	Spirontocaris spina - 1, 7-10, 12, 14, 21, 23-26, 31-32
6179160301	Lebbeus groenlandica - 16, 21, 31
6179160305	Lebbeus polaris - 1, 16, 21, 22, 24, 27, 28, 30-34
6179160404	Eualus fabricii - 3, 17
6179160405	Eualus suckleyi - 10, 16, 31, 32
6179160406	Eualus gaimardii - 1-3, 5-7, 9-11, 16-18, 20-22, 25, 26, 28, 30, 31, 34
6179160412	Eualus macilenta - 1, 2, 4-13, 16-20, 22, 24-32, 34

Appendix A. Continued.

TAXONOMIC CODE	SPECIES NAME - TRAWLS IN WHICH PRESENT
	FAM. PANDALIDAE
6179180102	Pandalus goniurus - 2, 3, 5-8, 10-12, 14, 32, 33
	FAM. CRANGONIDAE
6179220109	Crangon communis - 4, 5, 17
6179220201	Sclerocrangon boreas - 1, 3, 8, 10
6179220301	Argis lar - 5-7, 9
6179220302	Argis dentata - 6, 32
6179220501	Sabinea septemcarinata - 1, 2, 5, 7, 8, 11-34
	SUBORDER REPTANTIA
	SECTION ANOMURA
61830602	Pagurus sp. - 26, 31
6183060219	Pagurus trigonocheirus - 2, 10-14, 16-18, 21, 24, 28, 30-32, 34
6183060225	Pagurus rathbuni - 1, 4, 6, 8, 9, 11-13
6183060401	Labidochirus spendescens - 2, 11, 13, 16, 30, 34
	SECTION BRACHYURA
618701020201	Hyas coarctatus alutaceus - 1-4, 8-28, 30, 31, 34
6187010301	Chionoecetes opilio - 1, 4-7, 9, 11, 34
	PHYLUM SIPUNCULA
7200020102	Golfingia margaritacea - 1, 3, 4, 10
	PHYLUM ECTOPROCTA
78030101	Alcyonidium vermiculare - 1, 9
780302	Unidentified Flustrellidae - 10
7803020102	Flustrella gigantea - 9
781001	Beronicea meandrina - 17
7815020101	Eucratea loricata - 1, 16
78150805	Tegella spitzbergensis - 16
78152502	Dendrobeania levinseni - 7, 9
7815250202	Dendrobeania murrayana - 3, 10
7816130407	Rhamphostomella gigantea - 1
7816130501	Cystisella saccata - 16, 18
781622	Cellopora sp. - 10, 17
78163301	* Myriozoum orientale - 10
78	Flustra membranaceotruncata - 1
78	Flustra serrulata - 4, 9, 11
7815060101	Carbasea (Flustra) carbasea - 14
78	Escharopsis sarsi - 1, 10
	PHYLUM BRACHIOPODA
8005030101	Hemithiris psittacea - 27
	PHYLUM ECHINODERMATA
	CLASS ASTEROIDA
	FAM. PORCELLANASTERIDAE
8107020101	Ctenodiscus crispatus - 11-13, 29, 34

Appendix A. Continued.

TAXONOMIC CODE	SPECIES NAME - TRAWLS IN WHICH PRESENT
	FAM. BENTHOPECTINIDAE
810801	Pontaster tenuispinus - 23, 24, 25
	FAM. PORANIIDAE
8114030201	Poraniomorpha tumida - 20, 24, 25, 27, 30, 33
	FAM. ECHINASTERIDAE
81140401	Henricia sp. - 1, 17
81140401	Henricia sanguinolenta? - 14
	FAM. PTERASTERIDAE
8113040302	Pteraster militaris - 30
8113040303	Pteraster obscurus - 9, 17, 20, 24-26
	FAM. SOLASTERIDAE
8113010103	Crossaster papposus - 1, 3, 8-10, 14, 17, 20-32, 34
8113010202	Lophaster furcifer - 21, 23, 24, 28, 29
8113010301	Solaster dawsoni - 1, 11, 20, 24, 34
	FAM. ASTERIIDAE
81170304	Leptasterias sp. - 4, 5, 7, 9, 10, 13, 16, 22
8117030407	Leptasterias groenlandica - 5, 12, 16-33
81170304	Leptasterias hylodes c.f. L. arctica - 18
8117030701	Urasterias lincki - 15, 18, 19, 24, 28, 29, 31, 33
811703	Icasterias panopla - 21
	CLASS OPHIUROIDEA
	FAM. GORGONOCEPHALIDAE
8125030201	Gorgonocephalus caryi - 12, 19, 29, 33, 34
	FAM. OPHIURIDAE - 24, 25, 27, 28, 30-33
8127010401	Ophiocten sericeum - 19, 21, 23, 26, 31
81270106	* Ophiura c.f. robusta - 21, 23
8127010610	Ophiura sarsi - 1, 4-9, 11-13, 16-20, 22, 29, 34
8127010801	Stegophiura nodosa - 14, 15, 17
	FAM. OPHIACANTHIDAE
8128010105	Ophiacantha bidentata - 21, 23, 25, 26, 29-32
	FAM. OPHIACTIDAE
81290201	* Ophiopholis sp. c.f. O. aculeata - 26
	CLASS ECHINODEA
8149030201	Strongylocentrotis droebachiensis - 1, 3, 10, 17, 21, 23-26 28, 30-33
	CLASS HOLOTHUROIDEA
81720302	Psolus sp. - 1, 6, 8-10, 14, 16, 19, 20, 22, 24, 26, 27, 30 31, 33
81720601	Cucumaria sp. - 1, 2, 4-11, 16, 17, 20-22, 27, 34
8178030201	Myriotrochus rinkii - 5, 7, 8, 19, 30
	CLASS CRINOIDEA
8191010101	Heliametra glacialis - 11, 19-33
	PHYLUM CHORDATA
	SUBPHYLUM UROCHORDATA
	FAM. POLYCLINIDAE
8403020201	Synoicum pulmonaria - 9

Appendix A. Continued.

TAXONOMIC CODE	SPECIES NAME - TRAWLS IN WHICH PRESENT
8403020301	Aplidiopsis pannosum - 10
	FAM. CORELLIDAE
8404040101	Chelyosoma macleayanum - 10
	FAM. ASCIDIIDAE
8404050101	Ascidia prunum - 1, 23-26, 27, 28, 34
	FAM. STYELIDAE
8406010402	Dendrodoa pulchella - 16, 17
8406010601	Pelonaia corrugata - 4
	FAM. PYURIDAE
8406020201	Boltenia ovifera - 3, 10
8406020202	Boltenia echinata - 17
	FAM. MOLGULIDAE
8406030101	Molgula griffithsii - 20
	SUBPHYLUM VERTEBRATA
	CLASS OSTEICHTHYES
	FAM. GADIDAE
87910301	Arctogadus sp. - 34
8791030201	Boreogadus saida - 1-14, 16-22, 24, 26-29, 31, 34
	FAM. ZOARCIDAE
8793010403	Gymnelis viridis - 1, 4, 7, 9, 16, 25, 27, 28, 30-32
8793010709	Lycodes mucosus - 16, 24
8793010711	Lycodes polaris - 1, 4, 11, 14, 18-20, 22, 26, 29, 31, 32, 34
8793010712	Lycodes raridens - 1, 24
	FAM. COTTIDAE
8831010101	Icelus bicornis - 14, 20-22, 24, 26-32
8831010105	Icelus spatula - 1, 20, 31
8831020305	Artediellus scaber - 4-7, 9, 16-18, 31, 33
8831021304	Gymnocanthus tricuspis - 13, 14
8831023805	Triglops pingeli - 24, 28
	FAM. CYCLOPTERIDAE (=LIPARIDAE)
8831090504	Eumicrotemus derjugini - 16, 17, 20, 24-28, 30, 31, 33
88310908	Liparis sp. - 1, 2, 6, 12, 17-19, 21-24, 28-33
	FAM. AGONIDAE
8831080303	Aspidophoroides olriki - 1, 11, 12, 34
	FAM. STICHAEIDAE
8842120903	Lumpenus maculatus - 7
8842120904	Lumpenus medius - 18
8842121701	Eumesogrammus praecisus - 3, 14

* Taxonomic questions exist with these species because of confused synonomies, condition of the specimens, etc.

Appendix B

Data sheets from 1977 GLACIER trawl series.

Data are only presented for the 40 most common species or species groups of invertebrates and all species of fishes.

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 1 -77 DATE: 8 / 2 /77 START TIME 0000 HRS
METERS WATER 64 METERS WIRE 200 BOTTOM TIME 10+ MINS SPEED 3 KTS
START POS. 71°27' N 158°02' W BOTTOM TYPE mud with gravel
TOTAL WT. OF CATCH (gms) 34908
COMMENTS: trawl down about 1 hr, drifting, due to mechanical problems
sorted 1/2 trawl (481bs not sorted)

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		761.8			
Boreogadus saida	3	33.5	14.0	9.5	
Lycodes raridens	5	100.0	22.9	10.4	
Lycodes polaris	41	546.0	24.5	8.1	
Gymnelis viridis	1	2.4	8.5		
Liparis spp.	1	3.5	6.7		
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula	9	68.5	11.0	6.8	
Artediellus scaber					
Aspidophoroides olriki	3	5.3	6.8	5.1	
Eumesogrammus praecisus	1	2.6	8.6		
INVERTEBRATES					
Cnidaria		959.5			
Eunephthya spp.		475.0			
Annelida-Polychaeta		129.5			
Eunoe nodosa		x			
Gattyana cirrosa		x			
Brada granulata	23	35.0			
Mollusca-Gastropoda		339.9			
Natica clausa	1	3.4			
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.	23	187.5			3 species
Margarites costalis	3	3.5			
Mollusca-Bivalvia		113.5			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui					
Astarte crenata					

<u>OTTER TRAWL DATA--BEAUFORT SEA</u>

TRAWL #GLATR- 1 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		42.2			
Ampelisca eschrichti	2	1.4			
Rhachotropis aculeata	1	1.7			
Anonyx nugax	15	13.5			
Socarnes bidenticulatus	1	0.5			
Acanthostepheia behringiensis					
Stegocephalopsis ampulla	3	13.6			
Stegocephala inflatus	5	3.6			
Crustacea-Natantia		167.4			
Spirontocaris spina	8	23.2	1.62	1.03	5 ovig.♀; 1/25cm sm ovig.
Lebbeus polaris	3	12.0	1.62	1.15	
Eualus gaimardii	57	62.5	1.38	0.80	22 ovig.♀; 1.03cm sm ovig.
Eualus macilenta	47	36.0	1.06	0.82	none ovig.
Pandalus goniurus					
Sabinea septemcarinata	8	23.6	1.89	1.10	
Crustacea-Anomura		12.0			
Pagurus trigonocheirus					
Crustacea-Brachyura		1190.0			
Hyas coarctatus	35	600.0	7.3	1.7	15♀(6 ovig.), 18♂
Echinodermata-Asteroidea		484.5			
Crossaster papposus	8	70.5			
Leptasterias groenlandica					
Echinodermata-Ophiuroidea		4800			
Ophiura sarsi		4800			
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis	4	304.0			
Echinodermata-Holothuroidea		88.2			
Psolus sp.	1	76.0			
Cucumaria sp.	10	12.2			
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 2 -77 DATE: 8 / 2 /77 START TIME 0830 HRS
METERS WATER 45 METERS WIRE 200 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°19 N 160°01 W BOTTOM TYPE muddy
TOTAL WT. OF CATCH (gms) 651
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		26.3			
Boreogadus saida	6	23.2	9.0	6.4	
Lycodes polaris					
Gymnelis viridis					
Liparis spp.	1	3.1	5.8		
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria					
Eunephthya spp.					
Annelida-Polychaeta		5.8			
Eunoe nodosa					
Gattyana cirrosa		x			
Brada granulata	1	1.0			
Mollusca-Gastropoda		122.5			
Natica clausa	11	43.1			
Polinices pallida	4	3.2			
Trophonopsis beringi					
Buccinum spp.	4	12.3			3 spp
Margarites costalis	18	40.0			
Mollusca-Bivalvia		114.4			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui	46	79.2			
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 2 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		167.2			
Ampelisca eschrichti	1	x			
Rhachotropis aculeata	10	x			
Anonyx nugax	10	x			
Socarnes bidenticulatus					
Acanthostepheia behringiensis	11	x			
Stegocephalopsis ampulla					
Stegocephala inflatus	143	117.2			
Crustacea-Natantia		111.8			
Spirontocaris spina					
Lebbeus polaris					
Eualus gaimardii	135	74.5	.92	0.50	9 ovigerous
Eualus macilenta	20	16.0	.91	.79	none ovigerous
Pandalus goniurus	3	1.3	.79	.76	
Sabinea septemcarinata	8	20.0	1.61	0.60	1 ovig (1.61cm)
Crustacea-Anomura		18.7			
Pagurus trigonocheirus	2	9.0			
Crustacea-Brachyura		62.2			
Hyas coarctatus	4	62.2	5.5	1.8	3♂, 1(1.8cm) ♀
Echinodermata-Asteroidea		8.7			
Crossaster papposus	1	8.7			
Leptasterias groenlandica					
Echinodermata-Ophiuroidea					
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		13.2			
Psolus sp.					
Cucumaria sp.	8	13.2			
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 3 -77 DATE: 8 / 2 /77 START TIME 2014 HRS
METERS WATER 62 METERS WIRE 240 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°05' N 160°08' W BOTTOM TYPE rocky
TOTAL WT. OF CATCH (gms) 3748
COMMENTS: cod end torn out, part of catch lost

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		12.0			
Boreogadus saida	1	9.6	9.7		
Lycodes polaris					
Gymnelis viridis					
Liparis spp.					
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
Eumesogrammus praecisus	1	2.4	6.2		
INVERTEBRATES					
Cnidaria		2664			
Eunephthya spp.		2600			
Annelida-Polychaeta		14.4			
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		3.6			
Natica clausa					
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.					
Margarites costalis					
Mollusca-Bivalvia		2.4			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui	1	2.4			
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 3 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		3.7			
Ampelisca eschrichti					
Rhachotropis aculeata	2	1.7			
Anonyx nugax					
Socarnes bidenticulatus	2	1.0			
Acanthostepheia behringiensis					
Stegocephalopsis ampulla					
Stegocephala inflatus	1	1.0			
Crustacea-Natantia		74.8			
Spirontocaris spina	5	4.5	1.3	0.5	1 new molt
Lebbeus polaris					
Eualus gaimardii	17	16.3			5 ovig. few new molts
Eualus macilenta					
Pandalus goniurus	3	4.6	1.3	1.1	
Sabinea septemcarinata					
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura		73.0			
Hyas coarctatus	8	73.0			5 ♀ (4 ovig), 3 ♂
Echinodermata-Asteroidea		2.2			
Crossaster papposus	1	2.2			
Leptasterias groenlandica					
Echinodermata-Ophiuroidea					
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis	3	94.6			
Echinodermata-Holothuroidea					
Psolus sp.					
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 4 -77 DATE: 8 / 3 /77 START TIME 0757 HRS
METERS WATER 42 METERS WIRE 200 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°26' N 162°01' W BOTTOM TYPE muddy
TOTAL WT. OF CATCH (gms) 14218
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		123.8			
Boreogadus saida	22	85.0	9.5	6.4	
Lycodes polaris	3	20.5	16.4	5.7	
Gymnelis viridis	1	2.3	8.2		
Liparis spp.					
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber	4	16.0	7.2	5.8	
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		129.2			
Eunephthya spp.		129.2			
Annelida-Polychaeta		9.8			
Eunoe nodosa		x			
Gattyana cirrosa		x			
Brada granulata	3	3.8			
Mollusca-Gastropoda		39.6			
Natica clausa	9	11.4			
Polinices pallida	2	1.5			
Trophonopsis beringi					
Buccinum spp.					
Margarites costalis	2	2.2			
Mollusca-Bivalvia		75.8			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui	12	26.9			
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 4 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
Crustacea-Amphipoda		13.1			
Ampelisca eschrichti					
Rhachotropis aculeata	1	0.7			
Anonyx nugax	2	1.3			
Socarnes bidenticulatus	4	2.0			
Acanthostepheia behringiensis	6	4.7			
Stegocephalopsis ampulla					
Stegocephala inflatus	1	6.4			
Crustacea-Natantia		17.6			
Spirontocaris spina					
Lebbeus polaris					
Eualus gaimardii					
Eualus macilenta	26	16.4	1.11	.82	
Pandalus goniurus					
Sabinea septemcarinata					
Crustacea-Anomura		8.5			
Pagurus trigonocheirus					
Crustacea-Brachyura		90.7			
Hyas coarctatus	3	63.7	5.4	3.6	1 ovig ♀;. 2♂
Echinodermata-Asteroidea		19.8			
Crossaster papposus					
Leptasterias groenlandica	2	19.8			
Echinodermata-Ophiuroidea		13,600			
Ophiura sarsi		13,600			
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		63.5			
Psolus sp.					
Cucumaria sp.	23	63.5			
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 5 -77 DATE: 8 / 3 /77 START TIME 1233 HRS
METERS WATER 40 METERS WIRE 175 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°20' N 162°30' W BOTTOM TYPE
TOTAL WT. OF CATCH (gms) 7813
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		59.5			
Boreogadus saida	13	53.0	12.6	5.5	
Lycodes polaris	1	1.5	5.0		
Gymnelis viridis					
Liparis spp.					
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber	2	5.0	5.5	5.3	
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		173.3			
Eunephthya spp.		143.8			
Annelida-Polychaeta		11.0			
Eunoe nodosa		x			
Gattyana cirrosa		x			
Brada granulata	8	5.4			
Mollusca-Gastropoda		19.5			
Natica clausa	5	2.2			
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.	2	7.9			1 sp.
Margarites costalis	8	2.3			
Mollusca-Bivalvia		12.0			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui	3	6.4			
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 5 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. CMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		7.7			
Ampelisca eschrichti	1	1.0			
Rhachotropis aculeata					
Anonyx nugax	3	2.0			
Socarnes bidenticulatus					
Acanthostepheia behringiensis	7	4.7			
Stegocephalopsis ampulla					
Stegocephala inflatus					
Crustacea-Natantia		80.0			
Spirontocaris spina					
Lebbeus polaris					
Eualus gaimardii	103	50.0	1.05	0.5	7 ovig♀; (.86cm sm ovig)
Eualus macilenta	17	11.5	1.0	0.79	
Pandalus goniurus	7	6.8	1.41	0.9	
Sabinea septemcarinata	2	1.8	.99	0.8	
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura		17.8			
Hyas coarctatus					
Echinodermata-Asteroidea		112.7			
Crossaster papposus					
Leptasterias groenlandica	17	112.7			
Echinodermata-Ophiuroidea		7300			
Ophiura sarsi		7300			
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		12.5			
Psolus sp.					
Cucumaria sp.	7	12.5			
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 6 -77 DATE: 8 / 3 /77 START TIME 1840 HRS
METERS WATER 48 METERS WIRE 200 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°35' N 163°58' W BOTTOM TYPE
TOTAL WT. OF CATCH (gms) 8258
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		148.9			
Boreogadus saida	26	123.0	16.5	6.1	
Lycodes polaris					
Gymnelis viridis					
Liparis spp.	1	19.2	11.3		
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber	3	6.7	6.3	3.9	
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		71.4			
Eunephthya spp.		56.4			
Annelida-Polychaeta		11.4			
Eunoe nodosa		x			
Gattyana cirrosa		x			
Brada granulata	1	1.7			
Mollusca-Gastropoda		54.9			
Natica clausa	9	20.8			
Polinices pallida	1	2.1			
Trophonopsis beringi					
Buccinum spp.	4	12.3			1sp
Margarites costalis	1	0.6			
Mollusca-Bivalvia		48.8			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui	28	38.2			
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 6 -77. cont.

	NO.	TOT. WT.	SIZE-CMS		
SPECIES NAME	INDS.	GMS	MAX	MIN	COMMENTS
Crustacea-Amphipoda		9.4			
Ampelisca eschrichti		--			
Rhachotropis aculeata	1	1.0			
Anonyx nugax	1	1.6			
Socarnes bidenticulatus					
Acanthostepheia	1	0.9			
behringiensis					
Stegocephalopsis ampulla					
Stegocephala inflatus	7	5.1			
Crustacea-Natantia		55.8			
Spirontocaris spina					
Lebbeus polaris					
Eualus gaimardii	54	35.5	.99	.62	12 ovig
Eualus macilenta	17	11.0	.86	.75	8 almost ovig
Pandalus goniurus	1	0.8	.99		
Sabinea septemcarinata					
Crustacea-Anomura		3.0			
Pagurus trigonocheirus					
Crustacea-Brachyura		159.0			
Hyas coarctatus					
Echinodermata-Asteroidea					
Crossaster papposus					
Leptasterias groenlandica					
Echinodermata-Ophiuroidea		7500			
Ophiura sarsi		7500			
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus					
droebachiensis					
Echinodermata-Holothuroidea		190.9			
Psolus sp.		168.0			
Cucumaria sp.	6	22.9			
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 7 -77 DATE: 8 / 4 /77 START TIME 1020 HRS
METERS WATER 44 METERS WIRE 180 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°28' N 163°47' W BOTTOM TYPE Mud
TOTAL WT. OF CATCH (gms) 3945
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		73.1			
Boreogadus saida	15	54.4	9.8	5.8	
Lycodes polaris					
Gymnelis viridis					
Liparis spp.					
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber	4	16.5	7.4	5.2	
Aspidophoroides olriki					
Lumpenus maculatus	1	2.2	8.8		
INVERTEBRATES					
Cnidaria		135.5			
Eunephthya spp.		135.5			
Annelida-Polychaeta		28.3			
Eunoe nodosa		x			
Gattyana cirrosa		x			
Brada granulata	5	9.5			
Mollusca-Gastropoda		8.8			
Natica clausa	2	3.5			
Polinices pallida	1	0.2			
Trophonopsis beringi					
Buccinum spp.	3	2.6			1 sp
Margarites costalis	5	1.4			
Mollusca-Bivalvia		31.3			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui					
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 7 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		5.4			
Ampelisca eschrichti					
Rhachotropis aculeata	1	0.8			
Anonyx nugax	1	0.6			
Socarnes bidenticulatus					
Acanthostepheia behringiensis	4	2.8			
Stegocephalopsis ampulla					
Stegocephala inflatus					
Crustacea-Natantia		71.7			
Spirontocaris spina	1	2.4			ovig.
Lebbeus polaris					
Eualus gaimardii	62	42.0			9 ovig.
Eualus macilenta	23	14.6			10 almost ovig.
Pandalus goniurus	8	4.5			
Sabinea septemcarinata	6	6.1			
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura		17.6			
Hyas coarctatus					
Echinodermata-Asteroidea		3.2			
Crossaster papposus					
Leptasterias groenlandica	1	3.2			
Echinodermata-Ophiuroidea		3400			
Ophiura sarsi		3400			
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		163.5			
Psolus sp.	23	163.5			
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 8 -77 DATE: 8 / 4 /77 START TIME 2005 HRS
METERS WATER 44 METERS WIRE 180 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°44' N 162°69' W BOTTOM TYPE Mud
TOTAL WT. OF CATCH (gms) 3481
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		46.6			
Boreogadus saida	10	39.6	8.8	5.9	
Lycodes polaris					
Gymnelis viridis	2	7.0	10.2	9.8	
Liparis spp.					
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		395.0			
Eunephthya spp.		395.0			
Annelida-Polychaeta		30.8			
Eunoe nodosa					
Gattyana cirrosa		x			
Brada granulata	10	13.3			
Mollusca-Gastropoda		45.2			
Natica clausa	10	15.3			
Polinices pallida	2	5.5			
Trophonopsis beringi					
Buccinum spp.	9	16.7			3spp
Margarites costalis					
Mollusca-Bivalvia					
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui	3	8.0			
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 8 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		27.4			
Ampelisca eschrichti	2	1.3			
Rhachotropis aculeata	1	1.9			
Anonyx nugax	3	3.5			
Socarnes bidenticulatus	1	1.7			
Acanthostepheia behringiensis	11	9.3			
Stegocephalopsis ampulla	1	4.4			
Stegocephala inflatus	2	2.6			
Crustacea-Natantia		109.4			
Spirontocaris spina	8	9.9			
Lebbeus polaris					
Eualus gaimardii	113	77.2			
Eualus macilenta	10	6.4			
Pandalus goniurus	8	6.6			
Sabinea septemcarinata	2	2.4	1.0	0.9	
Crustacea-Anomura		5.9			
Pagurus trigonocheirus					
Crustacea-Brachyura		53.4			
Hyas coarctatus	4	53.4	5.7	1.3	2♂; 2♀;
Echinodermata-Asteroidea					
Crossaster papposus					
Leptasterias groenlandica					
Echinodermata-Ophiuroidea		1200			
Ophiura sarsi		1200			
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		1540.3			
Psolus sp.		1500.			
Cucumaria sp.	5	40.3			
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 9 -77 DATE: 8 / 5 /77 START TIME 0836 HRS
METERS WATER 50 METERS WIRE 200 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°07' N 161°00' W BOTTOM TYPE
TOTAL WT. OF CATCH (gms) 25225
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		35.3			
Boreogadus saida	4	19.0	10.3	7.4	
Lycodes polaris					
Gymnelis viridis	3	12.8	11.8	10.2	
Liparis spp.					
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber	1	3.5	6.0		
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		481.0			
Eunephthya spp.		481.0			
Annelida-Polychaeta		122.1			
Eunoe nodosa		x			
Gattyana cirrosa		x			
Brada ~~granulata~~ spp	33	72.5			granulata & inhabilis
Mollusca-Gastropoda		35.7			
Natica clausa					
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.	5	22.5			2 spp
Margarites costalis	1	3.0			
Mollusca-Bivalvia		68.9			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui	9	23.2			
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 9 -77 cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		2.3			
Ampelisca eschrichti					
Rhachotropis aculeata	3	3.5			
Anonyx nugax	19	13.8			
Socarnes bidenticulatus	3	3.0			
Acanthostepheia behringiensis					
Stegocephalopsis ampulla					
Stegocephala inflatus	2	1.6			
Crustacea-Natantia		28.9			
Spirontocaris spina	1	2.2	1.1		
Lebbeus polaris					
Eualus gaimardii	43	22.8	1.13	0.5	
Eualus macilenta	3	1.6	.92	.64	
Pandalus goniurus					
Sabinea septemcarinata					
Crustacea-Anomura		8.4			
Pagurus trigonocheirus					
Crustacea-Brachyura		308.0			
Hyas coarctatus	3	76.0	5.5	4.1	3♂
Echinodermata-Asteroidea		428.5			
Crossaster papposus	1	28.0			
Leptasterias groenlandica	152	357.0			
Echinodermata-Ophiuroidea		1800			
Ophiura sarsi		1800			
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		21562			
Psolus sp.		662			
Cucumaria sp.		20900			
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 10 -77 DATE: 8 / 8 /77 START TIME 0730 HRS
METERS WATER 102 METERS WIRE 400 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°12' N 158°35' W BOTTOM TYPE gravel, small rocks
TOTAL WT. OF CATCH (gms) 6651
COMMENTS: tore net.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		69.0			
Boreogadus saida	3	69.0	17.0	7.9	
Lycodes polaris					
Gymnelis viridis					
Liparis spp.					
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		469.3			
Eunephthya spp.		266.3			
Annelida-Polychaeta		14.6			
Eunoe nodosa		x			
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		220.7			
Natica clausa	3	1.8			
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.	11	89.2			3 spp
Margarites costalis	42	43.0			
Mollusca-Bivalvia					
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui	5	15.9 (Astarte montegui + Astarte crenata)			
Astarte crenata	3				

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 10 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
		30.08			
Crustacea-Amphipoda					
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax	3	4.1			
Socarnes bidenticulatus	1	x			
Acanthostepheia behringiensis					
Stegocephalopsis ampulla	1	} ~~16.7~~			
Stegocephala inflatus	15	}			
Crustacea-Natantia		833.7			
Spirontocaris spina	2	2.3			
Lebbeus polaris					
Eualus gaimardii	395	393.0			242 ovig ♀
Eualus macilenta	4	3.5			
Pandalus goniurus	3	4.9			
Sabinea septemcarinata					
Crustacea-Anomura		19.0			
Pagurus trigonocheirus	14	19.0			
Crustacea-Brachyura		111.5			
Hyas coarctatus	13	111.5	4.2	0.9	5♂; 6♀(4 ovig, sm ovig 3.7)
Echinodermata-Asteroidea		2.7			
Crossaster papposus	2	1.4			
Leptasterias groenlandica	1	1.3			
Echinodermata-Ophiuroidea					
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis		154.0			
Echinodermata-Holothuroidea		700.0			
Psolus sp.		700.0			
Cucumaria sp.		x			
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 11 -77 DATE: 8 / 7 /77 START TIME 0843 HRS
METERS WATER 100-120 METERS WIRE 480 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°45' N 155°43' W BOTTOM TYPE soft mud
TOTAL WT. OF CATCH (gms) 12584
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		55.6			
Boreogadus saida	9	46.8	10.8	8.0	
Lycodes polaris	2	2.8	6.5	6.2	
Gymnelis viridis					
Liparis spp.					
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki	5	6.0	6.6	4.3	
INVERTEBRATES					
Cnidaria		12.7			
Eunephthya spp.					
Annelida-Polychaeta		36.5			
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata	21	31.0			
Mollusca-Gastropoda		105.5			
Natica clausa	12	39.6			
Polinices pallida	2	2.6			
Trophonopsis beringi					
Buccinum spp.	5	9.4			
Margarites costalis	26	42.1			
Mollusca-Bivalvia		15.6			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui	3	2.6			
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 11 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		29.2			
Ampelisca eschrichti	2	2.0			
Rhachotropis aculeata	1	1.5			
Anonyx nugax	14	10.2			
Socarnes bidenticulatus					
Acanthostepheia behringiensis					
Stegocephalopsis ampulla	2	} ~~14.3~~			
Stegocephala inflatus	7				
Crustacea-Natantia		246.5			
Spirontocaris spina					
Lebbeus polaris					
Eualus gaimardii	8	8.0	1.1	0.8	2 ovig ♀ (1.0 sm ovig)
Eualus macilenta	135	109.5			50 almost ovig
Pandalus goniurus	12	43.5	2.5	1.2	
Sabinea septemcarinata	29	85.5			
Crustacea-Anomura		19.1			
Pagurus trigonocheirus	5	6.1			
Crustacea-Brachyura		90.1			
Hyas coarctatus	5	57.7	6.2	1.5	2♀, 3♂.
Echinodermata-Asteroidea		3539.0			
Crossaster papposus	29	239.0			
Leptasterias groenlandica					
Echinodermata-Ophiuroidea		8300			
Ophiura sarsi		8300			
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		10.0			
Psolus sp.					
Cucumaria sp.	4	10.0			
Echinodermata-Crinoidea		117.0			
Heliametra glacialis	6	117.0			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 12 -77 DATE: 8 / 9 /77 START TIME 1125 HRS
METERS WATER 400 METERS WIRE 1600 BOTTOM TIME 10 MINS SPEED 5 KTS
START POS. 71°55.5' N 154°16' W BOTTOM TYPE mud
TOTAL WT. OF CATCH (gms) 4945
COMMENTS: Many drilled and empty Macoma

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		372.9			
Boreogadus saida	24	329.0	18.0	7.8	
Lycodes polaris					
Gymnelis viridis					
Liparis spp.	1	25.7			
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki	10	18.2	7.1	5.3	
INVERTEBRATES					
Cnidaria					
Eunephthya spp.					
Annelida-Polychaeta		565.1			
Eunoe nodosa					
Gattyana cirrosa		x			
Brada ~~granulata~~ spp		561.0			
Mollusca-Gastropoda		392.0			
Natica clausa	12	95.5			
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.	30	211.0			3 spp.
Margarites costalis	2	6.1			
Mollusca-Bivalvia		205.1			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui	7				
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 12 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		1.6			
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax					
Socarnes bidenticulatus	1	1.0			
Acanthostepheia behringiensis	1	0.6			
Stegocephalopsis ampulla					
Stegocephala inflatus					
Crustacea-Natantia		169.2			
Spirontocaris spina	1	2.0			
Lebbeus polaris					
Eualus gaimardii					
Eualus macilenta	67	80.5			
Pandalus goniurus	11	83.2	2.4	1.4	4 ovig♀ (1.6cm ovig)
Sabinea septemcarinata	2	3.5	1.2	1.0	
Crustacea-Anomura		13.4			
Pagurus trigonocheirus					
Crustacea-Brachyura		1.7			
Hyas coarctatus	1	1.7	2.0		
Echinodermata-Asteroidea		95.5			
Crossaster papposus					
Leptasterias groenlandica	2	8.5			
Echinodermata-Ophiuroidea					
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea					
Psolus sp.					
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 13 -77 DATE: 8 / 10 /77 START TIME 1030 HRS
METERS WATER 55 METERS WIRE 240 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°35.4' N 153°41' W BOTTOM TYPE clayed mud
TOTAL WT. OF CATCH (gms) 4497
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		43.1			
Boreogadus saida	2	10.6	10.3	7.5	
Lycodes polaris					
Gymnelis viridis					
Liparis spp.					
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber					
Gymnocanthus tricuspis	1	32.5	12.8		
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		33.5			
Eunephthya spp.		33.5			
Annelida-Polychaeta		2.0			
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		64.1			
Natica clausa	1	2.7			
Polinices pallida					
Trophonopsis beringi	1	4.4			
Buccinum spp.					
Margarites costalis					
Mollusca-Bivalvia		15.5			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui					
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 13-77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
Crustacea-Amphipoda		25.2			
Ampelisca eschrichti	2	1.8			
Rhachotropis aculeata	2	2.0			
Anonyx nugax					
Socarnes bidenticulatus					
Acanthostepheia behringiensis	26	21.4			
Stegocephalopsis ampulla					
Stegocephala inflatus					
Crustacea-Natantia		41.5			
Spirontocaris spina					
Lebbeus polaris					
Eualus gaimardii					
Eualus macilenta	1	1.5	1.0		
Pandalus goniurus					
Sabinea septemcarinata	23	40	1.7	0.8	1 ovig
Crustacea-Anomura		36.8			
Pagurus trigonocheirus					
Crustacea-Brachyura		42.7			
Hyas coarctatus	2	42.7	5.0	3.8	1♂, 1♀.
Echinodermata-Asteroidea		2135			
Crossaster papposus					
Leptasterias groenlandica	4	19.5			
Echinodermata-Ophiuroidea		2050			
Ophiura sarsi		2050			
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea					
Psolus sp.					
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 14 -77 DATE: 8 / 11 /77 START TIME 2223 HRS
METERS WATER 50 METERS WIRE 218 BOTTOM TIME 2-5 MINS SPEED 3 KTS
START POS. 71°16' N 153°01.9' W BOTTOM TYPE rocky
TOTAL WT. OF CATCH (gms) 1582
COMMENTS: hung up on ice - on bottom an indeterminable length of time, 2 large rocks in net.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		76.9			
Boreogadus saida	10	62.8	12.6	7.0	
Lycodes polaris	2	8.2	9.3		
Gymnelis viridis					
Liparis spp.					
Eumicrotremis derjugini					
Icelus bicornis	1	2.0	5.6		
Icelus spatula					
Artediellus scaber					
Gymnocanthus tricuspis	1	0.7	4.1		
Aspidophoroides olriki					
Eumesogrammus praecisus	1	1.7	5.5		
INVERTEBRATES					
Cnidaria		51.5			
Eunephthya spp.					
Annelida-Polychaeta		3.0			
Eunoe nodosa		x			
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		13.7			
Natica clausa					
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.					
Margarites costalis	4	5.2			
Mollusca-Bivalvia		6.8			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus	14	5.1			
Astarte montegui					
Astarte crenata	1	1.7			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 14 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		28.0			
Ampelisca eschrichti	3	2.9			
Rhachotropis aculeata	31	21.0			
Anonyx nugax	3	3.2			
Socarnes bidenticulatus	1	0.9			
Acanthostepheia behringiensis					
Stegocephalopsis ampulla					
Stegocephala inflatus					
Crustacea-Natantia		63.7			
Spirontocaris spina	2	2.5			
Lebbeus polaris					
Eualus gaimardii	41	35.5			6 ovig
Eualus macilenta					
Pandalus goniurus	1	1.9			
Sabinea septemcarinata	11	23.8	1.8	0.7	1 ovig.
Crustacea-Anomura		31.0			
Pagurus trigonocheirus	8	31.0			
Crustacea-Brachyura		31.5			
Hyas coarctatus	4	31.5	4.0	1.8	3♂ ; 1♀
Echinodermata-Asteroidea		81.0			
Crossaster papposus	1	8.0			
Leptasterias groenlandica					
Echinodermata-Ophiuroidea		1.2			
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		86.6			
Psolus sp.		86.6			
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 15 -77 DATE: 8 / 12 /77 START TIME 1222 HRS
METERS WATER 31 METERS WIRE 120 BOTTOM TIME 9 MINS SPEED 3 KTS
START POS. 71°10' N 151°24' W BOTTOM TYPE clayed mud
TOTAL WT. OF CATCH (gms) ______
COMMENTS: mud ball, probably clogged after the first few minutes. Essentially nothing.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES					
Boreogadus saida					
Lycodes polaris					
Gymnelis viridis					
Liparis spp.					
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria					
Eunephthya spp.					
Annelida-Polychaeta					
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda					
Natica clausa					
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.					
Margarites costalis					
Mollusca-Bivalvia					
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui					
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 15 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda					
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax					
Socarnes bidenticulatus	1				
Acanthostepheia behringiensis					
Stegocephalopsis ampulla					
Stegocephala inflatus					
Crustacea-Natantia					
Spirontocaris spina					
Lebbeus polaris					
Eualus gaimardii					
Eualus macilenta					
Pandalus goniurus					
Sabinea septemcarinata	2				
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura					
Hyas coarctatus	1				♂
Echinodermata-Asteroidea					
Crossaster papposus					
Leptasterias groenlandica					
Echinodermata-Ophiuroidea					
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea					
Psolus sp.					
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 16 -77 DATE: 8 / 12 /77 START TIME 1430 HRS
METERS WATER 50 METERS WIRE 200 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°13.1' N 151°23' W BOTTOM TYPE rocky
TOTAL WT. OF CATCH (gms) 3684
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		57.1			
Boreogadus saida	8	32.3	11.5	5.5	
Lycodes mulosus	1	1.2	5.0		
Lycodes polaris					
Gymnelis viridis	1	1.8	7.7		
Liparis spp.	1	2.4			
Eumicrotremis derjugini	2	11.0			
Icelus bicornis					
Icelus spatula					
Artediellus scaber	4	8.4	7.8	3.0	
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		135.0			
Eunephthya spp.					
Annelida-Polychaeta		3.3			
Eunoe nodosa		x			
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		24.7			
Natica clausa					
Polinices pallida	1	1.2			
Trophonopsis beringi					
Buccinum spp.	1	21.0			1sp
Margarites costalis	2	2.5			
Mollusca-Bivalvia					
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus	5	1.3			
Astarte montegui					
Astarte crenata	6	4.2			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 16-77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		59.4			
Ampelisca eschrichti					
Rhachotropis aculeata	65	41.0			
Anonyx nugax					
Socarnes bidenticulatus					
Acanthostepheia behringiensis					
Stegocephalopsis ampulla	2	7.4			
Stegocephala inflatus	11	10.5			
Crustacea-Natantia		130.6			
Spirontocaris spina	11	14.5			
Lebbeus polaris	1	3.1			
Eualus gaimardii	70	68.5			12 ovig.
Eualus macilenta	12	8.5			
Pandalus goniurus					
Sabinea septemcarinata	10	24.0			
Crustacea-Anomura		105.0			
Pagurus trigonocheirus					
Crustacea-Brachyura		151.5			
Hyas coarctatus	28	151.5	4.5	1.5	18♀ (3 ovig)
Echinodermata-Asteroidea		72.5			
Crossaster papposus					
Leptasterias groenlandica	3	9.3			
Echinodermata-Ophiuroidea		200			
Ophiura sarsi		200			
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		164.2			
Psolus sp.	6	164.2			
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 17-77 DATE: 8 / 12 /77 START TIME 2005 HRS
METERS WATER 50 METERS WIRE 200 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°16.5' N 151°33' W BOTTOM TYPE rocky
TOTAL WT. OF CATCH (gms) 5430
COMMENTS:

tore net, 4 - 5 big rocks

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		61.3			
Boreogadus saida	5	24.5	10.8	7.4	
Lycodes polaris					
Gymnelis viridis					
Liparis spp.	4	6.4			
Eumicrotremis derjugini	1	5.9			
Icelus bicornis	1	1.5			
Icelus spatula					
Artediellus scaber	7	23.0			
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		19.0			
Eunephthya spp.					
Annelida-Polychaeta		6.0			
Eunoe nodosa					
Gattyana cirrosa		x			
Brada granulata					
Mollusca-Gastropoda		105.5			
Natica clausa	2	2.0			
Polinices pallida					
Trophonopsis beringi	7	12.0			
Buccinum spp.	5	27.3			2spp.
Margarites costalis	26	28.0			
Mollusca-Bivalvia		114.7			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui	132	94.6			
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 17 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		80.8			
Ampelisca eschrichti					
Rhachotropis aculeata	102	56.5			
Anonyx nugax					
Socarnes bidenticulatus					
Acanthostepheia behringiensis	1				
Stegocephalopsis ampulla					
Stegocephala inflatus	14	24.3			
Crustacea-Natantia		187.1			
Spirontocaris spina	12	15.2			1 ovig.
Lebbeus polaris					
Eualus gaimardii	90	110.0			23 ovig ♀.
Eualus macilenta	3	2.7			
Pandalus goniurus					
Sabinea septemcarinata	38	54.0	1.7	0.6	1 ovig
Crustacea-Anomura		12.9			
Pagurus trigonocheirus	20	12.9			
Crustacea-Brachyura		126.0			
Hyas coarctatus	30	126.0	6.0	1.4	21♂ ; 9♀
Echinodermata-Asteroidea		18.7			
Crossaster papposus	1	9.4			
Leptasterias groenlandica	6	9.3			
Echinodermata-Ophiuroidea		100.0			
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea		150.0			
Strongylocentrotus droebachiensis	2	150.0			
Echinodermata-Holothuroidea		1908			
Psolus sp.		1908			
Cucumaria sp.	4	8.0			
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 18 -77 DATE: 8 / 16/77 START TIME 0100 HRS
METERS WATER 40 METERS WIRE 160 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°06' N 149°42' W BOTTOM TYPE rocky/muddy - sticky mud
TOTAL WT. OF CATCH (gms) 2386
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		40.7			
Boreogadus saida	2	13.0	10.3	8.8	
Lycodes polaris	5	12.0	8.0	5.9	
Gymnelis viridis					
Liparis spp.	3	4.7			
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber	2	5.8			
Aspidophoroides olriki					
Lumpenus medius	1	5.2	12.3		
INVERTEBRATES					
Cnidaria		80.0			
Eunephthya spp.					
Annelida-Polychaeta		0.7			
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		76.8			
Natica clausa					
Polinices pallida	1	1.3			
Trophonopsis beringi					
Buccinum spp.	2	5.4			1 sp.
Margarites costalis	4	4.8			
Mollusca-Bivalvia		705.4			
Nuculana pernula	1				
Bathyarca glacialis					
Delectopecten greenlandicus		700			
Astarte montegui					
Astarte crenata	2	3.5			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 18 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
Crustacea-Amphipoda		20.2			
Ampelisca eschrichti	1	1.2			
Rhachotropis aculeata	33	17.0			
Anonyx nugax	1	0.4			
Socarnes bidenticulatus					
Acanthostepheia	3				
behringiensis					
Stegocephalopsis ampulla					
Stegocephala inflatus	2	1.8			
Crustacea-Natantia		100.8			
Spirontocaris spina	3	4.5			
Lebbeus polaris					
Eualus gaimardii	46	39.4			3 ovig
Eualus macilenta	3	3.0			
Pandalus goniurus					
Sabinea septemcarinata	33	53.6	1.5	0.7	
Crustacea-Anomura		38.7			
Pagurus trigonocheirus	14	38.7			
Crustacea-Brachyura		125.7			
Hyas coarctatus	9	125.7			5♂ ; 4 ovig ♀.
Echinodermata-Asteroidea		999.5			
Crossaster papposus					
Leptasterias groenlandica	7	47.5			
Echinodermata-Ophiuroidea		200			
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus					
droebachiensis					
Echinodermata-Holothuroidea					
Psolus sp.					
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 19 -77 DATE: 8 / 18 /77 START TIME 1603 HRS
METERS WATER 55 METERS WIRE 230 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 70°46' N 146°30' W BOTTOM TYPE
TOTAL WT. OF CATCH (gms) 643
COMMENTS: very clean bag

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		9.7			
Boreogadus saida	1	2.2	6.2		
Lycodes polaris	1	3.4	10.1		
Gymnelis viridis					
Liparis spp.	2	4.1	6.0	4.5	
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		24.1			
Eunephthya spp.					
Annelida-Polychaeta		3.2			
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		15.3			
Natica clausa					
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.	2	13.3			2 spp
Margarites costalis	1	1.6			
Mollusca-Bivalvia					
Nuculana pernula	2	1.7			
Bathyarca glacialis	14	18.2			
Delectopecten greenlandicus		91.8			
Astarte montegui	2	2.5			
Astarte crenata	2	2.5			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 19 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
Crustacea-Amphipoda					
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax					
Socarnes bidenticulatus					
Acanthostepheia behringiensis					
Stegocephalopsis ampulla					
Stegocephala inflatus					
Crustacea-Natantia		6.6			
Spirontocaris spina					
Lebbeus polaris					
Eualus gaimardii					
Eualus macilenta	2	1.8			
Pandalus goniurus					
Sabinea septemcarinata	3	4.8	1.2	1.0	
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura		25.0			
Hyas coarctatus	1	25.0	5.0		♂
Echinodermata-Asteroidea		266.0			
Crossaster papposus					
Leptasterias groenlandica	3	12.0			
Echinodermata-Ophiuroidea		126.0			
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea					
Psolus sp.					
Cucumaria sp.					
Echinodermata-Crinoidea		22.0			
Heliametra glacialis		22.0			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 20 -77 DATE: 8 / 26 /77 START TIME 2125 HRS
METERS WATER 56 METERS WIRE 200 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 70°09' N 141°17' W BOTTOM TYPE Rocky
TOTAL WT. OF CATCH (gms) 5071
COMMENTS: Big rock in trawl

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		114.3			
Boreogadus saida	11	75.8	13.2	6.7	
Lycodes polaris	1	5.4			
Gymnelis viridis					
Liparis spp.					
Eumicrotremis derjugini	1	7.2			
Icelus bicornis	6	} 25.9			
Icelus spatula	4	}			
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		79.5			
Eunephthya spp.					
Annelida-Polychaeta		22.0			
Eunoe nodosa		x			
Gattyana cirrosa					
Brada granulata	2	3.7			
Mollusca-Gastropoda		250.6			
Natica clausa					
Polinices pallida					
Trophonopsis beringi	4	5.0			
Buccinum spp.					
Margarites costalis	43	31.0			
Mollusca-Bivalvia		618.7			
Nuculana pernula	11	5.5			
Bathyarca glacialis	2	3.1			
Delectopecten greenlandicus		594.0			
Astarte montegui					
Astarte crenata	4	8.3			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 20-77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		54.7			
Ampelisca eschrichti	1				
Rhachotropis aculeata					
Anonyx nugax	13	24.2			
Socarnes bidenticulatus					
Acanthostepheia behringiensis	14				
Stegocephalopsis ampulla					
Stegocephala inflatus	17	22.3			
Crustacea-Natantia		384.9			
Spirontocaris spina					
Lebbeus polaris					
Eualus gaimardii	3	2.7			
Eualus macilenta	3	2.2			
Pandalus goniurus					
Sabinea septemcarinata	169	380.0			12 ovig
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura		39.0			
Hyas coarctatus	3	39.0	3.9	3.6	3 ♀
Echinodermata-Asteroidea		369.5			
Crossaster papposus					
Leptasterias groenlandica	86	103.9			
Echinodermata-Ophiuroidea		49.4			
Ophiura sarsi		41.4			
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		723.0			
Psolus sp.		647.0			
Cucumaria sp.	72	76.0			
Echinodermata-Crinoidea		2198.6			
Heliametra glacialis	11	2198.6			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 21 -77 DATE: 8 / 27 /77 START TIME 0243 HRS
METERS WATER 80 METERS WIRE 320-370 BOTTOM TIME 10 MINS SPEED 3KTS
START POS. 70°17' N 141°39' W BOTTOM TYPE rocky
TOTAL WT. OF CATCH (gms) 2071
COMMENTS: Tore 2 big holes in net - big rock and much small gravel.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		38.6			
Boreogadus saida	1	21.0	13.5		
Lycodes polaris					
Gymnelis viridis					
Liparis spp.	2	10.0			
Eumicrotremis derjugini					
Icelus bicornis	4	8.6			
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		7.2			
Eunephthya spp.					
Annelida-Polychaeta					
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		2.4			
Natica clausa					
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.					
Margarites costalis					
Mollusca-Bivalvia		47.5			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus		47.5			
Astarte montegui					
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 21 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		30.3			
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax	6	8.0			
Socarnes bidenticulatus					
Acanthostepheia behringiensis					
Stegocephalopsis ampulla	3	4.2			
Stegocephala inflatus	11	16.3			
Crustacea-Natantia		150.9			
Spirontocaris spina	7	11.7			2 ovig.♀ (0.7cm)
Lebbeus polaris	3	5.4			1 ovig♀ (1.2cm)
Eualus gaimardii	7	10.7			none ovig.
Eualus macilenta					
Pandalus goniurus					
Sabinea septemcarinata	52	96.5			none ovig.
Crustacea-Anomura		1.6			
Pagurus trigonocheirus	1	1.6			
Crustacea-Brachyura		53.7			
Hyas coarctatus	3	53.7	5.8	3.8	1♂, 2♀
Echinodermata-Asteroidea		272.8			
Crossaster papposus	28	152.5			
Leptasterias groenlandica	21	17.8			
Echinodermata-Ophiuroidea		88.5			
Ophiura sarsi					
Ophiacantha bidentata		x			
Echinodermata-Echinoidea		101.0			
Strongylocentrotus droebachiensis	9	101.0			
Echinodermata-Holothuroidea		2.5			
Psolus sp.					
Cucumaria sp.	2	2.0			
Echinodermata-Crinoidea		1200.			
Heliametra glacialis		1200.0			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 22-77 DATE: 8 / 27 /77 START TIME 0735 HRS
METERS WATER 50 METERS WIRE 200 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 70°18.4' N 142° 37' W BOTTOM TYPE Rocky
TOTAL WT. OF CATCH (gms) 3233
COMMENTS: several large rocks

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		45.2			
Boreogadus saida	4	18.0	9.5	7.2	
Lycodes polaris	1	1.7	5.7		
Gymnelis viridis					
Liparis spp.	1	18.5	10.5		
Eumicrotremis derjugini					
Icelus bicornis	1	7.0	7.2		
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		72.5			
Eunephthya spp.		28.0			
Annelida-Polychaeta		15.8			
Eunoe nodosa		x			
Gattyana cirrosa					
Brada granulata	3	7.8			
Mollusca-Gastropoda		121.8			
Natica clausa					
Polinices pallida	2	4.0			
Trophonopsis beringi	3	8.0			
Buccinum spp.	3	16.9			
Margarites costalis	42	37.5			
Mollusca-Bivalvia		171.7			
Nuculana pernula	9	8.5			
Bathyarca glacialis	1	2.0			
Delectopecten greenlandicus		129.0			
Astarte montegui	2				
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 22-77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		26.7			
Ampelisca eschrichti					
Rhachotropis aculeata	1	2.0			
Anonyx nugax	17	17.0			
Socarnes bidenticulatus	1	*			
Acanthostepheia behringiensis	2	2.0			
Stegocephalopsis ampulla					
Stegocephala inflatus	5	3.7			
Crustacea-Natantia		61.3			
Spirontocaris spina	7	6.4			
Lebbeus polaris	2	2.0			
Eualus gaimardii	4	5.2			
Eualus macilenta	2	2.3			
Pandalus goniurus					
Sabinea septemcarinata	22	45.4			
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura		33.2			
Hyas coarctatus	3	33.2	4.2	3.1	1♀
Echinodermata-Asteroidea		87.8			
Crossaster papposus	4	33.3			
Leptasterias groenlandica	35	54.5			
Echinodermata-Ophiuroidea		100			
Ophiura sarsi					
Ophiacantha bidentata		*			
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		2187.4			
Psolus sp.		2150.			
Cucumaria sp.		37.4			
Echinodermata-Crinoidea		211.5			
Heliametra glacialis	9	211.5			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 23-77 DATE: 8 / 27 /77 START TIME 1248 HRS
METERS WATER 75 METERS WIRE 284 BOTTOM TIME 5 MINS SPEED 3 KTS
START POS. 70°30.5' N 142°21' W BOTTOM TYPE hard gravel, rock
TOTAL WT. OF CATCH (gms) 2077
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		4.3			
Boreogadus saida					
Lycodes polaris					
Gymnelis viridis					
Liparis spp.	1	4.3	6.4		
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		60.5			
Eunephthya spp.					
Annelida-Polychaeta					
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		56.3			
Natica clausa					
Polinices pallida					
Trophonopsis beringi	4	5.8			
Buccinum spp.	1	9.7			
Margarites costalis	4	3.0			
Mollusca-Bivalvia		339.0			
Nuculana pernula					
Bathyarca glacialis		223.5			
Delectopecten greenlandicus		27.5			
Astarte montegui					
Astarte crenata	30	88.0			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 23 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		~~29.5~~			
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax					
Socarnes bidenticulatus					
Acanthostepheia behringiensis					
Stegocephalopsis ampulla	1	1.5			
Stegocephala inflatus	28	28.0			
Crustacea-Natantia		7.8			
Spirontocaris spina	1	2.0			
Lebbeus polaris					
Eualus gaimardii					
Eualus macilenta					
Pandalus goniurus					
Sabinea septemcarinata	3	5.8			
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura		41.2			
Hyas coarctatus	3	41.2	4.7	2.9	2 ♂ ; 1 ♀ .
Echinodermata-Asteroidea		49.8			
Crossaster papposus	3	26.0			
Leptasterias groenlandica	3	2.5			
Echinodermata-Ophiuroidea		20.5			
Ophiura sarsi					
Ophiacantha bidentata		*			
Echinodermata-Echinoidea		60.7			
Strongylocentrotus droebachiensis	3	60.7			
Echinodermata-Holothuroidea					
Psolus sp.					
Cucumaria sp.					
Echinodermata-Crinoidea		1400.			
Heliametra glacialis		1400.			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 24 -77 DATE: 8 / 27/77 START TIME 2247 HRS
METERS WATER 105 METERS WIRE 400 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 70°36.5' N 143°55' W BOTTOM TYPE
TOTAL WT. OF CATCH (gms) 6753
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		197.3			
Boreogadus saida	2	32.5	13.7	11.8	
Lycodes raridens	2	4.3			
Lycodes polaris					
Gymnelis viridis					
Lycodes mucosus	1	2.0			
Liparis spp.	1	33.5	12.8		L. herschelinus
Eumicrotremis derjugini	1	7.8	7.2		
Icelus bicornis	32	108.2			
Icelus spatula					
Artediellus scaber					
Triglops pingeli	1	9.0	10.3		
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		71.7			
Eunephthya spp.					
Annelida-Polychaeta		12.0			
Eunoe nodosa		x			
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		199.4			
Natica clausa					
Polinices pallida					
Trophonopsis beringi	34	6.0			
Buccinum spp.	2	6.5			2 spp.
Margarites costalis	5	4.9			
Mollusca-Bivalvia		1666.1			
Nuculana pernula	6	4.6			
Bathyarca glacialis	195	239.5			
Delectopecten greenlandicus		1300			
Astarte montegui					
Astarte crenata	55	122.0			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 24 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
Crustacea-Amphipoda		16.9			
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax	2	3.2			
Socarnes bidenticulatus					
Acanthostepheia behringiensis	2	2.4			
Stegocephalopsis ampulla	1	4.6			
Stegocephala inflatus	4	5.2			
Crustacea-Natantia		415.8			
Spirontocaris spina	4	12.9			
Lebbeus polaris	1	1.7			
Eualus gaimardii					
Eualus macilenta	1	1.2			
Pandalus goniurus					
Sabinea septemcarinata	150	400.0			
Crustacea-Anomura					
Pagurus trigonocheirus	2	10.8			
Crustacea-Brachyura		108.0			
Hyas coarctatus	7	108.0	5.5	2.2	6♂; 1 non-ovig. ♀ .
Echinodermata-Asteroidea		456.2			
Crossaster papposus	23	228.0			
Leptasterias groenlandica	20	58.8			
Echinodermata-Ophiuroidea		1800.			
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis	6	152.2			
Echinodermata-Holothuroidea		9.2			
Psolus sp.	1	9.2			
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis		1300			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 25 -77 DATE: 8 / 28/77 START TIME 2330 HRS
METERS WATER 110 METERS WIRE 400 BOTTOM TIME 05 MINS SPEED 3 KTS
START POS. 70°43.8' N 145°02' W BOTTOM TYPE Hard, rocky
TOTAL WT. OF CATCH (gms) 2036
COMMENTS:
Hole in net, probably didn't lose much

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		57.3			
Boreogadus saida					
Lycodes polaris					
Gymnelis viridis	1	5.0	11.6		
Liparis spp.					
Eumicrotremis derjugini	3	24.3			
Icelus bicornis	9	28.0			
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		9.5			
Eunephthya spp.					
Annelida-Polychaeta		16.4			
Eunoe nodosa		x			
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		24.2			
Natica clausa					
Polinices pallida					
Trophonopsis beringi	3	4.2			
Buccinum spp.	1	2.6			1 sp
Margarites costalis	15	13.8			
Mollusca-Bivalvia		186.3			
Nuculana pernula	7	4.8			
Bathyarca glacialis	29	37.0			
Delectopecten greenlandicus		139.0			
Astarte montegui					
Astarte crenata	3	5.5			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 25-77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		19.5			
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax	1	1.4			
Socarnes bidenticulatus					
Acanthostepheia behringiensis	2	2.0			
Stegocephalopsis ampulla	8	12.2			
Stegocephala inflatus	5	5.9			
Crustacea-Natantia		233.1			
Spirontocaris spina	5	13.2			
Lebbeus polaris					
Eualus gaimardii	1	2.6			
Eualus macilenta	2	2.3			
Pandalus goniurus					
Sabinea septemcarinata	75	215.0			9 ovig.
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura		20.2			
Hyas coarctatus	2	20.2	3.7	3.3	1♂; 1♀.
Echinodermata-Asteroidea		185.5			
Crossaster papposus	12	121.3			
Leptasterias groenlandica	5	11.2			
Echinodermata-Ophiuroidea		66.0			
Ophiura sarsi					
Ophiacantha bidentata		x			
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis	10	199.2			
Echinodermata-Holothuroidea					
Psolus sp.					
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis		1000.			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 26-77 DATE: 8 /29 /77 START TIME 0155 HRS
METERS WATER 50 METERS WIRE 200 BOTTOM TIME 5 MINS SPEED 3 KTS
START POS. 70°35.5' N 145°13' W BOTTOM TYPE rocky
TOTAL WT. OF CATCH (gms) 1360
COMMENTS:
one 8" rock, no holes.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		80.0			
Boreogadus saida	3	40.2	12.8	10.4	
Lycodes polaris	1	7.0	11.8		
Gymnelis viridis					
Liparis spp.					
Eumicrotremis derjugini	3	32.8			
Icelus bicornis					
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria					
Eunephthya spp.					
Annelida-Polychaeta					
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		21.5			
Natica clausa					
Polinices pallida					
Trophonopsis beringi	3	6.2			
Buccinum spp.					
Margarites costalis	7	8.7			
Mollusca-Bivalvia		24.0			
Nuculana pernula	3	2.4			
Bathyarca glacialis	1	1.8			
Delectopecten greenlandicus		19.8			
Astarte montegui					
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 26 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		27.4			
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax	3	3.5			
Socarnes bidenticulatus					
Acanthostepheia behringiensis					
Stegocephalopsis ampulla	13	8.0			
Stegocephala inflatus	21	14.9			
Crustacea-Natantia		46.6			
Spirontocaris spina	3	4.3			
Lebbeus polaris					
Eualus gaimardii	4	4.0			
Eualus macilenta	2	1.8			
Pandalus goniurus					
Sabinea septemcarinata	16	35.5			2 ovig.
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura		20.2			
Hyas coarctatus	1	20.7	4.4		ovig ♀.
Echinodermata-Asteroidea		29.2			
Crossaster papposus	1	13.9			
Leptasterias groenlandica	3	3.3			
Echinodermata-Ophiuroidea		8.1			
Ophiura sarsi					
Ophiacantha bidentata		*			
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis	3	59.8			
Echinodermata-Holothuroidea					
Psolus sp.	33	431.0			
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis		600.0			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 27 -77 DATE: 8 / 29 /77 START TIME 1700 HRS
METERS WATER 54 METERS WIRE 225 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 70°40' N 145°32' W BOTTOM TYPE rocky?
TOTAL WT. OF CATCH (gms) 2184
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		32.7			
Boreogadus saida	1	11.2	11.0		
Lycodes polaris					
Gymnelis viridis	4	12.7			
Liparis spp.					
Eumicrotremis derjugini	1	5.7			
Icelus bicornis	3	3.1			
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		93.7			
Eunephthya spp.		20.7			
Annelida-Polychaeta		34.5			
Eunoe nodosa		x			
Gattyana cirrosa		x			
Brada granulata					
Mollusca-Gastropoda		167.7			
Natica clausa					
Polinices pallida					
Trophonopsis beringi	9	17.7			sp?
Buccinum spp.					
Margarites costalis	85	78.5			
Mollusca-Bivalvia		1192.5			
Nuculana pernula	16	164.0			
Bathyarca glacialis		71.5			
Delectopecten greenlandicus		359.0			
Astarte montegui		} 598.0			
Astarte crenata		}			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 27 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		55.2			
Ampelisca eschrichti	1	2.0			
Rhachotropis aculeata					
Anonyx nugax	20	15.3			
Socarnes bidenticulatus	1	1.7			
Acanthostepheia behringiensis	18	8.0			
Stegocephalopsis ampulla	1	1.7			
Stegocephala inflatus	9	6.2			
Crustacea-Natantia		45.2			
Spirontocaris spina	2	2.2			
Lebbeus polaris	1	1.0			
Eualus gaimardii					
Eualus macilenta	2	1.5			
Pandalus goniurus					
Sabinea septemcarinata	19	40.5			2 ovig
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura		44.5			
Hyas coarctatus	3	44.5	4.6	3.2	2 ♀ ; 1 ♂ .
Echinodermata-Asteroidea		120.1			
Crossaster papposus	2	15.8			
Leptasterias groenlandica	38	89.2			
Echinodermata-Ophiuroidea		50.0			
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		159.2			
Psolus sp.	10	155.5			
Cucumaria sp.	2	3.7			
Echinodermata-Crinoidea					
Heliametra glacialis	3	69.0			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 28-77 DATE: 8 / 29 /77 START TIME 1903 HRS
METERS WATER 110 METERS WIRE 426 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 70°50' N 145°31' W BOTTOM TYPE
TOTAL WT. OF CATCH (gms) 6500
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		148.8			
Boreogadus saida	1	7.7	10.0		
Lycodes polaris					
Gymnelis viridis	2	7.2	11.2	9.0	
Liparis spp.	2	19.7			
Eumicrotremis derjugini	7	76.5			
Icelus bicornis	8	25.2	7.3	5.2	
Icelus spatula					
Artediellus scaber					
Trigiops pingeli	1	12.5	12.0		
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		50.5			
Eunephthya spp.		5.5			
Annelida-Polychaeta		4.2			
Eunoe nodosa		x			
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		179.6			
Natica clausa					
Polinices pallida					
Trophonopsis beringi	15	15.4			
Buccinum spp.	2	6.0			2 sp
Margarites costalis	12	11.2			
Mollusca-Bivalvia		660.2			
Nuculana pernula	1	2.0			
Bathyarca glacialis	11	7.7			
Delectopecten greenlandicus		605.0			
Astarte montegui					
Astarte crenata	29	45.5			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 28 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. CMS	SIZE-CMS MAX	MIN	COMMENTS
Crustacea-Amphipoda		88.6			
Ampelisca eschrichti	1	1.5			
Rhachotropis aculeata					
Anonyx nugax	8	8.0			
Socarnes bidenticulatus					
Acanthostepheia behringiensis	6	3.8			
Stegocephalopsis ampulla	3	9.3			
Stegocephala inflatus	46	66.0			
Crustacea-Natantia		226.5			
Spirontocaris spina					
Lebbeus polaris	2	5.4			
Eualus gaimardii	2	3.6			
Eualus macilenta	16	13.5			
Pandalus goniurus					
Sabinea septemcarinata	74	200.0			8 ovig
Crustacea-Anomura					
Pagurus trigonocheirus	1	3.8			
Crustacea-Brachyura		129.0			
Hyas coarctatus	8	129.0	5.3	3.6	2♂; 6♀(2 ovig)
Echinodermata-Asteroidea		309.5			
Crossaster papposus	21	190.0			
Leptasterias groenlandica	4	9.4			
Echinodermata-Ophiuroidea		1150.			
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis		720.			
Echinodermata-Holothuroidea					
Psolus sp.					
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis		2800.			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 29 -77 DATE: 8 / 30 /77 START TIME 0855 HRS
METERS WATER 130 METERS WIRE 480 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 70°50' N 146°00' W BOTTOM TYPE
TOTAL WT. OF CATCH (gms) 2778
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		52.8			
Boreogadus saida	3	24.4	12.7	7.4	
Lycodes polaris	2	5.4	8.2	7.5	
Gymnelis viridis					
Liparis spp.	1	23.0	11.8		
Eumicrotremis derjugini					
Icelus bicornis	1	2.2	5.2		
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		212.5			
Eunephthya spp.		192.5			
Annelida-Polychaeta		11.8			
Eunoe nodosa					
Gattyana cirrosa		x			
Brada granulata					
Mollusca-Gastropoda		70.4			
Natica clausa					
Polinices pallida					
Trophonopsis beringi	4	5.6			
Buccinum spp.	6	58.9			2 spp
Margarites costalis	6	5.9			
Mollusca-Bivalvia		1504.9			
Nuculana pernula	60	34.3			
Bathyarca glacialis	849	900.0			
Delectopecten greenlandicus		120.6			
Astarte montegui					
Astarte crenata	192	550.0			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 29 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. CMS	SIZE-CMS MAX	MIN	COMMENTS
Crustacea-Amphipoda		22.1			
Ampelisca eschrichti	2	2.4			
Rhachotropis aculeata					
Anonyx nugax	2	2.2			
Socarnes bidenticulatus					
Acanthostepheia behringiensis	14	7.0			
Stegocephalopsis ampulla					
Stegocephala inflatus	9	8.2			
Crustacea-Natantia		42.4			
Spirontocaris spina					
Lebbeus polaris					
Eualus gaimardii					
Eualus macilenta	20	15.9			
Pandalus goniurus					
Sabinea septemcarinata	11	26.5			none ovig
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura					
Hyas coarctatus					
Echinodermata-Asteroidea		227.5			
Crossaster papposus	1	21.3			
Leptasterias groenlandica					
Echinodermata-Ophiuroidea		559.9			
Ophiura sarsi					
Ophiacantha bidentata		*			
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea					
Psolus sp.					
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis	3	8.5			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 30 -77 DATE: 8 / 30 /77 START TIME 1037 HRS
METERS WATER 54 METERS WIRE 200 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 70°38' N 146°04' W BOTTOM TYPE rocky
TOTAL WT. OF CATCH (gms) 4493
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES		33.1			
Boreogadus saida					
Lycodes polaris					
Gymnelis viridis	4	9.2	11.2	7.5	
Liparis spp.	3	18.5	9.3	6.5	
Eumicrotremis derjugini	1	1.4			
Icelus bicornis	1	4.0	6.8		
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		24.0			
Eunephthya spp.					
Annelida-Polychaeta		9.4			
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata	1	2.2			
Mollusca-Gastropoda		89.0			
Natica clausa					
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.					
Margarites costalis	27	29.3			
Mollusca-Bivalvia		149.3			
Nuculana pernula	8	6.3			
Bathyarca glacialis					
Delectopecten greenlandicus		143.0			
Astarte montegui					
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 30-77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		50.7			
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax	3	4.5			
Socarnes bidenticulatus	1	1.2			
Acanthostepheia behringiensis	5	2.8			
Stegocephalopsis ampulla	1	2.2			
Stegocephala inflatus	44	39.0			
Crustacea-Natantia		118.4			
Spirontocaris spina	6	10.0			
Lebbeus polaris	7	5.4			
Eualus gaimardii	33	31.5			4 ovig.
Eualus macilenta	10	7.2			
Pandalus goniurus					
Sabinea septemcarinata	25	64.3			3 ovig
Crustacea-Anomura		5.5			
Pagurus trigonocheirus	6	4.6			
Crustacea-Brachyura		81.0			
Hyas coarctatus	3	81.0	6.4	3.0	♂'s
Echinodermata-Asteroidea		297.5			
Crossaster papposus	21	246.0			
Leptasterias groenlandica	22	35.5			
Echinodermata-Ophiuroidea		30.0			
Ophiura sarsi					
Ophiacantha bidentata		*			
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis	10	305.0			
Echinodermata-Holothuroidea					
Psólus sp.		2200			
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis		1100			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 31 -77 DATE: 8 / 30 /77 START TIME 2152 HRS
METERS WATER 56 METERS WIRE 220 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 70°47' N 146°33' W BOTTOM TYPE
TOTAL WT. OF CATCH (gms) 4788
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		71.2			
Boreogadus saida	2	10.6	9.5	8.0	
Lycodes polaris	3	4.3	7.9	4.5	
Gymnelis viridis	1	3.2	9.5		
Liparis spp.	2	10.0	7.2	6.5	
Eumicrotremis derjugini	8	31.4			
Icelus bicornis	3	5.0	7.5	3.6	
Icelus spatula					
Artediellus scaber	2	6.7	7.0	4.5	
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		137.5			
Eunephthya spp.					
Annelida-Polychaeta		12.0			
Eunoe nodosa					
Gattyana cirrosa		x			
Brada granulata	1	2.0			
Mollusca-Gastropoda		81.8			
Natica clausa					
Polinices pallida					
Trophonopsis beringi	13				
Buccinum spp.	1	12.4			
Margarites costalis	28	29.0			
Mollusca-Bivalvia		545.8			
Nuculana pernula	37	21.6			
Bathyarca glacialis	1	2.7			
Delectopecten greenlandicus		516.0			
Astarte montegui	5	5.5			
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 31-77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
Crustacea-Amphipoda		66.9			
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax	10	14.1			
Socarnes bidenticulatus	1	2.0			
Acanthostepheia behringiensis	9	6.0			
Stegocephalopsis ampulla	5	4.2			
Stegocephala inflatus	50	42.6			
Crustacea-Natantia		203.1			
Spirontocaris spina	19	33.2			8 ovig.
Lebbeus polaris	6	11.4			
Eualus gaimardii	13	15.9			3 ovig.
Eualus macilenta	14	14.2			none ovig
Pandalus goniurus					
Sabinea septemcarinata	48	116.3			3 ovig.
Crustacea-Anomura		16.2			
Pagurus trigonocheirus					
Crustacea-Brachyura		60.3			
Hyas coarctatus	4	60.3	5.6	2.8	1♂, 3♀ (1 ovig)
Echinodermata-Asteroidea		687.8			
Crossaster papposus	7	81.0			
Leptasterias groenlandica	18	31.8			
Echinodermata-Ophiuroidea		138.0			
Ophiura sarsi					
Ophiacantha bidentata		*			
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis	6	155.3			
Echinodermata-Holothuroidea		1600			
Psolus sp.		1600			
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis		1000			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 32-77 DATE: 8 / 30/77 START TIME 2335 HRS
METERS WATER 90-110 METERS WIRE 375 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 70°56.5' N 146°32' W BOTTOM TYPE
TOTAL WT. OF CATCH (gms) 12100
COMMENTS: one fourth of trawl sorted but all fish and crustaceans counted.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		30.3			
Boreogadus saida					
Lycodes polaris	1	0.5	4.1		
Gymnelis viridis	3	12.1	12.0	9.2	
Liparis spp.	1	4.5	6.8		
Eumicrotremis derjugini					
Icelus bicornis	5	13.2	6.7	5.6	
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		2.5			
Eunephthya spp.					
Annelida-Polychaeta		8.7			
Eunoe nodosa		x			
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		6.9			
Natica clausa					
Polinices pallida					
Trophonopsis beringi	2	3.2			
Buccinum spp.					
Margarites costalis	3	3.7			
Mollusca-Bivalvia					
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus		1000			
Astarte montegui					
Astarte crenata	1	1.4			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 32-77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
Crustacea-Amphipoda		10.2			
Ampelisca eschrichti					
Rhachotropis aculeata	2	3.8			
Anonyx nugax					
Socarnes bidenticulatus	1	*			
Acanthostepheia behringiensis					
Stegocephalopsis ampulla	1	1.7			
Stegocephala inflatus	8	4.7			
Crustacea-Natantia		207.9			
Spirontocaris spina	22	'61.5			4 ovig.
Lebbeus polaris	6	7.8			
Eualus gaimardii					
Eualus macilenta	12	10.4			
Pandalus goniurus	1	2.5			
Sabinea septemcarinata	48	124.6			5 ovig.
Crustacea-Anomura		1.5			
Pagurus trigonocheirus	2	1.5			
Crustacea-Brachyura					
Hyas coarctatus					
Echinodermata-Asteroidea		10.0			
Crossaster papposus	1	2.0			
Leptasterias groenlandica	3	8.0			
Echinodermata-Ophiuroidea		122.3			
Ophiura sarsi					
Ophiacantha bidentata		*			
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis	3	80.5			
Echinodermata-Holothuroidea					
Psolus sp.					
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis		1100			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 33 -77 DATE: 8 / 31 /77 START TIME 0937 HRS
METERS WATER 70 METERS WIRE 240 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 70°53' N 147°01 W BOTTOM TYPE rocky
TOTAL WT. OF CATCH (gms) 8100
COMMENTS: net torn, big catch, split to sort (about 1/4), all fish and Hippolytid shrimps done

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		44.8			
Boreogadus saida					
Lycodes polaris					
Gymnelis viridis					
Liparis spp.	1	38.8	13.6		
Eumicrotremis derjugini	1	2.0			
Icelus bicornis					
Icelus spatula					
Artediellus scaber	1	4.0	6.0		
Aspidophoroides olriki					
INVERTEBRATES					
Cnidaria		4.5			
Eunephthya spp.					
Annelida-Polychaeta					
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		1.1			
Natica clausa					
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.					
Margarites costalis					
Mollusca-Bivalvia		762.3			
Nuculana pernula	2	2.8			
Bathyarca glacialis	1	2.0			
Delectopecten greenlandicus		750.0			
Astarte montegui					
Astarte crenata	3	7.5			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 33 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
Crustacea-Amphipoda		22.0			
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax					
Socarnes bidenticulatus					
Acanthostepheia behringiensis	16	9.2			
Stegocephalopsis ampulla	1	2.5			
Stegocephala inflatus	7	8.5			
Crustacea-Natantia		37.7			
Spirontocaris spina					
Lebbeus polaris	1	1.7			
Eualus gaimardii					
Eualus macilenta					
Pandalus goniurus	1	7.5			
Sabinea septemcarinata	16	28.5			none ovig.
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura					
Hyas coarctatus					
Echinodermata-Asteroidea		295.1			
Crossaster papposus					
Leptasterias groenlandica	2	2.8			
Echinodermata-Ophiuroidea		LOTS			
Ophiura sarsi					
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis	1	40.1			
Echinodermata-Holothuroidea		66.3			
Psolus sp.	5	66.3			
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis		800.0			

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 34 -77 DATE: 9 /3 /77 START TIME 2317 HRS
METERS WATER 150 METERS WIRE 550 BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. 71°59' N 155°42' W BOTTOM TYPE
TOTAL WT. OF CATCH (gms) 7567
COMMENTS: no rocks in trawl

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
FISHES		43.6			
Boreogadus saida	2	12.7	10.2	8.0	
Lycodes polaris	17	29.4	10.2	5.2	
Gymnelis viridis					
Liparis spp.					
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula					
Artediellus scaber					
Aspidophoroides olriki	1	1.5	5.2		
INVERTEBRATES					
Cnidaria		53.2			
Eunephthya spp.		29.0			
Annelida-Polychaeta					
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda		441.1			
Natica clausa					
Polinices pallida	1	1.0			
Trophonopsis beringi					
Buccinum spp.					
Margarites costalis	1				
Mollusca-Bivalvia		5.5			
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui	6	5.5			
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 34 -77. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda		16.6			
Ampelisca eschrichti					
Rhachotropis aculeata					
Anonyx nugax	2	1.5			
Socarnes bidenticulatus					
Acanthostepheia behringiensis	2	2.4			
Stegocephalopsis ampulla					
Stegocephala inflatus	9	8.5			
Crustacea-Natantia		127.3			
Spirontocaris spina					
Lebbeus polaris	4	6.9	1.3	1.1	
Eualus gaimardii	1	5.3			
Eualus macilenta	68	78.3	1.15	.89	
Pandalus goniurus					
Sabinea septemcarinata	9	36.8			
Crustacea-Anomura		15.5			
Pagurus trigonocheirus	4	12.0			
Crustacea-Brachyura		49.6			
Hyas coarctatus	1	4.9	2.8		♀.
Echinodermata-Asteroidea		3004.9			
Crossaster papposus	1	3.0			
Leptasterias groenlandica					
Echinodermata-Ophiuroidea		3741.0			
Ophiura sarsi		3700.			
Ophiacantha bidentata					
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea		1.4			
Psolus sp.					
Cucumaria sp.	1	1.4			
Echinodermata-Crinoidea					
Heliametra glacialis					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 1 -'76 DATE: 8 / 30 /'76 START TIME 1230 HRS
METERS WATER 123 METERS WIRE ______ BOTTOM TIME 15 MINS SPEED 3 KTS
START POS. 71°19' N 152°34' W BOTTOM TYPE pebble
TOTAL WT. OF CATCH (gms) ______
COMMENTS:

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES					
Boreogadus saida	24		16.8	9.0	
Lycodes raridens	3		10.0	9.0	
Lycodes polaris	4		22.2	8.1	
Gymnelis viridis					
Lycodes rossi	2		12.6	9.1	
Liparis spp.	4		11.0	7.0	
Eumicrotremis derjugini					
Icelus bicornis					
Icelus spatula	6		10.0	6.8	
Artediellus scaber					
Aspidophoroides olriki	16		6.5	4.1	
Lumpenus fabricii	10		16.8	8.5	
INVERTEBRATES					
Cnidaria					
Eunephthya spp.					
Annelida-Polychaeta					
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda					
Natica clausa					
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.	10				
Margarites costalis					
Mollusca-Bivalvia					
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui					
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 1 - 76 cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	MIN	COMMENTS
Crustacea-Amphipoda					
Ampelisca eschrichti					
Rhachotropis aculeata	2				
Anonyx nugax	86				
Socarnes bidenticulatus					
Acanthostepheia behringiensis					
Stegocephalopsis ampulla					
Stegocephala inflatus	12				
Crustacea-Natantia					
Spirontocaris spina	8		1.6	1.4	6 ovig
Lebbeus polaris					
Eualus gaimardii	32		1.8	0.8	2 ovig
Eualus macilenta	224		1.1	0.9	none ovig
Pandalus goniurus	4		1.5		
Sabinea septemcarinata	70		2.0	1.1	12 ovig
Crustacea-Anomura					
Pagurus trigonocheirus					
Crustacea-Brachyura					
Hyas coarctatus	25		6.0	1.8	
Echinodermata-Asteroidea					
Crossaster papposus	15				
Leptasterias groenlandica	3				
Echinodermata-Ophiuroidea					
Ophiura sarsi		*			
Ophiacantha bidentata		*			
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea					
Psolus sp.	4				
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis	12				

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 2-76 DATE: 8 / 3 /76 START TIME 2330 HRS
METERS WATER 40 METERS WIRE ______ BOTTOM TIME 10 MINS SPEED 3 KTS
START POS. ______ N ______ W BOTTOM TYPE Rock, pebble, shell
TOTAL WT. OF CATCH (gms) ______
COMMENTS: one large rock, several small ones in trawl.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
FISHES					
Boreogadus saida	9		16.3	7.6	
Lycodes mucosus	1				
Lycodes polaris	36		21.0	6.3	
Gymnelis viridis	4		13.5	4.8	
Liparis spp.	1		5.8		
Eumicrotremis derjugini					
Gymnocanthus tricuspis	3		8.0	5.8	
Icelus bicornis					
Icelus spatula					
Artediellus scaber	6		8.0	4.0	
Triglops pingeli	1		10.5		
Aspidophoroides olriki	1		4.3		
Eumesogrammus praecisus	1	15.2	12.8		
Lumpenus fabricii	1		12.2		
INVERTEBRATES					
Cnidaria					
Eunephthya spp.					
Annelida-Polychaeta					
Eunoe nodosa					
Gattyana cirrosa					
Brada granulata					
Mollusca-Gastropoda					
Natica clausa					
Polinices pallida					
Trophonopsis beringi					
Buccinum spp.					
Margarites costalis					
Mollusca-Bivalvia					
Nuculana pernula					
Bathyarca glacialis					
Delectopecten greenlandicus					
Astarte montegui					
Astarte crenata					

OTTER TRAWL DATA--BEAUFORT SEA

TRAWL #GLATR- 2 -76. cont.

SPECIES NAME	NO. INDS.	TOT. WT. GMS	SIZE-CMS MAX	SIZE-CMS MIN	COMMENTS
Crustacea-Amphipoda					
Ampelisca eschrichti	10				
Rhachotropis aculeata	76				
Anonyx nugax	12				
Socarnes bidenticulatus					
Acanthostepheia behringiensis					
Stegocephalopsis ampulla					
Stegocephala inflatus	2				
Crustacea-Natantia					
Spirontocaris spina	2		1.0		
Lebbeus polaris					
Eualus gaimardii	134				few ovig
Eualus macilenta	12				none ovig
Pandalus goniurus					
Sabinea septemcarinata	54		2.0	0.8	some ovig
Crustacea-Anomura					
Pagurus trigonocheirus	6				
Crustacea-Brachyura					
Hyas coarctatus	13		5.1	1.5	
Echinodermata-Asteroidea					
Crossaster papposus	2				
Leptasterias groenlandica	3				
Echinodermata-Ophiuroidea					
Ophiura sarsi		x			
Ophiacantha bidentata		x			
Echinodermata-Echinoidea					
Strongylocentrotus droebachiensis					
Echinodermata-Holothuroidea					
Psolus sp.	1				
Cucumaria sp.					
Echinodermata-Crinoidea					
Heliametra glacialis					

APPENDIX II

Observations on the Food of Ringed Seals and
Bowhead Whales in the Region of Point Barrow, Alaska

In Press in Canadian Field Naturalist

OBSERVATIONS ON THE FOOD OF RINGED SEALS AND BOWHEAD WHALES IN THE REGION OF PT. BARROW, ALASKA

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Ringed seals, *Phoca (Pusa) hispida* and bowhead whales, *Balaena mysticetus* are ecologically important components of the Chukchi-Beaufort marine ecosystem. Ringed seals are present in the area throughout the year in association with sea ice. Their numbers and spatial distribution vary greatly in relation to seasonal changes in ice cover. Bowhead whales winter in the Bering Sea and summer in the Beaufort Sea and Amundsen Gulf. They pass close to Point Barrow during their spring and fall migrations. Both species are regularly taken by Eskimo hunters from the settlement of Barrow.

Ringed seals are presently numerous in this region and are probably at or near the carrying capacity of their habitat. The Bering-Chukchi-Beaufort Sea population of bowhead whales was greatly reduced during the late 19th century and the population is still below the level which existed prior to commercial whaling. Ecological relationships between these two marine mammals are unclear. This note presents the results of preliminary studies which indicate that in the vicinity of Point Barrow, Alaska, these two species utilize the same primary prey items and that some competition for food may exist.

Methods and Materials

Samples utilized in this study included the entire contents of stomachs obtained from 16 ringed seals and small subsamples of stomach contents from two bowhead whales. All animals were taken in the vicinity of Point Barrow (71°23'N, 156°30'W). Pertinent information about these animals is given in Table 1.

When possible, each seal was weighed and measured, and the date, time and location of capture noted. Age determinations were based on examination of claws and/or teeth. All contents of the seal stomachs were gently washed on a 1.0 mm mesh screen and preserved in 10 percent formalin for later examination. The two subsamples of stomach contents from bowhead whales were preserved in 10 percent formalin. Length, sex and date of kill were noted for each whale.

Laboratory analysis of material involved macroscopic sorting followed by microscopic examination and identification of prey. Food items were identified using appropriate taxonomic keys and voucher specimens maintained at our laboratory and at the University of Alaska Marine Museum Sorting Center. The volume of each type of food was measured by water displacement. Where possible, numbers and size ranges of prey items consumed were determined.

Results

As no clear time, sex or age related differences in diet were apparent, the data from all 16 ringed seals were pooled. Over three-quarters of the combined total volume of food was euphausiids (*Thysanoessa inermis* and *T. raschii*), which occurred in 11 of 16 stomachs examined. Gammarid amphipods (*Anonyx nugax*, *Gammaracanthus loricatus*, *Acanthostepheia behringiensis*, *Gammarus zaddachi* and *Atylus* sp.) were also found in 11 stomachs but comprised only 4.6 percent of the combined total volume. Hyperiid amphipods (*Parathemisto libellula* and *P. abyssorum*) occurred in seven stomachs, always in association with euphausiids, and accounted for 0.3 percent of the total combined volume. Isopods (*Saduria entomon*) were found in only two stomachs but made up 15.9 percent of the total combined volume. This high percentage was largely the result of a seal taken on 13 June 1976 the stomach of which contained 200 ml of *Saduria*. Shrimp (*Sclerocrangon boreas*, *Lebbeus polaris* and *Pandalus* sp.), mysids (*Mysis litoralis* and *Neomysis rayii*) and squid (species unknown) appeared in a few stomachs in small volumes. Fishes were represented almost entirely by otoliths. Otoliths of 30 polar cod (*Boreogadus saida*), 2 capelin (*Mallotus villosus*) and 1 saffron cod (*Eleginus gracilus*) were identified. Fish remains occurred in five seal stomachs.

Subsamples of stomach contents from bowhead whales consisted of 17.5 ml from specimen number 76-B-6F and 33.0 ml from number 76-B-7F. Since only subsamples were examined, pooling of data may not be justified. However, prey items in the two samples were similar and little error should result from combining them.

Euphausiids (all identifiable material was Thysanoessa raschii) made up 90.3 percent of the total combined volume. Gammarid amphipods (Gammarus zaddachi, Acanthostepheia behringiensis, Monoculoides zernovi and Rozinante fragilis) accounted for 6.9 percent and the hyperiid amphipod Parathemisto libellula made up 2.7 percent. One sample contained a partial carapace of an unidentifiable shrimp, the other contained a small pebble.

Discussion

The primary items found in the stomachs of ringed seals taken from different geographical regions indicate marked variation in food consumed. In an examination of 47 ringed seal stomachs taken near Baffin Island during August and September, Dunbar (1941) found that the amphipod Parathemisto (= Themisto) libellula was the predominant food. Mysids (Mysis oculata) were commonly eaten and other amphipods, euphausiids and fishes were occasionally consumed. The same general results were reported by McLaren (1958).

In the northwestern Bering Sea and the Sea of Okhotsk, euphausiids (Thysanoessa raschii) appear to be the chief food item. Shrimps, amphipods and various schooling fishes are sometimes important in the diet (Fedoseev 1965, Fedoseev and Bukhtiyarov 1972, Nikolaev and Skalkin 1975).

Kenyon (1962) found shrimp (Pandalus sp.) to be the primary food with fishes, mysids and gammarid amphipods eaten in small quantities in

Bering Strait during May and June. Johnson et al. (1966) in an extensive investigation of the foods of ringed seals near Point Hope and Kivalina, Alaska, found fishes (Boreogadus saida, Eleginus gracilus, and cottids) to be the main food during November through February. Beginning in March and continuing through June, crustaceans (shrimps, amphipods, crabs and mysids) made up the bulk of the ringed seal's diet at these locations. Results from other localities in the eastern Bering and Chukchi Seas follow the same general pattern (Lowry, Frost and Burns, unpublished data).

It appears that food consumed by ringed seals at any given place and time will consist of the most abundant and available suitable species which, in the western Beaufort Sea during late spring and summer, apparently is euphausiids. It is noteworthy that a seal collected 150 km east of Point Barrow, 35 km offshore on 20 August 1976 (data not included in this report) had also eaten almost entirely euphausiids. In 247 ringed seal stomachs containing food, which we have examined from Alaskan waters other than the Beaufort Sea, euphausiids have occurred in only 15. Of those, 11 were taken in the northeastern Chukchi Sea, at Point Hope, in late May 1976.

Bowhead whales are considered to feed in a skimming mode utilizing their highly specialized baleen plates (Nemoto 1970). They would therefore be expected to feed mostly on copepods and to a lesser extent on euphausiids and other zooplankters. Tomilin (1957) cited indirect evidence indicating that the copepod Calanus finmarchicus and the pteropod Limacina helicina are major food items. MacGinitie (1955) reported that bowheads (presumably near Barrow) ate euphausiids, mysids, pteropods and copepods. Mitchell (1975) indicates that in the eastern Arctic, bowheads sometimes eat benthic amphipods as well as mysids and other similar zooplankters.

The results of our very limited sample of stomach contents from bowhead whales agree closely with the statements of Mitchell (1975). Euphausiids are, by far, the most important food item. Hyperiid amphipods which are apparently associated with swarms of euphausiids were much less common. The finding of a considerable number of benthic gammarid amphipods indicates that bowheads sometimes forage very near or on the bottom, at least in shallow water areas. Indications of benthic foraging have been observed and photographed during aerial surveys of bowheads close to shore immediately east of Point Barrow (J. Burns, unpublished observations).

As mentioned previously, bowhead whales migrate apparently in response to seasonal changes in ice conditions. Whales captured at Point Hope and Point Barrow during the northward spring migration in April through June have empty or near empty stomachs (Johnson et al. 1966; Durham 1972; Marquette 1977; G. Seaman, personal communication). Whether or not bowheads feed on the wintering grounds is not known. Suitable types of foods are available in portions of the Bering Sea, at least during the spring and summer (Nemoto 1957).

Biological processes in the Beaufort Sea are, to a large degree, regulated by the quantity and character of sea ice. Bowhead whales are the most ice-adapted of mysticete cetaceans and ringed seals are the most ice-adapted pinniped occurring in the northern hemisphere. In the northern portion of their range these two species show broad dietary overlap. Ringed seals are, however, highly euryphagous, and utilize many species of fishes and crustaceans. Bowhead whales are considerably more stenophagous and depend mostly on swarms of small to medium-sized zooplankton.

The Beaufort Sea experiences extreme year to year variation in the extent of summer sea ice cover. Although sea ice provides a substrate for a special group of algae (Meguro et al. 1966), the primary effect of ice cover is a lowering of overall productivity by drastically decreasing light penetration (Mohr and Tibbs 1963). A decrease in the total primary production of the area would result in lower productivity at higher trophic levels. Stirling et al. (1977) speculate that reduced production caused by the heavy ice conditions of the winter of 1973-1974 may have been responsible for an observed decrease in productivity of ringed and bearded seals. The long term ecological effect of fluctuations in annual production would be difficult to predict. However, it seems likely that short-lived, stenophagous species would be most rapidly and acutely affected. Specific data on trophic interaction of major components of the Arctic ecosystem are urgently needed as potentially drastic long-term environmental modifications such as offshore oil drilling are imminent.

Bowhead whales, which are currently reduced in numbers and "officially" considered as a rare and endangered species, were once abundant in Arctic waters. Scheffer (1976) indicates that the pre-exploitation population level comprised about 10,000 animals and estimated the present population to be about 2,000. No long-term data are available for ringed seal numbers. An estimate of the early spring population of ringed seals in the area where bowheads summer (Beaufort Sea and Amundsen Gulf) is at least 30,000 animals (Burns and Harbo 1972, Stirling et al. 1977). This number increases greatly during the summer, with the seasonal influx of seals from the south. Two interesting questions arise. As the bowhead population declined, did populations of other marine mammals or birds increase because of increased abundance of food? Will bowhead whales be able to regain their former population levels and, if so, will it be at the expense of other species? Unfortunately, no data exist to answer the first question and too little information is presently available to adequately answer the second.

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Table 1. Ringed seal and bowhead whale specimens from which stomach contents were examined.

Specimen #	Date of Capture	Sex	Weight (kg)	Standard length	Age (yrs)	Source of Specimen
BP-1-75	11-VIII-75	M	–	86.2 cm	3	ADF&G[1]
BP-2-75	IV to VI-75*	M	55.5	119.7 cm	10	NARL[2]
BP-3-75	IV to VI-75*	M	48.2	115.4 cm	11	NARL
BP-4-75	IV to VI-75*	M	50.9	121.5 cm	17	NARL
BP-5-75	IV to VI-75*	M	47.3	117.8 cm	10	NARL
BP-6-75	IV to VI-75*	F	43.2	112.5 cm	13	NARL
BP-7-75	IV to VI-75*	M	37.7	110.4 cm	4	NARL
BP-8-75	IV to VI-75*	M	35.0	113.7 cm	6	NARL
BP-9-75	IV to VI-75*	M	53.6	124.0 cm	18	NARL
BP-11-75	3-IX-75	F	11.8	–	pup	ADF&G
BP-2-76	11-V-76	M	49.8	121.5 cm	8	NMFS[3]
BP-4-76	25-V-76	M	–	106.0 cm	6	NMFS[3]
BP-5-76	25-V-76	M	–	97.0 cm	5	NMFS[3]
BP-6-76	13-VI-76	M	59.1	125.0 cm	14	ADF&G
BP-11-76	7-VIII-76	M	40.9	119.1 cm	8	ADF&G
BP-12-76	7-VIII-76	F	38.6	114.4 cm	11	ADF&G
76-B-6F	10-IX-76	F	–	16.0 m	–	NMFS[4]
76-B-7F	20-IX-76	F	–	14.3 m	–	NMFS[4]

* Exact date of capture unknown but estimated from reproductive state of specimens.

1 Provided by Alaska Department of Fish and Game personnel.
2 Provided by Naval Arctic Research Laboratory personnel.
3 Provided by Robert Everitt, National Marine Fisheries Service.
4 Provided by J. R. Patee and Robert Everitt, National Marine Fisheries Service.

ANNUAL REPORT

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

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April 1, 1978

I. Summary

The objective of this study was to determine the kinds and rates of occurrence of natural pathological conditions and their causative agents in the living populations of bearded and ringed seals of the Beaufort Sea.

Necropsies were performed on 16 ringed seals, Phoca hispida, and 5 bearded seals, Erignathus barbatus, collected during the multidisciplinary research cruise of the USCGC GLACIER in the Beaufort Sea during August and September 1977. Each of these pinnipeds was found to have several kinds of endoparasitic helminths and about half of them exhibited pathological conditions in the liver.

II. Introduction

A. General nature and scope of study

The goal of this study was to provide baseline information on the incidence and causes of pathological conditions occurring in marine mammal populations of the Beaufort Sea.

B. Specific objectives

To determine the causes and rates of occurrence of parasitological and pathological conditions in living marine mammal populations in the Beaufort Sea through necropsy of individuals collected non-selectively.

C. Relevance to problems of petroleum development

Marine mammals are the only resident top level consumers in the Beaufort Sea ecosystem. Because of this, their health and welfare, is indicative of the "health" of the marine ecosystem itself, since they are the ultimate recipients of all changes that take place within the system, from perturbation and pollution to simple physical disturbance. Because they tend to be long-lived, they can provide a cumulative historical record of past conditions, e.g., in their overall growth and the growth of certain body parts, and in their stores of certain pollutants, such as heavy metals and pesticides. They also are responsive to short-term changes, which are reflected in their migrations, nutrition, and reproduction.

III. Current state of knowledge

There is little published information on either parasitology or pathology of ringed and bearded seals from the Beaufort Sea. Cooper (1921) reported on cestodes and trematodes from these hosts collected on the Canadian Arctic expedition of 1913 to 1918 in Amundsen Gulf, eastern Beaufort Sea. Since that time, Smith and Geraci (1974) and Geraci and Smith (1976) have reported on the effects of crude oil on ringed seals of the Beaufort Sea. Their conclusions were that brief contact with crude oil in open water may cause severe, though transient eye problems, while chronic exposuer (e.g. during the period of ice cover) may cause permanent eye damage. Oiling of newborn pups is expected to lead to mortality through toxic effects of ingestion and interference with thermoregulation. They also speculated that the effects of exposure to oil may be enhanced by the additional stresses of molt, unfavorable weather, and shortage of food.

At present, the best known cause of ringed and bearded seal mortality is predation by polar bears and arctic foxes. Smith (1976) estimated that between 21 and 58 percent of newborn ringed seal pups in Amundsen Gulf and Prince Albert Sound were killed by arctic foxes in the spring of 1973 and 1974. This estimate, coupled with that of numbers utilized by polar bears (Stirling and Archibald, 1977), suggests that predation is the principal cause of mortality of these two pinnipeds in the Arctic.

Stirling et al. (1977) reported a significant unexplained decline in both ringed and bearded seals from 1972 to 1974 in the eastern Beaufort Sea. They estimated a total population decrease of 56.6% and advanced the hypotheses that this was due to either extensive mortality coupled with reduced productivity or large-scale emigration. They speculated that the ususually heavy ice cover in the winter of 1973-74 led to the seals' having difficulty in maintaining breathing holes, and perhaps, to reduced primary productivity due to the reduction of available light. The latter may have led, in turn, to scarcity of prey for the seals. The decline in seal populations was recognized also in the western Beaufort Sea by J.J. Burns (unpublished data), and with it was a corresponding rise in seal populations in the Chukchi Sea. That is, there appeared to have been a mass emigration from the Beaufort to the Chukchi, perhaps to avoid the heavier ice of the Beaufort Sea. Associated with the decline in the Beaufort was a marked reduction in reproductive effort and in physical condition of the remaining seals, which suggest a scarcity of winter food supplies (mainly polar cod). The explanation of this mystery probably is complex. Hopefully, further international multi-disciplinary research will be done, in an effort to provide the solution.

IV. Study area

The study area was from Pt. Barrow eastward to Demarcation Point, along the continental shelf and northward to the pack ice.

V. Sources, methods, and rationale of data collection

Necropsy of specimens was performed as soon as possible after they were killed and was in accordance with procedures outlined in the project manual for postmortem examination. The primary objective of this was to obtain adequate samples of each species with which to describe the normal rates of occurrence of parasites and pathogenic conditions in the living populations and to obtain materials for comparison with samples of the same species of seals from other areas of Alaska.

Histopathological and other materials collected during the necropsies were transported back to the University of Alaska-Fairbanks at the end of the field period for processing, analysis and/or distribution to various specialists for further study. These comprised mainly (1) samples for serological, heavy metals, and hydrocarbon analysis, (2) preserved tissues for histopathological examination, (3) microbiological isolates, and (4) parasites for specific identification.

VI. Results

In the course of this cruise in the Beaufort Sea (USCGC GLACIER, 1 August-5 September 1977), project personnel examined 16 ringed seals and 5 bearded seals. Each of these was taken non-selectively, as regards their health and general physical condition.

Blood samples from these were analyzed for serum antibodies to leptospirosis, a common bacterial infection of pinnipeds farther south, by the Virology-Rabies Unit, Alaska Division of Public Health, Fairbanks. Each gave negative results to challenge by *Leptospira pomona* monovalent antigen.

Blubber and other tissue samples for hydrocarbon and heavy metals analysis were collected and are being stored, pending availability of funding for that work.

Tissues for histopathological examination from selected animals were submitted to the Department of Pathology, Johns Hopkins University Medical School, Baltimore, for diagnosis, the results of which are not yet available. Our findings of gross and hostopathology included (a) focal hepatitis, probably of parasitic origin, in seven of the ringed seals, (b) hepatic abscess and biliary fibrosis due to an occluded bile duct (by the trematode, *Orthosplanchnus fraterculus*) and, probably, ancillary bacterial infection, in one bearded seal, (c) ulceration of the lower small intestine in another bearded seal, due to a heavy infection by the acanthocephalan *Corynosoma validum* and (d) superficial wounds in two ringed seals. The helminth parasites of these 21 pinnipeds were as summarized in Tables 1 and 2.

VII. Discussion

The findings thus far are extremely limited though comparable with those from ringed and bearded seals of the Bering Sea. While most of the animals examined exhibited some gross pathological condition, few of these appeared to be severe enough to cause debiliation or seemed likely to contribute to eventual mortality. The focal lesions in the liver were like those found commonly in harbor, spotted, and ribbon seals farther south, in which they appear to be caused by migration of larval helminths through the tissue. They seem to be of little importance in terms of the general health of the seal. Ulceration of the gastrointestinal tract by helminths also is relatively common in several species of seals but usually appears to be a temporary condition of little consequence, with healing taking place successfully, immediately after the helminths (whose life-span in most cases probably is no more than a few weeks or months) are passed.

The hepatic granuloma and associated fobrous thickening of the bile ducts in the one bearded seal also seems to be common in bearded seals elsewhere, but it appears to be a more long-term, chronic inflammation than the foregoing and may have a much greater effect on the seal. We have

Table 1. Helminth Parasites of ringed seals in the Beaufort Sea
USCGC GLACIER August-September 1976
(16 examined)

	Diphyllobothrium sp.	Diplogonoporus tetrapterus	Contracaecum osculatum	Phocanema decipiens	Corynosoma strumosum	Corynosoma semerme	Corynosoma hadweni	Bulbosoma sp.	Anophryocephalus ochotensis
Number infected	5	6	9	1	16	9	16	1	1
Percent infected	31	38	56	6	100	56	100	6	6

Table 2. Helminth parasites of bearded seals in the Beaufort Sea
USCGC GLACIER August-September 1976
(5 examined)

	Diphyllobothrium cordatum	Diphyllobothrium lanceolatum	Diphyllobothrium sp.	Pyramicocephalus phocarum	Orthosplanchnus fraterculum	Phocanema decipiens	Contracaecum osculatum	Corynosoma validum
Number infected	5	5	1	4	3	5	1	5
Percent infected	100	100	20	80	60	100	20	100

found no healed lesions of this type, as yet, in more than 100 bearded seals examined, which may indicate that the condition is terminal and an important cause of death in this species.

The superfical wounds in the two ringed seals presumably were made by the claws of their principal predator, the polar bear. In both cases, these appeared to be healing well, with no secondary bacterial infection. As noted earlier, predation by polar bears seems to be a major cause of ringed seal mortality, though its real rank, relative to other causes, is not presently known.

VIII. Conclusions

Our extremely small sample of seals from the Beaufort Sea does not lend itself to reaching any conclusions as to the overall health and well-being of the population at this time.

IX. Needs for further study

Our sample of ringed and bearded seals from the Alaskan continental shelf of the Beaufort Sea is extremely small and needs to be greatly augmented. The opportunity to do so exists, since the specimen collections by personnel of RU# 230, 232 are continuing, and a large backlog of parasitological material from some 50 additional ringed and bearded seals from previous collections is on hand. Only the funds for processing these materials are lacking.

Since it is conceivable that environmental pollution has played a part in the decline of seal populations in the Beaufort Sea, perhaps even as a consequence of recent oil exploration and development there, it seems essential to explore that possibility at once. The personnel and facilities for analysis of the stored backlog of tissue samples exists in projects RU# 162/275, which should be funded and encouraged to work up these materials.

X. Summary of third quarter operations

A. No activities undertaken

B. Problems encountered/ recommended changes

None

C. Estimate of funds expended

All funds allocated to this project have been expended.

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ANNUAL REPORT

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Pages: 42

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

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Introduction

This project is a detailed study of the population dynamics, life history and some aspects of the ecology of the Steller sea lion (*Eumetopias jubatus*). In addition to the sea lion investigations, the work has been expanded to include an examination of the distribution and abundance of belukha whales (*Delphinapterus leucus*) in Cook Inlet and the distribution and abundance of sea otters (*Enhydra lutris*) near the south end of the Kodiak Archipelago. As in the past, the basic objectives of the sea lion work are to provide information on population status, seasonal distribution, movement patterns, population composition and segregation, use of critical habitats, food habits, reproductive biology and productivity. Other objectives include collection of information on growth, pathology and environmental contaminant loads. The basic objectives of the belukha work are to gather information on seasonal distribution, and abundance and use of critical habitats; to test practicality of survey methods and to supply information which can be used to design a research project on this important population. Basic objectives of the sea otter work are to provide information on the distribution of sea otters in the area between Kodiak Island and Chirikof Island, to identify specific areas critical to these sea otters and to determine the extent of repopulation in this former sea otter habitat.

This study has been carefully designed to examine the potential impacts associated with exploration for, development of and transportation of crude oil and natural gas reserves in the Gulf of Alaska. All three species studied under this research project are vulnerable to Outer

Continental Shelf oil and gas development through direct contact and contamination, indirect contamination of food sources or habitat, and disturbance generated by activities associated with exploring for and recovering oil and gas.

For a detailed description of the study area, current state of knowledge and sources, methods and rationale of data collection, see Calkins and Pitcher (1977) and Schneider (1976a and 1976b).

Results and Discussion

Breeding Rookeries and Hauling Areas

One survey was made this year of part of the breeding rookeries and hauling areas of the Gulf of Alaska. The south side of the Alaska Peninsula from Cape Douglas to Unimak Pass (including the north side of Unimak Island and Ugamak Island) was surveyed on March 16 through 18, 1977. All known winter hauling areas were visited and all sea lions were photographed and counted from these photos (Table 1).

Comparison of these figures with those from March 1976 shows only one substantial difference. The sea lion count at Puale Bay totaled 14,234 with one roll of photos lost, and we estimated over 20,000 sea lions were present in Puale Bay at the time of the survey. The normal count of sea lions in this area is 1000 to 3000 animals. Most of the 20,000 animals sighted on this survey were in large rafts in the water near the normal haulout. All of the available surface for hauling-out which has traditionally been used was in use by sea lions. There was much area nearby which has not been used by sea lions in the past and which was not being used at the time of the survey; the bulk of the animals present rested in large rafts in the water.

There is no known explanation why such large numbers of sea lions were present at Puale Bay. It is possible that this is the normal total number of animals which uses Puale Bay haulout, but all are seldom present at one particular time. It may also be possible that this represents a movement of animals into or through the area. If this represents movement of animals into the area, it could have been a normal, annual occurrence or it could have been an aberrant movement of sea lions into Shelikof Strait.

One hundred and six sea lions were sighted at Acheridin Point on Unga Island. This is the first time sea lions have been reported here. This location is probably used as a "stopover area" as defined by Calkins and Pitcher (1977).

Two hauling areas were visited in the March Survey which have not been visited in the past by this research unit. These haulouts were Ugamak Island, nearby Round Island and Oksenof Point on the north side of Unimak Island. In March 1960, Kenyon and Rice (1961) surveyed the Eastern Aleutians and reported 19,400 sea lions at Ugamak and Round Island, and 4,000 at Oksenof Point. We photosurveyed the same areas in March 1977 and counted 509 sea lions at Ugamak and Round Islands and 102 at Oksenof Point. This substantial difference in numbers of sea lions supports the conclusion reached by Braham et. al. (1977) that a significant reduction has occurred in the sea lion population in the eastern Aleutians, either by emigration, mortality, or substantially reduced natality.

Total counts of the hauling area were made at Cape St. Elias as often as practical between March 9, 1977 and June 14, 1977. Sea lions use two locations for hauling out at Cape St. Elias. During the winter they haul out on the west and southwest side of the Pinnacle, where large boulders have fallen from the sides of the Pinnacle and form a relatively stable platform for hauling. Approximately 450 m to the south, an uplifted marine sediment peninsula forms the summer hauling area where some breeding and pupping takes place. For the purpose of this report, the winter area will be referred to as "the Pinnacle" and the summer area will be referred to as "the Peninsula".

Figure 1 shows the population counts made at Cape St. Elias from 9 March to 14 June. Use of the Peninsula hauling area commenced on 1 April and use of the Pinnacle was last noted on 15 May. The maximum count of 1,400 animals occurred on 24 May on the Peninsula. As could be expected, counts were minimal during periods of inclement weather. Low counts on April 9, April 19, April 29-30 and May 17-18 coincided with major storms from the east and southeast. Replacement to pre-storm population levels generally took less than 24 hours.

Distribution and Movements

Distribution and movements studies of sea lions were concentrated at Cape St. Elias. A total of 7,048 pups were branded at seven locations in 1975 and 1976 (Table 2). At least one branded animal from each location was seen at Cape St. Elias in Spring 1977. One hundred and twenty-two animals were catalogued and sketches of the brands were made (Table 3). Daily observations were recorded on these animals as shown in Figure 2.

Table 1. Steller seal lion haulouts surveyed on the south side of the Alaska Peninsula March 1977.

Name	Lat.	Long.	Photo Count
Island SW Takli I.	58° 03' 40"	154° 27' 35"	413
Puale Bay	57° 40' 55"	155° 24' 05"	*14234+
Chowiet Island	56° 00' 40"	156° 41' 00"	1147
Sutwik Island	56° 32' 10"	157° 20' 05"	22
Kak Island	56° 17' 15"	157° 50' 00"	15
Castle Rock	55° 16' 45"	159° 29' 45"	613
Atkins Island	55° 03' 05"	159° 29' 45"	931
Churnabura Island	54° 45' 15"	159° 33' 00"	1216
Nagai Island	54° 56' 00"	160° 15' 10"	416
Sea Lion Rocks	55° 04' 50"	160° 30' 45"	300
Acheredin Point	55° 07' 40"	160° 48' 12"	106
Pinnacle Rock	54° 46' 15"	161° 45' 45"	152
Clubbing Rocks	54° 42' 50"	162° 26' 45"	29
Sanak Reef	54° 17' 45"	162° 42' 30"	610
Bird Island	54° 40' 15"	163° 17' 30"	62
Ugamak Island	54° 12' 30"	164° 46' 20"	509
Oksenof Point (Unimak Island)	54° 06' 30"	164° 33' 17"	102

* One roll of film was under exposed and uncountable. There were probably greater than 20,000 sea lions.

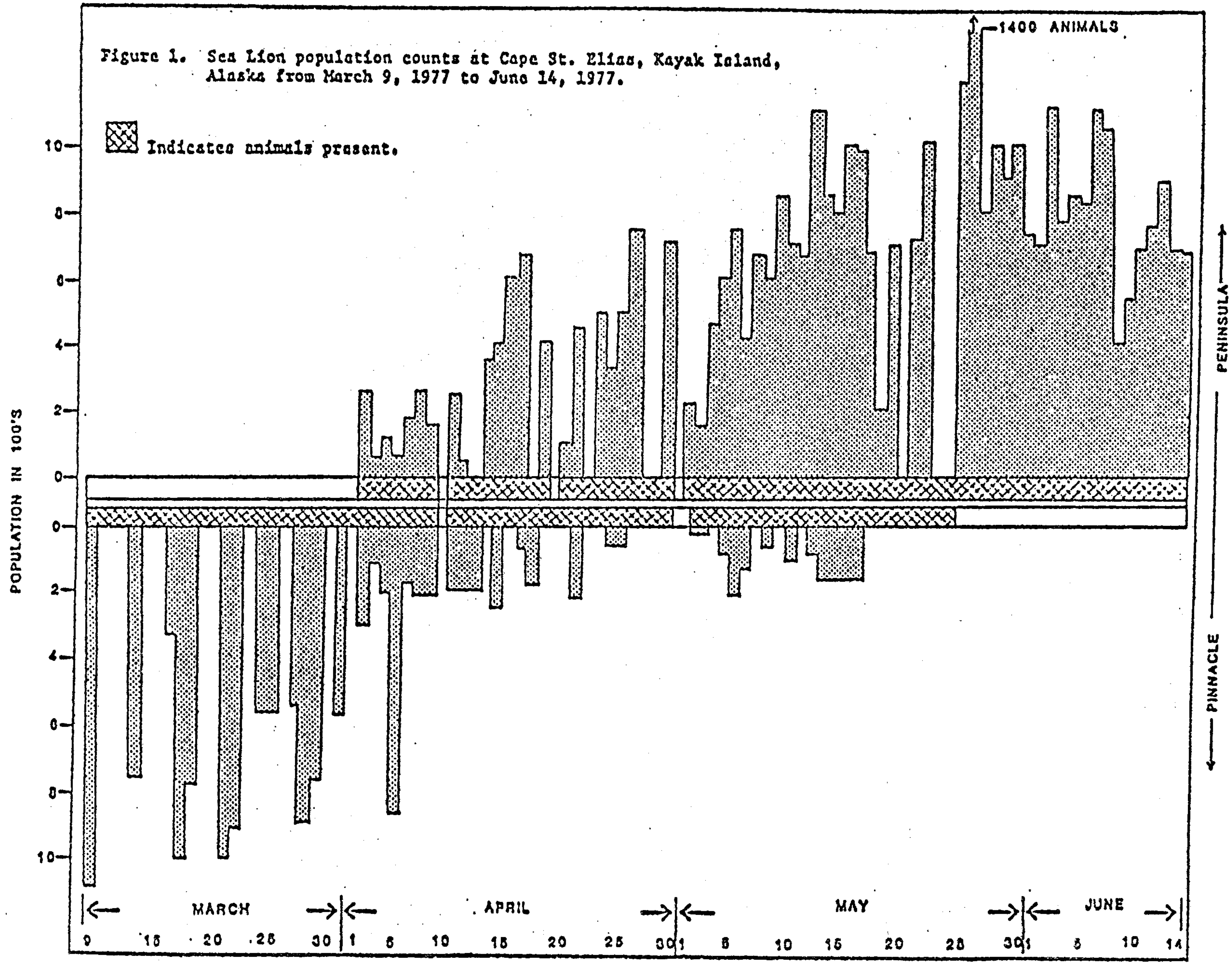

Figure 1. Sea Lion population counts at Cape St. Elias, Kayak Island, Alaska from March 9, 1977 to June 14, 1977.

Table 2. Sea Lion Branding Data.

Year	Location	Brand symbol	Shoulder	# branded	% of total branded animals that year
1975	Sugarloaf, Barren Islands	X	Left	719	55
1975	Marmot Island, north of Kodiak	O	Left	600	45
1976	Sugarloaf, Barren Islands	X	Right	1,443	25
1976	Marmot Island, north of Kodiak	T	Right	3,669	64
1976	Outer Island, Kenai Peninsula	V	Right	249	4
1976	Fish Island, Wooded Island Group P.W.S.	E	Right	29	0.5
1976	Pinnacle, Cape St. Elias, Kayak Is.	L	Right	23	0.4
1976	Seal Rock, Hinchinbrook Entrance, P.W.S.	J	Right	316	6

Figure 2. Resight pattern of individually recognized sea lions at Cape St. Elias, Kayak Island, Alaska, March 8, 1977 to June 14, 1977. Includes October 28-31, 1977.

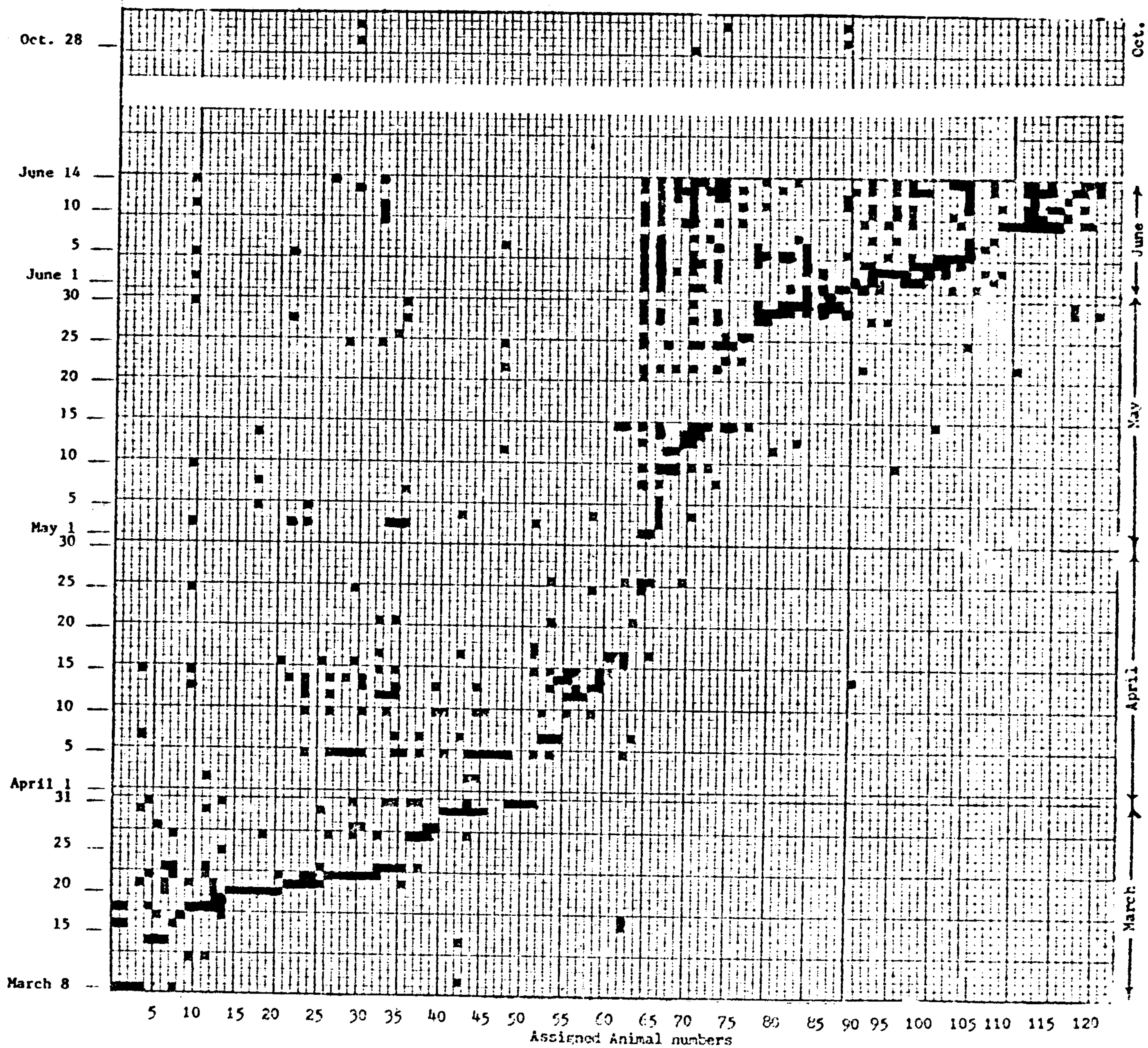

Table 3. Sea lions catalogued at Cape St. Elias March 9 through June 1977. Brands have been graded - good, ok, poor.

Number	Name	Sex	Brand	Notes (n) = nursing
1		F		Pink scar on left rib w/(n) 1976 pup
2				Pup belonging to #1
3			J	Right shoulder, Brand ok
4			X	Left shoulder, Brand poor, (n)
5			J	Right shoulder, Brand ok
6		F		Large female, 6 pointed scar on left flank (n)
7			?	Left shoulder brand - unknown
8			?	Right shoulder brand - unknown
9			J	Right shoulder, Brand ok
10		M	?	Left shoulder brand - unknown
11		F		Huge scars across spine
12		F		Net neck
13			O	Left shoulder, Brand ok
14			J	Right shoulder, Brand poor
15			X	Right shoulder, Brand ok
16		F		
17				1976 pup with injured left fore flipper
18		M		Huge scar on left shoulder and throat
19				Right shoulder brand - unknown
20		F		Scar on chest and left side of throat (n)
21			E	Right shoulder, Brand good
22			X	Right shoulder, Brand ok
23			L	Right shoulder, Brand ok
24	Check J		J	Right shoulder, Brand good
25	Wire neck			

continued

Table 3 continued.

Number	Name	Sex	Brand	Notes (n) = nursing
26			J	J Right shoulder good
27			X	X
28				Left shoulder scar - not a brand
29		M	X	X
30			J	J (n)
31			J	J (n)
32	Nevada		?	Right shoulder brand - unknown
33	Toot		?	Probable R (n) right shoulder brand unknown
34	Crab		X	X
35	Tooth		X	X (n) left shoulder bad
36				Scar on scalp of 2-3 year old
37			J	J right shoulder good
38	Ulu		?	Right shoulder brand - unknown
39	Pipe		?	Probable L Right shoulder, bad
40			J	J right shoulder good
41			0	0 (n) left shoulder bad
42		M		6" healed dark scar left rib
43		M		12" pink draining scar - wound
44			?	left shoulder brand - unknown (n)
45		F		Scar between shoulder blades
46			L	L Right shoulder, good
47			?	Right shoulder brand - unknown (n)
48	Arrowhead		?	Right shoulder brand - unknown
49	String bull	M		Medium size bull with parts of line and halibut hooks in mouth
50	String bull	M		Medium size bull with parts of line and halibut hooks in mouth

continued

Table 3 continued.

Number	Name	Sex	Brand	Notes (n) = nursing
51	String bull	M		Medium size bull with parts of line and halibut hooks in mouth
52	Healed Net Neck	F		A female with a brown line low on neck that was a healed net neck mark
53			J	J (n) right shoulder good
54	P.P. #1			Very small pup with chin sore
55	P.P. #2			Very small pup (n) - lighter pelage
56			?	Right shoulder brand - unknown
57	Topknot	M		Very large lump under skin over right eye
58		F		Scar on right side mid rib - healed
59		F		Scar on left side aft of shoulder off spine
60	Square J		J	J right shoulder brand poor
61		F		Female with scar (n)
62	Blue Net Neck	F		Pale pelage
63		F		Female with slash on right shoulder (n)
64				Scar on right hip
65	Cleaver	M		Wound on left rib
66		F		Left shoulder wound
67	Chevron	M		Wound on hip astraddle the spine
68	Healed Net Neck	M		Similar to #52 except sex
69			J	J right shoulder brand poor
70	Alaska	F	?	Left shoulder brand - unknown
71	Bulged Net Neck	F		Net neck with distinctive virus scars on hip
72	Mouse		X	X right shoulder brand poor
73		F	X	Distinctive triangle scar (n) right shoulder
74	M		T	T - very poor, looked like letter M right shoulder

continued

Table 3 continued.

Number	Name	Sex	Brand	Notes (n) = nursing
75	Killer bull	M		Missing left fore flipper and huge hip scar
76	Cat		X	X right shoulder - poor
77			J	J right shoulder - good
78			X	X right shoulder - good
79		F		Wounded 1976 pup
80			E	E right shoulder - poor
81			J	J right shoulder - poor
82	Bell		X	X left shoulder - poor
83			V	V right shoulder - good
84	Pink Pistol		L	L Right shoulder - ok
85	Green Rope Neck	F		1/4" green rope - loose - (n)
86			X	X left shoulder - good
87		M		
88	C.S.P. #4	M	?	Left shoulder brand - unknown - collected
89			O	O left shoulder - good
90		M	?	Left shoulder brand - unknown
91		F		Female that #55 belonged to - scar on left hip similar to #75
92				Left shouler scar - not a brand
93			O	O left shoulder - good
94		M		Bull with net wound 3/4 of the way around his shoulder from 40# monofiliment
95	Leaf			Right shoulder scar - not a brand
96			?	Right shoulder brand - unknown (n)
97			L	L right shoulder, ok

continued

Table 3 continued.

Number	Name	Sex	Brand	Notes (n) = nursing
98	F		T	T right shoulder bad
99			?	Right shoulder brand - unknown
100		F	X	X left shoulder bad
101			J	J right shoulder good
102			0	0 left shoulder bad
103			J	J right shoulder good
104			X	X left shoulder bad
105	Hairy 0	M	0	0 left shoulder good
106		M	E	E (n) right shoulder good
107				Right shoulder wound
108		F	X	X left shoulder bad
109	Gull	F		Left shoulder wound
110	Canada #2	M		
111			?	Left shoulder brand - unknown
112		M		Rectangle across top of shoulder
113	Fox Face	M		Pink virus spot of top of hip with 2 black spots in it
114	Swallow			
115			0	0 left shoulder ok
116			?	Right shoulder brand - unknown (n)
117	Bird		X	X left shoulder bad
118			X	X left shoulder good
119	Man		?	Left shoulder brand - unknown
120		M	?	Left shoulder brand - unknown
121				Right shoulder wound, blind in left eye
122			?	Left shoulder brand - unknown

On 16 days between March 9, 1977 and April 15, 1977 brand counts were made on the Pinnacle. The percentage each rookery represents of the total recognized brands is given in Table 4. Forty-two percent of the recognized brands were 1976 Sugarloaf pups which represented 25 percent of the total branded animals in 1976. Twenty-seven percent of the recognized brands were 1976 Marmot Island brands which represented 64 percent of the total branded animals in 1976. Seventeen percent of the recognized brands were 1976 Seal Rocks brands which represented 6 percent of the total branded animals in 1976 (Tables 2 and 4).

The average percent of recognizable branded animals relative to total animals on the Pinnacle was 10 percent. On April 10, 1977 it was unusually high at 28 percent. This was one of the first days that large numbers of animals had hauled and remained on the Peninsula (Figure 1). Of the 181 animals on the Pinnacle on April 10, 122 (67%) were 1976 pups, of these 50 (41%) had recognizable brands.

As the animals began hauling on the Peninsula, rather than the Pinnacle, we stopped attempting to get brand totals. The visual distance to the Peninsula was too great and the view angle was so low that totals would not have been comparable day by day, nor comparable to counts made on the Pinnacle.

During the first two weeks of April the animals began hauling out in large numbers on the Peninsula. Concurrent with this new pattern was the decrease of familiar distinctive brands from the Pinnacle hauling area. By April 15, 1977, over 75 percent of all animals catalogued

Table 4. Complete counts of branded animals at Cape St. Elias March 9 through April 15.

Date	X left shoulder	O left shoulder	X right shoulder	T right shoulder	J right shoulder	V right shoulder	E right shoulder	L right shoulder	Total per day	Percent Observed Nursing
March 9			5	3	2				10	-
March 13			4	3					7	-
March 14	1		17	10	8				36	-
March 17		1	12	5	7	2		1	28	-
March 18	1	1	15	6	7	1		1	32	-
March 19	4		24	11	9	1			49	20
March 20	1		17	15	4	2	1		40	8
March 21	5		24	13	4	2	1	1	50	14
March 22	2		16	9	9	3	1	2	42	7
March 23	2		17	11	5	5	2		42	12
March 27	3		11	14	9	3	1	4	45	22
March 28	3		12	9	8			1	33	21
April 5	2	1	18	10	7	1	1	3	43	14
April 10	4	1	19	14	9		1	2	50	1
April 14			14	9	3	1	2	1	30	13
April 15	1		10	10	6	1			28	0
Total	29	4	235	152	97	22	10	16	565	
% each rookery represents of total recognizable brands	5%	0.7%	42%	27%	17%	4%	2%	3%		

prior to that date were gone from the Cape area (Figures 1 and 2). Frequently young animals were seen offshore west of the Cape. Often these animals were subsequently observed to haul-out at Cape St. Elias. No other animals were observed which displayed generalized movements.

Late in April it became apparent that a new group of animals was arriving to occupy the Peninsula unlike the former population shift from the Pinnacle hauling area. Comparing the recognizable individuals in Figure 1 to Figure 2 it is apparent that, even early in April when the animals began hauling on the Peninsula, many of them were new animals to the Cape area. This indicates that the winter population of the Cape is oriented toward the Pinnacle hauling area and the summer residents are oriented toward the Peninsula. The apparent shift from the Pinnacle to the Peninsula may represent movement of winter animals away from the Cape area, with replacement on the Peninsula rookery by different animals.

Among the observed branded animals, the low percentage of branded animals from Marmot Island and the high percentage of Sugarloaf animals could indicate that the area between these two major rookeries is, to some degree, a range distribution boundary; it is important to remember, however, that all of the pups leave Sugarloaf with the cows in the late fall while many pups remain through the winter at Marmot. The high percentage of animals from Seal Rocks relative to the low number branded could indicate a close association between Seal Rocks and Cape St. Elias.

Sex and age composition counts are presented in Table 5. The only

Table 5. Sex and Age Composition counts of sea lions on Cape St. Elias, March 16 through May 13, 1977.

Date	Large Adult Male	Adult Male	Subadult Male	Female	1976 Pup	Unid.	Total	Notes
3-16-77		24			10		327	
3-22-77		22			est.400		800-900	This includes 2yr.old in the 400.
3-25-77		3		11	13	1	28	Early animals on Peninsula
4-4-77	3			4	4		12	Total on Pinnacle
4-7-77		2	6		34		128	Peninsula animals
4-16-77		4	11	15	-----5-----		51	Pinnacle animals
4-17-77	6	12	6	very few	77		164	Pinnacle animals
4-21-77		12		5	22		90	Pinnacle animals
4-21-77	25	5	6		49		121	Peninsula animals(PM)
4-21-77	40	32					205	Peninsula animals(AM)
4-24-77	12			5	4		52	Pinnacle animals
4-25-77	11	14		7	21		56	Pinnacle animals
5-4-77		45	7	6	5		70	Pinnacle animals
5-5-77	----87-----				16		191	Pinnacle animals
5-6-77	----57-----		12	3	1	-0-	73	Pinnacle animals
5-8-77	----45-----		13	-0-	1	-0-	59	Pinnacle animals
5-13-77	---114-----		6	15	11	2	148	Pinnacle animals

sexual segregation on the Pinnacle was a male area at the south end of the haulout. Animals on the Peninsula segregated into groups of large territorial males, smaller territorial males, two-year-olds, subadult males, males of all ages and one area that appeared to be occupied by animals of all ages and both sexes.

Pupping

Pupping at Cape St. Elias appeared to occur approximately within the same time frame as noted by Calkins and Pitcher (1977). The first live birth occurred on May 29, 1977 and the first observed copulation was on June 1, 1977. Nine of 16 known live births occurred before June 14, 1977. Major causes of mortality were drowning and trampling as the tide concentrated the adults into confined areas.

On March 16, 1977 a premature pup was observed on the Pinnacle. Between March 16 and May 7, a total of 20 premature births were recorded at Cape St. Elias. One premature pup was noted at the Wooded Islands on April 7, 1977 on a brief visit there. None of these premature pups survived.

The reasons for premature pupping in Stellar sea lions is not known at present. Further investigation is necessary to determine its cause and extent in the Gulf of Alaska.

Female Age of Productive Maturity

Productive maturity, the age at which a female first produces offspring, appears to be attained by female sea lions in the Gulf of Alaska between the ages of 3 and 6 years (Table 6). About 70 percent of our sample became mature at 5 and 6 years of age.

Pregnancy Rates

Age specific pregnancy rates are presented in Table 7. No animals 2 years old or younger were pregnant. The combined pregnancy rate for maturing age classes (3-6 years) was 45 percent. The pregnancy rate for mature age classes (7-30 years) was 81 percent.

Reproductive Failures

Reproductive failures may be classified into three categories: (1) a missed pregnancy where either fertilization did not occur or the blastocyst failed to implant, (2) resorption of an embryo and (3) abortion in which the fetus was expelled from the uterus (Craig 1964; Bigg 1969).

A total of 13 reproductive failures were noted. Five of these involved initial pregnancies while the other eight occurred in multiparous females. Of the initial pregnancies which failed, two ovulated and did not breed or there was mortality of the blastocyst. One female had resorbed a fetus and another was observed aborting about 2.5 months before the normal pupping date. Of the failures occurring in multiparous females, five appeared to be abortions, two were resorptions and one was of undetermined origin.

Table 6. Proportion of female Steller sea lions attaining productive maturity by age class.

Age (years)	Number of Females	Number of Primiparous Females	Percentage of Primiparous Females
0-2	22	0	0
3	15	3	20
4	15	2	13
5	7	2	29
6	5	2	40
7	7	0	0
8	5	0	0
9-30	39	0	0

Table 7. Age specific pregnancy rates of 117 female Steller sea lions collected in the Gulf of Alaska.

Age (Years)	Total Females	Pregnant Females	Pregnancy Rate (%)
0-2	22	0	0
3	15	3	20
4	15	8	53
5	7	4	57
6	5	4	80
7	8	5	63
8	6	6	100
9	6	5	83
10	6	5	83
11	3	3	100
12	5	5	100
13	4	3	75
14	6	6	100
15-19	5	4	80
20-30	4	1	25

A 4-year-old, multiparous female collected on February 11, 1977 had a newly implanted fetus weighing 0.4 g. The fetus was comparable in size to those normally found in early to mid-October. Timing of the reproductive cycle was about 4 months late.

Male Sexual Maturity and Seasonal Spermatogenetic Activity

Because of the seasonal nature of our collecting effort (all collections have taken place between October 1 and June 30) and because our sample was heavily biased towards females, only limited data are available on male reproduction. One of four 3-year-old males was mature (Table 8). All males 4 years old and older in our sample were mature. The data on seasonal spermatogenetic activity are presented in Table 9. These limited data indicate spermatogenetic inactivity between October and February, transition in March and April and spermatogenetic activity from April through May. We know that breeding takes place into July (Calkins and Pitcher 1977) but do not know when the cessation of sperm production occurs.

Food Habits

Biomass measurements such as volume are generally considered the best indicator of prey utilization (Fiscus and Baines 1966). Volumetric measurements may give a distorted view in cases where different prey species are digested at different rates or when meals are at different stages of digestion when the animals were collected. Frequency of occurrence analysis may suggest greater than actual importance of small

Table 8. Age of sexual maturity in 23 male Steller sea lions collected in the Gulf of Alaska based on the presence of abundant epididymal sperm during the period 13 April - 27 May.

Age (Years)	No. of Males	Epididymal Sperm Absent	Epididymal Sperm Trace	Epididymal Sperm Abundant	% Mature
0-2	12	12		0	0
3	5	4		1	20
4	1			1	100
5	1			1	100
7	1			1	100
11	2			2	100
12	1			1	100

Table 9. Seasonal spermatogenetic activity in 22 male Steller sea lions, 5 years and older, collected in the Gulf of Alaska.

Time Period	Epididymal Sperm None	Epididymal Sperm Trace	Epididymal Sperm Abundant
12-27 Oct.	3		
5-19 Nov.	9		
10-17 Feb.	2		
22 March	2	1	
20-28 April			3
21-23 May			2

prey that are frequently encountered in low numbers. Frequency of occurrence also may exaggerate the importance of items which have persistent skeletal components that remain in the stomach for extended periods. Direct numerical comparisons of prey species are misleading unless all items are of similar size.

Data were compiled by geographic location for the Gulf of Alaska. The subdivisions included the Kodiak Island area, the outer Kenai coast and Prince William Sound. We do not have complete seasonal coverage as no sea lions have been collected between 1 June and 1 October.

The major prey eaten by sea lions in the Kodiak area were capelin (*Mallotus villosus*), pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus macrocephalus*) (Table 10). Octopus (*Octopus* sp.) was a major item by frequency of occurrence analysis, but was relatively unimportant by volume. The remains of a harbor seal (*Phoca vitulina*) were found in the stomach of an adult male sea lion. Along the outer Kenai coast, pollock was the dominant prey, accounting for over 90 percent of the volume of stomach contents (Table 11). In Prince William Sound, pollock was again dominant, followed by herring (*Clupea harengus*) and squids (Table 12).

Mean volume of stomach contents per animal collected in Prince William Sound was 2,423 cc compared to 473 cc along the Kenai coast and 206 cc in the Kodiak area. This suggests that Prince William Sound may be an important feeding area. The large difference may also have resulted from animals feeding nearshore where collecting took place. If sea

Table 10. Summary of composition of stomach contents from 71 Steller sea lions collected in the Kodiak Island area, Alaska.

Prey Item	Occurrences Number	Occurrences %	Volume cc	Volume %
Cephalopoda (Total)	13	20.0	205	1.4
Decapoda (squids)	2	3.0	75	0.5
Octopoda (*Octopus* sp.)	10	15.4	110	0.8
Unid. cephalopod remains	1	1.5	20	0.1
Decapoda (Crustacea) (Total)	6	9.2	60	0.4
Crangon sp. (shrimps)	2	3.0	20	0.1
Pandalus sp. (shrimps)	1	1.5	10	0.1
Hyas lyratus (spider crab)	1	1.5	10	0.1
Chionoectes sp. (tanner crab)	2	3.0	20	0.1
Unid. Invertebrate remains	1	1.5	10	0.1
Rajidae				
Raja sp. (skate)	1	1.5	960	6.6
Salmonidae				
Oncorhynchus sp. (salmon)	1	1.5	250	1.7
Osmeridae				
Mallotus villosus (capelin)	8	12.3	7,895	54.0
Gadidae	22	33.8	4,820	33.0
Gadus macrocephalus (Pacific cod)	6	9.2	1,190	8.1
Theragra chalcogramma (pollock)	16	24.6	3,630	24.8
Zoarcidae				
Lycodes sp. (eelpouts)	1	1.5	10	0.1
Cottidae				
Dasycottus setiger (sculpin)	1	1.5	10	0.1
Pleuronectidae (Total)	5	7.7	100	0.7
Eopsetta jordani (petrale sole)	2	3.0	70	0.5
Hippoglossoides elassodon (flathead sole)	2	3.0	20	0.1
Limanda aspera (yellowfin sole)	1	1.5	10	0.1
Unid. fish remains	5	7.7	50	0.3
Phoca vitulina (harbor seal)	1	1.5	250	1.7
TOTALS	65	99.2	14,620	100.0

Table 11. Summary of composition of stomach contents from 34 Steller sea lions collected along the outer Kenai coast, Alaska.

Prey Item	Occurrences Number	%	Volume cc	%
Gastropoda	1	2.6	10	0.1
Cephalopoda (Total)	5	13.2	50	0.3
Decapoda (squids)	2	5.3	20	0.1
Octopoda (*Octopus* sp.)	3	7.9	30	0.2
Decapoda (Crustacea) (Total)	3	7.9	30	0.2
Crangon sp. (shrimps)	1	2.6	10	0.1
Pandalus sp. (shrimps)	2	5.3	20	0.1
Clupeidae				
Clupea harengus (herring)	1	2.6	20	0.1
Gadidae (Total)	24	63.2	15,725	97.8
Eleginus gracilis (saffron cod)	1	2.6	190	1.1
Gadus macrocephalus (Pacific cod)	4	10.5	630	3.9
Theragra chalcogramma (pollock)	19	50.0	14,905	92.7
Scorpanenidae				
Sebastes sp. (rockfish)	1	2.6	10	0.1
Cottidae				
Hemilepidotus sp. (sculpin)	1	2.6	10	0.1
Trichodontidae				
Trichodon trichodon (Pacific sandfish)	1	2.6	220	1.4
Pleuronectidae				
Lepidopsetta bilineata (rock sole)	1	2.6	10	0.1
TOTALS	38	99.8	16,085	99.9

Table 12. Summary of composition of stomach contents from 88 Steller sea lions collected in Prince William Sound, Alaska.

Prey Item	Occurrences Number	%	Volume cc	%
Cephalopoda (Total)	32	24.4	14,992	7.0
Decapoda (squids)	29	22.1	14,972	7.0
Octopoda (*Octopus* sp.)	3	2.3	20	tr*
Decapoda (Crustacea)				
Unid. shrimps	3	2.3	30	tr
Clupeidae				
Clupea harengus (herring)	15	11.5	54,060	25.4
Osmeridae				
Mallotus villosus (capelin)	1	0.8	10	tr
Gadidae (Total)	67	51.1	135,222	64.4
Eleginus gracilis (saffron cod)	1	0.8	625	0.3
Gadus macrocephalus (Pacific cod)	8	6.1	1,195	0.6
Theragra chalcogramma (pollock)	58	44.3	133,402	62.6
Scorpaenidae				
Sebastes spp. (rockfishes)	3	2.3	3,020	1.4
Cottidae (Total)	4	3.1	4,920	2.3
Enophrys sp. (sculpin)	1	0.8	400	0.2
Hemilepidotus sp. (sculpin)	2	1.5	4,510	2.1
Hemitripterus sp. (sculpin)	1	0.8	10	tr
Agonidae				
Agonus acipenserinus (sturgeon poacher)	1	0.8	60	tr
Trichodontidae				
Trichodon trichodon (Pacific sandfish)	1	0.8	80	tr
Pleuronectidae				
Platichthys stellatus (starry flounder)	1	0.8	800	0.4
Miscellaneous stomach contents				
Fucus sp. (algae)	1	0.8	10	tr
Green algae	1	0.8	10	tr
Plastic	1	0.8	10	tr
TOTALS	131	100.4	213,224	100.0

*tr = less than 0.1%.

lions in the Kodiak and Kenai areas were feeding offshore and collections took place inshore the stomach contents would consist of digested remains.

Elemental Analysis of Tissues

Elemental analyses of liver samples have been completed on 16 sea lions. The sample was biased toward adult females (14 of 16). Table 13 shows the results of these analyses. Little interpretation can be made at this time.

Belukha Surveys

Belukha surveys have been conducted in Cook Inlet twice to date. The first survey was flown on January 11, 1978. A total of 92 belukhas were sighted approximately midway between Cape Ninilchik and Kalgin Island. They were probably all within one large pod although they were in three somewhat separate groups; all within 1 to 2 km from each other. Coverage of the Inlet was incomplete. Inclement weather in the study area delayed and hampered the survey. No belukhas were sighted in other locations.

The second survey was conducted on March 1 and 2. Again poor weather delayed the survey, but when conditions improved they became excellent for the two days of this survey. The entire inlet was well covered and a total of 182 belukhas were sighted in the two days. Most of the belukhas observed in March were strongly associated with shallow bays or

Table 13. Elemental analysis of sea lion liver samples, in parts per million.

	Age Class							
Element	5	7	8	9	12	12	12	13
Ag	0.25	0.18	0.30	0.08	0.17	0.16	0.20	0.23
Al	1.18	1.93	1.91	2.25	9.41	0.66	7.50	5.06
As	3.8	4.67	1.51	2.20	4.44	5.01	3.09	0.19
B	1.24	0.81	0.06	0.08	1.14	1.32	0.60	6.53
Ba	0.01	0.02	0.01	0.02	0.04	0.01	0.02	0.10
Be	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.01
Bi	16.04	19.92	13.22	10.28	36.73	16.00	10.30	56.36
Ca	43.67	59.27	55.84	34.52	39.12	27.59	40.88	99.36
Cd	0.57	0.28	0.72	0.67	2.56	2.17	1.10	0.48
Co	0.32	0.51	0.02	0.22	<0.10	0.16	0.02	<0.01
Cr	<0.01	0.20	<0.01	<0.01	0.08	<0.01	<0.01	0.12
Cu	35.06	18.78	10.81	3.91	56.06	37.62	75.34	60.26
Fe	211.10	92.35	74.83	76.51	58.18	128.26	145.07	108.34
Hg	44.21	35.42	30.91	38.37	55.30	40.13	22.42	52.62
Org Hg	11.49	11.69	7.11	15.35	12.17	18.06	6.95	20.00
Mg	132.43	125.95	170.98	137.81	150.84	138.55	183.86	157.24
Mn	3.15	3.06	3.02	2.84	4.27	3.75	3.44	3.25
Mo	2.25	2.52	1.44	1.08	1.35	0.86	2.52	1.41
Na	1308.2	1273.8	1180.2	790.8	998.2	783.0	695.8	1345.80
Ni	<0.01	1.07	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
P	2085.3	1848.9	2130.9	2002.2	2382.3	2098.8	2781.7	2083.1
Pb	0.31	1.69	2.06	2.74	1.62	<0.01	0.84	1.06
Se	13.12	10.18	8.63	10.16	17.01	8.36	5.71	16.09
Si	160.68	129.08	169.74	264.66	150.89	173.60	188.34	210.85
Sn	32.38	42.90	33.89	28.97	46.75	28.82	46.76	32.39
Ti	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
V	1.34	1.16	1.51	1.72	3.59	1.30	2.35	2.73
W	0.10	3.90	2.42	6.46	9.79	7.80	1.10	15.04
Zn	28.29	27.57	28.76	52.09	230.00	40.00	45.53	78.36

Continued

Table 13. Continued.

	Age Class							
Element	13	14	15	15	15	16	20	30
Ag	0.07	0.12	0.10	0.09	0.09	0.18	0.20	0.18
Al	3.43	3.29	15.76	0.50	14.09	4.80	1.28	5.26
As	3.38	6.23	3.20	2.43	6.82	6.20	0.22	3.47
B	0.32	2.03	1.64	0.03	1.58	11.47	0.04	2.52
Ba	0.82	0.02	0.06	0.01	0.02	0.06	0.02	0.08
Be	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Bi	29.81	10.20	30.02	27.02	6.70	19.92	33.42	26.52
Ca	19.26	25.27	27.60	27.61	40.71	44.80	30.60	33.98
Cd	8.36	2.36	12.37	4.34	4.11	2.03	1.56	2.08
Co	0.02	0.08	0.02	0.02	0.84	0.77	0.03	0.02
Cr	0.12	<0.01	<0.01	0.44	<0.01	<0.01	0.13	<0.01
Cu	17.28	32.94	44.86	15.10	34.54	67.50	29.14	51.66
Fe	73.27	45.42	47.02	54.91	140.22	54.94	35.88	142.54
Hg	57.93	53.84	56.67	48.55	75.23	47.41	83.56	94.74
Org Hg	20.85	21.00	25.51	18.93	15.06	15.17	28.41	38.84
Mg	150.21	154.87	162.83	137.57	160.47	138.32	135.04	145.92
Mn	2.36	3.58	4.46	2.15	4.18	5.66	2.86	2.76
Mo	1.31	1.76	2.53	1.01	1.56	1.75	1.07	2.44
Na	533.2	552.2	625.8	779.2	698.2	890.2	715.4	1196.20
Ni	<0.01	<0.01	<0.01	<0.01	<0.01	5.25	<0.01	<0.01
P	2504.5	2392.7	2580.9	2097.7	2448.9	2060.3	2177.1	2265.1
Pb	2.34	1.34	<0.01	2.02	<0.01	0.37	1.10	<0.01
Se	28.22	16.51	17.48	14.69	23.86	14.30	26.70	71.80
Si	208.08	191.20	240.64	154.42	161.04	270.57	164.17	194.65
Sn	41.36	43.10	50.22	48.24	46.66	44.67	36.03	37.47
Ti	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01
V	1.92	1.25	4.04	1.57	3.22	2.29	1.98	2.48
W	5.94	7.83	0.59	1.89	1.55	16.94	16.56	13.52
Zn	38.26	34.14	59.40	74.97	41.12	39.34	39.60	41.76

shoals. No belukhas were sighted north of east and west foreland, although ice conditions would have permitted their passage.

Growth

A total of 190 sea lions have been taken in this study. Figures 3 through 6 present growth curves for the standard length measurements, girth measurements, weight measurements and neck measurements by sex and age class of all sea lions taken to date.

It is apparent from Figure 3 that female sea lions reach an approximate maximum length in their fifth to sixth year, and although somewhat variable, level out after that. Males continue to grow at least through their 13th year. Even in the first year, males average slightly longer than females and they appear to grow at a faster rate than females. Females appear to attain their maximum girth in the sixth to eighth year (Figure 4). Males continue to grow in girth at least through their 13th year. Males and females grow in girth at approximately the same rate through the first year, but then males grow at a faster rate than females. Females attain their maximum weight in their sixth to seventh year (Figure 5). Males appear to attain their maximum weights in their 10th to 13th year, although the sample size for males older than 10 years is insufficient to show a "leveling off". In Figure 6 the mean neck circumference of sea lion's is shown. It is apparent that males have a larger mean neck circumference by the end of the first year and continue to grow throught their 13th year while females attain their maximum neck circumference in the sixth to seventh year.

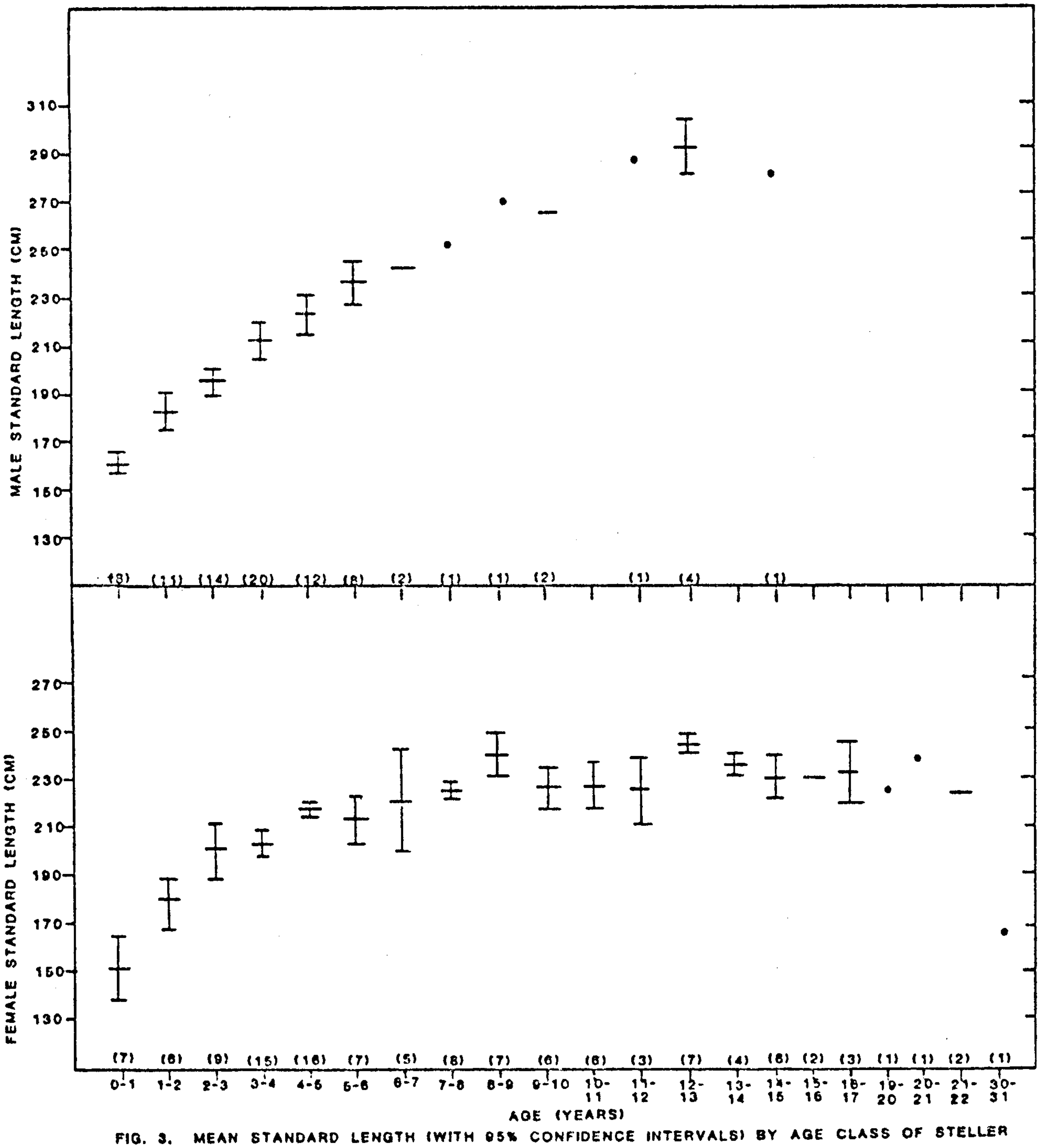

FIG. 3. MEAN STANDARD LENGTH (WITH 95% CONFIDENCE INTERVALS) BY AGE CLASS OF STELLER SEA LIONS TAKEN IN THE GULF OF ALASKA. (N).

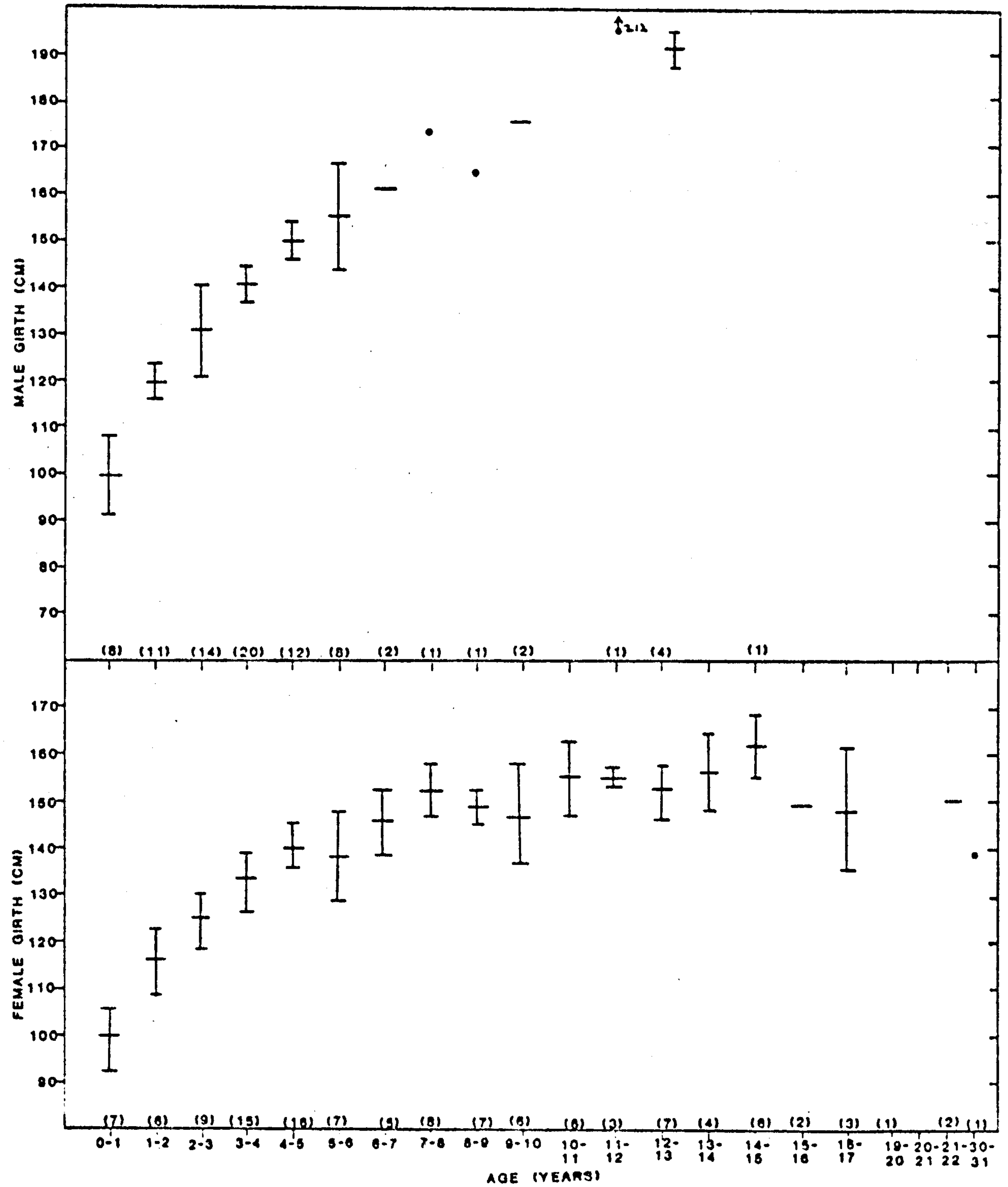

FIG. 4. MEAN GIRTHS (WITH 95% CONFIDENCE INTERVALS) BY AGE CLASS OF STELLER SEA LIONS TAKEN IN THE GULF OF ALASKA. (N).

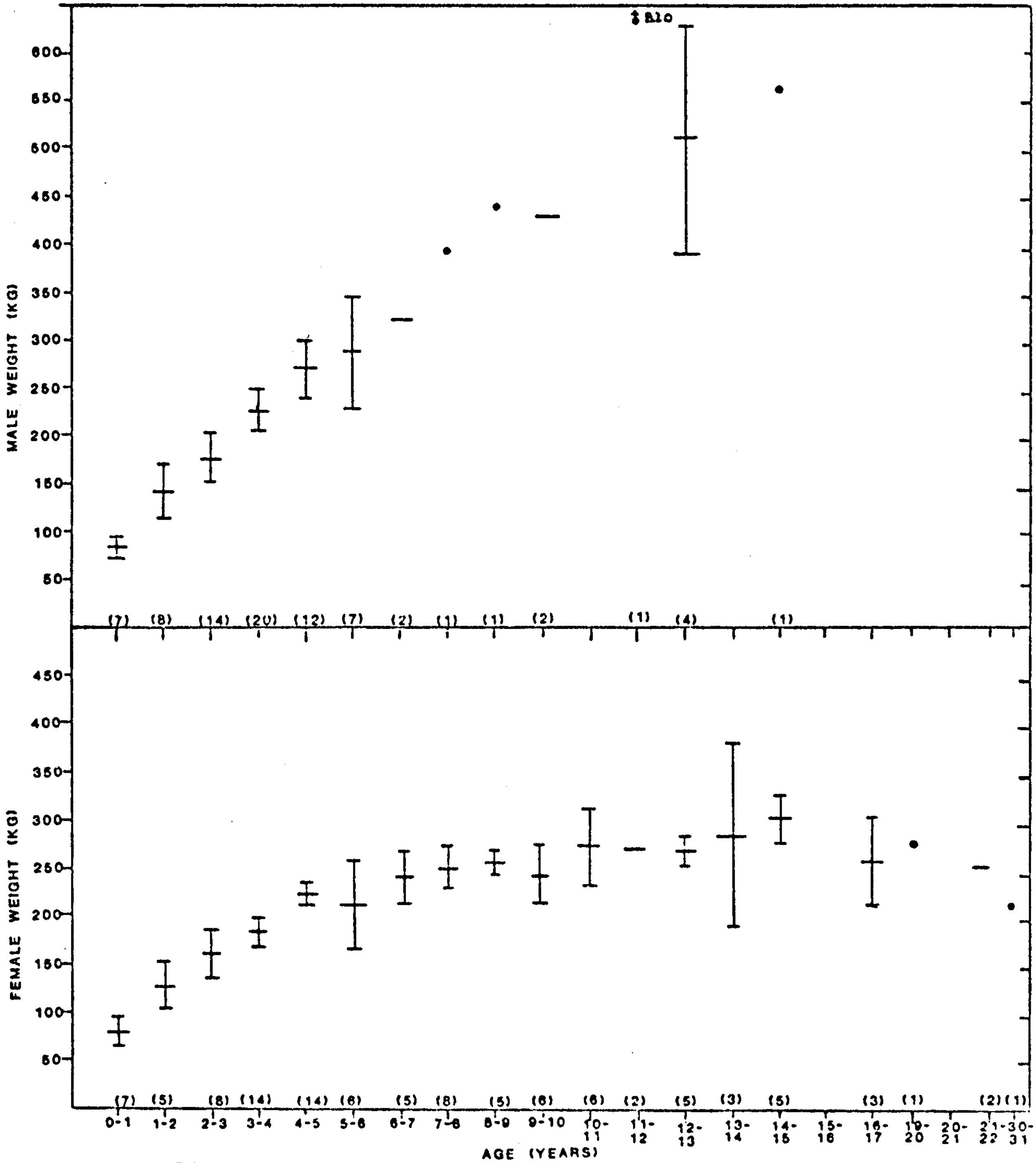

FIG. 5 MEAN WEIGHTS (WITH 95% CONFIDENCE INTERVALS) BY AGE CLASS OF STELLER SEA LIONS TAKEN IN THE GULF OF ALASKA. (N).

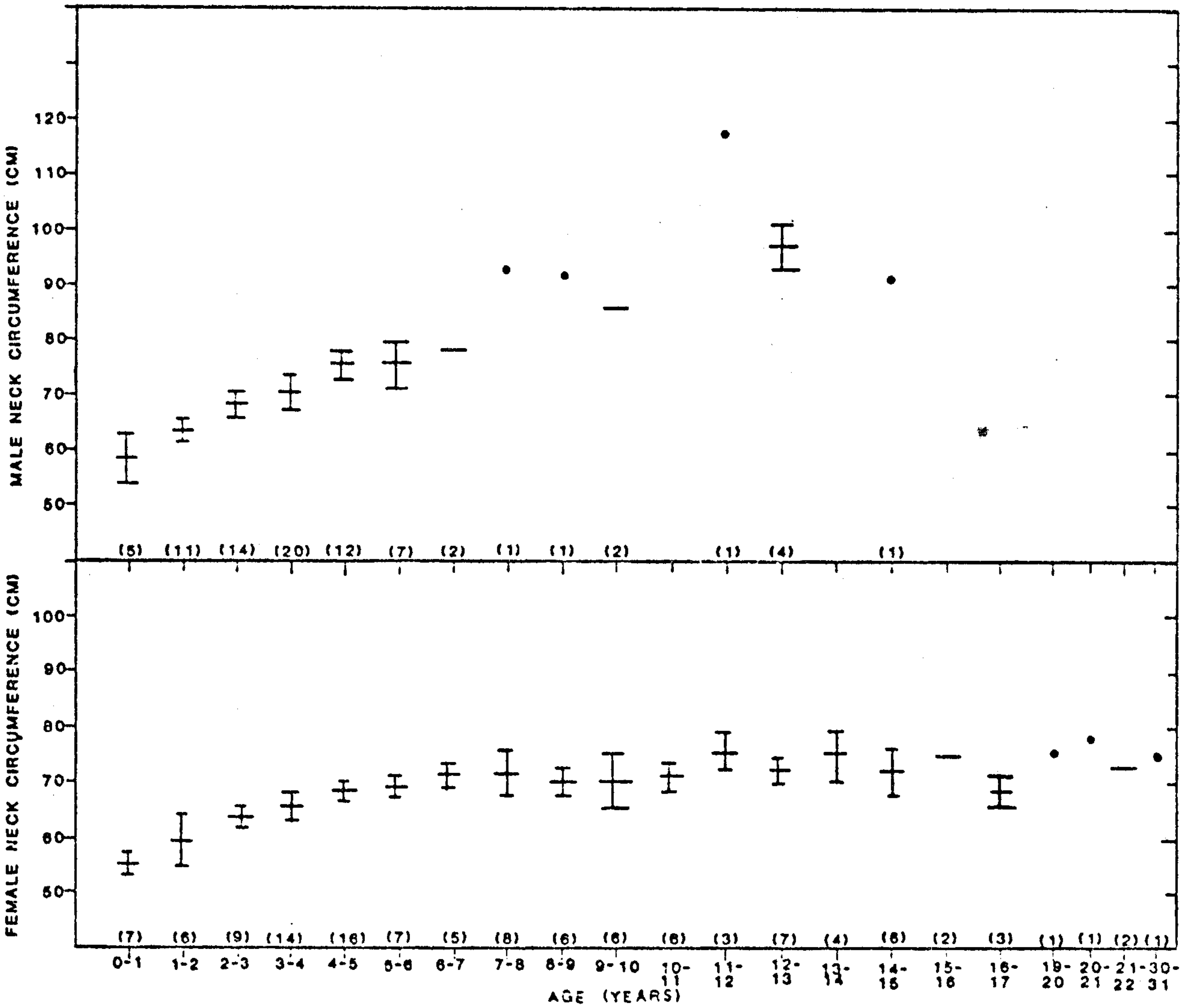

FIG. 6. MEAN NECK CIRCUMFERENCE (WITH 95% CONFIDENCE INTERVALS) BY AGE CLASS OF STELLER SEA LIONS TAKEN IN THE GULF OF ALASKA. (N).

Conclusions

It is apparent from the data presented that Cape St. Elias is an important hauling area in terms of movements of sea lions in the Gulf of Alaska. Counts of branded animals show that a high percentage of those present are branded. This indicates that Cape St. Elias is used heavily by sea lions of younger (than three years) age classes. Many of these animals were born at rookeries where branding took place.

A generalized movement pattern from west to east is becoming clear. Sea lions which were branded at Marmot Island, off Kodiak, Sugarloaf Island in the Barren Islands and Outer Island along the Kenai Peninsula are moving eastward to the haul-outs in Prince William Sound, Cape St. Elias, Middleton Island and possibly the haul-outs in Southeastern Alaska. At present we do not know if this movement is an annual migration, or what age classes and sexes are involved. Certainly, it is important to determine if these animals return to the west in the spring to breed.

The high numbers of sea lions sighted at Puale Bay can not be explained at present. This could be an important indicator of changes which may be occurring in sea lion distribution. This area should be monitored closely to see if this increase in numbers is permanent or if it was an isolated occurrence.

The occurrence of premature pupping at the sea lion hauling areas could have a substantial effect on the population. Although Fay (pers. comm.)

feels as though this may be a natural event which has always occurred in sea lion populations, we do not know the extent or the total impact on the population. Further investigation into the causes and consequences of premature pupping in sea lions appears warranted.

Our data indicated that female Steller sea lions became reproductively mature between 3 and 6 years of age. About 70 percent attained maturity at 5 and 6 years of age. The pregnancy rate for mature age classes (7-30 years) was 81 percent. The rate for maturing age classes (3-6 years) was 45 percent. Reproductive failures were noted in 13 of 95 females between 3 and 30 years old.

Limited data on male reproductive biology indicated that some animals become mature as early as 3-years of age. Seasonal spermatogenetic activity appeared to run from March or April into late (?) summer. All males collected between October and February were inactive.

Major prey of sea lions in the Kodiak area were capelin, walleye pollock and Pacific cod. Animals collected along the Outer Kenai coast had fed primarily on pollock. In Prince William Sound, the major prey were pollock, herring and squid.

Needs for Further Study

The investigation of sea lion movements and distribution should be continued. Branded animals in the Gulf are yielding valuable information and this work should be intensified in order that we may learn more about some specific concerns.

Sea lion distribution investigations should be intensified during the breeding period from May 1 though July 15. Known age animals should be returning to the rookeries to breed as the three and four-year-old age classes. Fidelity to rookeries of birth can be determined as well as the degree and distance of breeding away from the rookeries of birth.

The search for branded animals should be extended to some of the larger hauling areas outside the Gulf of Alaska, both in the Aleutian Islands and Southeastern Alaska. This is essential if we are to determine the extent of sea lion movements and how important the Gulf of Alaska is to the sea lion population as a whole in Alaskan waters.

The sea lion hauling area at Paule Bay should be monitored closely to determine if the increase in numbers observed there in March 1977 was a permanent increase, or merely an isolated occurance.

Premature pupping in sea lions should be investigated. Counts of premature pups should be made as often and at as many hauling areas as possible with a concurrent intensive investigation of the pathological causes of this phenomenon.

Belukha work should be emphasized in lower Cook Inlet although not at the expense of sea lion research. A detailed research project on belukha life history, biology, ecology, population status, distribution, abundance and taxonomic status should begin immediately. The possibility that this may be a separate subspecies and the fact that it is a small and probably reduced stock makes it particularly vulnerable to Outer Continental Shelf oil and gas development and production. It would be impossible to even begin to consider measures to protect and maintain this stock makes a great deal more were known about it. It is my opinion that the best way to approach this problem would be to create a new research unit for the purpose of studying belukhas in Cook Inlet.

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ANNUAL REPORT

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Research Unit: RU-481
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A Survey of Cetaceans of Prince William Sound And Adjacent Vicinity - Their Numbers And Seasonal Movements

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

Basic objectives of this first year of a planned three-year project are to document the relative numbers and seasonal distribution of cetaceans in Prince William Sound, Alaska, and to determine major foraging and accumulation areas for principal species.

II. INTRODUCTION

Between mid-January 1977 and 10 October 1977, periodic field surveys were conducted in Prince William Sound and the adjacent northern Gulf of Alaska. These surveys were designed to identify and enumerate the various whales and porpoise found in these areas. The results presented here represent part of the effort by the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the Alaska Department of Fish and Game to obtain baseline resource data from outer continental shelf areas in Alaska. These data will be used by the Bureau of Land Management (BLM) to evaluate the probable impacts on natural resources from development of petroleum reserves in Alaskan waters.

The objectives of this study are to:

1. Determine relative numbers and seasonal distribution.
2. Determine major foraging and accumulation areas.

While marine scientists feel confident that an oil spill in an area inhabited by sea otters, _Enhydra lutris_, will be extremely damaging to those otters actually oiled by the spill, there is much less concurrence about the effects of oil spills on cetaceans. Kooyman, _et. al_. (1975) found that gray whales, _Eschrichtius robustus_, actively take surface water into the upper sacs of the respiratory system. Should these findings apply to most, or all cetaceans, it would indicate a much higher vulnerability to oil spills by these animals than originally suspected. Of more general importance than the effect of oil spills on cetaceans is the likelihood of disturbance to cetacean populations by exploratory and development activity in the lease areas and from or by marine petroleum transport corridors, such as Hinchinbrook Entrance and the port of Valdez. The Marine Mammal Protection Act states that it is illegal to harass marine mammals without a permit, and the House report (supra note 22, at 4155) defines harass to include "the operation of motor vessels in waters in which these animals are found" (Coggins, 1975). The National Marine Fisheries Service, however, has promulgated regulations which make only intentional harassment of cetaceans illegal.

III. CURRENT STATE OF KNOWLEDGE

We have been unable to find published evidence of previous cetacean survey work in Prince William Sound. The U.S. Fish and Wildlife Service (FWS), the Alaska Department of Fish and Game (ADFG), the National Park Service (NPS), the U.S. Forest Service (FS), and personnel of the National Marine Fisheries Service (NMFS), as well as numerous commercial fishermen have reported incidental sightings of cetaceans in Prince William Sound during the course of other activities. A list of cetaceans known to occur in the Sound is included in Table 1.

We know, from conversations with people and organizations familiar with Prince William Sound, that certain species of large whales occur on a semi-regular seasonal basis, and that at least two species of porpoise occur in the Sound year-round. However, until now, we have had no knowledge of numbers of animals in this area. Brochures produced by the FS and the NPS provided information on cetaceans those groups had seen; and Karl Schneider, Ken Pitcher, and Don Caulkins of ADFG provided us with records of their previous and current cetacean sightings. Jim Johnson of the NMFS mentioned sighting numerous Humpback whales, *Megaptera novaeangliae*, in Prince William Sound during the early 1950's; while Jim King of the FWS mentioned that he saw no Humpbacks in the Sound in the late 1950's. Pete Isleib of Cordova saw very few Humpbacks in the mid to late 1960's in the Sound, but noted that they were becoming more numerous in the early 1970's. Fin whales, *Balenoptera physalus*, have been reported in the Sound by the FS and NPS, but we considered this species a highly variable visitor until over 50 fin whales were sighted during a FWS aerial survey over Prince William Sound in 1975. All sources reported minke whales, *Balaenoptera acutorostrata*, to be common visitors, perhaps residents of the Sound. Both commonly sighted species of small cetaceans, Dall porpoise, *Phocoenoides dalli*, and the harbor porpoise, *Phocoena phocoena*, were reported to occur in varying numbers throughout the year by several sources, including BLM, FWS, NMFS, NPS, and local fishermen. Gray whales have been sighted passing through the northern Gulf of Alaska on their annual migration by Richard MacIntosh of the Kodiak laboratory of the NMFS. Gray whales have also been sighted in the Kodiak area by other NMFS personnel (Rice and Wolman, 1971), and by FWS observers aboard OCSEAP vessels near Montague Strait in Prince William sound.

Thus it was clear, before this project started, that people from various agencies had seen whales and porpoise in and near Prince William Sound. It was also clear that no systematic effort had been made to quantify the numbers and distribution of cetaceans in the Sound, even though sizeable populations of whales and porpoises were thought to inhabit the area.

IV. STUDY AREA

Prince William Sound is located in southcentral Alaska at the northernmost point of the Gulf of Alaska (Figure 5). Central latitude and longitude of the area is approximately 60°30'N, 147°00'W, though the study includes an area of over 10,000 km^2. The Sound is characterized by a series of deep glacier-fed fjords around the perimeter while several large barrier islands form the southern boundary. Because of its protected nature and oceanic accessability through two major entrances, Hinchinbrook Entrance to the east and Montague Strait to the west, the Sound has recently been described as a potential petroleum cesspool due to the wind and current patterns in the Gulf of Alaska (NEGOA Synthesis Meeting, December 1976, Anchorage, AK). While it has the potential of becoming a cesspool in the future, at present Prince William Sound is a relatively untouched marine gem with extensive natural resources. Marine mammals, birds, fish, invertebrates, and macrophytes abound, and at present undergo relatively light utilization by man, with the exception of salmon, herring, king, and tanner crabs and certain macrophytes.

The climate in Prince William Sound is decidedly northern maritime with rain and clouds common in spring, summer, and fall, and snow and rain common in winter. Temperatures are mild with highs in the summer generally less than 18°C and lows in the winter normally above 5°C. Wind is a common feature with two general patterns visible. Winds tend to be light and variable in the summer, but change to heavy SW to SE blows in fall, winter, and spring when associated with the passage of frontal lows. Throughout the year, but especially during high pressure periods in the winter, the winds change more to N to NE and blow down canyons and fjords with velocities of 70 knots or greater.

During the passage of occluded lows, the entire area may be blanketed by fog and low clouds for several days, but during periods of high pressure, visibility may exceed 100 km. Marine water temperatures (surface) range from 11° to 13°C in the summer to 3° to 6°C in the late winter.

Because of the abundance of forage fish in Prince William Sound, high trophic level consumers, such as marine mammals and birds, find this area a nearly ideal niche, especially in spring, summer and fall. Commonly utilized forage fish include herring (*Clupea harengus pallasi*), capelin (*Mallotus villosus*), pollock (*Theragra chalcogramma*), and sand lance (*Ammodytes hexapterus*).

V. METHODS

To date, the study has attempted to utilize semi-standardized marine mammal survey techniques (Leatherwood and Platten, 1975). These have included strip census techniques from fixed-wing aircraft and surface vessels, streamer tag development for mark-recapture studies, and natural mark cataloging for unique individuals.

Strip census techniques as utilized in marine mammal studies vary considerably from one study to the next because of the different characteristics of various orders of marine mammals. For the aerial survey portion of our study, we have flown predetermined fixed transects, at fixed altitudes and speeds, and have attempted to actually measure the distance from the aircraft to the marine mammal target using a standardized commercial inclinometer to measure the vertical angle from the aircraft to the target. Using the computation, $B = a/\text{Tan}B$ *or* $b = a \text{ Cot } A$, the horizontal distance between the survey aircraft and the target may be determined. This distance clearly varies as a function of observer experience, weather and sea condition, and platform speed and altitude (Caulley, 1974). In order to minimize the effects of the above variable parameters, we have utilized a standard platform, the Office of Aircraft Service's McKinnon Turbo-Goose, N-780, which has been redesigned especially for over-water aerial surveys. The aircraft is equipped with a Global Navigation Inc. GNS-500 VLF Navigator. This instrument provides a continuous digital output of the plane's position in longitude and latitude measured to 1/10 arc minute. All sightings are voice recorded on magnetic tape by the starboard or port observer for later analysis. Information collected on each sighting includes, but is not limited to; species identification, time, position, platform altitude and speed, number of targets sighted, inclinometer angle, and comments on specific animal behavior observed. On return to Anchorage, the tapes are manually stripped of information and resulting data is coded on EDS approved marine mammal sighting records and batch submitted for processing.

Vessel surveys differ significantly from aircraft surveys in that several activities in addition to marine mammal observations are conducted. These include remote tagging of both large and small cetaceans; and the collection of certain environmental data such as surface water temperature, water depth, weather pattern, wind speed and direction, sea state, air temperature, and barometric pressure. These data, along with the sighting data, are recorded on EDS approved records. Submission of data records to the keypuncher occurred on a regular basis. Final data submission was in December 1977. During vessel surveys, a marine mammal watch is posted continuously during daylight hours.

The track design of the vessel surveys is quite different from those described above for the aircraft. Because we are interested in describing areas of extensive utilization, we attempt to transverse area that have been reported as whale "hot spots" in the past. In addition to covering these "hot spots", we survey as much of the rest of Prince William Sound as possible.

VI. RESULTS

The data presented here represent those collected during the report period (1 April - 10 October 1977) plus migratory data for the California gray whale, Eschrichtius robustus. While our data now represents effort over the great part of two field seasons, we make no attempt to extrapolate our findings to long-term cetacean population levels, and hope that readers will not assume such extrapolations valid without additional seasonal study.

Field effort increased significantly in 1977 due in large part to the transfer of project funds to the Fish and Wildlife Service in early January 1977. Prior to that time we had been conducting investigations based only on a letter of acceptance from the Boulder NOAA/OCSEAP office.

During 1977 we conducted 5 aerial surveys representing 3475 km of survey trackline completed and 6 vessel surveys covering 5005 km. Combined trackline totals represent 8480 km of survey effort. During our surveys we actually sighted (by count) 2757 cetaceans or 0.325 cetaceans/trackline km. Statistical data relating to cetacean sightings in 1977 is shown in Table 1.

Annotated Species Accounts

Dall porpoise - *Phocoenoides dalli*. Clearly the numerically dominant cetacean in Prince William Sound, Dall porpoise were sighted throughout the year. During this report period we observed Dall porpoise on 409 occasions. These sightings represented a counted population of 1665 individual porpoises. Average Dall porpoise group size was 4.17 porpoise/group ($\pm$ 4.55), and group sizes ranged from 1 to 35 individuals per group. Larger groups have been sighted in winter by Alaska Department of Fish and Game biologists (Hall and Tillman 1977).

Sightings of Dall porpoise accompanied by calves have been limited to spring (March-April) and late summer (August-October). Newborn Dall porpoise in Prince William Sound frequently have light gray pigmentation in the head area, and are thus distinct from adults by coloration as well as size. As the young porpoise grow the gray pigmentation fades to a "skullcap" surrounding the blowhole. By mid-summer (July) these young animals are indistinguishable from older Dall porpoises by coloration, though they still are smaller in size. Observation of the gray area is difficult due to light reflection and refraction near the water surface. We found that reliable observation of this gray coloration in young Dall porpoise could only be accomplished by standing directly over the animal as it rode the bow wave of the tagging vessel. This we were able to do by mounting a 1 meter long bow pulpit to the foredeck of the tagging vessel, thus allowing us to observe from almost 1 meter ahead of the cutwater. We are unable to find previous reference to this color pattern phenomena in young Dall porpoise and look forward to additional independent observations from other investigators.

During the 1977 field season a total of 23 Dall porpoise were marked with modified FH-69 Floy porpoise tags. Thus far we have had one (1) reliable resight of a tagged animal. A Dall porpoise tagged in Wells Canal near Whittier (60°47'N, 148°21'W) on 12 May 1977 was resighted by an Alaskan Department of Fish and Game enforcement vessel in Chatham Strait (58°05N135°))'W) on 12 August 1977. During the 90 day interval between tagging and resight the porpoise covered a minimum of 821 km (9.12 km/day) at an average speed of 0.38 km/hr. Since Dall porpoise are capable of extremely active swimming behavior, it is perhaps reasonable to assume that this marked animal covered much more than the straight line minimum of 821 km.

The uniformly gray Dall porpoise sighted twice in 1976 in Prince William Sound was sighted 3 times in 1977 from the vessel, but not at all from the aircraft. An additional sighting of a uniformly gray Dall porpoise was reported by C.S. Harrison, U.S. Fish and Wildlife Service, from near the Barren Is. in 1975. Thus we have a total of 6 sightings of a uniquely pigmented adult Dall porpoise from in and near Prince William Sound. In 1976 this animal was accompanied by 50 and 2 other Dall porpoises respectively. In 1977, in Prince William Sound, the gray Dall porpoise was accompanied by 10 Dall porpoise on two occasions and by 7 Dall porpoise on the third occasion. We attempted capture of the gray Dall in August of 1977, and though the animal was netted while bow riding, it managed to escape from the head net before we could examine it. As soon as it escaped, the entire group of accompanying Dall porpoise sounded and surfaced very quietly several hundred yards away from the capture boat. Although the gray Dall porpoise was extremely visible when near the vessel due to its light gray color, after the aborted capture attempt we found it almost impossible to identify the gray animal when it surfaced in a group of normally pigmented Dall porpoise. Only by using 7 x 50 binoculars could we identify the gray animal at over 100 yds. It is unlikely that other investigators would recognize this animal unless they were actively checking <u>every</u> Dall porpoise sighted.

We believe it possible that the 5 sightings of this unique animal (in Prince William Sound) over a 24 month period represent home range records, especially for summer use of Prince William Sound. If this hypothesis of a limited home range is correct, it substantiates the data of Moorjohn (unpubl. ms.) for Dall porpoise in Monterey Bay, California, but conflicts with the movement recorded for the Floy tag marked animal mentioned above. Clearly, additional study is necessary to delineate the seasonal movements of Dall porpoise, not only in Alaska, but throughout the North Pacific.

Utilizing a population estimator developed by Höglund, Nilsson and Stålfelt (1967) and discussed by Eberhardt (1968) we estimate that as many as 3588 Dall porpoise may occupy Prince William Sound in summer. The population estimate assumes an exponential decay of sighting efficiency as distance from the survey aircraft to animal increases. We tested this using a X^2 G.O.F. test and developed a X^2 value of 75.60 (n=110). The X^2 table value for 22 degrees of freedom (α=.05) is 32.67; therefore there is a significant difference between our observed sighting distance values and the expected. We must therefore assume two things: (1) the population of Dall porpoise in Prince William Sound is not 3588, and (2) that our sighting efficiency decay is not exponential in nature. We will attempt to develop another estimate for Dall porpoise population levels in Prince William Sound in our final report using another (as yet unknown) estimator.

Harbor porpoise - <u>Phocoena phocoena</u>. Harbor porpoise were infrequently encountered anywhere in Prince William Sound between May and September, however, a large population of this species occupies the area in and near Hinchenbrook Entrance from mid-September until late April. We sighted 89 harbor porpoise in and near Hinchenbrook Entrance during a 6 mile long segment of an aerial survey completed in September 1977. These porpoise, when near Hinchenbrook Entrance, are always associated with the plume of turbid water from the Copper River. As soon as we flew over the less turbid water of the Gulf of Alaska or Prince William Sound, sightings of this species declined to almost zero. We presume they are feeding in the more turbid water from the Copper River, perhaps on perhaps on forage species concentrated by the edge effect and mixing of the Copper River plume with the Gulf of Alaska waters in Hinchenbrook Entrance. In 1977 we sighted 219 harbor porpoise on 136 occasions. One-hundred-ten (110) of the sightings were made during aerial surveys and the majority of vessel sightings were made in early May during the nearshore Gulf of Alaska cruise of the tagging vessel.

Pacific white sided porpoise - Lagenorhynchus obliquidens. We made no sightings of this transient porpoise in or near Prince William Sound in 1977. Surface waters were not as warm as in 1976 and we suspect this may have affected the distribution of these animals, or at least the prey on which they feed.

Killer Whale - Orcinus orea. In 1977 we observed 453 killer whales on 34 occasions ($\bar{x}$ = 13.35/group ($\pm$ 18.58). Our first observations of killer whales in 1977 in Prince William Sound were in May, and we continued to see them through our final cruise in early October.

One group of more than 55 animals was sighted in Knight Passage near La Touche Island in May. We believe as much as 20% (12 animals) of the group may have been newborn calves. These calves stayed very close to what we assumed were their mother, blew more frequently than the group as a whole, and appeared to have an almost orange tinted pigmentation in the ventral anterior region. K.C. Balcomb (National Marine Fisheries Service pers. comm.) has also noted this orange tint in newborn killer whale calves in Puget Sound.

At no time during our encounters with killer whales did we notice aggression on the part of the whales. Quite the contrary was true. If we pursued the animals to obtain photographic records and reliable group size counts, we found the whales to be extremely elusive. However, by matching our vessel speed to the swimming speed of the herd, we were able to approach the animals repeatedly. On one occasion in August, two killer whales left the main group, approached the tagging vessel and rode both the stern and bow waves for a few moments before rejoining the herd proper. If we were careful not to harass the whales we found them quite curious and frequently they would approach the boat and swim under it apparently examining the vessel visually.

In our 1976 annual report we mentioned observing a large male killer whale with a distinctive curve in the trailing edge of the dorsal fin. In 1977, this characteristic was observed in virtually every large male killer whale. K.C. Balcomb, pers. comm., has observed this trait in one male killer whale in Puget Sound. We believe it possible that the peculiar dorsal fin curve in large male killer whales in Prince William Sound may represent a genetic trait, thus raising the possibility of a resident and genetically isolated population of killer whales in Prince William Sound. Disturbance or exploitation of a resident population of killer whales would, we believe, be more deleterious than disturbance or exploitation of a genetically mixing population of whales.

In 1977, as in 1976, killer whales were rarely sighted in Prince William Sound east of 147° W. longitude. We believe that killer whales primarily inhabit Southwestern Prince William Sound and only infrequently venture into Orca Bay, Port Gravina, Port Fidalgo or the Valdez Arm.

Minke whale - Balaenoptera acutorostrata. This species, the smallest of North Pacific baleen whales, was frequently sighted in Prince William Sound from May through October. In 1977 we sighted 98 minke whales on 55 occasions ($\bar{x}$ = 1.78/group ($\pm$ 2.65).

We found minke whales easy to approach if we were careful not to vary engine speed during the approach. In this manner we were able to tag 3 of a group of 12 we sighted in June 1977. Minke whales appear to be quite curious and frequently approached the tagging vessel if we lay dead in the water. No obvious minke whale calves were spotted in Prince William Sound. We estimate most of those sighted to be about 6-8 meters long.

While minke whales were sighted throughout Prince William Sound, we were almost always able to find one or more in the west side of Hinchenbrook Entrance near Montagne Pt. The largest group of minke whales (12) was sighted just north of Naked Island in June.

Gray whale - Eschrichtius robustus. These, the most primitive of baleen whales, pass through the northern Gulf of Alaska twice a year on their migration to and from the polar seas. In spring (March-May) and fall (Nov.-Jan.) gray whales closely follow the coast around the Gulf of Alaska, frequently passing through both Hinchenbrook Entrance and Montague Strait.

Gray whales are the subject of a separate publication by one of us (J.H., et. al.) and will be treated superficially here. From our aerial surveys throughout Alaska, and the spring census at Cape Sarichef on Unimak Is., we know that over 10,000 gray whales pass through the northern Gulf of Alaska twice each year. While gray whales cannot be considered residents of Prince William Sound, they pause in both major entrances to the Sound and thus are exposed to crude carrying traffic of increasing intensity. Effects of Very Large Crude Carriers on whales have not been demonstrated, but collisions are possible between these slow moving whales and the tankers carrying Trans-Alaska Pipeline oil from Valdez. During our aerial survey of the northern Gulf of Alaska on 14 April 1977 we sighted 44 gray whales between Gore Pt. and Cape St. Elias.

Humpback whale - Megaptera movaeangliae. We sighted 282 humpbacks on 59 occasions in 1977 ($\bar{x}$ = 4.78/group ($\pm$ 6.62). As in 1976, the majority of our sightings occurred near Chenega Island and in the general area between Naked, Perry and Eleanor Islands.

We attempted to photograph the ventral surface of the fluke of every humpback sighted and have now accumulated a catalog of photographs representing 35 individual humpback whales. Five of the 35 were sighted two or more times in 1977. Because we could not meet the assumptions required for the Lincoln index technique for population estimates derived from mark-recapture studies, we are unable to provide a reliable population estimate for humpback whales in Prince William Sound in 1977, though the population is clearly greater than 35, the maximum number of humpbacks sighted on any one cruise. We believe it realistic to hypothesize that several groups of humpbacks may utilize Prince William Sound during spring, summer, and fall. It is possible that each group is in residence from a few days to a few weeks and then moves on to another area. In October 1977 we observed several humpbacks near Chenega Island, some of which had been sighted previously. Later in the cruise (5 October 1977) we sighted a group of 15 humpbacks apparently just entering Prince William Sound through Hinchenbrook Entrance. Though we were able to photograph flukes of 12 of the 15 animals, later examination of the photographs indicated that this group had not been sighted previously in Prince William Sound in 1977. We think it unlikely that we would have overlooked such a large group of balenopterid whales on our previous cruises in 1977. Additional study would be required before a clear picture of seasonal population density and utilization by humpback whales in Prince William Sound can be obtained.

Humpbacks were the most difficult of the baleen whales to mark with the Floy tag. Frequently the whales were virtually unapproachable, though we were able to successfully mark 8 individuals in 1977.

Finback whale - Balaenoptera physalus. Finbacks, the largest whales sighted in Prince William Sound, were seen on 9 occasions. This represented a counted population of 40 animals ($\bar{x}$ = 4.44/group ($\pm$ 3.50). This species appears to limit its use of Prince William Sound to April, May and June, with a few staying on until early July. The animals appear to be spending a few days in Prince William Sound during their summer migration into Soviet waters in the western Bering Sea (Berzin & Rovenin, 1966). Though they are probably transients, during May and June finbacks may be quite abundant. We observed 12 in the Hinchenbrook Entrance on 6 June 1977, and successfully marked 7 of the 12 with the Floy tag. While investigators in the Western Atlantic have found finbacks difficult to approach for marking purposes, (R. Maiefski, pers. comm.), we found finbakcs in Prince William Sound to be unusually docile and they almost universally allowed us to approach very close with the tagging vessel.

VII. DISCUSSION AND CONCLUSIONS

Although we feel much more comfortable with the data representing almost two years effort, we still are unable to accurately predict the probable population levels for most cetaceans utilizing Prince William Sound. At best we might offer an educated guess at peak population levels, realizing that populations are anything but static and that immigration and emmigration are not only uncontrollable but uncalculable without further study.

Unsubstantiated Estimates of Cetacean Populations
(Seasonal Peaks) in Prince William Sound, Alaska

Dall porpoise	3,500+	
Harbor porpoise	500+	
Killer whale	100+	
Minke whale	50+	
Fin whale	50+	
Humpback whale	50+	
Gray whale	10,000+	(pass through the study area)

We believe it highly possible that the Dall porpoise and killer whales represent a nearly resident population during the summer. We base this on the frequent resighting of a uniformly gray Dall porpoise in 1976 and 1977, and the 5 sightings of a large (70+) group of killer whales over an eight week period. All 5 killer whale sightings were within 16 km of the original sighting, and virtually every large male killer whale sighted had the peculiar curve in the posterior edge of the dorsal fin.

Further marking studies of minke, humpback and fin whales would be necessary if one were interested in knowing if the same individuals utilize Prince William Sound year after year.

IX. NEED FOR FURTHER STUDY

We believe the need for continued study is obvious to anyone who has read this far; however project funds have been reduced severely for FY 78, and we anticipate no additional field work will be funded for this project.

X. SUMMARY OF FOURTH-QUARTER ACTIVITIES

Data analysis by ADP and final data submission. Annual Report preparation.

Table 1. 1977 Field Data

RU-481

Species	Total Sighting Sample Size	Average Group Size	Group Size Standard Deviation	Aerial Survey Sample Size	Aerial Survey Average Sighting Distance (yards)	Visible Tags Deployed	Tag Recoveries	% Tag Recoveries	Total Animals Sighted
Dall Porpoise	409	4.17	4.55	110	270.46 yds.	23	1	4.34	1665
Harbor Porpoise	136	1.61	1.76	100	270.23 yds.				219
Killer Whale	34	13.35	18.58						453
Minke Whale	55	1.78	2.65			4	0		98
Humpback Whale	59	4.78	6.62			8	0		282
Finback Whale	9	4.44	3.50			8	0		40
Totals	702					43			2757

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RECEPTORS -- BIRDS

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ANNUAL REPORT

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

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Alaska Department of Fish and Game

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I. Summary

Marine birds annually congregate in large numbers along the coast of Alaska. The magnitude of these aggregations depends on the species involved, location and season of year. Coastal areas are used in summer by breeding, molting and foraging birds, in fall and spring by migrating birds, in winter by foraging, overwintering species and year-round by many birds that reside in or are endemic to Alaskan waters.

For the past two and one half years, the overall objective of this project was to quantify the seasonal distribution of birds in coastal habitats. A second objective was to determine which areas or habitats are critical to the welfare of marine birds. An area or habitat was termed "critical" if species preferred and were dependent upon it, if it was used by a large number of individuals, if the bird species were particularly vulnerable to oil development, or if it was used by an endangered species. Certain habitats or areas are critical at only short periods during the year, and therefore it has been a part of this project to determine what seasons are the most crucial for birds. In combination with the bird surveys, the coastline of Southcentral Alaska was subjectively classified into habitats from the high tide to storm-surge line.

Studies for the current reporting period were confined to Bristol Bay and Lower Cook Inlet. In May 1977, aerial surveys were conducted along the north coast of the Peninsula and northern Bristol Bay to determine bird distribution and abundance during spring migration. Protected waters, including bays, lagoons and river deltas along that coastline, were densely populated with a variety of staging birds. Every estuary appeared to provide enough variation in habitats that a slightly different species composition was found in each one. Nearshore subtidal, littoral and supratidal areas were all very important foraging and roosting areas for birds.

Brant were the most numerous bird recorded, and this species almost exclusively used eelgrass beds in Izembek Lagoon and other adjacent estuaries. The next most abundant species, Emperor Geese, preferred sandspits and mud/sand flats with associated intertidal areas from Cinder River to Izembek Lagoon. Both species could be quite vulnerable to oil spills. The world's population of the dark-color phase Brant and most of the world's population of Emperor Geese use the north side of the Alaska Peninsula during migration. An untimely, catastrophic spill could destroy both populations either directly or through habitat destruction.

Thousands of sea ducks also used the same estuaries in spring as Brant and Emperors and could likewise be greatly affected by oil. Dabbling ducks (over 90 percent Pintails) were most dense in Port Heiden, Ugashik Bay and Kvichak Bay where densities as high as 50 birds/km^2 were recorded. Shorebirds, although not as abundant in spring as in fall, were recorded in large numbers in several of the estuaries. Both dabbling ducks and shorebirds would most be affected in the event of an oil spill by destruction of food organisms in intertidal and supratidal areas.

It may be necessary to use drastic measures (e.g. dispersants) or develop suitable techniques to prevent oil from entering the highly productive estuaries on the north side of the Alaska Peninsula when oil development and tanker traffic warrant it.

Gulls were the only species group that were as abundant on exposed coastline as in protected waters. Densities reached approximately 26 birds/km of beach. Because little is known of their food habits in that region, predictions on how they may be affected by oil spills cannot be made.

Surveys in northern Bristol Bay went only as far as Kulukak Bay, but several areas of importance were noted. The floodplain at the mouth of the Kvichak River, which is inundated only by storm tides, contained a wide variety of birds, and densities reached 306 shorebirds/km^2 and 236 dabblers/km^2 on the 7 May survey. For the second consecutive year Scaup were numerous along the coast in the Flounder Flats area of Nushagak Bay. Densities of Scaup were the densest (11/km) of any bird species recorded along the North Bristol Bay coast on the 13 May survey. Black Scoters were the next most abundant species. Over 1100 were observed in one openwater transect 30 km long in Nushagak Bay. In Nushagak Bay at the same time, but not within the boundaries of the transect, were several flocks of over 10,000 King Eiders.

All these species would be greatly affected by an oil spill during a spring storm. If they were not killed directly by oil contamination, their food organisms on which they depend during migration could be destroyed. Depending on recovery times of the benthos on which birds feed, the effects on avian populations could be long lasting.

During the relatively mild winter of 1977-78, bird densities were low for most areas in Lower Cook Inlet except outer Kachemak Bay. Comparatively high densities of scoters, alcids, eiders and larids were found on both shoreline counts and pelagic transects in that region. High, nearshore densities extended beyond Anchor River on the east side of the inlet. This should be considered when decisions are made for location of onshore facilities during oil development. If current patterns and wind would push spilled oil around Anchor Point into outer Kachemak Bay, thousands of vulnerable birds would be affected.

Low densities of birds were found on three trans-inlet transects and only moderate wintering bird densities were found in Kamishak Bay. In a heavy ice year, fewer birds would likely be found in Kamishak Bay. Based on this winter's surveys only, it appears as if few wintering birds would be affected by oil spills or development in the middle or western sides of Lower Cook Inlet. If oil were spilled during winter months and deposited in Kamishak Bay, it may affect birds indirectly in other seasons by destroying their food organisms. Planned research will determine bird use of Kamishak Bay in the other seasons.

II. Introduction

Productive coastal regions in Alaska provide ideal habitat for marine birds. Nearshore subtidal, intertidal and supratidal zones all supply substantial food resources for avian populations. Coastal cliffs, talus slopes, coastal meadows, barrier islands and other physiographic features provide suitable nesting habitat, and migrating birds use river deltas, lagoons and intertidal mudflats for staging. Ice-free coastal waters are used by over-wintering birds, and in summer many nonbreeding and molting species forage nearshore.

Because this nearshore and littoral region is so crucial to Alaska's marine avifauna, it is essential to assess the magnitude of bird use of this area in time and space. Most previous bird surveys have been conducted in offshore, pelagic waters or in specific waterfowl concentration areas. Many were only qualitative in nature or limited in scope. King and McKnight (1969) tried specifically to determine bird use of nearshore waters by flying a sawtooth pattern out to 19 km in Bristol Bay, but little information was gathered on bird use of littoral and supratidal habitats. The present study was designed to quantify bird use along the coast, in nearshore waters, and in supratidal regions.

Emphases of studies for this report period were in Bristol Bay and Lower Cook Inlet. Objectives of the bird surveys were to determine seasonal density distribution, migratory routes, chronology of migrations, breeding locales and critical habitats for all bird species utilizing the littoral zone within the study areas. In Lower Cook Inlet this study was also to determine winter distribution and abundance of marine birds in relation to ice conditions and other environmental parameters.

Oil and gas development with various related activities has been recognized as posing the greatest potential threat to marine birds in Alaska. Catastrophic spills could impact large numbers of sea ducks and other seabirds utilizing nearshore areas for foraging. If oil gets into estuaries or on mudflats thousands of waterfowl and shorebirds could be affected. Chronic pollution, although less obvious, may be as devastating to birds as a catastrophic spill. Food organisms will likely be destroyed by small spills, and this, in turn, will have deleterious effects on birds if it is continued for long periods of time.

This study will help determine seasonal abundance of birds and enable the establishment of priorities for critical avian habitats. Those most important to birds can hopefully be protected in the event of a spill or avoided by onshore development and vessel traffic.

III. Current state of knowledge

Little quantitative information is available on marine bird use of coastal habitats within the regions of Alaska that were studied during this report period (Bristol Bay and Lower Cook Inlet). Past knowledge of birds in these areas was summarized in earlier reports of Research Unit #3 (Arneson 1976a, 1977a). Most available information from past expeditions and surveys consists only of species lists of birds observed, data on game ducks and geese or pelagic distribution and abundance of birds.

In the Bristol Bay region, more recent and thorough data are available for Cape Peirce (Petersen and Sigman 1977) and the Port Moller-Nelson

Lagoon area (Gill et al. 1977). These studies recorded specific information on bird use of coastal areas and were not restricted to any species group. Both migration and habitat use of nearby marine waters was monitored. Emphasis of the Nelson Lagoon study was on seasonal use by shorebirds and waterfowl, and the Cape Peirce study stressed colonial nesting seabirds and sea ducks.

Less bird information is available for the second region - Lower Cook Inlet - under study by this Research Unit during the report period. Most recently, Erikson (1977) summarized data from bird studies conducted in 1976. Baseline seasonal information on bird distribution and abundance for both pelagic and shoreline areas was gathered. Only one survey per season was completed for shoreline and pelagic regions, in all but the Kachemak Bay area where several surveys were conducted during migration.

IV. Study Area

During this report period, the areas of study included Bristol Bay and the north side of the Alaska Peninsula from 1 April 77 to 30 September 77 (Figures 1 and 2). From 1 October 77 to 30 March 78 research was confined to Lower Cook Inlet (Figure 3). In addition, incidental bird observations were summarized from Cape St. Elias in the Northeast Gulf of Alaska and Tugidak Island at the south end of Kodiak Island.

In Bristol Bay, coastal areas surveyed included exposed sandy beaches; protected bays, lagoons and embayments; river deltas; coastal floodplains; mud and sand flats; creek mouths; sand and gravel islands and sandspits. The bank of the beach is typically low with a sand/gravel substrate. Lowland areas are generally covered with a sedge/grass complex, drier areas contain upland heath, and ground cover on beach fringes and barrier islands is beach rye. The Walrus Islands, on the other hand, are mostly rocky with frequent high cliffs and talus slopes. The entire coast is essentially treeless.

By contrast, the coastline of Lower Cook Inlet is bordered by spruce forest in most areas. The shoreline is more varied with lowlands and cliffs, rock and mud/sand flats, straight and indented coastline with several long beaches, bays and river mouths. Much of the survey work was in open water of Kamishak Bay, a relatively shallow area with volcanic Augustine Island in its center. Current patterns within Lower Cook Inlet tend to congregate large quantities of debris into Kamishak Bay, and it is therefore assumed that oil spills will also eventually end up in Kamishak.

V. Methods

<u>Bristol Bay</u>: For the first time in this project a helicopter was used for shoreline counts and pelagic transects. As in the past, observers enumerated birds on both sides of the aircraft. During shoreline counts the shoreside observer covered the area to high tide, and the seaside observer looked out to 200 meters from the aircraft. In supratidal lowlands, a total count of birds was attempted. We flew at an altitude of approximately 30 meters and at about 100 km/hr.

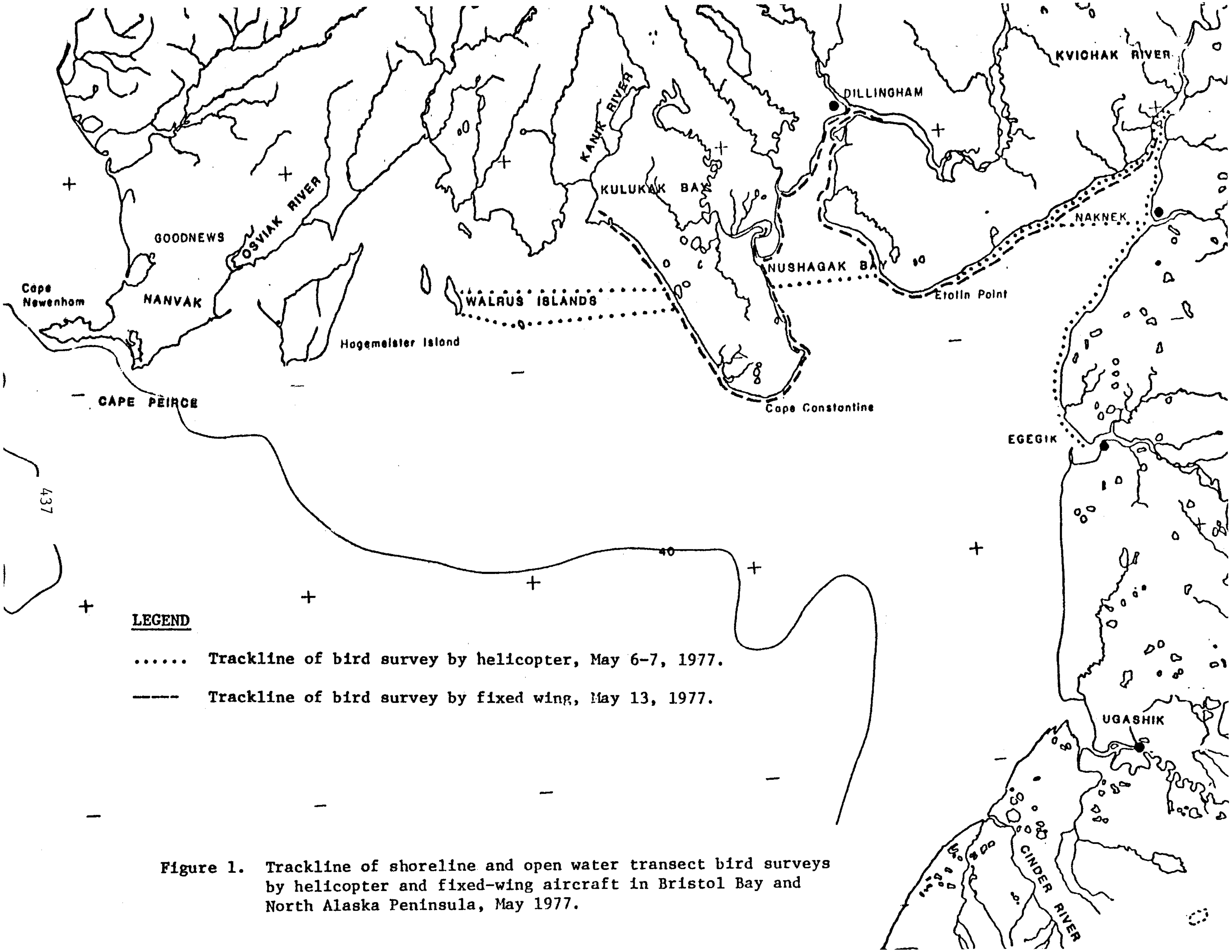


Figure 1. Trackline of shoreline and open water transect bird surveys by helicopter and fixed-wing aircraft in Bristol Bay and North Alaska Peninsula, May 1977.

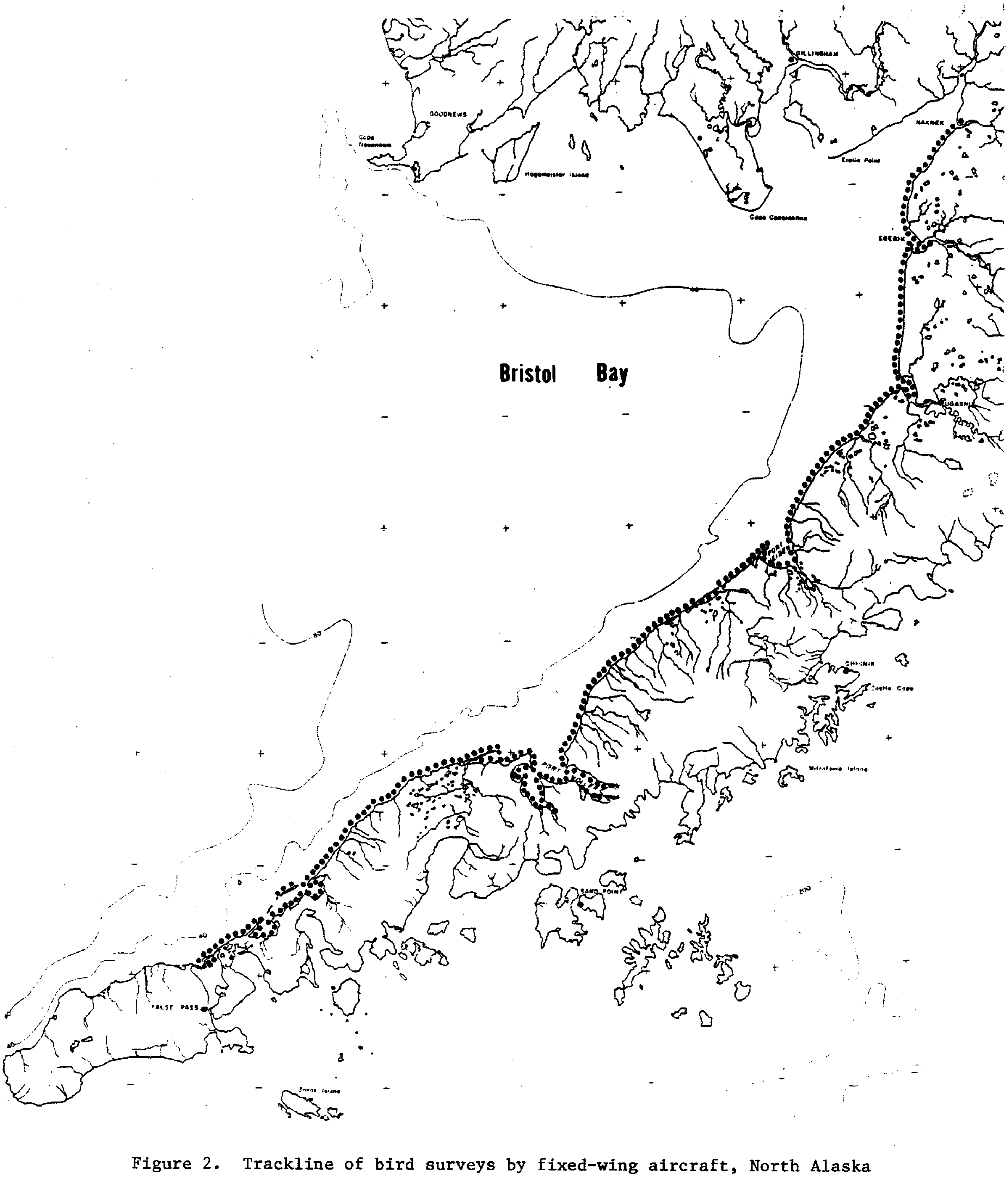


Figure 2. Trackline of bird surveys by fixed-wing aircraft, North Alaska Peninsula, May 11-12, 1977.

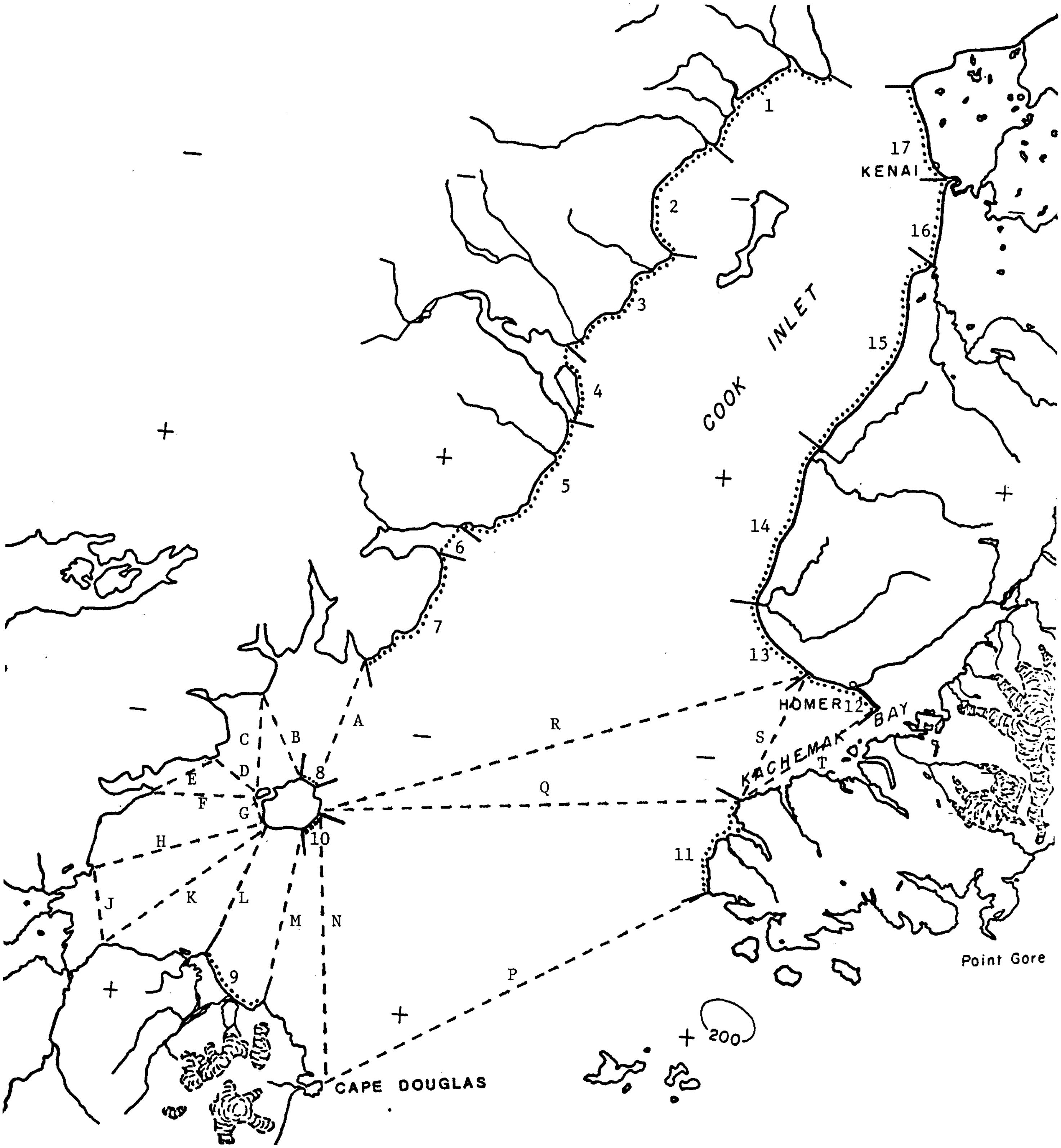


Figure 3. Trackline of shoreline stations and pelagic transects for bird surveys flown in Lower Cook Inlet, Winter, 1977-78.

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

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

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

In June and July, in conjunction with a reconnaissance of the Walrus Islands, 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 one-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.

Lower Cook Inlet: Shoreline survey techniques described above were used from West Foreland to Oil Point, along portions of Kamishak Bay, and from Homer Spit to East Foreland. Line-of-sight pelagic transects were flown in Kamishak Bay, across the Inlet, and in Outer Kachemak Bay, with observers looking 100 meters from each side of the aircraft. Minute intervals along the transect were recorded by stopwatch so that approximate locations of birds were known.

VI. Results

Bristol Bay - Spring surveys: Coastal surveys during May 1977 in Bristol Bay/Alaska Peninsula were broken into four segments for analysis and comparison. Species composition of total birds observed for the four surveys is presented in Table 1 and the combination distance and area surveyed is given at the bottom. When surveys of stations followed the coastline, a distance was recorded and densities are given in birds/km. When total coverage of an supratidal or water area was attempted, an area was recorded and densities are given in birds/km^2. Bird summarizations, therefore, are given in either density format depending on the sampling technique utilized.

Because identical stations were intentionally flown on both the helicopter survey in early May and the fixed-wing survey several days later, a

Table 1. Species list of birds observed on four aerial surveys of North Alaska Peninsula and North Bristol Bay, May 1977.

Species	N. AK Pen. 6 May Total No.	N. AK Pen. 10-12 May Total No.	N. Br. Bay 7 May Total No.	N. Br. Bay 13 May Total No.
Loon-unid	2	12		1
Sm Loon	2	33	12	79
Lg Loon	3	6	2	5
Co Loon	1	3		2
Ar Loon	4	20	1	4
RT Loon	4	45	9	60
Grebe-unid	6	5	2	3
RN Grebe	3	19		10
Ho Grebe	1	4	2	16
Cormorant-unid	2	38	1	10
Sm Cormorant		6	2	2
DC Cormorant		7		71
Swan	9	160	9	24
Dark Goose	87	198	333	69
Canada Goose	485	106	373	328
Brant		54,733		16
Emp Goose	2	31,057		76
WF Goose	3	19	80	53
Snow Goose	60	324	60	215
Duck-unid	52	191	9	704
Dabbler	1,279	6,122	3,935	1,200
Mallard	56	163	21	47
Gadwall	4	135	2	3
Pintail	1,551	5,842	3,020	936
GW Teal	35	97	19	2
Am Wigeon	38	23	6	9
No Shoveler	30	179	14	39
Diver	49	34	23	126
Redhead				4
Canvasback				4
Scaup	580	1,711	451	4,880
Gr. Scaup	2	55	11	14
Goldeneye	12	21	4	20
Bufflehead	6	14	5	15
Sea Duck	36	2,955	20	52
Oldsquaw	25	999	312	191
Harlequin		301		113
Eider		410		
St. Eider		23,272		26
Lg Eider		271	24	29
Co Eider		1,201		44
Ki Eider	4	30	217	29
Scoter	23	1,785	861	113
WW Scoter		81	69	3
Su Scoter		2	2	10
Bl Scoter	274	6,137	1,509	597

Table 1. (continued)

Species	N. AK Pen. 6 May Total No.	N. AK Pen. 10-12 May Total No.	N. Br. Bay 7 May Total No.	N. Br. Bay 13 May Total No.
Merganser	35	58	4	24
Co Merganser			4	
RB Merganser	164	202	93	395
Hawk-unid		1		2
Bald Eagle	2	47	2	2
Ma Hawk	2		2	2
Falcon-unid		1		2
Ptarmigan	10	4	4	12
SH Crane	55	118	41	34
Sm Shorebird	1,098	4,715	6,694	3,534
Phalarope	2	18		89
Med Shorebird	1,533	2,366	1,740	413
Plover	623	1	14	2
AG Plover			10	
BB Plover	503	5	1	
Turnstone		158		
Bl Turn		37		5
Co Snipe	2		2	
Rock Sand		71		489
Dowitcher	15	2		
Lg Shorebird	7	426	51	10
Whimbrel		4		
Yellowlegs	1	3	17	3
Mixed Shorebird	82	1,510	2,020	2,734
Jaeger	1	13	1	8
Par Jaeger	2	2	7	
LT Jaeger				1
Gull	440	20,236	358	856
Lg Gull	133	7,232	627	1,026
Gl Gull	8	36	1	6
GW Gull	260	6,551	722	99
He Gull	5	2	2	1
Sm Gull	11	310	75	97
Mew Gull	1,646	1,107	265	419
Bon Gull	16			
Kittiwake	7	5,308	7	1
Sab Gull		21		1
Tern		1,360	1	343
Ar Tern	3			
Alcid-unid	1	1	2	
Murre	1	33	182	2
Pi Guillemot		6		
Sn Owl		1		
SE Owl	1	1		1
Passerine	6	137		70
Raven	6	34	4	8
TOTAL	11,411	191,054	24,378	20,947
Distance/Area in Survey	102.2km $69.4km^2$	1294.2km $873.4km^2$	80.2km $126.4km^2$	378.7km $99.9km^2$

comparison was made of changes in species composition and densities for both North Bristol Bay and North Alaska Peninsula (Table 2).

Data for the survey from the Naknek River to Bechevin Bay on 10-12 May are summarized in Tables 3 and 4. This includes a comparison of "protected" versus "exposed" areas along the Alaska Peninsula coast and a comparison of the bird densities among estuaries in the region (data for Kvichak Bay are from the 6 May 1977 helicopter survey). Table 5 lists bird densities for protected and exposed areas of North Bristol Bay.

Subdivisions used in the analysis of both regions are shown in Figure 4. Exposed stations of North Alaska Peninsula are Nos. 2,4,6,8,10,12,17 and and of North Bristol Bay are Nos. 2,3,7 and 8. The remaining stations in each region were classified "protected." More detailed bird data for these stations are available.

Bristol Bay - Summer surveys: A reconnaissance of the Walrus Islands was conducted in summer 1977 in anticipation of future bird colony studies in that area. Because the proposed sale of oil lease tracts in Bristol Bay was indefinetly postponed, future studies in the area were curtailed. A detailed summary of the survey in the Walrus Islands has been completed (Arneson 1977b) and tables of the results of boat transects and colony population estimates are in Appendix I.

Lower Cook Inlet - Winter surveys: Three bird surveys were conducted during the 1977-78 winter: early winter, 22 November 1977; mid-winter, 12 January 1978; and late winter, 3 March 1978. Table 6 shows the relative abundance of birds between nearshore and pelagic areas from these surveys. Total numbers of each species or group are listed in Table 7. Seventeen shoreline stations and 18 pelagic transects were flown. Relative abundance and distribution of birds as a result of these surveys are depicted in Figures 5 to 10.

To compare bird abundance within divergent regions of Lower Cook Inlet, shoreline stations were grouped into three sections: Stations 1-7, Northwest side; Stations 8-10, Kamishak; Stations 11-17, East side (refer to Figure 3). Pelagic transects were also grouped into three sections: Transects A-N, Kamishak; Transects P-R, Across Inlet; Transects S and T, Outer Kachemak. The most abundant bird species groups from shoreline surveys are compared between regions and surveys in Table 8 and from pelagic surveys in Table 9. Data were combined from the three surveys to give overall winter densities and percent composition in Tables 10 and 11 for shoreline and pelagic areas, respectively.

VII. Discussion

Bristol Bay: The magnitude and dynamics of bird use of coastal areas in Bristol Bay during spring migration were revealed in surveys conducted in May 1977. Protected waters including estuaries and river deltas supported thousands of geese, sea ducks, gulls and dabbling ducks. Shorebirds, although abundant, did not reach the numbers that they presumably do during fall migrations. Chronology of migration and distribution within the region varied from species to species.

Table 2. A comparison of bird densities in two surveys several days apart of identical stations in both North Bristol Bay and North Alaska Peninsula, May, 1977.

	North Bristol Bay				North Alaska Peninsula	
	7 May 77 Birds/km	7 May 77 Birds/km²	13 May 77 Birds/km	13 May 77 Birds/km²	6 May 77 Birds/km	10 May 77 Birds/km²
Loons	0.3		0.6	0.2	0.2	Tr
Grebes	0.1		0.3	0.3	Tr	
Cormorants	Tr		Tr		Tr	0.1
Swans	0.1	0.1	Tr	0.3		
Geese	0.5	27.4	0.2	2.5	0.7	
Unidentified Ducks	0.1		1.8	8.1	Tr	
Dabblers	0.9	235.8	0.3	26.8	5.3	0.2
Divers	3.5	1.2	17.2	8.7	8.5	2.3
Sea Ducks	2.2		6.3		2.1	2.6
Eiders	0.3		0.2			
Scoters	1.8		5.5		1.6	1.9
Mergansers	1.3	0.5	0.8	0.2	2.4	0.8
Eagles, etc.	Tr	0.1	0.1		Tr	Tr
Ptarmigan	Tr	0.1		0.2		
Cranes		1.4		0.1		
Total Shorebirds	16.9	306.1	1.0	77.7	51.4	0.3
Small Shorebirds	3.0	207.4	0.3	34.6	14.9	0.3
Med. Shorebirds	1.7	55.7	0.6	2.0	36.0	0.1
Large Shorebirds		2.3		0.1	0.1	
Mx. Shorebirds	12.2	40.7		40.9	0.5	
Jaegers	Tr	Tr	Tr		Tr	
Gulls	20.2	16.2	5.3	17.9	33.4	31.7
Terns	Tr		0.3	1.5	Tr	0.1
Alcids						Tr
Owls				Tr		
Corvids		0.1	0.1			Tr
Other Passerines			Tr	0.1		
TOTAL	44.4	589.1	34.3	144.7	104.5	38.2

Table 3 . Bird densities in protected and exposed coastal areas of North Alaska Peninsula, May 10-12, 1977.

	Protected		Exposed		Total	
	Birds/km	Birds/km^2	Birds/km	Birds/km^2	Birds/km	Birds/km^2
Loons	Tr	0.1	0.1	Tr	Tr	0.1
Grebes	Tr	Tr	Tr	0.1	Tr	Tr
Cormorants	Tr	Tr	0.1		Tr	Tr
Swans	Tr	0.2		0.3	Tr	0.2
Geese	34.7	71.6	0.5	0.6	21.1	67.8
Unidentified Ducks	Tr	0.1	tr	1.0	Tr	0.2
Dabblers	4.6	10.1	0.1	13.5	2.8	10.3
Divers	1.0	0.7	0.7	2.9	0.9	0.8
Sea Ducks	20.7	17.5	13.1	1.1	17.7	16.6
Eiders	13.0	15.5	4.3	0.3	9.6	14.7
Scoters	6.5	0.6	4.7	0.7	5.8	0.6
Mergansers	0.1	0.1	0.2	0.4	0.1	0.1
Eagles, etc.	Tr	Tr	Tr	Tr	Tr	Tr
Ptarmigan		Tr				Tr
Cranes	Tr	0.1		0.3	Tr	0.1
Total Shorebirds	2.6	6.8	1.0	24.5	1.9	7.8
Small Shorebirds	0.7	3.5	0.5	22.9	0.6	4.5
Med. Shorebirds	1.5	1.5	0.3	1.5	1.0	1.5
Large Shorebirds	0.1	0.4	Tr	Tr	Tr	0.4
Mx. Shorebirds	0.4	1.4	0.2		0.3	1.3
Jaegers	Tr	Tr		Tr	Tr	Tr
Gulls	19.7	14.8	25.6	1.5	22.1	14.1
Terns	0.6	0.5	1.0	0.7	0.7	0.5
Alcids	Tr		0.1		Tr	
Owls		Tr		Tr		Tr
Corvids	Tr	Tr	Tr		Tr	Tr
Other Passerines	Tr	0.2	Tr		Tr	0.1
TOTAL	84.1	122.8	42.5	46.9	67.5	118.7
Distance/Area	777.4km	826.2km^2	516.8km	47.2km^2	1294.2km	873.4km^2

Table 4. Densities of bird groups using littoral or supratidal regions in estuaries of North Alaska Peninsula, May 1, 1977.

	Kvichak Bay		Egegik Bay		Ugashik Bay	
	Birds/Km	Birds/Km^2	Birds/Km	Birds/Km^2	Birds/Km	Birds/Km^2
Loons	0.2	Tr	0.2		0.1	0.3
Grebes	Tr	0.2				Tr
Cormorants			0.2	0.3		
Swans		0.2	Tr		Tr	0.2
Geese	1.1	11.6	0.1		0.3	2.7
Unid. Ducks	0.3		0.2		Tr	0.8
Dabblers	3.9	50.1	1.7	1.1	2.4	27.0
Divers	10.0	1.2	9.1	0.2	1.8	1.0
Sea Ducks	0.6	5.4	16.9	0.5	8.4	0.1
Eiders		0.1	3.5		1.6	
Scoters	0.1	4.7	13.4	0.5	6.7	0.1
Mergansers	2.8	0.7	0.1	0.2	0.1	0.2
Eagles, etc.	tr	0.1				Tr
Ptarmigan		0.1				
Cranes		1.2	0.1			0.3
Total Shorebirds	30.0	5.7	5.0		5.5	6.0
Small Sh.	10.4	1.1	1.7		2.7	3.6
Med. Sh.	19.5	3.3	0.4		1.2	2.2
Lg. Sh.	Tr	0.1				0.3
Mx. Sh.		1.3	3.0		1.6	Tr
Jaegers	Tr				Tr	Tr
Gulls	24.3	4.3	9.7	0.6	9.6	4.5
Terns	Tr		0.2	0.2	0.2	0.8
Alcids		0.1				
Owls		Tr				Tr
Corvids		0.1				Tr
Other Passerines		0.2				0.4
TOTAL	73.2	82.1	43.6	3.7	28.5	44.4
Distance/Area Surveyed	47.4Km	39.7Km^2	33.4Km	16.1Km^2	64.8Km	131.0Km^2

Continued

Table 4. Continued.

	Cinder River		Port Heiden		Seal Islands	
	Birds/Km	Birds/Km^2	Birds/Km	Birds/Km^2	Birds/Km	Birds/Km^2
Loons	0.1	0.1	0.1	0.1		Tr
Grebes			Tr	0.1		Tr
Cormorants						
Swans		0.5		0.2		0.1
Geese		8.5	152.5	49.0		47.3
Unid. Ducks		0.1				
Dabblers	3.1	15.4	43.9	21.8		8.8
Divers	0.8	0.5	0.6	1.2	0.2	0.4
Sea Ducks	1.4	3.2	23.3	1.4	1.2	24.5
Eiders	0.6	1.4	1.2	Tr	0.3	21.3
Scoters	0.8	0.5	9.1	1.2	0.2	1.2
Mergansers		0.1		0.2	0.2	0.2
Eagles, Etc.	Tr		Tr	Tr		Tr
Ptarmigan				Tr		Tr
Cranes		0.1		0.5		
Total Shorebirds	15.2	21.9	2.7	11.0		5.6
Small Sh.	0.8	11.4	1.3	3.5		3.1
Med. Sh.	14.2	2.4	0.5	4.4		2.1
Lg. Sh.	0.2	2.0	1.0	0.4		
Mx. Sh.		6.0		2.7		0.4
Jaegers	Tr	Tr				
Gulls	10.1	6.7	13.2	16.2	44.5	34.5
Terns		0.6	Tr	1.0	15.9	0.5
Alcids						
Owls						
Corvids		Tr	Tr	0.1		Tr
Other Passerines		Tr		1.0		
TOTAL	32.1	59.7	236.3	103.9	62.1	122.0
Distance/Area Surveyed	33.1Km	149.3Km^2	44.6Km	70.7Km^2	10.9Km	85.6Km^2

Continued

Table 4. Continued.

	Port Moller Complex Birds/Km	Port Moller Complex Birds/Km^2	Izembek Lagoon Birds/Km	Izembek Lagoon Birds/Km^2	Bechevin Bay Birds/Km
Loons	Tr				
Grebes	Tr				
Cormorants	Tr		Tr		
Swans	Tr		0.1		
Geese	22.6	476.1	60.5	118.8	0.2
Unid. Ducks	Tr		Tr		
Dabblers	2.1	1.8	2.7	0.4	
Divers	0.6	1.6	0.1	0.5	0.1
Sea Ducks	38.4	39.2	6.6	31.2	1.9
Eiders	26.4	34.4	6.1	28.6	
Scoters	11.4		0.1	0.6	0.8
Mergansers	0.1	0.4	Tr	Tr	
Eagles, Etc.	0.1	0.1		Tr	Tr
Ptarmigan					
Cranes					
Total Shorebirds	1.8	5.4	1.3	0.7	
Small Sh.	Tr	1.3	0.9	0.5	
Med. Sh.	1.5	4.1	0.4	0.2	
Lg. Sh.	Tr				
Mx. Sh.	0.2				
Jaegers	Tr			Tr	
Gulls	29.5	175.3	11.8	11.8	14.0
Terns	0.3	4.3	0.6		
Alcids	Tr		Tr		
Owls					
Corvids	Tr	0.1	Tr		
Other Passerines	Tr		Tr		
TOTAL	95.6	704.4	83.9	163.5	17.0
Distance/Area Surveyed	324.6Km	15.8Km^2	211.3Km	357.7Km^2	39.4Km

Table 5. Bird densities in protected and exposed coastal areas of North Bristol Bay, May 13, 1977.

	Protected		Exposed		Total	
	Birds/Km	Birds/Km^2	Birds/Km	Birds/Km^2	Birds/Km	Birds/Km^2
Loons	0.1	0.1	0.7		0.4	0.1
Grebes	0.1	0.1	Tr		0.1	0.1
Cormorants		0.1	0.4		0.2	0.1
Swans		0.1	Tr	0.7	Tr	0.2
Geese	0.6	5.3	Tr	13.4	0.3	6.3
Unid. Ducks	0.4	3.0	2.0	0.8	1.1	2.7
Dabblers	0.6	22.3	0.3	8.9	0.4	20.7
Divers	7.2	4.2	16.0	28.3	11.5	7.2
Sea Ducks	1.4		4.8	4.0	3.1	0.5
Eiders	Tr		0.6	1.6	0.3	0.2
Scoter	1.3		2.5	1.5	1.9	0.2
Morgansers	1.0	0.1	1.0	1.2	1.0	0.3
Eagles, etc.	Tr	Tr	Tr		Tr	Tr
Ptarmigan		0.1				0.1
Cranes	Tr	0.1		2.1	Tr	0.3
Total Shorebirds	0.8	79.7	0.3	7.4	0.5	70.7
Small Sh.	0.3	39.2	0.2	7.0	0.3	35.2
Med. Sh.	0.2	9.8	Tr	0.2	0.1	8.6
Lg. Sh.	Tr	0.1	Tr	0.2	Tr	0.1
Mx. Sh.	0.2	30.6	0.1		0.1	26.8
Jaegers		Tr	Tr	0.1	Tr	Tr
Gulls	1.5	10.1	7.1	0.8	4.3	8.9
Terns	0.6	0.7	0.6	5.4	0.6	1.2
Alcids			Tr		Tr	
Owls		Tr				Tr
Corvids			Tr		Tr	
Other Passerines	0.3	Tr	Tr		0.2	0.9
TOTAL	14.6	126.1	33.4	73.2	23.8	119.5
Distance/Area	193.6Km	87.6Km^2	185.1Km	12.3Km^2	378.7Km	99.9Km^2

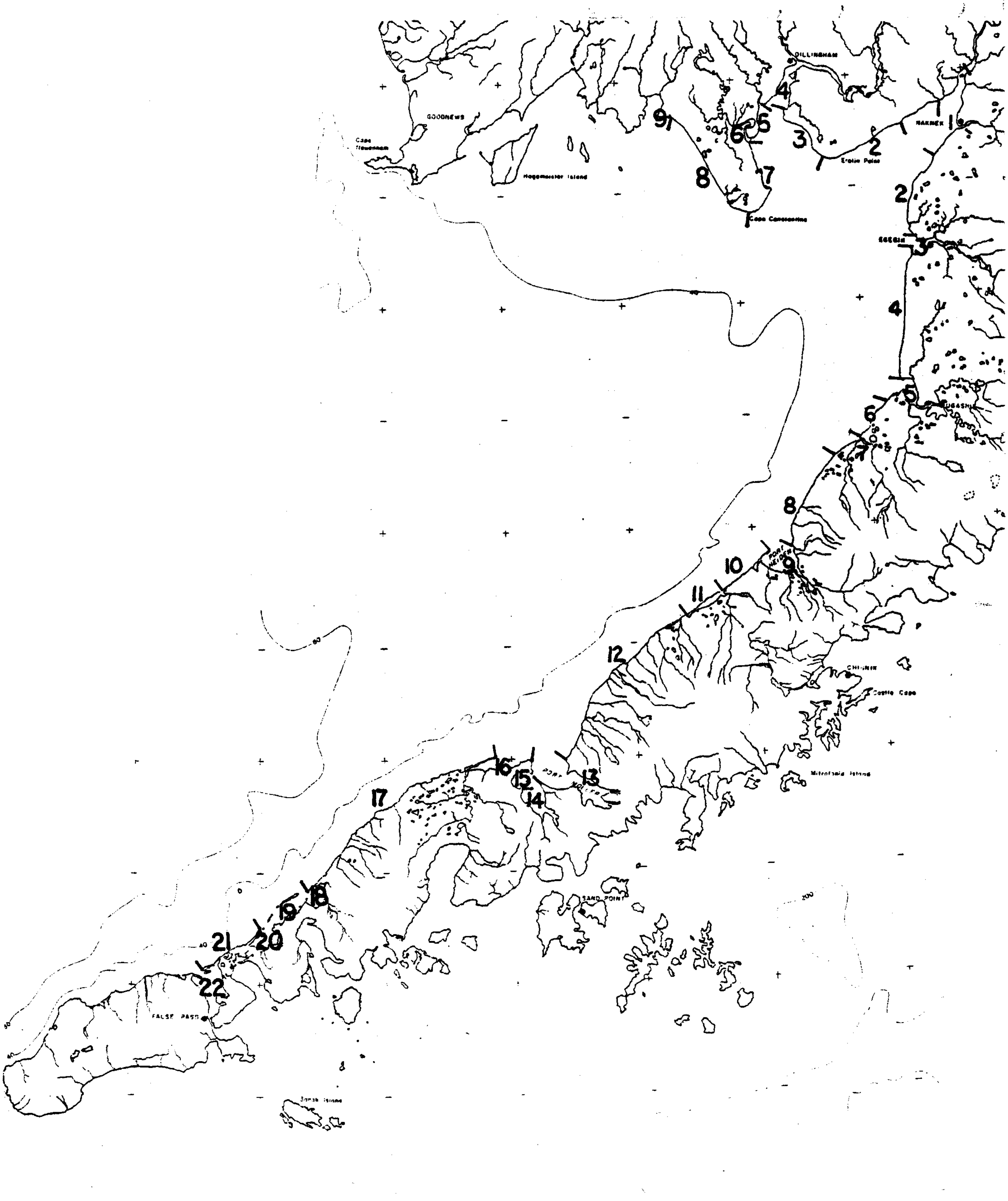


Figure 4. Subdivisions of North Alaska Peninsula and North Bristol Bay used in the analysis of bird data from aerial surveys, May 1977.

Table 6. Relative abundance of bird species groups in shoreline and pelagic surveys of Lower Cook Inlet, Winter 1977-78.

Species Group	Percent of Total Birds	
	Shoreline	Pelagic
Cormorant	5	1
Eiders	12	23
Scoters	43	24
Other Seaducks	9	17
Gulls	25	15
Alcids	4	18
Other	3	1

Table 7. Total number of birds by species or group in three areial surveys of shoreline stations and pelagic transects in Lower Cook Inlet, 1977-78.

Species or Group	Shoreline Stations			Pelagic Transects		
	22 Nov. 1977	12 Jan. 1978	3 Mar. 1978	22 Nov. 1977	12 Jan. 1978	3 Mar. 1978
Loon	7		14	1		3
LgLo	7	8	11	4	4	
SmLo	1		3			
Greb	8		8			
RnGr	1					
Fulm					6	
Shea				4		
Corm	73	35	183	10	22	6
SmCo		1	4			1
EmGo		2				
Mall				1		
Scau		2	5			
Buff	2		1			
SeDu	136	13	77	8	12	33
Olds	59	32	201	18	337	53
Harl	26		31		2	4
Eide	83	98	37	7	8	31
StEi	9		25	65	9	136
LgEi				120		
CoEi	52	123	265	19	119	104
KiEi		60			3	6
Scot	993	626	345	48	390	71
WWSc	7	38	89	8	85	19
SuSc	14	22	79	10	9	1
BlSc	157	217	141		9	17
Merg	23					
RBMe	1					
BaEa	1	2	1			
MeSh	26		1	15		
Gull	98	227	227	39	8	30
LgGu	110	27	136	59	11	44
GlGu			1			
GwGu	35	54	106	22	48	83
HeGu			1	1	2	
SmGu	338	28	51	22		4
BlKi	5			6		2
MeGu	21		96	11	6	14
SeBi				1		2
Alci	40		8	2		5
SmAl	12	2	1		8	9
SLAl	1					
Murr	84	1	51	86	87	237
Mule	7		9	1	9	7
PiGu	28		10	16	4	7
Pass	38	1				
Rave	3	1	3			
NWCr		3				
SnBu	1					
Total	2507	1623	2221	604	1198	929

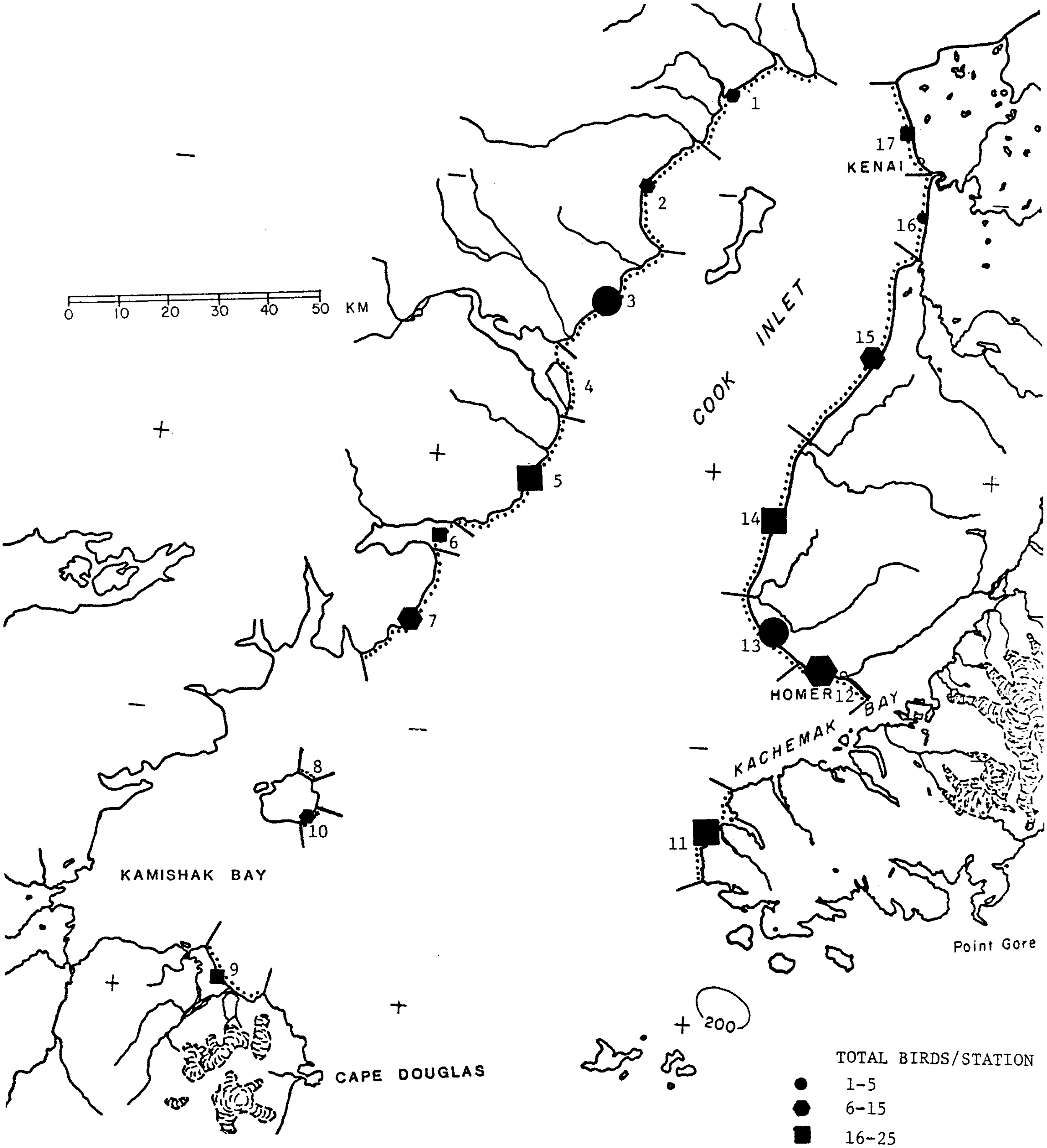
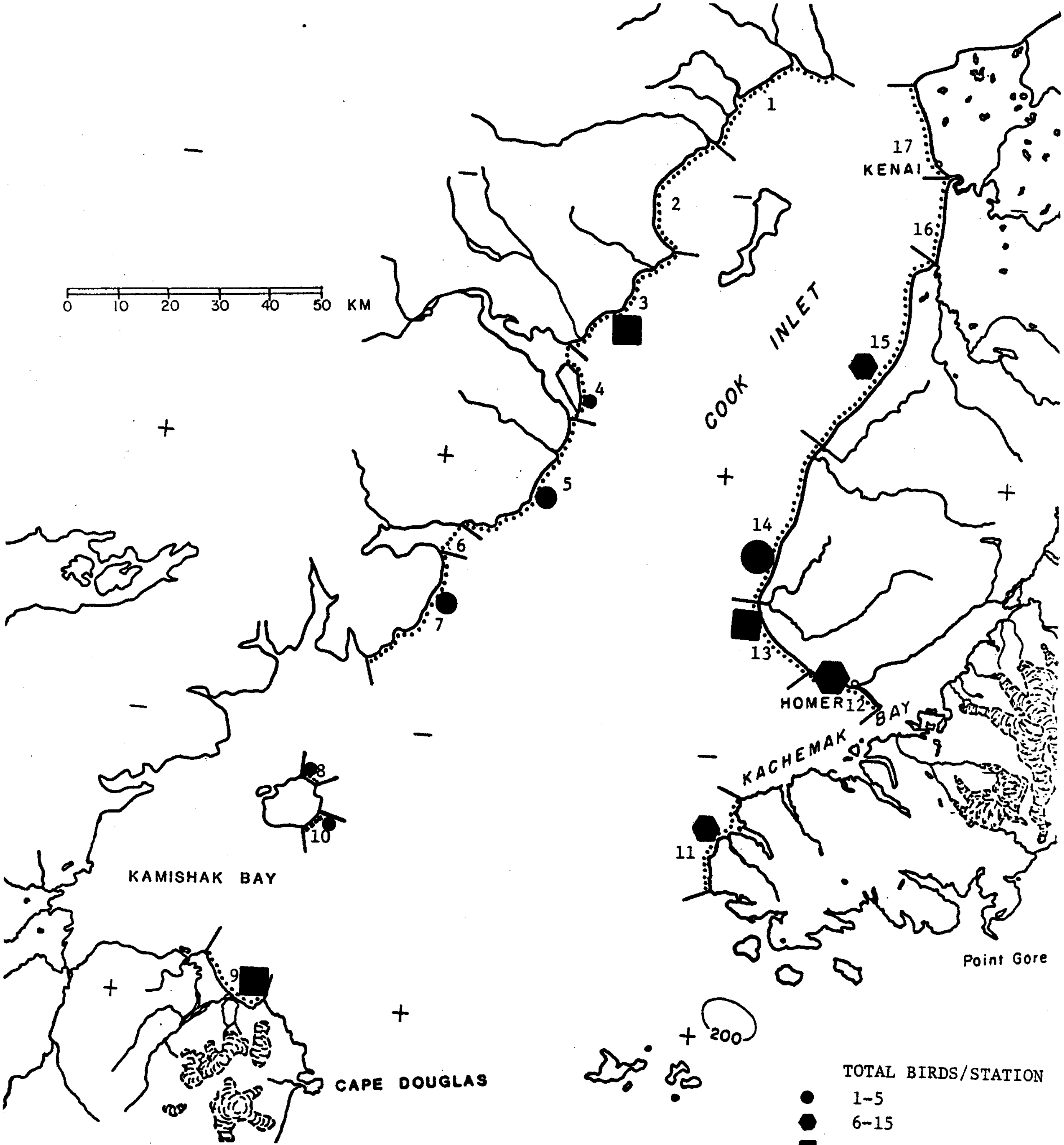


Figure 5. Number of birds observed along shoreline on survey of 16 stations in Lower Cook Inlet, 22Nov77, ADFG.



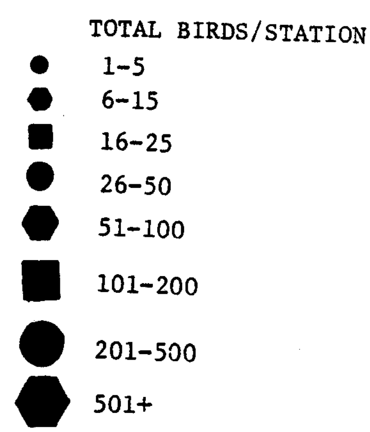


Figure 6. Number of birds observed along shoreline on survey of 17 stations in Lower Cook Inlet, 12 Jan 78.

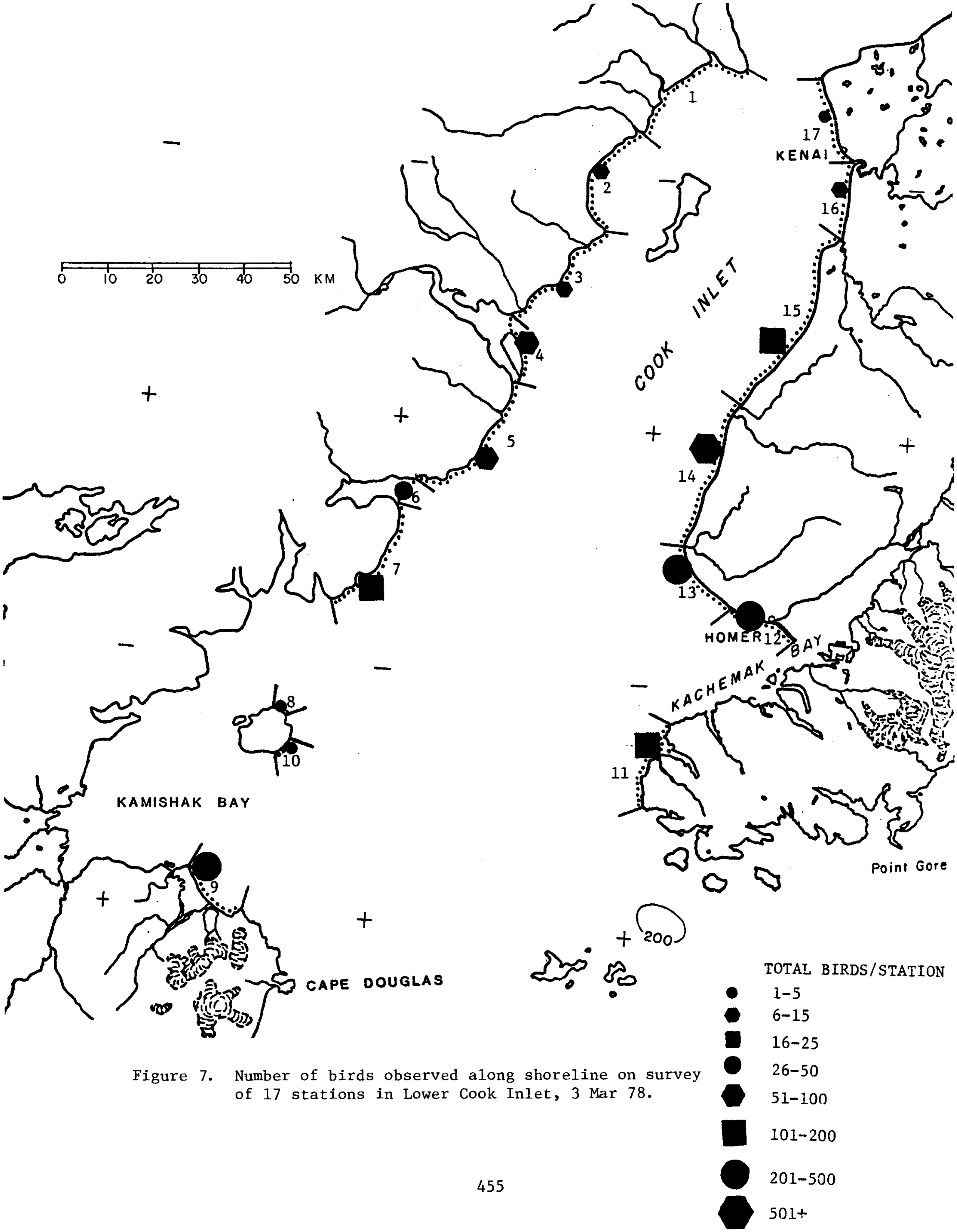


Figure 7. Number of birds observed along shoreline on survey of 17 stations in Lower Cook Inlet, 3 Mar 78.

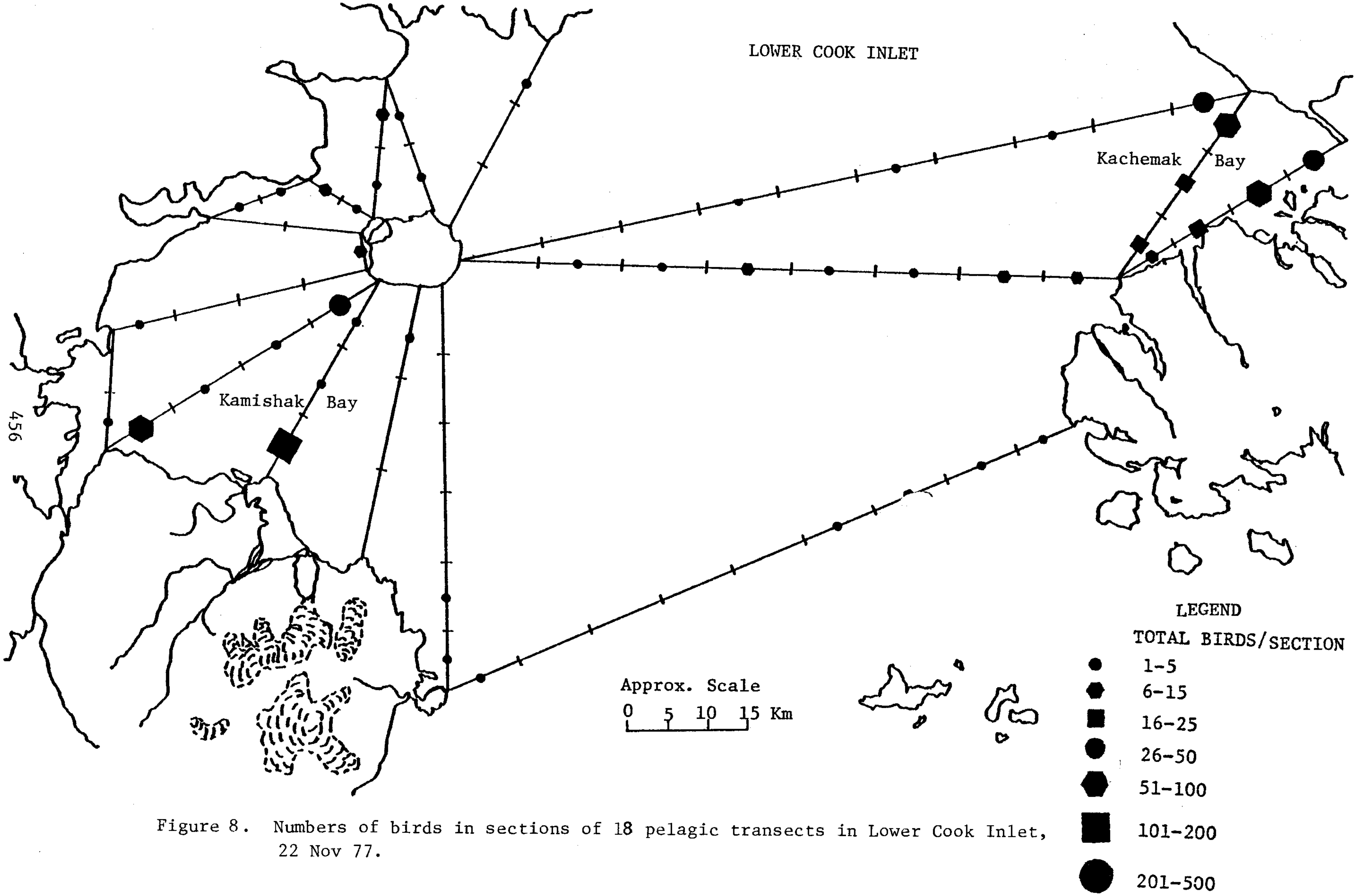


Figure 8. Numbers of birds in sections of 18 pelagic transects in Lower Cook Inlet, 22 Nov 77.

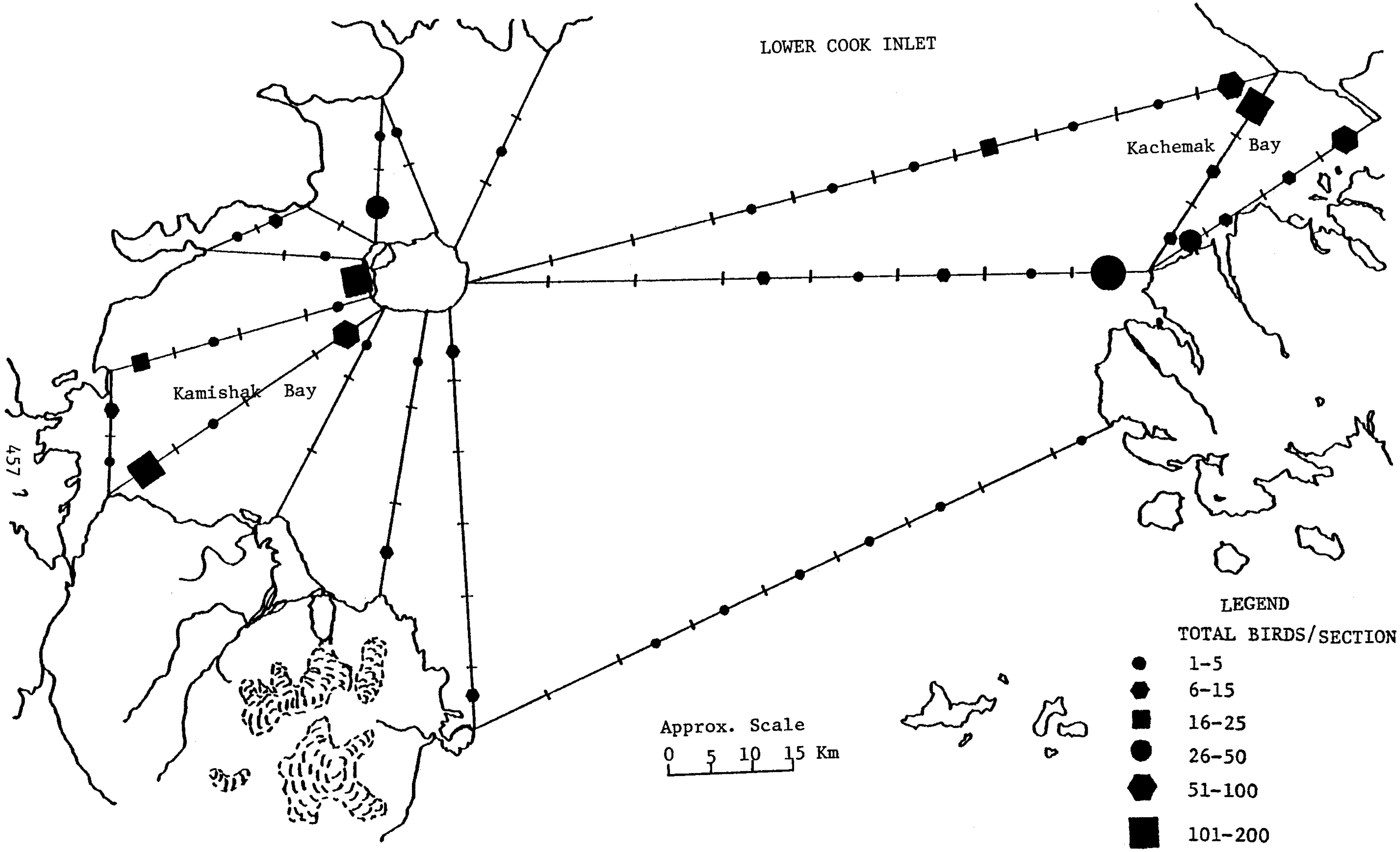


Figure 9. Number of birds in sections of 18 pelagic transects in Lower Cook Inlet, 12 Jan 78.

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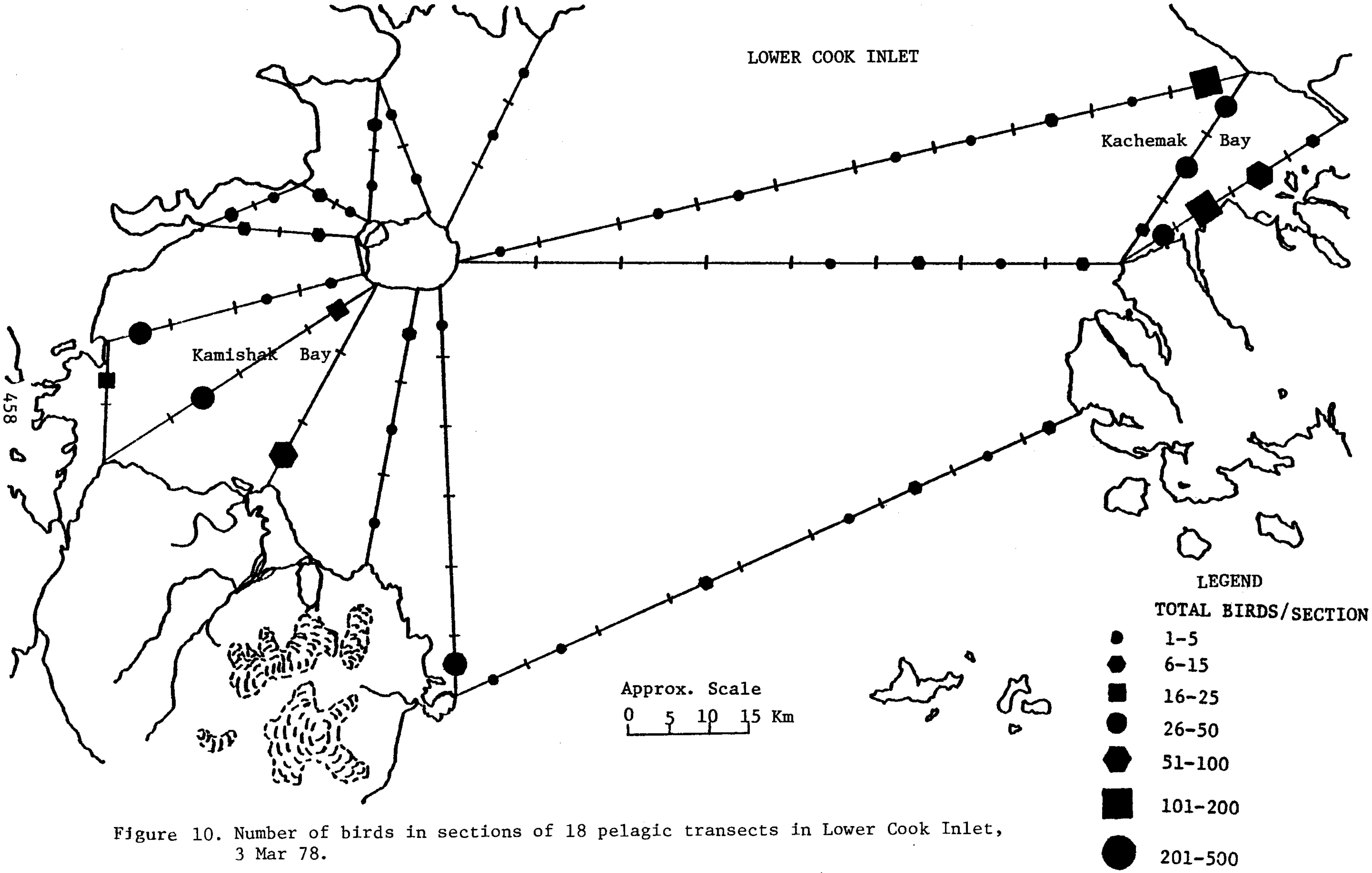

Figure 10. Number of birds in sections of 18 pelagic transects in Lower Cook Inlet, 3 Mar 78.

Table 8. Relative abundance and percent composition of the most abundant bird species groups for three shoreline surveys in three regions of Lower Cook Inlet, Winter, 1977-78.

	22 November 1977			12 January 1978			3 March 1978		
Species Groups	NW side	Kamishak	East side	NW side	Kamishak	East side	NW side	Kamishak	East side
				Abundance - Birds/km of transect					
Eiders	-	-	0.8	Tr	-	1.6	Tr	Tr	1.9
Scoters	0.1	0.4	6.7	0.1	3.1	4.7	0.5	2.1	3.0
Other Seaducks*	0.2	-	1.1	Tr	Tr	0.2	0.2	0.3	1.6
Larids	2.5	0.4	0.9	1.4	2.0	0.2	1.3	6.2	1.3
Alcids	-	-	1.0	-	Tr	Tr	0.2	Tr	0.3
Other Birds	0.1	0.4	1.0	Tr	-	0.3	0.1	-	1.3
				Composition - Percent of Total					
Eiders	-	-	7	2	-	23	1	1	20
Scoters	3	36	58	8	59	66	24	24	32
Other Seaducks*	6	-	10	2	1	3	7	3	17
Larids	87	33	8	87	39	3	57	72	14
Alcids	-	-	8	-	1	1	7	1	3
Other Birds	3	30	8	1	-	4	3	-	14

* Other Seaducks includes Oldsquaw, Harlequin Duck, and unidentified seaducks.

Table 9. Density and percent composition of the most abundant bird species groups for three pelagic surveys in three regions of Lower Cook Inlet, Winter, 1977-78.

	22 November 1977			12 January 1978			3 March 1978		
Species Groups	Kamishak	Across Outer LCI	Kachemak	Kamishak	Across Outer LCI	Kachemak	Kamishak	Across Outer LCI	Kachemak
Density - Birds/km^2									
Eiders	3.0	0.4	-	0.2	0.6	7.4	1.8	2.7	1.4
Scoters	0.4	0.4	1.6	2.5	4.7	6.6	0.6	0.5	3.8
Other Seaducks*	0.2	Tr	0.9	5.3	0.1	0.7	1.2	Tr	0.7
Larids	0.3	0.4	9.4	0.3	0.3	3.2	1.6	0.4	4.4
Alcids	Tr	0.4	6.8	-	0.6	6.1	Tr	0.9	17.5
Other Birds	0.4	0.1	0.4	Tr	0.4	1.0	0.1	0.1	0.2
Composition - Percent of Total									
Eiders	69	21	-	3	9	29	34	60	5
Scoters	10	21	8	30	71	26	10	10	14
Other Seaducks*	4	3	5	63	1	3	23	1	2
Larids	7	25	49	3	5	13	30	8	15
Alcids	1	22	35	-	9	24	1	19	62
Other Birds	8	7	2	1	5	4	1	1	1

* Other Seaducks includes Oldsquaw, Harlequin Duck, and unidentified seaducks.

Table 10. Density and percent composition of birds in three combined winter 1978 surveys in Lower Cook Inlet. Data are segregated into three regions and then combined for total Lower Cook Inlet.

Shoreline Stations

Species/Group	Northwest side Density Birds/km	Northwest side Composition %	Kamishak Density Birds/km	Kamishak Composition %	East side Density Birds/km	East side Composition %	Lower Cook Inlet Combined Density Birds/km	Lower Cook Inlet Combined Composition %
Cormorants	Tr	1	0	0	0.6	6	0.3	5
Eiders	Tr	1	Tr	Tr	1.5	16	1.3	12
Scoters	0.2	11	1.9	37	4.8	51	2.4	43
Other Seaducks*	0.1	6	0.1	2	1.0	10	0.5	9
Gulls	1.7	77	2.9	58	0.8	9	1.4	25
Alcids	0.1	3	Tr	1	0.4	5	0.2	4
Other	Tr	2	0.1	3	0.3	3	0.2	3
Total	2.2	101	5.1	101	9.3	100	5.6	101

* Other seaducks includes Oldsquaw, Harlequin Duck and unidentified seaducks.

Table 11. Density and percent composition of birds in three combined winter 1978 surveys in Lower Cook Inlet. Data are segregated into three regions and then combined for total Lower Cook Inlet.

Pelagic Transects

Species/Group	Kamishak Density Birds/km^2	Kamishak Composition %	Across LCI Density Birds/km^2	Across LCI Composition %	Outer Kachemak Density Birds/km^2	Outer Kachemak Composition %	Lower Cook Inlet Combined Density Birds/km^2	Lower Cook Inlet Combined Composition %
Cormorants	0.1	1	0.1	2	0.3	1	0.1	1
Eiders	1.7	28	1.2	28	2.9	12	1.6	23
Scoters	1.2	19	1.8	43	4.0	17	1.7	24
Other Seaducks*	2.2	37	0.1	1	0.8	3	1.2	17
Gulls	0.7	12	0.4	9	5.7	24	1.1	15
Alcids	Tr	Tr	0.6	15	10.1	42	1.2	18
Other	0.1	2	0.1	2	0.2	1	0.1	1
Total	6.0	99	4.3	100	24.0	100	7.0	99

* Other seaducks includes Oldsquaw, Harlequin Duck and unidentified seaducks.

In the Kvichak Bay area, where several stations were intentionally duplicated in bird censuses spaced several days apart, a dramatic change occurred in species composition and abundance. The most noticeable change was with shorebirds and in particular Black-bellied Plovers (classified medium shorebirds in Table 2). Relatively large numbers of this species and other shorebirds fed on the mudflats on both sides of Kvichak Bay on 6 and 7 May, but on 10 and 13 May, when replicate counts were made, most of the shorebirds had departed. A similar situation was true for dabbling ducks and Canada Geese on the North Bristol Bay side of Kvichak Bay. Although they were abundant on the first survey, most had migrated before the second survey.

Total bird densities dropped from 589 to 145 birds/km^2 in upland portions of North Bristol Bay between the first and second survey and from 44 to 34 birds/km along the coast. On the North Alaska Peninsula side, densities dropped from 105 to 38 birds/km. Gulls were the only species group that maintained relatively high densities from one survey to the next. However, many gulls are residents in the area and would not be expected to migrate.

Cinder River/Hook Lagoon was also surveyed twice because of a tape recorder malfunction on the first survey, and a similar change in species composition and abundance was noticed. Although surveys were separated by only two days, a striking change was made noticeable by an increase of Bar-tailed Godwits and decrease in Gadwalls from the first to the second counts.

By comparing bird densities in exposed versus protected areas, several marked differences were noted. As expected, densities on the North Alaska Peninsula were greater in protected nearshore and supratidal areas. Exposed areas had approximately one-half the total bird densities as did coastline portions and there were one-third fewer on upland areas than in protected estuaries. This difference was largely a result of large numbers of geese and sea ducks that congregated in the estuaries. Those few geese that were found in exposed areas were normally Emperors roosting on sandy beaches of sandspits and barrier islands near estuaries or Brant migrating northeasterly along the coast.

Surprisingly low densities of shorebirds were observed in both protected and exposed areas. The highest densities were those of small shorebirds in the exposed coastal floodplain areas, but since such a small area was surveyed, this does not represent large numbers (just over 1,000) of shorebirds.

Along coastal areas, gulls were more abundant on exposed beaches than in protected waters. They were relatively evenly spaced along the entire beach. Small groups of 10-20 were observed roosting on the sand, feeding in intertidal areas or flying up and down the coast. Occasionally, concentrations of several hundred were found bathing at mouths of streams or roosting on the sand.

Bird densities in North Bristol Bay differed markedly from those on North Alaska Peninsula. Along protected coastlines, total bird densities were almost one-sixth fewer on North Bristol Bay than on North Alaska

Peninsula. Values in other categories were more similar in density but species composition differed. Few geese were observed in North Bristol Bay by comparison, and those seen were predominately Canada Geese. On the 6 May and 13 May North Bristol Bay surveys, there were 73 percent Canada, 16 percent White-fronted, 12 percent Snow and 48 percent Canada, 31 percent Snow, 11 percent Emperor Geese, respectively. By comparison, there were 63 percent Brant and 36 percent Emperor Geese on the 10-12 May survey of North Alaska Peninsula.

Sea ducks were much less abundant in nearshore waters in North Bristol Bay than on North Alaska Peninsula but diving ducks were substantially more dense. On exposed and protected shorelines there were 16.0 and 7.2 diving ducks/km, respectively, versus 0.1 and 4.6 ducks/km in North Alaska Peninsula. Over 96 percent of the diving ducks in North Bristol Bay were Scaup, and 41 percent of the Scaup were found in station 3 or the Flounder Flats area of Nushagak Bay.

Although not evident from the data of coastal surveys, thousands of King Eiders were foraging far offshore throughout Nushagak Bay on May 7. Because of the mild winter in 1976-77, King Eiders were able to winter all along the north side of the Alaska Peninsula and gradually moved farther north as spring progressed. Thousands had been sighted outside of Egegik Bay a couple of months earlier (Bob Gill pers. comm.).

Dabbling ducks were an important component of the avifauna in floodplain portions of both North Bristol Bay and North Alaska Peninsula. Over 90 percent of the dabblers in both areas were Pintails. Use of this region by dabblers may be greater in fall migration, but analysis of data from fall surveys has not been completed for verification.

Densities of shorebirds were much greater in inter- and supratidal areas of Bristol Bay than in similar areas of North Alaska Peninsula. Almost 80 shorebirds/km^2 were recorded in protected upland portions of North Bristol Bay versus only 6.8/km^2 in similar habitat of North Alaska Peninsula. In both cases, it appeared that small-sized sandpipers outnumbered those classified medium-sized shorebirds. However, size determination from aircraft is difficult, and species identification is almost impossible except on larger, more distinct species.

Several interesting observations were derived from the comparison of bird densities in estuaries of North Alaska Peninsula (Table 4). In several estuaries, geese far outnumbered other species present, but goose species composition differed among areas. Most of the geese in Izembek Lagoon were Brant and the remainder were Emperor Geese. Brant were recorded in small numbers in Port Moller, Seal Islands, Port Heiden and Cinder River, but Emperor Geese predominated in these bays. Snow geese were the most numerous species at Ugashik Bay and Canada Geese prevailed in Kvichak Bay.

Dabbling ducks were relatively numerous in only three estuaries: Port Heiden, Ugashik Bay and Kvichak Bay. The two northernmost estuaries were the only areas with comparatively great densities of diving ducks. These densities approximated those found in North Bristol Bay. Sea ducks were widely distributed but densest at Port Moller (particularly in Nelson Lagoon) and Izembek Lagoon. Of the sea ducks identified to species on the North Alaska Peninsula survey, 73 percent were Steller's Eiders and 19 percent Black Scoters. Common Eiders comprised only four percent and Oldsquaw three percent of the total. Mergansers were common only in Kvichak Bay and several hundred were observed in the fresh water of Naknek River.

The densest concentrations of shorebirds were found in Kvichak Bay on the 6 May survey and in Cinder River/Hook Lagoon. Medium-sized shorebirds were more abundant than small shorebirds in both these areas. Cinder River also had the greatest population of large shorebirds (predominately Bar-tailed Godwits).

Gulls were abundant in all estuaries but most dense in the Seal Islands and Nelson Lagoon (Port Moller) areas where numerous sandbars and barrier islands provided suitable nesting habitat. Gulls were the only abundant bird group in the St. Catherine Cove and Hook Bay portions of Bechevin Bay. The tern migration was just beginning at the time of the survey and only low numbers were seen in most areas.

The densest concentration of total birds (704 birds/km^2) in all estuaries was in the Port Moller supratidal areas. This value is inflated in that only a small area (15.8 km^2) of upland was surveyed, and this area was the loafing site for many Emperor Geese and gulls. Most estuaries supported reasonably large bird numbers. Smallest numbers of birds were found in Bechevin and Egegik Bays.

Lower Cook Inlet Shoreline Stations: Sea ducks comprised the largest percentage (64 percent) of birds found on shoreline portions of surveys in Lower Cook Inlet during winter 1977-78. Most common were scoters (all three species combined), followed by eiders and other sea ducks including Oldsquaws and Harlequin Ducks. Black Scoters were the most abundant of those scoters identified, but the composition of large numbers of unidentified scoters cannot be assumed to follow that of those identified. An unexplained decrease in scoter density and percentage occurred between the first and last shoreline surveys. Perhaps migration to summer areas had begun.

Common Eiders were the most numerous eiders, and few of the other eider species were seen along shoreline counts. A marked increase in numbers of Common Eiders occurred from the November to March surveys but total numbers were relatively small. Oldsquaws were most abundant in the March survey and at that time were distributed along the eastern shore from Homer Spit to north of Ninilchik.

Greatest densities of sea ducks were on shoreline Stations 12, 13 and 14 which had mean densities of 43, 14 and 11 birds/km, respectively. Most birds were within 150 meters of the shore. By March many birds (particularly Oldsquaws) moved north into Station 15, and Station 14 had more than Stations 13 and 12. Weather cannot be ruled out as a factor affecting this distribution because northeast winds made the coast from Anchor River to Homer the leeward portion. Conditions were much worse in Kamishak Bay, particularly in November and January. However, a more plausible explanation is that an abundance of food organisms attracted birds to that shore. Winds were not strong in Lower Cook Inlet on the March survey, yet seaducks congregated in the same coastal areas as before.

Few sea ducks were found along the shoreline of the northwest side and in Kamishak Bay. Greatest densities were in Station 9 in January and March and in Station 7 in March. Most were scoters with occasional flocks of Oldsquaws.

Gulls represented the next most abundant bird group in shoreline counts. Glaucous-winged Gulls were the most widespread and were observed on 66 percent of shoreline stations. On the Northwest side, larids were by far the most abundant group. A flock of approximately 200 Mew and Glaucous-winged Gulls remained in the vicinity of Tuxedni Bay and Polly Creek throughout the winter. Relatively large numbers of gulls were recorded for Kamishak Bay during the March survey, but the length of shoreline stations in that area was so small that this may represent an inflated value and may not be typical of other parts of the bay. Of the three regions, gulls were least abundant on the east side of Lower Cook Inlet.

Other species groups were much less abundant on shoreline stations. Although cormorants comprised five percent of the total, the majority were observed on the March survey. That increase may have been the result of severe, prolonged stormy weather prior to the survey that may have "pushed" the cormorants into Lower Cook Inlet from the exposed southern coastline of the Kenai Peninsula. It may also represent seasonal movements by cormorants at that time of year.

Four percent of the total birds seen on shoreline counts were alcids, the majority of which were murres. As with cormorants, most murres were observed in the March survey. The effect of the aforementioned storm on murres was more dramatic and obvious than the effect on cormorants. Just prior to the survey murres were found well inland from Upper Cook Inlet, and substantial numbers of dead and dying murres were found in Resurrection Bay. During the survey, distribution of murres was highly unusual. Two were seen along the shore near Nikiski on the east side of Lower Cook and as high as Station 3 on the west side. For that time of year, this distribution would be entirely unexpected. While flying the March survey we observed about 24 dead, floating murre-like birds. More were reported in Kachemak Bay by fisherman in boats.

<u>Lower Cook Inlet Pelagic Transects</u>: As with shoreline stations, sea ducks comprised almost two-thirds of all birds recorded on pelagic transects. However, eiders were almost as abundant as scoters, and other sea duck species, particularly Oldsquaw, made up a larger percentage of the total. Sea ducks preferred nearshore waters to those offshore. They were one-third as abundant on pelagic transects as on shoreline stations.

The composition of sea ducks did not change between surveys and within regions in a regular pattern. In Kamishak Bay, eiders predominated in November, Oldsquaw in January and numbers were more equal in March. On transects across the inlet in January, scoters were the most abundant sea duck, but in March eiders predominated.

The scoters in January were largely found in two locations on the trans-inlet transects. One location was west of Point Pogibshi and the other southwest of Bluff Point. Both areas have been recognized in the past as having scoter concentrations in winter. This is the third consecutive winter that scoters, particularly White-Winged scoters, have been observed in the area southwest of Bluff Point. This area was also used by Steller's and Common Eiders but in lesser numbers.

On the two outer Kachemak Bay transects, sea ducks were less abundant than other bird species (7.7 vs 16.3 birds/km^2). Scoters were only slightly more numerous than eiders (4.0 vs 2.9 birds/km^2), and few Oldsquaws and Harlequin Ducks were recorded.

Gulls were densest (9.4 birds/km^2) in the November survey of Outer Kachemak Bay. This represented the second highest density of birds in all three winter pelagic surveys. Gulls were eight times more dense in Outer Kachemak Bay than in Kamishak Bay. Twelve percent of the birds in Kamishak Bay were gulls while in Outer Kachemak gulls made up 24 percent. During a survey on 1 April 1976, this species composition was reversed. Only one percent of the birds in Kachemak Bay were gulls while 18 percent were gulls in Kamishak Bay (Arneson 1976b).

Alcid distribution was more consistent. Only a few were counted in all three surveys of Kamishak Bay, and there were similar findings in the 1976 survey. Moderate numbers were found on transects across the inlet, but highest densities were recorded in Outer Kachemak Bay. The highest density, 17.5 birds/km^2, was found on the March 1978 survey. Forty-two percent of the birds observed in Outer Kachemak in the three surveys were alcids. Common Murres far outnumbered the next two most abundant alcids-Pigeon Guillemots and murrelets.

Other species or groups made up an insignificant proportion of the total birds in pelagic transects in comparison to the previously discussed groups. Interestingly, shearwaters were still present in Lower Cook Inlet in November when four were observed in Transect Q. Northern Fulmars, surprisingly, were only observed on the January survey and then only in small numbers (six).

VII. Conclusions

Bristol Bay: The importance of the Bristol Bay region to migrating birds was further substantiated by surveys conducted in May 1977. Over 200,000 birds were enumerated along coastal areas of North Alaska Peninsula and North Bristol Bay. Densities as high as 704 birds/km^2 in supratidal sedge/grass habitat and 236 birds/km along coastal beaches were recorded.

Protected waters of estuaries and river deltas supported the greatest densities of most species. Much variability in bird densities and species composition existed among estuaries in the region, and it was obvious that each bay, lagoon and delta had its own intrinsic value to particular species or groups. The most important habitat types within protected waters are intertidal mud/sand flats and sedge/grass meadows that are occasionally flooded by storm tides. Nearshore subtidal areas also likely supply large proportions of diving and sea duck food organisms.

Brant were the single most abundant bird species along the coast in May 1977. Almost all were found in Izembek Lagoon. Emperor Geese and Steller's Eiders were next in abundance and most of these birds were found in estuaries from Port Heiden south. Canada, White-fronted and Snow Geese were more abundant in North Bristol Bay and as far south as Ugashik Bay on North Alaska Peninsula.

In spring, shorebirds are more dense on the northern portions of the region, particularly in Kvichak Bay. Small sandpipers are slightly more abundant than medium-sized shorebird species. Black-bellied Plovers and Rock Sandpipers were the most abundant medium-sized shorebirds that we identified.

The dynamic nature of spring migration was evident when stations in Kvichak Bay and Cinder River were reflown two to six days after the initial survey. Large numbers of Canada Geese, Pintails and Black-bellied Plovers that were present on intertidal and supratidal areas on the 6-7 May surveys were almost gone by 10 and 13 May. There also appeared to be differential migration corridors used by birds. Shorebirds, Canada, White-fronted and Snow Geese, and Pintails likely migrated overland to use the north portion of Bristol Bay whereas others like Emperor Geese, sea ducks and loons followed much of the coastline throughout the area, and others like Brant usedonly a few areas on North Alaska Peninsula and then traveled over Bristol Bay to nesting or other staging areas.

Gulls were the only species group that were as abundant or more abundant along exposed coastline as in protected waters. This species group was normally second or third in abundance for all survey types and locations, and therefore was an important part of the avifauna of the region.

Further analysis will determine differences in species composition and densities between spring and fall migration. Some species use the region more in the fall than spring and vice versa. Nonetheless, this coastline is extremely valuable to staging birds to provide sufficient energy stores for migration.

Lower Cook Inlet: As a result of aerial bird surveys in Lower Cook Inlet during the 1977-78 winter Outer Kachemak Bay was determined to be by far the most important region for wintering birds. The greatest species diversity and highest densities were found on both pelagic transects and shoreline counts in that region during the 1977-78 winter. These high coastal densities extended northward to Anchor River and beyond. The most abundant species found in this area (scoters, alcids, eiders and larids) will be susceptible to oil if spills occur in the region. For the third consecutive year a concentration of scoters was observed south of Bluff Point, and the area appears to be very important to several thousand birds.

Kamishak Bay had much lower densities, and concentrations were found in varying locations on the three identical surveys. Sea ducks were the predominate species group although the composition consisted of more eiders than scoters as opposed to more scoters than eiders in Kachemak Bay. Few alcids or other species vulnerable to oil spills were found in the region.

Low densities of wintering birds were found in open water between Kamishak and Kachemak Bays and along the shoreline of Northwest Lower Cook Inlet. The only concentration was a flock of gulls that remained near Tuxedni Bay all winter, but ice conditions in a "normal" winter may preclude their presence in the area. Large flocks of eiders and possibly other birds were apparently missed on our 3 March survey. The previous day during a survey of marine mammals, Don Calkins reported seeing hundreds of eiders in Kamishak Bay and another large flock of unidentified birds between Anchor Point and Chinitna Bay in open water. Although our transect pattern thoroughly covered Kamishak Bay, we did not see such concentrations. Diel movements must have put the birds out of our line-of-sight but still within Lower Cook Inlet. Because of this discrepancy, it is possible that our survey techniques and results did not reflect an accurate picture of what was present.

For the second consecutive winter, relatively mild temperatures prevailed in the Gulf of Alaska, and what effects that may have had on bird distribution and abundance are unknown at present. Severe winds persisting for several days before the last survey also may have affected bird distribution and definitely caused natural mortality in Common Murres.

IX. Summary of 2nd Quarter Operations

A. Aircraft activities

1. Field trip schedule: A combination shoreline/open water survey was conducted in a chartered Grumman Widgeon on 12 January 78. An identical survey was flown on 3 March 78.

2. Scientific party: For both surveys, bird observers were Paul Arneson and Marilyn Allen, Alaska Department of Fish and Game, Anchorage, Alaska.

3. Methods: The same methods described earlier in this report were used in surveys during this quarter.

4. Localities: The same shoreline stations and pelagic transects were surveyed as those shown in Figure 2.

5. Data collected: In both surveys 17 shoreline stations totaling 375 km and 18 pelagic transects totaling 650 km or 130 km^2 were flown. A minimum of 24 species and 2,821 individuals were observed on the January bird survey and 27 species with 3,150 individuals were observed in the March survey.

An experimental analysis was submitted to NODC/EDS to test the feasibility of using that type of analysis in the final report. This included mapping distribution and abundance of bird species. A computer program was written for summarizing bird distribution and abundance in Bristol Bay.

6. Milestone chart: See Table 12 for an updated version of planned and completed research and data management for Fiscal Year 1978.

   Two slippages in last year's Milestone Chart occurred. One was a planned (or hoped for) bird survey of the Aleutian Shelf region in summer 1977. Due to increased aircraft costs, money for bird surveys was expended before this flight could be conducted. It is expensive to fly this area since a twin-engine, amphibious aircraft is necessary, and insufficient funds were available to do a suitable job.

   Secondly, I had hoped to be able to find time enough to summarize the past two years' work into final report form before beginning the Lower Cook Inlet work. The workload of a continuing field season, frequent meetings and an unforeseen problem with habitat coding errors precluded the completion of a report.

B. Problems encountered/recommended changes

During this quarter weather posed the greatest problem. Although weather predictions were favorable for the first two bird surveys, when we got to Kamishak Bay sea states were higher than is desirable for bird surveys. Consequently, birds may have been missed making our counts lower. Identification of birds was also more difficult, but it was not felt that a substantial underestimation of numbers resulted from the poor survey conditions.

The winter, in general, was milder than normal and may influence the outcome of our surveys. It is unknown whether our counts would be decreased (or increased) in a more severe winter.

Prior to the March survey, a severe storm (high winds) in the Gulf of Alaska had lasted for almost two weeks. This obviously changed the distribution pattern of some birds (as reflected by unusual Common Murre sightings), but the overall effect on our survey results is unknown.

The unavoidable problems with logistics and data management occurred this quarter as in the past, but are not major enough to elaborate.

MILESTONE CHART

Table 12.

Project Research Unit #3 Principal Investigator Paul D. Arneson Date FY 1978

	Quarters											
	1			2			3			4		
Major Milestones	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Lower Cook Inlet Winter Bird Surveys		▲		▲		▲						
Kamishak Bay Spring Waterfowl Surveys							△					
Kamishak Bay Spring Shorebird Surveys								△				
Kamishak Bay Bird Colony Field Work									○	○	○	
Summarization of Summer Field Work												⬡
Quaterly Reports			■			■			□			□
Annual Reports						■						

Milestones: ▲ Completed

△ Proposed

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APPENDIX I

Because results of the June-July 1977 field work in the Walrus Islands, Bristol Bay were thoroughly summarized in the Quarterly Report dated 30 September 1977, they will not be reiterated here except for the following two tables. These give basic information of seabird abundance on colonies and use of nearshore waters by marine birds. A publication is planned that will give more specific information on birds in the Walrus Islands.

APPENDIX II

Marine mammal observers W. L. Cunningham and M. S. Stanford arrived at Cape St. Elias, Kayak Island, Northeast Gulf of Alaska on 7 March 1977 to begin sea lion observations under RU #243. In addition to their duties concerning sea lions, they collected marine bird information. This included both local use of the area by birds and spring migration information. Stanford remained on the island until 27 April and Cunningham left 14 June. Some of the data they collected are shown in Table 1 and Figure 1.

Although information from this region was not a part of the objective of RU #3, it was felt important enough to include here because it gives us a much better understanding of what is happening in NEGOA. These data complement those being gathered on the Copper River Delta by other ornithologists.

Table 1. 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

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

Table 1. Appendix II. Total number of birds observed during 211 sea watches from 14 March to 14 June 1977, Cape St. Elias, Kayak Island, Alaska.

Species	Total No.	Species	Total No.
Common Loon	9	Surf Scoter	2,070
Arctic Loon	196	Black Scoter	414
Red-throated Loon	9	Red-breasted Merganser	47
Loon (Unid.)	14,051	Black Oystercatcher	43
Horned Grebe	4	Whimbrel	72
Shearwater (Unid.)	3,072	Western Sandpiper	16
Fork-tailed Storm-Petrel	1	Parasitic Jaeger	1
Leach's Storm-Petrel	40	Long-tailed Jaeger	1
Double-crested Cormorant	65	Jaeger (Unid.)	3
White-flanked Cormorant	431	Glaucous-winged Gull	1,533
Cormorant (Unid.)	79	Herring Gull	6
Goose (Unid.)	39	Black-legged Kittiwake	
Canada Goose	220	Northerly	25,255
Brant	292	Southerly	12,057
Mallard	68	Common Murre	1,242
Pintail	1,608	Pigeon Guillemot	2
Green-winged Teal	80	Marbled Murrelet	96
Northern Shoveler	34	Kittlitz's Murrelet	1
Scaup (Unid.)	854	Tufted Puffin	713
Goldeneye (Unid.)	6	Alcid (Unid.)	8
Oldsquaw	3	Tree Swallow	2
Harlequin Duck	60	Common Raven	3
White-winged Scoter	268	Savannah Sparrow	1

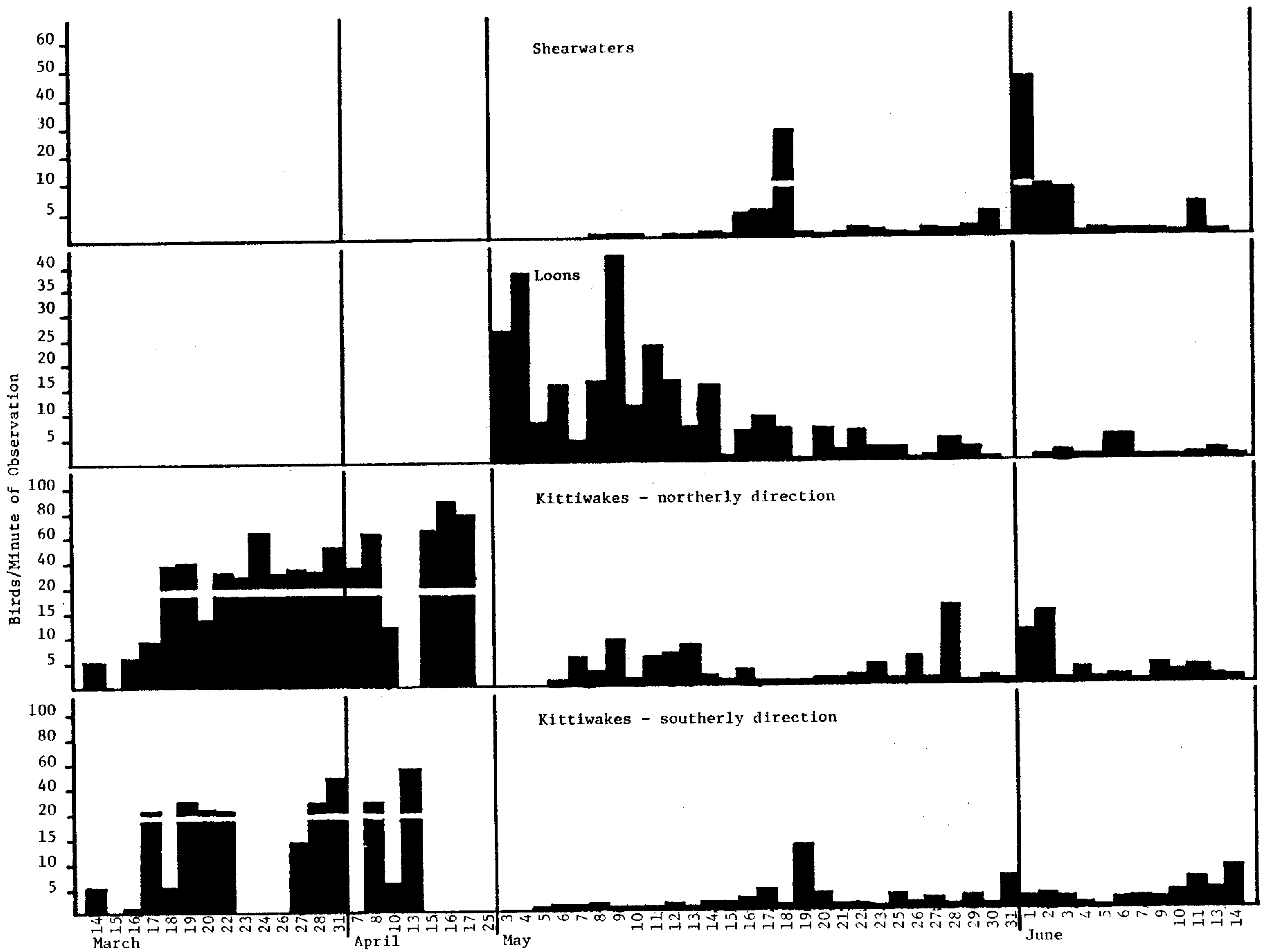

Figure 1. Appendix II. Migratory patterns of bird species/groups from sea watches at Cape St. Elias, Kayak Island, Alaska, Spring, 1977.

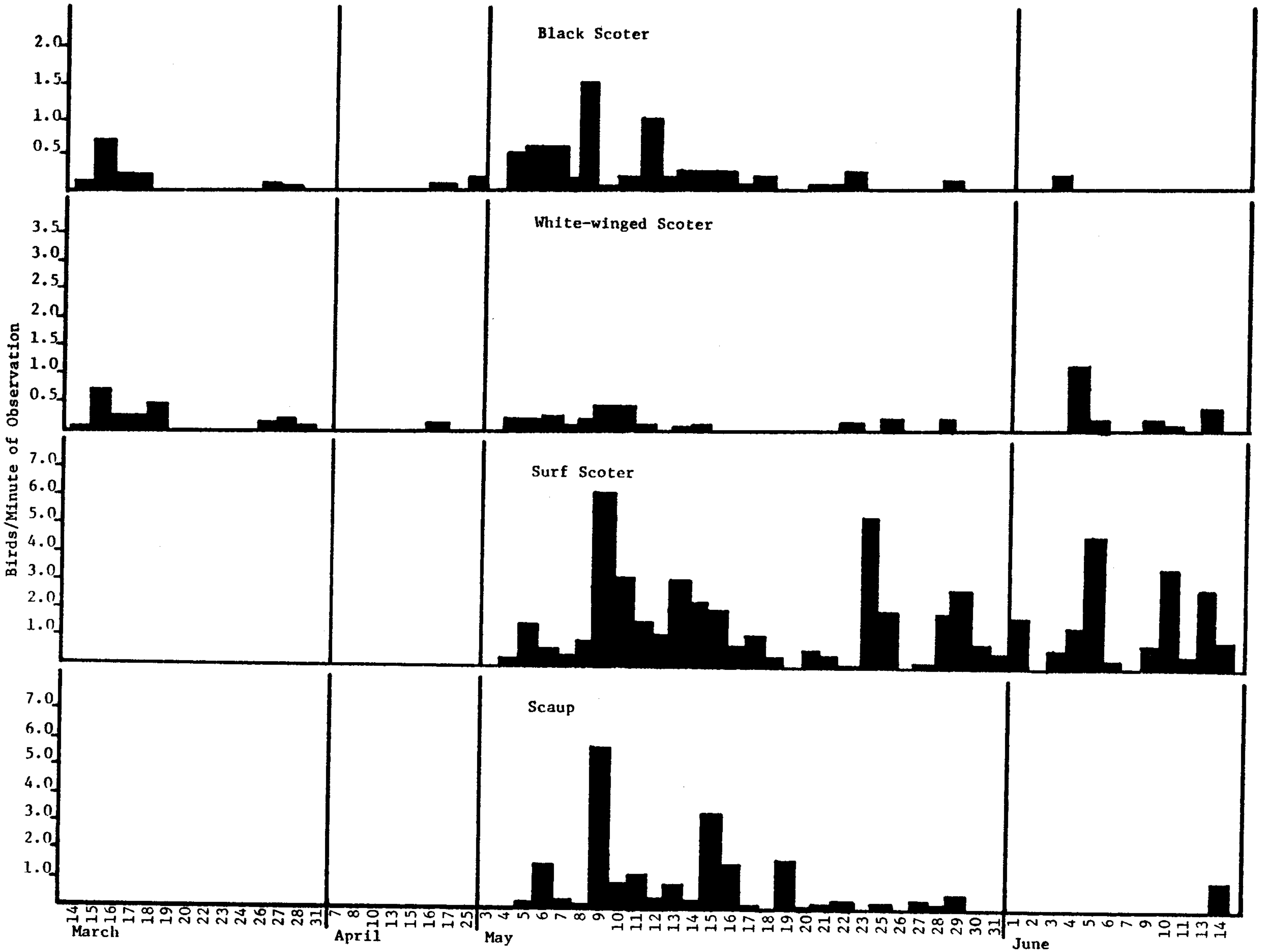

Figure 1. Appendix II (continued).

The same researchers departed mid-March 1978 to again gather marine mammal/bird data at Cape St. Elias until mid July.

During their stay in 1977, they conducted 211 Type II sea watches totaling 37.2 hours. A minimum of 41 species were recorded during sea watches. Observations made at other times, including during hikes into the interior of the island, resulted in recording an additional 38 species, for 79 species total.

The table and figure are only a cursory summarization of the data. Complete analysis and summarization will be done when the second field season is completed. A week of observation was missed between 25 April and 3 May, and there is therefore a substantial gap in the data which will hopefully be filled this year. That period is when many species are migrating. Included in the graphs are only species exhibiting a migratory pattern. Several species--including Cormorants, Glaucous-winged Gulls, Common Murres and Tufted Puffins--nest in the area and therefore would move back and forth across the sea watch observation post. Their movements were not graphed. The label--birds/minute of observation--was used to standardize the data. Because observation times frequently varied from day to day, the information had to be put on a standard base.

Early in the season, Black-legged Kittiwakes exhibited diel movement patterns moving north of the island (toward the gyre?) in the morning and returning to somewhere south of the island in the evening. This was a substantial migration involving thousands of birds, and it is unknown at this time what was represented by the movement. It could be hypothesized that they headed north to feed all day and returned to bathe, preen and roost at a fresh water source in the evening. A movement of this type at Crooked Island was suggested by Arneson (1977b).

APPENDIX III

Although not a part of the objectives of this research unit, information on birds utilizing Tugidak Island at the south end of Kodiak Island was summarized using existing data from the area. A table of that information follows. It is an area that may be affected by oil and gas development, and therefore I considered it beneficial to include the table. More specific information by ornithological studies on Tugidak Island would be helpful.

Partial List of Birds of Tugidak Island

Species	Use	Habitat	Season	Source
Common Loon	N	U, O	S, Su	1, 3
Red-throated Loon	F	U, O	Su	3, 5
Cormorant Red-faced and/or Pelagic	N, F	O, Z	S, Su, F	3
Whistling Swan	N	U, B	S, Su	3, 4, 5
Emperor Goose	W	S, L	W	2
Mallard	M, SN?	U, B	S	4
Gadwall	M	U, B	S	4
Pintail	N	U, B	S, Su	4
Green-winged Teal	M	U, B	S	4
American Wigeon	M	U, B	S	4
Scaup spp.	M	U, B, L	S	4
Old Squaw	M, W	L, O	W	2
Harlequin Duck	F	O	S	4
Steller's Eider	W, M	L, O, U?	W	2, 4, 5
King Eider	W	L, O	W	2
Surf Scoter	W	O	W	2
Black Scoter	W	L, O	W	2
Red-breasted Merganser	N	U, B	Su	4, 5
Rough-legged Hawk	N	T	S, Su	4, 5
Bald Eagle	N, W	T, S	W, S, Su, F	1, 2, 3, 4, 5
Marsh Hawk	M	T, C	F	3
Osprey	N	T	Su	1
Peregrine Falcon	N	T	S, Su	1, 5
Willow Ptarmigan	N, W	T, C	W, S, Su, F	1, 3, 5
Semipalmated Plover	N	S, L	Su	3, 4, 5
Wandering Tattler	M	Z	Su	5
Northern Phalarope	SN, M	U	S, Su	3, 4, 5
Common Snipe	SN, M	U	S, Su, F	3
Short-billed Dowitcher	SN, M	U, C	S, Su	3, 4, 5
Western Sandpiper	M	Z	Su	5
Least Sandpiper	N	T, Z	Su	1, 4, 5
Rock Sandpiper	M, W?	L, Z	Su, W?	5
(Small Shorebird)	W	S	W	2
Parasitic Jaeger	N	T, S, C	S, Su	1, 3, 4, 5
Long-tailed Jaeger	N	T, S, C	S, Su	1, 3, 4, 5
Glaucous-winged Gull	N, W	S, C, Z, L	W, S, Su, F	2, 3, 4, 5
Mew Gull	N, W	S, C, Z, L	S, S, Su, F	2, 3, 4, 5
Black-legged Kittiwake	F	O	S	4
Arctic Tern	N	S, C, Z, L, B	Su	3, 4, 5
Common Murre	F	O	Su	5
Pigeon Guillemot	F	O	Su	4
Horned Puffin	FD, F?	O	Su	5
Tufted Puffin	FD, F?	O	Su	3, 5
Short-eared Owl	N	T, C	Su	1, 3, 4, 5

Partial List of Birds of Tugidak Island (cont'd.)

Species	Use	Habitat	Season	Source
Violet-green Swallow	M	B, U	S	1
Bank Swallow	N	Z, B, U	S, Su	3, 5
Common Raven	SN?, F	T, S, C, Z	Su	3, 5
Northwestern Crow	F	S, C, Z	Su	1, 3
Rusty Blackbird	M	T, U	F	3
Grey-crowned Rosy Finch	M	T, Z	Su	1
Savannah Sparrow	SN	T, C	S, Su	3, 4, 5
Dark-eyed Junco	M	T	S	1
Golden-crowned Sparrow	M	T	S	3
Fox Sparrow	M	T	Su	5
Song Sparrow	N	T, Z, C	S, Su	1, 4
Lapland Longspur	SN	T, C	S, Su	1, 3, 4, 5

Use:

- N nesting
- SN suspected nesting
- M migration
- W wintering
- F feeding nearshore
- FD found dead

Habitat:

- S sand dune/spit
- T tundra
- B brackish pond
- U upland pond
- L lagoon
- C coastal meadow
- O ocean
- Z beaches, bluff

Season:

- S Spring(Apr.,May)
- Su Summer(Jun.-Aug.)
- F Fall(Sep.-Nov.)
- W Winter(Dec.-Mar.)

Source:

1	Bishop-Lortie	25 April-31 July, 1964
2	Arneson-Berns	28 February, 1976
3	Johnson-Johnson	Summer, 1976
4	Harrison-Wohl	28-29 May, 1977
5	Kelly-Lynn	Summer, 1977

Assumed Red Phalarope and Long-billed Dowitcher of Johnson-Johnson were actually Northern Phalarope and Short-billed Dowitcher.

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

I. Breeding bird use of barrier islands in the northern Chukchi and Beaufort Seas

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1 April 1978

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I. Summary of objectives, conclusions and implications with respect to OCS oil and gas development

Between Cape Lisburne and Demarcation Point there are over 60 barrier islands and spits in the nearshore waters of the Chukchi and Beaufort seas. These islands and spits provide a unique seabird nesting habitat that is not found elsewhere in the state of Alaska. Because the islands offer ideal platforms for drilling rigs and causeways, the exploitation of oil and gas from beneath the Chukchi and Beaufort seas will result in increased human activity on and next to the islands. In 1976 a survey of these islands was conducted in order to determine the importance of these islands to nesting birds. Information on breeding phenology and clutch size was also obtained.

A total of 1,900 nests of seabirds was found. Common Eiders were the most abundant species with 1,006 nests. Glaucous Gulls were next in abundance with 474 nests being found. Six other seabird species nested on the islands in lesser numbers. The single most important factor in determining the importance of an island to breeding birds is the timing of breakup of ice surrounding the island. For this reason, islands near river mouths receive the heaviest use. Early breakup prevents fox from visiting the island and preying on eggs and chicks. While only minimal time could be spent studying the substrate and cover needs of nesting birds it is obvious that they play an important though secondary role.

While the total number of nests on barrier islands is low when compared to the overall bird resources of the Arctic coast of Alaska, the number of nests is large when the low productivity of the nearshore waters in early summer is considered. Islands that are known to support a large population of a single species or small populations of a number of species can be considered to be unique or critical habitats. Steps should be taken to minimize the impacts on such islands or to schedule human activities when breeding birds are not present. Islands with smaller populations should also be protected but restrictions on human activity need not be as severe.

Because this study identifies which factors are most important in determining the use of islands by breeding birds, it may be possible to increase bird numbers by substrate and cover manipulation on selected islands. Such manipulation would lessen the impact that man's activities will have in reducing the overall number of birds breeding on the islands.

II. Introduction

A. General nature and scope of study

One of the primary problems faced by Arctic seabirds during the breeding season is predation on eggs and chicks by arctic fox (*Alopex lagopus*). A variety of nesting patterns has evolved to deal with this problem. These have been summarized by Larson (1960). A number of species nest on rock cliffs or in talus slopes that are inaccessible to fox. Another group nests on nearshore islands with the nests usually being placed on flat ground. The latter group includes Oldsquaw (*Clangula hyemalis*), Common Eider (*Somateria mollissima*), Sabine's Gull (*Xema sabini*), Glaucous Gull (*Larus hyperboreus*) and Arctic Tern (*Sterna paradisaea*). All of these species are also found breeding on mainland tundra. In the case of the gulls and tern, however, the majority of nests on the mainland are located on islands in ponds and rivers.

The Arctic coast of Alaska from Cape Lisburne to Demarcation Point has little coastal relief with low tundra directly abutting the sea. Over 60 barrier islands are found along this section of coast with an additional 15 major spits that are connected to the mainland but which in many ways provide the same habitat as that found on barrier islands. Barrier islands are typically long, narrow sand and gravel bars with their long axis paralleling the coast. Vegetation is usually sparse or lacking. These islands are used as breeding sites by the island-nesting seabirds mentioned above. In order to determine the extent of this use a census was conducted in 1976 to obtain information on the number of nesting birds, nest site selection and breeding phenology.

All information obtained by this study has been sent to the U.S. Fish and Wildlife Service in Anchorage for inclusion in their colony catalogue being generated as part of R.U. 338.

B. Specific objectives

The specific objectives of this study were:

(1) To determine the species and numbers of birds breeding on islands and spits along the northern Alaskan Chukchi and Beaufort Sea coasts.

(2) To determine what physical and environmental parameters determine the species and numbers breeding on these islands.

(3) To determine the phenology of use by breeding birds with respect to dates of occupation, laying, hatching and fledging.

C. Relevance to problems of petroleum development

Barrier islands and sand and gravel spits connected to the mainland can be expected to undergo a variety of impacts as a result of petroleum exploration and exploitation. Their location in the nearshore waters makes them ideal platforms for oil wells. They will, in some instances, eliminate the need for artificial islands or the use of drilling platforms designed to withstand the pressures of moving pack ice. Their composition and shape make them ideal causeways for roads or pipelines. The gravel found on many islands is of use to industry for the construction of roads and pads on the mainland.

In addition to the above direct impacts on barrier islands, there will be increasing aircraft traffic over and to and from the islands thus increasing the disturbance of breeding birds. The yearly barge traffic to Prudhoe Bay has forced the Coast Guard to erect aids to navigation on a number of islands. Some of these need to be serviced every summer thus causing disturbance during a critical time for breeding birds.

A knowledge of which islands are most important to breeding birds and when they are most important will allow human activities to be planned to minimize impacts on the barrier island breeding populations.

III. Current state of knowledge

The only previous major survey of breeding birds on the northern Alaskan barrier islands is that of Gavin (1976) who censused the islands from Harrison Bay to Camden Bay (Thetis Island to Flaxman Island) from 1970 to 1975. Almost all other censusing has been opportunistic in nature. Bartonek (unpublished) censused a number of islands in the Beaufort in 1971. Divoky et al. (1974) reported on Black Guillemot (*Cepphus grylle*) breeding on barrier islands in 1972. They also obtained information on other species breeding on some of the islands. Schamel (1974) censused the breeding birds of Stump and Egg Islands in 1971 and 1972. Schmidt (1970) censused the islands off the eastern coast of the Arctic National Wildlife Refuge.

IV. Study area

The 1200 km of coastline from Cape Lisburne to Demarcation Bay has a rather homogeneous nearshore environment. Sea ice is present and coverage complete or nearly complete from October to late May. Ice decomposition occurs from June to late July. Breakup of ice in the lagoons usually precedes breakup of ice on the seaward side of the island by one to two weeks. Water near the islands is ice free or nearly so in August and September.

One of the major events in the nearshore area that affects species breeding on barrier islands is the river overflow that typically occurs in late May. The shorefast ice prevents rivers from flowing directly into the sea and rivers empty on top of the nearshore ice flooding the area near the mouth of the river. Thus areas near river mouths have open water at least one month earlier than inshore areas that are unaffected by river runoff. The river runoff remains on top of the ice a number of days and then flows down through the ice as soon as cracks and holes form. A deposit of detritus is left on top of the ice. This decreases the albedo and increases the rate of melting of the ice and adds to the early breakup of ice near river mouths. This early breakup is important to species breeding on the islands since it isolates some islands early in the year and prevents fox from visiting the islands during breeding. In areas unaffected by river runoff islands do not become surrounded by water until a moat is formed around the islands. The absorption of solar radiation by islands melts the ice immediately adjacent to the island thus forming a moat. The size of the moat increases slowly and in the Beaufort the moat usually is a distinct structure until mid-July when breakup of near-shore ice begins to occur at a rapid rate.

A major difference in the islands in the Chukchi and Beaufort is the well developed vegetated dunes found on most Chukchi islands and absent on Beaufort islands. Such dunes may be correlated with the greater wave action present in the Chukchi. The islands in the Chukchi, especially south of Icy Cape, have wide sloping beaches seaward of the dunes which are usually found in mid-island. Islands in the Beaufort have narrow beaches and no similar dunes. They usually have little if any vegetation.

V. Sources, methods and rationale of data collection

An attempt was made to visit the islands during the period when eggs were present in the greatest number of nests. Transportation to islands was done by zodiac raft, canoe and helicopter. Each of the islands was censused by foot. The clutch size of each nest was determined and a sample of eggs was floated to determine approximate dates of laying and hatching. This method of egg flotation is described in Hays and LeCroy (1971). Whenever possible, information was obtained on nest placement in relation to cover and substrate.

The visibility of nests varies among the species. In general, for Black Brant, Glaucous Gull and eiders all nests can be located in one visit. Old-squaw and Black Guillemot are less obvious and approximately 90 percent of the nests of these species will be located. Sabine's Gull and Arctic Tern nests are usually found by locating territorial pairs and then searching for the eggs. Approximately 75 percent of these species would be found in a single search. The primary purpose of our censusing was to determine the use of barrier islands by breeding seabirds and passerine nesting was recorded only incidentally.

VI. Results

A. Geographic accounts

The species and numbers of birds found breeding on barrier islands in 1976 is given in Table 1. The locations of the islands are shown in Figures 1-20.

1. Cape Lisburne to Kasegaluk Lagoon (Figures 1-3)

No barrier islands are present in this section of coastline. Spits associated with enclosed lagoons and stream mouths provide a small amount of nesting habitat for the species under consideration. Only a small number of Arctic Terns has found on these spits in 1976.

2. Kasegaluk Lagoon (Figures 3-6)

Kasegaluk Lagoon and its associated spits and barrier islands are the largest such land form in the world being almost 200 km in length. There are a number of rivers and streams that enter into the lagoon, the Utokok and Koklik being the two largest.

Islands in this chain are subjected to the most wave action of any of the islands censused. Seaward beaches are characteristically wide with a gentle slope. Low vegetated sand dunes are usually present on the mid-line of the islands. Dune vegetation is principally *Elymus* sp. On the lagoon side of the islands patches of *Carex* sp. and *Puccinellia* sp. are present at the water's edge. On a number of islands vegetation is stabilized enough for fox dens to be present. A number of dens were found on our 1976 visits.

Human use of these islands is not extensive. The village of Pt. Lay was located on a barrier island until recently when it was relocated on the adjacent mainland. Natives from Pt. Lay still camp on the island during the summer and "egg" the surrounding area. In 1976 an oil exploration company was using the abandoned DEW-line site at Icy Cape. At times when there was a land connection between the mainland and the islands personnel from the camp took track vehicles to the island.

All of the islands are used by breeding birds. Arctic Terns breed on all the islands with a total of 96 nests being found. Common Eider were found on all islands with the highest densities being found on Solovik Island and on the island east of Akoliakatat Pass. Both these islands are associated with areas of river overflow.

3. Kasegaluk Lagoon to Barrow (Figures 6-9)

The spits associated with the mouth of Wainwright Inlet and the spits and islands next to Peard Bay are the only suitable nesting areas for the species being considered. J. Burns (pers. comm.) reported numbers of Oldsquaw nesting at the mouth of Wainwright Inlet in past years but these spits were inundated with water at the time of our 1976 visit.

Point Franklin spit had only one Arctic Tern nest on it but it is isolated enough from the rest of the mainland that in some years nesting may be more common.

Only one of the Seahorse Islands has a suitable habitat for breeding birds. A series of atypically high dunes (5m) is present on approximately a hectare of the island. The dune is coverd by *Elymus arenarius* and *Puccinellia* sp. During the summer Eskimos regularly camp at an abandoned DEW-line station at Peard Bay. They usually visit the Seahorse Islands early in the summer in order to obtain eggs. This occurred in both 1975 and 1976 and is the reason the nest totals in Table 1 are so low. In 1977 when no egging occurred the following nests were found on a 1 August visit.

	nests
Arctic Tern	34
Common Eider	5
Black Guillemot	4
Oldsquaw	2

All of the nests were located in or directly next to the vegetation on the dunes.

4. Point Barrow spit and the Plover Islands (Figures 9-10)

Point Barrow spit and the Plover Islands enclose Elson Lagoon. The spit and islands are gravel with most areas devoid of vegetation. Except for Cooper Island there is little driftwood or similar cover on the islands. A large barge is present on Deadman Island and all of the Black Guillemot nests were under it. While the Plovers are a major group of barrier islands they differ from other such islands because there is no river that affects the area immediately surrounding the islands. Two large rivers enter into Dease Inlet and another into Iko Bay but their mouths are not close enough to directly affect the area near the islands. For this reason the islands lack both Common Eider and Glaucous Gulls. Doctor Island shown on charts is either gone or is now part of Deadman Island.

A large quantity of man-made debris on Cooper Island provides nests for an increasing Black Guillemot population. The Arctic Tern colony is also closely associated with the debris and may be the reason the colony is the largest in the study area.

The breeding birds of Cooper Island have been studied intensively since 1975 as part of R.U. 196.

5. Eskimo Islands (Figure 12)

These islands are remnants of the mainland tundra. They are covered with tundra vegetation and have mud sides. None of the species considered by this study were found during a visit in 1972.

6. Thetis Island to Flaxman Island (Figures 13-16)

This area contains 34 barrier islands. A number of islands in this area have a considerable coverage of vegetation. These include Pingok, Bodfish and Flaxman. Fox dens are present on a number of these islands. Human use of these islands has been regular in recent history. Thetis Island has a cabin on it and has been used as a fishing camp. Pingok also has a cabin on it and has been used as a field camp by investigators from the Naval Arctic Research Lab. Cross Island has the remains of a cabin on it and Flaxman Island has Leffingwell's cabin, a state historical site. Gull Island has undergone major changes in shape as part of oil activities.

The Colville and Sagavanirktok Rivers have major overflows of water on the nearshore ice in spring. There are also a number of other rivers that empty into this section of coastline so that breakup of nearshore waters is substantially earlier than other areas. Common Eiders and Glaucous Gulls are the primary species in this area. The close association of these two species with areas affected by river overflow will be discussed in the species accounts.

7. Camden Bay to Demarcation Point (Figures 17-20)

The Beaufort coast from Flaxman Island to the Hulahula River has no major barrier islands. East of Barter Island, however, there is a major system of barrier islands. All of the islands west of Icy Reef are rather narrow and low, and for this reason are poor quality nesting habitat. Part of Nuvagapak Island was under water during our 1976 visit. Icy Reef is quite different from any other of the islands censused. It has large stones making up much of the west end. Large pieces of driftwood are also found on Icy Reef due to its proximity to the mouth of the Mackenzie River. As in other areas the most important islands are ones that are close to river mouths. Icy Reef has a large area of ice on its southern side that persists for most of the summer. This allows fox to visit the island during the breeding season.

B. Species Accounts

1. Black Brant (Figures 21 and 22)

The Black Brant is a maritime goose that reaches its highest breeding densities on wet tundra on the mainland. It is especially abundant in river deltas. During the non-breeding season Brant are found in salt marshes and littoral habitat. We found a total of 110 nests on 9 islands. Black Brant breed early in the summer and some of our visits to the islands occurred after young had left the nest. The adults and young form large groups and remain on the islands so we were able to estimate the number of nests by counting young.

All areas where Black Brant were found breeding were near the mouths of large rivers. In the Chukchi Sea the only nests were found at the mouth of the Utokok River (Figure 21). Nests in the Beaufort were at the mouths of the Colville, Sagavanirktok, and Egaksrak Rivers (Figure 22).

Adult Brant undergo a flightless period shortly after the young leave the nest. Because new flight feathers must develop before the fall migration, it is important that breeding occur early in the season. This is apparently the reason that nesting was found only at river mouths. The availability of food appears to have no effect on breeding localities since *Carex* sp. and *Puccinellia* sp. are present on the landward beach of most barrier islands.

Egg laying on the barrier islands occurred from 14 to 23 June in 1976 (Figure 35). Bergman et al. (1977) found Brant on the tundra near Prudhoe Bay initiating laying between 5 and 18 June. Clutch sizes in 1976 were similar to other studies. The 47 nests at the mouth of the Sagavanirktok River had 4.5 eggs per nest. Bergman et al. (1977) found an average of 5 eggs per nest west of Prudhoe Bay. Palmer (1976a:366) gives the average clutch size as 4.5 eggs per nest.

2. Oldsquaw (Figures 23 and 24)

Oldsquaw are a ubiquitous part of the coastal avifauna in northern Alaska. They are common to abundant as a breeding bird on the tundra and are found in nearshore waters as soon as river mouths become open and moats begin to form along the mainland and around barrier islands. In July and August they roost in large numbers on the barrier islands.

Oldsquaw nest in surprisingly low numbers on barrier islands. A total of 46 nests was found on 10 islands. A total of nine nests was found on Kasegaluk Lagoon in an area affected by river overflow (Figure 23). In the Beaufort Sea, 12 nests were found on the Plover Islands, one on Lion Point and 18 on Egaksrak Island (Figure 24). Oldsquaw breeding distribution does not appear to be related to areas of river runoff as is true for the other two waterfowl species that breed on barrier islands. While the nests in the Chukchi were at a location where river runoff occurs early, 12 nests were found on the Plover Islands where no early river runoff occurs and breakup occurs late in the season. It may be that Oldsquaws nest on islands where

Arctic Terns are present in numbers. In the Chukchi Sea all Oldsquaw nests were on islands with Arctic Tern colonies of over 10 nests. No Oldsquaw nested on Seahorse Island in 1976 where only 12 Arctic Tern nests were present. In 1977 35 Arctic Tern nests and 2 Oldsquaw nests were found. The Oldsquaw nests on Cooper Island are all located in close proximity to Arctic Terns even though suitable nest sites are available elsewhere on the island.

The close association of breeding Oldsquaw and Arctic Terns has been reported before (Evans 1970). It is presumed that Oldsquaw benefit from the association due to the tern's nest defense against avian predators (Larson 1960). At Churchill, Manitoba, Evans (1970) found this association to be most important on islands and less important on the mainland.

Egg laying by Oldsquaw occurred between 16 and 30 June (Figure 35). The average clutch size was 6.4 eggs per nest. Bergman et al. (1977) found 6.7 eggs per nest on the mainland tundra.

3. Common Eider (Figures 25 and 26)

Common Eiders were the most abundant and widespread species breeding on barrier islands. A total of 1,006 nests was found. The species occurred on 50 percent of the islands censused. Of the 586 nests found in the Chukchi Sea 500 were on two islands (Table 1). Both of these islands are located at the mouths of rivers. An association with river mouths was also found in the Beaufort Sea. No nests were found on the Plover Islands, a group of islands not affected by river runoff. All nests in the Beaufort were found east of Thetis Island, an area with numerous rivers emptying into the sea. Common Eider are well distributed throughout this area. The largest Beaufort colony is on Cross Island where 139 nests were present.

Schamel (1974) has shown that moat formation around an island is necessary before breeding eiders occupy the nest sites. The location of the islands where we found eider breeding confirm this observation. Schamel (1974) discussed the selection of nest sites on Egg Island. He believed that *Elymus* sp. was the preferred cover with driftwood being used only if vegetation was unavailable. The eider colony on Cross Island is associated with an abandoned Eskimo cabin. Nests are found in, directly next to, and in the area immediately adjacent to the cabin. Eiders will readily use cover provided by man as has been shown in areas where eider down is harvested on a commercial basis (Palmer 1976b:56).

We found most Common Eiders to lay between 18 and 27 June in 1976. Average clutch size for 834 nests was 3.77 eggs per nest. Cooch (1965) found 3.44 eggs per nest on Baffin Island.

4. Snow Geese

Gavin (1976) reports that between 50 and 60 pairs of Snow Geese (*Chen caerulescens*) breed on Howe Island in certain years. In 1976 we noted the presence of the species on Howe Island but in order to avoid disturbance we did not visit the island. The colony on Howe is apparently one of the largest in the state.

5. Glaucous Gull (Figures 27 and 28)

Glaucous Gulls were uncommon breeders in the Chukchi Sea with 13 active and 15 empty nests being found. The nesting areas in the Chukchi were all at river mouths. The bulk of the 445 nests in the Beaufort was in the area between the Colville River and Camden Bay. This area has numerous rivers emptying into it. The close association this species has with areas of river runoff is shown by the 151 nest colony located on Niakuk Island. Niakuk is found at the mouth of the Sagavanirktok River and is surrounded by water as soon as the river starts to flow.

Glaucous Gulls prey to a large extent on the eggs and young of other birds. For this reason they lay their eggs early in the season and are feeding their young at a time of maximum food abundance (Figure 35). In 1976 we found the bulk of Glaucous Gull egg laying to occur in the first week in June with hatching occurring in late June and early July. Average clutch size for 402 nests in the Beaufort Sea was 2.7 eggs per nest.

6. Sabine's Gull (Figures 29 and 30)

Sabine's Gulls are uncommon breeders in the study area. Only two nests were found in the Chukchi Sea and three in the Beaufort.

7. Arctic Tern (Figures 31 and 32)

Arctic Terns were common breeders on barrier islands in the Chukchi. Breeding pairs were on 88 percent of the islands with 117 nests being found (Table 2). In the Beaufort the species was less common with nesting occurring on only 28 percent of the islands. Of the 84 nests in the Beaufort 58 were on Cooper Island. The reason for the difference in the percent of islands used in the two seas is apparently the availability of cover. Protection from prevailing winds is required for terns to breed in an area. The Chukchi islands with their patches of vegetation provide better cover than the Beaufort islands which provide cover only in the form of driftwood. Because the terns require wind protection that is low enough to not greatly obstruct the view of an adult bird sitting on the nest, much of the driftwood on the Beaufort islands is too high. On Cooper Island planks and boards are frequently used for protection. The large accumulation of lumber on Cooper is apparently the reason it is the largest tern colony in the study area.

Most egg laying occurred in the last week in June. The average clutch size for 114 nests in the Chukchi was 1.2 eggs per nest. Beaufort nests excluding Cooper Island had an average of 1.3 eggs per nest. Cooper Island nests had 1.7 eggs per nest. Bengston (1971) found 1.7 eggs per nest in Arctic Terns breeding on Spitsbergen.

8. Black Guillemot (Figures 33 and 34)

The Black Guillemot is a cavity nester usually found breeding in talus slopes. It has spread into the northern Chukchi and Beaufort by nesting in driftwood or man-made debris on barrier islands (MacLean and Verbeek 1968; Divoky et al. 1974).

A total of 50 nests was found. Nests were most common in the Barrow region with 49 being found between Peard Bay and the eastern Plover Islands. Only one nest was found outside of this region, a single nest on Jago Spit.

The major factor that determines the distribution of Black Guillemots in the study area is the availability of nest sites. Nest sites appear to be the limiting factor for guillemots throughout their breeding range (Storer 1952). Few natural cavities are available to Black Guillemots in northern Alaska. While natural driftwood is used on Seahorse Island, it does not offer as much protection as man-made debris. Burrows are also used when they are available but the presence of permafrost and the erosion associated with bluffs limit burrow nesting in arctic Alaska. Man-made debris provides stable nest sites with suitable cover.

All of the nests found on Seahorse Island were in natural sites. A driftwood pile contained all the nests in 1976 but in 1972 and 1975 nests in burrows in the sand dunes were also found. On Pt. Barrow spit in 1976 all but one nest was in man-made debris. One nest was found in a fox den. The 15 nests on Deadman Island were all under a single barge. Cooper Island has nests under a variety of man-made structures with plywood, wallboards and boxes being the most commonly used sites. An attempt to maximize the number of potential nests on Cooper has increased the breeding population from 10 nests in 1972 to 37 nests in 1977. East of Cooper one nest was found under a barge on Igalik Island and single nests were found in oil barrels on Sanigaruak Island and Jago Spit. While oil drums are the most common man-made debris on the Arctic coast, they are not good Black Guillemot nest sites. In general guillemots cannot enter a drum until after rusting has occurred and by then the barrel is usually too decomposed to provide good cover.

Black Guillemots have long incubation and chick periods (28 and 35 days). Egg laying does not begin until late June, however (Figure 35). This means that chicks are fledging in late August and early September. The reason for this late initiation of breeding is not known. Food may be most available to guillemots during the open water period when the water around the island is essentially ice free. Guillemot chicks hatch during the beginning of the open water period. Guillemots differ from other species breeding on the barrier islands in that they have no major fall migration. They winter in the pack ice from the northern Bering Sea to Pt. Barrow. Thus the time and energy demands at the end of the breeding season are not severe.

The clutch size of 50 nests found in 1976 was 1.94 eggs per nest. Winn (1950) and Preston (1968) found 1.8 eggs per nest at a western Atlantic colony.

9. Horned Puffin

The Horned Puffin (*Fratercula corniculata*) is a cavity nester that is known to breed as far north as Cape Lisburne. It occurs regularly in the Chukchi Sea as far north as Pt. Barrow.

While there is no positive evidence of Horned Puffin breeding on barrier islands north of Cape Lisburne, there is evidence that nesting could occur if proper nest sites were available. In early July and again in early August 1972 a pair of Horned Puffins was flushed from the sand dunes on Seahorse Island. There are a number of burrows in the dunes. Black Guillemots bred in one of the burrows in 1972 and two in 1975. All of the burrows were examined in 1972 but no direct evidence of Horned Puffin breeding was found. During the 1972 visits the two puffins circled the island constantly and acted similar to breeding birds that have been scared off their nest.

In 1976 and 1977 a single Horned Puffin was seen on Deadman Island associated with the barge that contained Black Guillemot nests. It roosted on top of the barge with the guillemots but it was not observed entering any of the nesting spaces on the barge.

In 1976 and 1977 a single Horned Puffin visited Cooper Island in late July and August. It roosted on top of Black Guillemot nest sites and was seen examining cavities under debris. It was observed brooding a Black Guillemot chick and may have been responsible for a number of dead Black Guillemot chicks found with wounds on the neck and head.

VII. Discussion

A. Importance of barrier islands to breeding birds

A critical habitat or area is usually defined as a habitat or area that is of vital importance to a species or group of species such that if the habitat or area became unusable the annual cycle of the specie(s) would be severely disrupted. It is generally assumed that such a disruption would ultimately result in a decrease in the specie(s) population. If the above definition is correct it appears that the barrier islands cannot be classified as critical habitat. The total number of birds breeding on the barrier islands is far less than what had been anticipated and the islands appear to be of minimal importance to the species that breed on them. The Glaucous Gull, Sabine's Gull and Arctic Tern are common to abundant late summer migrants on the Alaskan Arctic coast. Breeding densities of these species are low on the mainland tundra and it had been presumed that the adults and young seen in migration were coming from the nearshore islands. In light of the data presented by this study it now appears that the fall migrants are coming from the Canadian arctic. Oldsquaw and Brant are common tundra nesters (Bergman et al. 1977) that have only minor parts of their total populations breeding on the barrier islands. This leaves only the Common Eider and Black Guillemot as species which may have significant portions of their populations breeding on barrier islands. The Black Guillemot has a circumpolar breeding distribution with large numbers present in the north Atlantic and eastern Arctic. In Alaska it breeds from St. Lawrence Island north to the Beaufort Sea. At the present time quantitative information on breeding is not available for a number of sites but it appears that the fifty pairs breeding on barrier islands may constitute the majority of the Alaskan population of Black Guillemots. The Common Eider has a circumpolar breeding distribution. In Alaska it breeds as far south as Kodiak Island. Barry (1968) estimated that one half million Common Eiders migrate past Pt. Barrow every year. There is no estimate of numbers breeding in Alaska south of Cape Lisburne but the number is certainly higher than the amount breeding on islands in Alaska north of Cape Lisburne. The Snow Goose, a species that is a rare breeder in Alaska but common in Canada and the Soviet Union, apparently has its largest Alaskan colony on Howe Island.

Due to man's parochial approach to natural resource management it is possible to define a habitat or area as critical if the majority of a population found within a given political unit uses the habitat or area. Thus for Alaska it is possible to say that for Black Guillemot and Snow Geese the barrier islands are critical breeding habitat. Howe Island, which has the largest Snow Goose colony in the state, and the islands with numbers of Black Guillemots (Seahorse, Deadman, Cooper) could be considered critical habitat in the strict sense.

It is important to remember that while barrier islands do not support large numbers of birds this is due in large part to the high arctic characteristics of the nearshore environment surrounding the islands. The ice that surrounds the islands keeps primary productivity of nearshore waters low and allows fox access to the islands. The low productivity of high arctic areas makes them appear to be of less importance to birds than subarctic areas. If priority is placed solely on the number of birds in an area most of the arctic would be considered less important than other areas in the state. The high arctic should be considered as a separate region where levels of abundance will be lower but this lessened abundance should not be thought of as an excuse to provide less protection to an area than in more productive southern regions. Areas within the high arctic need to be compared to other high arctic areas when determinations on critical habitat are being made.

Barrier islands are unique breeding habitats worthy of protection because they are the only such habitats in the United States. Certain islands deserve increased protection due to the number of breeding birds or unique species assemblages. The following is a list of such islands based on our 1976 findings:

Solovik Island

Solovik Island is a good representative of the type of island present in the Chukchi with a good amount of vegetation on low relief dunes. It has 300 Common Eider, 25 Black Brant and 20 Glaucous Gull nests. The nests are most common on the northern half of the island where vegetation is more abundant. Eiders use the vegetation for cover and the nests are dispersed over a wide area.

Island east of Akoliakatat Pass

This island has 200 Common Eider nests and thus is comparable in size to the colony on Solovik.

Seahorse Island

The largest of the Seahorse Islands has unique vegetated dunes that are not found elsewhere north of Cape Lisburne. In addition to providing breeding habitat for Arctic Terns, Common Eider and Oldsquaw, the dunes provide one of the few places on the Arctic coast where burrow nesting birds can either find or create nest sites.

Cooper Island

Cooper Island is the largest of the Plover Islands. It also has the most debris and apparently due to this the largest number of breeding birds. The island is an example of a breeding colony not associated with river runoff. Breeding on the two islands next to it, Tapkaluk and Martin, is minimal. Human activity on the latter islands would have little effect on breeding birds.

Thetis Island

While the number of birds breeding on Thetis is not exceptionally large, this may be due to the presence of humans associated with the cabin on the island. The island's location makes it an ideal site for species associated with river mouths.

Niakuk Island

Niakuk has the largest Glaucous Gull colony in the area studied. Its proximity to the mouth of the Sagavanirktok River makes it an ideal location for a number of species.

Cross Island

Cross Island has the largest Common Eider colony in the Beaufort. Even though it is rather close to the mouth of the Sagavanirktok River the area around the island remains covered with ice until late in the summer. Cross is 18 km from shore and this may play a part in isolating it from fox predation thus allowing it to maintain its large population. At present all of the nests are clustered around an abandoned Eskimo cabin and an aid to navigation tower.

The islands listed above are those where human activity should be as carefully regulated as possible in order to not disturb breeding populations. This does not mean that other islands do not have breeding populations worthy of protection. The above islands appear to be unique enough to warrant complete protection. For other areas it is hoped that human activities could be carried out on those islands which have been shown to be used least by breeding birds. It is doubtful that every island in each island chain will have to be occupied by humans in the course of oil exploration and production. Thus certain productive islands in every stretch of coast could be left alone. This will speed recolonization of islands after human disturbances are removed from the island.

In many cases man's activities can be scheduled so as to avoid conflict with birds breeding on the barrier islands. Figure 35 shows those times that are most critical for nesting birds. In general scheduling all human activities between 15 September and 1 May will assure that man's activities will not directly affect breeding populations.

B. Factors determining distribution and abundance of birds breeding on barrier islands and their implications for oil and gas development

Two factors are most important in determining the importance of an island to breeding birds. Foremost is the degree of isolation an island has from terrestrial predators, which in the area studied means arctic fox. Of secondary importance is the amount and quality of cover available to nesting birds.

Because islands near river mouths are isolated from terrestrial predators early in the breeding season they are of most importance to breeding birds. For this reason all islands that are near the mouths of rivers are potentially more important to birds than islands away from river mouths. Certain islands near river mouths were found to have few or no birds breeding on them in 1976. This could be due to a fox visiting the island early in the breeding season or to lack of suitable cover. It should be recognized that even though we found little use of some islands near rivers, such islands are potentially islands that could support large populations and should be considered as such.

The activities of man on the islands can be expected to increase predation on eggs if suitable precautions are not undertaken. It appears likely that oil companies will want to build causeways to some of the islands for transportation purposes. The "Arco causeway" almost connects Stump Island with the mainland. Such causeways effectively stop an island from being an island and allows terrestrial predators free access to nesting areas.

It is likely that camps will be established on islands during the winter and removed before the start of breeding in order to avoid direct disturbance of breeding birds. Precautions will have to be taken that these camps do not attract arctic fox since increasing fox populations on and next to barrier islands during the winter will certainly decrease breeding populations.

The second most important factor in determining the suitability of an island for breeding birds is cover. Cover provides protection from the wind and also helps to make a nest and incubating adults less obvious to potential predators. The lack of suitable cover on many of the islands, especially in the Beaufort, deters birds from breeding in greater numbers. The Plover Islands are a good example of this. There is only minimal breeding occurring on most of the islands but Cooper with its large amount of debris supports large Arctic Tern and Black Guillemot populations. The difference in the percent of islands used by Arctic Terns in the Chukchi versus the Beaufort is an indication of the lack of cover in the Beaufort Sea. The importance of cover to eiders is shown by the large number of nests associated with the cabin on Cross Island.

The fact that increased cover will increase the breeding densities of birds breeding on barrier islands will allow oil companies, and the political units that lease areas to them, to carry out programs which can minimize the total impact that drilling will have on barrier island breeding populations. If drilling does occur on an island with a breeding population, an attempt should be made to improve breeding habitat on neighboring islands. If Cross Island were to be leased for drilling the nearby islands should have cover suitable for eiders placed on them. While this could most easily be done with natural driftwood or man-made structures, patches of vegetation could also be used. Because eider down is harvested commercially in the eastern Arctic some work has been done to determine what type of cover will increase densities of nesting eiders (Belopolskii, 1961). The specific type of cover to be placed on islands will depend on the location. Cover suitable for eiders should be put on islands near river mouths. Cover for Arctic Terns, Black Guillemots and Oldsquaw could be placed on islands not directly affected by rivers.

It is realized that such a program of habitat enhancement will not greatly change the importance of barrier islands to breeding birds. Such a program could easily be carried out, however, by companies and government agencies working on and near the islands thus minimizing the cost of such a project. Because oil companies are frequently looking for ways in which to prove that their presence in an area has either helped, or at least not hurt, populations of animals, they may be very willing to participate in such work. It should also be pointed out that attempts to "clean up" islands, as was done on the Plover Islands in 1976, have the direct effect of decreasing cover for birds. While "eyesores" are something that should not be tolerated, it should be realized that certain man-made structures can benefit birds.

C. The importance of barrier islands to summer and fall migrants

The small breeding populations on most of the barrier islands might give the impression that the islands are not important to birds. While the fallacy of comparing these islands with islands further south has already been discussed, it should also be mentioned that in August and September the shorelines of barrier islands have the highest density of birds of any of the habitats present on this section of coast. RU 3/4 and Connors (RU 172) and Johnson (RU 470) have shown that the barrier islands and spits are important to large numbers of birds with one thousand birds per kilometer being a not uncommon density. Any assessment of the importance of barrier islands to birds must be done with a consideration of breeding birds and the summer and fall migrants.

VIII. Acknowledgements

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Table 1.
Species and number of birds breeding on barrier islands between Cape Lisburne and Demarcation Point.

Island or Spit	Fig. #	Colony #	Area (km^2)	Length (km)	Number of nests
Spit 8 km east of Cape Lisburne Air Force Base	1	1	0.3	2.6	Arctic Tern 2
Spit at mouth of Ayugatak Creek	1	2	0.03	0.3	Arctic Tern 1
Ayugatak Lagoon Spit	1	3	0.8	7.2	Arctic Tern 1
Omalik Lagoon Spit	3	4	0.2	2.9	Arctic Tern 4
Spit at southern end of Kasegaluk Lagoon	3	5	7.1	23.6	Common Eider 4 Arctic Tern 1
Island between Naokok Pass and Kukpowruk Pass	4	6	4.5	24.0	Pintail 1 Oldsquaw 1 Common Eider 4 Semipalmated Sandpiper 1 Arctic Tern 14 Savannah Sparrow 1
Island between Kukpowruk Pass and Akunik Pass	4	7	5.7	27.2	Oldsquaw 3 Common Eider 14 Glaucous Gull 2 Sabine's Gull 2 Arctic Tern 27 Savannah Sparrow 1 Snow Bunting 1
Island between Akunik Pass and Utukok Pass	5	8	5.3	23.7	Black Brant 25 Common Eider 11 Glaucous Gull 1 Arctic Tern 8

Table 1. (cont.)

Island or Spit	Fig. 3	Colony #	Area (km^2)	Length (km)	Number of nests
Solivik Island	5	9	7.8	28.2	Black Brant 25 Oldsquaw 2 Common Eider 300 Glaucous Gull 20 Arctic Tern 18
Icy Cape Spit	5	10	4.2	30.4	Black Brant 6 Common Eider 31 Glaucous Gull 1 Arctic Tern 3
Island east of Akoliakatat Pass	6	11	2.1	8.5	Oldsquaw 3 Common Eider 200 Arctic Tern 17
Island west of Pingorarok Pass	6	12	2.7	10.7	Common Eider 22 Glaucous Gull 5 Arctic Tern 4
Spit opposite Mitliktavik	6	13	2.1	17.6	Arctic Tern 4
Wainwright Inlet Spits	6	14	13.0	22.2	Oldsquaw numerous in certain years (John J. Burns pers. comm.).
Pt. Franklin Spit	7 & 8	15	4.5	13.0	Arctic Tern 1 10 adult Black Guillemots present on spit. Eggshell found in oil barrel.

Table 1. (cont.)

Island or Spit	Fig. #	Colony #	Area (km^2)	Length (km)	Number of nests
Seahorse Islands	8	16	0.3	2.5	Arctic Tern* 1972 Black Guillemot 6 (Divoky et al. 1974)
					Arctic Tern 10 1975 Black Guillemot 5 (Divoky)
					Arctic Tern 12 1976 Black Guillemot 4
Peard Bay Spit	8	17	0.9	9.0	No nests found.
Pt. Barrow Spit	9	18	2.5	12.0	Black Guillemot 7
Deadmans Island	9	19	2.0	0.3	Black Guillemot 15, all under a single barge.
Tapkaluk Islands	9	20	1.8	12.4	Arctic Tern 3
Cooper Island	10	21	1.5	6.0	Sabine's Gull* 1972 Arctic Tern* Black Guillemot 10 (Divoky et al. 1974)
					Oldsquaw 3 1975 Sabine's Gull 4 Arctic Tern 51 Black Guillemot 17 (Divoky & Boekelheide)
					Oldsquaw 11 1976 Baird's Sandpiper 2 Sabine's Gull 5 Arctic Tern 58 Black Guillemot 21
Martin Island	10	22	0.7	7.9	No nests found in 1975 or 1976.

* Species present but number of nests not noted.

Table 1. (cont.)

Island or Spit	Fig. #	Colony #	Area (km^2)	Length (km)	Number of nests
Sanigaruak Island	10	23	0.2	2.5	Arctic Tern 2 Black Guillemot 1
Igalik Island	10	24	0.4	3.2	Black Guillemot 1 1972 Oldsquaw 1 Sabine's Gull 1 Arctic Tern 7 Black Guillemot 1 (Divoky et al. 1974)
Kulgurak Island	10	25	0.5	5.0	No nests found.
Pogik Island Complex	12	26	1.8	4.7	Not visited.
Eskimo Islands	12	27	1.2	5.1	1972 No nests found. (Bartonek & Divoky)
Thetis Island	13	28	0.5	4.2	Black Brant 3 Common Eider 38 King Eider 2 Glaucous Gull 4 Arctic Tern 1
Spy Islands	14	29	0.5	5.4	Common Eider 4 Glaucous Gull 3
Leavitt Island	14	30	0.3	2.5	No nests found. Fox tracks present.
Pingok Island	14	31	4.0	11.2	No nests found. Fox tracks present.
Bertoncini Island	14	32	0.2	0.8	No breeding birds observed during aerial reconnaissance.
Bodfish Island	14	33	0.6	0.8	No breeding birds observed during aerial reconnaissance.

Table 1. (cont.)

Island or Spit	Fig. #	Colony #	Area (km^2)	Length (km)	Number of nests
Cottle Island	14	34	0.9	6.8	No nests found.
Long Island	14	35	1.0	11.1	Common Eider 24 King Eider 1 Glaucous Gull 13 Arctic Tern 1
Island southeast of Long Island	14	36	0.1	0.5	Common Eider 1 Glaucous Gull 11
Egg Island	14	37	0.1	1.9	Black Brant 1 1971 Common Eider 24 Glaucous Gull 16 Arctic Tern 5 (Gavin 1976)
					Common Eider 35 1972 King Eider 3 Glaucous Gull 3 Arctic Tern 5 (Schamel 1974)
					Common Eider 24 1976 Glaucous Gull 21
Stump Island	14	38	0.4	4.4	Common Eider 10 Glaucous Gull 5
Gull Island	15	39	0.3	0.5	Not visited.
Reindeer Island	15	40	0.2	2.5	Common Eider 4 Glaucous Gull 1
Argo Island	15	41	0.1	0.8	Glaucous Gull 2
Niakuk Island	15	42	0.1	1.2	Black Brant 5 Common Eider 12 Glaucous Gull 151

Table 1. (cont.)

Island or Spit	Fig. #	Colony #	Area (km2)	Length (km)	Number of nests
Howe Island	15	43	0.75	0.5	Not visited. Used by Snow Geese. (Gavin 1976)
Duck Island	15	44	0.1	0.5	Black Brant 35 Common Eider 2 Glaucous Gull 22
Foggy Island	15	45	4.7	6.3	No nests found.
Spit west of Pt. Brower	15	46	0.2	1.0	Black Brant 7 Common Eider 5 Glaucous Gull 71
Spit southeast of Pt. Brower	15	47	0.1	1.0	Canada Goose 2 Glaucous Gull 10
Spit southeast of Pt. Brower	15	48	0.1	0.5	Common Eider 1 Glaucous Gull 3
Cross Island	15	49	0.5	4.1	Common Eider 97 1970 Sabine's Gull* Arctic Tern* (Gavin 1976)
					Common Eider 73 1971 Glaucous Gull 3 Sabine's Gull 1 (Gavin 1976)
					Common Eider 90 1972 Sabine's Gull 2 Arctic Tern 2 (Divoky)
					Common Eider 139 1976 Glaucous Gull 2 Sabine's Gull 1

* Species present but number of nests not noted.

Table 1. (cont.)

Island or Spit	Fig. #	Colony #	Area (km^2)	Length (km)	Number of nests
Narwhal Island	15	50	0.3	3.5	Common Eider 33 Glaucous Gull 1 Arctic Tern 1
Jeanette-Karluk Island	15	51	0.3	5.4	Common Eider 5 Arctic Tern 1
Lion Point Spit	15	52	0.2	1.9	Oldsquaw 1 Common Eider 6 Glaucous Gull 5
Tigvariak Island	15	53	3.4	3.2	Not visited.
Pole Island	16	54	0.6	4.8	Common Eider 50 1972 Glaucous Gull 1 (Watson & Divoky)
					Common Eider 64 1976 Glaucous Gull 1
Belvedere Island	16	55	0.4	6.2	Common Eider 10 Glaucous Gull 1 Arctic Tern 2
Challenge Island	16	56	0.1	0.1	Common Eider 4 Glaucous Gull 4 Arctic Tern 1
Alaska Island	16	57	0.4	5.9	Common Eider 12 Glaucous Gull 1
Duchess Island	16	58	0.3	2.9	No nests found. Fox tracks present.
North Star Island	16	59	0.2	2.4	Common Eider 2 - Both nests had been preyed upon by arctic fox.

Table 1. (cont.)

Island or Spit	Fig. #	Colony #	Area (km^2)	Length (km)	Number of nests
Flaxman Island	16	60	3.3	11.1	Whistling Swan 1 1971 Oldsquaw 5 Common Eider 6 White-winged Scoter 1 (Gavin 1976) No nests found 1976.
70° 00' 00" 145° 12' 30", island south of Konganevik Pt.	17	61	0.1	0.8	Common Eider 8 Glaucous Gull 28
Arey Island	19	62	1.3	11.5	Common Eider - Some nests found, none with eggs. Fox tracks present.
Barter Island Spits	19	63	2.5	7.0	Common Eider 1 1975 (Divoky & Boekelheide) No nests found 1976.
Bernard Spit	19	64	1.5	8.5	Common Eider 1
Jago Spit	19	65	0.6	6.0	Common Eider 4 Arctic Tern 3 Black Guillemot 1
Island between Tupkaurak Island and Jago Spit	19	66	0.1	0.3	Arctic Tern 1
Tapkaurak Island	19	67	0.9	11.6	No nests found.
Pokok Spit	20	68	0.7	9.5	Not visited.
Nuvagapak Island	20	69	0.1	6.0	Arctic Tern 1

Table 1. (cont.)

Island or Spit	Fig. #	Colony #	Area (km^2)	Length (km)	Number of nests
Egaksrak Island	20	70	0.6	9.0	Oldsquaw 18 Common Eider 1 Glaucous Gull 39 Arctic Tern 2
Icy Reef	20	71	2.9	30.6	Baird's Sandpiper 1 Fox on island.
Islands south of west end of Icy Reef	20	72	0.1	0.1	Black Brant 2 Common Eider 6 Glaucous Gull 31
Island at west side of Demarcation Bay	20	73	0.1	0.1	Black Brant 2 Glaucous Gull 15
Demarcation Pt. Spit	20	74	0.8	4.5	Not visited.

Table 2. Summary of breeding bird use of barrier islands in 1976.

Chukchi Sea (17 islands censused)

Species	Number of nests	Islands with nests	Percent of islands used (17 total)
Black Brant	56	3	18
Oldsquaw	9	4	24
Common Eider	586	8	47
Glaucous Gull	29	5	29
Sabine's Gull	2	1	6
Arctic Tern	117	15	88
Black Guillemot	4	1	6
Total	803	16	94

Beaufort Sea (50 islands censused)

Species	Number of nests	Islands with nests	Percent of islands used (50 total)
Black Brant	54	6	12
Oldsquaw	31	5	10
Common Eider	420	25	50
King Eider	3	2	4
Glaucous Gull	445	24	48
Sabine's Gull	3	2	4
Arctic Tern	84	14	28
Black Guillemot	46	6	12
Total	1,086	38	76

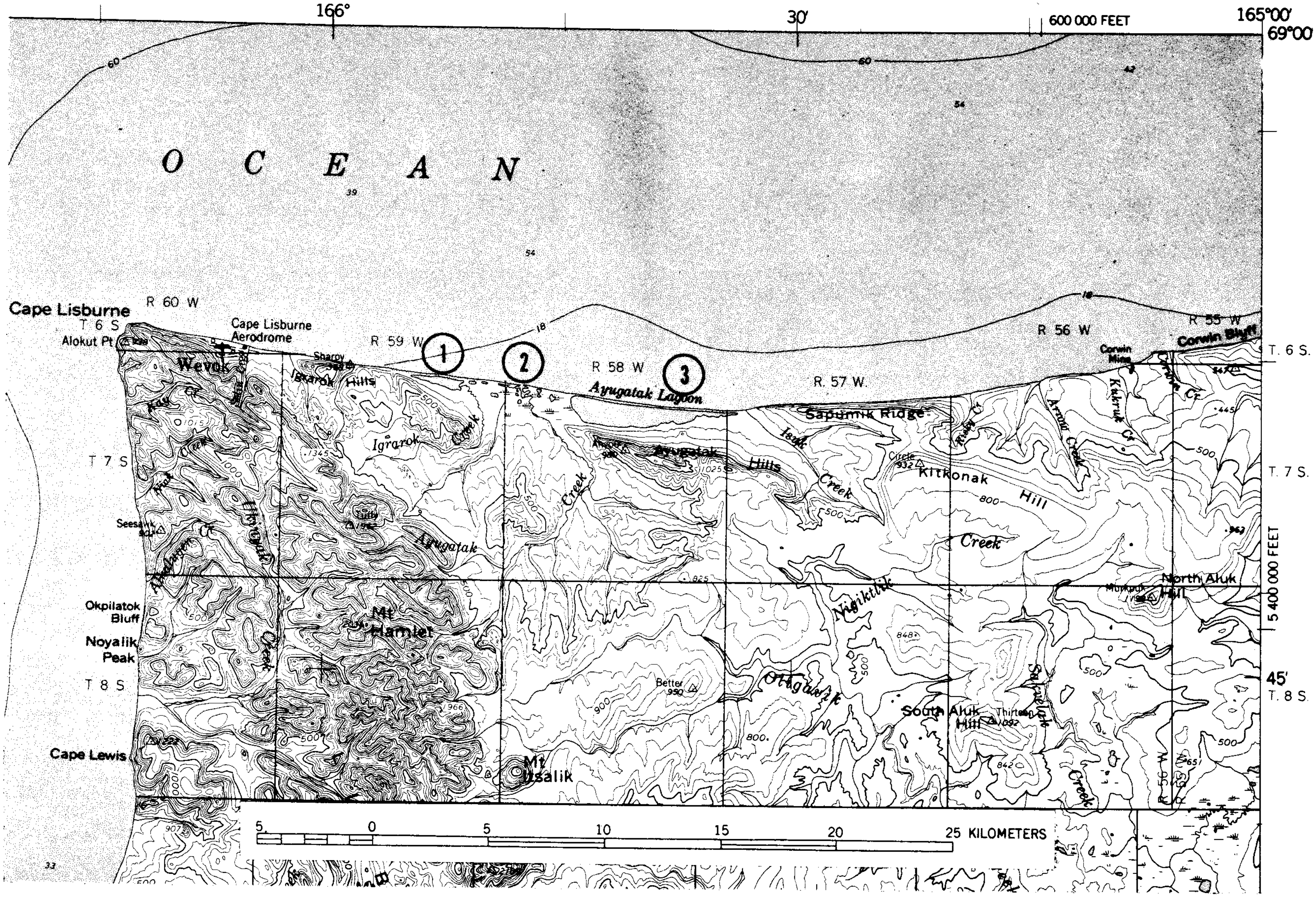


Figure 1. Location of spits used by breeding birds in vicinity of Cape Lisburne in 1976.

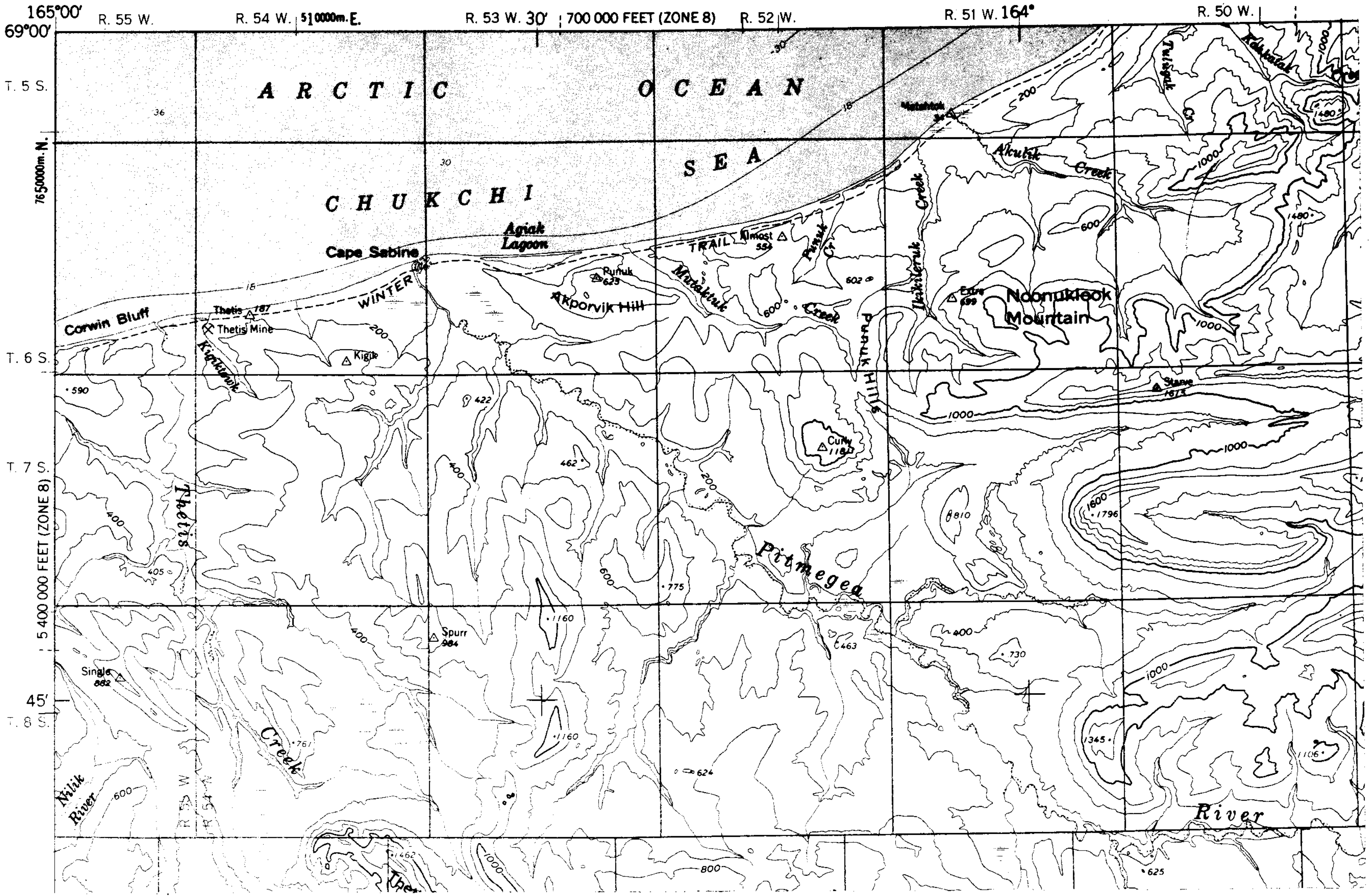


Figure 2. Coastline in vicinity of Cape Sabine.

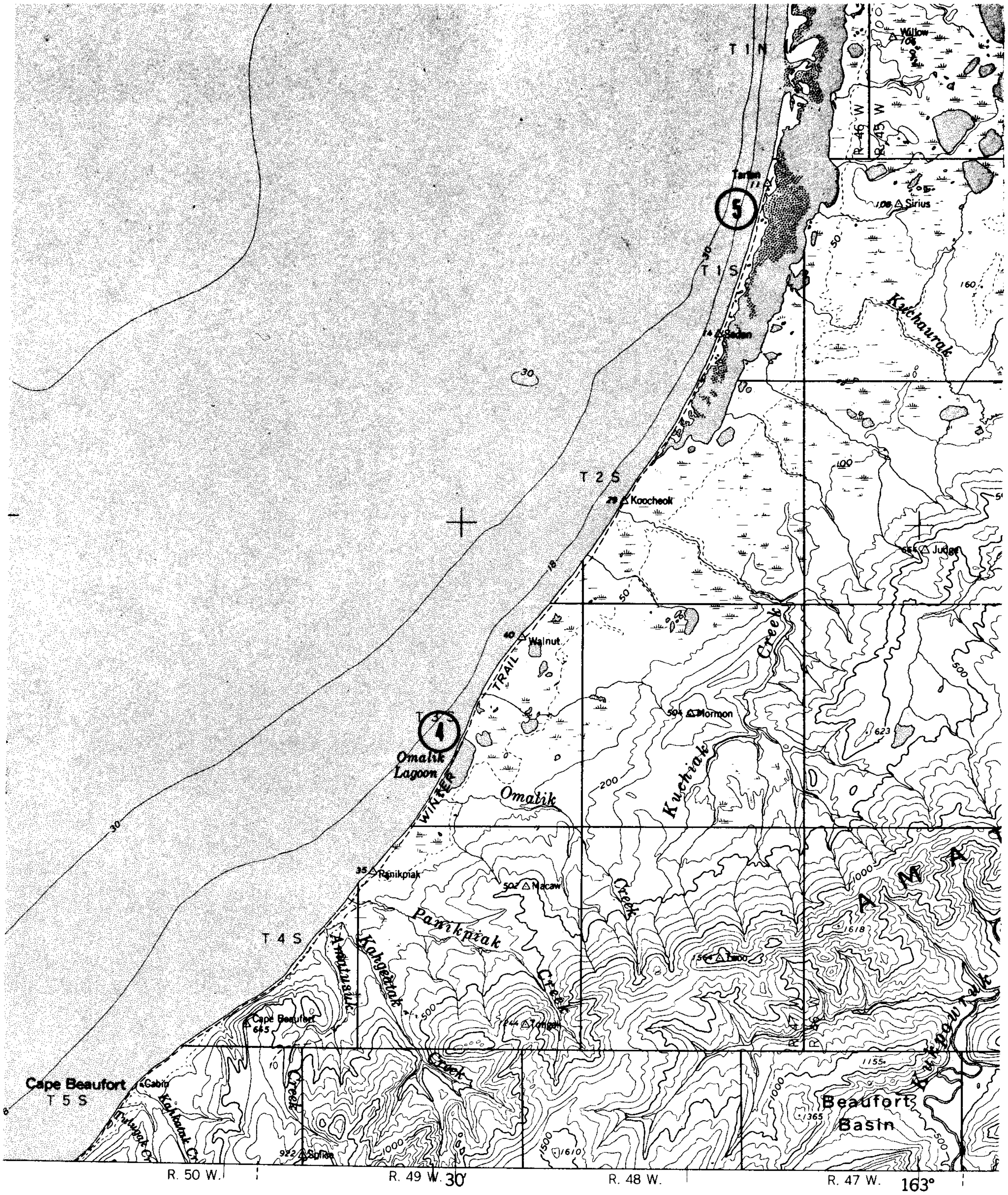


Figure 3. Location of spits used by breeding birds in vicinity of southern Kasegaluk Lagoon in 1976.

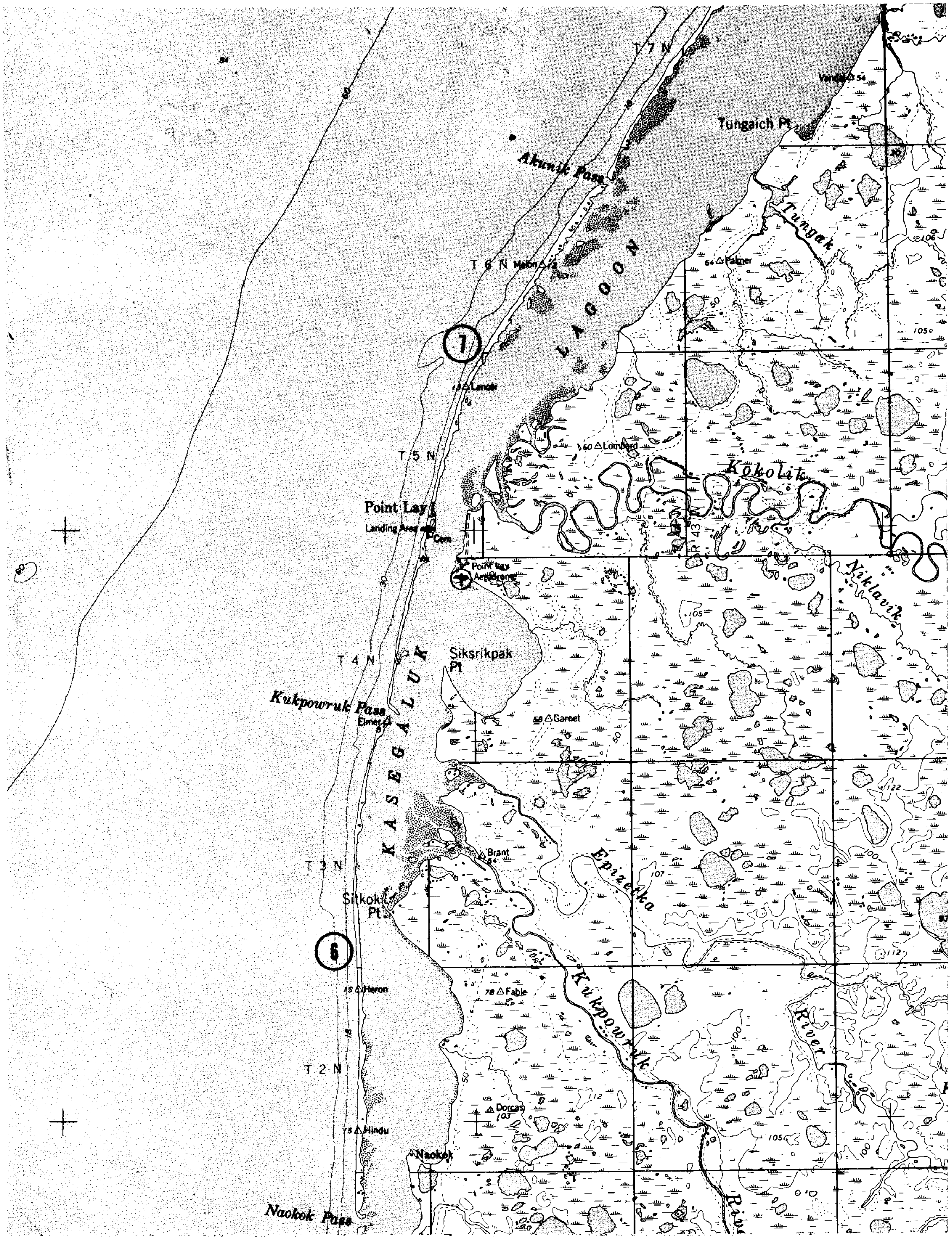


Figure 4. Location of barrier islands used by breeding birds in vicinity of Point Lay in 1976.

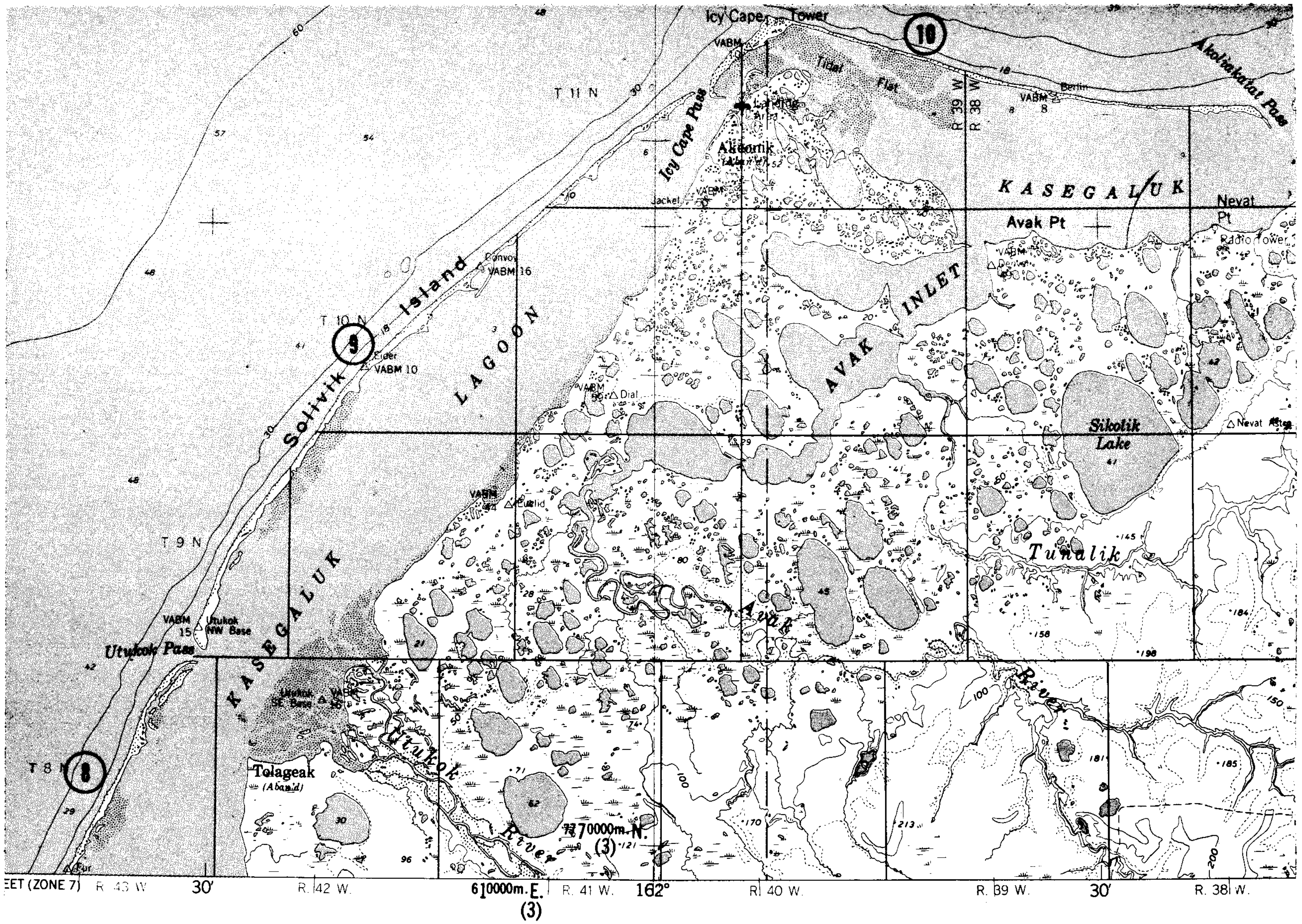


Figure 5. Location of barrier islands used by breeding birds in vicinity of Icy Cape in 1976.

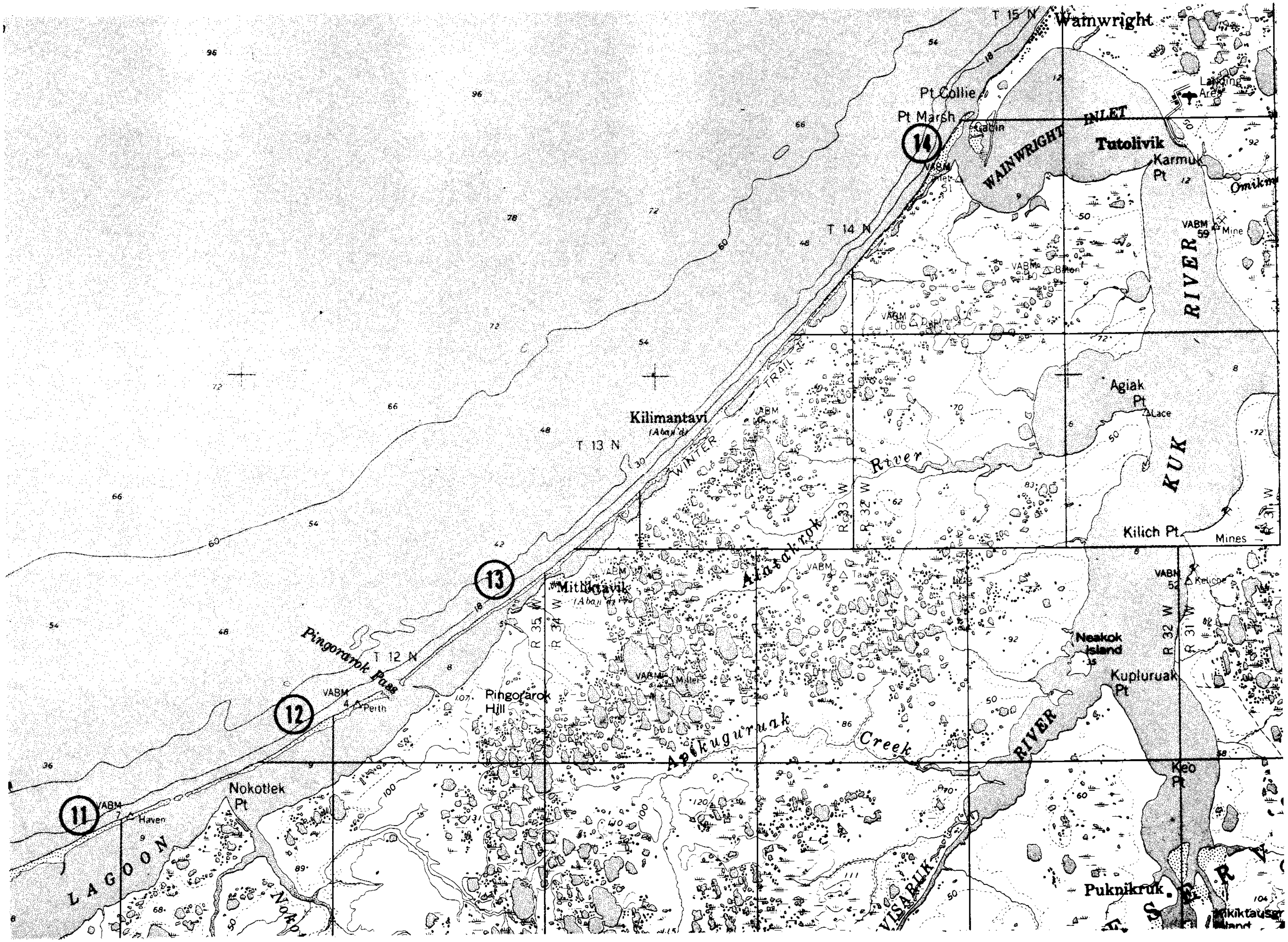


Figure 6. Location of barrier islands and spits used by breeding birds in vicinity of northern Kasegaluk Lagoon in 1976.

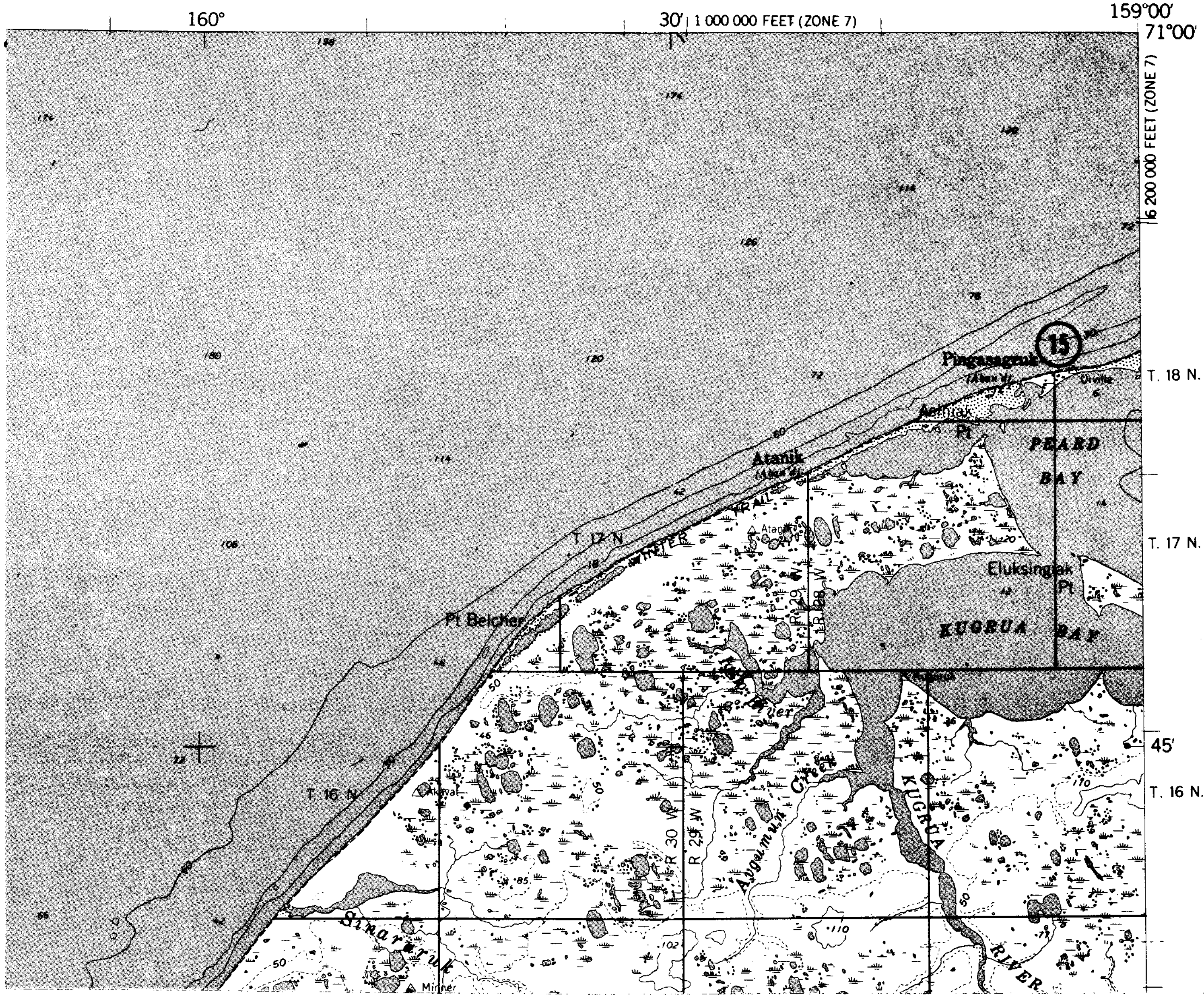


Figure 7. Location of spits used by breeding birds in vicinity of Point Belcher in 1976.

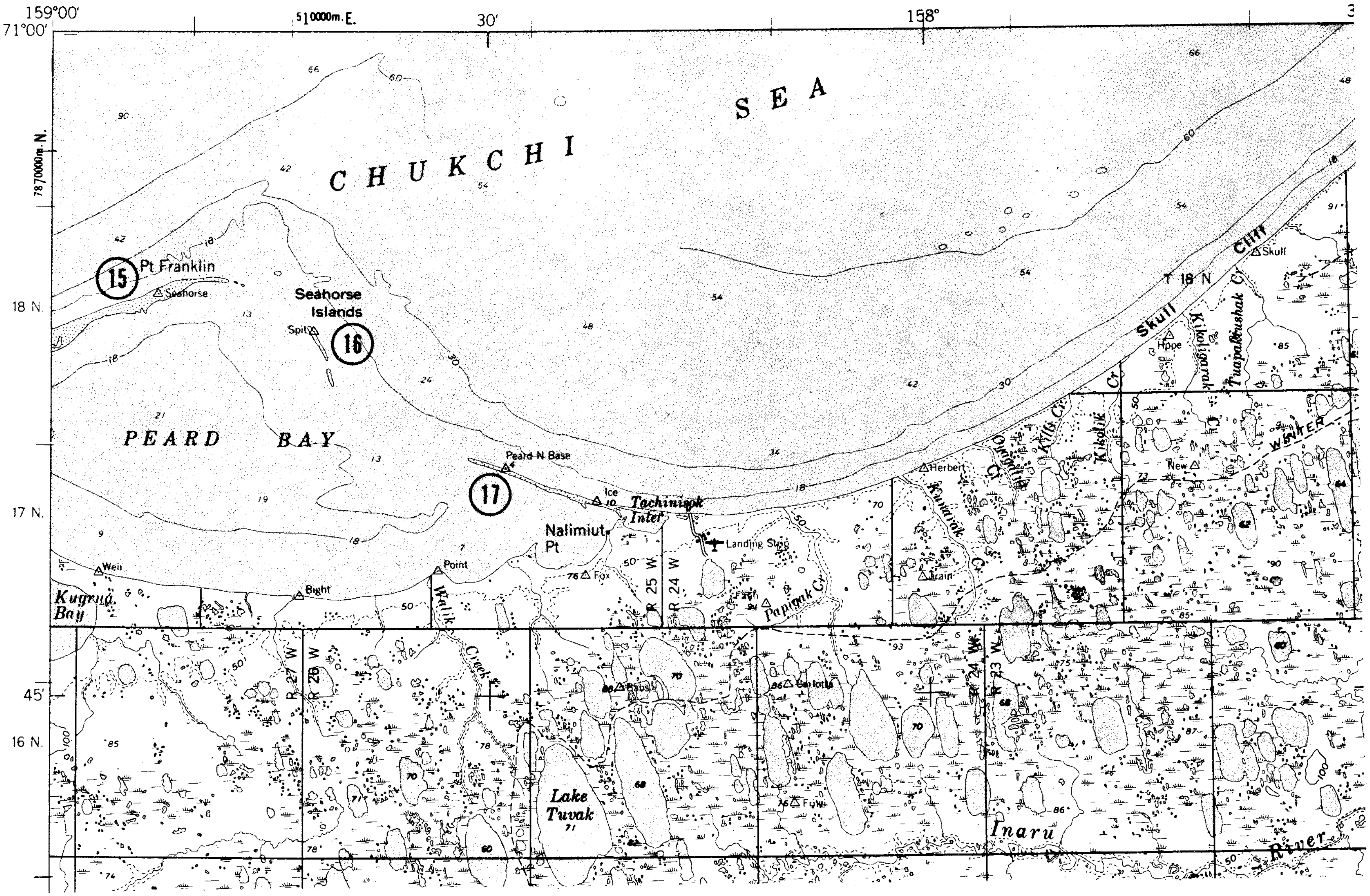
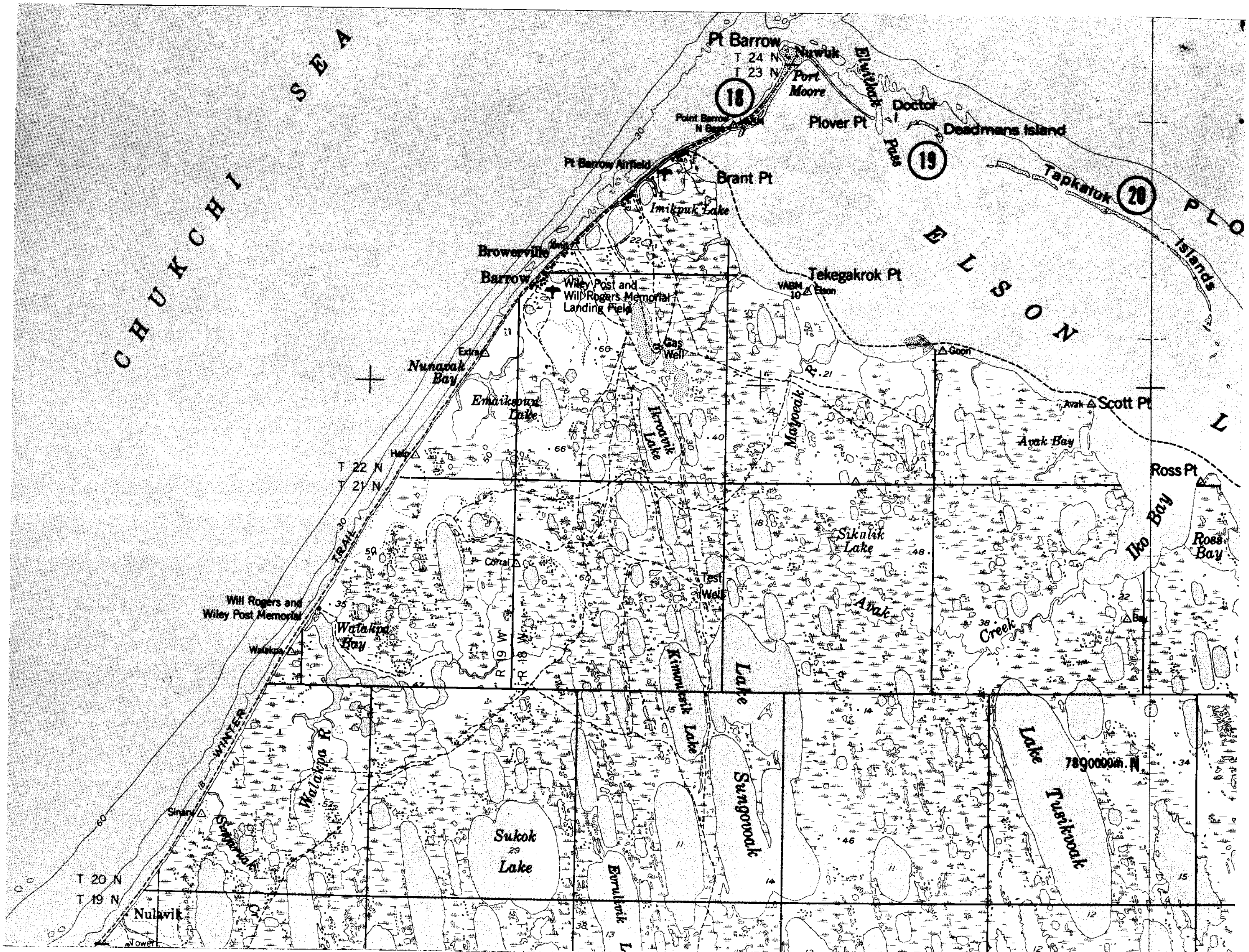


Figure 8. Location of barrier islands and spits used by breeding birds in vicinity of Peard Bay in 1976.



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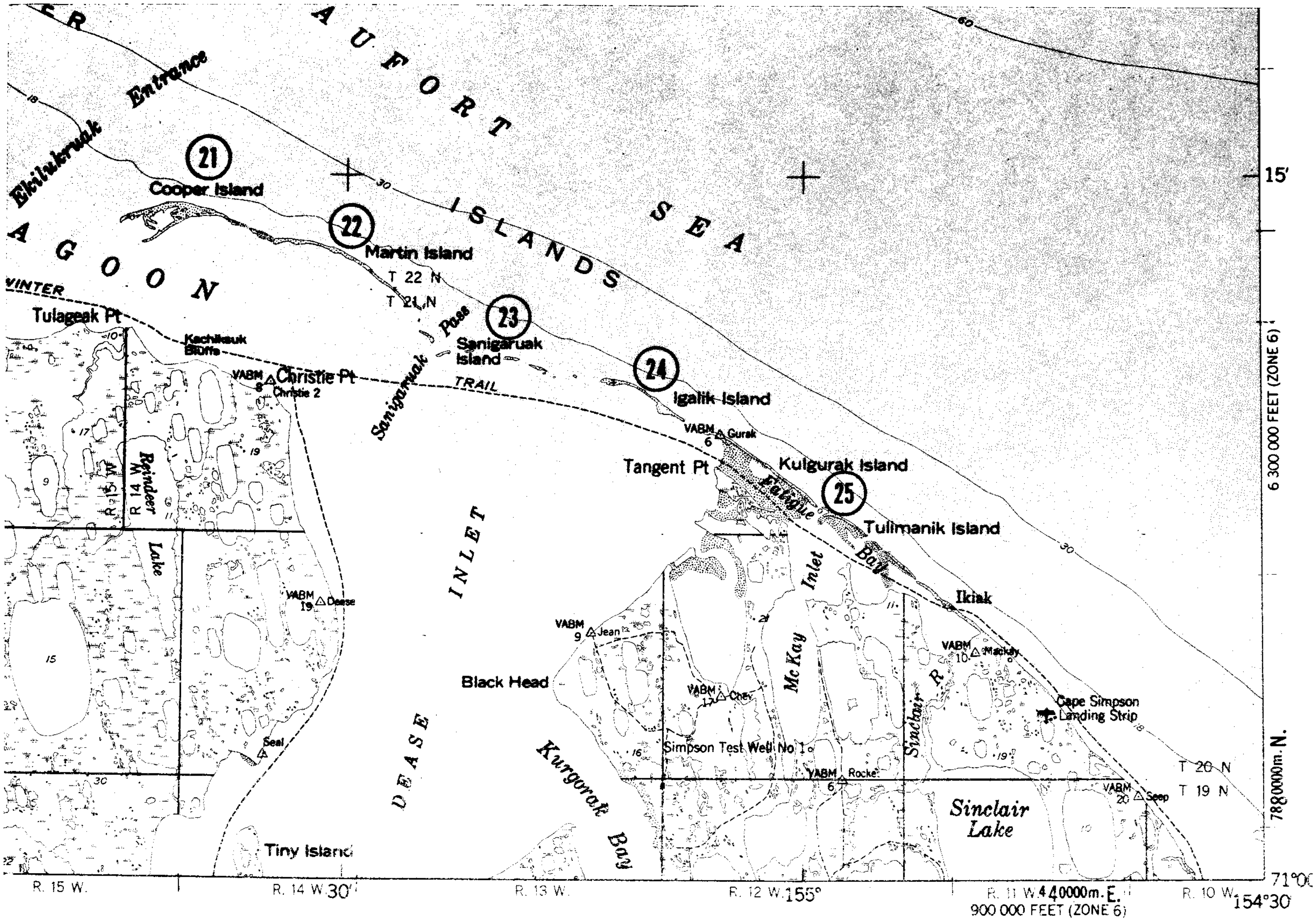

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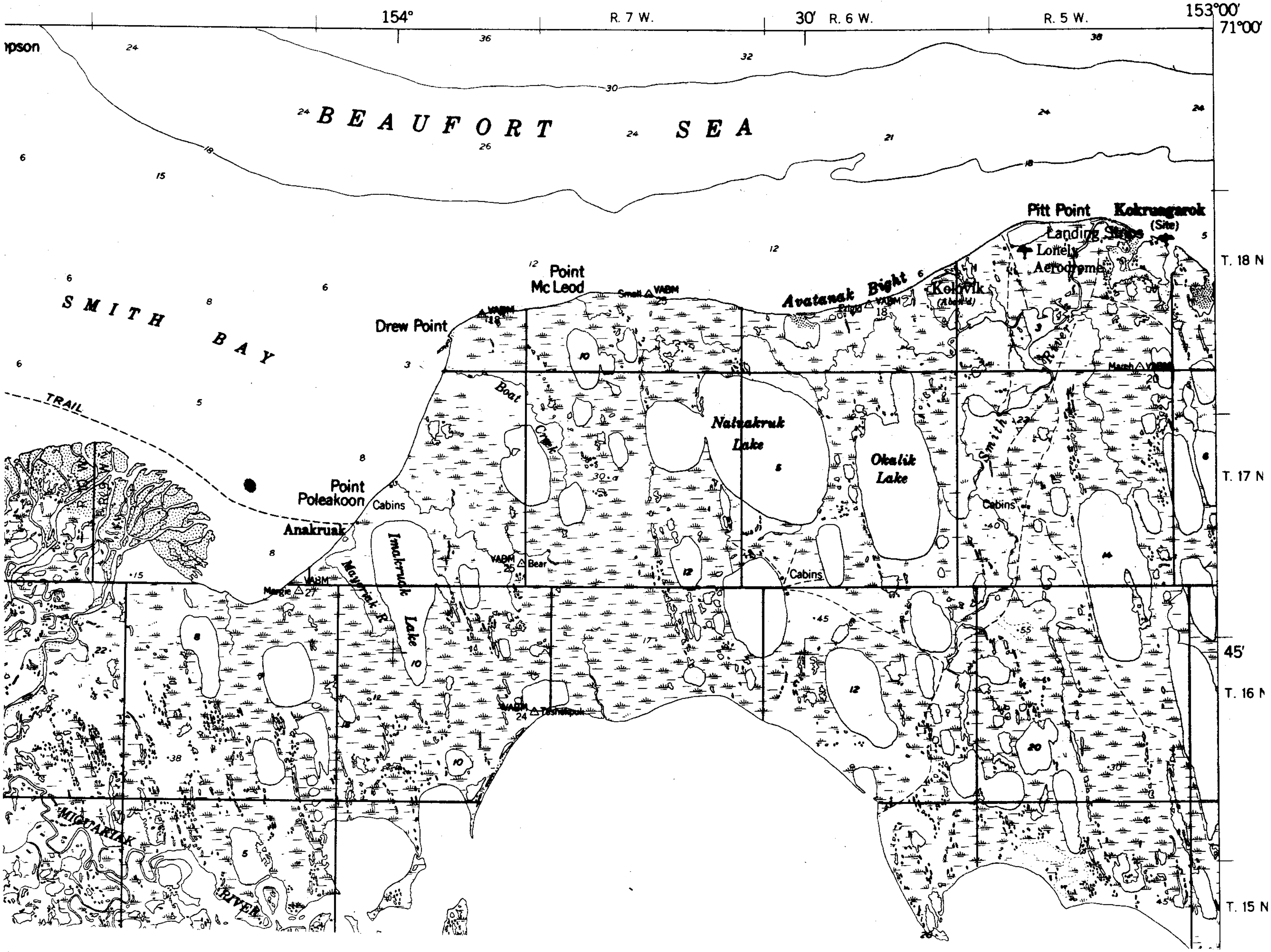

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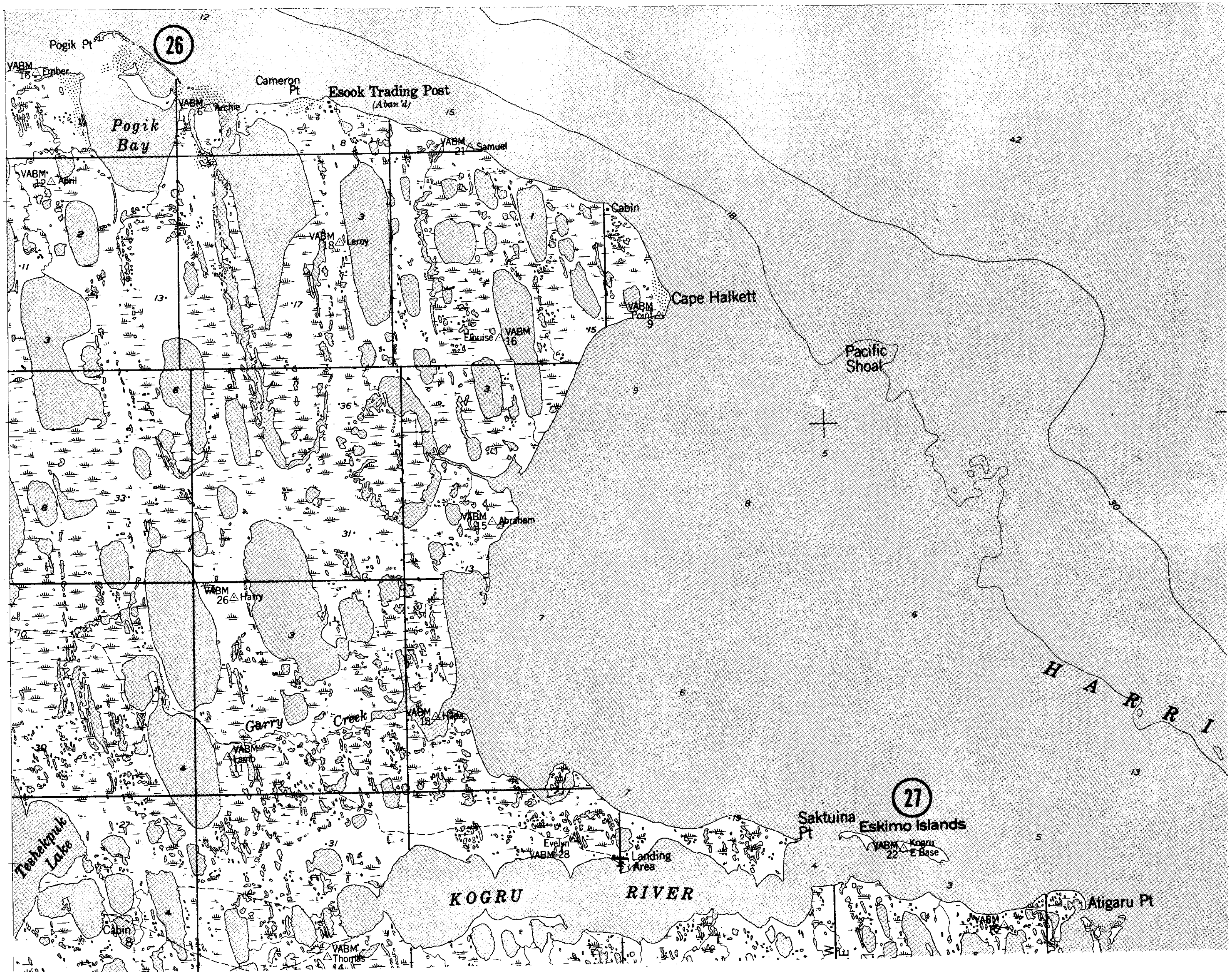

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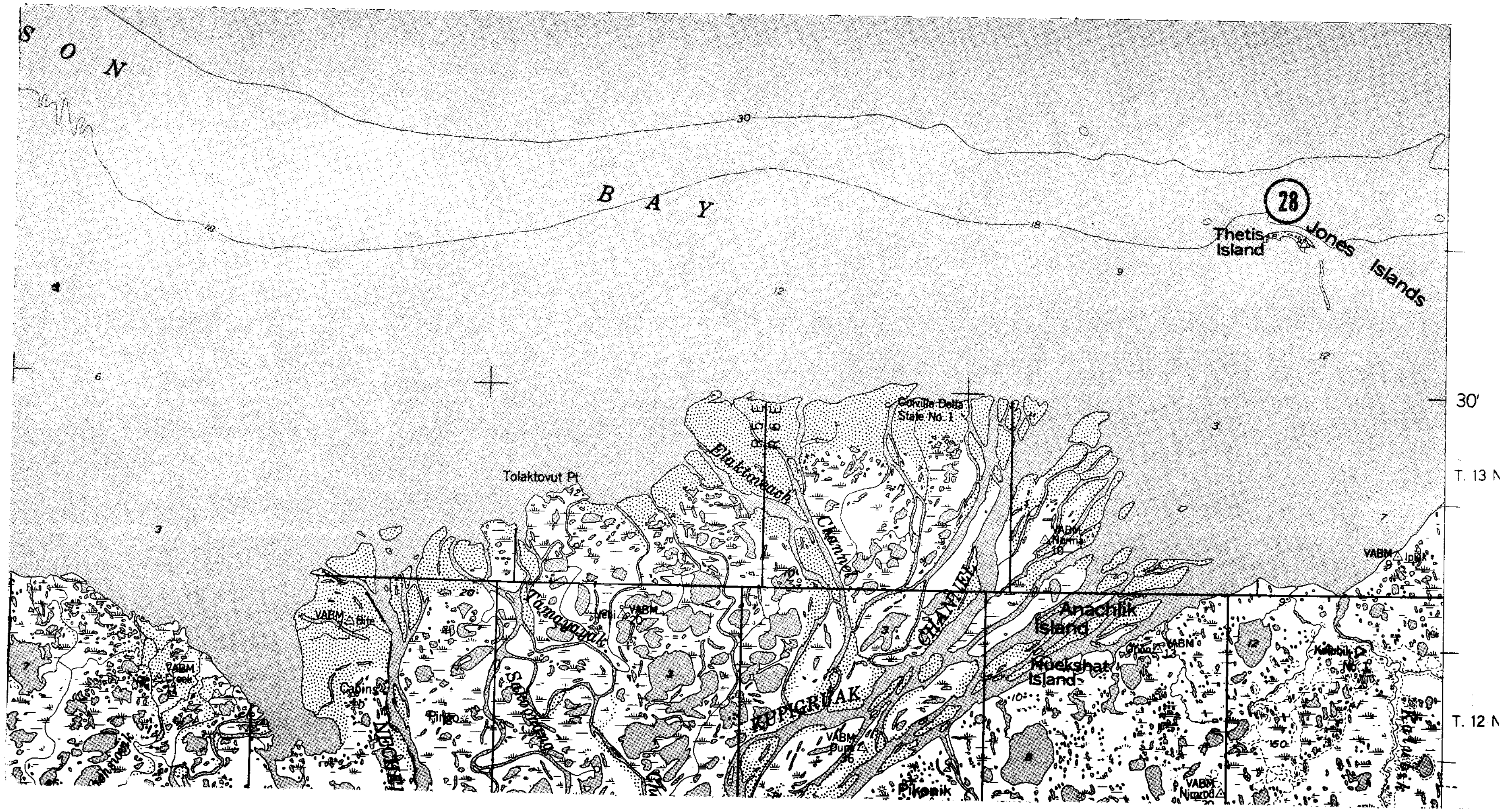

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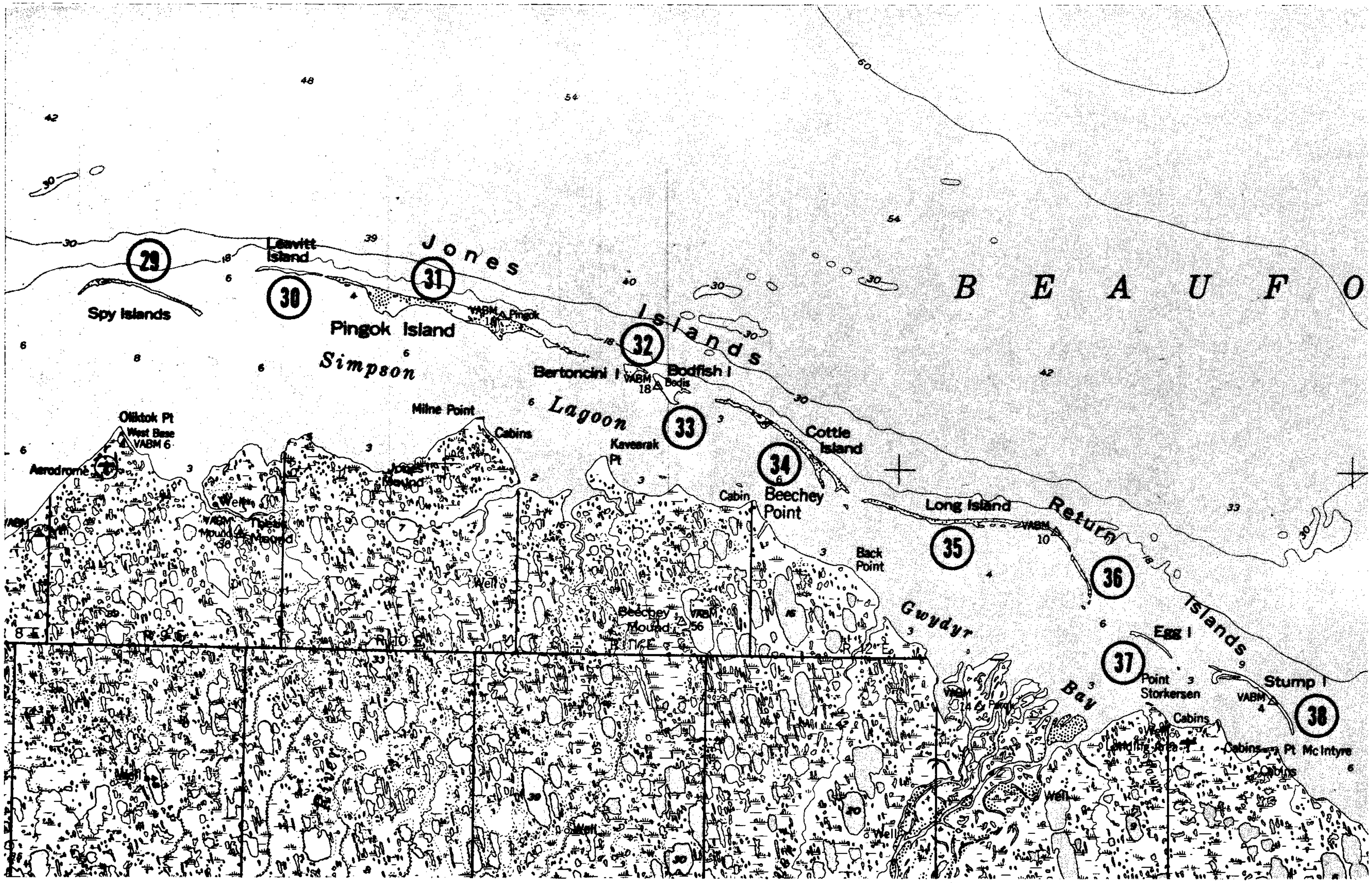

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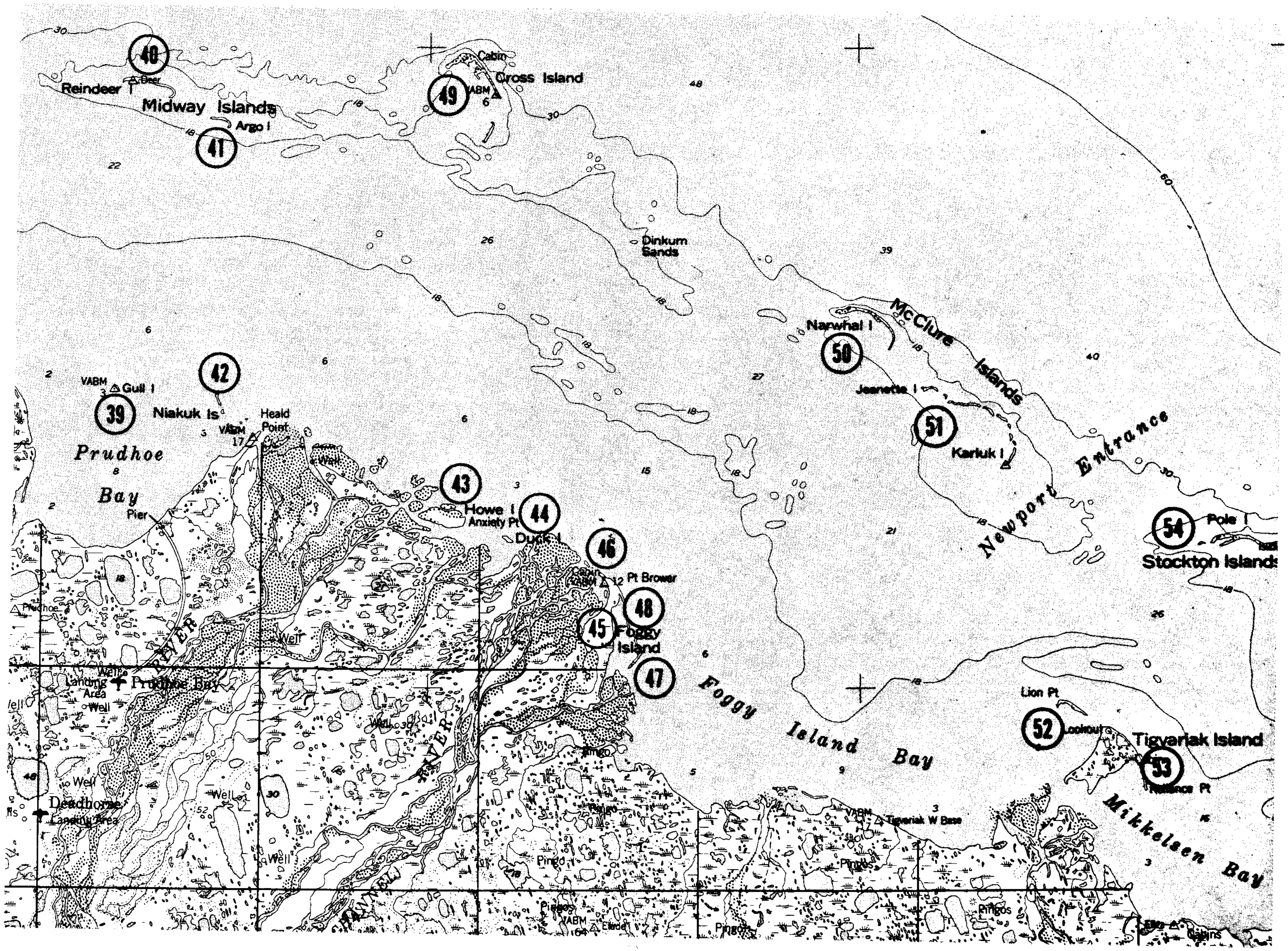

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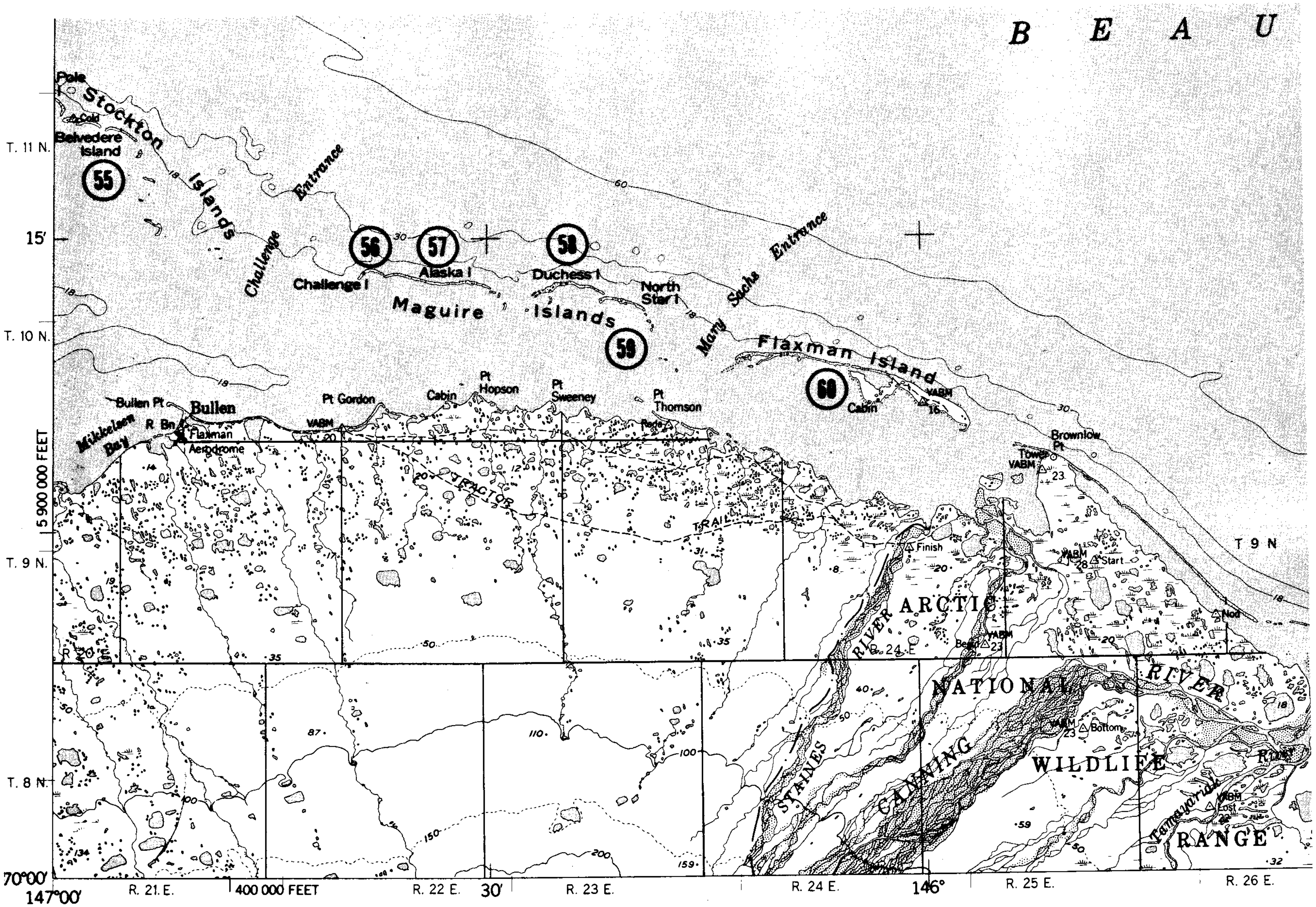

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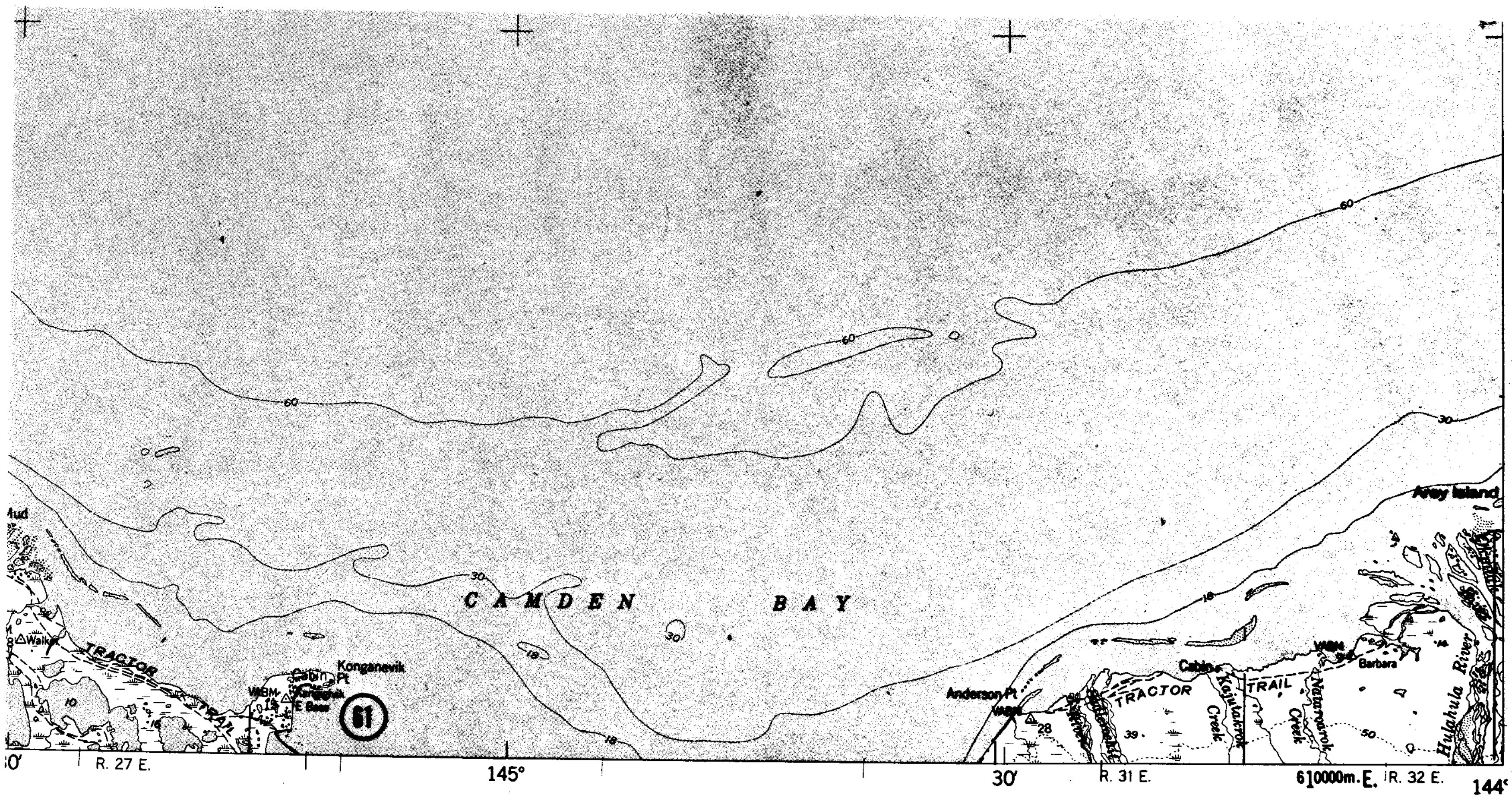

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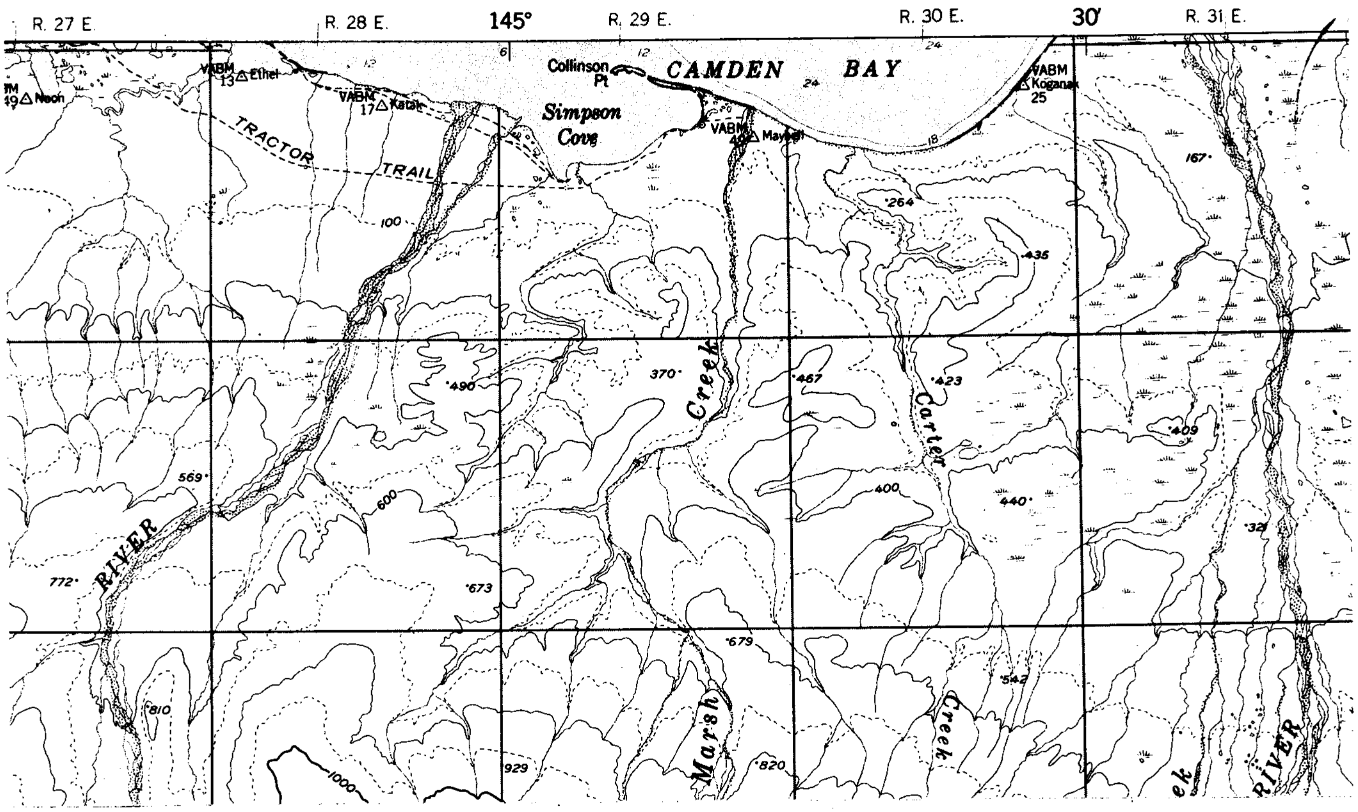

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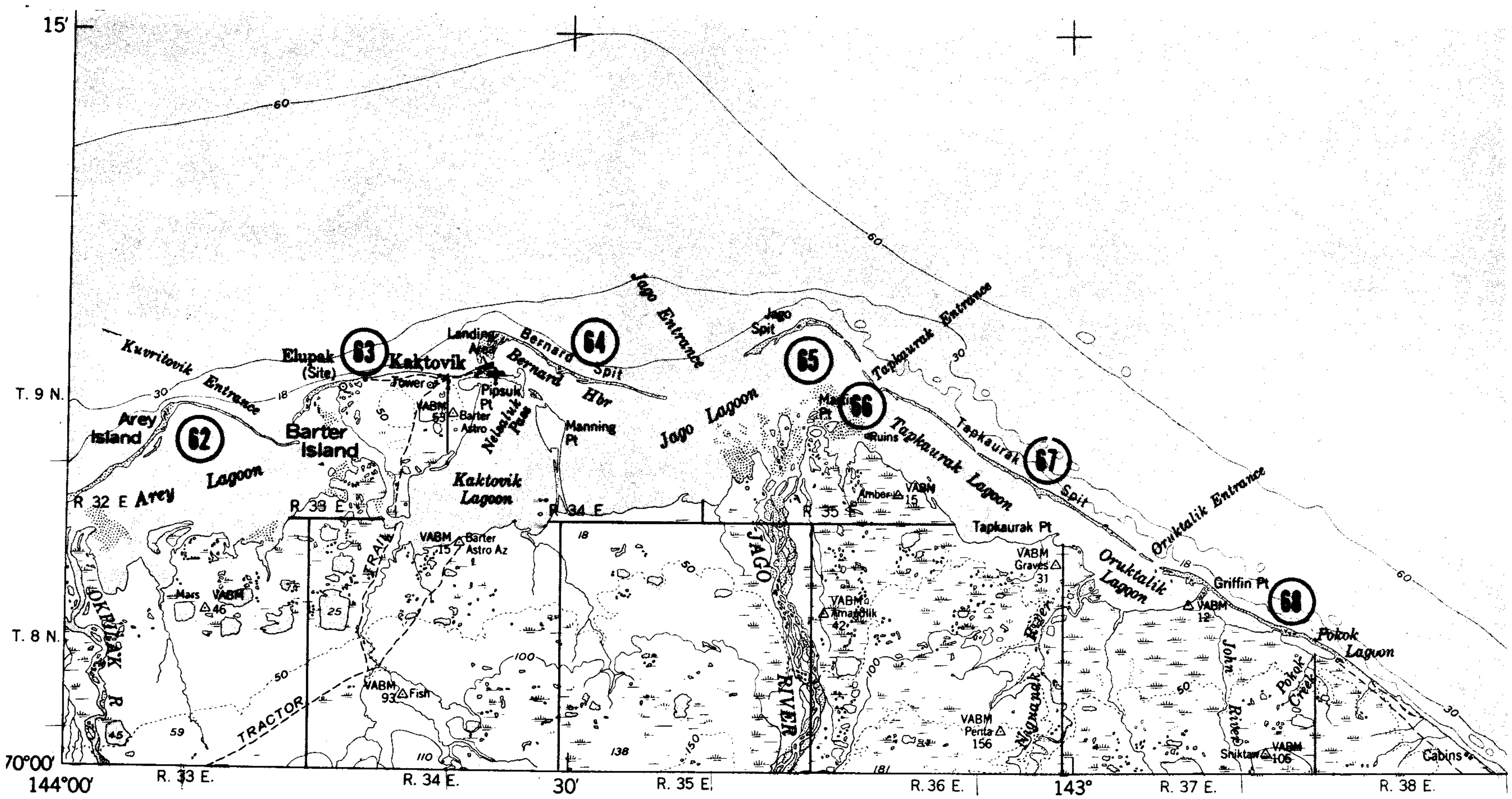

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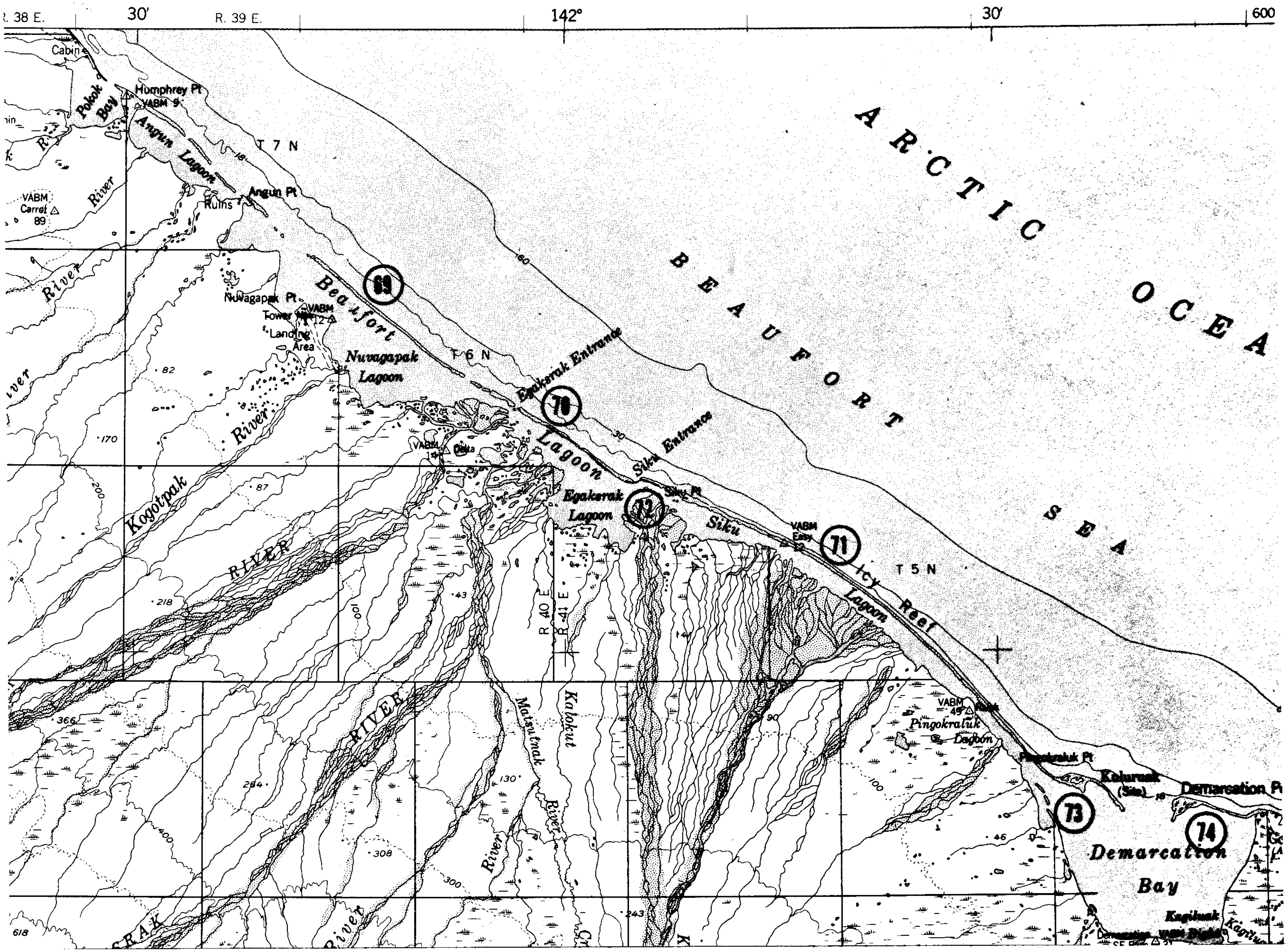

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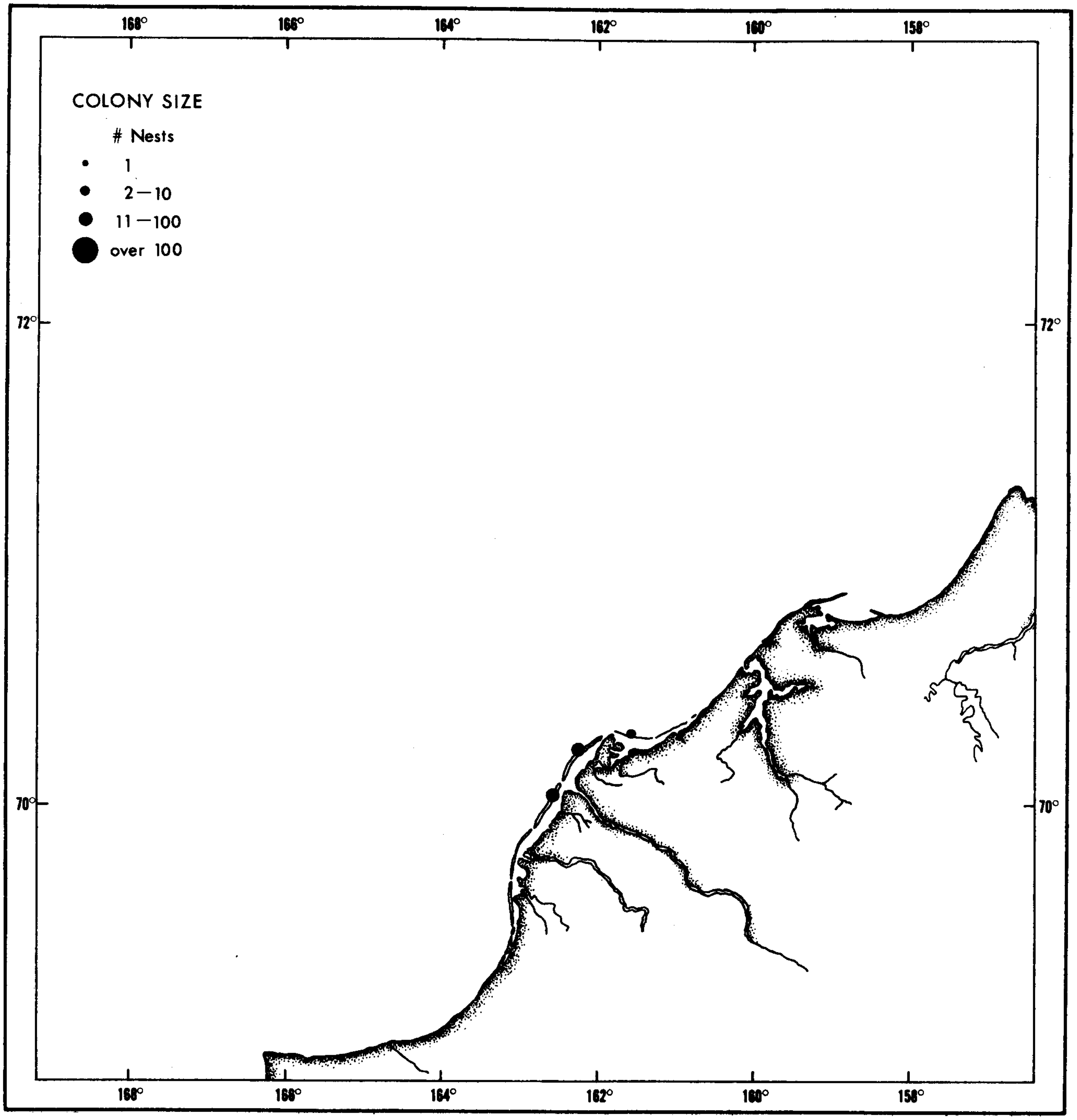

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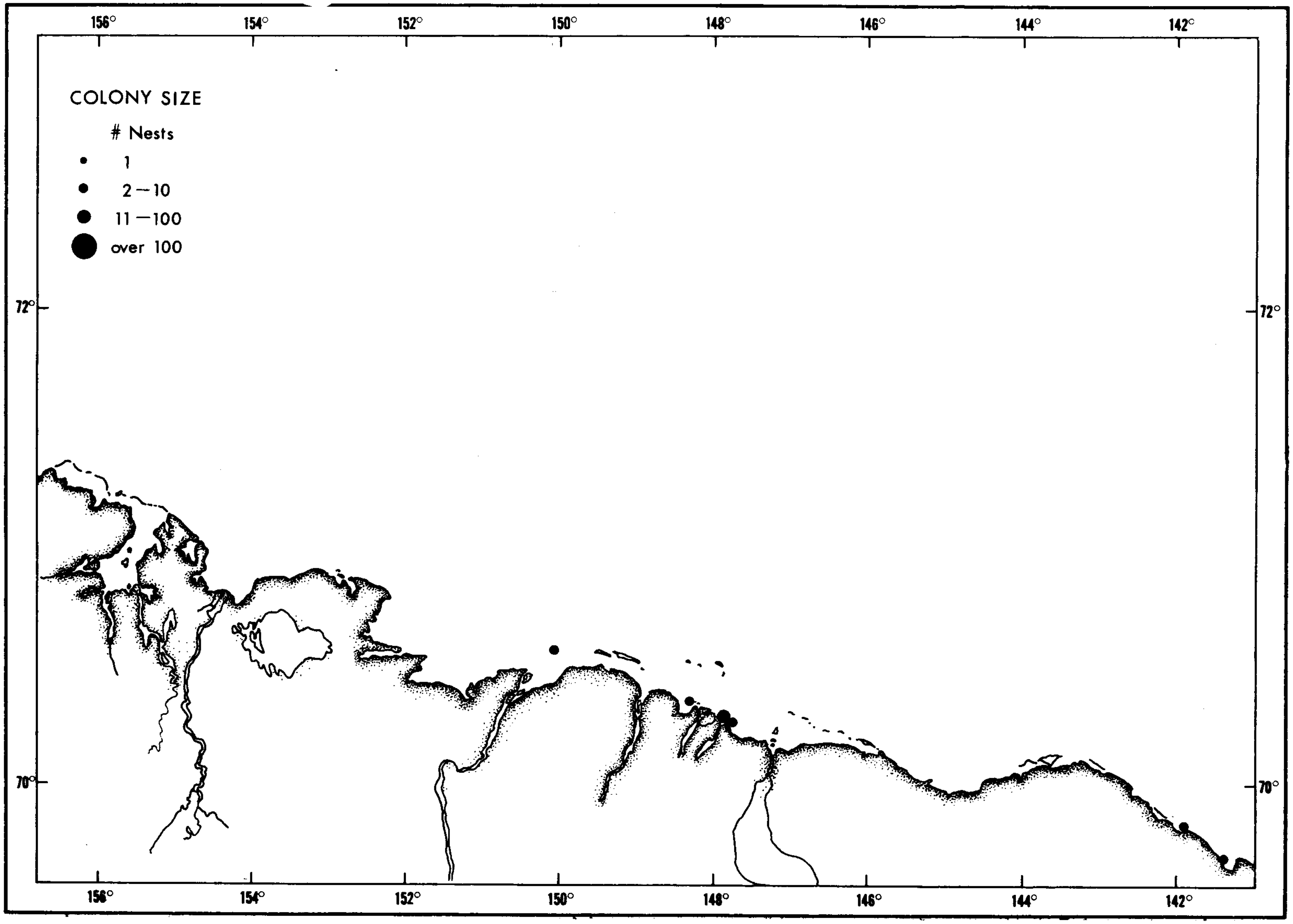

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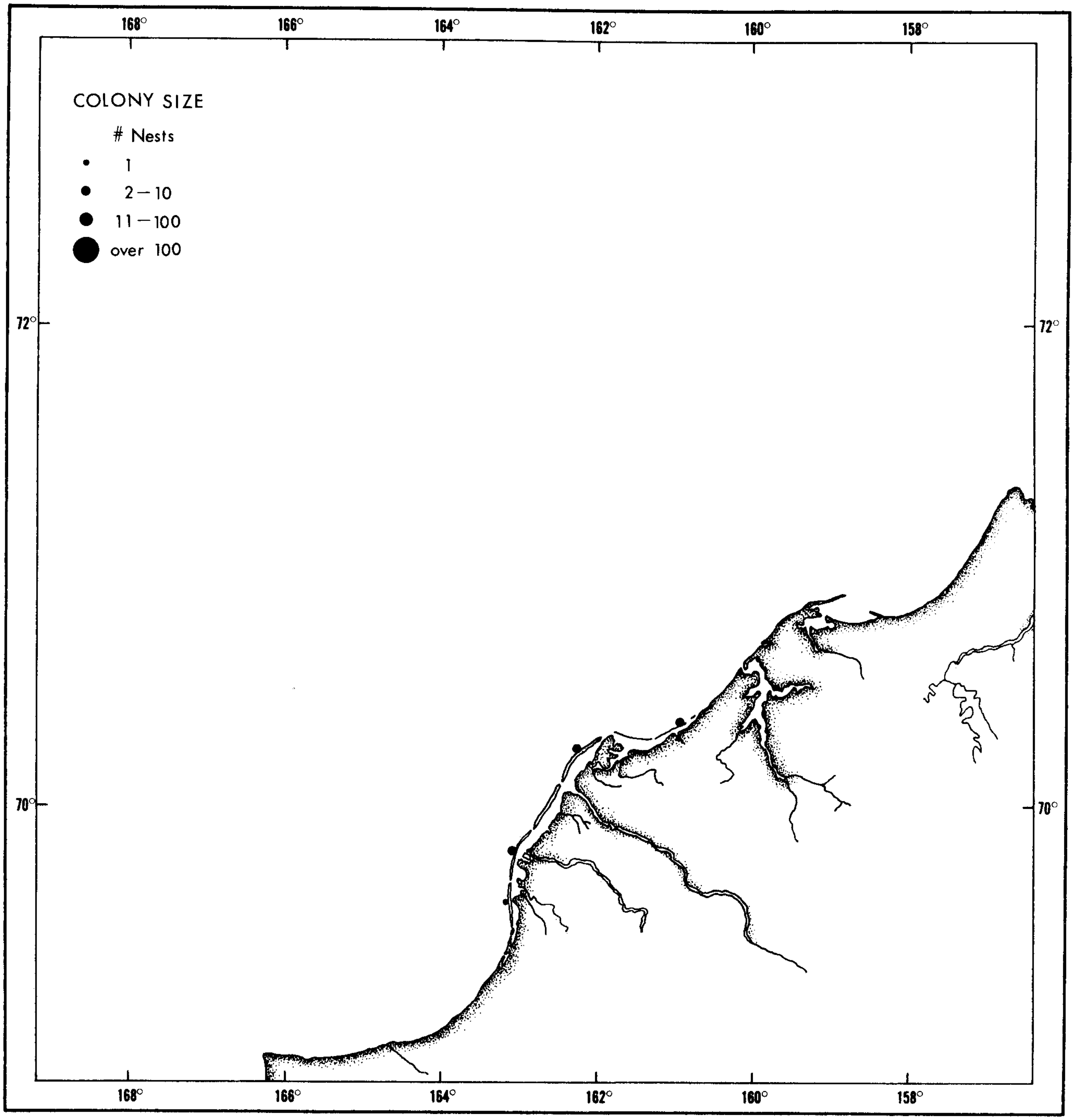

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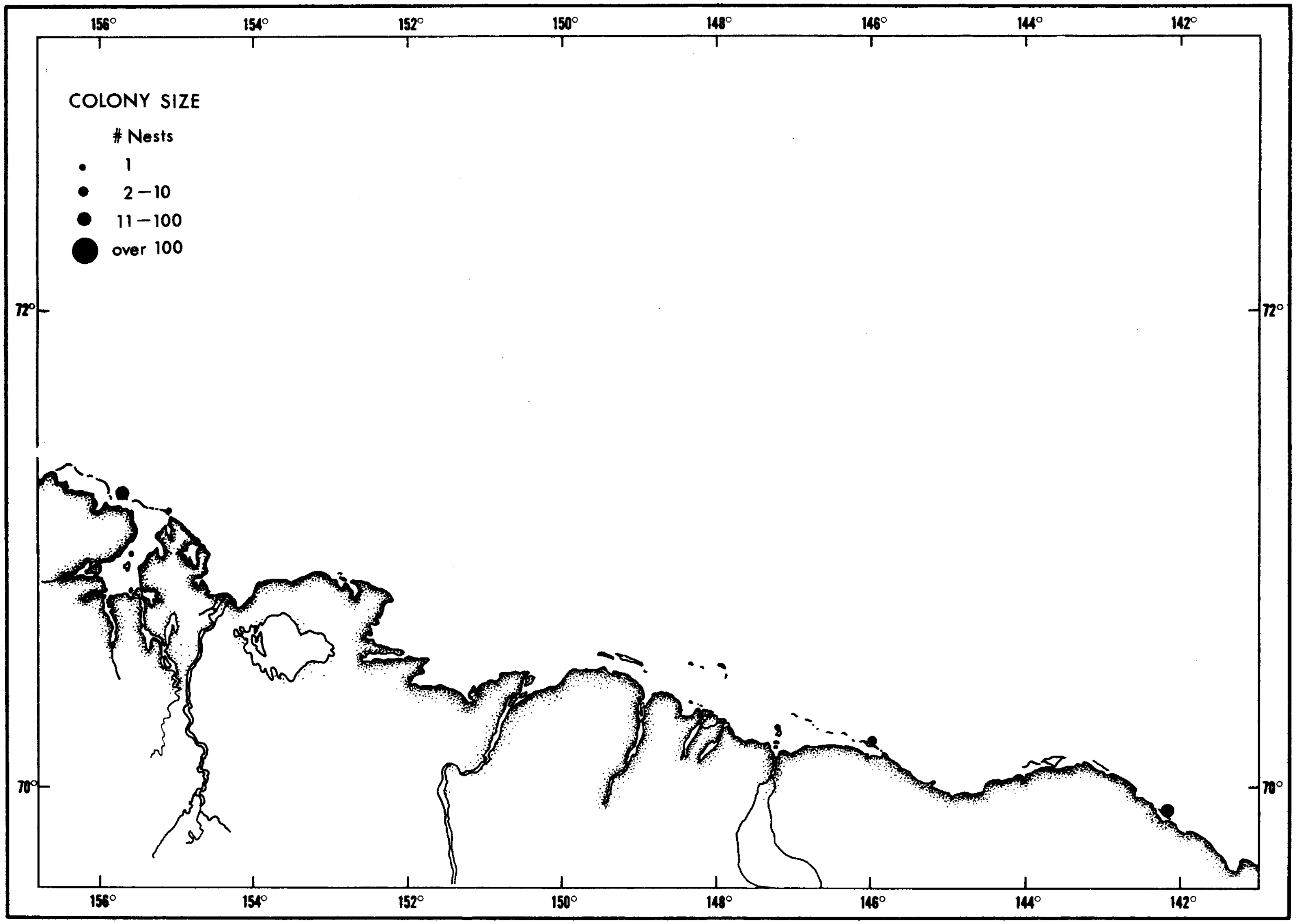

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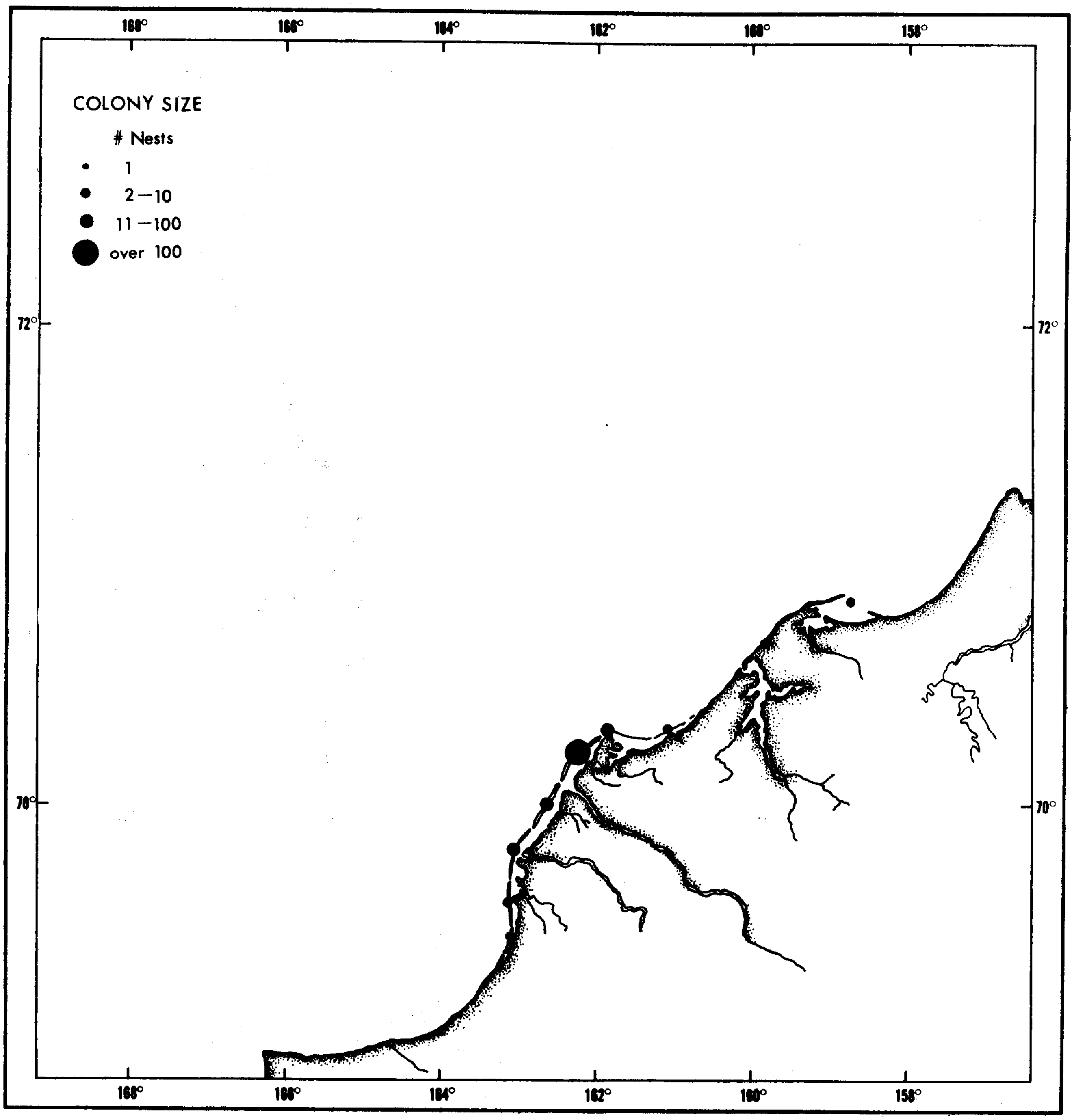

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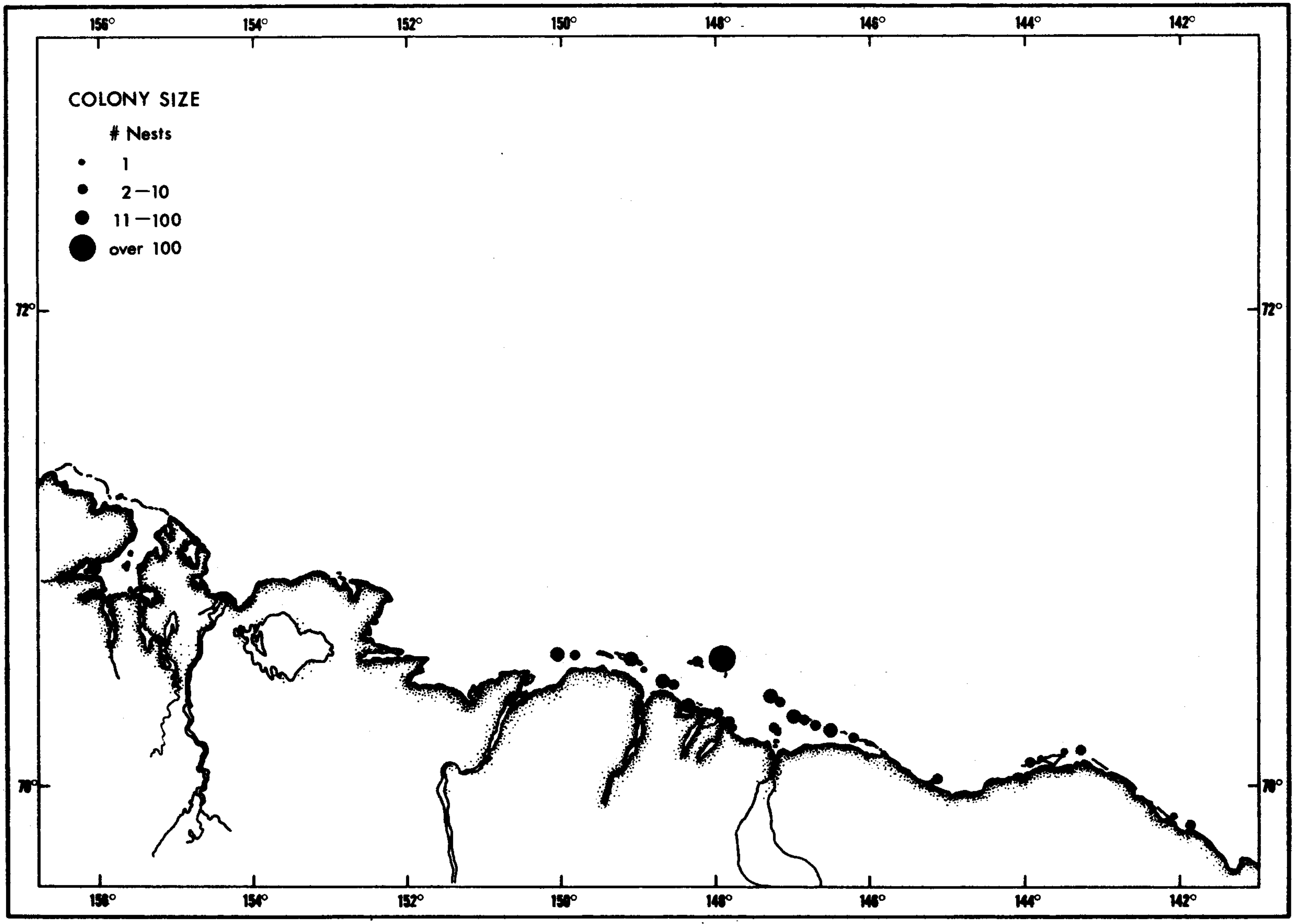

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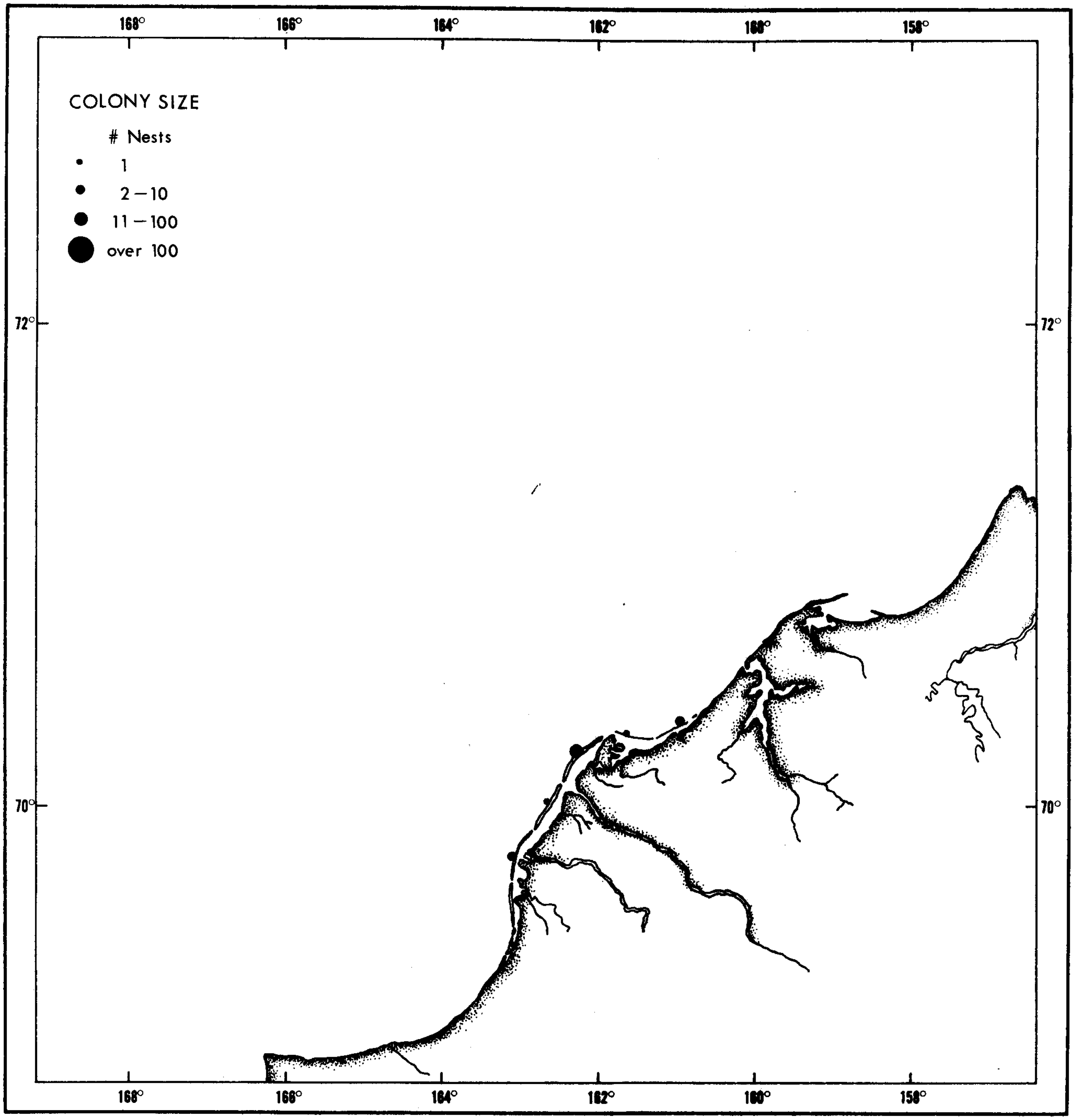

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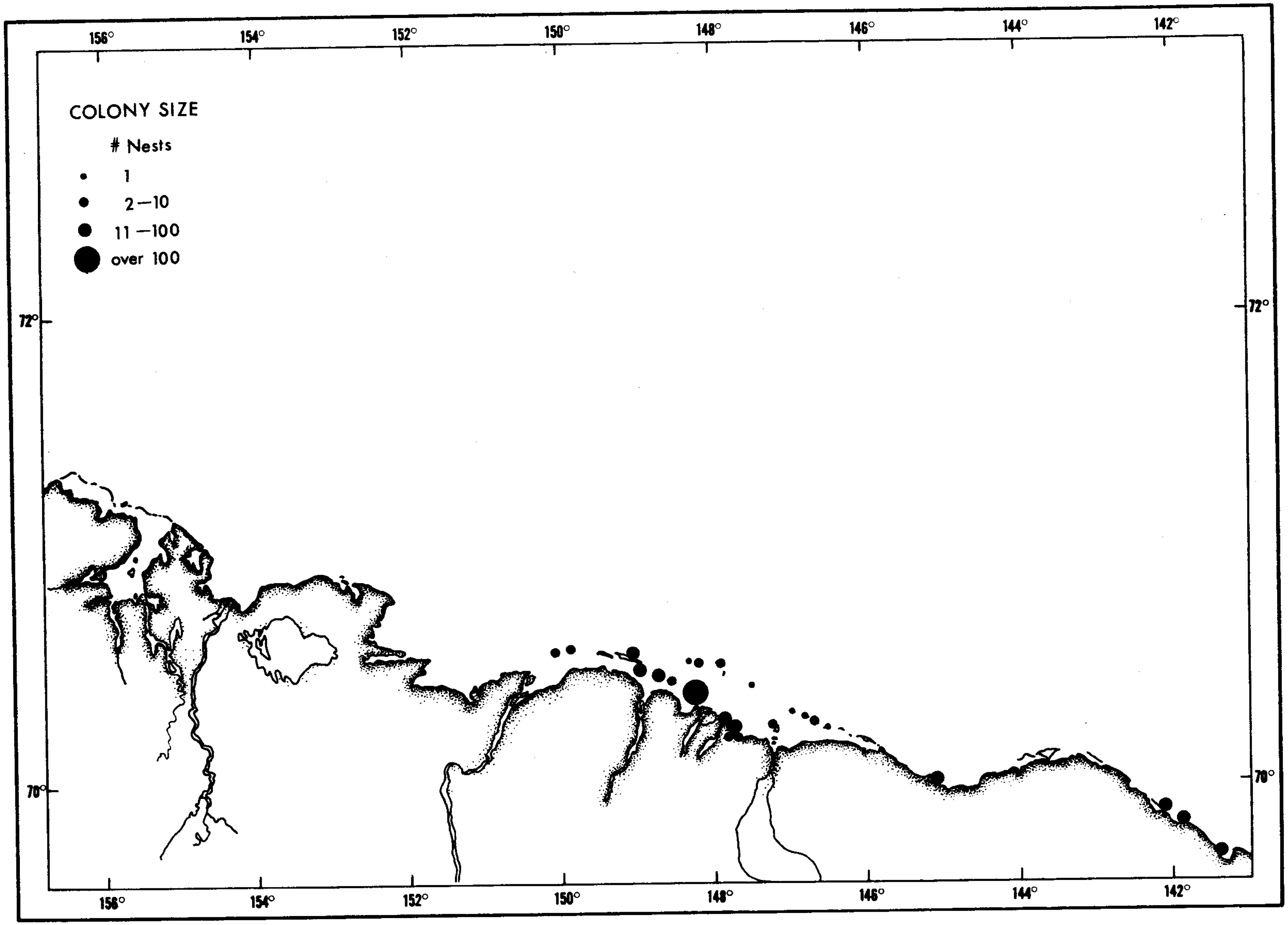

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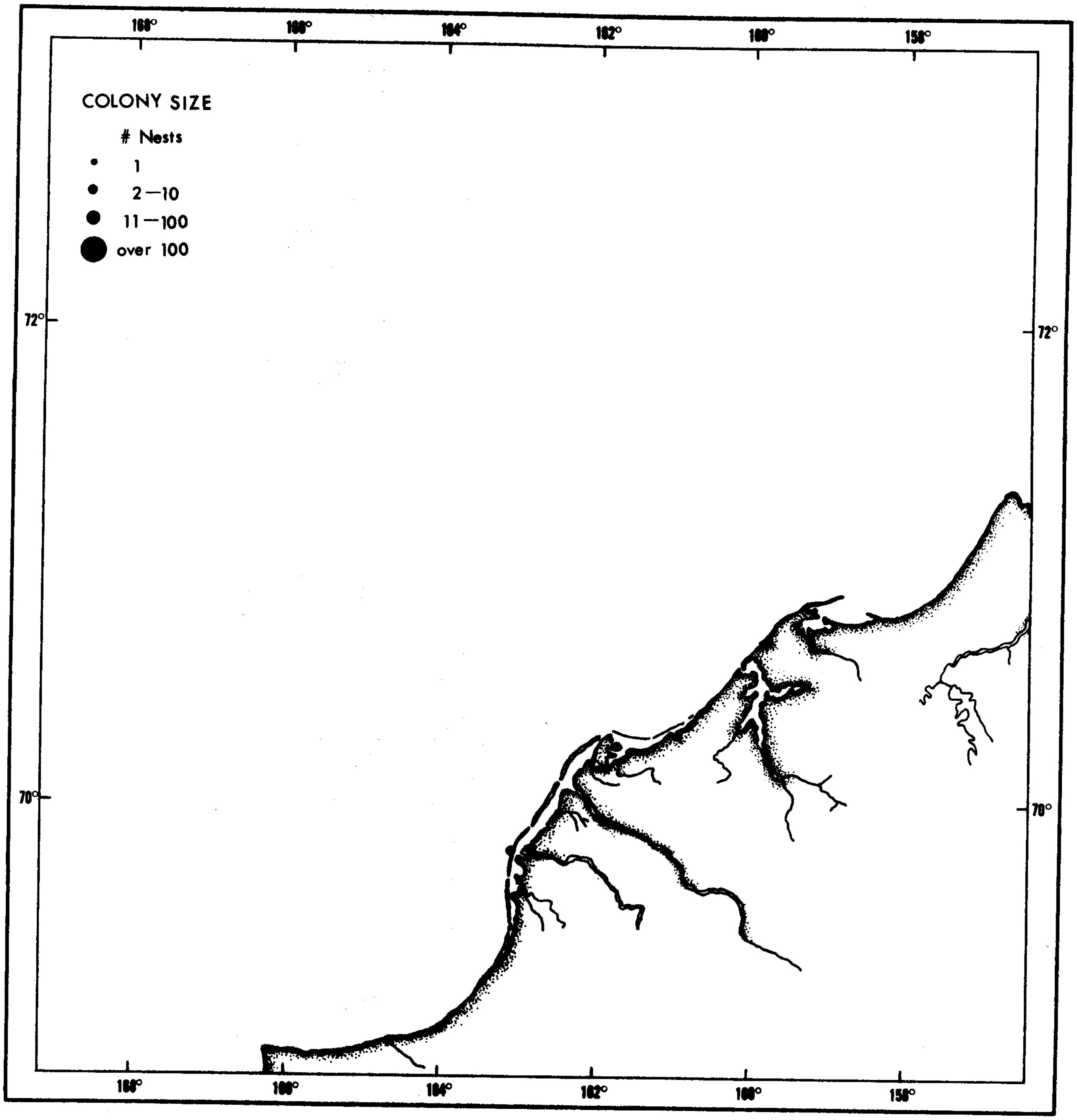

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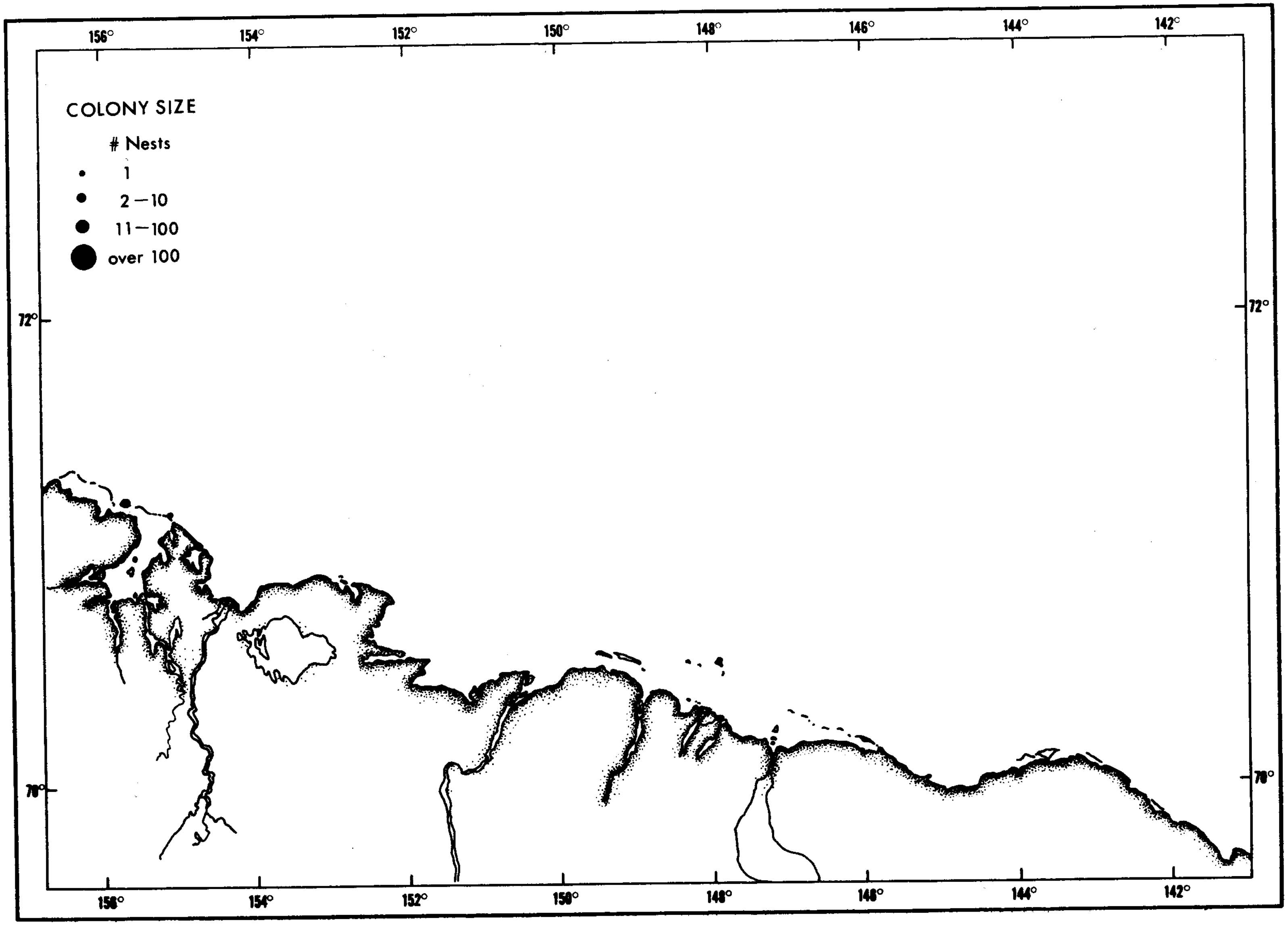

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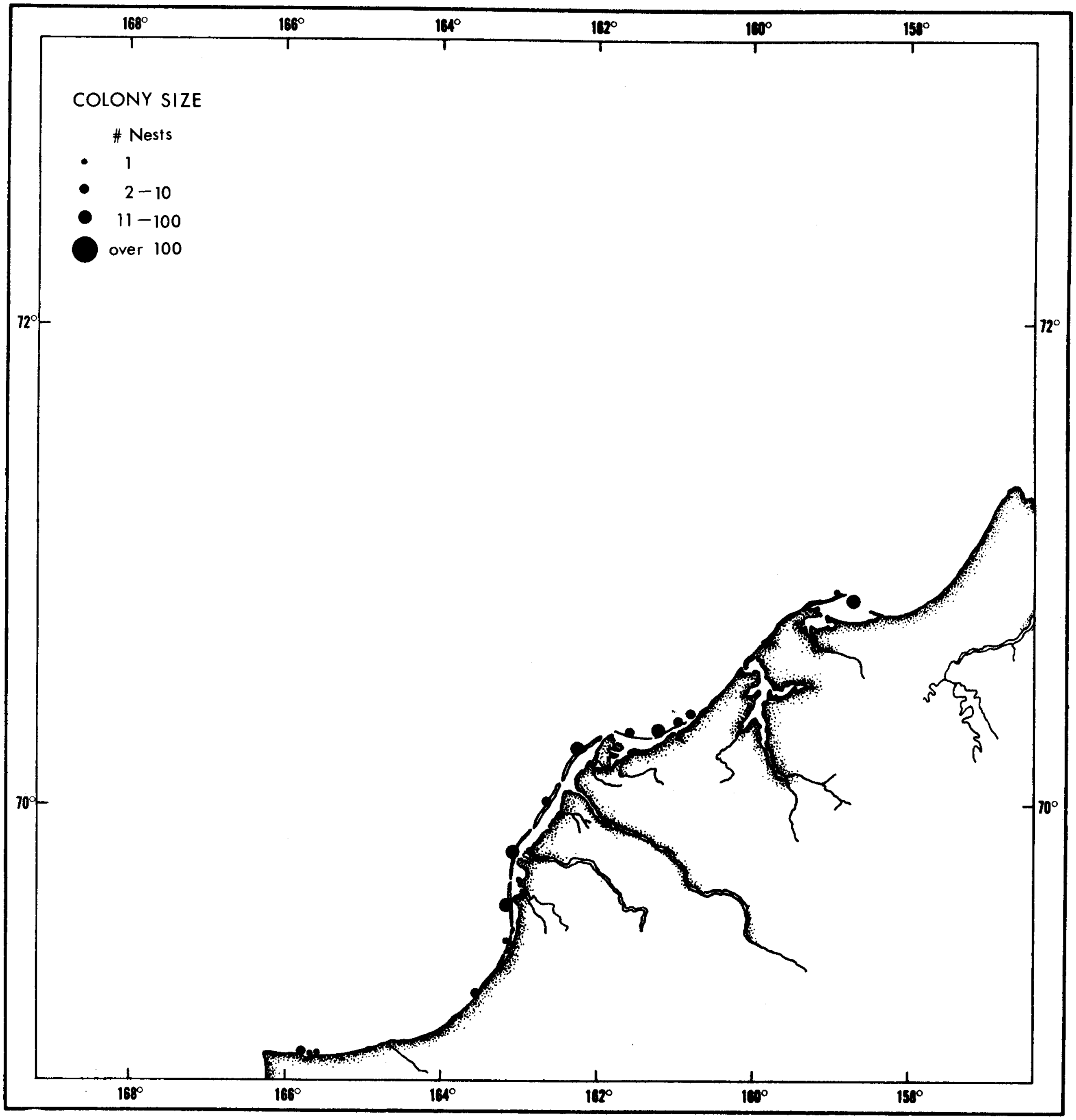

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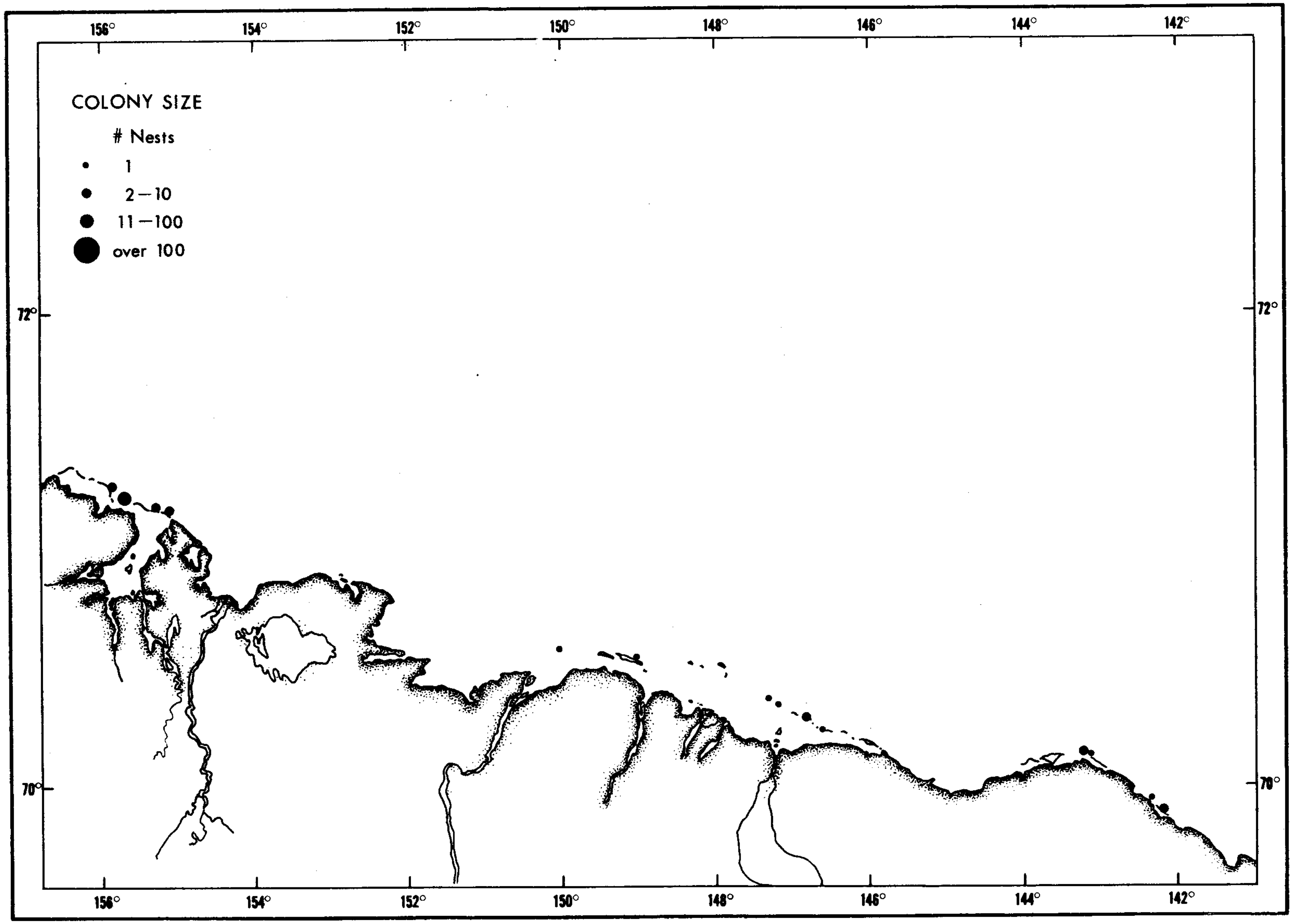

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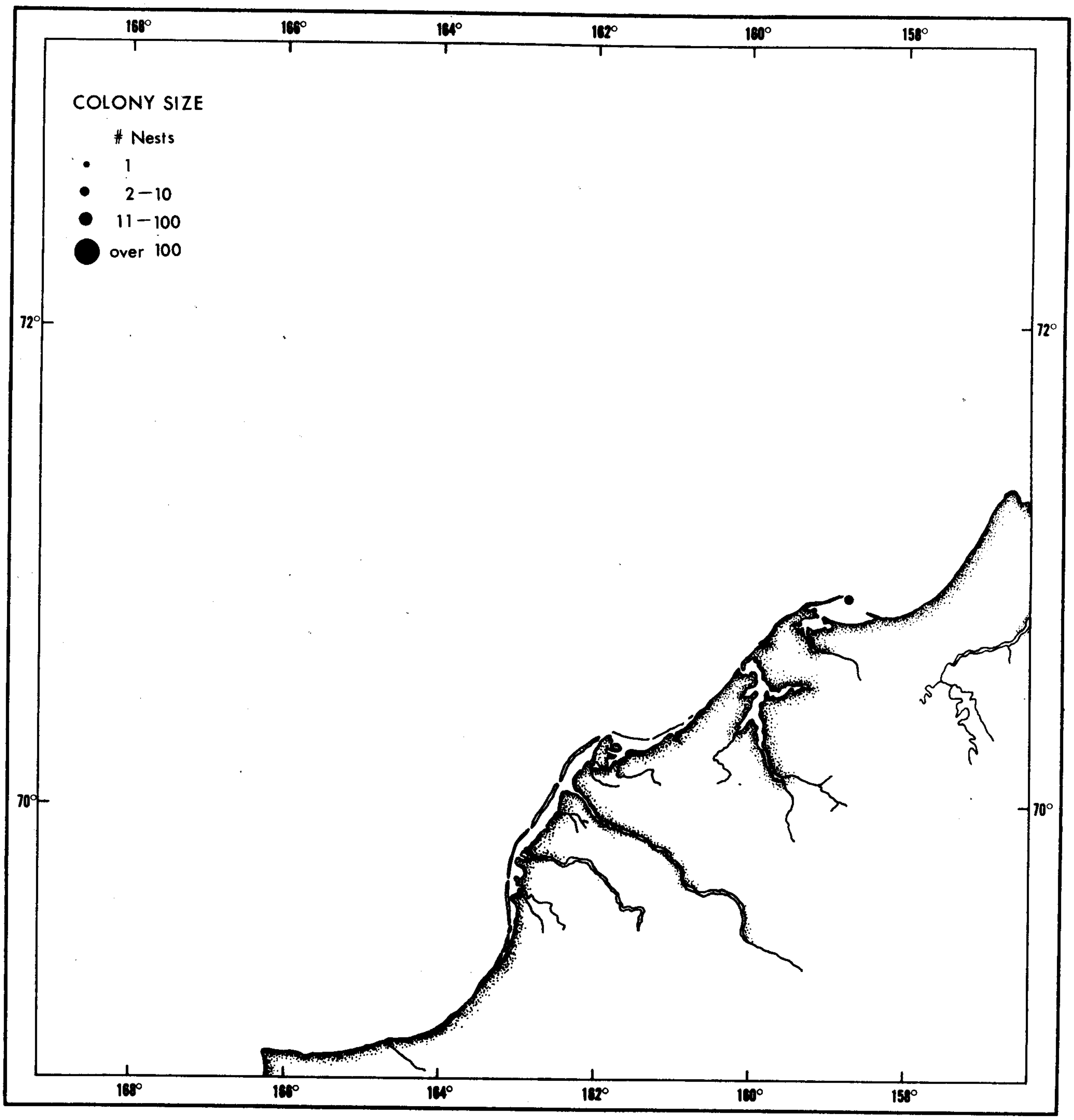

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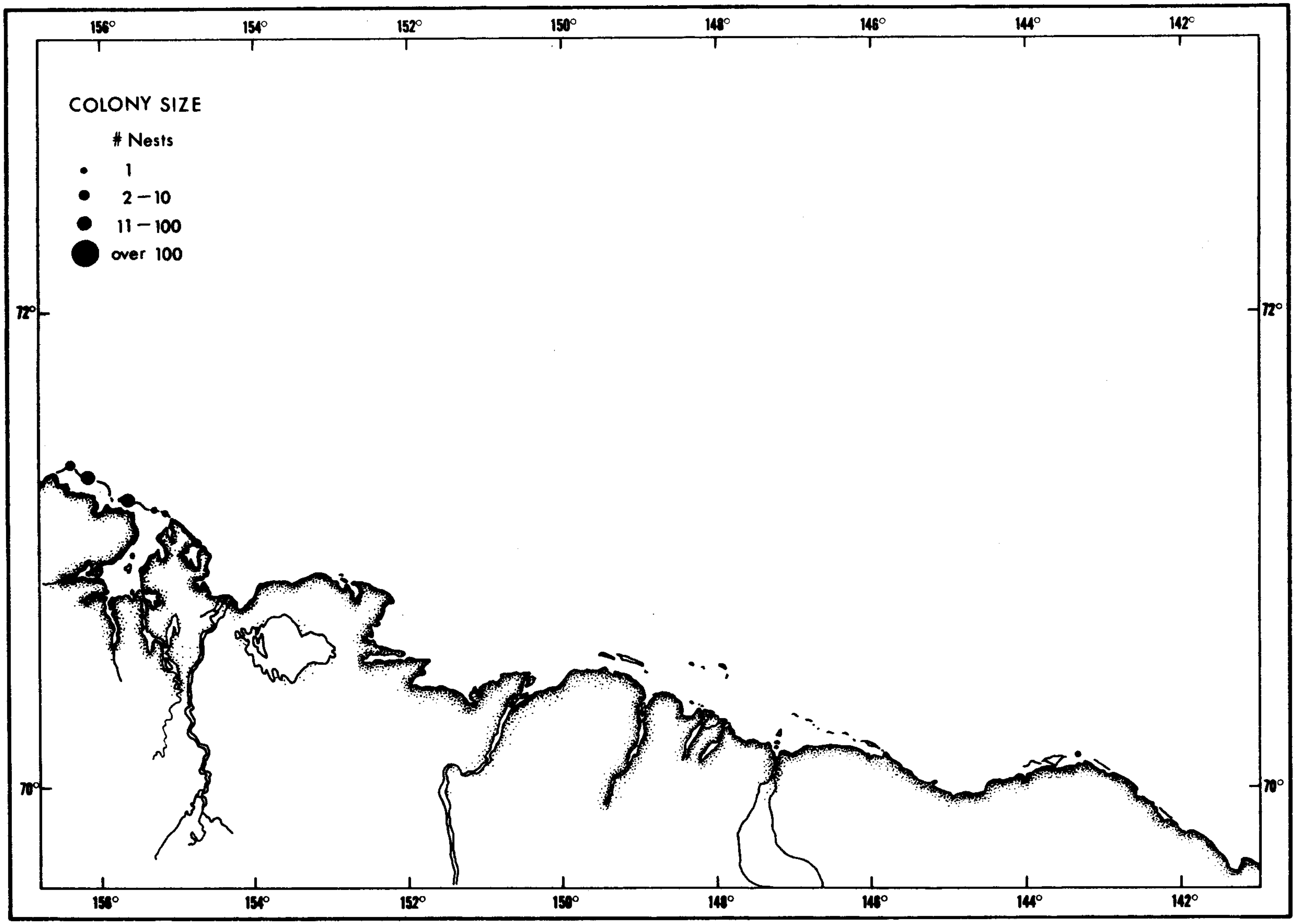

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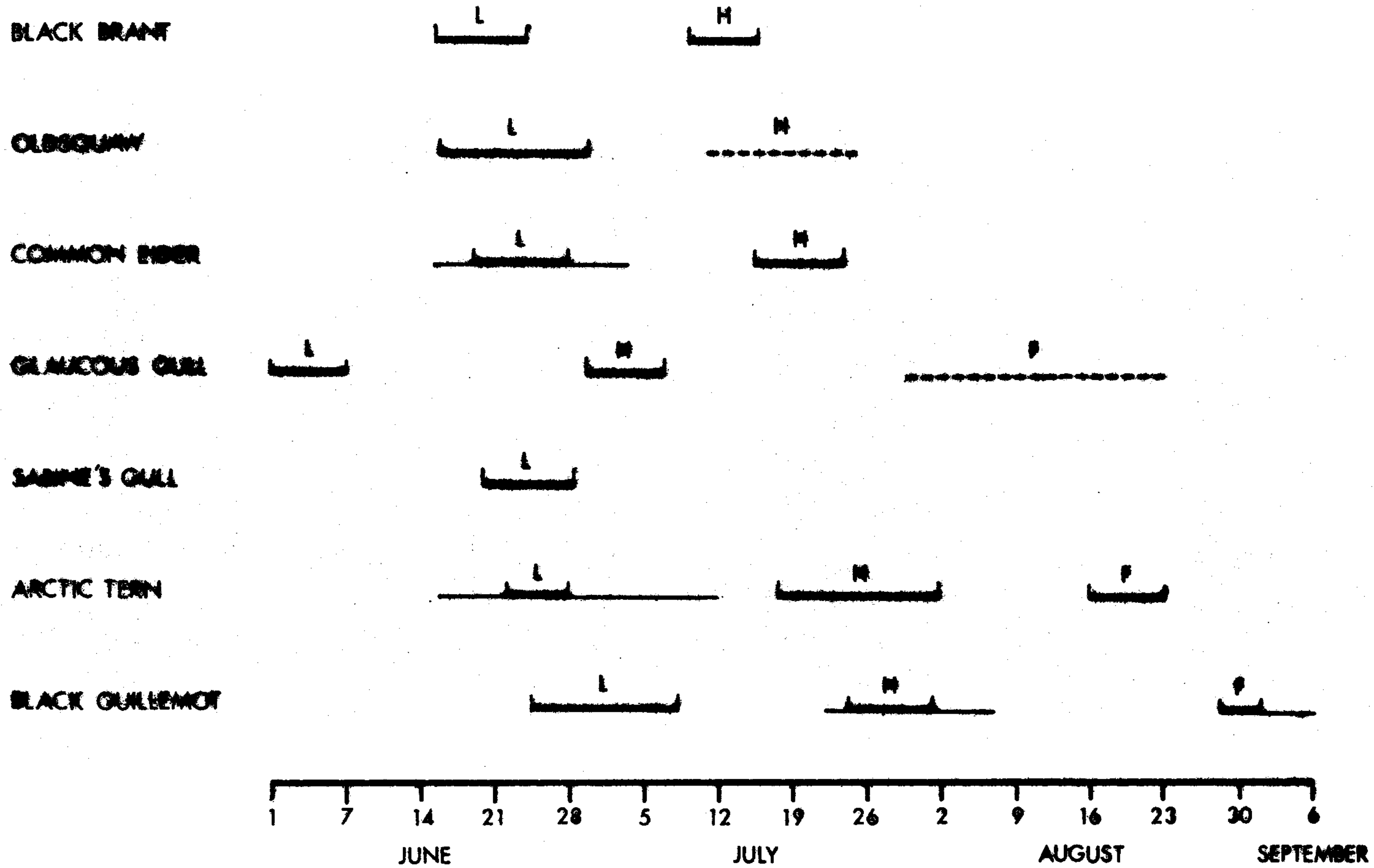

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Identification, Documentation and Delineation of Coastal Migratory Bird Habitat in Alaska

II. Feeding habits of birds in the Beaufort Sea

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I. Summary of objectives, conclusions and implications with regard to OCS oil and gas development

In 1976 as part of a general survey of avian use of coastal habitats in the Beaufort Sea a number of birds were collected so that their stomach contents could be analyzed. An attempt was made to collect the most common species in the Beaufort and to carry out the collections throughout the period when birds are present and at a number of locations. The objectives of the study were to determine which prey species are most important to the birds feeding in the Beaufort and the relative importance of these species throughout the summer and fall.

This report presents the first information on the food of marine birds in the Beaufort Sea. No detailed analysis of the stomach contents is being attempted until an OCSEAP format is developed that will allow computer analysis. Preliminary results show that a variety of crustaceans are consumed by nearshore birds with amphipods, mysids and euphausids being the principal prey. For species occurring further offshore Arctic Cod (*Boreogadus saida*) is the most important food. Further analysis of the data will allow the determination of the time periods when each prey species is most important and the habitat in which the prey is usually consumed. The sensitivities of these prey species and habitats can then be examined in order to determine how oil and gas development will affect the populations the birds feed on.

II. Introduction

A. General nature and scope of study

The coastal waters of the Beaufort Sea comprise the only true high arctic nearshore area present in Alaska and the United States. Ice cover is complete or nearly complete for nine months of the year. The presence of ice prevents birds from occupying the Beaufort for most of the year. Although ice begins to decompose in early May, bird use of the nearshore waters is low until late July when the shorefast ice is decomposing at a rapid rate. At this time birds that breed on the tundra are moving to marine waters. From early August to mid-September bird use of the nearshore Beaufort is high. During this period the Beaufort is a major feeding area for migrant birds.

In 1976 as part of an avifaunal survey of the Arctic coast of Alaska the Alaska Department of Fish and Game collected birds in order to determine the prey preferences of species feeding in the Beaufort. This study was the first research on food habits for Beaufort seabirds and we tried to sample a wide geographic area with emphasis on those species that were present in the greatest numbers.

B. Specific objectives

The specific objectives of this study were:

(1) To determine the food items of birds in the nearshore waters of the Beaufort Sea.

(2) To determine how the importance of specific food items changes with time, ice cover and geography.

(3) To determine which prey species are most important to birds feeding in the nearshore Beaufort Sea.

C. Relevance to problems of petroleum development

The impact of oil and gas development on bird populations is usually thought of in terms of spilled oil directly oiling birds and causing mortality. Far more important, however, may be the physical and chemical changes that will occur in an environment that may disrupt the trophic system that supports the birds. An example of such impacts includes the chronic low level fuel spills associated with humans that could cause mortality of prey organisms.

Because such indirect effects will have to be assessed from lower trophic levels it is important to know the major prey items for species in a given area. With a knowledge of which prey organisms are most important to birds it is possible to test their sensitivities in order to determine how oil development will affect the system that supports the birds.

III. Current state of knowledge

While much work has been done on the feeding habits of Alaskan arctic species when they are on the tundra, there is almost no information for prey taken in marine or littoral waters. Watson and Divoky (1972) and Divoky (1975) reported on stomach contents collected in the ice in the extreme western Beaufort and Chukchi. Swartz (1966) reported on the food eaten by cliff nesting species at Cape Thompson in the southern Chukchi.

IV. Study area

The nearshore waters of the Beaufort Sea are true high Arctic waters being little influenced by warmer water from further south. As is characteristic of high arctic areas productivity is low and the period of productivity is short. This is due in large part to the poor mixing of water covered by pack ice which limits the amount of nutrients available for primary productivity.

The period when birds are present in the study area is determined largely by the decomposition and formation of the pack ice. In May a flaw lead forms between the shorefast ice and the free-floating pack. This lead is little used by birds except as a migratory pathway for eiders. During June and most of July the shorefast ice decomposes slowly. Moats form along the shoreline and around islands and melt ponds cover much of the shorefast ice surface. In late July the decomposition of shorefast ice is almost complete with leads and open water being common. In early August shorefast ice is no longer recognizable and multi-year ice characteristic of the main pack ice begins to drift into shore. There is usually a period in late August when little or no ice is present in nearshore waters. After this open water period there is a period of freeze up that usually occurs in late September or early October. The above periods describe what generally occurs in the nearshore waters of the Beaufort. The free-floating pack ice occurs offshore in the Beaufort throughout the year. Its position is dependent on wind conditions. It can be 300 km offshore or pushed up next to the mainland.

The periods described above are important in determining bird use of the nearshore Beaufort. During the shorefast ice period through the disappearance of the shorefast ice bird use is rather low. When the drifting ice period begins in early August large numbers of birds are leaving the tundra for the littoral zone. It is during this period when the nearshore Beaufort is most important to birds and when birds are intensively feeding in marine waters. This feeding continues through August with bird numbers decreasing as species migrate south. By the time of freeze up in the fall all but a few high arctic species have left the Beaufort.

V. Sources, methods and rationale of data collection

Birds were collected with shotguns. The stomach and esophagus were removed as a unit and put in formalin. When field conditions prevented the stomach from being removed immediately a small quantity of formalin was pumped down the esophagus. This was done to prevent further digestion of the stomach contents. Specific information on time, habitat, and ice conditions was obtained for all specimens collected. All birds were examined and information on weight, gonad size, fat and molt was obtained.

An attempt was made to collect those species which are most abundant in the Beaufort. Whenever possible birds that had been observed feeding were collected.

In the laboratory the contents of the esophagus and stomach were weighed separately. The contents of each were then separated into the lowest possible taxonomic units and weighed. Whenever possible the items in the stomach were measured. Examples of all taxonomic units were kept and sent to the Sorting Center of the Institute of Marine Science of the University of Alaska for verification.

VI. Results

Summaries of the prey items found in each species of bird are presented in Tables 1 through 12. Table 13 summarizes Tables 1 through 12. No information on Red Phalaropes (*Phalaropus fulicarius*) is presented. All stomachs of this species contained what was classed as invertebrate chyme. Further analysis of these specimens has to be done by specialists familiar with all the body parts of the prey organisms.

VII. Discussion

The analysis of information obtained from the stomach contents awaits the approval of an OCSEAP bird specimen form so the data can be put into a computer compatible format and analyzed. This will allow the determination of which prey items are most important in specific time periods, geographic areas and habitats. The format is apparently near completion and such analysis will follow. For the present time a qualitative analysis of the trophics of the nearshore Beaufort will have to suffice.

Shorefast ice period

During the period when the shorefast ice is slowly decomposing there is little use of nearshore waters. Moats next to the shoreline and barrier islands provide most of the open water. Stream and river mouths usually have open water associated with them.

During this time little food is available to surface feeders. Arctic Terns (*Sterna paradisaea*) breeding on Cooper Island regularly search the nearby moats and leads but until mid-July most of their food is obtained on the mainland. During this period Arctic Terns also are seen feeding at the mouths of streams where amphipods are locally abundant. Other than terns few surface feeding birds are present in the nearshore during this period. Oldsquaw (*Clangula hyemalis*) and loons (*Gavia* sp.) are found in the nearshore during the shorefast ice period. Loons are usually found near stream mouths where they apparently feed primarily on amphipods (Table 1). Oldsquaw are found wherever open water is present. Although they feed primarily on amphipods at stream mouths in other areas filamentous algae may be important. Oldsquaw near Cooper Island are frequently seen surfacing with algae in their beaks. The lack of prey available to diving species is demonstrated by the feeding behavior of Black Guillemots (*Cepphus grylle*) on Cooper Island. They do very little feeding near the island but fly out to sea to feed on Arctic Cod (*Boreogadus saida*).

Shorefast ice breakup

This period is usually rather short in that once decomposition of shorefast ice reaches a certain point it rapidly loses the characteristic of shorefast ice. During this period much more potential feeding space becomes available for birds. Lagoons are no longer frozen to the bottom. Offshore areas have more leads and cracks present. Any area where water is moving, such as in passes between islands or stream mouths, usually has a large section of open water associated with it.

During this period Arctic Cod become more available in the drifting pack ice just off the barrier islands. Arctic Terns on Cooper Island are able to obtain Arctic Cod rather easily one or two kilometers from shore. Amphipods also become more available to surface feeders as feeding flocks of Arctic Terns are present in areas where the ice is decomposing.

During this period large numbers of male Oldsquaw move from the tundra to the nearshore waters. Bivalves and amphipods are probably the primary prey.

Drifting ice

During this period pieces of multi-year ice drift into the nearshore waters. Associated with this ice is the under-ice fauna composed of Arctic Cod and amphipods. Ice cakes that drift close to the shoreline frequently have feeding birds associated with them. *Apherusa glacialis* is apparently the most important prey species associated with these ice cakes.

During this period there is also an increase in zooplankton that is not usually associated with ice. A concentration of copepods, mysids and euphausids is present along the beach and attracts large numbers of shoreline migrants such as phalaropes, Arctic Terns, and Sabine's Gulls (*Xema sabini*).

Oldsquaw numbers continue to increase in lagoons with the primary prey items being bivalves and crustaceans.

Open water

There is little ice near shore during this period although the main pack ice can be a few kilometers offshore. Copepods, mysids and euphausids continue to be common at the shoreline. In some years chaetognaths are also abundant. Feeding flocks continue to be found at the shoreline with the number of birds decreasing during August.

Offshore habitats

Figure 13 shows that while invertebrates are important to the bulk of the nearshore species, the primary prey for species that occur most frequently offshore such as Black-legged Kittiwake (*Rissa tridactyla*), Thick-billed Murre (*Uria lomvia*) and Black Guillemot, is fish, primarily Arctic Cod.

VIII. Conclusions

No detailed analysis of the stomach contents presented in this report is being attempted until a data format for bird stomach contents is approved by OCSEAP. This report does provide the first overview of prey consumed by birds in the nearshore Beaufort Sea. Amphipods, mysids and euphausids are important to a number of nearshore species. More pelagic species consumed primarily fish.

IX. Acknowledgements

Specimens were collected by Robert Boekelheide, Doug Forsell, Edward Good, Thomas Harvey, Katherine Hirsch, Karen Oakley, Ken Wilson, Doug Woodby and the principal investigator.

Stomachs were analyzed by Beth Chiodo, Harriet Huber, Karen Oakley and the principal investigator.

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Table 1. Stomach contents of Arctic Loons collected in the Western Beaufort Sea, July 9, 1976.

No. of stomachs = 2
Total weight = 5.6 grams

Food items	% total weight	% occurrence
Plant material - wood	< 1	50
Amphipoda	100	100
Amphipod chyme	84	100
Pseudalibrotus littoralis	13	50
Gammarus sp.	4	50

Table 2. Stomach contents of Oldsquaws collected in the Western Beaufort Sea, June-October, 1976.

No. of stomachs = 93
Total weight = 317.8 grams

Food items	% total weight		% occurrence	
Plant Material	8		40	
Echiuroid worm - *Echiurus echiurus*	<1		1	
Polychaeta	1		3	
Aremicola sp.		1		1
Helicriptis sp.		<1		1
Polynode polychaete		<1		1
Copepoda	3		9	
Mysidacea	20		16	
Mysis spp.		20		14
Mysis relicta		<1		2
Cumacea - *Diastylis sulcata*	<1		5	
Isopoda - *Saduria entomon*	4		6	
Amphipoda	23		38	
Unidentified		10		14
Apherusa glacialis		8		8
Gammarus spp.		3		6
Onisimus spp.		2		2
Onisimus glacialis		<1		2
Onisimus littoralis		<1		1
Acanthostephia behringiensis		1		1
Acanthostephia incarinata		<1		2
Acanthostephia spp.		<1		1
Pseudalibrotus sp.		1		2
Pontoporeia spp.		1		2
Pontoporeia affinis		<1		2
Pontoporeia femorata		<1		1
Hyperia sp.		<1		1
Atylus carinatus		<1		1
Gammaracanthus loricatus		<1		3
Monoculodes sp.		<1		1

Table 2. (cont.) Stomach contents of Oldsquaws collected in the Western Beaufort Sea, June-October, 1976.

Food items	% total weight		% occurrence	
Euphausiacea	17		13	
Thysanoessa sp.		12		8
Thysanoessa raschii		4		3
Unidentified		1		2
Decapoda - Crab legs	<1		1	
Exoskeleton	1		4	
Invertebrate Chyme			2	
Bivalvia	22		59	
Unidentified		9		47
Portlandia oleacina		8		3
Cytodaria sp.		4		3
Cytodaria kurriana		1		4
Yoldia hyperborea		<1		1
Liocyna fluctuosa		<1		1
Fish - *Boreogadus saida*	<1		1	

Table 3. Stomach contents of Steller's Eiders collected in the Western Beaufort Sea, September 5, 1976.

No. of stomachs = 3
Total weight = 6.2 grams

Food items	% total weight	% occurrence
Amphipoda	100	100
Amphipod chyme	56	100
Onisimus spp.	29	33
Onisimus littoralis	13	33
Ischyrocerus sp.	2	33
Atylus sp.	<1	33
Weyprechtia sp.	<1	33

Table 4. Stomach contents of Common Eiders collected in the Western Beaufort Sea, August 22, 1976.

No. of stomachs = 2
Total weight = 41.3 grams

Food items	% total weight	% occurrence
Mysidacea - *Mysis relicta*	14	50
Isopoda - *Saduria entomon*	85	100
Amphipoda - *Onisimus* sp.	<1	50
Bivalvia	<1	50
Gastropoda	<1	50

Table 5. Stomach contents of King Eiders collected in the Western Beaufort Sea, June-September, 1976.

No. of stomachs = 16
Total weight = 178.6 grams

Food items	% total weight		% occurrence	
Plant material	1		31	
Echiuroid worm - *Echiurus echiurus*	<1		6	
Polychaeta - *Cistenides* sp.	<1		19	
Copepoda	<1		6	
Isopoda - *Saduria entomon*	89		63	
Amphipoda	2		19	
Gammaracanthus loricatus		1		13
Gammarus sp.		<1		6
Lysianassidae		<1		6
Acanthostephia behringiensis		<1		6
Weyprechtia heuglini		<1		6
Decapoda	<1		6	
Bivalvia	1		19	
Gastropoda	1		13	
Unidentified		1		6
Oenopota laevigata		<1		6
Invertebrate chyme	5		6	

Table 6. Stomach contents of Glaucous Gulls collected in the Western Beaufort Sea, June-September, 1976.

No. of stomachs = 21
Total weight = 132.3 grams

Food items	% total weight		% occurrence	
Plant material	2		24	
Echiuroid worm - *Echiurus echiurus*	4		5	
Mysidacea - *Mysis* sp.	3		19	
Isopoda - *Saduria entomon*	7		5	
Amphipoda	< 1		14	
Apherusa glacialis		< 1		4
Unidentified		< 1		10
Euphausiacea - *Thysanoessa raschii*	9		14	
Decapoda	< 1		10	
Bivalvia	7		14	
Polinicus sp.		4		10
Neptunia sp.		3		5
Buccinum sp.		< 1		5
Fish	49		24	
Boreogadus saida		44		10
Unidentified		5		14
Mammal material (bones & fur)	8		19	
Unidentified material	10		19	

Table 7. Stomach contents of Black-legged Kittiwakes collected in the Western Beaufort Sea, June-September, 1976.

No. of stomachs = 25
Total weight = 109.4 grams

Food items	% total weight		% occurrence	
Plant material	<1		8	
Mysidacea - *Mysis* sp.	1		8	
Amphipoda	7		20	
Pseudalibrotus sp.		7		4
Apherusa glacialis		<1		16
Bivalvia	<1		12	
Fish - *Boreogadus saida*	91		76	
Unidentified chyme	<1		4	

Table 8. Stomach contents of Ross' Gulls collected in the Western Beaufort Sea, June-September, 1976.

No. of stomachs = 12
Total weight = 19.5 grams

Food items	% total weight	% occurrence
Mysidacea - *Mysis* sp.	8	42
Euphausiacea	90	50
Diptera	<1	8
Tunicata - *Pelonaia corrugata*	1	8
Fish - *Boreogadus saida*	1	33

Table 9. Stomach contents of Sabine's Gulls collected in the Western Beaufort Sea, June-September, 1976.

No. of stomachs = 21
Total weight = 22.3 grams

Food items	% total weight		% occurrence	
Plant material - *Cyperacea* seeds	<1		5	
Copepoda	13		5	
Calanus glacialis		5		5
Calanus hyperboreus		4		5
Euchaeta sp.		4		5
Mysidacea - *Mysis* sp.	38		10	
Amphipoda	29		52	
Apherusa glacialis		27		48
Acanthostephia sp.		1		10
Onisimus sp.		<1		5
Hyperoche medusarum		<1		5
Gammarus sp.		<1		5
Ischyrocerus sp.		<1		5
Aceroicles sp.		<1		5
Gammaracanthus loricatus		<1		5
Amphipod chyme		<1		5
Euphausiacea	10		10	
Thysanoessa raschii		5		5
Thysanoessa spp.		5		5
Bivalvia - *Liocyna fluctuosa*	<1		5	
Invertebrate chyme	<1		5	
Fish - *Boreogadus saida*	10		29	

Table 10. Stomach contents of Arctic Terns collected in the Western Beaufort Sea, June-September, 1976.

No. of stomachs = 48
Total weight = 77.3 grams

Food items	% total weight		% occurrence	
Mysidacea - *Mysis* sp.	18		35	
Amphipoda	21		33	
Amphipod chyme		7		15
Pseudalibrotus littoralis		4		2
Pseudalibrotus glacialis		< 1		4
Pseudalibrotus spp.		2		7
Onisimus littoralis		3		2
Apherusa glacialis		3		13
Gammarus sp.		2		8
Hyperia sp.		< 1		4
Parathemista libellula		< 1		4
Euphausiacea	18		15	
Thysanoessa spp.		12		4
Thysanoessa raschii		5		2
Thysanoessa inermis		1		8
Crustacean chyme	2		4	
Invertebrate chyme	2		4	
Fish	39		29	
Boreogadus saida		23		21
Mallotus villosus		8		2
Fish chyme		8		13
Ammodytes hexapterus		< 1		2

Table 11. Stomach contents of Thick-billed Murres collected in the Western Beaufort Sea, June-September, 1976.

No. of stomachs = 9
Total weight = 229.7 grams

Food items	% total weight		% occurrence	
Amphipoda	<1		44	
Gammaracanthus loricatus		<1		22
Amphipod chyme		<1		22
Fish	99		100	
Boreogadus saida		98		100
Ammodytes hexopterus		1		11

Table 12. Stomach contents of Black Guillemots collected in the Western Beaufort Sea, August 12 and 13, 1976.

No. of stomachs = 2
Total weight = 6.3 grams

Food items	% total weight		% occurrence	
Amphipoda	2		50	
Apherusa glacialis		1		25
Unidentified		1		25
Fish - *Boreogadus saida*	98		100	

Table 13. Summary of stomach contents collected in 1976 showing percent of total weight for each species of bird.

Species	n	Plant material	Echiurius	Polychaeta	Copepoda	Mysidacea	Cumacea	Isopoda	Amphipoda	Euphausiacea	Decapoda	Crustacean chyme	Insecta	Gastropoda	Bivalvia	Invertebrate chyme	Tunicata	Fish	Mammal material	Unidentified chyme
Arctic Loon	2	< 1							100											
Oldsquaw	99	8	< 1	1	3	20	< 1	4	23	17	< 1	1			22	1		< 1		
Steller's Eider	3								100											
Common Eider	2					14		85	< 1					< 1	< 1					
King Eider	16	1	< 1	< 1	< 1			89	2		< 1			1	1	5				
Glaucous Gull	21	2	4			3		7	< 1	9	< 1				7			49	8	10
Black-legged Kittiwake	25	<1				1			7						<1			91		<1
Ross' Gull	12					8				90			< 1				1	1		
Sabine's Gull	21		< 1		13	38			29	10					< 1	< 1		10		
Arctic Tern	48					18			21	18		2				2		39		
Thick-billed Murre	9								<1									99		
Black Guillemot	2								2									98		

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Reproductive Ecology, Foods and Foraging Areas of Seabirds Nesting on the Pribilof Islands

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1 April 1978

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

The objectives of the research detailed below were to obtain data on the breeding season ecology of the eleven seabird species nesting on the Pribilof Islands of Alaska and to determine what aspects of this ecology would be particularly sensitive to potential oil development activities. To these ends data on 1) seasonal timing of reproduction, 2) reproductive success, 3) growth rates, 4) food habits and 5) foraging areas were sought.

Data suitable for baseline use were obtained in the summers of 1975, 1976 and 1977 for timing of reproduction for Black-legged Kittiwake (Rissa tridactyla), Red-legged Kittiwake (R. brevirostris), Common Murre (Uria aalge) and Thick-billed Murre (U. lomvia) and to a modest extent for Red-faced Cormorants (Phalacrocorax urile). Measures of reproductive success were obtained for Fulmar (Fulmarus glacialis), Red-faced Cormorant, Black-legged and Red-legged Kittiwakes, Common and Thick-billed Murres, Parakeet Auklets (Cyclorrhynchus psittacula) and Horned Puffins (Fratercula corniculata). We determined the growth rates of the young of Red-faced Cormorant, Black-legged and Red-legged Kittiwakes, Common and Thick-billed Murres, Parakeet Auklets and Horned Puffins. Foods brought to young Red-faced Cormorants, Black-legged and Red-legged Kittiwakes, Common and Thick-billed Murre, Least Auklets (Aethia pusilla), Parakeet Auklets, and Horned Puffins were collected in sufficient number to give a reasonable impression of the foods used by these species in rearing their young. Few data were gathered on the breeding biology of Crested Auklets (A. cristatella) or Tufted Puffins (Lunda cirrhata). Preliminary indications of foraging areas for species nesting in the Pribilofs were obtained during cruises in August 1975, June and July 1976, and July and August 1977. On three occasions the effect of aircraft movements close to seabird colonies were noted.

Although we have had very little direct experience with aircraft flying in the vicinity of the nesting colony, all indications are that both fixed wing aircraft and helicopters cause major disruptions of nesting birds and lowering of reproductive success in murres. The implication is that in OCS oil development and in the coincident monitoring of natural populations, all aircraft should be restricted from flying near colonies. It is likely that, in terms of on-going oil production, disturbance by aircraft could be as damaging to bird reproduction as spilled oil. These tentative observations have the further implication that aircraft should not be used to monitor the reproductive output of Kittiwakes or the size of bird colonies if these operations require flying in the proximity of cliffs while murres have either eggs or chicks.

II. INTRODUCTION

In the face of impending oil exploration and extraction in the outer continental shelf of Alaska, it is imperative that thorough baseline research be conducted on all aspects of the environment in potentially affected areas. One segment of the environment which is particularly sensitive to spilled oil is seabird populations. The Bering Sea is home to some of the greatest concentrations and the greatest diversity of seabirds in the world. Baseline studies of these populations are necessary in order to identify areas of particularly great sensitivity from which oil should be excluded, to identify areas in which special priority should be given to the clean-up of spilled oil, and to provide evidence as to the effects of spilled oil on avian populations.

The following is an annual report on the first three seasons' field work conducted in the summers of 1975, 1976 and 1977. These studies obtained data on the reproductive success, the food habits and foraging areas of eleven species of seabirds breeding on St. Paul Island in the Pribilof Islands, Alaska.

In studying the reproductive biology of each species the goal of the scientific party was to establish timing of breeding, number of eggs laid, hatching and fledging success, and growth rates and causes of mortality of young. All of these factors are indicators of the health of seabird populations. Knowledge of when and why the normal stresses in the reproducive cycle occur will facilitate predictions of the possible effects of oil spills on these systems. Nesting seabirds are particularly vulnerable to spilled oil, as they are tied to restricted areas by their need to incubate eggs or feed developing young. Young birds, newly departed from their nests, may also be unusually vulnerable to oil on the sea because of incomplete development of flying ability and inexperience in foraging. In addition, certain cliff nesting species may be vulnerable to disturbance by aircraft.

Data on the foods and foraging areas used by seabirds were collected in order to determine in which ocean areas oil spills would be particularly damaging to Pribilof Island populations. Knowledge of the food chains upon which the seabirds are dependent is also necessary to establish both the role the seabirds play in the marine ecosystem and the potential vulnerability of seabirds should certain other marine species be damaged by oil.

III. CURRENT STATE OF KNOWLEDGE

At present a vast literature exists on the effects of oil pollution on seabirds. Vermeer and Vermeer (1974) provide an annotated bibliography of 232 entries through December 1973. Many of the papers listed, as well as others, document the numbers of oiled birds found after spills of various sorts. Other studies listed in Vermeer and Vermeer provide useful data for predicting the consequences of spills in general. More recently Holmes and Cornshaw (1977) have reviewed the biological effects of petroleum on birds, with a particular emphasis on physiological effects.

Several persons have noted differences in behavior of birds confronted by spilled oil. Curry-Lindahl (1960) has observed Oldsquaw (Clangula hyemalis), a species of sea-duck which breeds in small numbers on St. Paul Island (Preble and McAtee 1923 and pers. obs., this study), to be attracted to patches of oil at sea. When Common Murres encounter oil, they have been noted to dive as they entered a slick (Bourne 1968). These particular birds resurfaced clear of the slick. In contrast, a Herring Gull (Larus argentatus) and a Black-legged Kittiwake upon encountering the same slick, rose into the air and flew away.

Differences in reaction to oil spills such as those mentioned above may account for differences in vulnerability of species to population loss when oil is spilled. Milon and Bougerol (1967 in Vermeer and Vermeer 1974) have documented changes in the populations of seabirds on the Ile Rouzic in France subsequent to the Torrey Canyon disaster. In less than a month's time the Atlantic Puffin population was reduced from about 5000 pairs to 600 pairs. Likewise Razorbilled Auks (Alca torda) were reduced from 800 individuals to 100, and Common Murres from 400 to 100. In contrast, gulls (L. marinus, L. argentatus and L. fuscus) decreased about 10% and of 40-50 Fulmars, only 2 birds were stained. Kittiwakes were not present at the time of the spill and suffered no apparent effect. Other studies similarly showed breeding alcids and gannets to be very vulnerable to oil spilled by the Torrey Canyon (O'Connor 1967, Phillips 1967, Monnat 1967). For lack of adequate baseline data on numbers and timing of breeding, Phillips (1967) was unable to determine what effect, if any, the oil had on other colonies. It will be interesting to learn what happens to these populations and their reproductive success given the Amoco Cadiz spill in March 1978, on the nearby coast of Brittany.

The results of the Torrey Canyon and other studies, albeit fragmentary, provide an important lesson for OCSEAP studies in Alaska. They show that alcids (murres, auklets and puffins) and sea ducks are especially vulnerable to spilled oil. The vulnerability of alcids is a critical problem in relation to Alaskan oil recovery, as the majority of the breeding seabirds congregated into massive colonies are alcids. In fall and winter sea ducks may occur in vast numers, also creating the potential for the devastation of populations.

Oiling may affect the survival and reproduction of waterfowl in several ways. Experiments by Hartung (1965) and Grau et al. (1977) have shown that waterfowl reproduction can be damaged both by the ingestion of oil, which may cause inhibition of egg laying or altered yolk structure, and by oil transferred from the plumage of an adult to its egg which will greatly reduce hatchability. Hartung and Hunt (1966) have shown that ingested oils also cause a number of toxic effects on waterfowl. Hartung (1967) and McEwan and Koelink (1973) have shown that heat loss increased for ducks with oiled plumage. Hartung (1967) further showed that heat loss increased with increased dosage of oil and that death came after most fat reserves were exhausted. Since oiled birds usually refrained from eating, Hartung (1967) concluded that starvation, accelerated by rapid use of fat reserves for thermal maintenance, was often the cause of death. If during reproductive efforts a bird's fat reserves were drawn down, we might expect otherwise healthy adult birds to have an increased susceptability to death by even moderate to light oiling.

Although the seabird colonies of the Pribilof Islands are some of the largest in Alaska, surprisingly little is known about them. Palmer (1899) provides an annotated checklist of 69 species that contains little useful information on either numbers or phenology. Preble and McAtee (1923) list 137 species as known to occur in the Pribilof Islands, of which 23 are recorded as breeding. Their paper provides fragmentary information on numbers, timing of breeding and food habits, and somewhat more useful data on spring arrival and fall departure dates. While much of the data will prove useful for comparative purposes, virtually none are sufficient to provide a baseline comparison.

In recent studies, Kenyon and Phillips (1965), Sladen (1966) and Thompson and DeLong (1969) provide updates on the records of unusual species visiting the islands. The work of Kenyon and Phillips (1965) is of particular interest as it provides one of the few indications of changes in numbers of Red-legged Kittiwakes, a species endemic to the Bering Sea. Whereas Prentis (1902 cited in Preble and McAtee 1923) found in 1895 that Red-legged Kittiwakes "at the southwestern portion. . . form nearly one-half of the kittiwakes. . . on the north side of St. Paul they were numerous," Kenyon and Phillips counted 346 nests on St. Paul in 1954 but estimated that there were many more out of sight from the observer on the cliff top. In 1975 we estimated from the cliff tops that there were no more than two or three hundred Red-legged Kittiwake nests on St. Paul. In 1976 a careful count from the bottom of the cliffs of all Red-legged Kittiwake nests on St. Paul found about 850 nests. This number is a tiny fraction of the total Kittiwake population on St. Paul. Kenyon and Phillips also suggest that Red-legged Kittiwakes breed later in the year than Black-legged Kittiwakes and that the former species is left with less choice nest sites.

The population of a second species may have also declined. In view of the description in Gabrielson and Lincoln (1959, p. 501) it appears that the Crested Auklet population has decreased in numbers.

Finally, DeLong and Thompson in various reports of the Smithsonian Institution Pacific Ocean Biological Survey provide scattered data on the numbers and phenology of some of the nesting seabirds (see Thompson, 1964, 1965, 1966).

There exist several papers of a general nature which are relevant when considering the reproductive ecology of Pribilof Island seabirds. Belopol'skii's (1957) work on the seabirds of the Barents Sea provides a basis for comparison with work in the Bering Sea and some very useful insight about the ecology and behavior of seabirds. Shuntov (1974) gives a useful overview of pelagic birds in the Bering Sea as well as touching on relevant aspects of marine productivity and ocean circulation. Swartz (1966) in a chapter on the birds of Cape Thompson provides much interesting data on the numbers, phenology, and ecology of the seabirds. However, in spite of a three-year study, he has little on reproductive success of birds other than kittiwakes. Food data were mostly restricted to murres, kittiwakes and Glaucous Gulls. Dick and Dick (1971) provide phenological data on the seabirds on Cape Pierce. These will be of interest to compare with the data from the Pribilof Islands, as both are at similar latitudes.

The spatial distribution of foraging activity by nesting seabirds is relevant to OCS oil production because the distribution of the foraging birds will affect their potential vulnerability in the event of an oil spill (Vermeer and Vermeer 1975, Clark 1973, Joensen 1972 and others). At present two schools of thought exist as to the dispersion of foraging activity. Cody (1973), on the basis of field work on the west coast of North America and Iceland, believes that alcid species differ from one another in their foraging zones at sea, and that colony size, chick growth rates and weight at fledging are related to the distance off-shore of the foraging zone. In contrast, other workers (Sealy 1973, Scott 1973) have emphasized the importance of large aggregations of seabirds into mixed species foraging flocks. These flocks apparently concentrate at "hot-spots" where food is particularly abundant. Bedard (1969a, 1976) studying the small auklets of St. Lawrence Island, Alaska, also emphasizes that the three species, Least Auklet, Crested Auklet and Parakeet Auklet, were usually found foraging together. Given this divergence of opinion and the importance of spatial distribution in determining vulnerability of seabirds to oil, determination of the actual distribution of the foraging activity of Pribilof Island seabirds is important for developing predictions on the potential impact of an oil spill.

IV. STUDY AREAS

Within the Pribilofs seabirds breed on all four islands, St. George, St. Paul, Otter and Walrus. The major focus of our studies of reproductive biology was on the populations of the larger islands, St. George and St. Paul; however, we did conduct brief surveys of the small seabird populations of Otter and Walrus Islands. For observations of reproductive biology we used ten study sites on St. Paul (Figure 1) and one on St. George (Figure 2) in 1975. For this study, areas referred to as "Southwest Cliffs" are located between Southwest Point and Einahnuhto Bluffs on St. Paul; likewise, the "Ridge Wall Cliffs" are coastal cliffs in the vicinity of Ridge Wall which itself is inland (Figure 1). In Figure 2, the 1975 Red-legged Kittiwake study area on St. George is located just east of the Staraya Artil Seal Rookery, which is not labeled on this map.

For 1976 breeding information we observed seabirds at eleven study sites in six different areas of St. Paul Island (Figure 3) and at three study sites on St. George (Figure 2). Areas on St. Paul referred to as "Gun Emplacement," "Rush Gap" and "Rush South" are located at or just north of the Einahnuhto Bluffs on the west end of the island.

On St. Paul in 1977 we continued observations of reproductive biology at the same sites used in 1976 with the exception of the Polovina site which was dropped (Figure 3). On St. George in 1977 we established several sites for observation of breeding seabirds on the higher cliffs of the north and south side of the island in addition to the 1976 sites; Figure 4 presents the locations of these twelve study sites which were located in five areas of St. George.

During the years of study we collected birds for food habits information at Southwest Point and at the base of Zapadni Point near Antone Lake on St. Paul. In 1976 and 1977 mist-netting of Least Auklets for foods and breeding phenology information was done principally at East Landing beach, St. Paul. On St. George in 1977 we collected most birds for food samples at Staraya Artil beach (Figures 3 and 4).

Pelagic foraging areas were studied on five cruises. Figures 5-9 illustrate the approximate cruise tracks and the number of separate transect segments within each 10' x 10' block of latitude and longitude. In 1975 and 1976 we concentrated our effort in the immediate vicinity of the islands in order to examine if there was a clear spatial segregation of foraging effort by different species in different zones around the islands, or if birds tended to be clumped into large foraging flocks of one or more species at "hot-spots" of local food abundance. In 1977 we extended the range of our two cruises to study foraging patterns farther out to sea from the islands. The shipboard helicopter available in 1977 allowed us to supplement surface observations with twelve aerial surveys which are mapped on Figures 10 and 11.

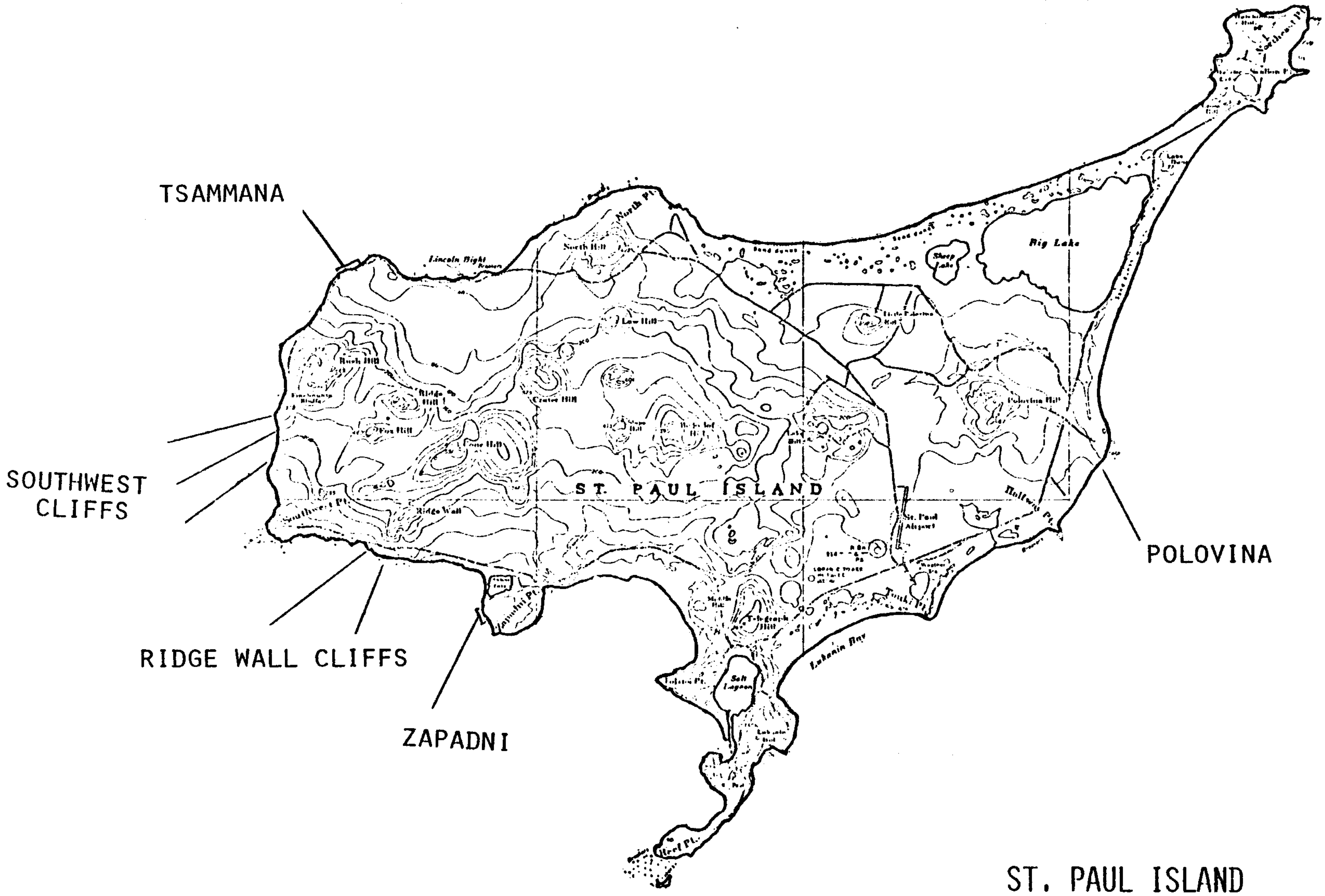
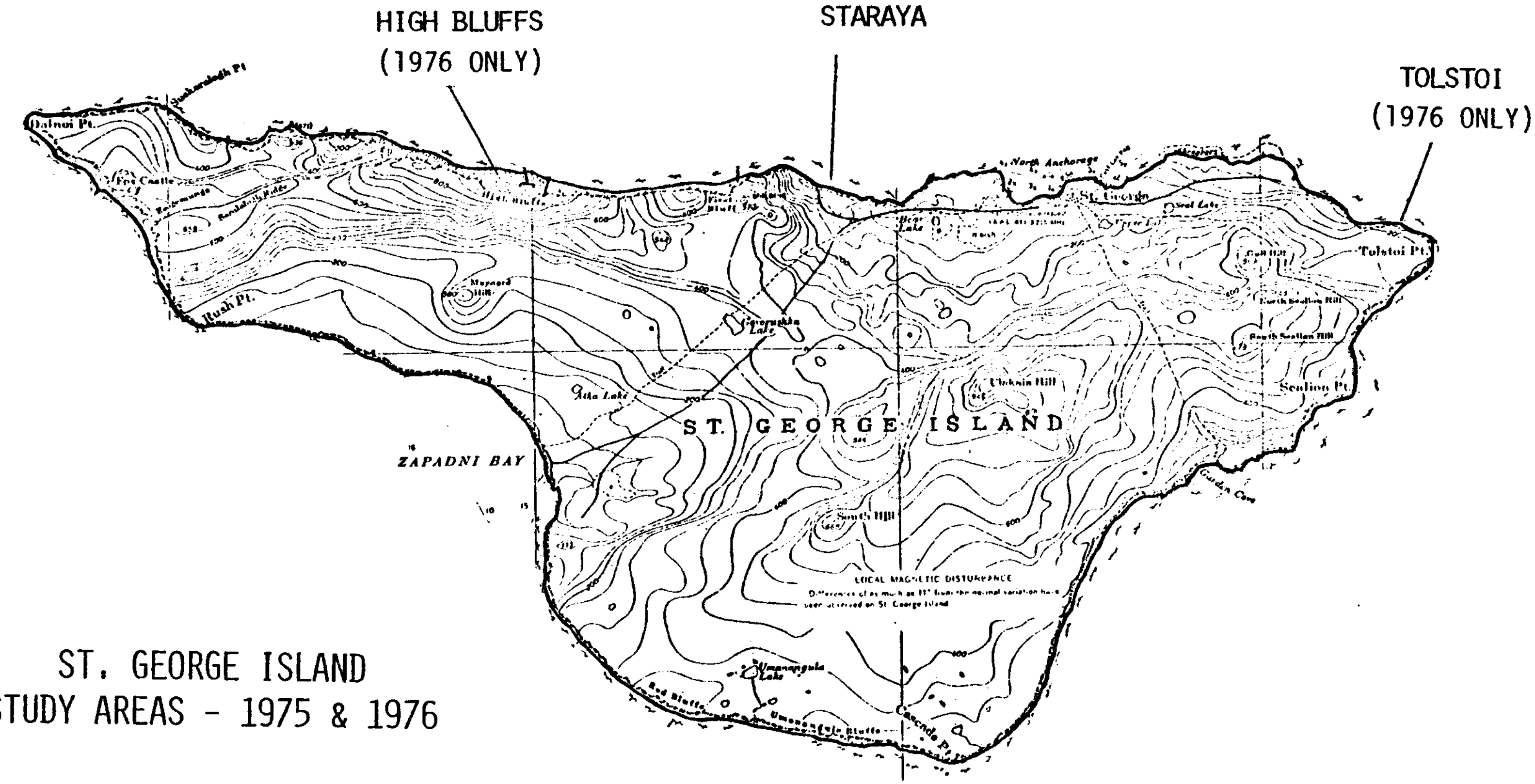


FIGURE 1.

ST. PAUL ISLAND
STUDY AREAS - 1975



ST. GEORGE ISLAND
STUDY AREAS - 1975 & 1976

FIGURE 2.

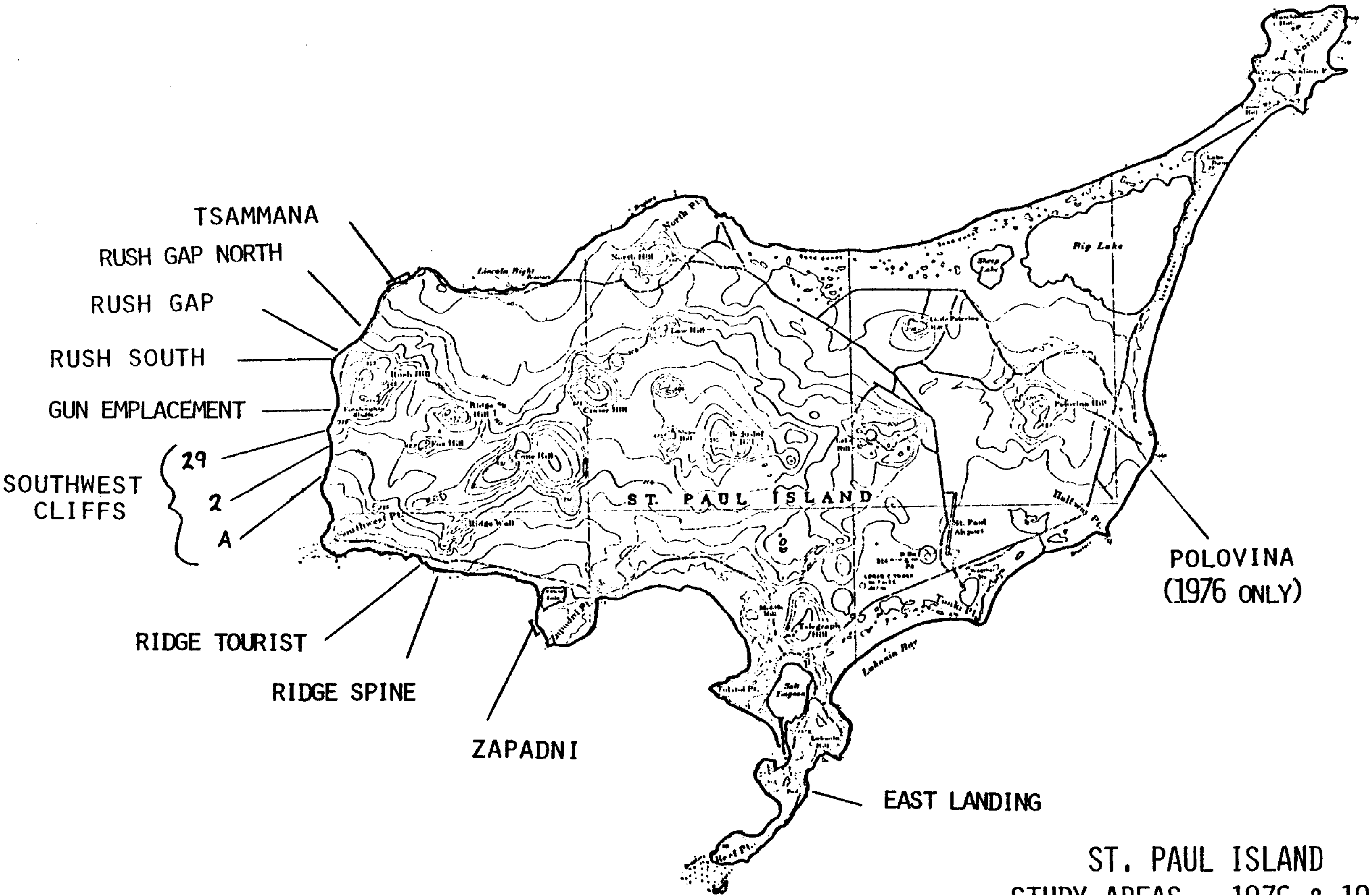
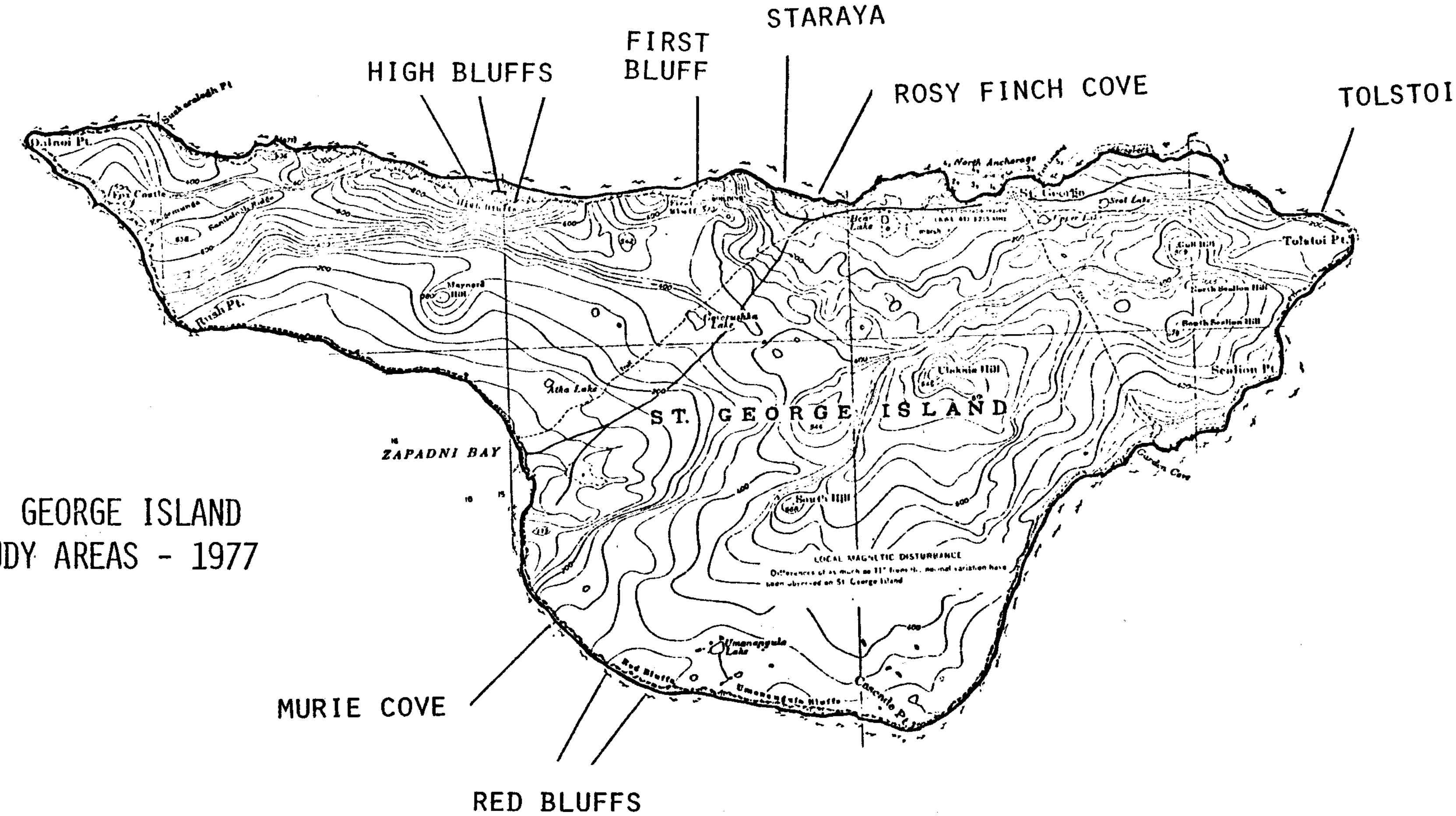


FIGURE 3.

ST. PAUL ISLAND
STUDY AREAS - 1976 & 1977



ST. GEORGE ISLAND
STUDY AREAS - 1977

FIGURE 4.

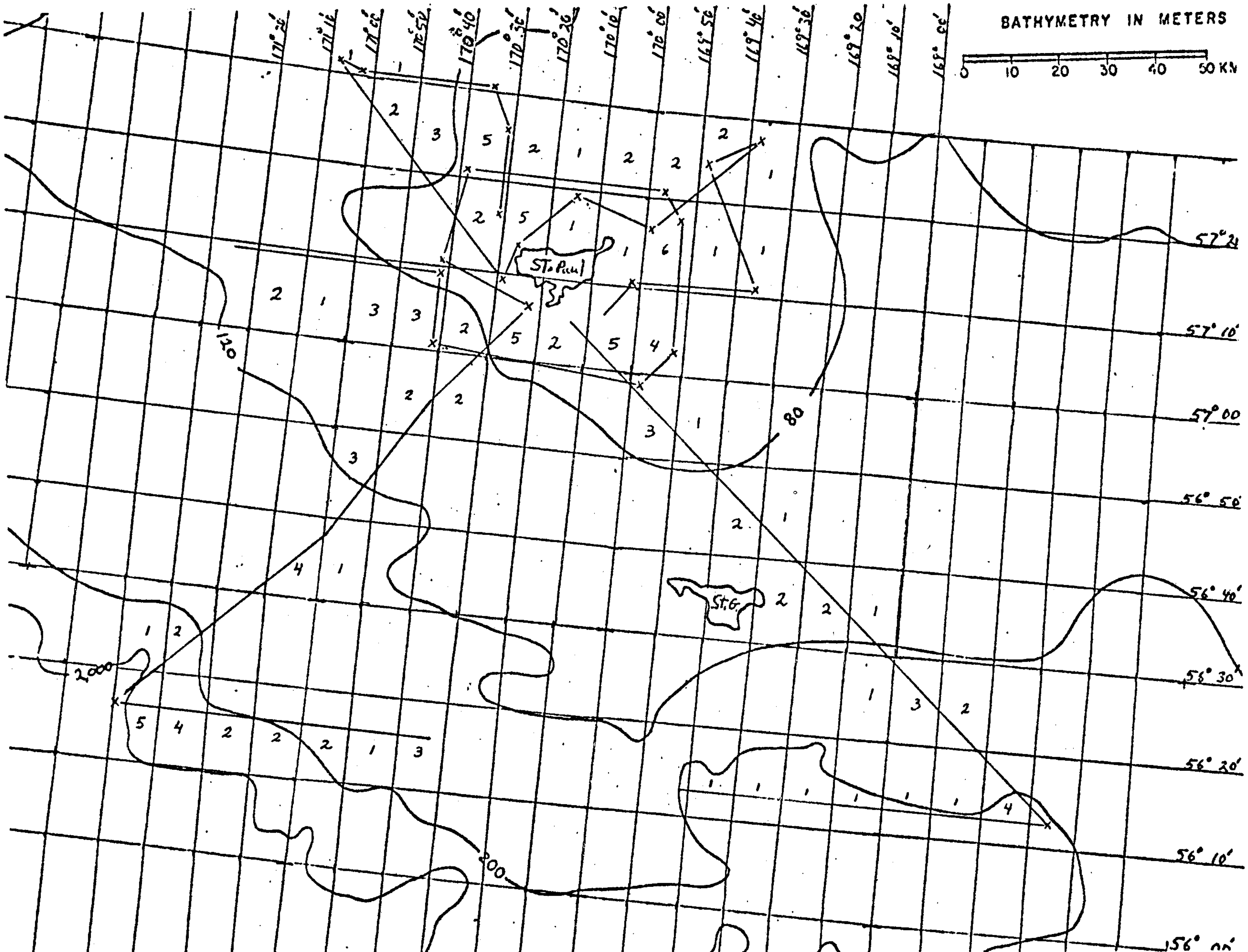


Fig. 5. Approximate cruise track of the R/V Discoverer, 21-24 August 1975, The number of transects run in each 10'x10' block is indicated.

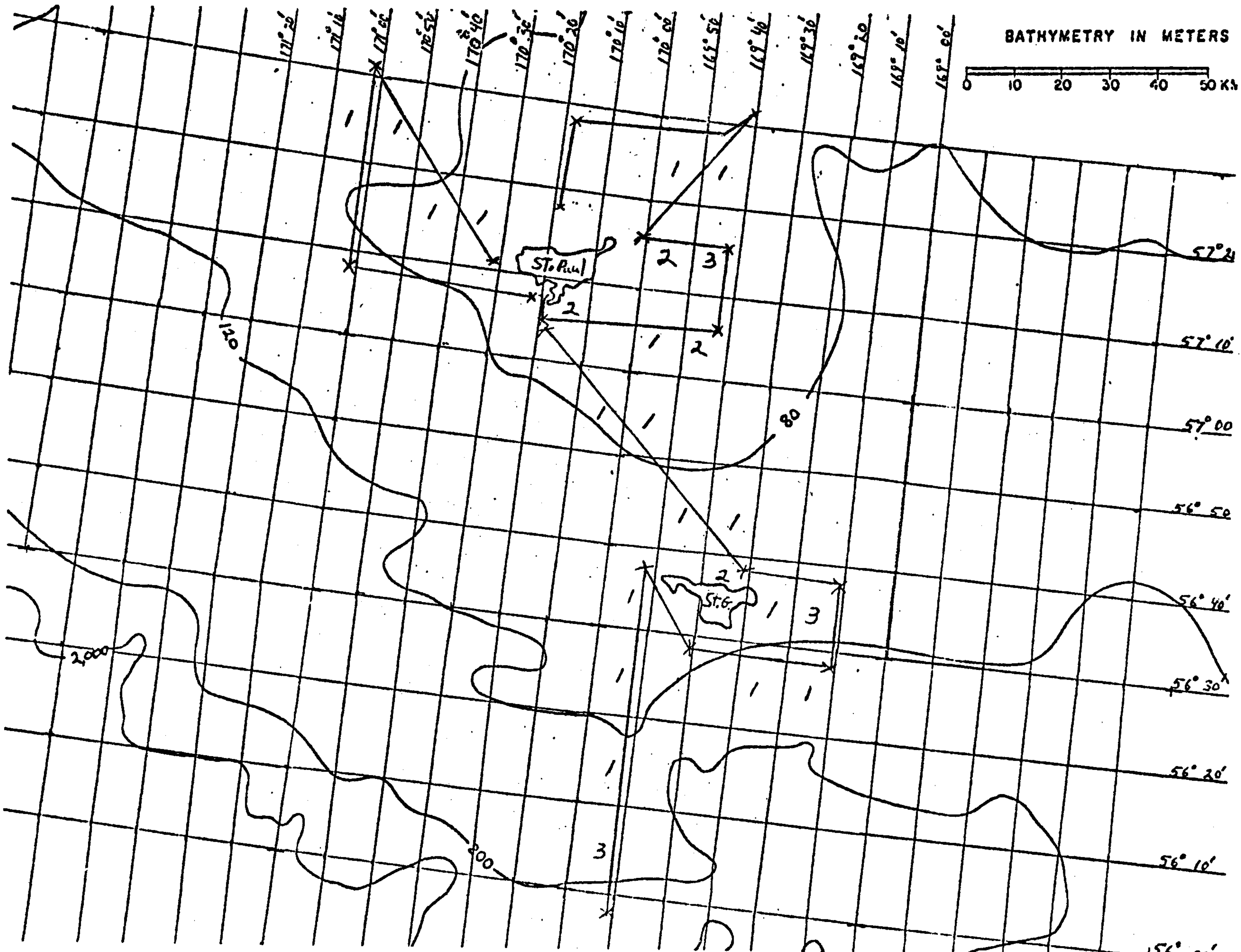


Fig. 6. Approximate cruise track of the R/V Moana Wave, 2-4 June 1976. The number of transects run in each 10'x10' block is indicated.

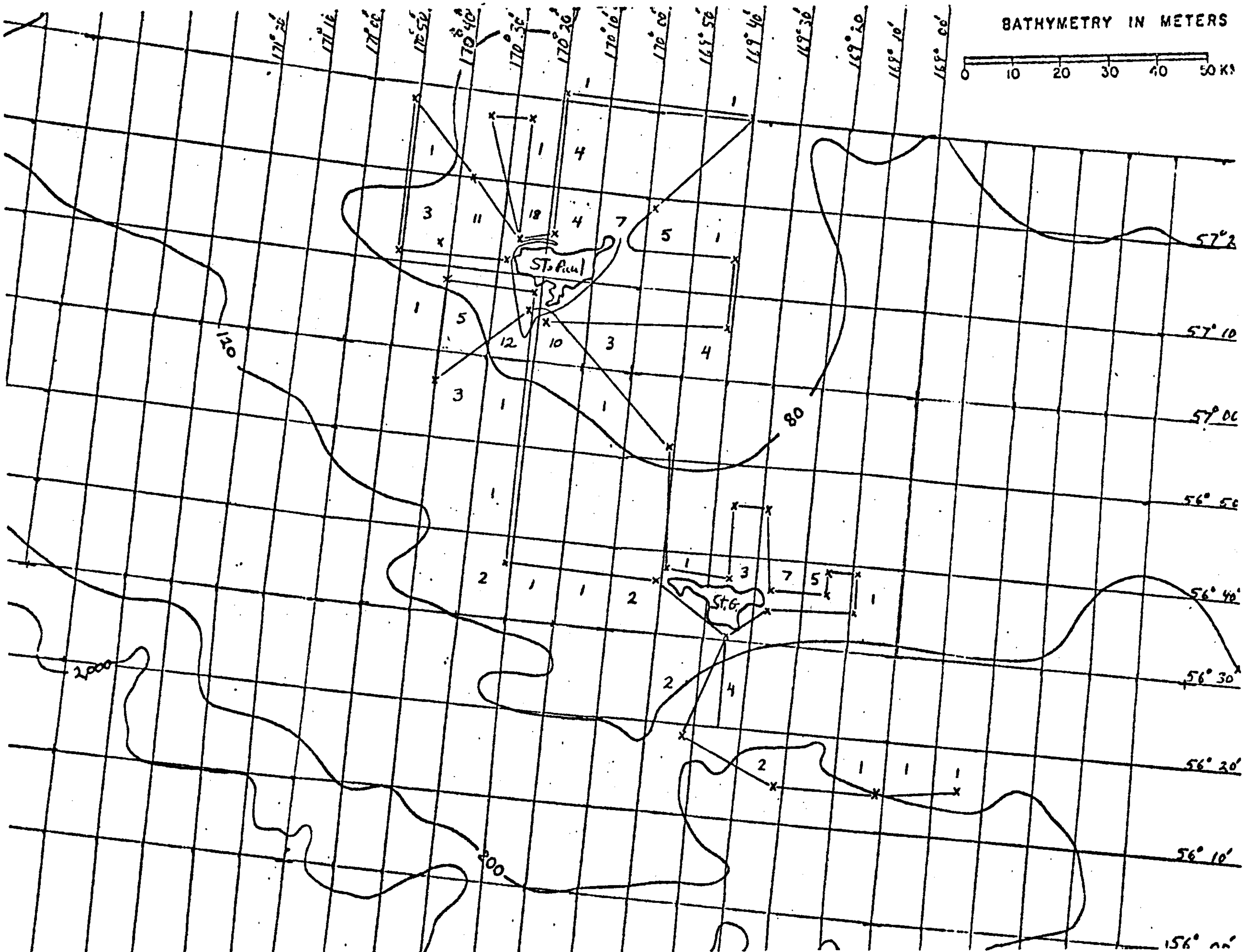


Fig. 7. Approximate cruise track of the R/V Moana Wave, 7-12 July 1976. The number of transects run in each 10'X10' block is indicated.

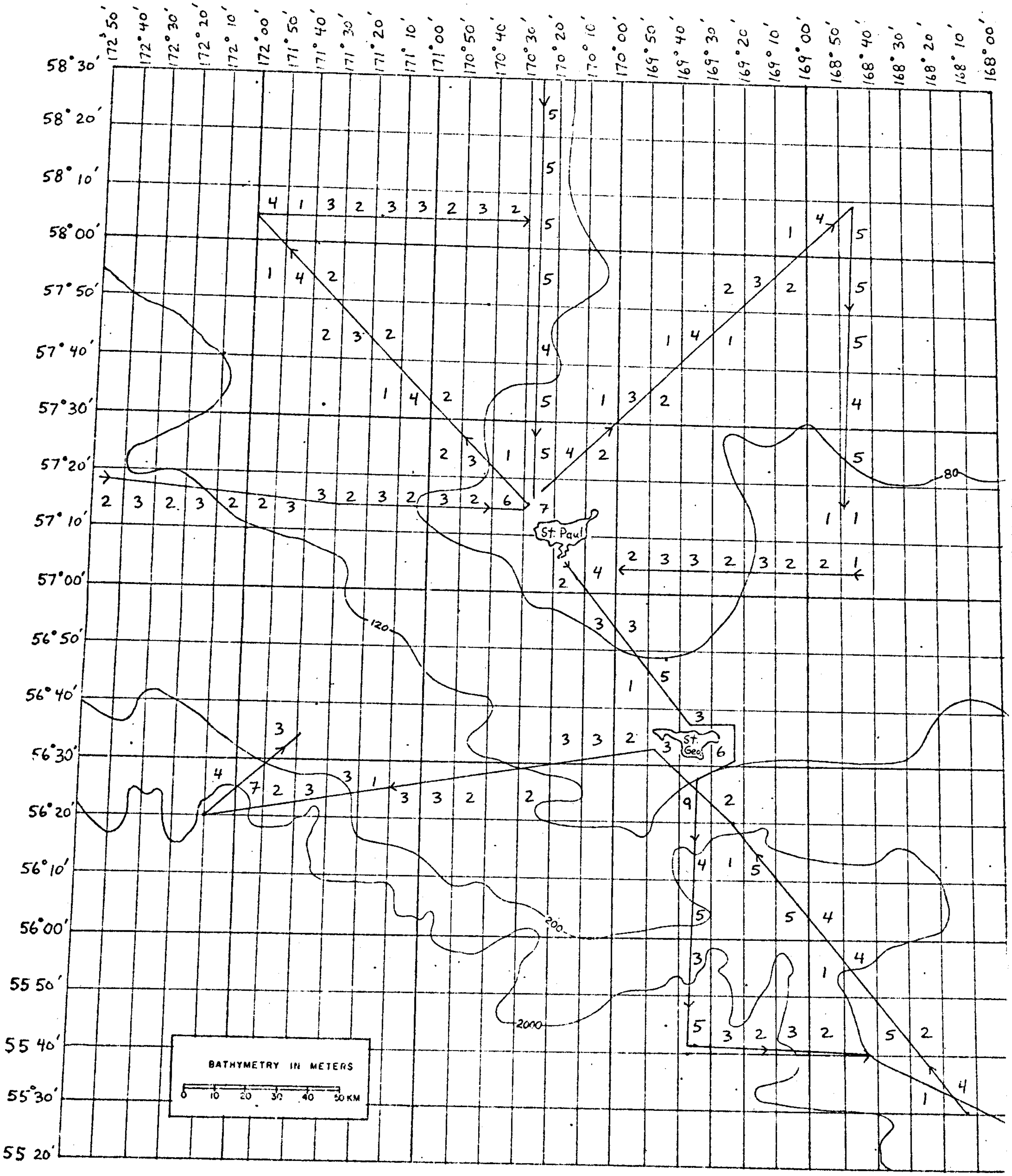


Figure 8. Approximate cruise track of the R/V Surveyor, 7-11 July 1977. The number of transects run in each 10' x 10' block is included.

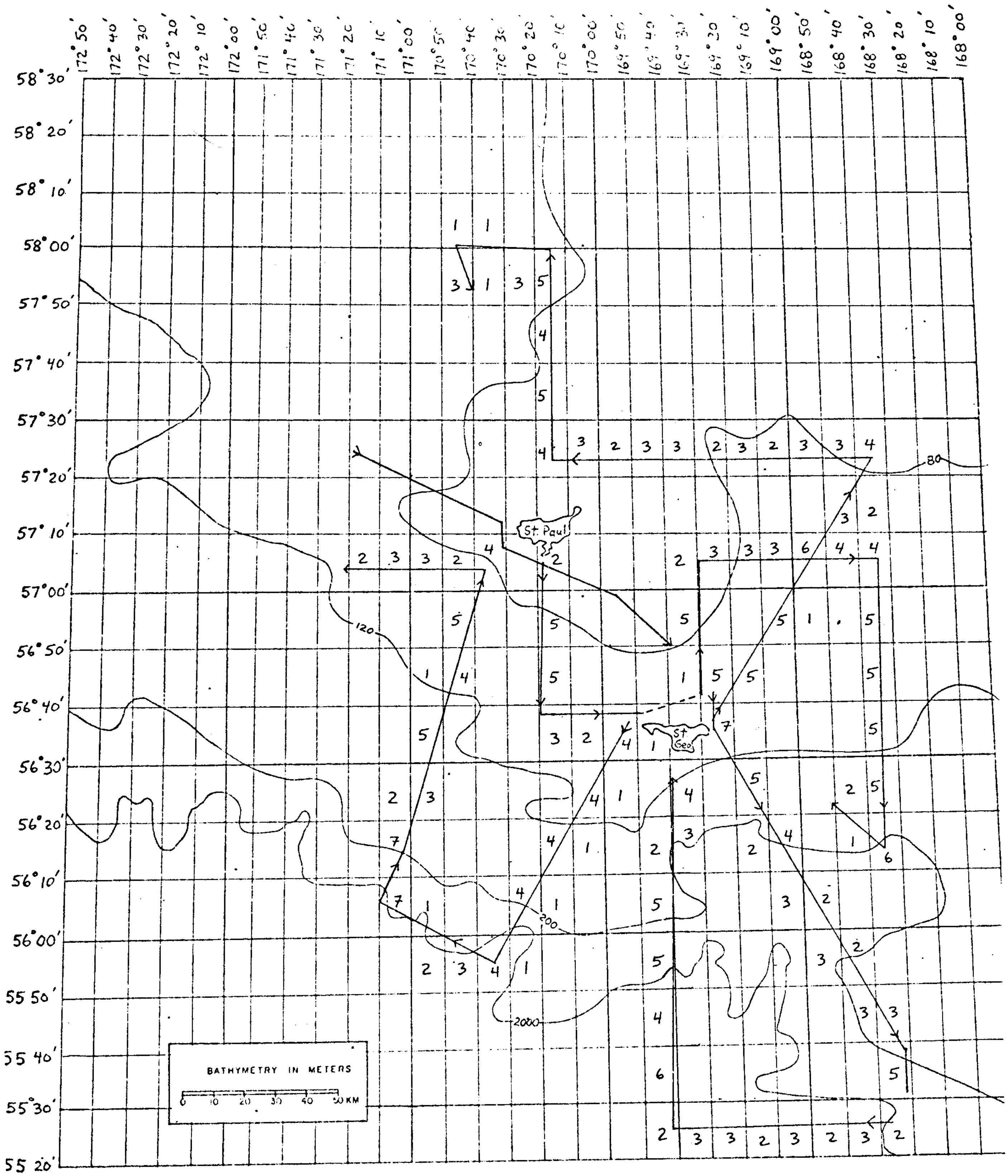


Figure 9. Approximate cruise track of the R/V Surveyor, 1-5 August 1977. The number of transects run in each 10' x 10' block is included.

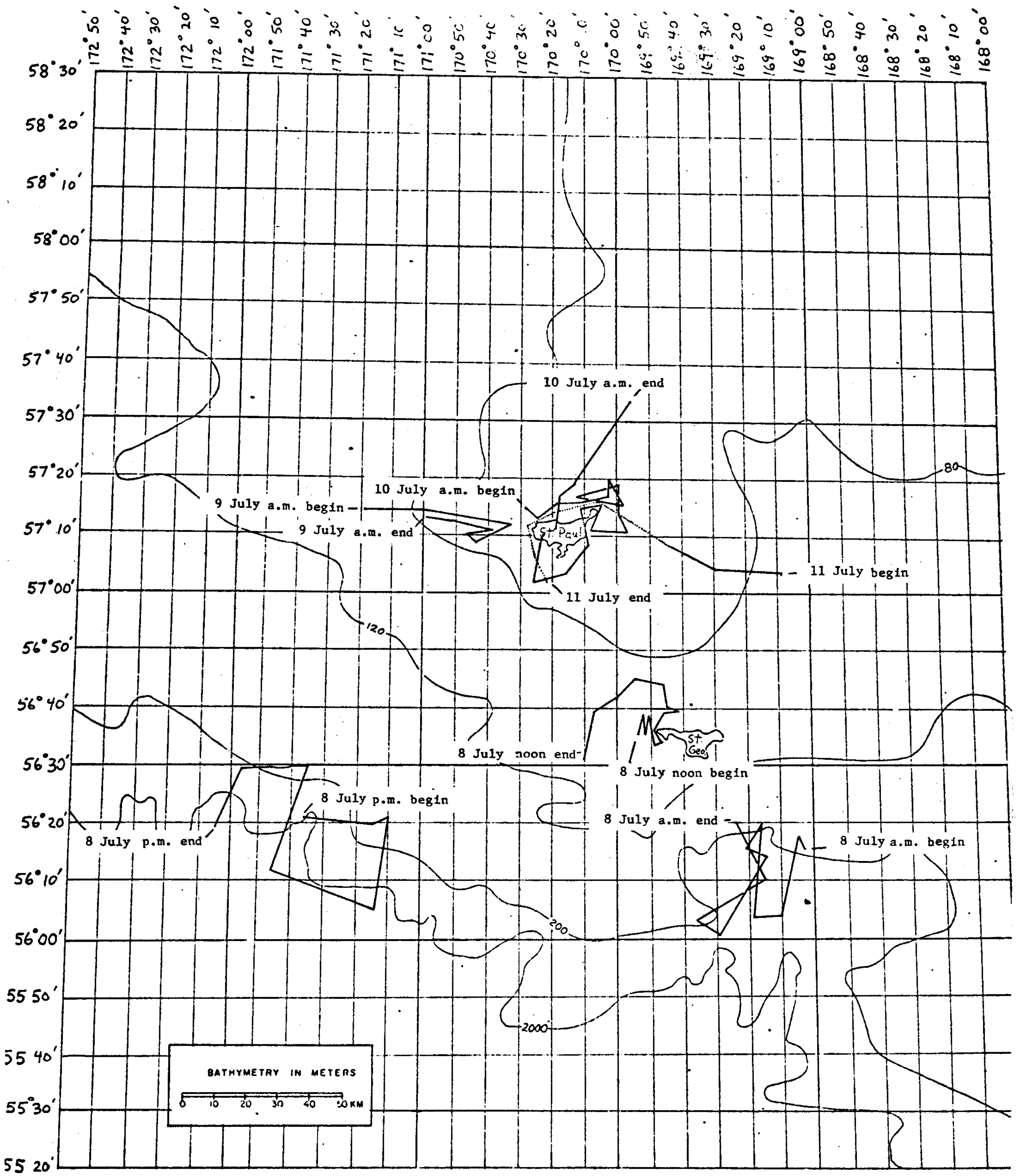


Figure 10. Approximate flight track of the R/V Surveyor helicopter surveys, 7-11 July 1977.

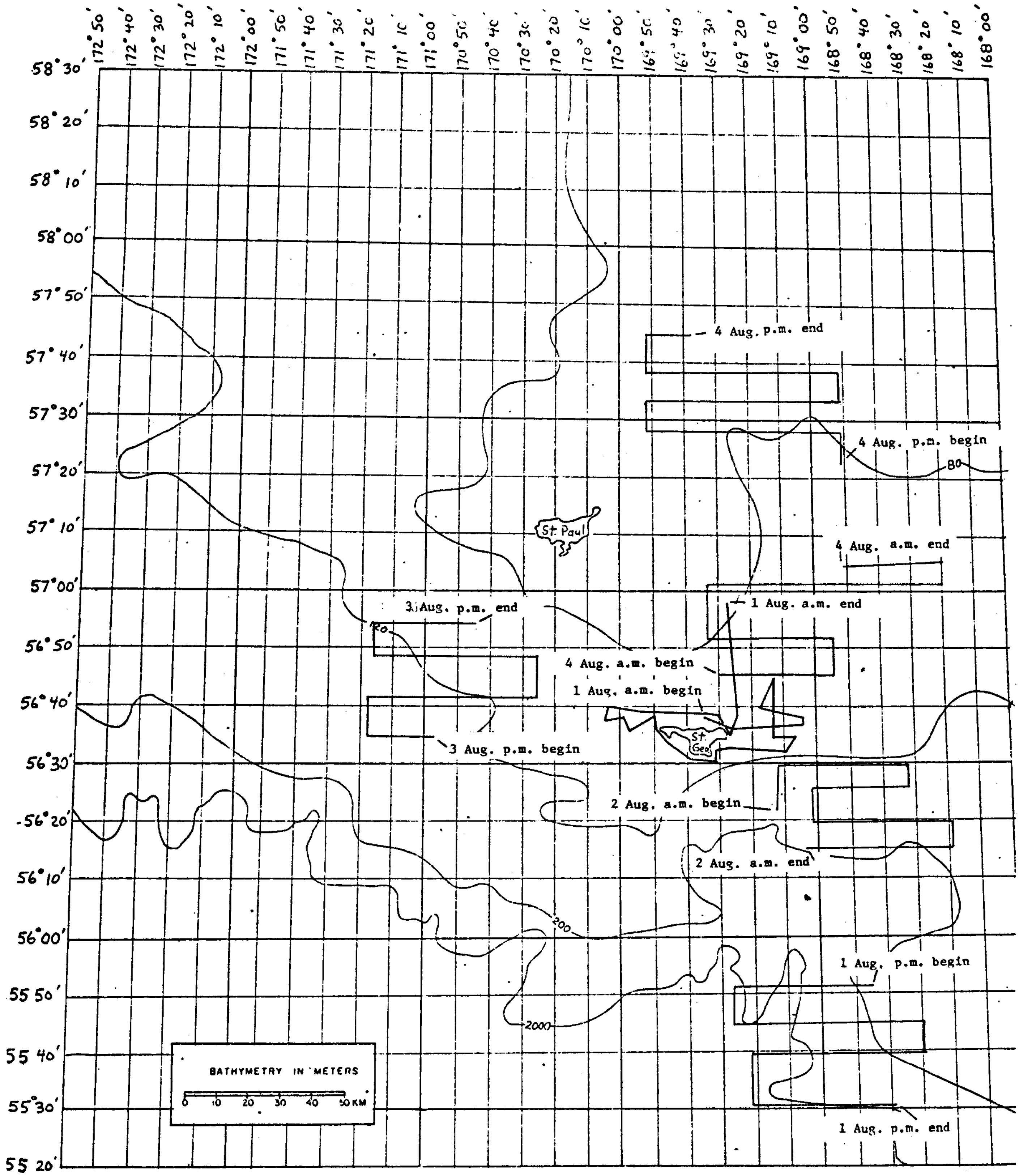


Figure 11. Approximate flight track of the R/V Surveyor helicopter surveys, 1-5 August 1977.

V. METHODS

1. Rationale

Several variables which influence reproductive success and growth rates impinge on any natural study. These variables include: 1) year to year changes in the ecosystem, 2) variations in the exposure of different nest sites, and 3) variations in the age and experience of nesting individuals being studied.

Variable 1, year to year variations can only be understood by a multiple year study; one year's efforts represent but a single data point for understanding the input of this variable. The possible distortions that variables 2 and 3 might cause to a baseline study can be minimized within a single year's study by choosing a sufficiently large number of subsampling areas and by following the success of an adequate number of nests in each area. The number of separate sites to be chosen will depend on the dispersal of nests and on local conditions. The number of nests to be studied in each area should be at least 15-20, if possible, so that individual variations and chance events will not unduly distort the results obtained.

2. Reproductive Success and Phenology

Seabirds breeding on St. Paul Island nest on cliff ledges, in holes and crevices in the cliffs or beneath the rocks of boulder beaches. For ledge-nesting species (fulmars, Red-faced Cormorant, Black-legged and Red-legged Kittiwakes, Common and Thick-billed Murres), data on reproductive success can be obtained relatively easily by observation of many nests at a time from locations at the top or bottom of the cliffs. Accurate data on the hole-nesting species (Tufted and Horned Puffins, and Crested, Least and Parakeet Auklets) must be obtained by looking into each hole individually.

The basic techniques for obtaining data on the reproductive success of the six ledge-nesting species, the Horned Puffin and the Parakeet Auklet were to locate nests, number them individually, and count the eggs or chicks contained in those nests usually every three to seven days, either until chicks fledged and left the nest, or until total egg or chick loss occurred. Inaccessible nests were reidentified each visit according to a sketch map (1975) or black-and-white photographs (1976 & 1977).

All Fulmar nests studied were inaccessible to us so that all of our observations are from clifftop. In 1975 and 1976 we attempted to follow the fate of several nest sites mapped and identified as above. Since Fulmars may spend several seasons visiting a nest site before actually breeding, in 1976 we began by recording all birds in a given area but used as a measure of reproductive success only those which consistently occupied their nest-sites during the incubation phase, or which had built a nest. Yet in the Pribilofs, Fulmars rarely build nests and it is very difficult to distinguish an incubating bird from one which is just sitting. Sitting Fulmars rarely move. Therefore, in 1977 to avoid the necessity of subjectively determining what constitutes a nesting attempt, we chose the number of young fledged per the mean number of adults present within a defined study area as an index of the colony's reproductive success. We made counts of adults during the mid-day period of peak attendance (Hickey & Craighead 1977) and followed as individual nests the fates of all eggs and chicks we observed. The loss of all down by a chick which had reached adult size constituted a fledged bird.

Egg and chick counts for the Horned Puffin, for part of the kittiwake and for the Red-faced Cormorant samples were made by using a ladder at the bottom of the cliff to reach into nests and nesting holes in the cliff. A ladder was also used on St. George to check murre and cormorant nests for reproductive success and chick growth rates. These nests were identified by a number painted on the cliff.

For the two kittiwake species and Red-faced Cormorants, the sample of nests in 1975 on St. Paul included some which could only be viewed from below, and consequently counts of eggs and tiny chicks were impossible. However, data from these nests were used to calculate both fledging success and approximate egg-laying dates, as large chicks or incubating parents could be easily seen.

In addition to counts of eggs and chicks for individual pairs of Common and Thick-billed Murres, in 1975 certain ledges were chosen for study on which many birds bred and where it was impossible to tell individual eggs or chicks apart. In these areas the largest number of eggs and chicks on each ledge was used to calculate hatching and fledging success. These figures represent the maximum possible breeding success for those pairs rather than the exact percentages. This measure was not used in 1976.

It is often difficult for an observer to tell whether a murre is incubating an egg or brooding a small chick merely by the position of the bird. As with many of the other species nesting on the cliffs of the Pribilof Islands, the murres were reluctant to move away from eggs or small chicks long enough for an observer to count them. There were very few individual nests or broad ledges of Common Murres that were close enough to the top of the cliff for an observer to persuade the birds to move. In addition, large numbers of murres that frequented these ledges appeared to be non-breeders. In 1975 on St. Paul Island we counted eggs and chicks at murre ledges after scaring off the adults by shouting or by dangling a rope over the cliff edge. In working with two murre species it was imperative that the birds not be scared suddenly in order to minimize egg and chick loss. Murres were gradually alerted to our presence so that they would move slowly away from the eggs or chicks before they left their nesting ledges. However, some eggs were lost when adults inadvertently kicked them off the ledges. While these eggs were not included in the calculations of reproductive success, hatching success on our murre study ledges was very low in 1975, and we felt that we may have influenced our results by our scaring of the birds. Many additional eggs may have been lost when the crowds of adults returned to the ledges after our departure from the area.

In 1976 on St. Paul we used two methods to assess murre reproductive success, to see whether or not our studies the previous year had had unanticipated effects. At several sites the scaring methods employed in 1975 were used, and at other sites the observer did not scare the birds, but sat quietly for an hour or so at each visit watching to see by the birds' behavior whether they were incubating eggs, brooding young, or were non-breeders. In 1976 and 1977 the use of black-and-white photographs of each ledge made the task of assigning an individual number to each egg or young far easier.

In 1977 on St. Paul we continued to observe Thick-billed Murres on both undisturbed ledges and at intentionally disturbed scare sites by mapping nest-sites individually on photographs. However, with our lower number of personnel on St. Paul in 1977, we did not attempt to follow Common Murres nest-sites individually on their densely packed ledge; rather we counted total numbers of eggs and chicks on ledges visible from clifftop. On one ledge to which we climbed to weigh Common Murre chicks for growth, we individually followed the fate of eggs.

On St. George in both 1976 and 1977 we located no small Common Murre ledges easily observable from the cliff tops. At the Staraya Artil study site we could reach a small ledge by ladder; here we assessed reproductive success by climbing up to the site, which disturbed the adults and caused them to fly off. Thick-billed Murres at our ladder sites were studied in the same fashion. In 1977 we observed Thick-billed Murres at three additional undisturbed sites from clifftop on St. George at which we individually followed egg fates with photograph maps.

Thus, our methods of studying murres have by necessity varied between islands and from year to year. Unfortunately, this has injected several types of observer disturbance into our data set; hence, the reported results may not be equivalent between islands and years.

All probable nest sites located for Tufted Puffins and Crested Auklets were inaccessible. No accessible nest sites of the Parakeet Auklet were located until the end of their breeding season in 1975, but in the 1976 season we were able to document Parakeet Auklet reproductive success.

The most common nesting location for Least Auklets in the Pribilof Islands is one to two feet below the surface of the ground between the rocks of boulder beaches. In digging to check nest contents, it is inevitable that the nest itself is destroyed. We dug up only one such nest in 1975 which was located by the noises made by the chick. In 1975 and 1976 accessible nests located in small holes in a cliff could be reached by using a ladder.

To gather breeding biology data on those ledge and hole nesting species accessible to us, we visited study sites on St. Paul about twice weekly. On St. George in 1976 visits to study sites were more sporadic since our personnel were not present on that island continuously during that summer. In 1977 we had personnel on St. George throughout the summer and they visited ladder-accessible sites twice weekly and visually observed sites once weekly. The cliffs of St. George are less accessible by road than those of St. Paul; hence, observations on that island are more difficult and more time consuming.

3. Growth Rates

Growth rates of young seabirds have been shown in past studies to be strongly correlated with fledging success (Hunt, 1972; Hunt and Hunt, 1975, 1976).

Data on growth rates of the chicks of seven species (Red-faced Cormorant, Black-legged and Red-legged Kittiwakes, Common and Thick-billed Murre, Parakeet Auklet and Horned Puffin) were obtained by weighing chicks periodically, usually at least twice a week. Chicks were individually marked with numbered plastic leg bands, placed in cloth bags and weighed with Pesola spring scales (300g to 5kg capacity, depending on the species and the size of the chick). The weight of the bag and of any food regurgitated by the chick were subtracted from the total weight to obtain the weight of the chick.

In all of the above species, with the exception of the murres, the typical growth pattern is a period of rapid and steady weight gain followed by either a plateau or a slight decline in weight prior to fledging. In these cases the growth rate for the straight-line portion of the growth curve was calculated by the formula:

$$\frac{\text{weight}_2 - \text{weight}_1}{\text{day}_2 - \text{day}_1}$$

where the gain in weight between the first weighing and the peak weight is divided by the number of intervening days, yielding an average number of grams gained per day.

In 1976 our attempts to weigh Red-faced Cormorant young until their peak weight caused some premature fledgings which probably resulted in the death of some young. To avoid this mortality, in 1977 we weighed these chicks only until they were over 1000g in weight. In our 1976 data the growth rate derived from the first weight to the 1000g level is essentially the same as that derived from the first and peak weights.

Murre chicks hatch at 65-70 grams and gain weight for 10-15 days. Many of them will reach a plateau or begin to lose weight when their contour feathers begin to grow in. Then there is a second period of weight gain, sometimes followed by a slight drop in weight just before the chick goes to sea. This pattern is not always consistent, however; some chicks may not lose weight at all during the period of contour feather growth. We have used for comparative purposes the number of grams per day that a chick gains during the first growing phase.

An important parameter for chick survival is its weight when it leaves the cliffs to go to sea. It is presumed that a heavy chick will be more likely to survive than one which is light and has little fat reserves. Our data for both species of murres show a positive correlation between the number of grams gained per day until the first peak of growth and the last weight obtained before the chick leaves the island.

4. Food Sampling

Our foods information comes from four sources: 1) With a shotgun we killed adult birds and collected their stomach contents. 2) We collected regurgitation from chicks. 3) We mist-netted adult Least Auklets and obtained regurgitations, which provide most of our data on that species. 4) We photographed birds, principally Common and Thick-billed Murres, holding fish in their bills prior to feeding their young and obtained limited information from this source.

Once or twice each week we collected birds of several species for 3-4 hours per session. On the average, 10-15 birds were killed each week; we removed these birds' stomachs for future content analysis. Many carcasses provided material for study skins or museum skeletons. In 1976 about half of the birds shot were frozen after food was removed and subsequently sent to an endoparasitologist for study.

As the field season progressed and chicks began hatching, we were able to obtain food samples from Red-faced Cormorant, Black-legged Kittiwake and Red-legged Kittiwake chicks. Chicks often regurgitated while being weighed, and during August and September samples from these species were obtained entirely by this method of collection from chicks rather than by shooting. We continued to shoot puffins, murres, Crested and Parakeet Auklets during this time, but collected samples from Least Auklets by mist-netting adults returning with food for their chicks. A bird containing food in its gular pouch would regurgitate as it hit the net.

Food samples were preserved in plastic Whirl-pak bags in 70% ethanol, and labeled as to sample number, species, island and date collected.

5. Distribution of Foraging Seabirds

During the three years of this study we have made five cruises to survey the distribution of seabirds foraging around the Pribilof Islands: in 1975 we made one cruise from 21 to 24 August aboard the Discoverer; in 1976, two cruises from 2 to 4 June and from 7 to 12 July aboard the Moana Wave; and in 1977, two cruises from 7 to 11 July and from 1 to 5 August aboard the Surveyor. On the August 1975 Discoverer cruise observations were made by Doug Causey and Doug Schwartz. For the June 1976 cruise Doug Causey was the sole observer; on the July 1976 cruise George Hunt and Zoe Eppley were aided by Doug Forsell of the U.S. Fish and Wildlife Service. In 1977 project personnel on the cruises consisted of Barbara Burgeson, George Hunt, Bill Rodstrom and Ron Squibb in July and George Hunt, Maura Naughton, Bill Rodstrom, Sam Sharr and Melody Roelke of the National Marine Fisheries Service in August.

These personnel took observations almost continuously during daylight hours. On the cruises with a large enough party aboard, one person recorded and either one or two, when bird densities were high, observed. From the ship's flying bridge (an eye level of 21m above water surface on both the Discoverer and Surveyor, and 10m on the Moana Wave) observers counted the number of birds within each of three 100m zones from dead ahead to 90° one side of the ship to 300m from the ship. We recorded flying birds and birds on the water separately and noted flight direction and relevant behavior patterns such as feeding. Ship personnel kept a course register, and meterological and oceanographic data throughout observation periods.

During all transects, care was taken to ensure that observations were of a natural situation, not of a situation influenced by the ship's presence in the water. Garbage and refuse were dumped only at the completion of the observations. We attempted to count circling or ship-following birds only once.

In 1977 we were able to augment our shipboard observations with aerial transects made from the Surveyor's Bell Ranger II helicopter. An observer in the co-pilot seat of the helicopter recorded into a cassette recorder the number of birds flying or on the water within a zone 50m wide along the path of the helicopter. The pilot maintained a nearly constant speed of 75mph and altitude of 125 feet; at the constant altitude the observer estimated the transect width to be counted from marks on the helicopter bubble. The helicopter's computer provided constant position readings accurate to one-quarter mile.

6. Survey of Otter and Walrus Islands

A brief survey of Otter and Walrus Islands was conducted by Molly Hunt and Laurie Holmgren using a Coast Guard helicopter on 9 August, 1975, an unusually bright and clear day. The main purpose of the flight was to census by photography a colony of Common Murres reported breeding in large numbers on Walrus Island early in the century, which had by 1954 declined in size due to crowding by Steller's Sea Lions. Each island was circled twice at an altitude of 800 feet with the helicopter staying approximately 500 feet out from the edge of Walrus Island and 1000 feet out from the cliffs of Otter Island. Slides were taken using High-speed Ectachrome film in a Nikon camera with an 80-200mm zoom lens. A second brief survey of Walrus and Otter Islands by helicopter was made by Doug Causey on 10 June 1976, another day clear enough for photographing the seabird colonies. The helicopter circled Walrus Island twice and Otter Island once. Otter Island was visited again for several hours on 12 June 1976 by Doug Causey and officials of the National Marine Fisheries Service. Transportation was by Coast Guard helicopter. Causey spent the time there photographing and censusing the cliff.

7. Effects of Helicopter Traffic on Cliff Nesting Seabirds

On 10 June 1976, Doug Causey joined Dr. Ted Merrill on the Bell Ranger II helicopter piloted by Lt. Winter for determinations of the distance from the cliffs at which the helicopter would cause birds to depart their nest sites. At this time the murres had yet to lay eggs.

Because of the variations in airspeed it was not possible to calculate the distance of the helicopter from the cliff when murres would start to stream from their ledges. Instead all three observers independently estimated the distance and then agreed on a best estimate of the distance at which the birds first took flight.

Three types of trials were performed. In the first, the aircraft flew at an airspeed of 120 mph directly at the cliff face 35m above the highest point from a starting point 1000m out from the cliff. In this case, birds departing the cliff flew into the rotor of the helicopter and this method was judged too dangerous to repeat. In the second set of trials, the aircraft again flew straight at the cliffs from a distance of 1000m, but at an altitude 100m above the highest point of the cliff. Three passes were made at different sections of cliffs at airspeeds of 125 mph, 105 mph and 90 mph.

In the third set of trials, the aircraft was flown into the wind at an altitude 100m above the highest point of the cliff parallel and to the cliff face at various distances out from the cliff. Airspeed for three passes was 100 mph, while one pass was at 110 mph and a fifth at 125 mph. Again, no two passes were done in the same area of cliff.

8. Nest Attendance

In 1975 and 1976 we took data on colony attendance by cliff nesting species over a cycle of 36 hours. In 1975 we counted every three hours the numbers of murres and Black-legged Kittiwakes present. In 1976 we counted every half hour and included in our count murres, both kittiwake species, Red-faced Cormorants and small alcids. The 1976 data were given to Dr. J. J. Hickey for presentation in his Census of Seabirds on the Pribilof Islands (1977).

In 1977 on both St. Paul and St. George we followed nest attendance of marked individuals of both kittiwake species during watches of 31 to 46 hours duration. On St. George we also observed attendance of marked Thick-billed Murres at a few nest sites during these watches. At each nest site one adult of the pair was marked with picric acid (yellow) applied from a spray gun. For kittiwakes dyeing the tail produces the most visible mark; for murres dye marks on the white feathers at the sides of the breast and under the tail are most visible. For observation we chose several nests which could be viewed from one point on the beach. At every half hour during attendance watches the observer noted which adult of each pair was present at the nest site. During watches after chicks had hatched the observer kept as continuous a watch as possible to note the occurrence and time of chick feedings. We could not observe activity at nest sites during the hours of darkness; however, during one watch observers did remain on the beach overnight to note movement to and from the cliff.

VI. RESULTS

A. Data Collected

Tables 1, 2 and 3 provide a numerical summary of the different types of data gathered during the 1975, 1976 and 1977 seasons, respectively.

TABLE 1

Types of Data Collected, Pribilof Islands 1975

1. Work on the Islands

	Number of Days of Observations at Study Sites									
	St. Paul Island									
Breeding Species	Tsammana	Southwest Cliffs	Ridge Wall	Zapadni	Polovina	Staraya Artel St. George Is.	Total days observation	Number of nests observed	Number of chicks for growth data	Number of food samples collected
Fulmar	-	6	-	-	-	-	6	43	-	1
Red-faced Cormorant	15	-	19	6	18	-	58	83	8	37
Black-legged Kittiwake	20	-	17	9	-	-	46	185	34	123
Red-legged Kittiwake	17	10	18	8	-	11	64	51	18	12
Common Murre	17	27	24	3	24	-	95	49	-	21
Thick-billed Murre	17	27	27	10	25	-	106	89	7	20
Horned Puffin	15	5	20	2	-	-	42	11	8	4
Tufted Puffin	-	4	10	2	-	-	16	-	-	2
Crested Auklet	-	-	-	-	-	-	-	-	-	6
Least Auklet	-	-	6	5	-	-	11	-	-	52
Parakeet Auklet	-	-	-	-	-	-	-	-	-	8

2. Pelagic Seabird observations aboard the Discoverer

Days of observations	Total transects run	Total numbers of birds seen	km surveyed
4	130	28,000	670

TABLE 2

TYPES OF DATA COLLECTED -- PRIBILOF ISLANDS 1976

1. Work on the Islands

Number of Days of Observations at Study Sites

	St. Paul Island						St. George Island				Number of nests observed		Number of chicks for growth data		Number of food samples collected
Breeding Species	Polovina	Zapadni	Ridge Wall	Southwest Cliffs	Gun Emplacement	Rush Gap	Tsammana	Staraya Artel	Tolstoi	High Bluffs	St. Paul	St. George	St. Paul	St. George	Both islands
Fulmar	-	-	-	16	-	18	-	-	-	-	23	-	-	-	-
Red-faced Cormorant	24	-	27	-	3	25	22	27	-	-	82	11	17	10	38
Black-legged Kittiwake	-	-	26	-	25	26	28	26	16	-	155	36	36	24	120
Red-legged Kittiwake	-	-	26	-	25	26	28	26	16	4	75	89	5	32	97
Common Murre	21	24	24	16	-	-	17	11	-	-	70	11	7	6	36
Thick-billed Murre	22	24	24	11	-	-	22	23	-	-	98	40	21	10	31
Horned Puffin	-	-	15	-	-	-	23	-	-	-	27	-	10	-	11
Tufted Puffin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12
Crested Auklet	-	-	-	-	-	-		-	-	-	-	-	-	-	9
Least Auklet	-	-	7	-	-	-	-	-	-	-	-	-	-	-	37
Parakeet Auklet	-	-	11	-	-	-	13	-	-	-	7	-	2	-	14

2. Pelagic seabird observations aboard the Moana Wave

	Days of observations	Total transects run	Total numbers of birds seen	km surveyed
June	3	39	6,057	241
July	4	146	51,544	567

TABLE 3

TYPES OF DATA COLLECTED, PRIBILOF ISLANDS 1977

1. Work on the Islands

Number of Days of Observations at Study Sites

	St. Paul Island						St. George Island						
	Zapadni	Ridge Wall	Southwest Cliffs	Gun Emplacement	Rush Gap	Tsammana	Staraya	Tolstoi	Rosy Finch	First Bluff	High Bluff	Red Bluff	Total Days Observation
Fulmar	-	-	12	-	16	-	-	-	18	-	-	19	65
Red-faced Cormorant	-	31	-	-	22	22	-	35	19	-	-	-	129
Black-legged Kittiwake	-	25	-	27	27	30	31	35	18	19	18	19	249
Red-legged Kittiwake	-	25	-	27	27	30	31	35	-	19	18	19	231
Common Murre	19	18	21	-	17	13	31	-	-	-	-	-	124
Thick-billed Murre	19	18	21	-	17	18	31	35	-	9	-	19	187
Horned Puffin	-	-	-	-	-	16	-	-	-	-	-	-	16
Tufted Puffin	-	-	-	-	-	-	-	-	-	-	-	-	-
Crested Auklet	-	-	-	-	-	-	-	-	-	-	-	-	-
Least Auklet	-	-	-	-	-	-	-	-	-	-	-	-	-
Parakeet Auklet	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 3 (cont.)

TYPES OF DATA COLLECTED, PRIBILOF ISLANDS 1977

1. Work on Islands (cont.)

Breeding Species	Number of Nests Observed		Number of Chicks for Growth Rates		Number of Food Samples Collected	
	St. Paul	St. George	St. Paul	St. George	St. Paul	St. George
Fulmar	22	47	-	-	-	-
Red-faced Cormorant	54	27	4	14	12	24
Black-legged Kittiwake	125	102	22	21	108	86
Red-legged Kittiwake	61	212	3	42	43	120
Common Murre	30	15	9	4	16	3
Thick-billed Murre	103	100	17	36	35	33
Horned Puffin	10	-	6	-	13	-
Tufted Puffin	-	-	-	-	3	-
Crested Auklet	-	-	-	-	6	-
Least Auklet	-	-	-	-	39	42
Parakeet Auklet	-	-	-	-	14	-

TABLE 3 (cont.)

TYPES OF DATA COLLECTED, PRIBILOF ISLANDS 1977

2. Pelagic seabird observations aboard the Surveyor
(Helicopter surveys not included)

	Days of Observation	Total Transects (10 min.) Run	KM Surveyed	Birds Seen
July	5	346	737	33,359
August	5	358	673	24,000

B. Reproductive Success

1. Northern Fulmar (Fulmarus glacialis)

Fulmars on St. Paul Island nest almost exclusively in shallow caves or on ledges at least a foot deep on the high cliffs of the western end of the island. Fulmars on St. George are more numerous than on St. Paul and nest in similar habitats on the high cliffs all around the island. Hickey and Craighead (1977) estimate Fulmars to number about 700 on St. Paul and 70,000 on St. George. Fulmars breeding on the Pribilofs are almost exclusively light phase; less than one in 1000 Fulmars observed on the colony by Hickey and Craighead (1977) were dark phase.

Only a small percentage of Fulmars breeding on the Pribilofs actually build a nest. Incubation time in Fulmars is approximately 50-60 days and the chicks fledge in about two months.

Although our 1976 observations of Fulmars on St. Paul were not begun until 22 July, the first eggs must have been laid by the beginning of June. The first chicks were seen in the third week of July and hatching continued into the second week of August.

Of 23 nest sites followed, 15 had eggs and chicks were seen at twelve sites. Of the three that did not hatch, one was destroyed by a rock slide, one rolled out of a nest and at the third site no chick was ever seen. Ten of the twelve chicks fledged. Of the chicks that did not fledge one chick disappeared and the other was killed by a rock slide.

In 1977 we studied Fulmars at two sites on St. Paul and at two sites on St. George. From our observations of eggs and newly hatched chicks at these sites, egg laying was well under way by late May and continued at least through mid-June. Our earliest observations of chicks were in late July. By the second week of September several chicks within our study areas had shed all their down and gained a plumage which was almost indistinguishable from that of an adult sitting on the cliff.

In our Murie Cove study area on St. George, several eggs were present within Fulmar territories but were never observed by us to be incubated by the birds holding these territories. We twice observed an adult Fulmar approach one of these untended eggs only to be driven off by the territory holder. Perhaps these eggs were laid by Fulmars which did not secure nesting territories.

Table 4 illustrates Fulmar reproductive success by the index of young fledged per mean number of adults present in a study area. Although this crude index does not consider the variability of the ratio of breeding to non-breeding adults between study sites, it is repeatable and allows comparisons between sites and years. For 1977 this index shows a rather uniform production of from 0.24 to 0.41 young fledged per adult on the cliff among our four study areas. When compared with our observations on St. Paul in 1976, the hatching and fledging success of Fulmars in our 1977 study areas appears similar.

TABLE 4.

FULMAR REPRODUCTIVE SUCCESS -- 1977

	ST. PAUL		ST. GEORGE	
	Southwest - 29	Rush Gap S.	Rosy Finch Cove	Murie Cove
Total Adults in Study Area:				
range	4 - 35	13 - 43	3 - 54	36 - 151
mean	20.6	28.7	34.2	75.2
observed during	17 Jun - 16 Sep	27 May - 16 Sep	28 Jul - 14 Sep	26 Jul - 13 Sep
no. observations	16	20	7	8
Minimum no. eggs	7	15	15	32
Minimum no. hatched	7	13	14	24
No. young presumed fledged	5	10	14	23
No. young fledged / Mean total adults in study area	0.24	0.35	0.41	0.30

2. Red-faced Cormorant (Phalacrocorax urile)

The Red-faced Cormorant is endemic to the Bering Sea. In our Annual Report for 1975 we estimated that there might be as few as 200 pairs of Red-faced Cormorants breeding on St. Paul Island. On 26 July 1976 we censused cormorant nests along the cliffs of the west end of the island from Tsammana to the High Bluffs west of Rush Hill. This census was conducted from the beach below the cliffs, an area normally difficult to get to except during very low tides. As a result of this census, our estimate of the number of cormorants breeding on St. Paul has been revised upward to approximately 450 breeding pairs. Hickey and Craighead (1977), using other census methods, estimate abut 2,500 adult Red-faced Cormorants on St. Paul, a figure which seems high to us. They estimate about 5000 birds on St. George Island.

Red-faced Cormorants in the Pribilof Islands tend to be clumped on certain cliffs despite the apparent availability of potential nest sites in other areas. While nests of "nearest neighbor" cormorants were sometimes separated from one another by ledges of murre and kittiwake nests, it was unusual to find a single cormorant nest farther than twenty meters from another one.

On St. Paul Island we found that many cormorant nest sites that were occupied in 1975 were unoccupied in 1976; and new areas were colonized in 1976. In the recent past, cormorants bred at the Reef Point cliffs next to the village of St. Paul (Max Thompson, pers.), where they did not breed in 1975, 1976, or 1977. Similarly, the ledges occupied at our St. George, Staraya site in 1976 were not re-occupied by cormorants in 1977. It is unclear whether the shifts in breeding sites result from a lack of site tenacity on the part of individual pairs of cormorants, or whether the shifts represent a turnover of adults in a small population as a result of natural mortality combined with shooting by Aleuts.

In 1977 we observed Red-faced Cormorants at five study sites on St. Paul and at four sites on St. George. In this year we arrived in the field early enough to document egg laying. Table 5 gives the mean dates of laying and hatching observed within our sites; for nests which already had eggs at our earliest observation, we calculated a laying date from the observed hatching date and an average incubation period of 30 days.

For 1977 Figure 12 shows the percentage of nests containing eggs and young for the St. Paul sites and for one site on St. George; Figure 13 illustrates the initiation of laying, hatching and fledging for these sites. These data show that for both islands laying probably peaked near the first of June, hatching peaked about the first week of July, and fledging occurred through late August or early September. The observed breeding phenology of Red-faced Cormorants is similar both between islands and among the three years studied (Figures 12 and 14).

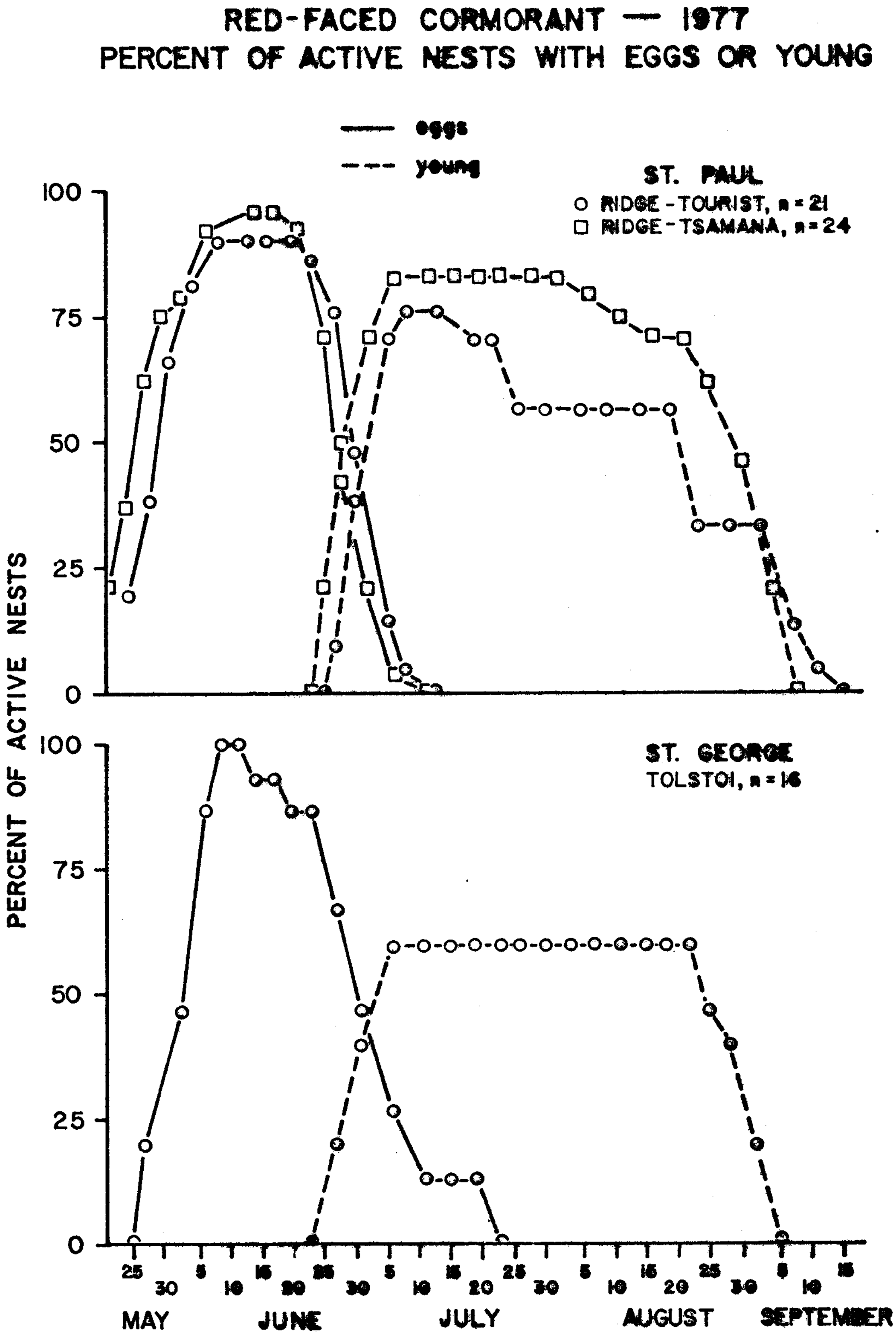
TABLE 5.

MEAN DATES OF LAYING AND HATCHING

RED-FACED CORMORANTS -PRIBILOF ISLANDS-1977

	St. Paul - $\bar{x} \pm$ S.D. (N)	St George - $\bar{x} \pm$ S.D. (N)
First Egg of Clutch	30 May $\pm$ 8 days (22)	4 June $\pm$ 6days(15)
First Hatch of Brood	1 July $\pm$ 3 days (11)	3 July $\pm$ 5 days(7)

FIGURE 12



RED-FACED CORMORANT — 1977
PERCENT OF ACTIVE NESTS WITH EGGS OR YOUNG
eggs
young
ST. PAUL
RIDGE-TOURIST, n = 21
RIDGE-TSAMANA, n = 24
ST. GEORGE
TOLSTOI, n = 16
PERCENT OF ACTIVE NESTS
100
75
50
25
0
25
30
5
10
15
20
25
30
5
10
15
20
25
30
5
10
15
20
25
30
5
10
15
MAY
JUNE
JULY
AUGUST
SEPTEMBER

FIGURE 13

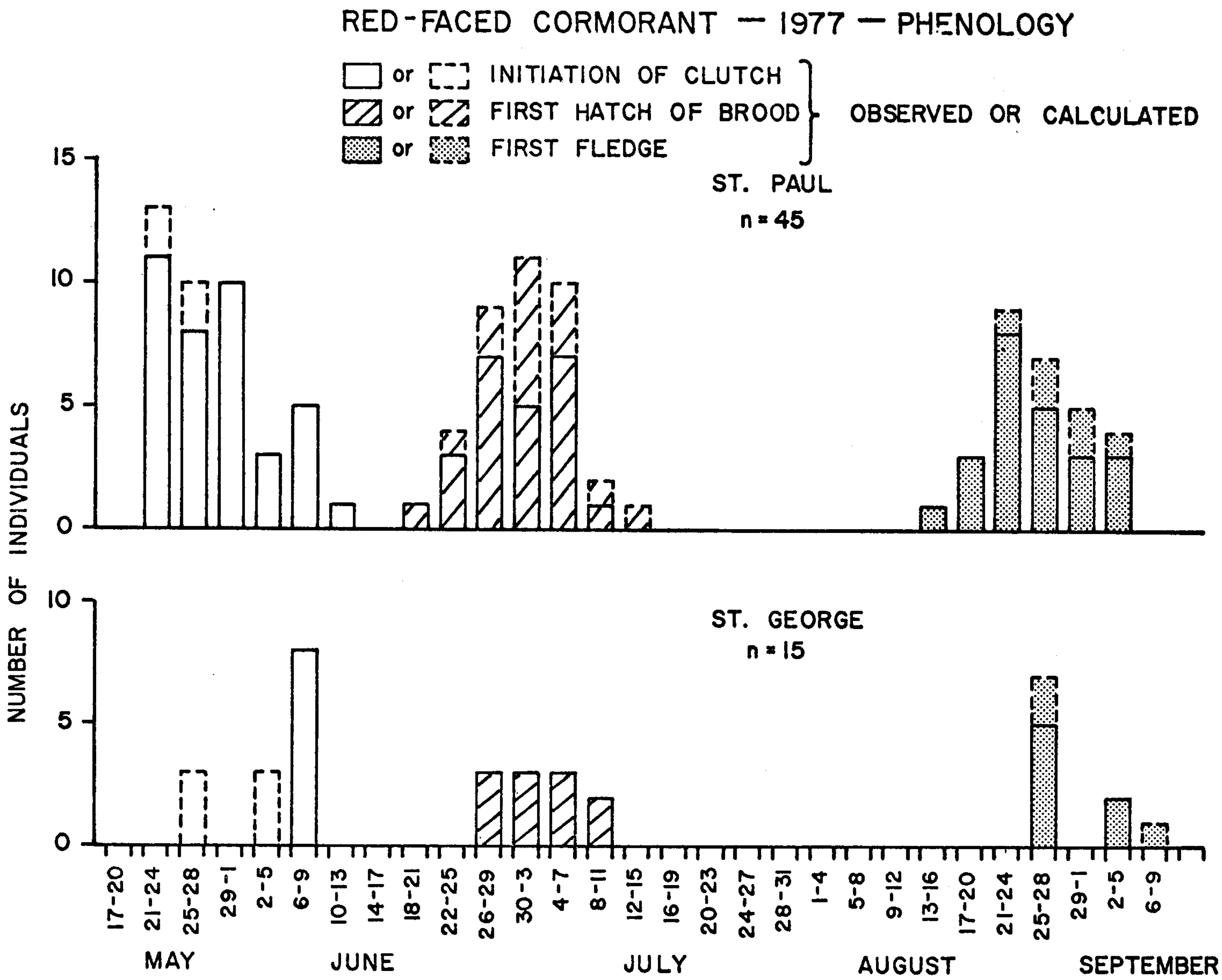
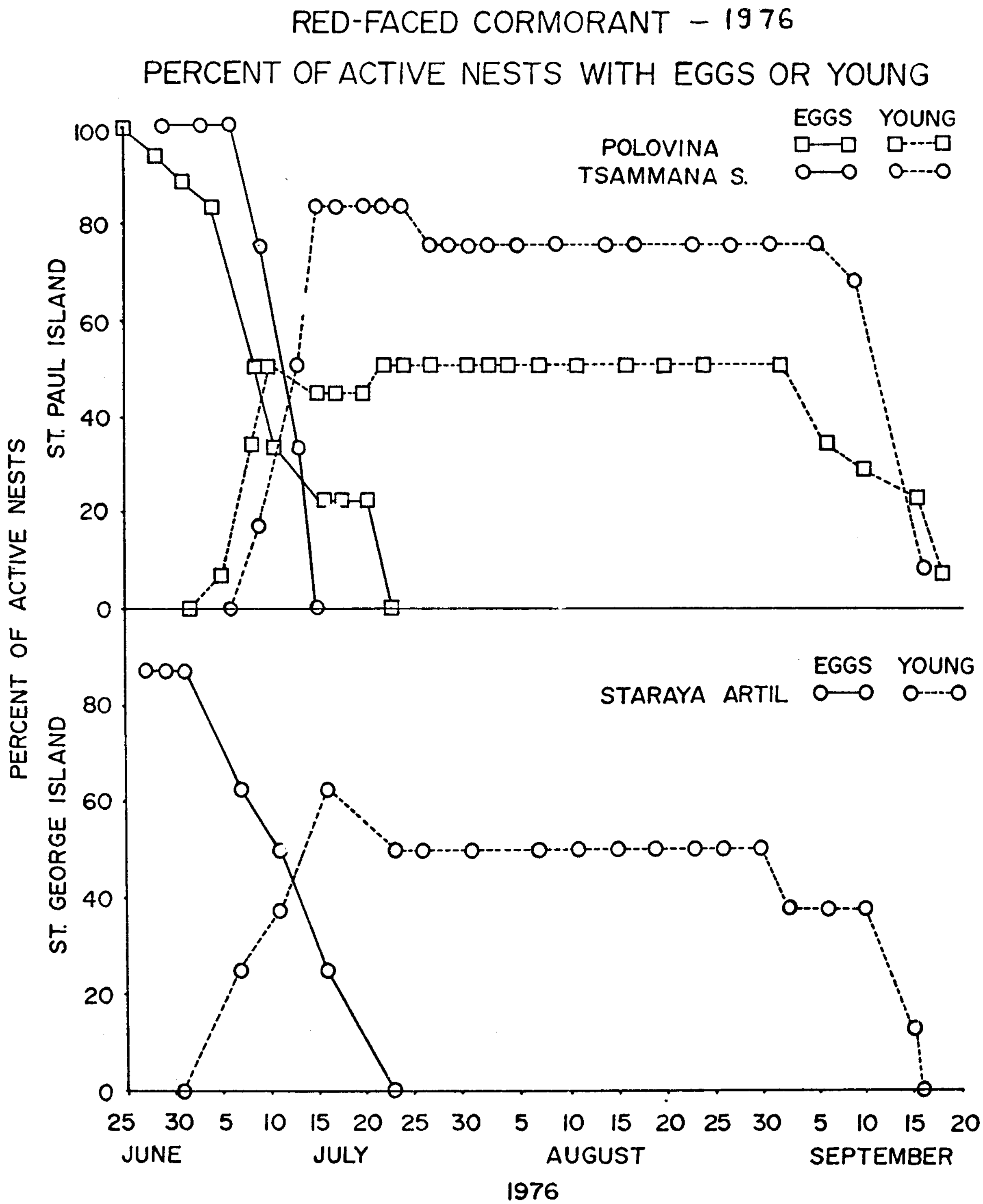

RED-FACED CORMORANT — 1977 — PHENOLOGY
or INITIATION OF CLUTCH
or FIRST HATCH OF BROOD
or FIRST FLEDGE
OBSERVED OR CALCULATED
ST. PAUL
n = 45
ST. GEORGE
n = 15
NUMBER OF INDIVIDUALS
15
10
5
0
17-20
21-24
25-28
29-1
2-5
6-9
10-13
14-17
18-21
22-25
26-29
30-3
4-7
8-11
12-15
16-19
20-23
24-27
28-31
1-4
5-8
9-12
13-16
17-20
21-24
25-28
29-1
2-5
6-9
MAY
JUNE
JULY
AUGUST
SEPTEMBER

FIGURE 14


RED-FACED CORMORANT – 1976
PERCENT OF ACTIVE NESTS WITH EGGS OR YOUNG
EGGS
YOUNG
POLOVINA
TSAMMANA S.
STARAYA ARTIL
PERCENT OF ACTIVE NESTS
ST. PAUL ISLAND
ST. GEORGE ISLAND
100
80
60
40
20
0
25 30 5 10 15 20 25 30 5 10 15 20 25 30 5 10 15 20
JUNE
JULY
AUGUST
SEPTEMBER
1976

Red-faced Cormorants lay 1-4 eggs. The tiny, blind young hatch at about 35 grams, without feathers, and are brooded closely for the first ten days to two weeks until they are covered with black down. During incubation and the early chick phase it is very difficult for observers to tell whether eggs or young are in the nest since the adults sit very tightly. Larger chicks are easy to see but until they are about a month old it is often difficult to distinguish how many are in the nest. Chicks fledge at about seven weeks after attaining a weight of 1800-2200 grams and growing contour and flight feathers.

The 1977 reproductive success for 54 Red-faced Cormorant nests at five St. Paul sites is given in Table 6. Those sites which were disturbed by ladder to weigh young are distinguished from sites which were only viewed from clifftop. Cormorant adults at Tsammana Cove nests flushed much more readily than nesting adults elsewhere and they abandoned these nests by 20 July. The reproductive failure at Tsammana Cove was probably not entirely the result of observer disturbance since the nearby disturbed nests at Tsammana North showed no such failure. This situation and the reduced clutch size of 2.2 eggs per nest at Tsammana Cove point to the probability that these were inexperienced birds which attempted to nest at the extreme edge of the colony. The Ridge Tourist site lost seven clutches to fox predation. The data of Table 6 do not include these clutches.

Table 7 gives parameters of reproductive success for our 1977 St. George study sites. The Red-faced Cormorant adults at Staraya and Rosy Finch Cove behaved similarly to those at Tsammana Cove on St. Paul: these birds flushed readily; many birds abandoned even before completing their nests; and at Rosy Finch Cove two females did not lay until the second week of July.

Of the parameters of reproductive success given in Tables 6 and 7, the "average young fledged per incubated nest" is least subject to observer bias. Though the "average young fledged per total nests" is subject to observers' differing interpretations of what constitutes a nest, this parameter is very important as an indicator of the proportion of nesting attempts which fledge young.

As Tables 6 and 7 illustrate, on both St. Paul and St. George the clutch size is relatively constant among study sites at about three eggs except for those marginal sites mentioned above. With the exception of a few nests fledging three young, it was typical for nests fledging young to fledge two on both islands in 1977. Differences in fledging success between study areas resulted primarily from variation in the proportion of nests fledging young and not from variation in the number of young fledged by a successful nest.

Table 8 gives a comparison of the reproductive success of cormorants on both islands for all years studied. For our observed sites reproductive success appears best in 1976; 1977 reproductive success on both islands is at a level more similar to that observed on St. Paul in 1975 than to 1976 observed success.

TABLE 6.

REPRODUCTIVE SUCCESS

RED-FACED CORMORANT -- ST. PAUL ISLAND 1977

	Ridge Tourist	Rush Gap	Tsammana South	Tsammana North (disturbed)	Tsammana Cove (disturbed)	Total (Undisturbed)	Total (Disturbed)
Total completed nests	21	9	13	6	5	43	11
# incubated nests	21	9	13	3	5	43	8
# nests known clutch size	8	2	2	3	5	7	8
mean clutch size	2.87	3.00	2.50	3.33	2.20	2.83	2.62
proportion of eggs hatched	0.75	0.50	0.40	0.50	0.00	0.61	0.26
total young fledged	31	10	20	4	0	61	4
proportion incubated nests fledging young	0.67	0.55	0.77	0.67	0.00	0.67	0.25
average young fledged/ incubated nests	1.48	1.11	1.54	1.33	0.00	1.41	0.50
average young fledged/ nest fledging young	2.21	2.00	2.00	2.00	-	2.10	2.00
average young fledged/ total nests	1.48	1.11	1.54	0.67	0.00	1.41	0.36

TABLE 7

REPRODUCTIVE SUCCESS

RED-FACED CORMORANT -- ST. GEORGE ISLAND 1977

	TOLSTOI, VISUAL	ROSY FINCH COVE	TOLSTOI, LADDER (disturbed)	STARAYA (disturbed)
Total completed nests	9	5	12	1
# incubated nests	9	3	11	1
# nests known clutch size	4	3	11	-
mean clutch size	3.00	2.33	2.91	-
proportion of eggs hatched	0.83	0.43	0.53	0.00
total young fledged	16	3	13	0.00
proportion incubated nests fledging young	0.78	0.33	0.45	0.00
average young fledged/ incubated nests	1.78	1.00	1.18	0.00
average young fledged/ nest fledging young	2.28	3.00	2.60	-
average young fledged/ total nests	1.78	0.60	1.08	0.00

TABLE 8

REPRODUCTIVE BIOLOGY

RED-FACED CORMORANT - PRIBILOF ISLANDS 1975-1977

	ST. PAUL			ST. GEORGE	
	1975 (4 sites)	1976 (6 sites)	1977 (5 sites)	1976 (1 site)	1977 (4 sites)
Total nests studied	88	82	54	11	27
# incubated nests	79 - 81	79	51	10	23
average clutch size	3.00	2.89	2.75	3.00	2.83
eggs hatched/ eggs laid	0.38 - 0.44	0.25 - 0.40	0.45	0.57	0.59
# young fledged/ incubated nest	1.31 - 1.38	1.52	1.27	1.60	1.39
young fledged/ total nests	1.20 - 1.24	1.46	1.20	1.45	1.23
average growth rate (g/day gained)	61.8 ± 10.2	60.2 ± 14.7	61.7 ± 8.1	48.5 ± 13.2	59.8 ± 6.9
chicks weighed for growth rates	8	17	4	11	14

Growth of chicks is also presented in Table 8. The 1976 data come from nests at the Polovina and Tsammana sites on St. Paul and Staraya Artil site on St. George. The 1977 growth data are from two nests at the Tsammana North site on St. Paul and from nests at the Tolstoi site on St. George. The average growth rates in the straight line portion of the growth curve were similar on St. Paul in all three years. Growth rates observed on St. George in 1976 were lower than those on St. Paul; but those measured on St. Paul and St. George in 1977 were similar. For all three years studied, a growth rate of around 50 to 60 g/day appears typical for Red-faced Cormorant chicks during the straight line period of growth.

3. Black-legged Kittiwake (Rissa tridactyla)

The Black-legged Kittiwake, unlike its congener the Red-legged Kittiwake, has a circum-polar and north temperate distribution. Of the two species of kittiwakes, the Black-legged Kittiwake predominates on St. Paul Island; and the Red-legged is more numerous on St. George. About 31,000 Black-legged Kittiwakes nest on St. Paul; and 72,000 on St. George (Hickey and Craighead 1977). Black-legged Kittiwakes build larger nests than Red-legged Kittiwakes, and place them on slightly deeper ledges.

In 1977 we observed 125 Black-legged Kittiwake nests at five sites on St. Paul. These five sites were the same as studied in 1976. At the Tsammana North site, nests were accessible by ladder; at other sites we made observations from the clifftops. On St. George in 1977 we increased the number of sites studied to include four visually observed sites in addition to the two ladder accessible sites, Tolstoi and Staraya, which were studied in 1976; in all, we studied 102 nests at St. George.

The visually observed sites on St. Paul, the visually observed sites at First Bluff and High Bluffs Middle on St. George and the ladder-accessible sites on St. George were mixed-species breeding stations in which both Black-legged and Red-legged Kittiwakes nested in close proximity. These mixed sites provide us with some control over variation due to nesting environment effects in comparing the two species.

In two cases we lumped 1977 St. George data from non-contiguous cliff sections for the purposes of this report. The data shown as High Bluffs Middle came from two small groups of Black-legged Kittiwakes breeding among large concentrations of Red-legged Kittiwakes on the High Bluffs. The Red Bluffs data came from two similar cliff sections on the south side of St. George.

In 1977 we followed the nesting activities of Black-legged Kittiwakes from prior to nest building in late May until most chicks were fledged in mid-September. Observed incubation periods ranged from an average of 26 days at St. George Tolstoi and Staraya sites to an average of 29 days at St. Paul Tsammana North. On both islands chicks began to fly at an average age of 43 days. After the initial fledging, young usually remained close to the nest for about 10 days before leaving the island.

At the ladder accessible sites the nesting phenology data are most satisfactory since we obtained accurate counts of eggs and chicks at each visit. Once chicks grew large enough, there was no problem seeing them from the clifftop at our visual sites. Thus, although initial egg and chick counts are less accurate, the final reproductive success data from our visual sites may be more representative than at the ladder sites, since the visual sites were less disturbed and more centrally located within the colony.

In 1977, although kittiwakes had occupied territories (many of which had old mud-platforms that had survived the winter) by late May, nest building did not begin in earnest until the second week of June. Table 9 and Figures 15, 16 and 17 summarize the breeding phenology of the Black-legged Kittiwake as observed in the Pribilofs during 1975, 1976 and 1977. In these graphs "calculated" data points were derived from observed laying or hatching dates and a known incubation period of 25 to 30 days. On both islands in 1976 and in 1977 laying began about the third week of June and peaked in early July; in these years hatching peaked near the end of July. For our study sites, timing on St. Paul was about a week later in 1975 than in 1976 and 1977.

Black-legged Kittiwake production of young on the Pribilofs in 1977 remained at a level of about one young fledged per every two nests as observed in the previous two years. Tables 10 and 11 present reproductive success parameters by study area for each of the two islands in 1977. Within these tables the categories "chick fledged/incubated nest" and "chicks fledged/nest built" are least effected by observer bias; some other categories are more subject to bias since it is often difficult to see eggs and small chicks under tight-sitting parents. There is some variation among the sites within each island. On St. Paul, Tsammana South had a slightly high fledging success per nest of 0.76; whereas the disturbed site, Tsammana North, fledged only 0.56 young per nest. On St. George the Tolstoi disturbed site where we concentrated our adult banding and marking efforts fledged a low 0.35 young per nest; yet the other ladder-accessible site, Staraya, had the highest observed fledging success of the island at 0.65 young per nest. For all nests observed on each island, St. Paul had a higher average fledging success per nest than did St. George in 1977 at 0.66 to 0.49. Table 12 summarizes the reproductive biology observed on St. Paul and St. George over the three years of study. In these years the observed fledging success per nest has varied within narrow limits around 0.5.

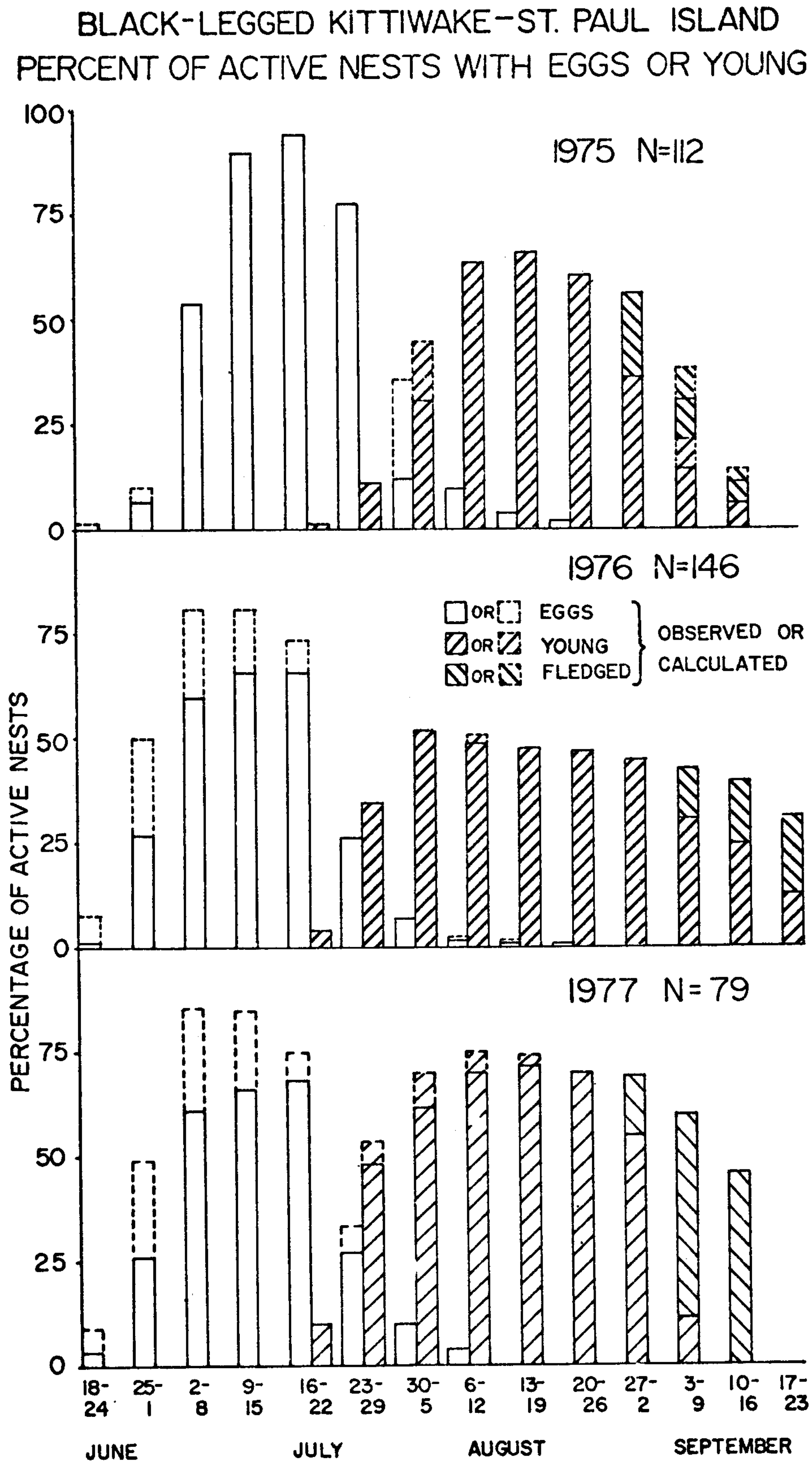
As noted in the above tables, the mean observed clutch size for the islands has remained around 1.4 eggs per incubated nest, although considerable variation does occur among study sites. Though almost half the observed clutches were of two eggs, none of the nests within our study areas have fledged two young during any of the three years of study; in most cases the second chick has disappeared within the first ten days after hatching. In the broods we weighed for growth, the heavier, older chick always survived longer. In six cases we observed directly or noted from wounds on the head of the smaller chick that the

TABLE 9

MEAN LAYING AND HATCHING DATES

BLACK-LEGGED KITTIWAKE - PRIBILOF ISLANDS 1975-1977

	St. Paul Island - $\bar{X}$ + S.D. (N)	St. George Island - $\bar{X}$ + S.D. (N)
1975 first egg of clutch	5 July ± 4.4 (47)	--
first hatch of brood	2 Aug. ± 4.7 (33)	--
1976 first egg of clutch	29 June ± 3.9 (46)	1 July ± 6.6 (21)
first hatch of brood	29 July ± 2.8 (23)	28 July ± 6.1 (17)
1977 first egg of clutch	30 June ± 4.7 (49)	30 June ± 5.2 (53)
first hatch of brood	28 July ± 4.9 (60)	27 July ± 4.6 (63)



BLACK-LEGGED KITTIWAKE-ST. PAUL ISLAND
PERCENT OF ACTIVE NESTS WITH EGGS OR YOUNG
1975 N=112
1976 N=146
1977 N=79
OR EGGS
OR YOUNG
OR FLEDGED
OBSERVED OR CALCULATED
PERCENTAGE OF ACTIVE NESTS
100
75
50
25
0
18-24
25-1
2-8
9-15
16-22
23-29
30-5
6-12
13-19
20-26
27-2
3-9
10-16
17-23
JUNE
JULY
AUGUST
SEPTEMBER

FIGURE 15

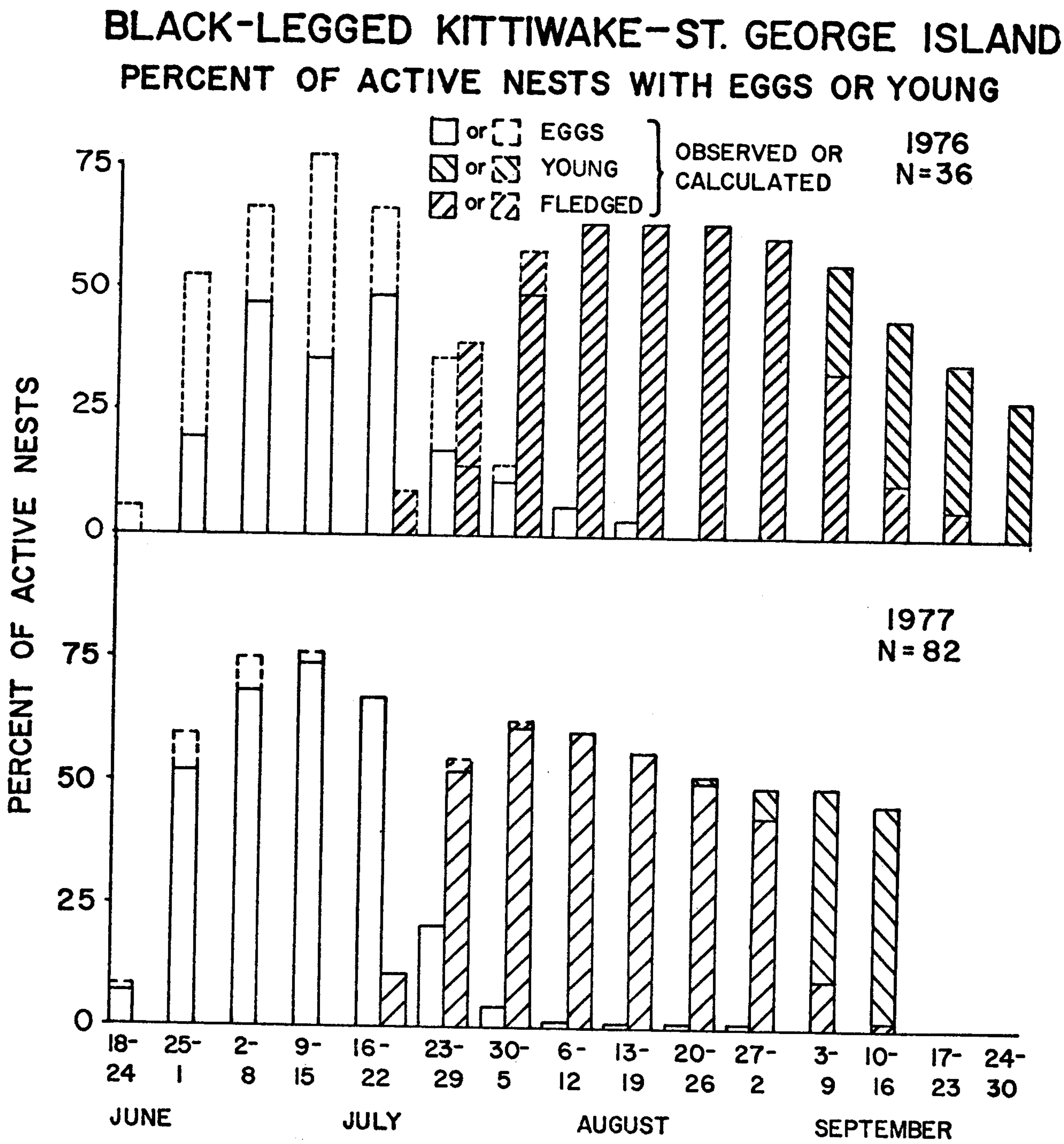

BLACK-LEGGED KITTIWAKE-ST. GEORGE ISLAND
PERCENT OF ACTIVE NESTS WITH EGGS OR YOUNG
or EGGS
or YOUNG
or FLEDGED
OBSERVED OR CALCULATED
1976
N=36
1977
N=82
PERCENT OF ACTIVE NESTS
75
50
25
0
18- 24
25- 1
2- 8
9- 15
16- 22
23- 29
30- 5
6- 12
13- 19
20- 26
27- 2
3- 9
10- 16
17- 23
24- 30
JUNE
JULY
AUGUST
SEPTEMBER

FIGURE 16

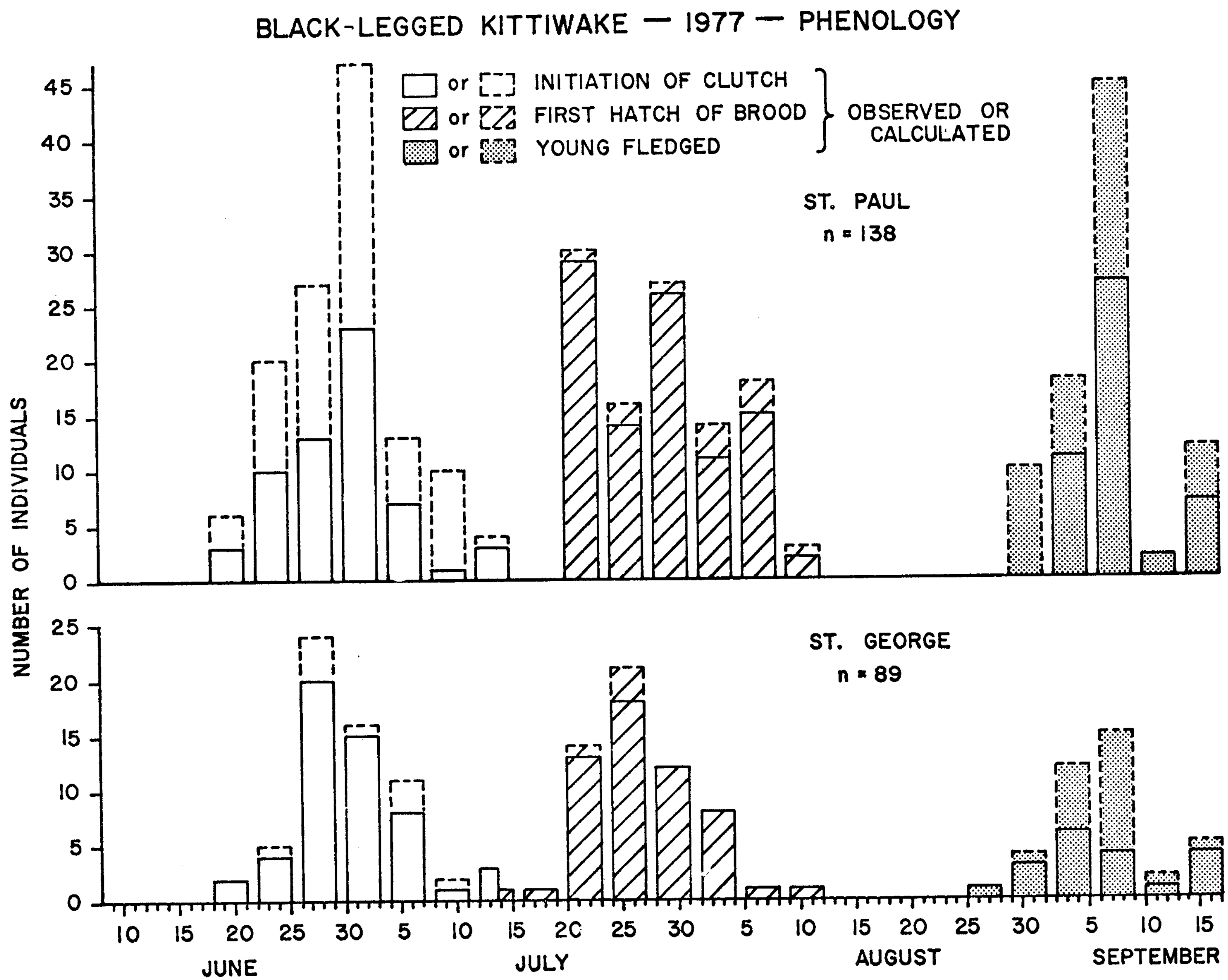

BLACK-LEGGED KITTIWAKE — 1977 — PHENOLOGY
or INITIATION OF CLUTCH
or FIRST HATCH OF BROOD
or YOUNG FLEDGED
OBSERVED OR CALCULATED
ST. PAUL
n = 138
ST. GEORGE
n = 89
NUMBER OF INDIVIDUALS
0 5 10 15 20 25 30 35 40 45
0 5 10 15 20 25
10 15 20 25 30 5 10 15 20 25 30 5 10 15 20 25 30 5 10 15
JUNE
JULY
AUGUST
SEPTEMBER

FIGURE 17

TABLE 10.

REPRODUCTIVE SUCCESS

BLACK-LEGGED KITTIWAKE - ST. PAUL ISLAND 1977

	Tsammana North (disturbed)	Tsammana South	Rush Gap	Gun Emplacement	Ridge Spine	Total
# nests	36	29	21	14	25	125
# incubated nests	33	26	17	14	23	113
# nests with known clutch size	36	23	13	12	14	98
mean clutch size	1.20	1.50	1.38	1.75	1.14	1.36
chicks hatched/ egg laid	0.70-0.77	0.62-0.87	0.78-1.00	0.43-0.71	0.86-0.93	0.65-0.82
chicks fledged/ chicks hatched	0.61-0.67	0.59-0.83	0.50-0.64	0.53-0.89	0.85-0.92	0.59-0.75
chicks fledged/ incubated nest	0.61	0.85	0.76	0.71	0.74	0.72
chicks fledged/ egg laid (known clutch)	0.47	0.49	0.50	0.38	0.69	0.49
chicks fledged/ nest built	0.56	0.76	0.62	0.71	0.68	0.66

TABLE 11.

REPRODUCTIVE SUCCESS

BLACK-LEGGED KITTIWAKE - ST. GEORGE ISLAND 1977

	TOLSTOI (disturbed)	STARAYA (disturbed)	ROSY FINCH COVE	FIRST BLUFF	HIGH BLUFFS MIDDLE	RED BLUFFS	TOTAL
# nests	23	20	13	11	10	25	102
# incubated nests	19	17	11	8	9	22	86
# nests with known clutch size	18	17	11	4	8	20	78
mean clutch size	1.55	1.29	1.73	1.25	1.26	1.50	1.46
chicks hatched/ egg laid	0.68-0.89	0.91	0.74-1.00	1.00	0.50-1.00	0.63-0.90	0.72-0.93
chicks fledged/ chicks hatched	0.28-0.37	0.65	0.31-0.43	0.60	0.40-0.80	0.41-0.58	0.41-0.54
chicks fledged/ incubated nest	0.42	0.76	0.54	0.62	0.55	0.59	0.58
chicks fledged/ egg laid (known clutch)	0.25	0.59	0.31	0.60	0.40	0.37	0.38
chicks fledged/ nest built	0.35	0.65	0.46	0.45	0.50	0.52	0.49

TABLE 12.

REPRODUCTIVE BIOLOGY

BLACK-LEGGED KITTIWAKE - PRIBILOF ISLANDS 1975-1977

	ST. PAUL ISLAND			ST. GEORGE ISLAND	
	1975	1976	1977	1976	1977
Total nests studied	185	155	125	36	102
# nests known clutch size	87	94	98	22	78
mean clutch size	1.44	1.46	1.36	1.36	1.46
chicks hatched/ egg laid	0.57-0.67	0.54-0.66	0.65-0.82	0.67-0.80	0.72-0.93
chicks fledged/ chicks hatched	0.57-0.68	0.58-0.70	0.59-0.75	0.71-0.85	0.41-0.54
chicks fledged/ egg laid	0.38	0.36	0.49	0.57	0.38
chicks fledged/ nest with eggs	0.54	0.53	0.72	0.75	0.58
chicks fledged/ total nests	0.44	0.42	0.66	0.58	0.49
mean growth rate (g/day gained)	17.9 ± 3.4	12.8 ± 4.9	14.5 ± 1.6	11.5 ± 2.6	13.8 ± 1.8
# chicks with growth data	34	33	22	24	21

larger chick vigorously pecked its smaller sibling. In several cases we found the smaller chick alive on the ground beneath its nests, and once saw the larger chick knock its sibling from the nest by an open-billed blow to the back of the head. However, in 1977 on St. Paul we observed two nests outside of our Tsammana South site from which two young probably fledged per nest; adults at another nest within our Ridge Tourist study area raised two young to four weeks of age before the young were shot by young boys. Thus, with the exception of the three nests on St. Paul in 1977, Black-legged Kittiwake nests fledging two young have not been seen on the Pribilofs from 1975 through 1977. In other parts of their range the Black-legged Kittiwake may lay up to three eggs and can fledge two or three young.

In 1977 we noted two other points of interest concerning variable clutch size in the Black-legged Kittiwake. For nests of known clutch size on both islands, those with two eggs had a higher average fledging success than did nests with one egg: fledging success of two-egg clutches averaged 0.82 on St. Paul and 0.62 on St. George; whereas, for one-egg clutches it averaged only 0.66 on St. Paul and 0.51 on St. George. Also, for two-egg clutches, one egg was consistently heavier than the other as shown in Table 13; in all known cases the egg first laid was the heavier. These findings are consistent with those of Maunder and Threlfall (1972) on Newfoundland. The relationship between the size of eggs from one-egg clutches to that of eggs from two-egg clutches is unclear.

Growth rates of Black-legged Kittiwake chicks are presented at the bottom of Table 12; our observed yearly averages range from 11.5 to 17.9 grams gained per day. The St. Paul young of 1975 showed the highest mean growth rate; average growth rates in 1976 were the lowest observed for both islands. In both 1976 and 1977 the growth rates from the St. Paul Tsammana North site were slightly higher than those observed at the Tolstoi and Staraya sites on St. George. Our observed growth rates of Black-legged Kittiwake chicks are not as closely correlated to fledging success as has been noted in some large larids (Hunt and Hunt 1976). In 1977 Black-legged young fledged at an observed average of 433g.

Black-legged Kittiwake breeding biology in the Pribilofs has offered no obvious correlations to weather patterns over the last three seasons. Precipitation was most continuous and temperatures averaged lowest in 1975; for these categories, 1977 was the mildest breeding season. Yet, no consistent patterns of timing, fledging success or rate of growth are apparent when related to these weather trends. Hence, the absolute weather trends may play a relatively minor role in reproductive success when compared to other factors such as food availability.

TABLE 13.

BLACK-LEGGED KITTIWAKE - PRIBILOF ISLANDS 1977

EGG WEIGHTS

First observation of egg (g): $\bar{X} \pm$ S. D. (n)

	St. Paul	St. George
Single egg clutch	53 ± 4 (21)	53 ± 4 (12)
Heavy egg of two	55 ± 5 (7)	52 ± 3 (12)
Light egg of two	52 ± 4 (7)	49 ± 3 (12)

4. Red-legged Kittiwake (*Rissa brevirostris*)

St. George Island is the most important breeding site in the world for the Red-legged Kittiwake, a species endemic to the Bering Sea. The population there numbers approximately 220,000 individuals, while on St. Paul the population is perhaps only one percent of that on St. George (Hickey and Craighead 1977). We conducted a census in July 1976 from which we estimate there were only 850 nests of Red-legged Kittiwakes on St. Paul Island.

Red-legged Kittiwakes place their nests on shorter, narrower ledges than Black-legged Kittiwakes, and a much higher percentage of nests are built under small overhangs. The nest itself is smaller in diameter and height than that of the Black-leg.

Red-legged Kittiwakes on St. Paul nest among groups of Black-legged Kittiwakes, sometimes singly or often in small aggregations of five to ten nests. From clifftops we observed Red-legged nests at five study sites; the same sites were observed in 1977 as in 1976. We were able to reach three nests by ladder at the Tsammana South site to weigh chicks for growth rates.

Red-legged Kittiwakes on St. George nest among pairs of Black-legged Kittiwakes at lower elevations or in single-species aggregations on the highest cliffs (Hickey and Craighead 1977). In 1977, we established several study sites which could be observed from clifftop on the higher cliffs of the north and south side of St. George; we also continued observations of the ladder-accessible Red-legged nests at the Tolstoi and Staraya sites which were extensively studied in 1976. Limited observations of the Red-legged Kittiwake nests at Staraya were also made in 1975.

Unlike the Black-legged Kittiwake, the Red-legged Kittiwake lays only one egg. Incubation in this species averages 29 to 32 days; chicks are capable of flight about 37 days after hatching. Young typically remain in the vicinity of the nest from a week to ten days after fledging before departing the cliffs, during which time they are still fed by the parents.

Red-legged Kittiwakes were well established on the cliffs of St. George by the middle of April 1977; these birds were on the water in the vicinity of the island by the first of that month. As with the Black-legged Kittiwakes, from the initial occupation of the cliffs, the territories occupied by Red-legged Kittiwakes were associated with decaying nest structures, which remain from the previous season. However, in 1977 nest building activity was not prevalent until the second week of June. The temporal pattern of laying, hatching and fledging is depicted in Figures 18, 19 and 20 and in Table 14. Though the ranges and modes of laying, hatching and fledging depicted in the above figures appear approximately the same for both islands, the observed mean laying and hatching dates for St. George in 1977 were again a few days behind those of St. Paul as was the case in 1976 (Table 14). The means of

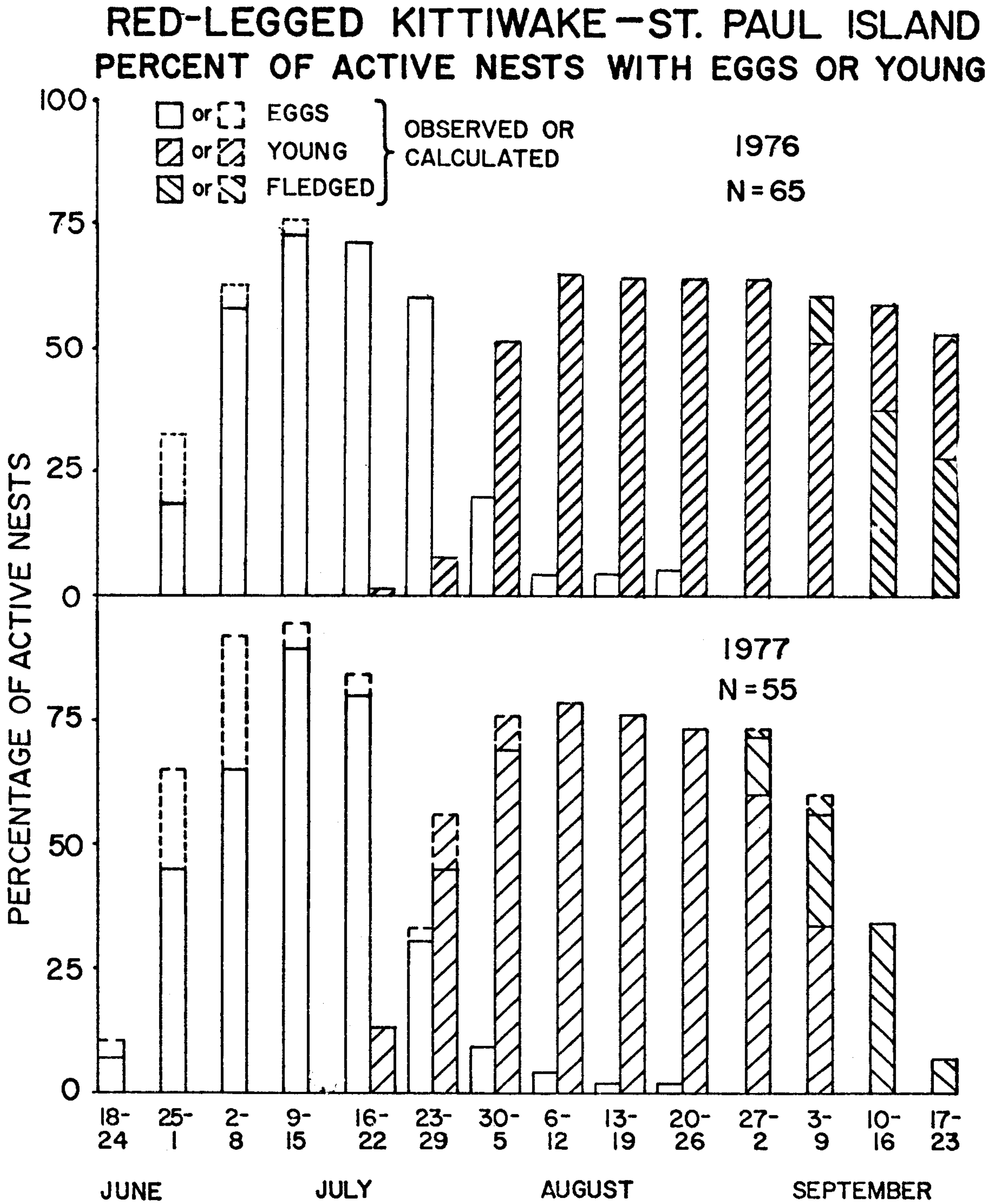

RED-LEGGED KITTIWAKE—ST. PAUL ISLAND
PERCENT OF ACTIVE NESTS WITH EGGS OR YOUNG
or EGGS
or YOUNG
or FLEDGED
OBSERVED OR CALCULATED
1976
N=65
1977
N=55
PERCENTAGE OF ACTIVE NESTS
100
75
50
25
0
18-24
25-1
2-8
9-15
16-22
23-29
30-5
6-12
13-19
20-26
27-2
3-9
10-16
17-23
JUNE
JULY
AUGUST
SEPTEMBER

FIGURE 18

RED-LEGGED KITTIWAKE — ST. GEORGE ISLAND
PERCENT OF ACTIVE NESTS WITH EGGS OR YOUNG

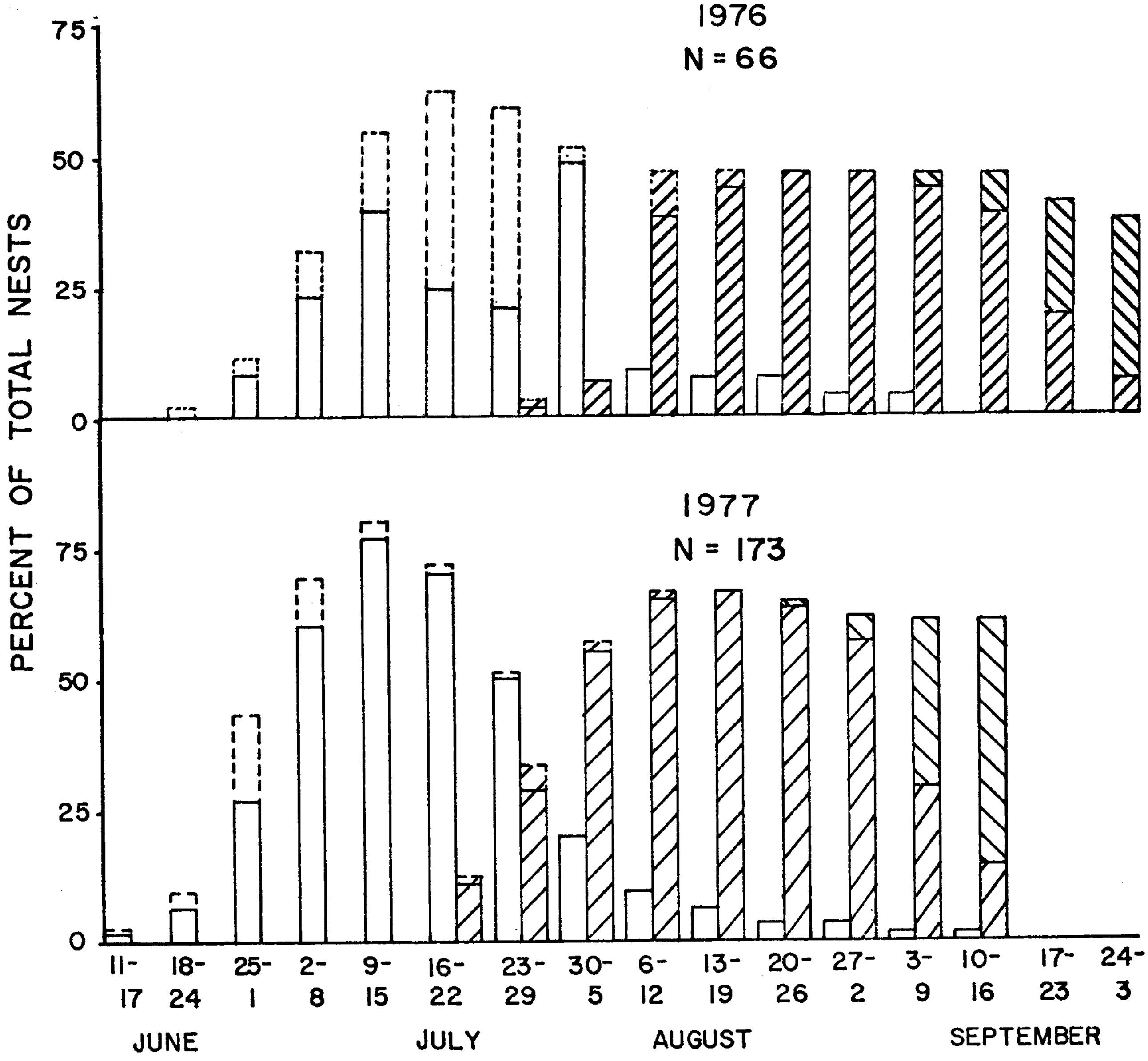


FIGURE 19

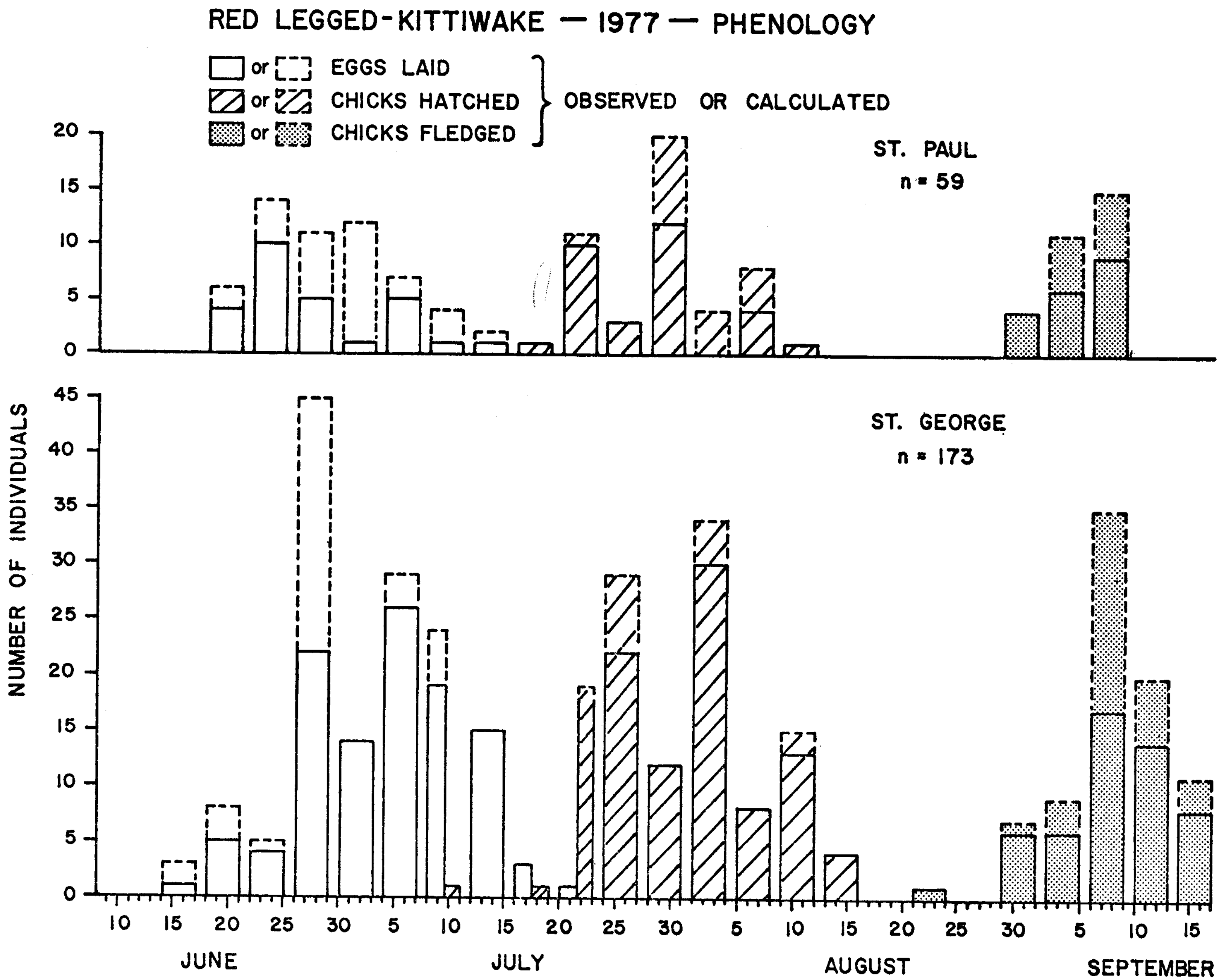

RED LEGGED-KITTIWAKE — 1977 — PHENOLOGY
or EGGS LAID
or CHICKS HATCHED
or CHICKS FLEDGED
OBSERVED OR CALCULATED
ST. PAUL
n = 59
ST. GEORGE
n = 173
NUMBER OF INDIVIDUALS
0
5
10
15
20
25
30
35
40
45
10
15
20
25
30
5
10
15
20
25
30
5
10
15
20
25
30
5
10
15
JUNE
JULY
AUGUST
SEPTEMBER

FIGURE 20

TABLE 14

MEAN LAYING AND HATCHING DATES

RED-LEGGED KITTIWAKE - PRIBILOF ISLANDS 1975-1977

		St. Paul Is. - $\bar{X} \pm$ S.D. (N)	St. George Is. - $\bar{X} \pm$ S.D. (N)
1975	Laying	6 July ± 2.0 (6)	--
	Hatching	31 July ± 0.0 (3)	1 Aug. ± 7.0 (19)
1976	Laying	3 July ± 4.5 (51)	7 July ± 6.0 (41)
	Hatching	31 July ± 4.7 (41)	5 Aug. ± 6.3 (35)
1977	Laying	25 June ± 4.8 (17)	4 July ± 7.2 (104)
	Hatching	27 July ± 6.7 (10)	31 July ± 8.3 (93)

laying and hatching given in Table 14 were derived from all nests for which this information was available, yet interesting differences occur between study sites for these parameters. On St. George in 1977 the mean observed hatching date of 26 nests located near the top of the 308m High Bluffs was 27 July; for 51 ladder-accessible nests at the Tolstoi and Staraya sites the mean hatching date was eight days later on 4 August. Such statistics may represent differences in the quality of the birds occupying the respective sites. However, this conclusion finds little support from the observed reproductive success data.

Reproductive success of Red-legged Kittiwakes at five sites on St. Paul and seven sites on St. George in 1977 are given in Tables 15 and 16 respectively; as with our Black-legged data from St. George, those data presented as High Bluffs Middle and Red Bluffs were grouped from nearby but non-contiguous cliff sections. Considerable variation occurs among study sites on both islands; fledging success per nest built ranges from below 0.4 to almost 0.9 on St. Paul and from 0.4 to 0.8 on St. George. This variation among sites correlates with no obvious parameter such as degree of observer disturbance, ledge altitude or species composition. The overall fledging success per incubated nest was the same on both islands at 0.7. Observed mortality was about 0.1 to 0.2 for both the egg and the chick stage with some variations among study areas.

Table 17 presents the observed reproductive success for both islands over the three years of this study. With the exception of the observations on St. Paul in 1975, Red-legged Kittiwakes within our study sites have fledged slightly better than one young per every two nests on the average. Again, with the exception of St. Paul in 1975, fledging success per incubated nest has been extremely consistent at 0.7 or better. The cause of this lower fledging success by the Red-legged nests observed on St. Paul in 1975 rests in an unusually high egg mortality of over 0.4; nestling mortality is consistently below 0.2 among observed nests in all years on both islands. The Red-legged Kittiwake fledges from its single egg clutch at least as many young as are fledged from the one to two egg clutches of the Black-legged Kittiwake in the Pribilof Islands.

Red-legged Kittiwake adults typically vary in weight from 340 to 420 grams during the breeding season. Though it is a smaller bird than its black-legged congener, which typically ranges from 390 to 520 grams during breeding, the Red-leg lays an egg of comparable size (50 x 3 g, n = 50). As shown at the bottom of Table 17, Red-legged young have typically grown at an observed rate of nearly 13 grams per day in all years on both islands. This rate of growth is about the same as that observed in Black-legged Kittiwakes though apparently less variable from year to year. Red-legged Kittiwake young fledge abut 30 grams lighter than do Black-legged Kittiwakes: 29 Red-legged young fledged at a mean of 404 $\pm$ 37g on St. George in 1977. This equal growth rate but lighter fledging weight observed in the Red-legged Kittiwake corresponds with its shorter observed fledging period of 37 days compared with the 43 days observed in the Black-leg.

TABLE 15.

REPRODUCTIVE SUCCESS

RED-LEGGED KITTIWAKE - ST. PAUL ISLAND 1977

	Tsammana South	Rush Gap	Rush South	Gun Emplacement	Ridge Wall	Total
# nests	10	9	6	22	14	61
# eggs laid	10	9	6	22	13	60
# chicks hatched	9	9	5-6	18-19	7-8	50-53
# chicks fledged	7	8	5	16	5	42
chicks hatched/ egg laid	0.90	1.00	0.83-1.00	0.82-0.86	0.54-0.61	0.83-0.88
chicks fledged/ chicks hatched	0.78	0.89	0.83-1.00	0.84-0.89	0.63-0.71	0.79-0.84
chicks fledged/ egg laid	0.70	0.89	0.83	0.73	0.38	0.70
chicks fledged/ nest built	0.70	0.89	0.83	0.73	0.36	0.69

TABLE 16.

REPRODUCTIVE SUCCESS

RED-LEGGED KITTIWAKE - ST. GEORGE ISLAND 1977

	Tolstoi (disturbed)	Staraya (disturbed)	High Bluffs East	High Bluffs Middle	High Bluffs West	First Bluff	Red Bluffs	Total
# nests	48	30	44	23	22	34	11	212
# eggs laid	39	28	37	19-22	20	31-33	11	185-190
# chicks hatched	26-29	26	35	11-22	16-18	26-29	9	149-168
# chicks fledged	20	24	30	10	13	24	8	129
chicks hatched/ egg laid	0.67-0.74	0.93	0.94	0.50-1.00	0.80-0.90	0.79-0.88	0.82	0.78-0.88
chicks fledged/ chicks hatched	0.69-0.77	0.92	0.86	0.45-0.91	0.72-0.81	0.83-0.92	0.89	0.77-0.86
chicks fledged/ egg laid	0.51	0.86	0.81	0.45-0.53	0.65	0.73-0.77	0.73	0.68-0.70
chicks fledged/ nest built	0.42	0.80	0.68	0.43	0.59	0.70	0.73	0.61

TABLE 17. REPRODUCTIVE BIOLOGY

RED-LEGGED KITTIWAKE - PRIBILOF ISLANDS 1975 - 1977

	St. Paul			St. George		
	1975	1976	1977	1975	1976	1977
Total nests studied	51	75	61	28	89	212
# nests with egg known	33	60	60	23	44	185-190
chicks hatched/ egg laid	0.55	0.83	0.83-0.88	0.83	0.77	0.78-0.88
chicks fledged/ chick hatched	0.83	0.94	0.79-0.84	0.84	0.91	0.77-0.86
chicks fledged/ egg laid	0.45	0.78	0.70	0.70	0.70	0.68-0.70
chicks fledged/ total nests	0.29	0.63	0.69	0.57	0.45	0.61
mean growth rate (g/day gained)	-	13.1 ± 0.7	13.6 ± 25	13.7 ± 3.7	12.4 ± 2.4	13.1 ± 2.3
# chicks with growth data	-	5	3	18	32	42

5. Common Murre (*Uria aalge*)

Most of the Common Murres nesting on the Pribilof Islands breed on wide ledges on which many birds of that species congregate in dense groups. A very small percentage of Common Murres breed on narrower ledges six inches to a foot wide, often among pairs of Thick-billed Murres. Murres build no nest; rather these birds lay a single egg on the bare rock and incubate by holding it on top of the feet against a brood patch in the stomach area. On both islands in 1977 the mean incubation period observed lasted 31 days, and chicks remained on nesting ledges an average of 21 days before going to sea. During this short time on the cliffs, their natal down is replaced by contour feathers, but the chicks attain less than one-quarter of their adult weight before leaving the islands. Once at sea, murre young continue to be fed by adults until independent. The population numbers approximately 190,000 individuals on St. George and 39,000 on St. Paul (Hickey and Craighead 1977).

In 1977 on St. Paul we counted eggs, young and adults present on three ledges along Zapadni Point, and one ledge each along Ridge Wall, the Southwest Cliffs and the Tsammana Cliffs. Also at one accessible ledge on Zapadni Point we observed fledging success and growth of chicks. On. St. George in 1977 we observed Common Murres only on the ladder accessible ledge at Staraya.

Common Murres were well established on their ledges when we arrived on the Pribilofs in the third week of May 1977. On St. Paul we first saw an egg on 21 June; by the end of June most Common Murres on nesting ledges had assumed incubation postures. On 22 July we first observed a Common Murre chick on St. Paul. The mean hatching date at the disturbed ledge at Zapadni Point was 14 August ± 6 days (n = 14); yet this was probably an unusually late ledge since we saw chicks at five or six undisturbed sites well before this date. At the Staraya ledge on St. George in 1977 the mean date of laying was 3 July ± 8 days (n = 14) and of hatching 4 August ± 7 days (n = 10). On both islands, almost all Common Murres were gone from the cliffs by 4 September. This pattern of breeding phenology is comparable with that of Common Murres in 1975 and 1976 as shown in Figures 21 and 22.

Because of the variety of methods we have used in studying Common Murres, our reproductive success data is not directly comparable from year to year and probably does not give an adequate representation of this species' production on the Pribilofs. Table 18 presents this reproductive success data for the three years of study. Common Murre reproductive potential is probably most nearly represented by the data from the 1976 undisturbed and the 1977 disturbed sites of St. Paul and the 1976 disturbed site of St. George. These three sites had consistent fledging rates of near 0.8 young fledged per young hatched. Egg mortality caused by the inevitable disturbance of observers, no matter how cautious, probably resulted in an unnaturally low fledging success per egg at these sites. An infestation of ticks aggravated by observer disturbance and

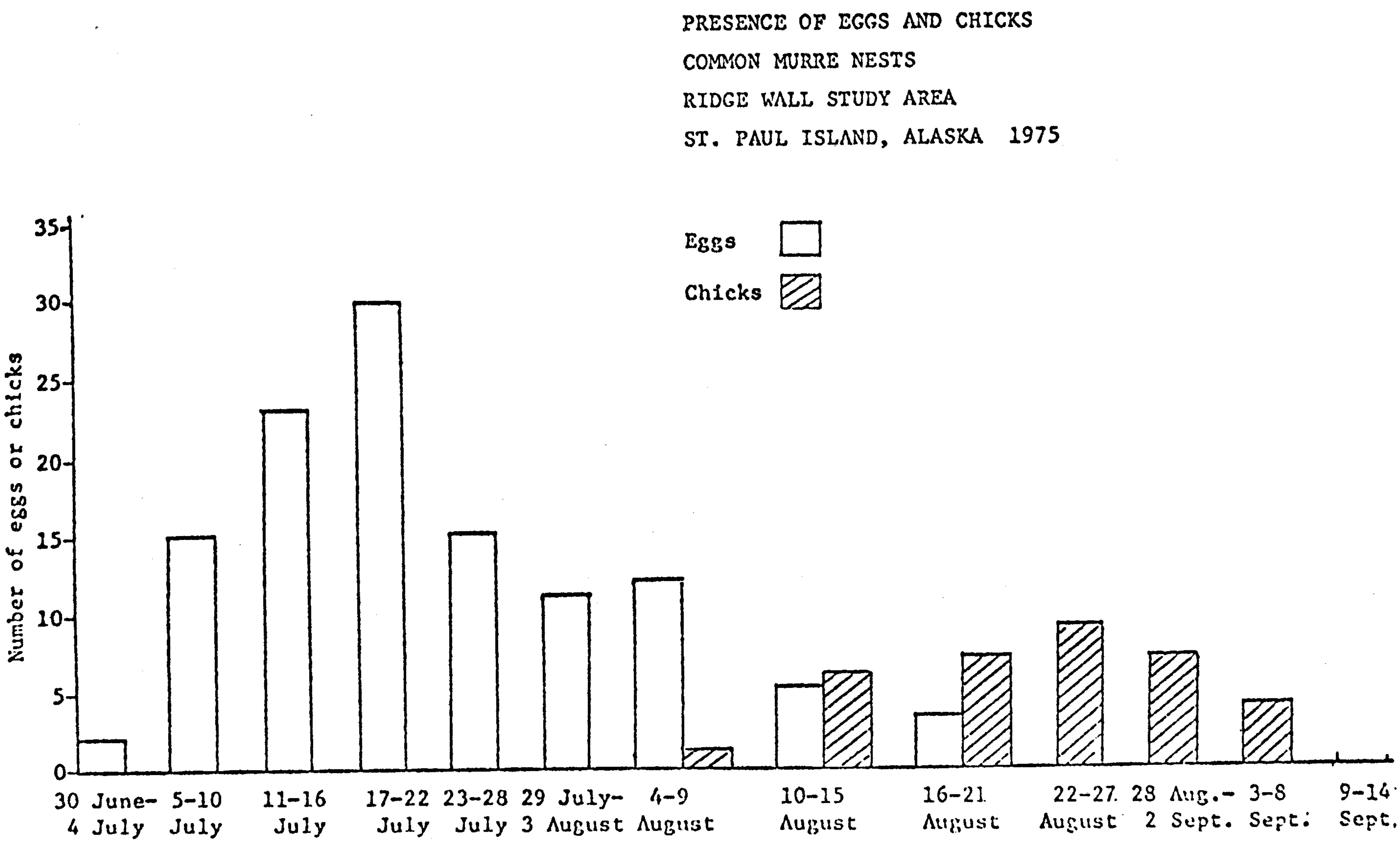


Fig. 2E. Timing of breeding of Common Murres, 1975

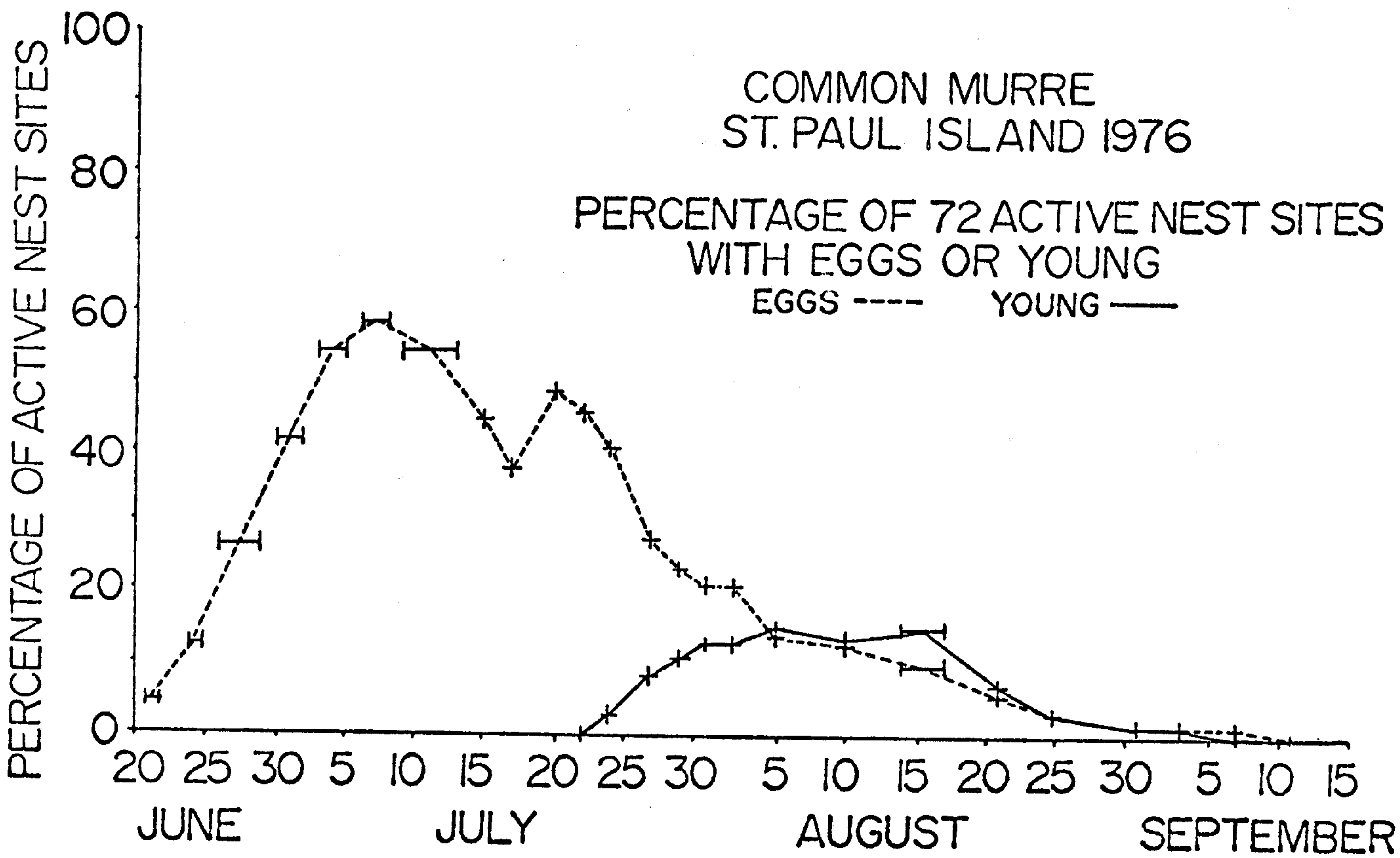


Fig. 22 Timing of breeding of Common Murres, 1976

TABLE 18.

REPRODUCTIVE SUCCESS

COMMON MURRE - PRIBILOF ISLANDS 1975-1977

	ST. PAUL ISLAND				ST. GEORGE ISLAND	
	1975 Disturbed	1976 Disturbed	1976 Undisturbed	1977 Disturbed	1976 Disturbed	1977 Disturbed
# eggs laid	18	54	16	30	11	15
# chicks hatched	2	1	12	14	9	9
# chicks fledged	0	0	9	12	7	3
hatched/laid	0.11	0.02	0.75	0.47	0.82	0.60
fledged/hatched	0	0	0.75	0.86	0.78	0.33
fledged/laid	0	0	0.56	0.40	0.64	0.20

poor drainage at the Staraya ledge on St. George contributed to its poor fledging success in 1977; at this site most mortality occurred during hatching or within a few days afterwards. In 1977, at the disturbed site at Zapadni Point on St. Paul most mortality occurred at the egg stage; much of it must have resulted from observer disturbance. The similarity of growth rates and fledging weights observed in 1976 and 1977 indicates that reproductive success was probably similar in both years.

At the St. George Staraya site in 1977, five weighed eggs averaged 117 $\pm$ 6g; here Commun Murre chicks hatched below 70g. Growth rates and fledging weights of chicks observed at accessible ledges in 1976 and 1977 are in Table 19. Sample sizes are small, but in both years surviving chicks grew slower and fledged 30g lighter at the St. George site than at the St. Paul site. Chicks at the St. Paul site gained around 8 to 9 grams per day and jumped from the cliff at about 200g. The data in this table also show a strong correlation between growth rate of a chick and its survival to fledging.

Their densely packed and typically remote and inaccessible ledges make the Common Murre a difficult species to monitor in the Pribilofs. Because of the time expense of gathering data, we do not consider the Common Murre optimally suited to baseline or comparative studies on these islands.

6. Thick-billed Murre (Uria lomvia)

The breeding biology of the Thick-billed Murre is similar to that of the Common Murre. However, preferred nesting habitat differs between the species: Thick-billed Murres tend to breed in linear formation on narrow ledges six inches to a foot wide, whereas Common Murres typically breed in dense aggregations on broad ledges. In 1977 Thick-billed Murres on our observed ledges incubated their eggs an average of 34 days before hatching their chicks which jumped from the cliffs after about 21 days. Thick-billed Murres are by far the most numerous of all seabirds in the Pribilof Islands, numbering approximately 1,500,000 on St. George and 110,000 on St. Paul (Hickey and Craighead 1977).

In 1977 on St. Paul we obtained visual data on Thick-billed Murre reproductive success and phenology at four ledges along Zapadni Point, one ledge on Ridge Wall, two ledges on the Southwest Cliffs, a ledge at Rush Gap North and a ledge at Tsammana North. At one of the Zapadni Point ledges and at the Southwest - 2 site, observers intentionally scared the birds to better see incubated eggs and tightly brooded young. We determined with certainty the fates of 28 eggs laid at the disturbed sites and 75 eggs laid at the undisturbed sites. In addition, from a ladder accessible ledge at the bottom of Ridge Wall, we weighed 17 chicks for growth rates.

TABLE 19.

CHICK GROWTH RATES

COMMON MURRE - PRIBILOF ISLANDS 1976-1977

	ST. PAUL ISLAND		ST. GEORGE ISLAND	
	1976	1977	1976	1977
# chicks	7	9	5	4
average g/day gained, first growing phase	6.8 ± 4.0	9.1 ± 1.3	5.5 ± 4.2	5.7 ± 2.5
# chicks not surviving	2	-	1	1
mean g/day gained, chicks not surviving	3.5 ± 3.9	-	- 0.5	2.2
# chicks surviving	5	9	4	3
mean g/day gained, first growing phase, surviving chicks	8.1 ± 3.5	9.1 ± 1.3	7.0 ± 2.9	6.9 ± 1.2
mean "fledging" mass (g), surviving chicks	207.8 ± 18.8	192.4 ± 17.2	176.8 ± 13.4	162.3 ± 21.7

On St. George in 1977 reproductive success and phenological data come from both undisturbed ledges viewed from clifftop and from disturbed, ladder accessible ledges at which we weighed chicks for growth. Thus, "disturbed" ledges from which we derived reproductive success data were subjected to different types of observer disturbance on the two islands. The types of disturbance at Thick-billed sites in 1976 was the same as that used in 1977 on the two islands. On St. George we followed with certainty the fates of 47 eggs laid by Thick-billed Murres on ledges atop First Bluff, at Murie Cove and at the easternmost of our two Red Bluffs sites. On ladder accessible ledges at the Tolstoi and Staraya sites we gained reproductive data from eggs at 53 nest sites; of these we weighed 36 chicks for growth.

By the last week of April 1977 Thick-billed Murres were regularly visiting the cliffs of St. George; their daily pattern of cliff attendance was well established by our 19 May arrival on the islands. Figures 23, 24 and 25 graphically represent the breeding phenology of this species on the Pribilofs over the three years of study. During these years laying has consistently peaked near the last week of June, hatching has been prevalent at the end of July, and most young have gone to sea by the first few days of September. Mean dates of laying and hatching in Table 20 show St. George to be several days behind St. Paul; however, undetected relaying by murres at the Staraya site which is heavily egged by Aleut villagers probably exaggerate this difference. On both islands laying dates appear to be a few days earlier in 1977 than in 1976, although in both years the mean hatching dates are about the same.

The observed reproductive success of Thick-billed Murres on the Pribilofs during this study is given in Table 21. Fledging success of hatched chicks is consistently high in all years on both islands. Chick mortality in undisturbed sites is well below 0.2 and was observed to be only 0.03 on St. Paul in 1977. Even at disturbed ledges, chick mortality rose above 0.3 only in 1976 on St. Paul. Eggs are much more vulnerable to human disturbance than are chicks. Even the 0.2 to 0.4 range of egg mortality observed at our "undisturbed" sites may be abnormally high since the most careful movements of observers along the clifftops inevitably disturb incubating murres to some extent. This variation and exaggeration of egg mortality accounts for much of the variation observed in fledging success per egg between islands and years; hence, the fledging success of hatched young is a much more reliable parameter for comparison. Since murres do not build nests to safely hold eggs and chicks, their reproductive success is particularly vulnerable to any form of human disturbance; they are especially vulnerable to disturbance during the egg stage.

Growth rates and fledging weights of Thick-billed Murre chicks for all years appear in Table 22. In both 1976 and 1977 surviving chicks at the St. Paul study site gained an average of near 12 g/day and fledged at near 200g or more. In the same years, surviving chicks at the St. George study areas gained only an average of 6 to 8 g/day and fledged 30 to 70g lighter than their average St. Paul counterpart. Some, but not all, of this

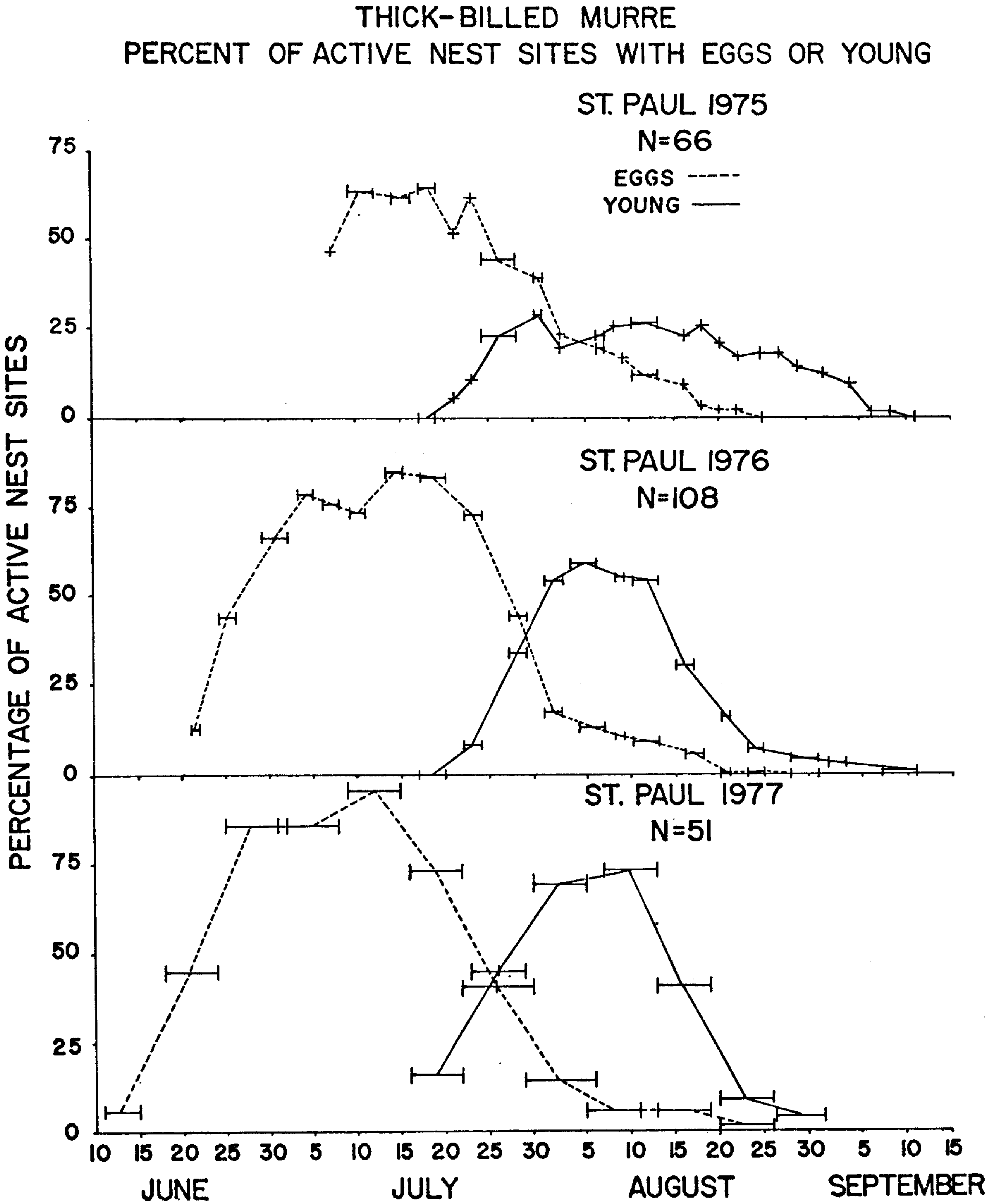


FIGURE 23. Thick-billed Murre nest-sites with eggs or young, St. Paul Is.

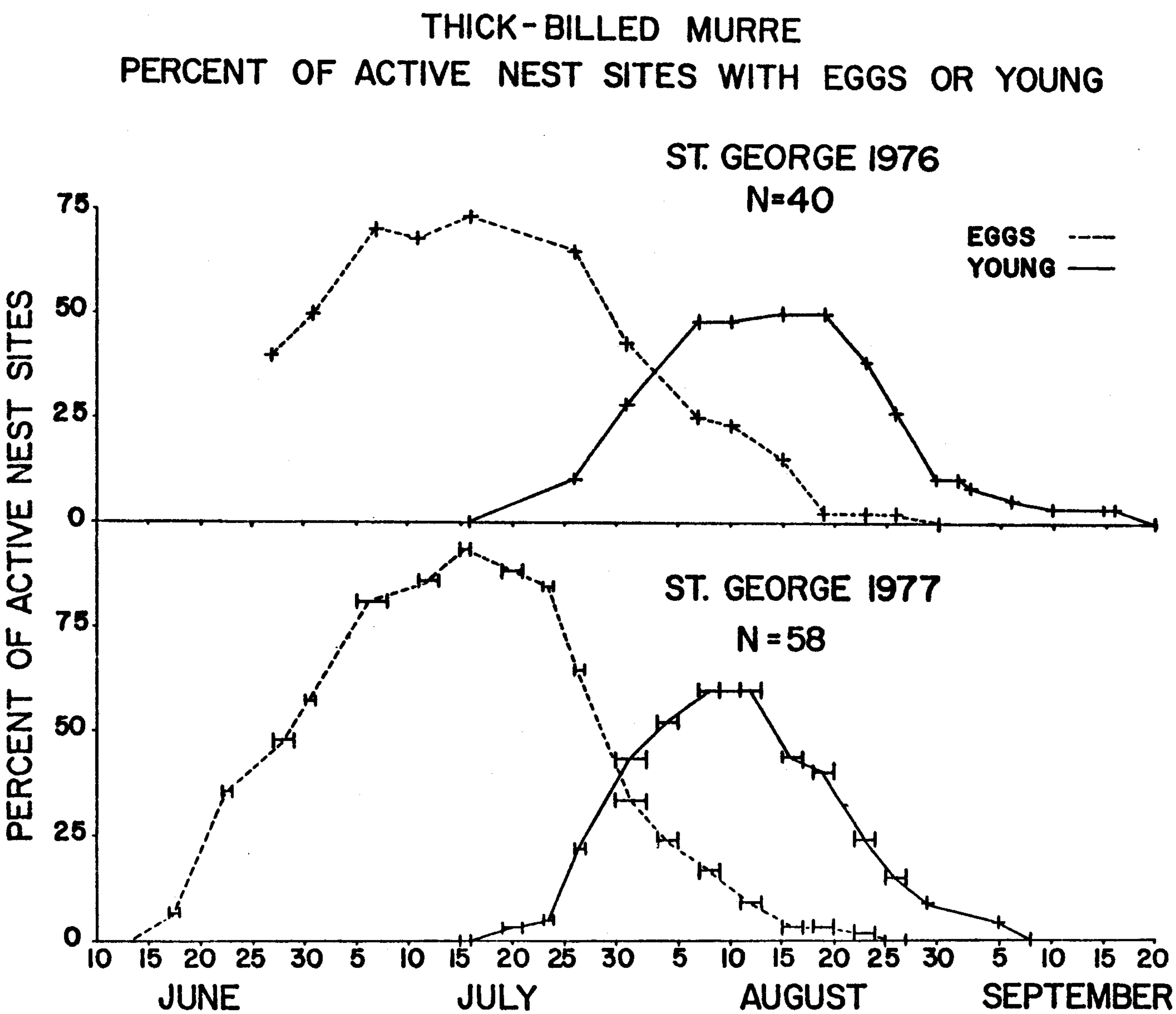
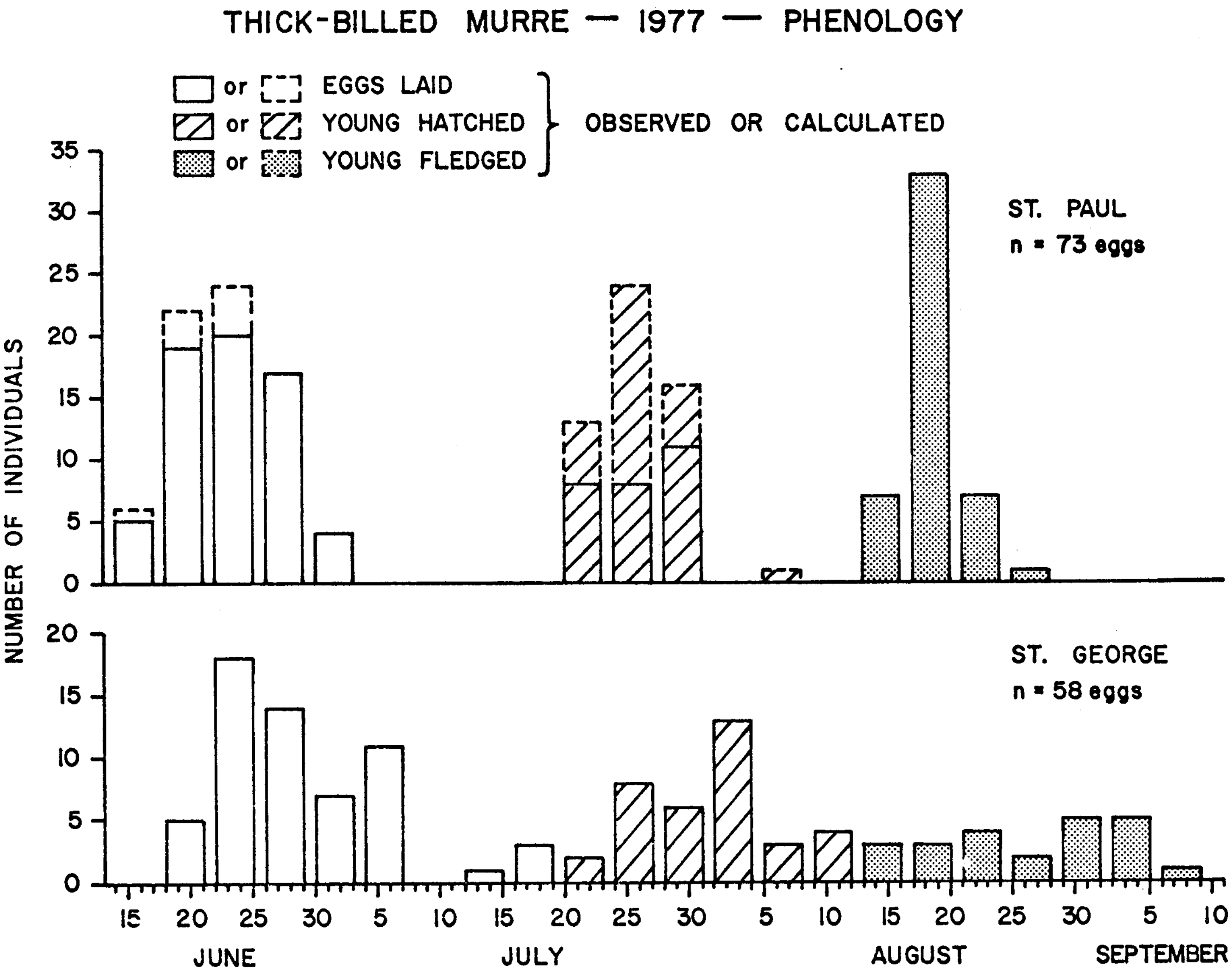


FIGURE 24. Thick-billed Murre nest-sites with eggs or young, St. George Is.



THICK-BILLED MURRE — 1977 — PHENOLOGY
or EGGS LAID
or YOUNG HATCHED
or YOUNG FLEDGED
OBSERVED OR CALCULATED
ST. PAUL
n = 73 eggs
ST. GEORGE
n = 58 eggs
NUMBER OF INDIVIDUALS
35
30
25
20
15
10
5
0
15 20 25 30 5 10 15 20 25 30 5 10 15 20 25 30 5 10
JUNE
JULY
AUGUST
SEPTEMBER

FIGURE 25

TABLE 20.

MEAN DATES OF LAYING AND HATCHING

THICK-BILLED MURRES -- PRIBILOF ISLANDS -- 1975-1977

		St. Paul Island - $\bar{X} \pm$ S.D. (n)	St. George Island - $\bar{X} \pm$ S.D. (n)
1975	Hatching	29 July ± 6.6 (23)	--
1976	Laying	30 June ± 7.8 (123)	2 July ± 9.8 (40)
	Hatching	31 July ± 6.4 (83)	3 August ± 9.1 (26)
1977	Laying	24 June ± 4.7 (109)	29 June ± 8.2 (53)
	Hatching	30 July ± 5.7 (34)	5 August ± 8.3 (43)

TABLE 21

REPRODUCTIVE SUCCESS

THICK-BILLED MURRE -- PRIBILOF ISLANDS 1975-1977

	St. Paul Island					St. George Island		
	1975 Disturbed	1976 Disturbed	1976 Undisturbed	1977 Disturbed	1977 Undisturbed	1976 Disturbed	1977 Disturbed	1977 Undisturbed
# eggs laid	66	51	47	28	75	42	53	47
# chicks hatched	34	22	40	19	59	27	33	30-34
# chicks fledged	25	14	34	16	57	22	29	28
hatched/laid	0.51	0.43	0.85	0.68	0.79	0.64	0.62	0.64-0.72
fledged/hatched	0.73	0.64	0.85	0.84	0.97	0.81	0.88	0.82-0.93
fledged/laid	0.38	0.27	0.72	0.57	0.76	0.52	0.55	0.59

TABLE 22

CHICK GROWTH RATES

THICK BILLED-MURRE -- PRIBILOF ISLANDS 1975-1977

	St. Paul Island			St. George Island	
	1975	1976	1977	1976	1977
# chicks	7	16	17	24	36
mean g/day gained, first growth phase	12.9 ± 5.5	11.7 ± 3.1	12.2 ± 3.1	5.8 ± 3.0	7.7 ± 3.2
# chicks died	1	0	0	1	2
mean g/day gained, chicks which died	2.5	-	-	1.7	4.2
# chicks surviving	6	16	17	23	34
mean g/day gained, first growing phase, surviving chicks	14.6 ± 3.3	11.7 ± 3.1	12.2 ± 3.1	6.0 ± 3.0	7.9 ± 3.2
mean "fleding" mass (g), surviving chicks	215.0 ± 22.3	218.6 ± 28.8	194.6 ± 19.5	147.8 ± 26.9	159.9 ± 23.9

difference may be attributed to differences between study sites: in 1977 on St. George, At Staraya chicks left the cliffs at 154 ± 20g (n = 28); whereas, at Tolstoi chicks jumped 30g heavier at 185 ± 26g (n = 6); yet at both sites the mean observed growth rates were below 9 g/day. As with Common Murres, growth rates are positively correlated with fledging success of individual chicks.

Of 35 eggs weighed at the St. George Staraya sites in 1977, the observed mean was 109 ± 10g. Of seven nest sites at which a second egg was laid after the first was destroyed, the initial egg averaged 114 + 2g; the relays at these sites had a mean of 102 ± 10g. Adult murres during breeding season weigh about 1000g.

7. Horned Puffin (Fratercula corniculata)

Horned Puffins in the Pribilof Islands nest in holes in the cliff face, and lay their single eggs in nests constructed of grass and bits of seaweed. Due to the presence of foxes, these birds do not nest in dirt burrows in the ground as they do in other parts of their range. Approximately 4,400 Horned Puffins breed on St. Paul and 28,000 on St. George (Hickey and Craighead 1977).

In 1976, with a major effort we located 27 Horned Puffin nests on St. Paul. Less extensive searching resulted in the location of 11 nests in 1975 and 10 nests in 1977 along Ridge Wall and at Tsammana. An extension ladder and often a flashlight were needed to locate and periodically check these nests. Since the few accessible nesting holes are scattered over long expanses of cliff, such work is very time consuming and produces much less data per man-hour than does work with ledge nesting species. We located no accessible puffin nests in the St. George study areas.

Horned Puffins were loitering on the cliffs by 20 May 1977. Assuming an average incubation period of 42 days (Sealy 1973) the Horned Puffins of our 1977 St. Paul sample laid eggs between 22 June and 10 July. These chicks hatched during the first three weeks of August. Puffin chicks fledge at about 40 days of age (Sealy 1973); those chicks for which we could determine this information fledged during the first three weeks of September. On St. George we first noticed Horned Puffin fledglings flying and loitering about the cliffs on 13 September. Horned Puffins were common on the cliffs and many chicks were still not fledged when we left the islands 21 September. Timing of breeding in 1975 and 1976 was similar to 1977.

The reproductive biology of Horned Puffins observed on St. Paul in 1975, 1976 and 1977 appears in summary in Table 23. For this report we have assumed that chicks which were still in the nest at our last observation fledged. The large variation in fledging success may be partly a product of our small sample and of the extreme disturbance to which these breeders were subjected. From the data available a fledging success per hatched chick of 0.8 may be representative; however, our data do not clearly define a normal pattern. Growth rates observed over the three years are much more consistent; surviving chicks gained an average 11 to 12 g/day. Within our samples Horned Puffins hatched at about 50 grams and reached peak weight at about 30 to 35 days of age.

TABLE 23.

REPRODUCTIVE BIOLOGY

HORNED PUFFIN -- ST. PAUL ISLAND

	1975	1976	1977
# nests	11	27	10
# eggs laid	11	25	10
Proportion of nests where hatching was known to have occurred	1.00	0.56	0.90
chicks "fledged"/ chicks hatched	0.45 - 1.00	.79	0.78 - 0.89
chicks "fledged"/ egg laid	0.45 - 1.00	.44	0.70 - 0.80
mean growth of surviving chicks (g/day)	11.1 ± 1.3	12.0 ± 2.1	11.5 ± 2.3
# chicks for which growth rates obtained	8	8	6

8. Tufted Puffins (*Lunda cirrhata*)

Tufted Puffins are uncommon on the cliffs of the Pribilof Islands. Hickey and Craighead (1977) estimate approximately 1,000 individual birds on St. Paul and 6,000 on St. George. Like the Horned Puffin, the Tufted Puffin nests in holes in the cliff face. In 1977 we first noticed Tufted Puffins on the St. Paul cliffs on 21 May and on St. George on 27 May. Adults were still present when we departed the Pribilofs on 21 September. We have located no nesting holes of this species accessible by ladder on either island during the last three seasons.

9. Crested Auklet (*Aethia cristatella*)

After Tufted Puffins, Crested Auklets are the least common breeding alcid on the Pribilofs. Hickey and Craighead (1977) estimate 6,000 individuals on St. Paul and about 12,000 on St. George. On St. Lawrence Island, where this species breeds in huge numbers, nests are located between the large boulders of talus slopes (Bedard 1969b). This type of habitat does not exist on St. Paul; here, Crested Auklets must nest either in holes in the cliff or among the rocks of boulder beaches along with its smaller cogener, the Least Auklet. On St. George many Crested Auklets breed among the boulders of large talus slopes which lie at the foot of the cliffs between High Bluffs and Dalnoi Point; on this island holes in the cliff wall also constitute a major part of their nesting habitat. We have located no accessible nests of this species.

Timing of breeding of this species is approximately the same as in the Least and Parakeet Auklets. Crested Auklets are present by 1 May and few individuals are seen on the islands after the middle of August.

10. Least Auklet (*Aethia pusilla*)

Least Auklets, the smallest of the alcids, are by far the most abundant of the hole-nesting seabirds on the Pribilofs. On St. Paul many of them nest in dense colonies among the boulders below the surface of three rocky barrier beaches (East Landing, Salt Lagoon and Antone Lake); others nest in the rocky rubble at the foot of the cliffs or in small holes in the cliff face. On St. George over a quarter of a million Least Auklets breed; over half of these are concentrated in an inland breeding colony on the north facing talus slope of Ulakaia Ridge. Like all alcids breeding in the Pribilofs the Least Auklets lay a single egg.

In the case of beach-nesting birds examination of nest contents effectively means destroying the nests: therefore we did not attempt to get information on reproductive success by this method. We were able to locate only two accessible nests in the cliff face in 1975 and 1976.

Least Auklets arrive on the islands in middle April. We have considerable evidence for nesting phenology on St. Paul from the mist-netting of adult Least Auklet on the East Landing and Salt Lagoon beaches in 1976 and 1977. When adults are incubating eggs their two brood patches are clear of feathers and are well vascularized. When the chick hatches after about a month of incubation, the parents begin carrying food in their gular pouch for their young; these adults regurgitate food upon hitting the mist net. Figure 26 presents the proportion of adults captured with bare brood patches or regurgitating food in both 1976 and 1977. All Least Auklets captured are included within these graphs; within our sample there was a greater probability of capturing adults with bare brood patches or regurgitating food in the evening than in the morning in both years. Breeding phenology is similar in both years. Our earlier samples in 1977 indicate egg laying began in early June. Hatching in both years probably began in the second week of July. Chicks fledge at about a month of age. Most chicks have fledged by the middle of August and Least Auklets are uncommon on the water close to the island by the last week of that month. A few late breeders may remain into early September.

11. Parakeet Auklet (*Cyclorrhynchus psittacula*)

Parakeet Auklets are ubiquitous but scattered on the cliffs of both St. Paul and St. George Islands, laying their eggs on the bare floor of small holes in the cliff face. Hickey and Craighead (1977) estimate over 60,000 Parakeet Auklets on St. George and over 15,000 on St. Paul. In 1975 and 1977 we located no accessible nests on St. Paul. In 1976 we located seven nests on St. Paul by using a ladder. No nests were found in the St. George study areas.

Of the seven nests from 1976, we have usable information on six. Four of the six eggs hatched in the last week of July, and two others never hatched. Egg-laying would have occurred during the third week of June, since incubation in this species is 35-36 days (Sealy and Bedard 1973). All four chicks fledged after a month in the nest, having grown to adult size and replaced their natal down with contour and flight feathers.

In two of the nests the chicks were accessible for handling and we obtained growth rates from them of 11.0 and 10.6 g/day during the straight-line portion of the growth curve. Hatching weight is about 31 grams. One of the two chicks attained a peak weight of 305 grams, then fledged a week later at a weight of 295 grams.

In 1977 Parakeet Auklets were present when we arrived on the islands on 20 May. Most birds of this species had departed the islands by the last week of August.

The effort we put into obtaining breeding data on Parakeet Auklets on St. Paul Island in 1976 yielded too small a sample to be able to draw any definitive conclusions. It is clear to us that it is more profitable to concentrate our efforts on species which are more accessible, and for which comparable data may be collected with relative ease on other islands and in other years. For these reasons we put very little effort into this species in 1977.

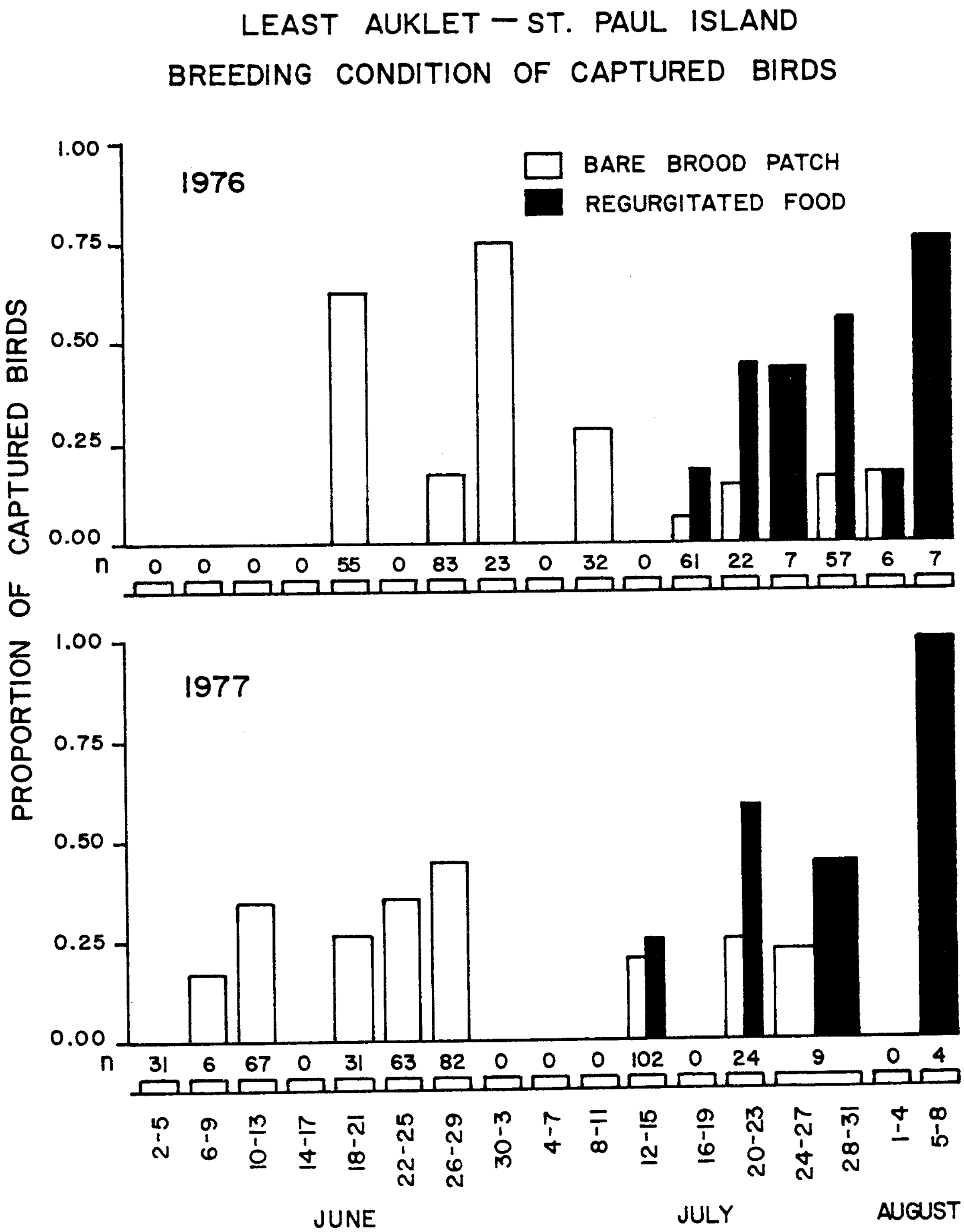

LEAST AUKLET — ST. PAUL ISLAND
BREEDING CONDITION OF CAPTURED BIRDS
1976
1977
BARE BROOD PATCH
REGURGITATED FOOD
PROPORTION OF CAPTURED BIRDS
1.00
0.75
0.50
0.25
0.00
n
0 0 0 0 55 0 83 23 0 32 0 61 22 7 57 6 7
31 6 67 0 31 63 82 0 0 0 102 0 24 9 0 4
2-5
6-9
10-13
14-17
18-21
22-25
26-29
30-3
4-7
8-11
12-15
16-19
20-23
24-27
28-31
1-4
5-8
JUNE
JULY
AUGUST

FIGURE 26

12. Other seabirds

a) Glaucous-winged Gull (Larus glaucescens)

Many immature and several adult Glaucous-winged Gulls are present on the Pribilofs throughout the summer scavenging from the seal and bird rookeries. In both 1976 and 1977 we observed a few nests of this species among nesting Red-faced Cormorants on two large offshore rocks about 500m east of Garden Cove, St. George. On 10 August 1977 at least four Glaucous-winged Gull chicks near fledging size were present on these rocks.

b) Red Phalarope (Phalaropus fulicarius)

Phalaropes migrate through the Pribilofs in large numbers and may use inshore waters as important foraging ground. On each 31 May, 1 and 2 June, 1977 we observed well over 2000 Red Phalaropes feeding in large rafts close to the northeast shores of St. George.

C. Nest Attendance

During the 1977 breeding season we carried out six watches of nest attendance by color-marked kittiwakes. Of these watches three were at the Tsammana South site on St. Paul; and three at the Tolstoi site on St. George. At both sites the kittiwakes were incubating eggs during the first watch, brooding small chicks during the second and brooding large chicks during the third. Watch duration varied from 31 to 46 hours. During each watch we observed attendance and chick feeding at about five to ten nests. In addition, at St. George Tolstoi site we color marked Thick-billed Murre adults at four nest sites and observed these birds during the latter two watches.

During the second watch on each island a few kittiwake pairs still had eggs or already had large chicks. For the results shown in the following tables we included the attendance patterns of these pairs with those of the first and third watches as appropriate.

The following assumptions apply to the data as presented. Adults are considered present on the nest the entire night if they were on the nest at the last observation before and the first observation after darkness. Changes between adults or changes between an occupied an an unoccupied status which took place during darkness are treated as if they occurred one-half way through the night. This latter assumption is probably false.

In the mean durations of adult attendance presented in Tables 24 and 25, we include open ended attendance bouts, i.e., those in which adult attendance on the nest extends to before or after we began observations. To exclude such bouts would greatly bias the data towards the very short visits, especially during incubation. Watches of 72 to 100 hours would yield data much more representative of the birds' attendance patterns, yet we did not have sufficient personnel for such efforts.

Tables 24 and 25 present the major points of nest attendance patterns observed in all watches for Red-legged and Black-legged Kittiwakes. The mean adult durations presented for the incubation stage are too short for both species because of the relatively brief length of our watches. During these watches kittiwakes of both species often remained on the nest for twenty hours or more; we have one observation for each species of an adult remaining continuously on the nest for over 41 hours. During the incubation stage watch on St. George observers who remained on the beach overnight noted no movement of birds to or from the cliff area being observed. During both the incubation and small-chick stage watches, adults continuously occupied their nests; although attendance bouts became somewhat shorter as chicks were fed after hatching. Yet, during the large-chick stage watch visits by adults became much shorter and nests remained unoccupied by adults for long periods: of Black-legged nests observed, 0.58 were unoccupied overnight on St. George and 0.71 on St. Paul; of

TABLE 24.

Black-legged Kittiwake -- Pribilofs 1977

Nest Attendance Watches

Period of Watch	Location	No. Nests Watched	Nest Contents	Duration of Adult Attendance (Hr.) $\bar{X} \pm$ S.D. (n)	Proportion Time Nest Unoccupied	Average No. Feedings Observed per Daylight Hour
2030 1 - 0900 3 Jul	St. G, Tolstoi	6	eggs	6.9 ± 6.1 (32)	0.0	--
1730 14 - 1500 16 Jul	St. P, Tsam S	8	eggs	14.1 ± 8.1 (23)	0.0	--
1600 28 - 1130 30 Jul	St. G, Tolstoi	8	chick <150g	8.7 ± 7.4 (43)	0.0	0.2
2000 1 - 1530 3 Aug	St. P, Tsam S	7	chick <200g	5.8 ± 4.0 (51)	0.02	0.3
1600 18 - 1200 20 Aug	St. G, Tolstoi	6	chick >340g	2.1 ± 3.8 (69)	0.48	0.2
1330 20 - 2100 21 Aug	St. P, Tsam S	7	chick >300g	2.2 ± 3.3 (37)	0.63	0.2

TABLE 25.

Red-legged Kittiwake -- Pribilofs 1977

Nest Attendance Watches

Period of Watch	Location	No. Nests Watched	Nest Contents	Duration of Adult Attendance (Hr.) $\bar{X} \pm S.D.$ (n)	Proportion Time Nest Unoccupied	Average No. Feedings Observed per Daylight Hour
2030 1 - 0900 3 Jul	St. G, Tolstoi	13	egg	8.6 ± 8.3 (54)	0.0	--
1730 14 - 1500 16 Jul	St. P, Tsam S	9	egg	17.0 ± 10.2 (24)	0.0	--
1600 28 - 1130 30 Jul	St. G, Tolstoi	7	chick $<$ 140g	10.9 ± 8.6 (29)	0.0	0.4
2000 1 - 1530 3 Aug	St. P, Tsam S	5	chick $<$ 200g	8.4 ± 5.0 (25)	0.0	0.1
1600 18 - 1200 20 Aug	St. G, Tolstoi	9	chick $>$ 230g	5.2 ± 6.0 (56)	0.30	0.2
1830 20 - 2100 21 Aug	St. P, Tsam S	6	chick $>$ 250g	3.1 ± 5.0 (38)	0.40	0.2

Red-legged nests observed, 0.42 were unoccupied overnight on St. George and 0.50 on St. Paul. Table 26 illustrates the change in distribution of adult attendance times towards those of shorter duration as the chicks became large. Coulson and White (1958) mention a breakdown of coordination of adult attendance at nests with very large young.

Tables 24 and 25 also present the mean observed frequencies of chick feeding for both kittiwake species. These figures represent a minimum since they are derived from a single observer's attempts to simulteneously watch several scattered nests. Even so, it is apparent that kittiwakes were feeding their young at least once every three to seven hours during daylight. We did not attempt to estimate the volume of food passed at each feeding; though, it is certainly greater for a very large chick than for a small one. On several occasions after the chick had not been fed for several hours, observers noticed the adult vigorously attempting to regurgitate food for the chick in a futile response to its begging. These unsuccessful feeding attempts were especially common in the early morning with adults which had occupied the nest for many hours.

Figure 27 illustrates the data we have for nest-site attendance by Thick-billed Murres. An adult remained overnight with the chick in all cases. The data suggest a pattern of one parent remaining with the chick for several hours during which the other may make short visits to the nest site to feed the chick. These data combined with a few observations of our color-marked adults diving in near shore waters before returning to the nest site suggest that some Thick-billed Murres may be foraging near shore for food for their chick, as well as foraging farther out in major feeding areas.

TABLE 26.

Kittiwake Nest Attendance Pattern -- Pribilofs 1977

Proportion of Continuous Attendance Bouts of Given Duration

Duration of Continuous Attendance (Hours)	≤0.1	≤0.3	≤0.5	≤1	≤3	≤5	≤10	≤15	≤20	≤25	≤30	>30
BLACK-LEGGED KITTIWAKE												
eggs: 14 nests, 55 bouts			.04	.05	.22	.04	.18	.16	.16	.13		.02
small chick (<150g): 15 nests, 94 bouts		.02	.02	.06	.17	.28	.19	.14	.05	.05	.01	
large chick (>300g): 13 nests, 106 bouts	.19	.20	.19	.08	.13	.07	.07	.04	.01	.01		
RED-LEGGED KITTIWAKE												
egg: 22 nests, 78 bouts			.13	.09	.13	.08	.04	.17	.18	.13	.05	.01
small chick (<150g): 12 nests 54 bouts			.07	.02	.13	.15	.17	.20	.18	.06	.02	
large chick (>230g): 15 nests, 94 bouts	.06	.12	.11	.11	.24	.10	.14	.05	.05	.02		

THICK-BILLED MURRE — ST. GEORGE, TOLSTOI 1977

PERIODS OF ADULT ATTENDANCE AT NEST-SITE

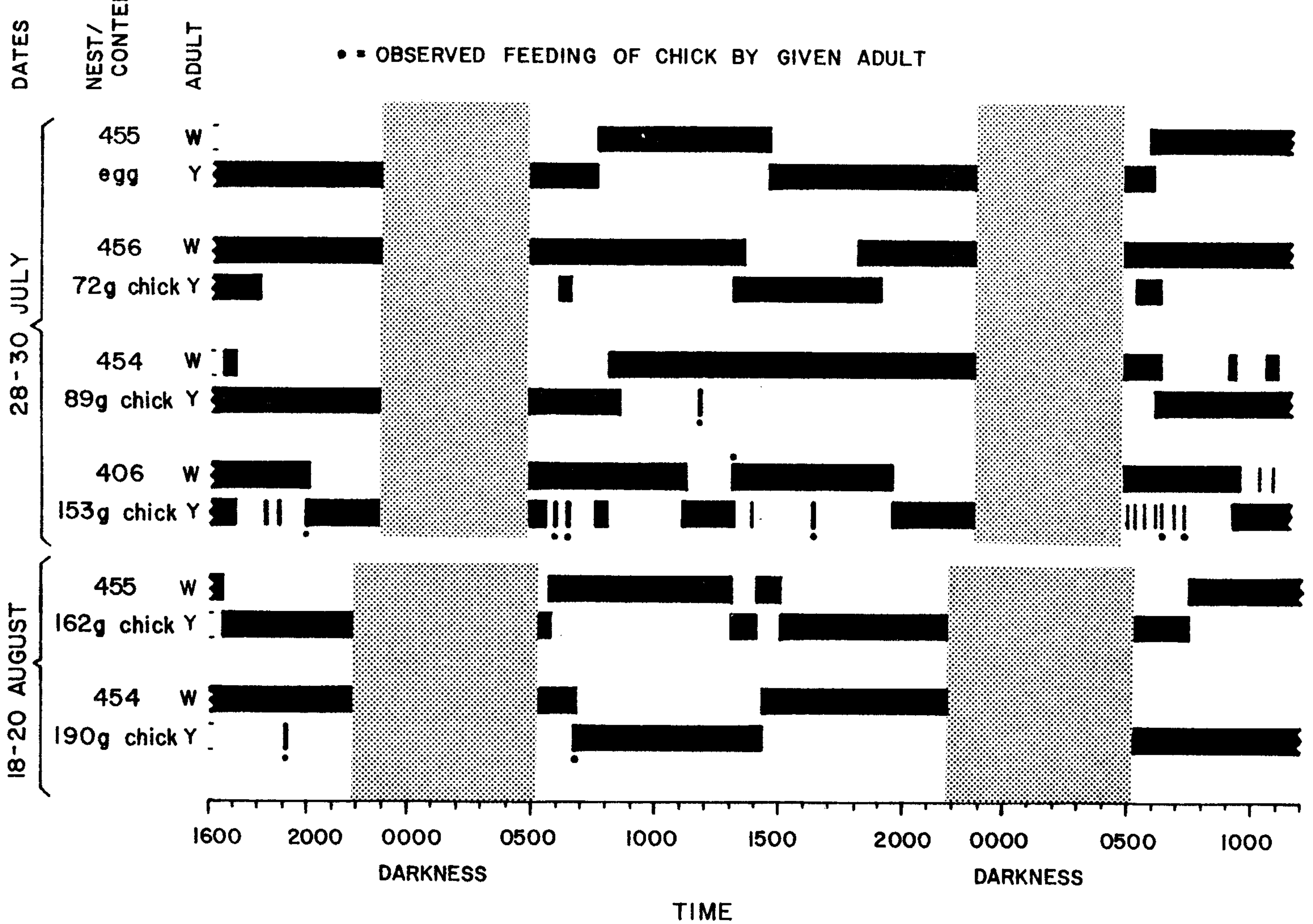


FIGURE 27. (Y = marked (yellow) adult; W = unmarked adult)

D. Foods used by Seabirds

Food habits data are presented in two ways, by percent occurrence and by percent volume. Percent occurrence is the percentage of samples in which a given food type was found. Since more than one type of food may be present in a sample, the total percent occurrences for a given bird species may seem to be more than 100%. Percent by volume is calculated on the basis of the total displaced volume of a given food type summed over all samples divided by the total displaced volume of all foods summed over all samples.

Each method has its advantages and disadvantages. Percent occurrence may over-estimate food types with longlasting hard parts and under-estimate soft foods that have no hard parts. On the plus side, quickly digested foods that nevertheless leave some hard parts are accorded a greater representation than if volume alone were used. Percent volumes tends to under-estimate the importance of foods, particularly large, quickly digested types, when all that is left is some small skeletal element. However, percent volume does provide a fairly good index of which foods are brought back to the colony in the largest amounts. This information may be particularly important in determining which foods are of critical importance for feeding of growing chicks.

Table 27 presents a summary of foods used by the seabirds of the Pribilof Islands. Reasonably large samples, adequate for comparing year to year and between island variation are available for all species except Fulmar, Horned and Tufted Puffin, and Crested Auklet. Sample sizes for Common Murre and Parakeet Auklet are also marginal. In 1977, fish continued to be the most important food resource, followed by amphipods (primarily hyperiids), polychaets and euphausiids. The appearance of nereidae as an important food is not a difference from past years, but rather is a result of improved identification of food items. Samples from 1975 are being re-checked for the mouth-parts of these worms, now that we know their origin. When the biomass of the seabirds is taken into account, then it is clear that the kittiwakes and murres will have the greatest impact on the marine environment near the islands. Their food is more than 75% fish. Tables 28-37 provide a more detailed analysis of foods used by the different bird species.

From Table 28 it is apparent that Red-faced Cormorants are taking primarily fish, most of which appear to be epibenthic forms. In addition, considerable quantities of shrimps and crabs are also used. In general, foods used in 1977 were similar in type and percent composition to those taken in 1976 and 1975. However, in 1977 fewer isopods and amphipods were taken and the amount of shrimp taken at St. Paul appeared to increase. However, given the small sample size, we are reluctant to ascribe much importance to this shift. When samples from the two islands in 1977 are compared, it can be seen that many fewer decapods appeared in the St. George samples. Individual samples from St. George also showed more diversity of prey taken than those from St. Paul, with the presence of larval fish being noted for the first time in cormorant food samples. Work is continuing on the identification of the different species of bottom-dwelling fish taken by cormorants.

TABLE 27

SUMMARY OF FOODS USED BY PRIBILOF ISLAND SEABIRDS

% SAMPLES CONTAINING FOOD TYPE

Species	# Samples with food			Mollusca			Cephalopoda			Polychaeta			Isopoda			Copepoda		
	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	1977
Fulmar	1	0	-	-	-	-	100	-	trace	-	-	-	-	-	-	-	-	-
Red-faced Cormorant	38	65	36	7.9	7.7	4.2	-	-	-	-	3.1	4.2	-	3.1	-	-	-	-
Black-legged Kittiwake	120	86	194	0.8	-	1.6	0.8	4.7	16.0	-	-	7.7	-	-	-	-	-	0.5
Red-legged Kittiwake	12	97	68	16.7	-	-	-	6.2	17.2	-	5.2	1.8	-	-	-	-	-	-
Common Murre	24	36	19	-	-	-	-	-	10.5	-	-	-	-	-	-	-	-	-
Thick-billed Murre	20	31	68	-	-	-	-	3.2	17.7	-	-	2.9	-	-	-	-	-	-
Horned Puffin	2	11	13	-	-	-	-	-	7.7	-	18.2	15.4	-	-	-	-	-	-
Tufted Puffin	3	12	3	33.3	-	-	-	-	-	-	50.0	66.7	-	-	-	-	-	-
Parakeet Auklet	11	14	14	-	-	-	-	-	-	-	7.1	78.6	-	-	-	-	-	-
Crested Auklet	6	9	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Least Auklet	56	37	81	12.5	56.8	2.5	-	-	-	1.2	-	1.2	-	2.7	-	41.1	100	79.1

TABLE 27 (cont.)

SUMMARY OF FOODS USED BY PRIBILOF ISLAND SEABIRDS

% SAMPLES CONTAINING FOOD TYPE

Species	Cumacea			Amphipoda			Euphausiacea			Decapoda			Crustacean mush			Fish		
	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	1977
Fulmar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-faced Cormorant	-	-	-	36.8	33.8	8.3	2.6	-	-	65.8	50.8	33.3	-	-	-	92.1	95.4	97.2
Black-legged Kittiwake	-	-	0.5	15.0	23.3	11.9	5.0	16.3	5.7	5.0	2.3	2.1	-	-	-	94.1	77.9	88.7
Red-legged Kittiwake	0.8	-	1.2	16.7	22.7	6.8	-	3.1	0.6	-	6.3	4.3	-	-	-	83.3	95.9	94.5
Common Murre	-	-	-	-	8.3	5.3	-	-	5.3	8.3	-	-	8.3	-	-	91.7	100.0	94.7
Thick-billed Murre	-	-	-	5.0	9.7	23.5	-	6.5	7.4	10.0	3.2	1.5	-	-	7.4	90.0	80.6	77.9
Horned Puffin	-	-	-	-	36.4	-	-	-	-	-	-	-	-	-	7.7	100.0	100.0	92.3
Tufted Puffin	-	-	-	-	33.3	33.3	-	-	-	33.3	-	-	-	-	33.3	33.3	100.0	66.7
Parakeet Auklet	-	-	7.1	18.1	42.9	57.1	9.0	50.0	57.1	-	-	-	45.5	-	14.3	45.5	57.1	71.4
Crested Auklet	-	-	16.7	66.7	22.2	66.7	33.3	88.9	33.3	-	-	-	-	-	-	33.3	-	50.0
Least Auklet	1.8	29.7	4.9	51.8	72.8	67.9	16.1	24.3	24.7	1.8	-	30.9	25.0	-	11.1	16.1	10.8	18.5

TABLE 28

FOODS USED BY RED-FACED CORMORANTS -- PRIBILOF ISLANDS 1975-1977

	% OCCURRENCE				% VOLUME			
	St. Paul			St. George	St. Paul			St. George
	1975	1976	1977	1977	1975	1976	1977	1977
Sample size	38	65	12	24	1803 ml	1783 ml	488 ml	998 ml
Food Types								
Mollusca (not squid)	7.9	7.7	0.0	4.2	trace	trace	0.0	trace
Marine worm	2.6	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Polychaeta (Nereidae)	0.0	3.1	0.0	4.2	0.0	trace	0.0	trace
Isopoda	0.0	3.1	0.0	0.0	0.0	0.1	0.0	0.0
Amphipoda	36.8	33.8	8.3	8.3	4.2	2.2	trace	trace
Gammaridea	34.2	27.7	8.3	0.0	3.9	0.4	trace	0.0
Hyperiidea	2.6	3.1	0.0	8.3	0.2	0.1	0.0	trace
Parathemisto libellula	2.6	1.5	0.0	0.0	0.2	0.1	0.0	0.0
Euphausiacea	2.6	0.0	0.0	0.0	trace	0.0	0.0	0.0
Decapoda	65.8	53.8	66.7	16.7	12.8	13.5	36.9	0.5
Shrimp	52.6	34.6	66.7	8.3	8.5	7.1	26.8	0.1
Lebbeus polaris	0.0	27.7	41.7	0.0	0.0	6.4	24.6	0.0
Lebbeus groenlandica	0.0	9.2	25.0	0.0	0.0	0.3	1.4	0.0
Argis crassa	0.0	7.7	0.0	0.0	0.0	0.4	0.0	0.0
Crab	52.6	33.8	41.7	8.3	3.7	3.7	8.2	0.4
Dematuras mandtii	0.0	18.5	25.0	4.2	0.0	1.3	0.4	trace
Haplogaster spp.	0.0	6.2	16.7	8.3	0.0	1.4	7.8	0.4
All Fish	92.1	95.4	91.7	100.0	66.5	83.2	65.0	99.5
Larval Fish	0.0	0.0	0.0	16.7	0.0	0.0	0.0	4.5
Gadidae	0.0	6.2	0.0	0.0	0.0	6.3	0.0	0.0
Ronquil jordanii	0.0	3.1	0.0	0.0	0.0	0.4	0.0	0.0
Ammodytes hexapterus	0.0	1.5	0.0	0.0	0.0	2.1	0.0	0.0
Cottidae	0.0	0.0	0.0	4.2	0.0	0.0	0.0	5.0
Triglops pingeli	0.0	0.0	8.3	0.0	0.0	0.0	2.7	0.0
Myoxocephalus spp.	0.0	1.5	0.0	0.0	0.0	0.9	0.0	0.0
Fish remains, unknown	92.1	86.2	83.3	87.5	66.5	96.5	62.3	90.0

Foods taken by Black-legged Kittiwakes from 1975-1977 on St. Paul and St. George Islands are presented in Table 29. Fish clearly remain the most important food type, with Gadids (mostly, if not all, pollack) and Myctophids being predominant. Also of importance were squid, polychaets, amphipods and euphausiids.

When foods taken in 1977 are compared with those taken in previous years, we can see that in general the diets remained similar. However, in 1977 the use of squid on both islands increased, but the proportion of euphausiids dropped, particularly on St. Paul.

Some interesting differences exist in the diets of Black-legged Kittiwakes on the two islands. On St. George squid, and euphausiids are taken in greater abundance than on St. Paul, and myctophid fish appear to be more important on St. George, at least on a percent volume basis, although not on a percent occurrence basis. In contrast, fewer nereidae were found in St. George samples than in those from St. Paul.

Red-legged Kittiwake food habits are shown in Table 30. Fish provide the major food resource, particularly Myctophidae, followed by Gadidae. Other items of importance include squid, amphipods and to a lesser extent shrimp.

When diets are compared between years, we see little change in the types of food taken. However, the percentage composition of the diet has shifted somewhat. In 1977 more squid were taken, particularly at St. George and many fewer amphipods were taken. The frequency of occurrence of shrimp in the diets of Red-legs was also reduced in 1977.

Between island differences in Red-legged Kittiwake diets are also of interest. St. George birds in 1977 took several varieties of food not found in our St. Paul samples including shrimp, crab and sandlance. No decapods were obtained in 1977 from Red-legs on St. Paul, and in 1976 there were fewer samples with decapods on St. Paul than on St. George. In 1977 on St. George the use of squid was higher than in 1976 on either island and much higher than on St. Paul in 1977. At the same time the proportion of fish used on St. George in 1977 dropped. Since squid were also used more heavily by Black-legged Kittiwakes on St. George in 1977, it is likely that there was an increase in the abundance of squid near St. George in 1977. Interestingly, myctophids are not less abundant in the Red-legged Kittiwake samples from St. Paul when compared to those from St. George.

Tables 31-33 allow a comparison of the diets of Black-legged and Red-legged Kittiwakes for the three years of study. For this comparison, data from the two islands are combined. In all three years squid were the more important in the diet of Red-legs than in Black-legs. Likewise, Red-legs took more fish than Black-legs. Among the fish taken, there is a clear partitioning of resources, with Red-legged Kittiwakes taking primarily myctophiids and Black-legged Kittiwakes taking primarily Gadids. Among amphipods, Red-legs take more Gammarids and Black-legs take more Hyperiids.

TABLE 29

FOODS USED BY BLACK-LEGGED KITTIWAKES -- PRIBILOF ISLANDS 1975-1977

	% OCCURRENCE					% VOLUME				
	1975	1976		1977		1975	1976		1977	
	St. Paul	St. Paul	St. George	St. Paul	St. George	St. Paul	St. Paul	St. George	St. Paul	St. George
Sample size	120	56	30	108	86	1808 ml	557 ml	260 ml	1153 ml	958 ml
Food Types										
Mollusca (not squid)	0.8	1.79	0.0	2.8	0.0	trace	trace	trace	0.1	0.0
Cephalopoda	0.8	1.79	10.0	13.9	13.6	trace	trace	5.4	4.5	3.5
Polychaeta (Nereidae)	0.0	0.0	0.0	10.1	4.7	0.0	0.0	0.0	1.0	0.2
Copepoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Calanus spp.	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	trace
Cumacea	0.8	0.0	0.0	0.0	1.2	trace	0.0	0.0	0.0	trace
Amphipoda	15.0	28.6	13.3	11.1	12.8	3.1	2.3	2.0	3.5	0.6
Gammaridea	0.8	3.6	10.0	.9	0.0	trace	trace	trace	trace	0.0
Hyperiidea	14.2	21.4	10.0	10.1	9.3	1.4	trace	trace	3.5	trace
Parathemisto libellula	13.3	17.6	6.7	3.7	5.8	1.7	2.0	1.9	3.1	0.6
Hyperoche medusarum	0.0	1.8	0.0	0.0	0.0	0.0	trace	0.0	0.0	0.0
Euphausiacea	5.0	16.1	16.7	1.9	10.5	2.2	11.1	5.0	1.7	1.7
Thysanoessa inermis	0.0	1.79	6.7	0.0	0.0	0.0	3.2	2.3	0.0	0.0
Thysanoessa longipes	0.0	1.79	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0
Thysanoessa raschii	1.7	1.79	6.7	0.9	2.3	0.5	0.2	1.5	1.7	0.9
Thysanoessa spinifera	0.0	3.57	0.0	0.0	0.0	0.0	trace	0.0	0.0	0.0
Decapoda	5.0	1.8	10.0	3.7	0.0	0.1	0.5	0.0	0.2	0.0
Shrimp	0.0	0.0	10.0	0.9	0.0	0.0	0.0	trace	0.2	0.0
Crab	5.0	1.8	0.0	2.8	0.0	0.1	0.5	0.0	trace	0.0
All Fish	94.1	75.0	83.3	89.8	76.1	94.7	87.1	87.7	90.4	94.1
Larval Fish	0.0	1.8	13.3	2.8	3.5	0.0	trace	9.2	3.2	1.0
Mallotus villosus	0.8	35.7	6.7	12.0	10.5	trace	29.6	4.6	11.3	6.4
Myctophidae	0.0	5.4	20.0	20.4	24.4	0.0	3.2	34.2	15.4	30.4
Gadidae	3.3	35.7	10.0	48.2	48.8	trace	33.6	11.5	47.4	45.4
Trichodon trichodon	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.5	0.0
Stichaeidae	0.0	1.8	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0
Ammodytes hexapterus	0.0	3.57	10.0	0.9	0.0	0.0	1.3	0.0	1.7	0.0
Unknown Fish	94.1	28.6	40.0	25.9	22.1	94.7	15.1	28.1	10.8	11.0

TABLE 30

FOODS USED BY RED-LEGGED KITTIWAKES -- PRIBILOF ISLANDS 1975-1977

	% OCCURRENCE					% VOLUME				
	1975	1976		1977		1975	1976		1977	
	Both Islands	St. George	St. Paul	St. George	St. Paul	Both Islands	St. George	St. Paul	St. George	St. Paul
Sample size	12	50	47	120	43	75 ml	739 ml	364 ml	1187 ml	343 ml
Food Types										
Cephalopoda	16.7	4.0	8.5	20.8	7.0	trace	trace	1.4	2.6	0.3
Polychaeta (Nereidae)	0.0	4.0	6.4	0.8	4.7	0.0	0.1	trace	trace	trace
Cumacea	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	trace	0.0
Amphipoda	16.7	24.0	24.0	7.5	4.7	trace	0.9	6.6	0.6	trace
Gammaridea	16.7	12.0	2.1	3.3	2.3	trace	0.8	trace	0.4	trace
Hyperiidea	0.0	8.0	21.3	2.5	2.3	0.0	0.1	6.6	trace	trace
Parathemisto libellula	0.0	2.0	19.1	1.7	2.3	0.0	trace	6.6	trace	trace
Hyperoche medusarum	0.0	8.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Euphausiacea	0.0	0.0	6.4	0.8	2.3	0.0	0.0	0.6	trace	2.0
Thysanoessa spinifera	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
Thysanoessa raschii	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	2.0
Decapoda	0.0	14.0	8.5	5.0	0.0	0.0	0.8	0.3	0.4	0.0
Shrimp	0.0	10.0	2.1	4.2	0.0	0.0	0.7	0.3	0.4	0.0
Crab	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	trace	0.0
All Fish	83.3	100.0	91.5	89.3	97.7	100.0	98.2	90.4	97.7	97.7
Mallotus villosus	0.0	8.0	4.3	0.0	0.0	0.0	6.8	5.2	0.0	0.0
Myctophidae	0.0	40.0	44.7	62.5	72.1	0.0	52.5	48.4	56.3	58.3
Gadidae	8.3	8.0	25.5	30.8	51.1	trace	6.8	13.5	33.4	39.4
Ammodytes hexapterus	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.8	0.0
Unidentified fish remains	0.0	44.0	8.5	18.3	2.3	0.0	27.6	9.6	7.1	trace

TABLE 31

FOODS USED BY BLACK-LEGGED AND RED-LEGGED KITTIWAKES

PRIBILOF ISLANDS 1975

	Black-legged Kittiwake	Red-legged Kittiwake	Black-legged Kittiwake	Red-legged Kittiwake
	% OCCURRENCE		% VOLUME	
Sample size	120	12	1808 ml	75 ml
Food Types				
Mollusca (not squid)	0.8	0.0	trace	0.0
Cephalopoda	0.8	16.7	trace	trace
Cumacea	0.8	0.0	trace	0.0
Amphipoda	15.0	16.7	3.1	trace
Gammaridea	0.8	16.7	trace	trace
Hyperiidea	14.2	0.0	3.1	0.0
Parathemisto libellula	13.3	0.0	1.7	0.0
Euphausiacea	5.0	0.0	2.2	0.0
Thysanoessa raschii	1.7	0.0	0.5	0.0
Decapoda	5.0	0.0	0.1	0.0
Crab	5.0	0.0	0.1	0.0
All Fish	94.1	83.3	94.7	100.0

TABLE 32

FOODS USED BY BLACK-LEGGED AND RED-LEGGED KITTIWAKES

PRIBILOF ISLANDS 1976

	Black-legged Kittiwake	Red-legged Kittiwake	Black-legged Kittiwake	Red-legged Kittiwake
	% OCCURRENCE		% VOLUME	
Sample size	86	97	817 ml	1103 ml
Food Types				
Cephalopoda	4.7	6.2	trace	0.5
Polychaeta (Nereidae)	1.2	5.2	0.4	0.1
Amphipoda	23.3	23.0	2.0	trace
Gammaridea	3.5	7.2	trace	0.5
Hyperiidea	17.4	14.4	trace	trace
Paratnemisto libellula	12.0	10.4	2.0	2.2
Hyperoche medusarum	1.2	4.1	trace	trace
Euphausiacea	16.3	3.1	16.82	0.3
Thysanoessa inermis	3.5	0.0	7.3	0.0
Thysanoessa longipes	1.2	0.0	2.1	0.0
Thysanoessa raschii	3.5	0.0	3.9	0.0
Thysanoessa spinifera	2.3	1.0	1.0	0.2
Thysanoessa spp	1.2	0.0	0.1	0.0
Decapoda	2.3	12.4	0.4	0.6
Shrimp	1.2	7.2	trace	0.5
All Fish	78.0	96.0	87.3	96.6
Larval Fish	5.8	0.0	2.9	0.0
Mallotus villosus	27.0	6.2	23.3	6.3
Myctophidae	10.5	42.3	13.1	51.1
Gadidae	24.4	16.5	26.1	7.8
Stichaeidae	1.2	0.0	0.9	0.0
Ammodytes hexapterus	2.3	0.0	1.5	0.0

TABLE 33

FOODS USED BY BLACK-LEGGED AND RED-LEGGED KITTIWAKES

PRIBILOF ISLANDS 1977

	Black-legged Kittiwake	Red-legged Kittiwake	Black-legged Kittiwake	Red-legged Kittiwake
	% OCCURRENCE		% VOLUME	
Sample size	194	163	2111 ml	1530 ml
Food Types				
Mollusca (not squid)	1.6	0.0	0.1	0.0
Cephalopoda	16.0	17.2	4.1	2.1
Polychaeta (Nereidae)	7.7	1.8	0.6	trace
Copepoda	0.5	0.0	trace	0.0
Calanus spp.	0.5	0.0	trace	0.0
Cumacea	0.5	1.2	trace	trace
Amphipoda	11.9	6.8	2.2	0.4
Gammaridea	0.5	3.1	trace	0.3
Hyperiidea	9.8	2.5	1.9	trace
Parathemisto libellula	4.6	1.8	2.0	0.1
Hyperoche medusarum	0.0	0.0	0.0	0.0
Euphausiacea	5.7	0.6	1.7	trace
Thysanoessa inermis	0.0	0.0	0.0	0.0
Thysanoessa longipes	0.0	0.0	0.0	0.0
Thysanoessa raschii	1.6	0.0	1.4	0.0
Thysanoessa spinifera	0.0	0.0	0.0	0.0
Thysanoessa spp.	0.0	0.0	0.0	0.0
Decapoda	2.1	4.3	0.1	0.3
Shrimp	0.5	3.1	0.1	0.3
Crab	1.6	1.2	trace	trace
All Fish	88.7	94.5	92.0	97.6
Larval fish	3.1	0.0	2.2	0.0
Mallotus villosus	11.3	0.0	9.1	0.0
Myctophidae	22.2	65.0	22.2	56.7
Gadidae	48.5	36.2	46.5	34.7
Trichodon trichodon	0.1	0.0	0.3	0.0
Stichaeidae	0.0	0.0	0.0	0.0
Ammodytes hexapterus	0.1	1.2	1.0	0.7
Unknown fish	24.2	14.1	10.9	5.5

Red-legs take relatively few euphausiids when compared to Black-legs, but take more decapods. Thus, while both species use the same range of food types, the proportions of these foods in the diets of the two kittiwakes are very different. Since the two species tend to forage in different areas (see below), there is probably little inter-specific competition for food.

Information on the diets of Common and Thick-billed Murres are presented in Table 34. Due to small sample sizes, data for the two islands were combined for Common Murres in 1975-1977 and for Thick-billed Murres in 1975 and 1976. Fish are the most important items in the diets of both species, but Thick-billed Murres take considerably more invertebrates than do Common Murres. In our 1976 report (Hunt 1977) we suggested that the two species of murres might be concentrating on different species of fish. Given our 1977 data, there is still some indication that Thick-billed Murres are taking more bottom fish, and Common Murres are taking somewhat more Gadidae, the most important species of fish for both species of murres. However, the differences in kinds of fish taken do not seem great, and it will be important to examine our 1978 data to see if these trends hold. Again, as in kittiwakes, squid were more important in 1977, particularly for Thick-billed Murres on St. George.

Table 35 presents data on foods used by Horned and Tufted Puffins. Samples sizes continue to be very small. Tufted Puffin data on present volume is misleading, as almost all data are derived from fragments of hard parts obtained from otherwise empty birds. Most Horned Puffin data derive from birds shot while returning to the colony at St. Paul with bill loads of fish. Tufted Puffins were rarely seen carrying food in their bills. Both species of puffins depend primarily on fish, although Horned Puffins used a modest amount of squid and Tufted Puffins took a surprisingly large number of polychaets.

Foods used by Parakeet and Crested Auklets, 1975-1977, are found in Table 36. Parakeet Auklets tend to use more fish, while Crested Auklets take more amphipods and euphausiids. However, within these latter two food types, it is possible that the two auklets take foods of different sizes. When the 1978 data are available, we will attempt to examine these food habits more closely in order to better compare them with the work of Bedard (1969a). It is interesting to note the large increase of nereid worms in 1977 in Parakeet Auklets.

Least Auklets (Table 37) appear to specialize on copepods of the genus Colonus. Most of those identified to species in 1976 were in the C. marshallaeglacialis complex. In 1977 samples, identifications were made only of C. cristatus, all other Colonus being lumped together. On this basis, there appears to be an increase in the use of C. cristatus in 1977, as well as an increase in the use of hyperiid amphipods. The tiny pelagic gastropod, Himacina helicina, was virtually absent from the samples from both islands this year, but more samples from both islands had more decapod larvae in 1977 than in previous years. Comparing the

TABLE 34

FOODS USED BY COMMON MURRES AND THICK-BILLED MURRES -- PRIBILOF ISLANDS 1975-1977

	% OCCURRENCE							% VOLUME						
	Common Murres			Thick-billed Murres				Common Murres			Thick-billed Murres			
	Both Islands			Both Islands		St. Paul	St. George	Both Islands			Both Islands		St. Paul	St. George
	1975	1976	1977	1975	1976	1977	1977	1975	1976	1977	1975	1976	1977	1977
Sample size	24	36	19	20	31	35	33	69 ml	148 ml	201 ml	18 ml	270 ml	526 ml	205 ml
Food Types														
Cephalopoda	0.0	0.0	10.5	0.0	3.2	8.6	27.3	0.0	0.0	3.3	0.0	trace	4.6	29.8
Polychaetea (Nereidae)	0.0	0.0	0.0	0.0	0.0	2.9	3.0	0.0	0.0	0.0	0.0	0.0	trace	trace
Amphipoda	0.0	8.3	5.3	5.0	10.0	31.4	28.0	0.0	2.0	2.4	trace	8.1	9.7	23.4
Hyperiida	0.0	0.0	5.3	5.0	10.0	31.4	28.0	0.0	0.0	2.4	trace	0.0	9.7	23.4
Parathemisto libellula	0.0	5.5	5.3	5.0	6.5	31.4	28.0	0.0	1.4	2.4	trace	8.1	9.7	23.4
Euphausiacea	0.0	0.0	5.3	0.0	6.5	8.6	6.1	0.0	0.0	4.3	0.0	5.2	3.8	3.9
Decapoda (crab)	8.3	0.0	0.0	0.0	3.2	2.9	0.0	trace	0.0	0.0	5.6	trace	0.4	0.0
Total Fish	91.7	100.0	94.7	90.0	80.6	88.6	66.7	98.6	97.9	88.6	88.9	72.6	81.9	80.5
Larval fish	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0
Mallotus villosus	0.0	8.3	5.3	0.0	6.5	0.0	6.1	0.0	6.1	trace	0.0	4.1	0.4	4.3
Myctophidae	0.0	0.0	5.3	0.0	0.0	2.9	0.0	0.0	0.0	trace	0.0	0.0	0.0	0.0
Gadidae	29.2	41.7	63.2	25.0	41.9	77.1	57.6	trace	68.2	87.1	trace	24.8	52.3	36.6
Theragra chalcogramma	0.0	25.0	26.3	0.0	16.1	17.1	0.0	0.0	49.3	81.9	0.0	16.7	46.0	0.0
Stichaeidae	0.0	0.0	0.0	0.0	6.5	0.0	3.3	0.0	0.0	0.0	0.0	7.8	0.0	3.4
Stichaeus punctatus	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9
Ammodytes hexapterus	0.0	0.0	0.0	0.0	3.2	0.0	6.1	0.0	0.0	0.0	0.0	trace	0.0	2.4
Cottidae	0.0	6.4	0.0	0.0	12.9	2.9	0.0	0.0	4.1	0.0	0.0	6.7	1.1	4.3
Flatfish	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	trace	0.0	0.0	0.0	4.9
Lepidopsetta spp.	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	trace	0.0	0.0	0.0	19.5
Unidentified crustacean & fish remains	8.3*	2.8	21.1	0.0*	9.7	25.6	18.1	98.6	0.7	1.4	88.9	3.3	8.6	5.1

*Crustacean remains only

TABLE 35

FOODS USED BY HORNED PUFFINS AND TUFTED PUFFINS -- ST. PAUL ISLAND 1975-1977

	% OCCURRENCE						% VOLUME					
	Horned Puffin			Tufted Puffin			Horned Puffin			Tufted Puffin		
	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	1977
Sample size	2	11	13	3	12	3	1 ml	70 ml	53 ml	1 ml	55 ml	6 ml
Food Types												
Mollusca (not squid)	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	trace	0.0	0.0
Squid	0.0	0.0	7.7	0.0	0.0	0.0	0.0	0.0	trace	0.0	0.0	0.0
Polychaetea (Nereidae)	0.0	18.2	15.4	33.3	50.0	66.7	0.0	trace	trace	100.0	trace	66.7
Amphipoda	0.0	36.4	0.0	0.0	33.3	33.3	0.0	27.1	0.0	0.0	9.1	trace
Hyperiida	0.0	0.0	0.0	0.0	0.0	33.3	0.0	0.0	0.0	0.0	0.0	trace
Parathemisto libellula	0.0	18.2	0.0	0.0	16.7	0.0	0.0	24.3	0.0	0.0	5.5	trace
Unidentified crustacean remains	0.0	0.0	7.7	0.0	0.0	33.3	0.0	0.0	1.9	0.0	0.0	33.3
All Fish	100.00	100.00	92.3	33.3	100.0	66.7	100.0	72.9	96.2	trace	61.8	trace
Larval fish	0.0	9.1	7.7 *	0.0	0.0	0.0	0.0	5.7	7.5	0.0	0.0	0.0
Mallotus villosus	0.0	9.1	0.0	0.0	8.3	0.0	0.0	14.3	0.0	0.0	5.5	0.0
Gadidae	0.0	9.3	23.1	0.0	83.3	33.3	0.0	1.4	23.1	0.0	32.7	trace
Theragra chalcogramma	0.0	0.0	7.7	0.0	0.0	0.0	0.0	0.0	9.4	0.0	0.0	0.0
Trichodon trichodon	0.0	0.0	30.8	0.0	0.0	0.0	0.0	0.0	24.5	0.0	0.0	0.0
Ammodytes hexapterus	0.0	0.0	30.8	0.0	0.0	0.0	0.0	0.0	30.2	0.0	0.0	0.0
Flatfish	0.0	0.0	7.7 *	0.0	0.0	0.0	0.0	0.0	7.5	0.0	0.0	0.0
Hexagramma stellerius	0.0	0.0	30.8	0.0	0.0	0.0	0.0	0.0	24.5	0.0	0.0	0.0
Unidentified fish remains	0.0	9.1	23.1	0.0	8.3	33.3	0.0	trace	1.9	0.0	9.1	trace

* Same Sample

TABLE 36

FOODS USED BY PARAKEET AUKLETS AND CRESTED AUKLETS -- PRIBILOF ISLANDS 1975-1977

	Parakeet Auklets % Occurrence			Crested Auklets % Occurrence			Parakeet Auklets % Volume			Crested Auklets % Volume		
	1975	1976	1977	1975	1976	1977	1975	1976	1977	1975	1976	1977
Sample Size	11	14	14	6	9	6	40 ml	119 ml	147 ml	57 ml	201 ml	54 ml
Food Types												
Mollusca (not squid)	0.0	14.3	0.0	0.0	0.0	0.0	0.0	trace	0.0	0.0	0.0	0.0
Gastropoda (*Limacina helicina*)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polychaeta (Nereidae)	0.0	7.1	78.6	0.0	0.0	0.0	0.8	0.0	40.1	0.0	0.0	0.0
Cumacea	0.0	0.0	7.1	0.0	0.0	16.7	0.0	0.0	trace	0.0	0.0	trace
Isopoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipoda	18.1	42.9	57.1	66.7	22.2	66.7	2.5	5.9	17.0	73.7	trace	0.0
Gammaridea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hyperiidea	9.0	28.6	57.1	66.7	0.0	66.7	2.5	5.9	17.0	73.7	0.0	55.6
Parathemisto libellula	9.0	21.4	35.7	66.7	0.0	50.0	2.5	2.5	16.3	73.7	0.0	29.6
Euphausiacea	9.0	50.0	57.1	33.3	88.9	33.3	2.5	53.8	15.0	26.3	99.5	40.7
Thysanoessa inermis	0.0	14.3	0.0	16.7	11.1	0.0	0.0	21.0	0.0	24.6	19.9	0.0
Thysanoessa raschii	0.0	14.3	21.4	0.0	11.1	33.3	0.0	31.1	15.0	0.0	49.8	35.2
Thysanoessa spinifera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thysanoessa spp.	0.0	0.0	0.0	0.0	22.9	0.0	0.0	0.0	0.0	0.0	14.4	0.0
Unidentified crustacean remains	45.5	0.0	14.3	0.0	0.0	0.0	5.0	0.0	trace	0.0	0.0	0.0
Total Fish	45.5	57.1	71.4	33.3	0.0	50.0	87.5	40.3	27.2	1.8	0.0	trace
Larval Fish	0.0	0.0	14.3	0.0	0.0	16.7	0.0	0.0	1.4	0.0	0.0	trace
Gadidae	0.0	0.0	50.0	0.0	0.0	16.7	0.0	0.0	12.9	0.0	0.0	trace
Ammodytes hexapterus	0.0	0.0	7.1	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0
Unidentified fish	45.5	57.1	21.4	33.3	0.0	50.0	87.5	40.3	12.2	1.8	0.0	trace
Unidentified remains	0.0	0.0	14.3	0.0	0.0	0.0	0.0	0.0	trace	0.0	0.0	trace

TABLE 37

FOODS USED BY LEAST AUKLETS -- PRIBILOF ISLANDS 1975-1977

	% OCCURRENCE					% VOLUME			
	1975		1976	1977		1975	1976	1977	
	St. Paul	St. George	St. Paul	St. Paul	St. George	St. Paul	St. Paul	St. Paul	St. George
Sample size	45	11	77	39	42		88 ml	44 ml	83 ml
Food Types									
Polychaetea (Nereidae)	0.0	0.0	0.0	0.0	2.4	not	0.0	0.0	trace
Gastropoda (Limacina helicina)	13.3	9.1	27.3	5.1	0.0		trace	trace	0.0
Copepoda	44.4	27.3	49.4	71.8	85.7	available	71.6	68.2	71.1
Calanus spp.	31.1	27.3	45.5	71.8	83.3		69.3	65.9	41.0
Calanus marshallae or glacialis	31.1	27.3	45.5	- *	- *		69.3	- *	- *
Calanus plumchrus	0.0	0.0	27.3	- *	- *		trace	0.0	0.0
Calanus cristatus	2.2	0.0	27.3	46.2	66.7		2.3	2.3	30.1
Cumacea	2.2	0.0	28.9	10.4	0.0		trace	trace	0.0
Isopoda	0.0	0.0	40.3	0.0	0.0		8.0	trace	0.0
Amphipoda	53.3	54.5	39.0	61.5	73.8		8.0	trace	trace
Gammaridea	6.6	18.2	6.5	7.7	33.3		trace	trace	10.8
Hyperiidea	40.0	45.5	29.9	61.5	61.9		8.0	[illegible]2.7	8.4
Parathemisto spp.	28.9	36.4	23.4	- *	- *		8.0	- *	- *
Euphausiacea	20.0	0.0	28.9	30.8	33.3		trace	trace	4.8
Thysanoessa spp.	0.0	0.0	0.0	5.1	4.8		trace	trace	trace
Thysanoessa inermis	0.0	0.0	2.6	3.2	2.4		trace	trace	trace
Thysanoessa raschii	6.6	0.0	5.3	5.1	11.9		trace	trace	4.8
Thysanoessa spinifera	0.0	0.0	5.3	0.0	0.0		trace	0.0	0.0
Decapoda larvae	6.6	18.2	0.0	33.3	28.6		0.0	trace	1.2
Small crustacean (unknown larval stupes)	0.0	0.0	0.0	12.8	16.7		0.0	trace	trace
Unidentified crustacean remains	22.2	36.4	84.2	23.1	0.0		trace	trace	0.0
Larval Fish	20.0	0.0	10.5	28.2	9.5		trace	trace	trace

* Species not identified

two islands, C. cristatus and a small Gammarid amphipod were more important on St. George than St. Paul. Larval fish were more important on St. Paul.

These data on the diets of Pribilof Island seabirds show that fish, particularly Gadids and myctophids are the most important food resource. Other important food resources are also identified and, as NOAA funds permit, it will be valuable to have other investigators determine the vulnerability of these species to oil pollution and other sorts of pollution associated with off-shore oil development. Also, as our data base expands, it will be valuable to relate changes in reproductive success to changes in diet composition to see if and when changes in the birds' diets are reflected by changes in reproductive output.

E. Distribution of Foraging Seabirds

We observed approximately 119,000 seabirds of 23 different species on 1900 km of surveys during five cruises on 21-24 August 1975, 2-4 June 1976, 7-12 July 1976, 7-11 July 1977, and 1-5 August 1977. A total of 1019 transects were made, with 704 occurring in 1977. For each transect we calculated the density of seabirds/km^2. The mean of these densities was then calculated for all transects in each 10' x 10' block of lattitude and longitude. For the 1977 cruises the maximum and minimum densities in each 10' x 10' block are also included. For the purpose of this analysis the five cruises will be used as measures of seabird distribution before colony occupation is complete (2-4 June), during incubation (7-12 July), and during the chick stage (1-5 August, 21-24 August).

Figures 28 and 29 (also Hunt 1977, figures 14, 15 & 16) show the mean densities of all species combined for each 10' x 10' block for the five cruises (see also Appendix figures 1 and 2, also Hunt 1977, Appendix I, figures 1-3). The two 1977 cruises ranged much further away from the islands and included many more transects than previous cruises, enabling us to get a more precise understanding of the more distant foraging areas used by Pribilof seabirds.

Helicopter surveys (Appendix, figures 3 & 4) of parts of the trackline of the ship showed considerable disparity between numbers obtained from the helicopter and from the ship. While it will be some time before the analysis of the helicopter transects is complete, it appears that shipboard estimates of ship-followers such as fulmars and kittiwakes are occasionally inflated, while it is not yet clear whether the shipboard census underestimates or overestimates the number of murres.

Highest densities on all five cruises were found within ten nautical miles of the islands and in the vicinity of the 200-meter depth curve south of St. George Island. Although many of the birds seen close to the islands were commuting to or from distinct foraging grounds, immense flocks of murres were seen on the water near the east end of St. George island on all five cruises and at the west end of St. George Island in the July 1976 cruise. Since only 10% of the murres of the Pribilofs nest on St. Paul Island, it is no wonder that only moderate numbers of murres are found in its off-shore waters. Murres were found in modest numbers scattered throughout most of the study area, up to 80 nautical miles away.

In general, storm-petrels and Red-legged Kittiwakes were concentrated at the 200-meter depth curve, shearwaters were seen in unevenly distributed flocks throughout the study area, and fulmars were scattered throughout with some concentration near St. George Island and the 200-meter depth curve. Five species were found primarily close to the islands; Red-faced Cormorants, Least, Crested, and Parakeet Auklets, and Horned Puffins. In contrast, Black-legged Kittiwakes and Tufted Puffins were scattered in relatively low densities throughout the study area.

Storm-petrels (Fork-tailed mainly; there were few sightings of Leach's) were scarce in June and July 1976, being seen on only three transects in June and on 14 of 146 in July. In July 1977 and August 1975 (Appendix, figure 5, Hunt 1977, Appendix I, figure 4), storm-petrels were seen mainly over the continental shelf edge but in relatively low numbers (5 - 10 birds/km^2). The number of storm-petrels increased in the August 1977 cruise (Appendix, figure 6) over the

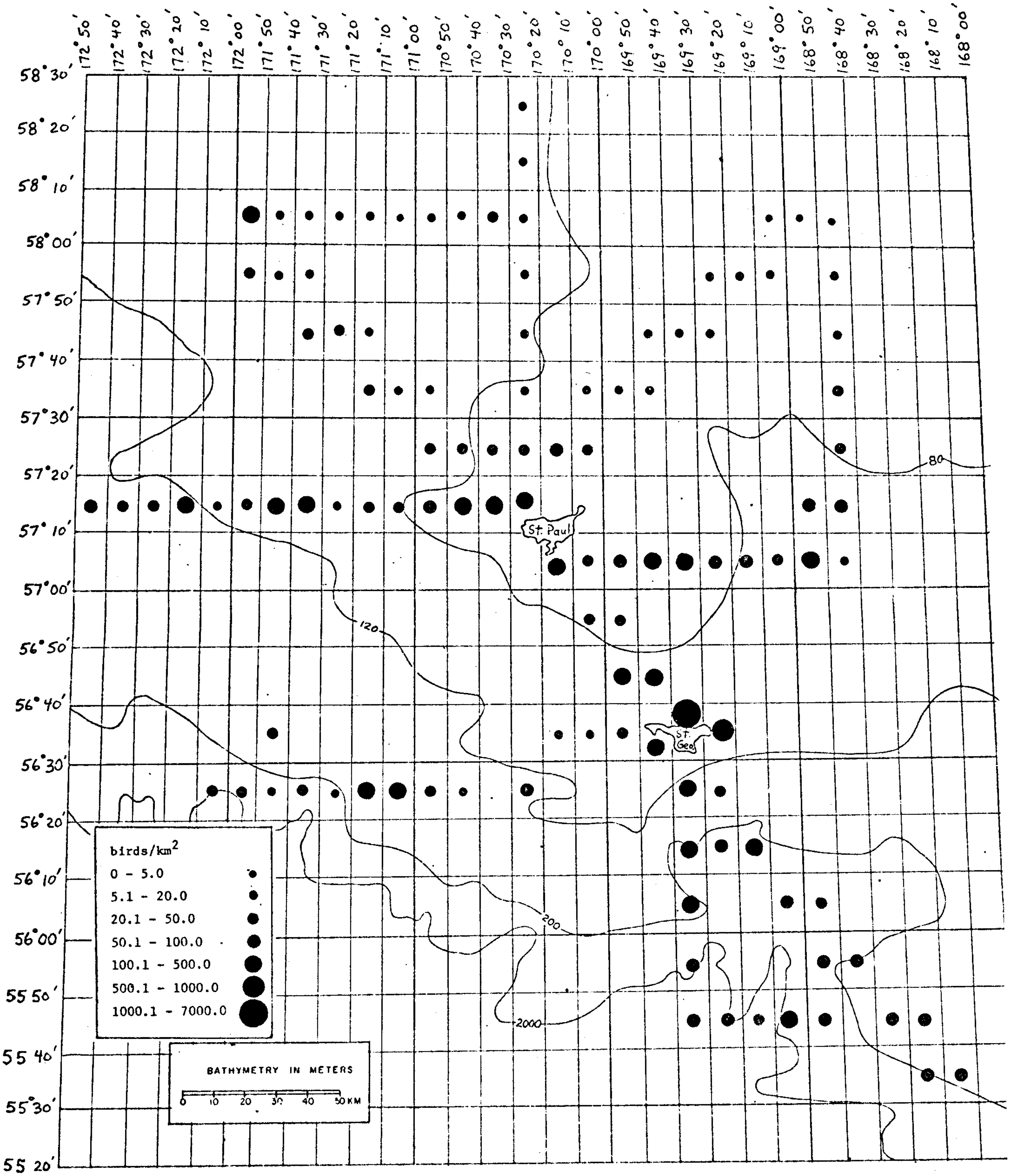


Figure 28. Mean densities of all seabirds observed in each 10' x 10' block, 7-11 July 1977.

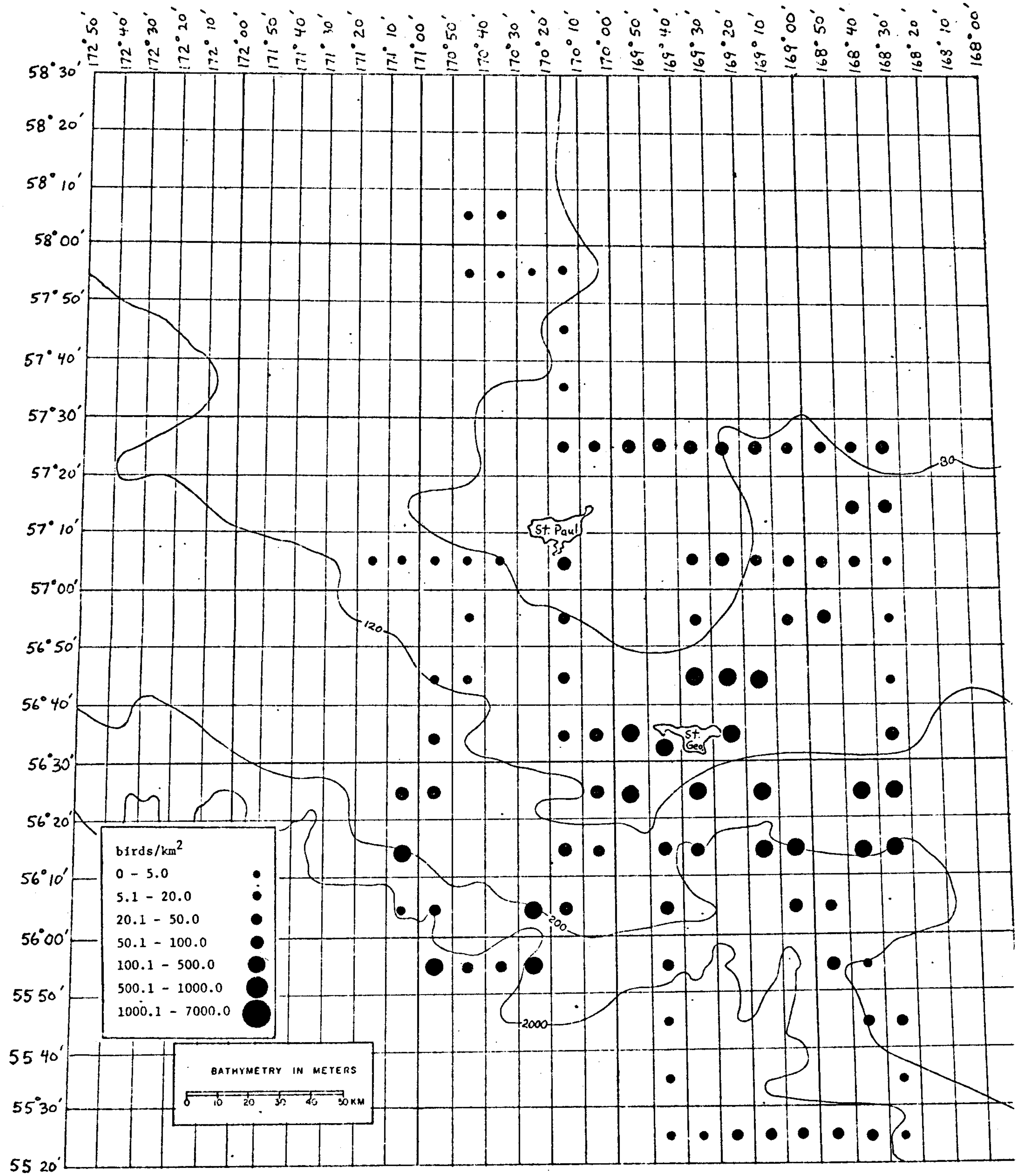


Figure 29. Mean densities of all seabirds observed in each 10' x 10' block, 1-5 August 1977.

continental shelf edge. On all cruises, except the July 1977 cruise, storm-petrels were virtually absent from the shallower continental shelf waters (less than 120m deep), while nearly all concentrations were in the vicinity of the 200-meter depth curve along the continental shelf edge. In July 1977 a surprising number were seen in shallow water west and north of St. Paul. The storm-petrels north of St. Paul were associated with whales.

Shearwaters (Short-tailed and Sooty) were also scarce in June and July 1976, occurring on only one transect in June and on 19 of 146 in July. On the July and August cruises of 1977, shearwaters were seen scattered in small numbers and with virtually no pattern to their distribution (Appendix, figures 7 & 8). In contrast, in August 1975, substantial densities ($\geq$ 15 birds/km^2) of shearwaters were encountered in many portions of the study area. (Hunt 1977, Appendix I, figure 5). The large variations in shearwater numbers from transect to transect and 10' block to 10' block emphasize the patchy nature of their distribution. Helicopter surveys in the vicinity of the ship transects showed no higher numbers than the ship surveys which helps confirm that we were not just missing ship-avoiding birds. While at present we lack evidence linking these dense flocks of shearwaters to local concentrations of food, such linkage is to be expected. The large flocks, which after feeding rest on the water and are sluggish, will be particularly vulnerable to oil spills in their vicinity.

Northern Fulmars were seen in low densities ($\leq$ 5 birds/km^2) on all five cruises in the shallower waters ($<$ 100m) of the continental shelf, excepting the waters immediately adjacent to the two islands (see Appendix, figures 9 and 10, Hunt 1977, Appendix I, figures 6, 7 & 9). Highest densities for all cruises were near the 200-meter depth curve to the south of St. George Island and immediately adjacent to the north side of St. George Island (where the largest Pribilof Fulmar colony exists). The June 1976 cruise also showed a lack of Fulmars ($<$ 5 birds/km^2) along the shelf edge south of St. George Island. However, these same waters yielded higher Fulmar densities ($\geq$ 15 birds/km^2) in July 1976, 1977, and the early August 1977 cruise. The late August 1975 cruise showed lower concentrations of Fulmars along the shelf edge than the July cruises.

Fulmars are notorious ship followers. While we took care to avoid counting obvious ship-following birds in our transects, we feel that Fulmars were attracted to our ship. During 1977 we used the Surveyor's helicopter to check the abundance of seabirds away from the Surveyor (see text figures 7, 8 and Appendix, figures 3 & 4). In most cases it was clearly evident that upon leaving the vicinity of the Surveyor, bird densities dropped off. Counts of Fulmar densities from the helicopter were consistently lower than those from the ship (Appendix, figures 11 & 12), and sometimes drastically less. The presence of foreign fishing vessels working to the south of St. George Island and west of St. Paul Island along the continental shelf edge may have increased the number of ship-following birds in these areas. With the helicopter we observed flocks of up to 5000 kittiwakes and Fulmars feeding on offal in the wakes of trawlers. In one instance, all Fulmars and kittiwakes seen flying within one nautical mile of the trawler were headed toward the trawler. The July 1976 cruise also found large numbers of Fulmars heading toward an enormous Fulmar flock several miles long, which trailed downwind from a factory ship southeast of St. George Island.

About half of the Fulmars seen at sea in the vicinity of the Pribilofs are from colonies other than the Pribilofs. Over 99% of the breeding Pribilof Fulmars are of the light phase (Hickey and Craighead, 1977), yet we observed 69% dark-phase Fulmars in July 1977, and 40% dark-phase Fulmars in August 1977 on our ship transects.

Flight directions of Fulmars in selected 10' blocks during the July 1976, 1977, and August 1977 cruises are given in the Appendix, figures 13 & 14; and Hunt 1977, Appendix I, figure 8). Of greatest interest are the morning and evening flight patterns south of St. George Island on the two July cruises. In the evening the preponderance of birds were moving south and southeast, away from the island (in July 1976, apparently commuting to join the flock of birds associated with a factory ship). One and two days later (1977 and 1976 respectively), most Fulmars were seen flying north toward St. George Island in the morning. Likewise, in the morning the predominent movement of Fulmars to the east of St. George Island was a westward flight toward the island. Data in the vicinity of St. Paul Island are insufficient to confirm these trends, but it appears that Fulmars may leave the islands in the afternoon and evenings to commence foraging and return in the early morning. How long they are away is not known. Figure 15 of Hickey and Craighead (1977) also suggests that Fulmars leave St. George in the evening and return in the morning.

Our August 1977 cruise again shows this pattern of movement away from the island in the evening and back in the morning, but not quite as clearly. It also shows that Fulmars have a tendency to pass by the ship in the direction of the ship's movement, a part of their ship-following behavior. It is not clear whether individual Fulmars make a wide circle and repass the ship a number of times or whether they make a single pass and move off ahead of the ship, but the net effect is to distort the apparent direction of movement of the birds, as well as inflate their numbers. However, when apparent flight directions, especially those opposite to the direction of the ship's movement, the observations of cliff attendance and the general distribution of Fulmars are all taken into account, it is clear that there is a general evening exodus from the islands and that the majority of the local breeding population of this species moves south to the continental slope to forage.

Red-faced Cormorants were generally restricted to the shallow waters in the immediate vicinity of the islands and their nearby reefs (Appendix figures 15 & 16, and Hunt, Appendix I, figures 10, 11 & 12). In June 1975 and August 1976, and 1977, numbers at sea were scarce, while in July 1976 and 1977, moderate densities were found close to the islands. This species takes much of its food from the bottom and no doubt requires relatively shallow water for foraging as well as nearby perches for drying feathers and preening. It is not clear why August numbers are lower than those in July.

Kittiwakes were seen in relatively low numbers (< 5 birds/km^2) in early June (see Hunt 1977, Appendix, figure 13) prior to the commencement of egg-laying and in moderate numbers (5-20 birds/km^2) on the July and August cruises (Appendix, figures 17, 18, 19 & 20; and Hunt 1977, Appendix I, figures 14 & 16), when the birds would have eggs and chicks respectively. Kittiwakes were generally not found at sea in large flocks in July or August, although occasional foraging flocks were seen.

On all five cruises sightings of Red-legged Kittiwakes were rare over the shallow continental shelf (< 100 meters deep; Appendix, figures 21 & 22; and Hunt 1977, Appendix, figure 15). They were concentrated near St. George Island (where the major portion of the world's population of this species breeds), and South of St. George Island along the deeper waters of the continental shelf edge (≥ 200 meters deep). A large proportion of Red-legged Kittiwakes were seen flying due south from St. George Island on both July cruises and in August 1977. (Appendix, figures 23 & 24; and Hunt 1977, Appendix I, figure 17). Our observations of flight directions over the deeper shelf edge areas (> 1000m) show that Red-legged Kittiwakes were still heading south into deeper water in the evenings and heading back from deeper water toward the St. George Island in the mornings. We suspect they forage at night over deep water well south of St. George Island. Figure 13 of Hickey and Craighead (1977) supports our observation that nesting Red-legged Kittiwakes leave St. George in the evening and return in the morning. Unlike the Black-legged Kittiwakes, Red-legged Kittiwakes were not seen in the foraging flocks close to the islands. The fact that a night-rising myctophid fish (lanternfish) was the major prey item of Red-legged Kittiwakes, lends further support to the idea that they forage at night over deep water.

Black-legged Kittiwakes have a more widespread distribution around the Pribilofs than the Red-legged Kittiwake (Appendix, figures 25 & 26). Although the highest concentration of Black-legged Kittiwakes were near the 200m depth curve south of St. George, low numbers occurred on nearly all transects, including the shallower waters of the continental shelf, where the Red-legged Kittiwake was absent. Flight directions of Black-legged Kittiwakes were similar to those of Red-legged Kittiwakes south of St. George Island (Appendix, figures 27 & 28; and Hunt 1977, Appendix I, figure 18). Although there was a trend of leaving the islands in the evenings, we saw no strong trend of flight towards the islands in the early morning. These observations of birds at sea are in general agreement with our information on colony attendance obtained in 1975 (Hunt 1976). Black-legged Kittiwakes are at their lowest numbers on the cliffs early in the morning, increase in numbers throughout the day, and start to decrease in numbers on the cliffs in the evening. As previously mentioned, kittiwakes were second only to Fulmars in their tendency to ship follow. Helicopter transects showed lower kittiwake densities away from the ship (see Appendix, figures 17-20).

Murres, the most abundant of the breeding seabirds of the Pribilof Islands, were also the most abundant bird at sea for all five cruises. Both Common and Thick-billed Murres nest on the Pribilofs, but because it is almost impossible to identify the two species with accuracy at a distance, records of the two species have been combined for the purposes of this report. However, Thick-billed Murres greatly outnumber Common Murres on the Pribilofs and most at-sea observations undoubtedly are of Thick-bills.

On most cruises, the greatest concentrations of murres were found just north and east of St. George Island (Appendix, figures 29 & 30; and Hunt 1977, Appendix I, figures 19, 21 & 22). To the north of St. George Island, most murres were commuters, while to the east and west of the island out to offshore reefs, huge rafts of murres were found on the water (Appendix, figures 31 & 32; and Hunt 1977, Appendix I, figure 20). These birds appeared to be foraging.

While it is hard to be certain that all birds in the flocks on the water were foraging, birds were diving and the flocks were attended by foraging kittiwakes and occasionally by cormorants. Large foraging areas of considerable importance were located 20-30 miles east of St. Paul in both July and August 1977 and northeast of St. Paul in August 1977. Moderately large numbers of murres were seen south of Otter Island in the tide rips, and south of St. George Island out to a distance of 30 nautical miles or more where birds concentrated near the 200-meter depth curve.

Flight directions of murres in selected grids are shown in Appendix, figures 33 & 34; and Hunt 1977, Appendix I, figure 23. South of St. George Island the majority of birds were flying south away from the island in the afternoon and north toward the island in the morning. East of St. Paul, most morning flights were toward St. George suggesting that this area is used primarily by St. George birds. Again, these at-sea observations fit with our data on murre colony attendance obtained in 1975 (Hunt 1976, also Hickey and Craighead 1977, figure 10). Ledge attendance was low in the early morning, rose throughout the day and dropped rapidly in the late afternoon and evening. Helicopter transects showed lower densities of murres than ship transects for given 10' blocks. (Appendix, figures 35 & 36). Also with the helicopter, we were better able to define the boundaries of huge feeding areas of murres in the shallow reef areas adjacent to St. George and St. Paul. However, due to the much longer time it takes to process and interpret the helicopter transects, some data have yet to be analyzed and are not included in this year's report.

In summary, the greatest concentrations of murres seen during all three cruises were found near the islands, particularly around St. George. Large numbers were also found far at sea and many of these birds were in the process of commuting to or from foraging grounds as far as 50 nautical miles away.

Sightings of Horned and Tufted Puffins on the 1975 and 1976 cruises were uncommon with slightly higher numbers close to the islands (Hunt 1977, Appendix I, figures 24-29). The June 1976 cruise had almost no puffins seen in the whole cruise including the waters adjacent to the islands. In July 1977, the more far-reaching cruise brought out a major difference in the foraging areas of the two puffins. (Appendix, Figures 37 & 39). Horned Puffins were rarely seen beyond 20 nautical miles off the islands while Tufted Puffins were seen regularly in low numbers on most transects and up to 60-70 nautical miles from either island. The August 1977 cruise showed the same patterns except for a small number of Horned Puffin sightings about 30 nautical miles northeast and east of St. Paul Island (Appendix, figures 38 & 40).

The auklets, for the purposes of this analysis, will be considered as a single group. Although Parakeet, Crested, and Least Auklets all were seen, the vast majority in the vicinity of the Pribilofs were Least Auklets.

Auklets were observed in low numbers during the June 1975 cruise (Hunt 1977, Appendix I, figure 30), mainly grouped within 10 nautical miles of the islands. The July 1976 cruise during their incubation period showed auklets concentrated in large numbers close to the islands (Hunt 1977, Appendix I, figure 31). The greatest numbers were found east of St. George Island in an area of cold water, presumably an area of upwelling. In contrast to the July 1976 cruise, in July 1977 auklets were found in low numbers up to 20 nautical miles away from the islands, although the majority of birds were close in to the island (Appendix, figures 41 & 43). During the August 1975 and 1977 cruises, auklets were more scarce (Appendix, figures 42 & 44; and Hunt 1977, Appendix I, figure 32), and dispersed farther away from the islands, although modest numbers were still to be found in the area east of St. George Island. This change reflects the dispersal of auklets from their island nesting colonies in early August.

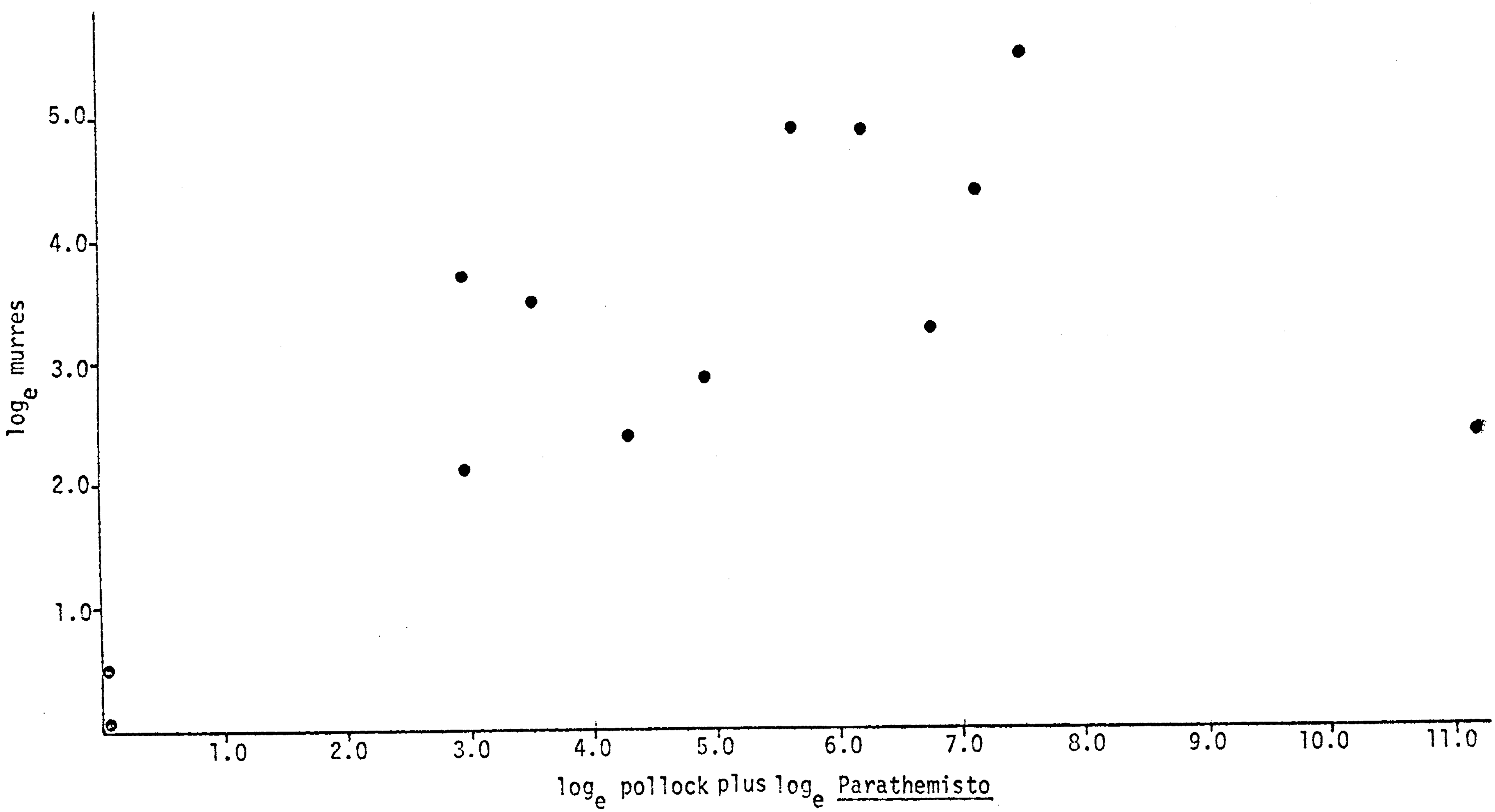
During the course of our studies, we have also attempted cooperative efforts with other investigators in order to relate the at-sea distribution of seabirds to the availability of their food resources or to physical oceanographic features. In 1975, we were able to conduct a very limited comparison of food availability with seabird distribution. Dr. Ted Cooney at the University of Alaska made 18 NIO Tucker Trawl tows in areas where we had bird observations. The results of these tows have become available to us in the past year. A second pilot effort to relate bird distribution to physical oceanographic data was conducted in 1977 with the aid of Drs. Tom Kinder, Lawrence Coachman and Jim Shoemaker of the University of Washington and the Pacific Marine Environmental Laboratory.

Preliminary analysis of the relationship between the distribution of foraging murres and the occurrence of their principal foods (Walleye Pollack, Therogra chalcogramma and Hyperiid amphipods of the genus Parathemisto) has been made for 13 stations that were sufficiently far from the islands that the results should not have been distorted by the presence of commuting birds. In Figure 30 we plot the relationship between $\log_e$ (1 + murres) and $\log_e$ (1 + Parathemisto). The logarithm of 1+ bird density or 1+ food density is plotted so that observations with zero organisms appear. The slope is statistically significantly different from random ($R = 0.57$, $p < 0.05$, $N = 13$) and shows murres were concentrated where their food resources were most abundant. The distribution of murres did not correlate significantly with the observance in the trawls of organisms not used by murres for food. The success of this small pilot project suggests that further examination of the relationship between the distribution of birds at sea and their food resources will prove profitable.

The distribution of foraging seabirds may also reflect physical features of the ocean that can be monitored by remote sensing. In 1976 and 1977 we found that satellite infrared imagery during the summer showed the Pribilof Islands are frequently surrounded by cooler surface water than is found $>$50km away from the islands. During August 1977, Tom Kiner, working with L. Coachman and J. Shoemaker, obtained CTD (conductivity-temperature-depth profiling system) data near the islands in the same areas where we had bird observations. We are using these data to address two questions: What is the physical cause of the cooler surface water near the islands? Is the distribution of foraging seabirds affected by the physical regime?

We can answer the first question confidently. In the shoaler water around the islands turbulence that is tidally generated at the bottom mixes the water completely, whereas in deeper water this mixing is unable to break

Fig. 30. $\log_e$ murres vs $\log_e$ pollock plus $\log_e$ <u>Parathemisto</u> at stations away from islands



down the stratification. Figure 31 illustrates how the temperature structure varies as St. Paul Islands is approached from the north: isotherms, tightly packed in the thermocline away from the island, splay to intersect either the bottom or the surface close to the island. This transition between the two-layered structure north of the island to the homogeneous water close to the island may be termed a "structural front."

One consequence of the front is that the surface temperature during summer accurately indicates the vertical structure. Figure 32, for instance, shows the correlation of surface to bottom density contrast (stratification) on surface temperature. Since surface temperature is easier to measure than vertical structure, surface temperature becomes a useful index of the physical environment.

Correlations with bird counts have been much less facile, and our efforts are very preliminary, but Figures 33 and 34 illustrate why we believe there may be an observable effect. Figure 33 shows surface minus bottom temperature versus depth of water, and suggests three separate regions. At depths less than 60m, the temperature difference is less than $3^{o}C$, while at depths exceeding 85m the temperature difference is greater than $6^{o}C$. Between these two regions is a transition with a wide range of temperature differences. This distribution is a result of the frontal structure illustrated in Figure 31: proceeding shoreward, we sequentially encounter the two-layered region, the transition (front), and finally the well-mixed region. While there are some complications evident, the salient feature in Figure 33 is the separation into two regions, separated by the front.

If the birds are strongly affected by the physical regime, then bird counts might show a rapid change across the front. Figure 34 illustrates this effect for all species of birds observed on the water in 10-minute observation periods versus depths (the logarithm of [1 + bird density] is plotted so that observations with no birds appear). Although the data in Figure 34 are few, having been selected for proximity to CTD stations, they suggest that the bird distribution does respond to the physical regime. At depths exceeding 80m, bird concentrations are all less than $20km^{-2}$, and most are less than $10km^{-2}$, while at depths less than 65m all concentrations are greater than $10km^{-2}$, and one half of the observations exceed $20km^{-2}$. The apparent division into two regions, similar to temperature differences in Figure 33, implies that the frontal regime may affect bird densities. Further examination of the bird distribution should confirm (or disprove) this implication, and perhaps suggest possible casual relationships. When all at-sea data are entered into the computer, it will be possible to see if in other areas surveyed the number of foraging birds changes rapidly as the front is crossed.

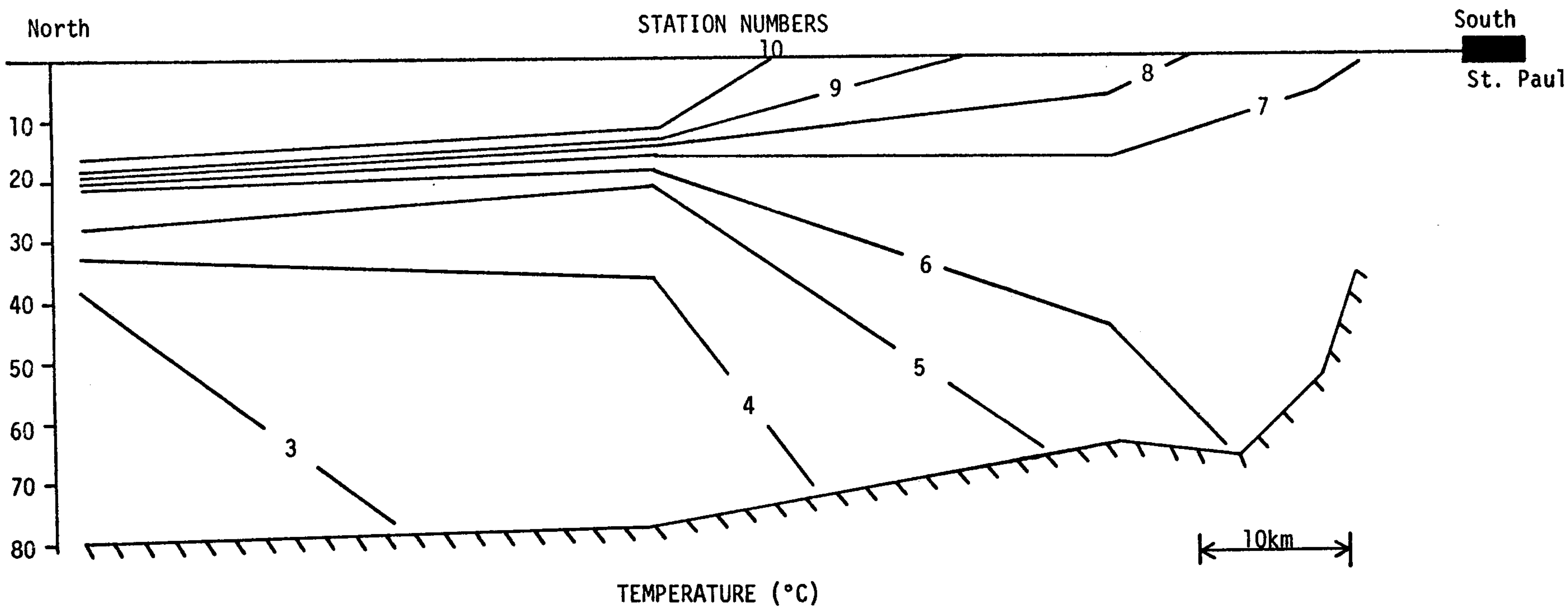


Fig. 31. Isotherms of water temperature (°C) north of St. Paul Island 5 August 1977.

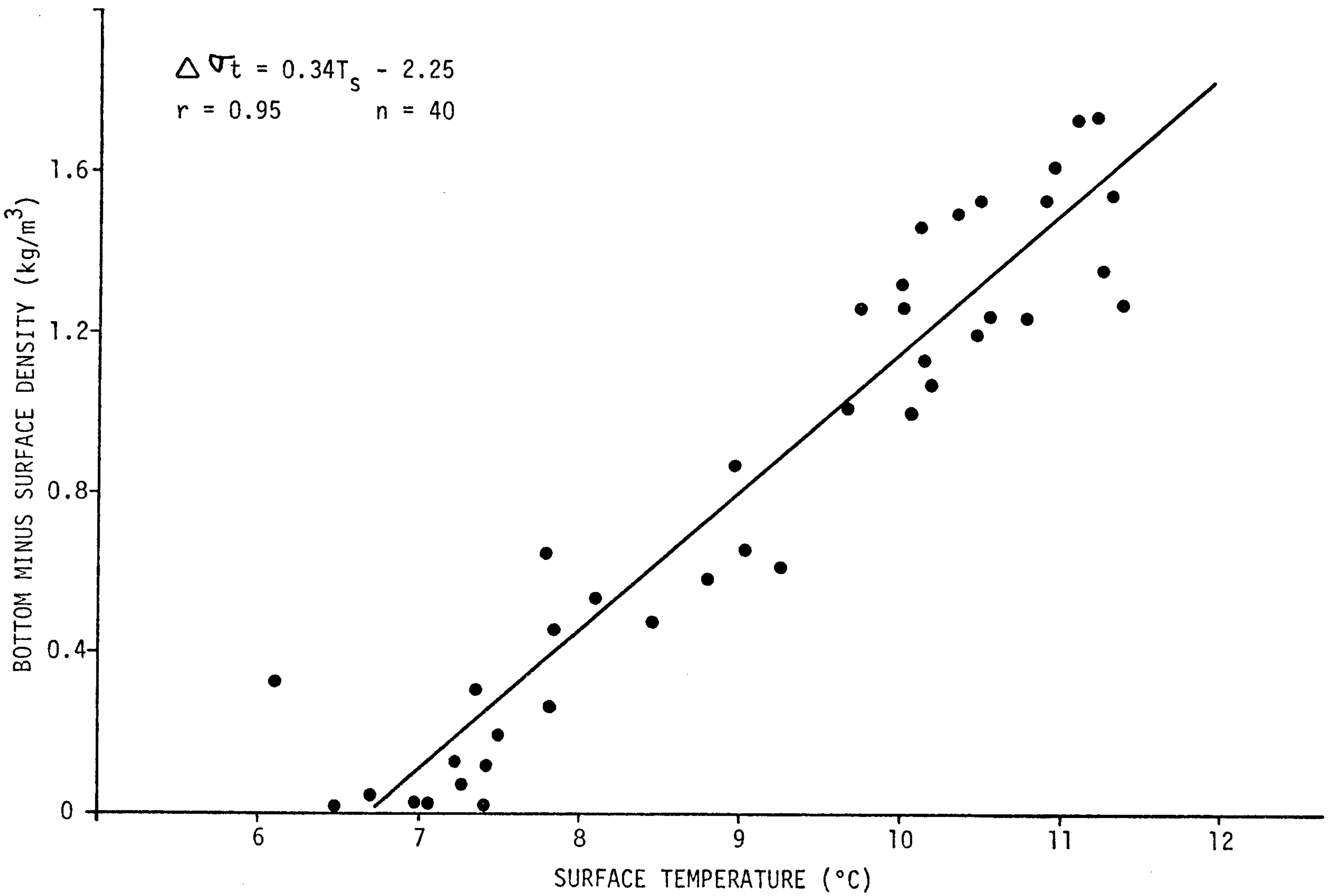


FIG. 32. Relationship between sea surface temperature and the disparity between surface and water density.

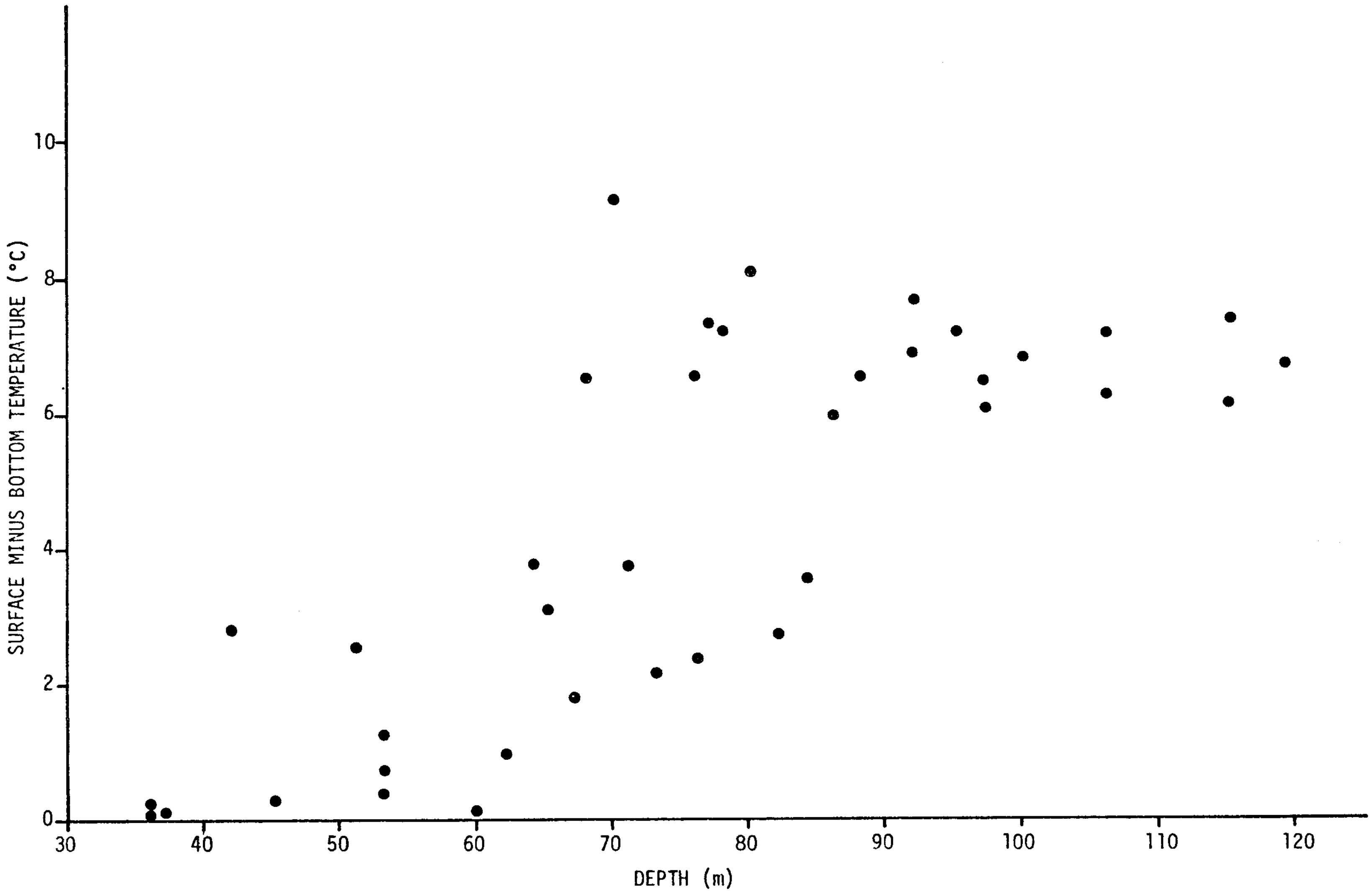


Fig. 33. The relationship between water depth and the desparity between surface and bottom temperatures.

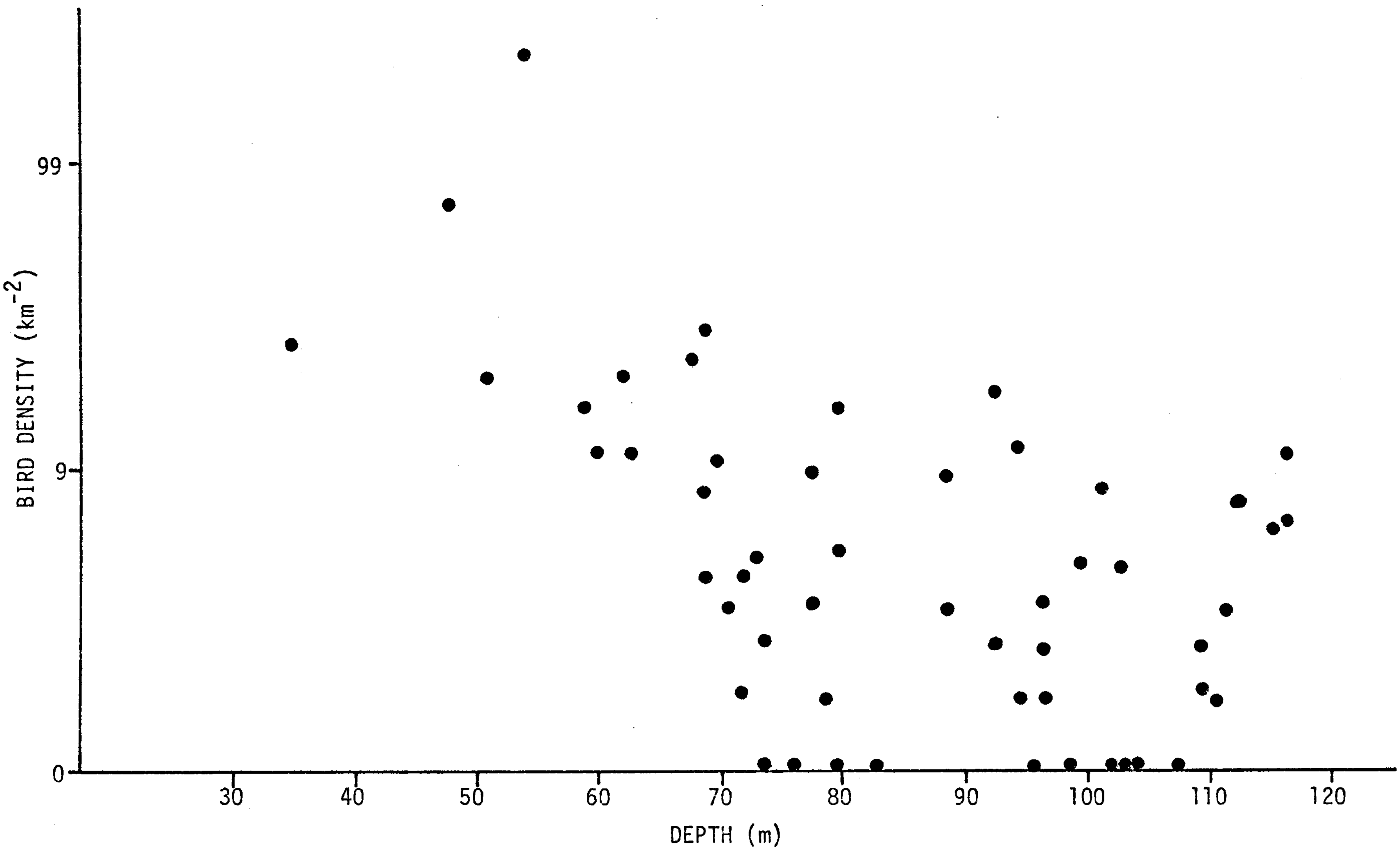


Fig. 34. Relationship between water depth and density of all species of birds on the water.

F. Survey of Otter and Walrus Islands

Slides taken during the August 1975 helicopter flight around Walrus Island confirmed observation made from the helicopter that the huge colony of Common Murres described in earlier literature was no longer present and has been replaced by large numbers of Steller's Sea Lions (Hunt 1976). The second helicopter survey in June 1976 confirmed observations made the previous August.

Although Causey did not have enough time to do a complete census of birds on the cliffs of Otter Island on 12 June 1976, he reported that the species composition was very similar to that of St. Paul. Thick-billed Murres were far more abundant than Common Murres, and almost all kittiwakes seen were Black-legs. Very few Red-legged Kittiwakes were present.

G. Effects of Helicopter Traffic on Cliff Nesting Seabirds

The results of the 10 June 1976 helicopter approaches to Otter Island with a Bell Ranger II are as follows. In the four approaches made directly at the cliff face, murres departed from the cliffs as the helicopter approached within 180-250 meters. There was some indication that as the airspeed of the helicopter was increased, and, presumable also its output of noise, murres would leave when the helicopter was further away. Thus as an airspeed of 125 miles per hour, murres were departing the cliffs when the helicopter was judged to be 225-250m away, but the birds allowed the helicopter to approach up to 180-200m when it had an airspeed of 90 miles per hour.

The trials in which passes were made parallel to the cliffs yielded similar results. At 500m and 350m no birds left the cliff, at 200-250m moderate numbers left the cliffs, and at 200m and 150m murres streamed from the cliffs in huge numbers.

In 1977 during aerial surveys of seabird foraging areas near the west end of St. George Island on 8 July, the Surveyor's Bell Ranger II helicopter flew within 600m of the cliffs. This disturbance caused over 1000 murres and several hundred kittiwakes to leave the cliffs. By this date most breeding murres and kittiwakes are incubating eggs.

VII. DISCUSSION

The observed reproductive success of the Probilof seabird colonies has been stable over the three years of this study, 1975 to 1977. The production of some species on the Pribilof Islands has been relatively low when compared to other areas in the world; yet there have been no reproductive failures similar to those observed in other areas of the Bering Sea during the last three years. Foraging seabirds are present over the shelf waters in all directions from the Pribilofs; particularly large concentrations occur in the vicinity of the islands and along the shelf edge to the south. Certain species show distinct foraging patterns. Some species, such as the Red-legged Kittiwake and Common Murre, specialize on a narrow range of prey species; others, such as the Black-legged Kittiwake and Thick-billed Murre, show greater variety in their diet.

On the Pribilofs seabird nesting is restricted to the cavities of boulder beaches and talus slopes, the inaccessible ledges of the shear cliffs and the crevices and holes within them. Arctic foxes presumably prevent seabirds from nesting in burrows on the tops of the islands as is common on islands free of terestrial predators. These small and agile animals move easily about all but the most vertical cliff faces preying on birds and their eggs; hence, successful breeders are restricted to the most inaccessible locations. Introduced cats, which are common in the villages, do not appear to be a major threat to the cliff nesting seabirds.

In our sample Fulmars produced between 0.2 and 0.4 fledglings per adult on the colony. Fisher and Lockley (1954:195) noted that inexperienced birds are common on tubenose colonies in late summer; the presence of such non-breeders would effect the above index. At-sea Fulmars are present in low densities in all directions from the Pribilofs; however, their ship-following habit has complicated our observations. Though less than one Fullmar in a thousand on the cliffs of the Pribilofs is dark phase (Hickey and Craighead 1977), about half of those seen at sea were dark phase. These observations correlate well with those of Shuntov (1974) and indicate that Fulmars from more than one population are foraging near the Pribilofs. Of other tubenoses, shearwaters occurred unevenly in flocks and in apparently lower numbers than observed in the area by Gould (1977); storm-petrels were concentrated over the shelf edge.

Red-faced Cormorants have consistently fledged slightly more than one young per nesting attempt in our 1975 to 1977 samples; successful pairs typically fledged two, and less often three, young. Apparently nesting space is not limiting since some changes occur in the location of breeding ledges from year to year. Cormorants forage primarily near the islands for bottom dwelling fish.

Black-legged Kittiwakes have fledged about one young per two nests in our cliff samples. In 1977 a few Black-legged nests on St. Paul fledged two young; no such broods were observed in either 1975 or 1976. However, Kenyon and

Phillips (1965:630) note that on the Pribilofs between 1947 and 1954 "the Black-legged Kittiwake usually lays two eggs and often two young are fledged." Within our sample less than half the pairs laid two eggs. This decrease in production may reflect a lowered availability of food to the parent kittiwake in waters of the vicinity of the Pribilofs. Pollack have been a major component of Black-legged Kittiwake food samples.

Reproductive success of Black-legged Kittiwakes on the Pribilofs in 1975, 1976 and 1977 appears low when compared to that of southeastern Alaska (Hunt 1977: Appendix 2) or elsewhere in the world. Observed clutches in the Pribilofs have had means near 1.4 eggs. Belopol'skii (1957) reports a mean of 1.96 for the Barents Sea. Coulson (1966) gives means between 2.11 and 2.35 eggs per nest for Northumberland, England colonies; Coulson and White (1958) found that inexperienced females laid fewer eggs. Swartz (1966) observed an average of 1.84 eggs per nest at Cape Thompson, Alaska. Although three-egg clutches are not unusual elsewhere, we have never seen a clutch of greater than two eggs in the Pribilofs. Similarly, Black-legged chick production in the Pribilofs (near 0.5 per nest, Table 12) appears low by comparison. Belopol'skii (1957) reports there are often three nestlings and occasionally the third chick dies for Barents Sea colonies. In England Coulson (1966) found chick production to vary from 0.92 to 1.72 young per nest. At Cape Thompson Swartz (1966) reported a fledging success per nest of 1.22 for 1960 and 0.72 for 1961. Chick growth rates in the Pribilofs have been comparable to those reported by the above authors, yet the parent kittiwakes in the Pribilofs have been providing for only one chick instead of two or three.

The bulk of world's Red-legged Kittiwakes breed on St. George Island. This species provides an interesting comparison to the ecology of its black-legged congener's Pribilof population. The Red-legged Kittiwake lays a single egg averaging just over one-eighth adult weight. On the Pribilofs the average Black-legged clutch amounts to just over one-sixth adult body weight. Yet from its smaller initial investment, the Red-legged Kittiwake has a fledging success per clutch equivalent to if not greater than that of its congener's Pribilof population.

Over the three years of study, growth rates of Red-legged young have varied closely around 13 g/day (Table 17). Whereas, those of Black-legged young have varied from less than 12 to almost 18 g/day (Table 12). Perhaps the Red-leg uses a more stable food source.

The diet of the Red-legged Kittiwake has been generally less diverse than that of the Black-legged Kittiwake within our samples. The Red-leg specializes more on fish prey and even within this class takes fewer species than the Black-leg (Tables 29 and 30). Myctophids (lanternfish) are the primary prey item of the Red-legged Kittiwake. These fish remain in deep water during daylight and rise to the surface during darkness.

Our observations of the Red-legged Kittiwake at sea show concentrations along and beyond the continental shelf edge to the south of St. George; Myctophid prey are presumably more available in these deep waters. From colony attendance observations and flight directions observed at sea, it is apparent that Red-legged Kittiwakes are visiting this area between dusk and dawn. Black-legged Kittiwakes are more widely dispersed at sea; this species was scattered at low densities throughout the areas surveyed around the Pribilofs. These observations correspond well with those of Shuntov (1974); he found Red-legged Kittiwakes more often over deep ocean waters and Black-legged more often over shelf waters.

Murres, by far the most numerous seabirds on the Pribilofs, here have a reproductive success apparently similar to other populations. Both Common and Thick-billed Murres show a similar fledging success of hatched young near 0.8 or more. Fledging success per egg, which is more effected by our methods and disturbance, probably has ranged from 0.4 to 0.7 (Table 18 and 21). At an observer disturbed site at Cape Hay in 1957, Tuck (1961) found 0.4 young fledged per pair. At the Cape Thompson sites of Swartz (1966), egg mortality varied between 0.26 and 0.52.

Growth rates of Thick-billed Murre chicks are available from two published studies. Calculations based on a graph in Tuck (1961) for Thick-billed Murres at Ungava Bay, 1954, yield a growth rate of 14.5 g/day. In contrast, Johnson and West (1975) provide a graph of data gathered on St. Lawrence Island in 1972 from which a growth rate of only 8 g/day results. In our Pribilof samples mean growth rates of Thick-billed Murre chicks which survived to jumping from the cliffs have varied from 6.0 g/day in 1976 on St. George to 14.6 g/day in 1975 on St. Paul (Table 22). In contrast, chicks which failed to survive had growth rates of 1.7 to 4.2 g/day. Apparently a wide range of growth rates is possible for chicks of this species before their survival on the cliffs is affected.

Thick-billed Murre food samples contained a greater diversity prey items than did those of the Common (Table 34; see also Spring 1971). Our Common Murre food samples indicate a specialization towards fish; collected bill-loads carried to the young by Common Murres were 90 percent pollack. Major Thick-billed foods collected included fish, squid and Hyperiid amphipods. Bill-loads of Thick-billed Murres were predominately pollack and squid, but several other fish species occurred.

Murres were present in low densities throughout our shipboard surveys. Greatest numbers occurred in the immediate vicinity of the islands and along the continental shelf edge to the south. Particularly high densities of murres in large rafts within a few nautical miles of the east and west ends of St. George have been observed on all cruises passing through those areas.

From our more extended 1977 shipboard surveys, a difference in the distributions of the two puffins is apparent. Horned Puffins tend to remain nearer the colonies; whereas Tufted Puffins ranged much farther out to sea. Shuntov (1974:124-129) describes the Tufted Puffin as the most pelagic of the alcids. Conversely, the auklets remained very near the islands during our cruises. Too little ship time was available to work out the differences in distribution of the three auklets within two to three miles from shore. Bedard (1969a) found that Crested and Parakeet Auklets ranged slightly farther offshore than did the Least Auklets. Yet after the young fledge in August, the auklets disappear from the immediate vicinity of the islands.

Various differences between the two islands are becoming apparent. There is more diversity in our samples of prey species taken on St. George Island than those from St. Paul for Thick-billed Murre, Red-legged Kittiwake, and Red-faced Cormorant. This is notably shown by heavier use of squid on St. George. In 1977, as squid use increased, fish went down for St. George Thick-billed Murres and Red-legged Kittiwakes. These differences probably reflect use of somewhat different foraging areas by birds of each island. Within our study areas, St. Paul murres grow faster and flege at heavier weights than St. George murres. St. George foraging areas may be more crowded than St. Paul. It is important to note that St. George is also much closer to the continental shelf edge, and that 90% of Pribilof birds nest on that island.

A final point of interest is the question of changes in size of the populations of species nesting on the Pribilof Islands. Hickey and Craighead (1977) point out that Least Auklets on St. George have declined in numbers while Black-legged Kittiwakes on at least St. Paul have increased and at least the part of the Red-legged Kittiwake population nesting on the low cliffs on St. Paul has remained stable over the last 20 years. We have previously mentioned that Crested Auklet numbers on St. Paul have apparently declined, and that based on Thompson's (per. com.) recollections of Red-faced Cormorants nesting activity near St. Paul village, this species may also have declined.

On the basis of our observations that Red-faced Cormorants may shift their nesting activity from one year to the next, we feel that it is almost impossible to determine population changes for this species without reasonably complete counts of their nests from the entire island. This information we have for 1976. On the other hand, independent reports of decreases in Least Auklets and Crested Auklet numbers may well be real and tied to some as yet unidentified change in their environment.

The possibility of an increase in the Black-legged Kittiwake population between 1954 and 1975-1976, a period when Red-legged Kittiwake numbers have apparently not expanded (at least on St. Paul) is of considerable interest, especially in light of an apparent decline in reproductive output. Two different theories may shed light on the apparent population increase.

Belopol'skii (1957) makes the point that changes in kittiwake populations are inversely related to changes in murre populations. At Barents Sea colonies, increases in kittiwake numbers have followed declines in murres and vice versa. The linkage between the species is apparently a combination of competition for food fishes needed to feed young and competition for nesting space (Belopol'skii 1957). On the basis of food preferences and nest site preferences, we would expect competition by Black-legged Kittiwakes for fish food to be most severe with Common Murres and competition for nest sites to be most intense with narrow ledge-nesting Thick-billed Murres. We know nothing of the past size or population changes in the Thick-billed Murre. However, we do know that the once immense Common Murre colony on Walrus Island no longer exists; the occupation of the top of the island by Steller's Sea Lions, first reported by Kenyon and Phillips (1965) as occuring in 1954, is now complete. While it is far from clear that this decline of a murre population is in any way tied to the apparent increase of Black-legged Kittiwakes on St. Paul Island, it will be most interesting to follow the changes of the population of this species in the future.

Second, recent changes in the population of Walleye Pollack may be affecting the populations of Black-legged Kittiwakes and both murres on the Pribilofs since heavy fishing of pollack beginning in 1964 has caused a decrease in pollack abundance since 1969 and has drastically reduced the older age classes (Pereyra, et al 1976). Because older pollack are canabalistic on juvenile pollack, the decrease in older age classes may increase the juvenile stocks and result in an increase in the total biomass for the species. (Laevastu and Favorite 1976, Favorite, et al 1977). These increases would be beneficial to both species of murres and Black-legged Kittiwakes. Also, juvenile pollack have diurnal movements near the surface during their juvenile stage (Straty, ms) where they are presumably preyed on by murres and kittiwakes. Pereyra, et al (1976) shows large numbers of predominately one-year old pollack near the Pribilofs. Although we do not have comparable data on past murre population estimates, the apparent increase in Black-legged Kittiwakes on St. Paul Island may be related to the rise in juvenile pollack populations around the Pribilofs. If that is so, we then are left with the perplexing question of why the apparent decrease in Black-legged Kittiwake reproductive success over the period when populations increased. Perhaps the decrease in reproductive success came subsequent to the increase in population size.

In order to better predict the future of these species, it will be important to gain a more complete understanding of the factors controlling reproductive success and population growth. A knowledge of winter mortality rates and patterns will be critical in this endeavor.

VIII. MANAGEMENT GUIDELINES CONCERNING OFFSHORE OIL DEVELOPMENT

A. Prediction of Potential Impacts

The Pribilof Island seabird colonies with over 2.2 million breeding birds constitute a valuable natural resource. The more than 1.6 million breeding Thick-billed Murres as a component of the Bering Sea ecosystem account for a biomass of over 1,600 metric tons. Almost a quarter-of-a-million Red-legged Kittiwakes breeding principally on St. George Island account for over ninety percent of the world population of that endemic species of the Bering Sea. Tens of thousands of Fulmars, Black-legged Kittiwakes, Common Murres, auklets and Horned Puffins also breed on these islands (Hickey and Craighead 1977). During the months of the breeding season the shelf waters of the southeast Bering Sea are the foraging grounds of these birds and their offspring and constitute a critical habitat. In the spring and fall other seabirds migrating to and from breeding colonies farther north move through this basin and depend on its food resources.

Breeding birds of the Pribilof colonies are present on their cliffs from middle April through October. The early breeders have eggs in their nests by late May, and the chicks of some late breeders will not fledge until the middle of October (Figure 35). Most species typically arrive on the island a month or more before egg laying to begin breeding activities. These species will be on the water in the vicinity of the islands some weeks before coming ashore. Hence, breeding seabirds of the Pribilofs may be associated with the shelf waters of the southeast Bering Sea from before April and until November. In addition, the relatively small population of Red-faced Cormorants remains associated with the islands throughout the year. When ice conditions permit, seabirds will use the waters near the Pribilofs even in mid-winter; murres were common off St. George in February 1978. Thus, seabirds breeding on the Pribilofs and foraging in nearby waters are vulnerable to the effects of oil exploration and development for the majority of the year.

Damage to the Pribilof seabird populations and their reproductive potential will result from the increased human activity and the inevitable spills which would be associated with offshore oil development or transportation of oil or equipment in the area. Since the seabirds nest on the inaccessible cliff faces, increased terrestrial activity associated with personnel on the islands should not greatly threaten the birds as long as they are not intentionally harassed. People and pets walking along clifftops will likely have minimal impact; perhaps some desertion of clifftop nests may result.

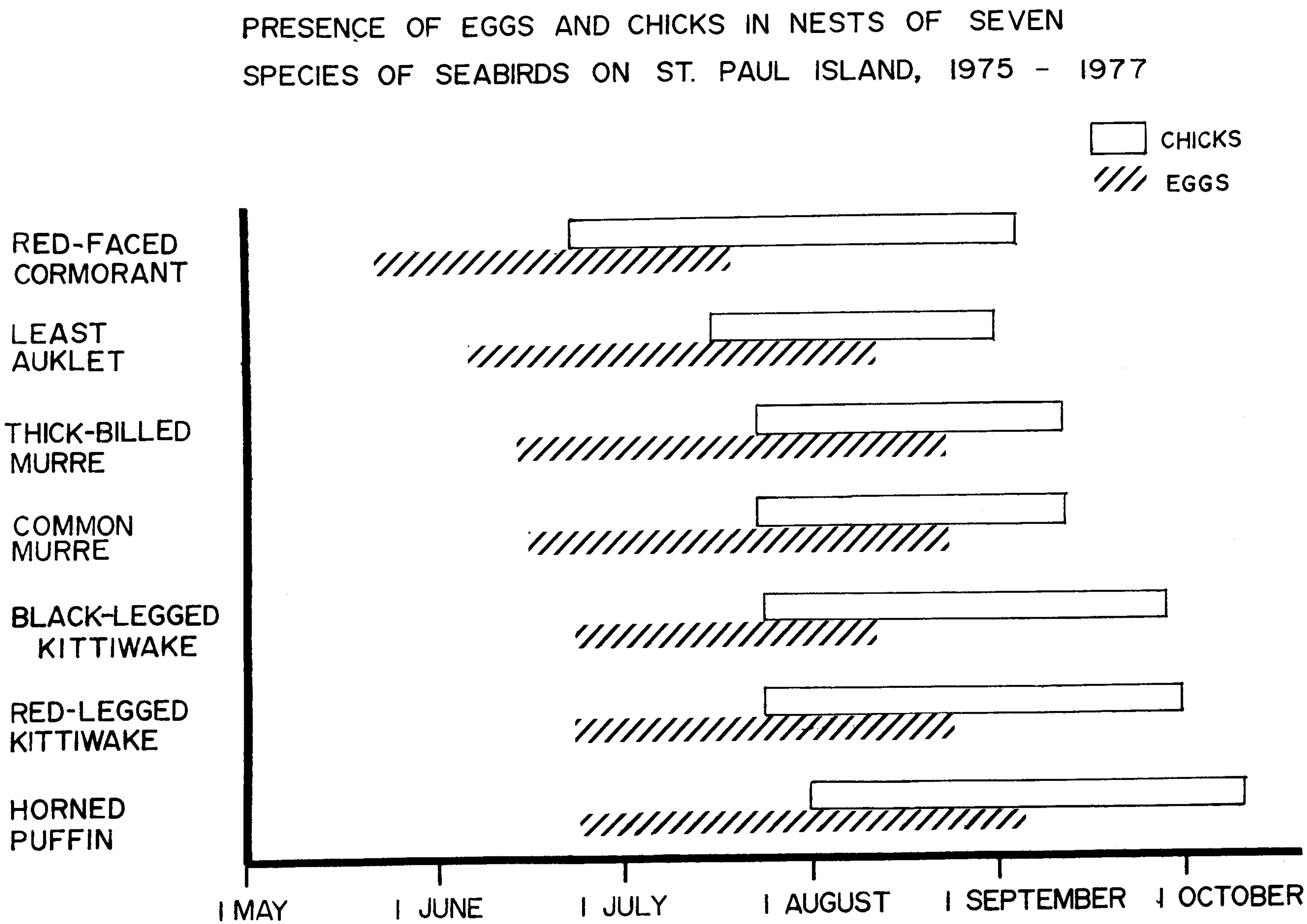


Fig. 35. Timing of breeding of seven species of seabirds, St. Paul Island 1975-1977.

The potential for disturbance from activity along beaches or in boats below nesting cliffs is far greater. Birds do not usually flush from nests because of the presence of people on the beach, but the potential for scaring large numbers of birds from nests and ledges is great. Loud noises, rock throwing, gun reports and even noise from outboard motors operated too close to the cliffs cause mass flights. The ledge-nesting murres which build no nest to hold the egg are especially vulnerable to flushing from disturbance; severely reduced reproduction results from masses of frightened murres kicking eggs from their ledges as they flee. On the Pribilofs large numbers of murres are incubating eggs from middle June until early August. Most beaches below major bird cliffs on the Pribilofs are inaccessible from land, but great disturbance will result from the operation of small boats and shooting below the cliffs.

Disturbance from increased air traffic flying close to nesting cliffs probably poses the greatest single threat to seabird populations next to massive oil spills. Although we do not have extensive data on the effects of different types of aircraft, in 1975 aerial photography efforts by the U.S. Fish and Wildlife Service in a P2V Neptune aircraft resulted in massive departures from the cliffs and an apparently related reduction of reproductive success in murres. Also, the relatively quiet Bell Ranger II helicopter of the NOAA Surveyor caused streams of murres to flush when it approached within a few hundred meters of the cliffs during our experiments and observations in 1976 and 1977. During each of our three years of study Reeves Aleutian Airways passenger aircraft and Coast Guard aircraft would occasionally approach too close to the high cliffs of St. George Island causing similar streams of murres and clouds of kittiwakes to depart the cliffs. Regulations restricting aircraft operation near the cliffs to insure undisturbed nesting areas as well as aircraft safety should be set and enforced. Yet, ultimately, the protection of the seabird colonies from unnecessary disturbance depends on the attitudes of the people living and working in the area of the Pribilofs. Development of a sympathetic attitude towards the potentials and the vulnerability of the seabird colonies through education among the parties involved would produce a more desirable result than would an intensive enforcement effort.

Spilled oil is the greatest potential threat to the ecosystem, hence the seabirds, of the southeast Bering Sea. The pelagic distribution of foraging seabirds is important in predicting the potential impact of an oil spill. If birds are widely dispersed at low densities, only an oil spill covering a vast area can cause serious damage to the entire seabird population. Conversely, if seabirds occur locally in extremely high densities, even a small spill can have devastating effects on the population. Such locally high densities may occur over small foraging grounds particularly rich in prey or in staging areas where birds gather prior to flying into the colony. Devastation of a given species' population will also result if acute or chronic oil spills or discharge of other material greatly reduces the availability of prey items upon which that species depends.

Foraging seabirds range widely in all directions from the Pribilofs. Yet certain areas in which high densities of seabirds regularly occur appear especially critical to the breeding populations (Figure 36). In the near shore waters of all islands high densities of birds occur; these waters are critical as foraging grounds of the cormorants, murres and auklets and

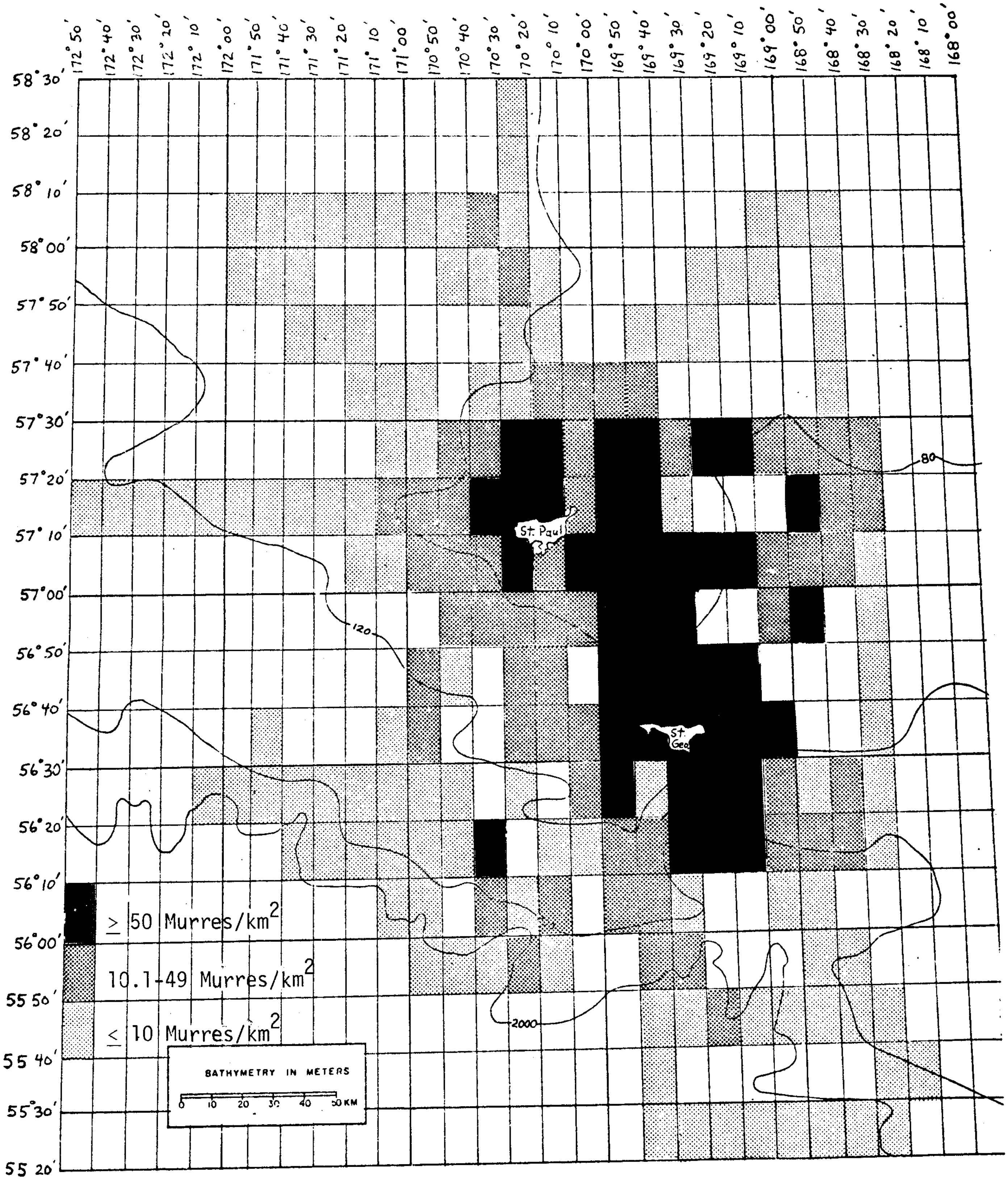


Fig. 36. Areas of High, Medium and Low Sensitivity to Spilled Oil Based on the Highest Average Density of Murres Seen, 1975-1977.

as staging areas of the auklets. Within 15 nautical miles to the east and within 10 nautical miles to the west of St. George Island massive concentrations of murres and auklets occur on the water; in these areas murre concentrations often rise above 500 to 1000 birds per km^2. These flocks are not always encountered in exactly the same location; changes in tides or upwelling may cause prey concentrations to vary in location. Somewhat lesser concentrations of murres are common within 10 nautical miles south of Otter Island and within 40 nautical miles east of St. Paul Island. The waters along and beyond the 200 m isobar of the shelf-break to the south and southwest of St. George also appear to be especially critical foraging areas. These waters are probably the major foraging area from which the Red-legged Kittiwake captures Myctophid lanternfish which rise to the surface during darkness. Also over this wide area large numbers of fulmars, shearwaters, storm-petrels and murres forage. These few, especially critical foraging areas should be protected from oil spills.

Murre young and flightless adults are especially vulnerable to local oil spills. During August murre young jump from the cliffs in a flightless condition and soon thereafter swim from near-shore waters with adults that molt their flight feathers at this time. Since both the young and the adult birds cannot fly during this period, local oil spills would have a devastating effect on them.

Oil floating immediately off-shore would have a serious effect on all seabirds, especially the alcids. Spilled oil washing ashore generally threatens only the small auklets. They frequently land on the boulders of the intertidal zone and would be oiled by residues washed up on the beaches. If heavy residues were storm-driven into the high intertidal zone, oil would possibly reach Least Auklet nest-sites in the boulder beaches. Other species rarely land on the beaches and presumably would not be harmed by beach-cast oil.

The seabird populations reflect the condition of the fishery on which they subsist. Both murre species and the Black-legged Kittiwakes of the Pribilofs depend heavily on pollack and squid. In addition, Hyperiid amphipods are a very important component in the Thick-billed Murre diet; various fish species and euphausids are of major importance to Black-legged Kittiwakes. Red-legged Kittiwakes specialize on fish, especially Myctophids. Severe damage to any of these prey populations because of drilling or transport operations would certainly damage the seabird populations. Conversely, reproductive failures of seabirds may reflect as yet undetected damages to these valuable fisheries.

B. Data as Baseline for Comparison

Our three years of study have produced a data set against which comparisons may be made in the future to judge the relative condition of the Pribilof Island seabird colonies. Hickey and Craighead (1977) provide repeatable population indices with which changes in population size may be monitored. This project has concerned itself primarily with parameters of reproductive biology, pelagic foraging distributions and food habits.

Several parameters within this report reflect the reproductive potential and success of the various seabird populations. Certain of them are particularly relevant to short-term colony-survey operations which may serve to monitor colony status in the future. Breeding phenology is such a parameter: if a population is significantly behind schedule in reaching a certain reproductive stage it will certainly result in lowered reproductive success or even failure whether the cause is weather, food availability or oil operations.

For surveys conducted early in the breeding season, clutch sizes and egg weights will indicate population reproductive potential; these parameters are related to food availability. In the Pribilofs a mean clutch of less than three eggs in the Red-faced Cormorant or disappearance of two-egg clutches in the Black-legged Kittiwake would probably indicate lowered food availability for these species. Belopol'skii (1957) believes that competition for food with murres has resulted in reduced kittiwake clutch size. When fish were scarce in 1942 and 1946 on Novaya Zemlya, kittiwakes consumed less fish and took more crustaceans than in other years; clutches were reduced from 3 to 2 eggs with 30-40 percent of the nest containing a single egg. Although murres lay only a single egg, weights of freshly laid eggs varied from 90 to 132g at the St. George Staraya site. Changes in the mean egg weight may be related similarly to food availability.

For surveys conducted later in the season, fledging weights and the proportion of successful nest structures provides indices of reproductive success. Fledging weights of murre chicks can be readily obtained by capturing them as they jump from cliffs in mid-August. In murres fledging weights are correlated with growth rates within a given cliff section. A close approximation of the fledging success per nest may be obtained for kittiwakes and cormorants by cliff-counts for the ratio of large chicks to nest structures during August. Care must be taken that these counts are made before a major part of the young begin fledging.

The many finer tuned indices of reproductive success generally require observers to remain on the islands for relatively long periods of time. Growth rates, hatching success and fledging success each require observations over periods of not less than three weeks around each specific event.

Any index taken alone may be misleading. For example, in murres the fledging success per hatched chick and mean fledging weight are the indices of colony success least affected by observer disturbance. Yet massive egg losses or poor hatching success resulting from disturbances due to greatly increased human activity in an area would not be reflected in these two indices.

On the Pribilof Islands four species of seabirds are particularly appropriate as indicators of colony health because of their ease of study and/or their large numbers. Red-faced Cormorants breed on the Pribilofs in relatively small numbers which can be accurately censused on at least St. Paul; their habit of often nesting on low ledges makes them especially accessible for observation. The ledge nesting kittiwakes breed in large numbers and are relatively accessible for observation. There exists a broad published literature on the Black-legged Kittiwake; OCSEAP investigators have well studied the widespread Alaskan colonies of this species. The accessible large numbers of Red-legged Kittiwakes on St. George demand that this Bering Sea endemics' most important breeding cliffs be carefully monitored. These two species of kittiwakes are less likely to be directly affected by spilled oil than the alcids. Therefore, the kittiwakes may be most useful as indicators of change in environmental conditions affecting food quality and availability. Thick-billed Murres, the most numerous bird on the Pribilofs are also one of the most vulnerable to disturbance or spilled oil; hence, this species may well provide an index of direct effects of spilled oil or disturbance for comparison. The other breeding seabird species are less accessible and less easy to study on the Pribilofs.

IX. NEEDS FOR FURTHER STUDY

Two kinds of long-term study are of critical importance to OCSEAP management decisions. These involve gaining knowledge through a banding program of movements between colonies and of the life span of the principal species of the seabird community. Without these data the impact of a spill and the rate of recovery of seabird populations cannot be predicted. These needs were discussed in our April 1, 1977 report and in the "white papers" developed by Dr. William H. Drury, Jr. and myself (Appendix II, III and IV).

Also mentioned in last year's annual report are the need for studies of foraging flights of individual birds using radio-tracking so that reproductive success can be linked to foraging areas, studies of the significance of the apparent surplus of individuals in the murre populations to reproductive success of breeding birds and a properly controlled study of the effects of aircraft disturbance on murre reproduction.

An additional study of significance to management decisions within OCSEAP would be to determine why the small auklets fail to breed on a number of coastal sites, such as the Cape Pierce/Cape Newenham, while they are present in numbers in the Pribilofs. Three possible hypotheses for this difference between the two areas are: 1) There are more large avian predators at mainland sites and these birds exclude the small alcids, 2) There is insufficient plankton of a suitable type sufficiently close to the colony to be usable and 3) plankton is present, but the water is too silty for the birds to forage effectively. Since oil development may result in changes in predator populations, damage to plankton populations or increased siltation, learning the cause(s) of the absence of small alcids would be of considerable value to OCSEAP. If, at the same time the food habits of kittiwakes at Cape Newenham could be determined, we might be able to know why that colony has large year to year fluctuations in reproductive success while those on the Pribilofs apparently do not fluctuate greatly.

X. ACKNOWLEDGEMENTS

We thank the National Marine Fisheries Service, Pribilof Island Program for continued support in providing housing, transportation and radio contact on the islands and help with field work. In particular Jack Adams, Ken Dzinbal, Al Groves, Dick Hajny and Mark Keyes on St. Paul Island and Roger Gentry, John Holt, Meolody Roelke, Dick Straud and Harold Thayer on St. George Island did much to ease our task.

We thank the Aleut Communities of St. Paul and St. George Islands who gave us permission to conduct this work, for transportation, support and a variety of different kinds of help. In particular, Gregg McGlashan and Dosy Merculief on St. George Island helped with field work and provided data for the Spring months before we arrived. On St. Paul Island, Phyllis Merculief collected Red-legged Kittiwake stomachs from birds shot by hunters, thereby increasing our knowledge of the food habits of this species.

We thank the many people who aided in identification of food samples. These include Eric Hochberg, Christian Fauchald, Richard Winn, Abe Fleminger, Ken Coyle, Gary Drusca, Mary Wickstern, Kathy Frost, Gerry Sanger and others.

Field work was done by Barbara Mayer, Bill Rodstrom, Sam Sharr, and Ron Squibb with help from Barbara Burgeson, Jeanne Koelling and Maura Naughton. Colony data were analysed primarily by Ron Squibb, at sea data by Bill Rodstrom and foods identifications by Barbara Mayer. Data management has been in the care of Grace Bush. Thanks go to Patricia Hindman and Barbara Burgeson for typing the report. Faye Alexander and Barbara Burgeson did the illustrations.

XI. Summary of Twelfth Quarter Activities

A. Ship and Laboratory Activities

1) Ship or field-trip schedule - not applicable
2) Scientific party

George L. Hunt, Jr.	Principal Investigator	Department of Ecology and Evolutionary Biology University of California Irvine, California
Barbara Mayer	Assistant Specialist	
Grace Bush	ADP Coder	
Bill Rodstrom	Laboratory Assistant	
Ron Squibb	Laboratory Assistant	

3) Field Sampling or Laboratory Analysis
   Food samples gathered during the 1977 field season were analysed.
4) Sample localities - not applicable
5) Data Analysed or Collected
   Data collected during the 1977 field season on reproductive success and at-sea distribution were analysed for inclusion in the 1 April 1978 annual report
6) Milestone chart and digital data submission schedules
   See attached
7) Meetings
   a) Hunt, Mayer, Rodstrom and Squibb attended the Pacific Seabird Group meeting at Victoria, British Columbia in January and participated in a workshop on the breeding biology and variations in reproductive success of Black-legged Kittiwakes organized by Hunt. As a result of this meeting three "white papers" (see Appendix II, III, and IV) were developed. Dr. William H. Drury took a major role in the collaborative authorship of these papers. The breeding biology of Puffins was also covered in a workshop.
   b) Hunt attended a meeting in Boulder, Colorado on 20-22 March 1978 to discuss ADP for bird colony data. This meeting served to deliniate the kinds of data to be taken in colony studies and the formats to be used in ADP.
   c) Hunt also attended a meeting in Seattle, Washington 26-28 March 1978 for a review of the OCSEAP program by the Office of Management and Budget. During this meeting there was also the opportunity to discuss the relationship of bird distribution and fish distribution with personnel of the National Marine Fisheries Service, Northwest Fisheries Center.

B. Problems Encountered

Most all aspects of the field work are going smoothly and no major problems are anticipated. Data flow to NODC has been greatly speeded by having a full-time coder. The acquisition of a Field Data Entry System should further smooth our data processing operation.

MILESTONE CHART

PROJECT: PRIBILOF ISLAND SEABIRDS   PRINCIPAL INVESTIGATOR: GEORGE L. HUNT JR   DATE:

MILESTONE: PLANNED △ COMPLETED ▲
ACTIVITY START ├──┤ END

1978

	MAJOR MILESTONES/ACTIVITIES
1	Submission of 1977-78 Annual Report
2	1st cruise - Surveyor, bird survey
3	1st PROBES cruise
4	2nd PROBES cruise
5	3rd PROBES cruise
6	2nd cruise - Disco
7	3rd cruise - Disco
8	Bill Rodstrom at St. Paul Is. 1978 season
9	Ron Squibb at St. George Is. 1978 season
10	Maura Naughton at St. Paul Is. 1978 season
11	George Hunt at St. Paul Is. 1978
12	Barbara Braun at St. Paul Is. 1978
13	Mary Pitts at St. George Is. 1978
14	Quarterly Reports to NOAA
15	Submission of 1975-033 Data
16	Submission of 1976-033 Data
17	Submission of 1977-033 Data-ship
18	Submission of 1977-033-Helicopter
19	Submission of 1977-035 Colony Data
20	Submission of 1975-77-035 Foods Data
21	Aerial Survey of at sea bird distribution
22	Analysis of 1978 Colony Data
23	Analysis of 1978 Cruise Data
24	Analysis of 1978 Foods Data
25	
26	
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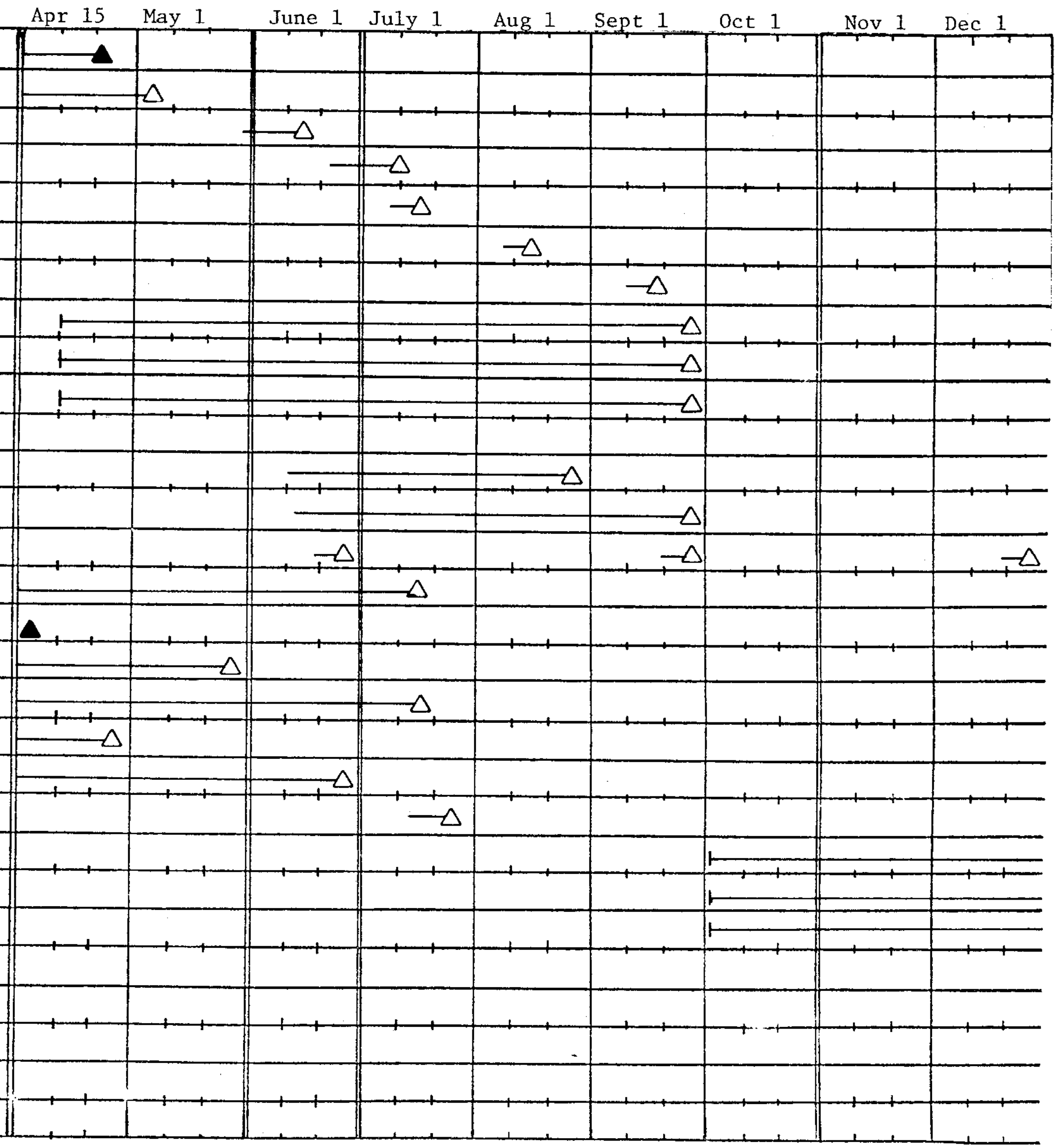
28	
29	



Status of Cruise and Colony Data

	Coded	Keypunched	Data Documentation	Taped	Delivered to NODC	Corrected and returned
Cruises - 033						
1975 Discoverer	UCI501	→	→	→	→	- - -→ 6/1/78
1976 Moana Wave I	UCI601	→	→	→	→	→
1976 Moana Wave II	UCI602	—	—	—	—	—
1977 Surveyor I	UCI701	→	- - -→	6/1/78	6/15/78	
1977 Surveyor II	UCI702 →	- - -	- - -→	6/1/78	6/15/78	
1977 Helicopter I	UCI703	- - -	- - -	- - -→	7/15/78	
1977 Helicopter II	UCI704	- - -	- - -	- - -→	7/15/78	
Colony - 035						
035SP7BLK	→	→	→	5/10/78	5/15/78	
035SP7RLK	→	→	→	5/10/78	↓	
035SP7CMU	→	→	→	5/10/78	↓	
035SP7TBM	→	→	→	5/10/78	↓	
035SP7NFU	→	→	→	5/10/78	↓	
035SP7RFC	→	4/28/78	→	5/10/78	↓	
035SP7HPU	→	→	→	5/10/78	↓	
035SG7BLK	→	→	→	5/10/78	↓	
035SG7RLK	→	→	→	5/10/78	↓	
035SG7CMU	→	→	→	5/10/78	↓	
035SG7TBM	→	→	→	5/10/78	↓	
035SG7NFU	→	→	→	5/10/78	↓	
035SG7RFC	→	4/28/78	→	5/10/78	↓	
Foods	→	7/15/78	- - -	- - -	- - -→	

SP7: St. Paul Island 1977
SG7: St. George Island 1977
BLK - Black-legged Kittiwake
RLK - Red-legged Kittiwake
CMU - Commun Murre
TBM - Thick-billed Murre
NFU - Northern Fulmar
HPU - Horned Puffin
RFL - Red-faced Cormorant

—— Completed

- - - Estimated dates to be delivered to NODC

All 1975 and 1976 colony data have been submitted to NODC

Summary of money expended

	Total appropriated 1975 - 1978	Total expended 1975 - 31 Mar 1978	Balance as of 31 Mar 1978
Salaries	$108,714	$78,977	$29,737
Employee benefits	16,928	7,882	8,146
Supplies	20,499	13,262	7,237
Equipment	8,647	8,790	193
Travel	37,966	25,019	12,947
Other	7,538	2,177	5,361
	$199,392	$136,107	$63,285

As of present estimates, there are adequate funds to complete the work contracted for through 30 September 1978.

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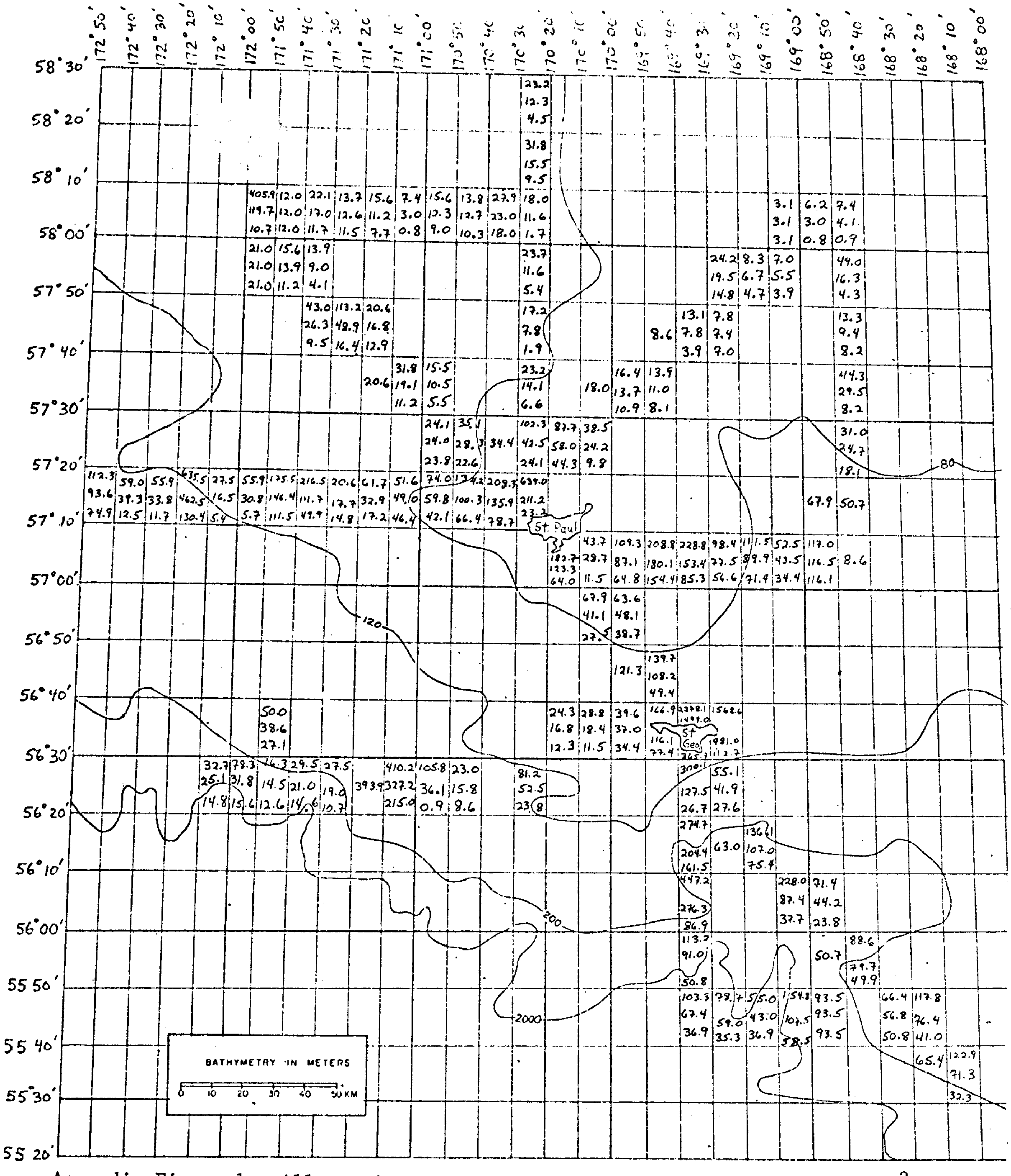
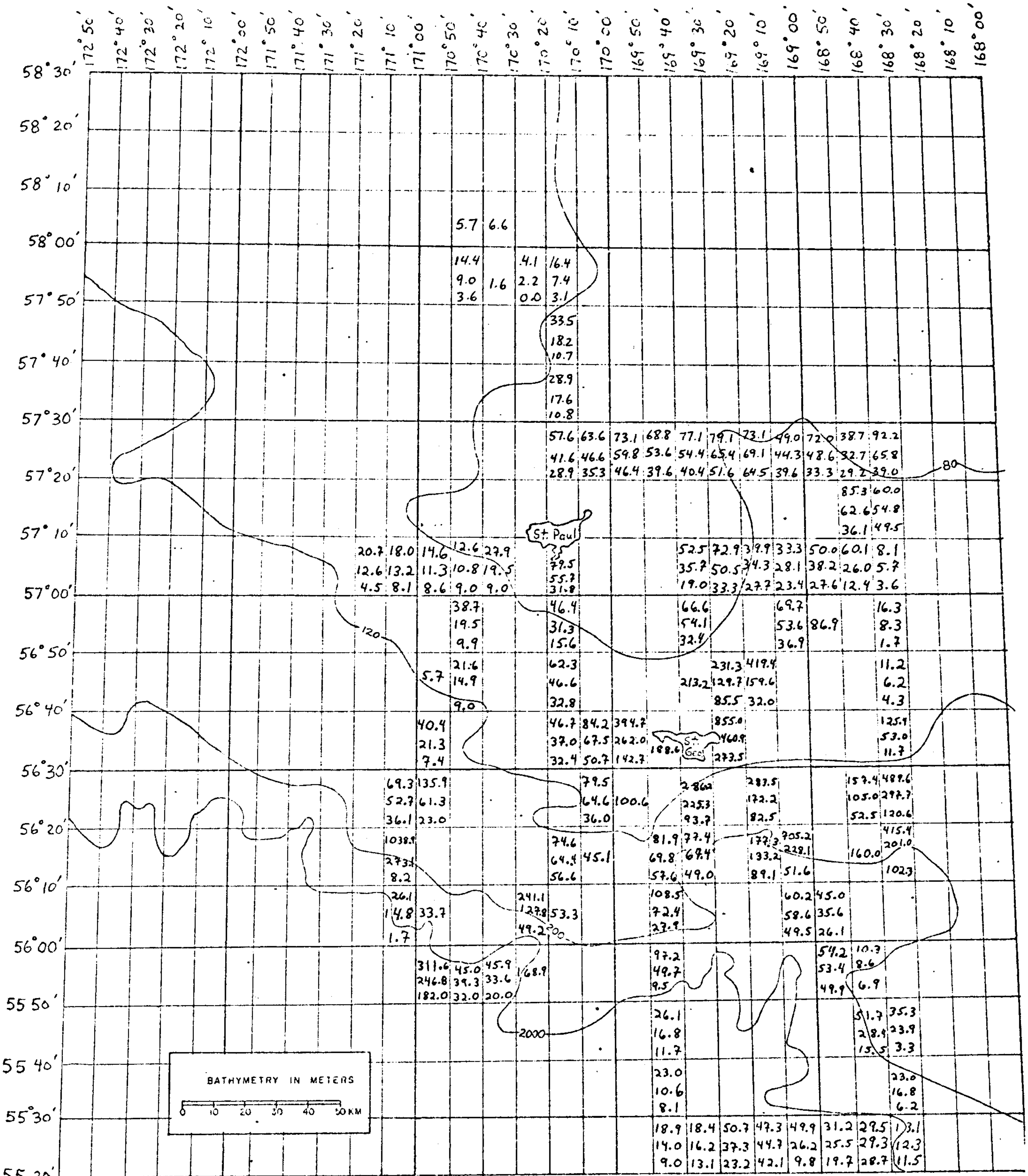
APPENDIX I

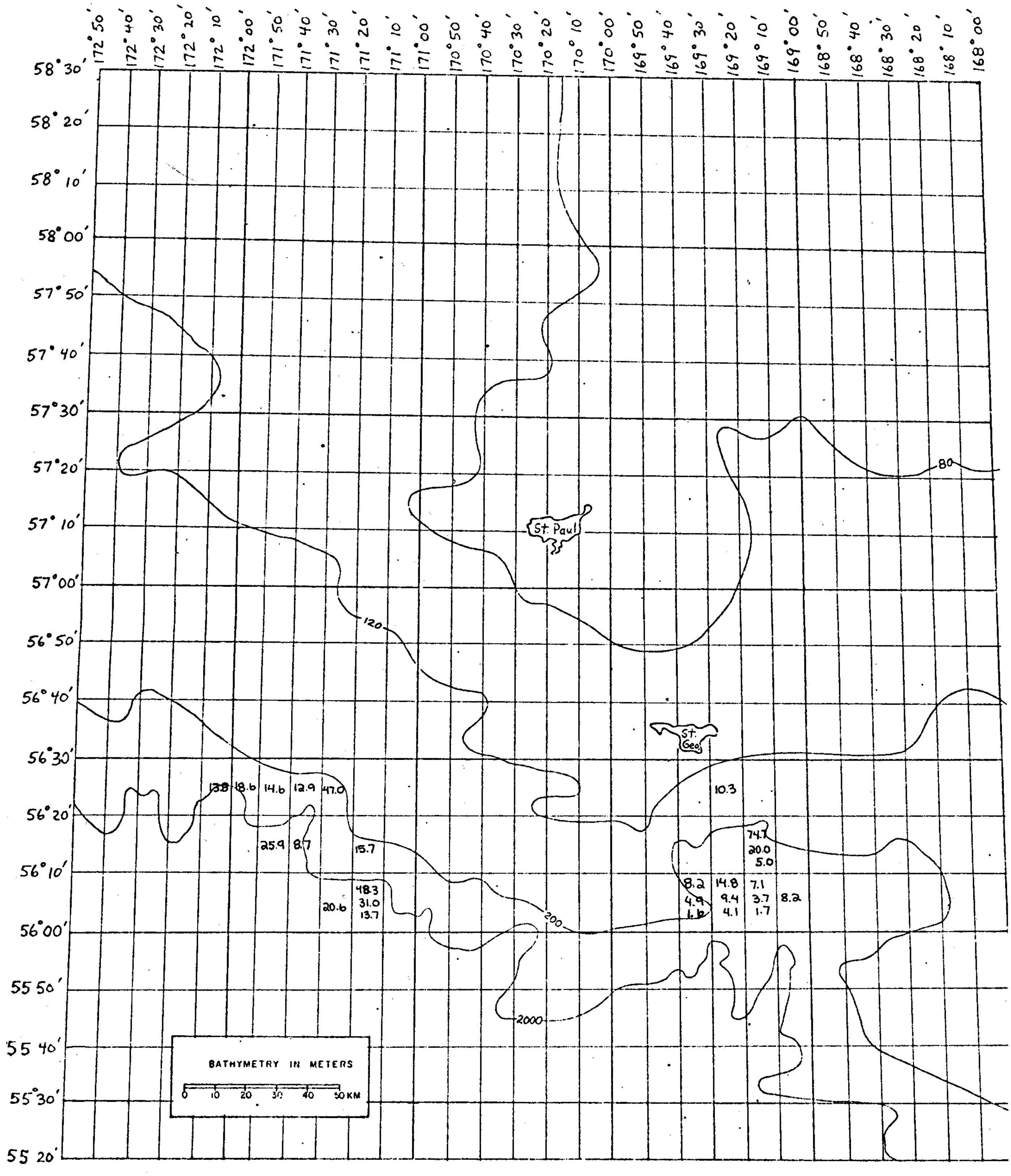
Figures 1 - 44 in Appendix I show densities of seabirds observed on the cruises of the R/V Surveyor, 7-11 July and 1-5 August 1977.



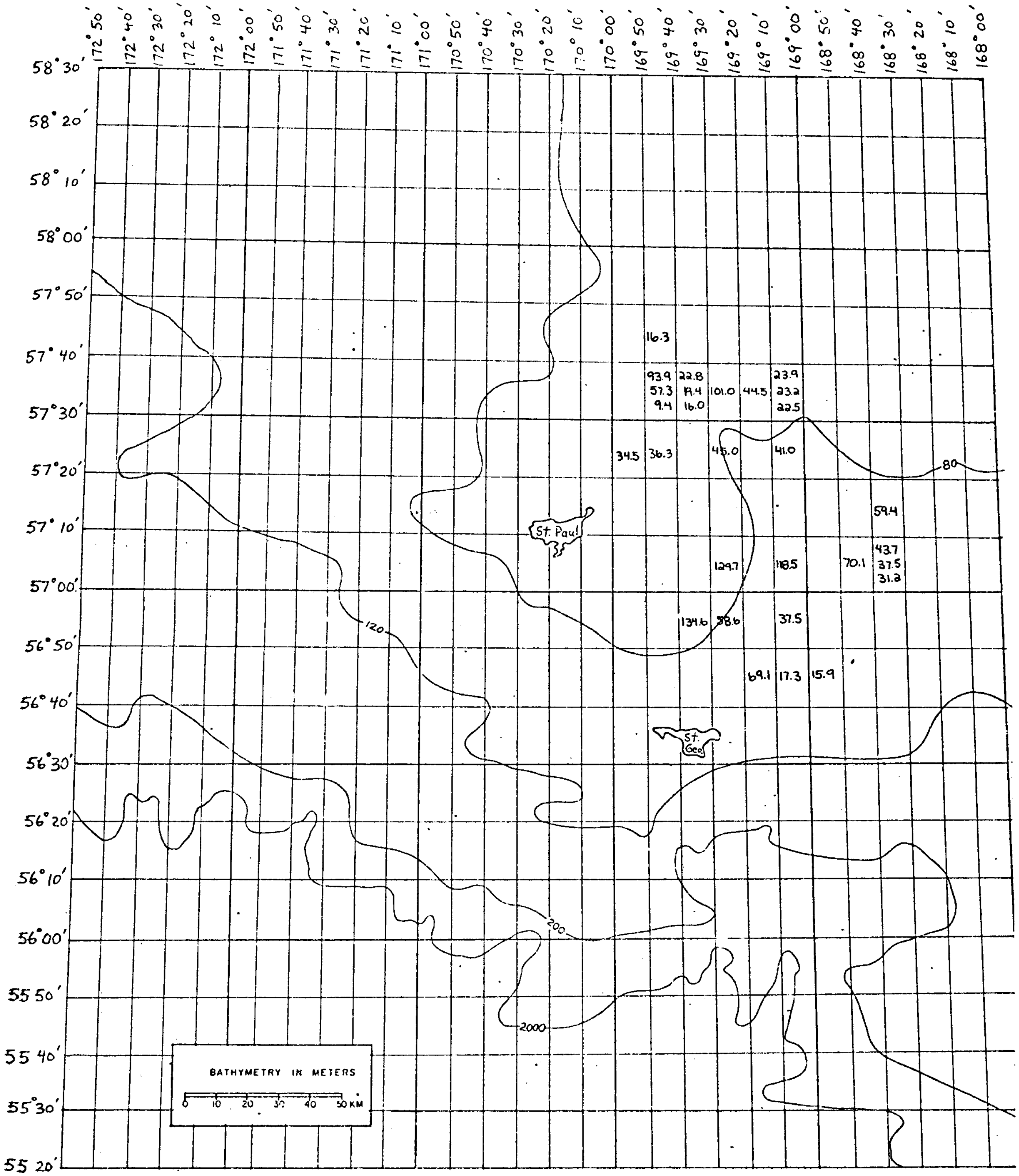
Appendix Figure 1. All species combined maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 7-11 July 1977.



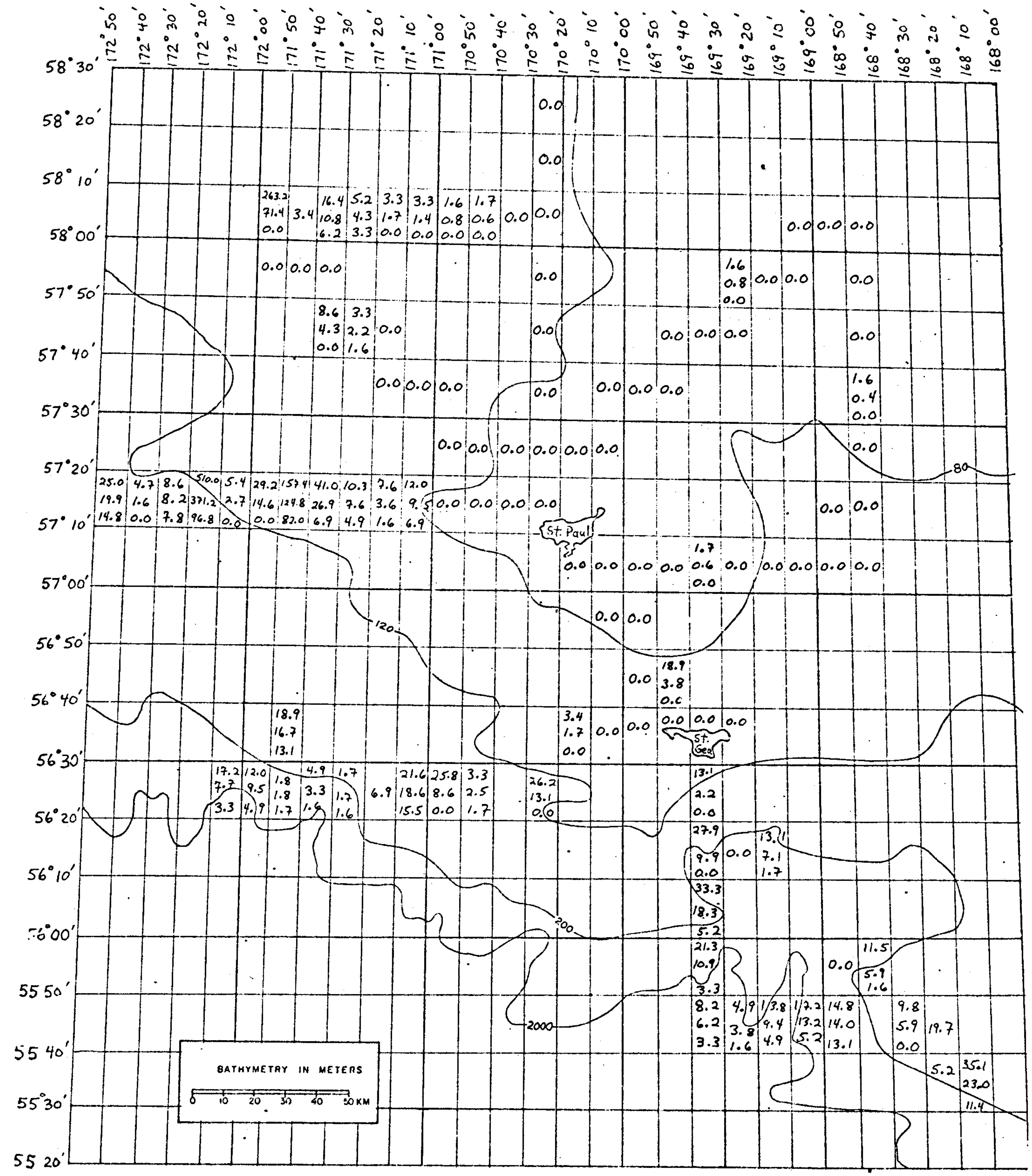
Appendix Figure 2. All species combined maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.



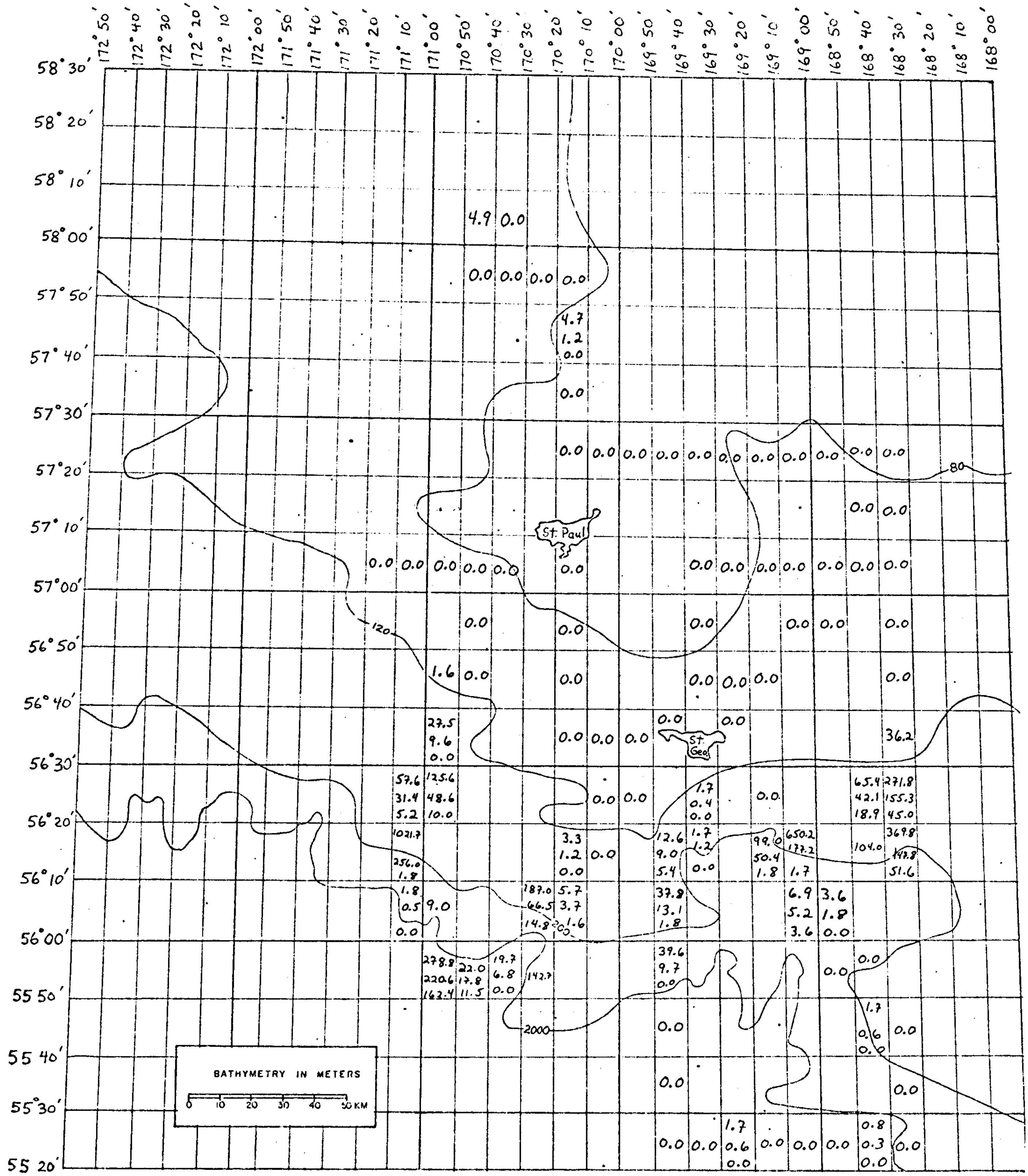
Appendix Figure 3. All species combined - maximum, mean, and minimum birds/km^2 for all analyzed helicopter transects within each 10' x 10' block, 7-11 July 1977.



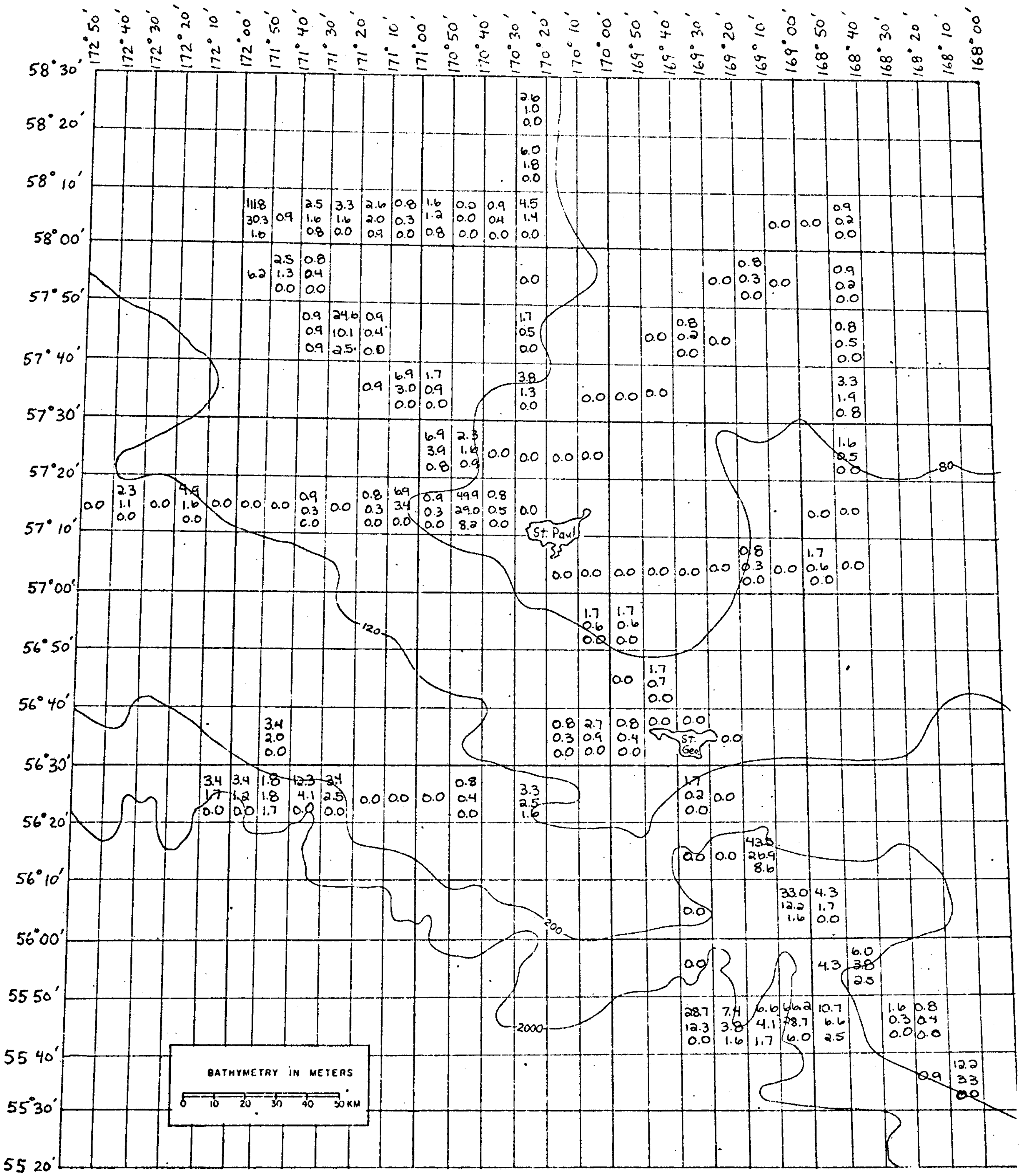
Appendix Figure 4. All species combined - maximum, mean, and minimum birds/km^2 for all analyzed helicopter transects within each 10' x 10' block, 1-5 August 1977.



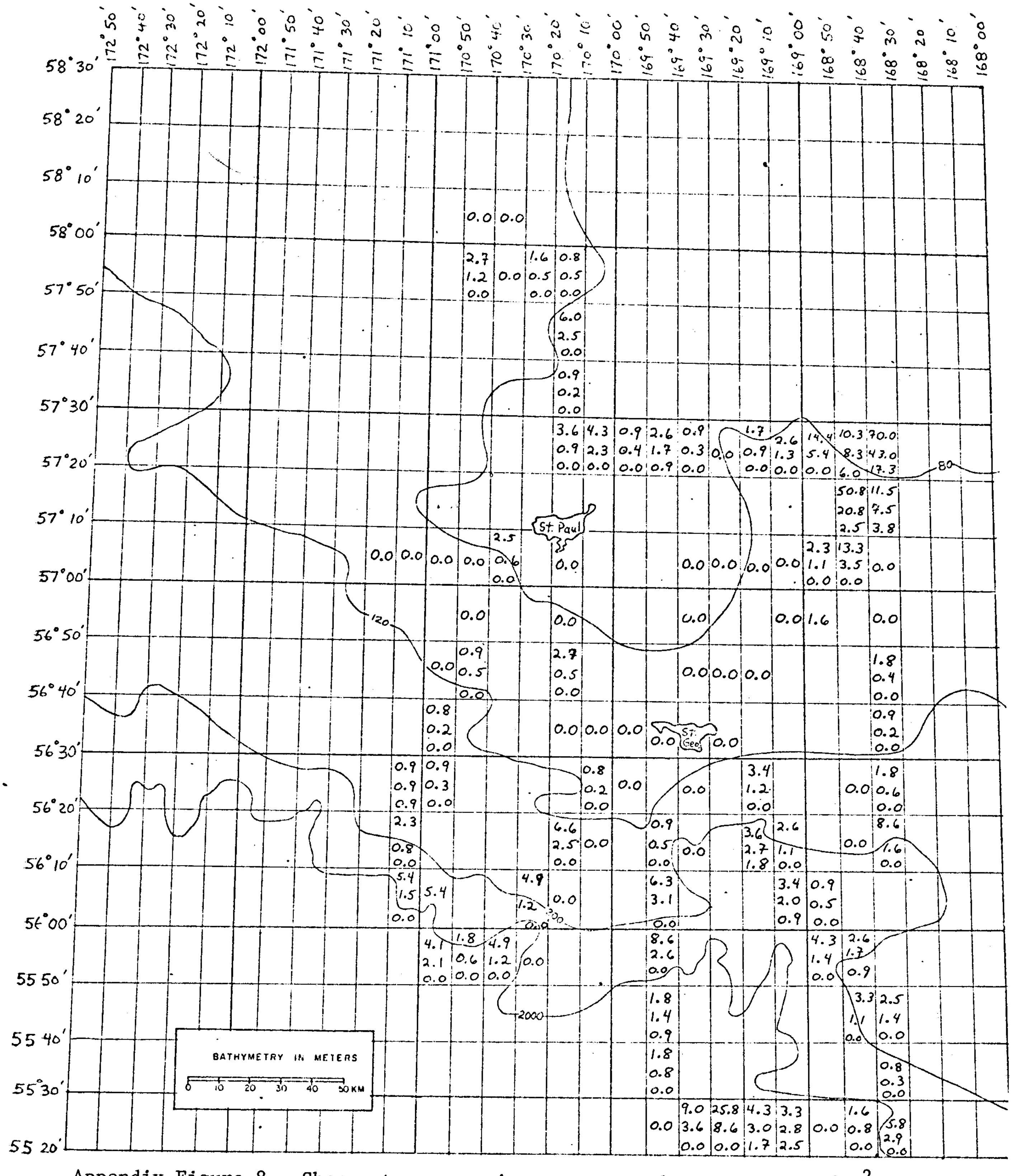
Appendix Figure 5. Storm-petrel - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 7-11 July 1977.



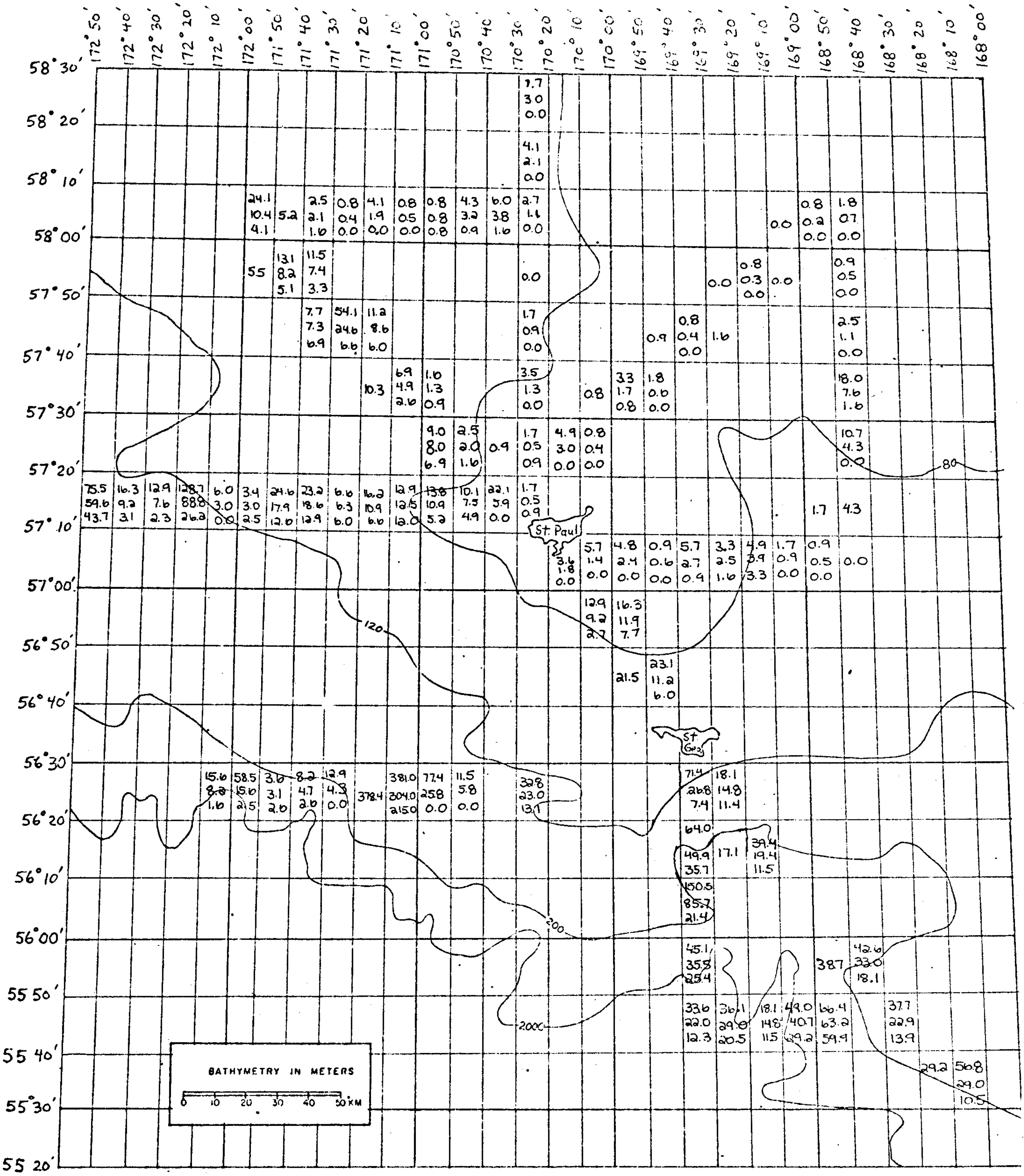
Appendix Figure 6. Storm-petrel - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.



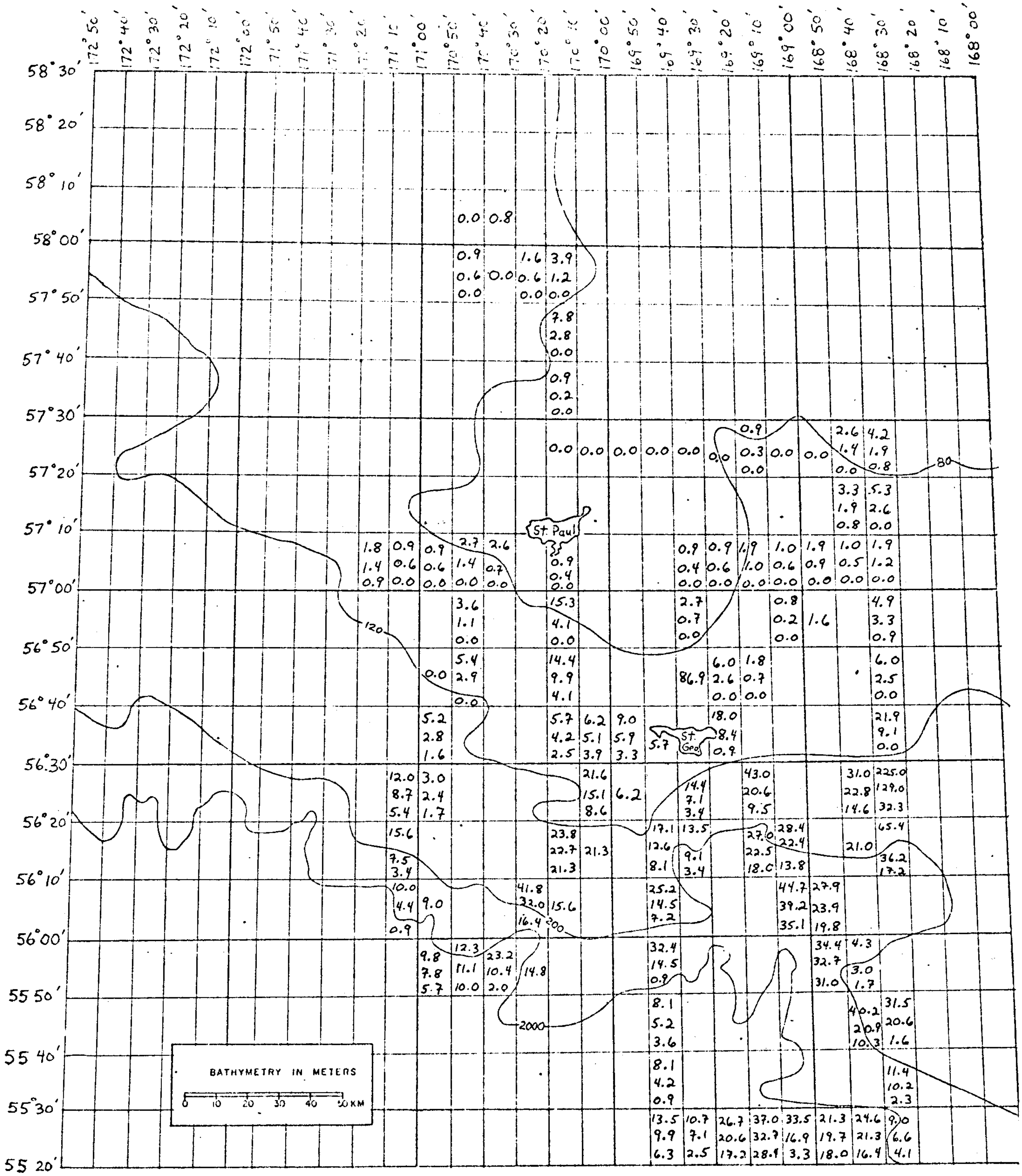
Appendix Figure 7. Shearwaters - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 7-11 July 1977.



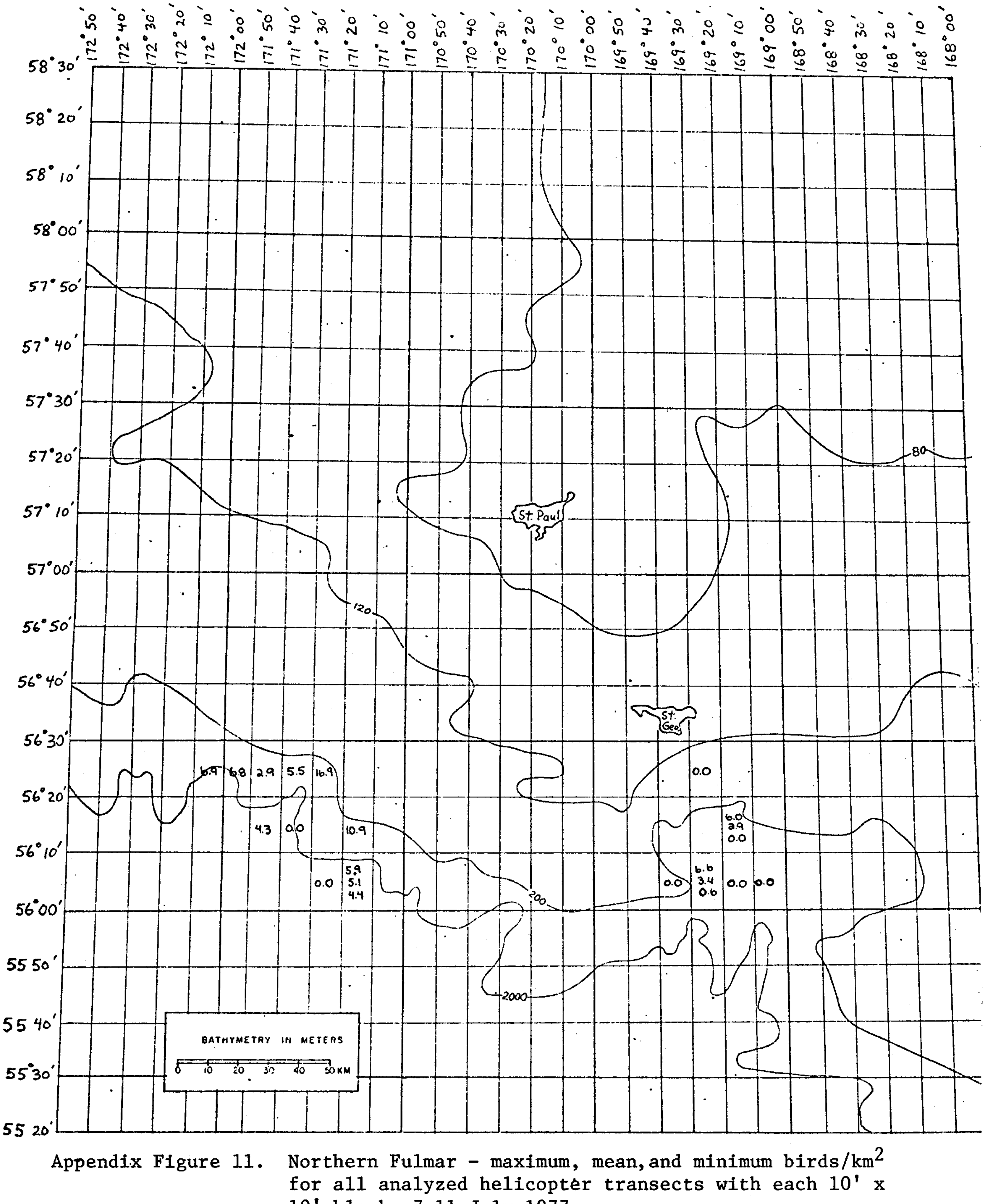
Appendix Figure 8. Shearwaters - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.



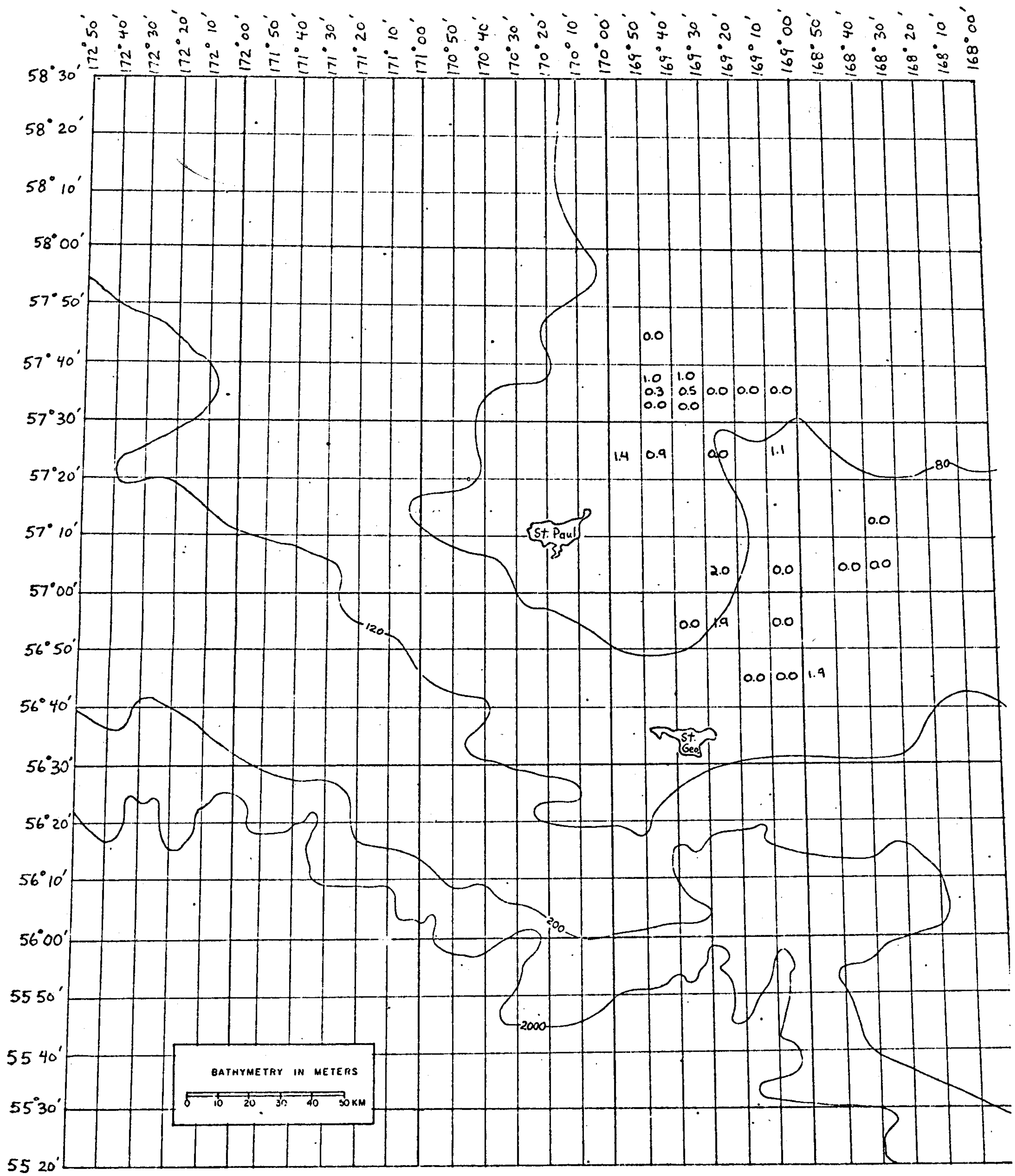
Appendix Figure 9. Northern Fulmar - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 7-11 July 1977



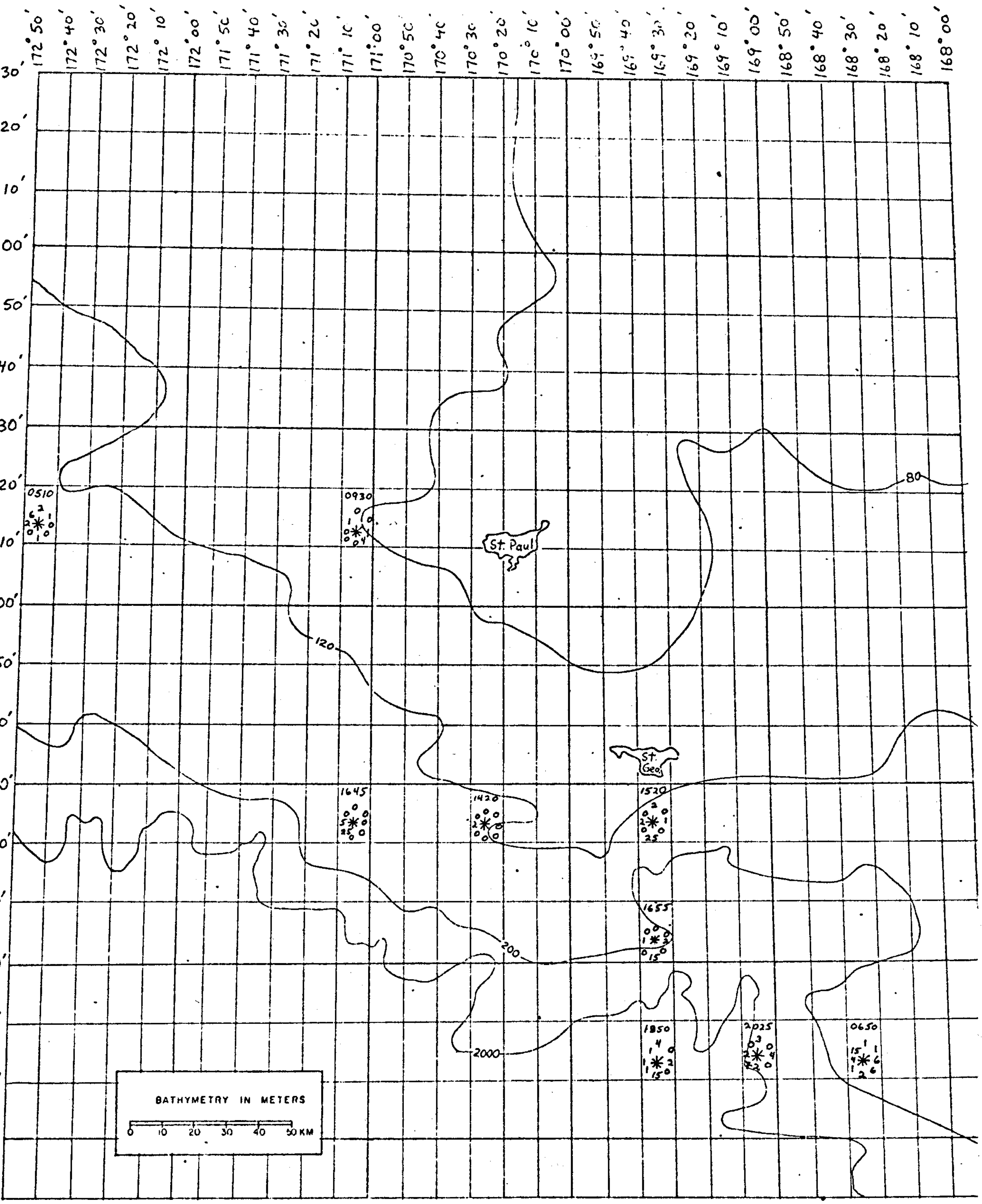
Appendix Figure 10. Northern Fulmar - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.



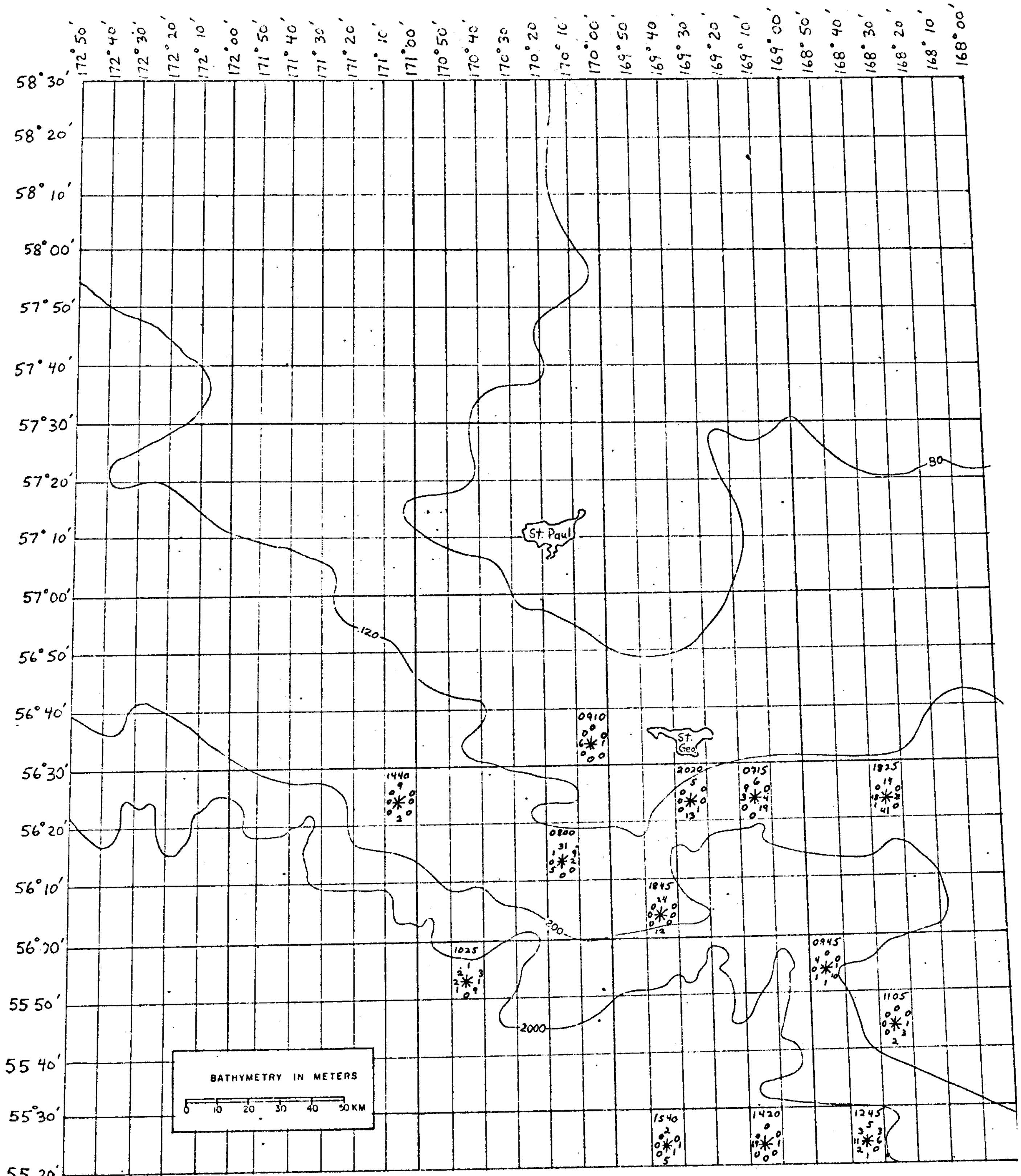
Appendix Figure 11. Northern Fulmar - maximum, mean, and minimum birds/km^2 for all analyzed helicopter transects with each 10' x 10' block, 7-11 July 1977.



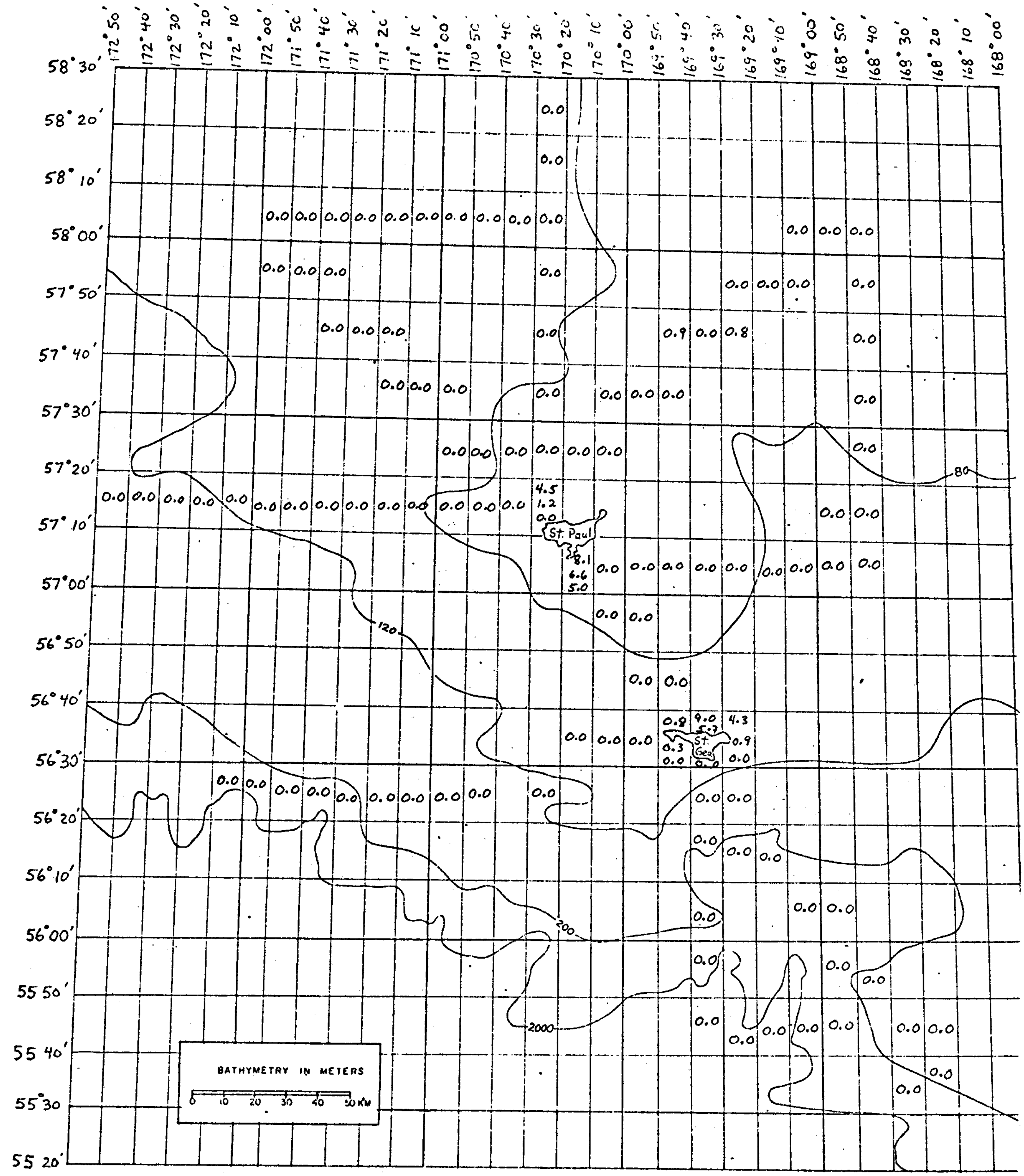
Appendix Figure 12. Northern Fulmar - maximum, mean, and minimum birds/km^2 for all analyzed helicopter transects within each 10' x 10' block, 1-5 August 1977.



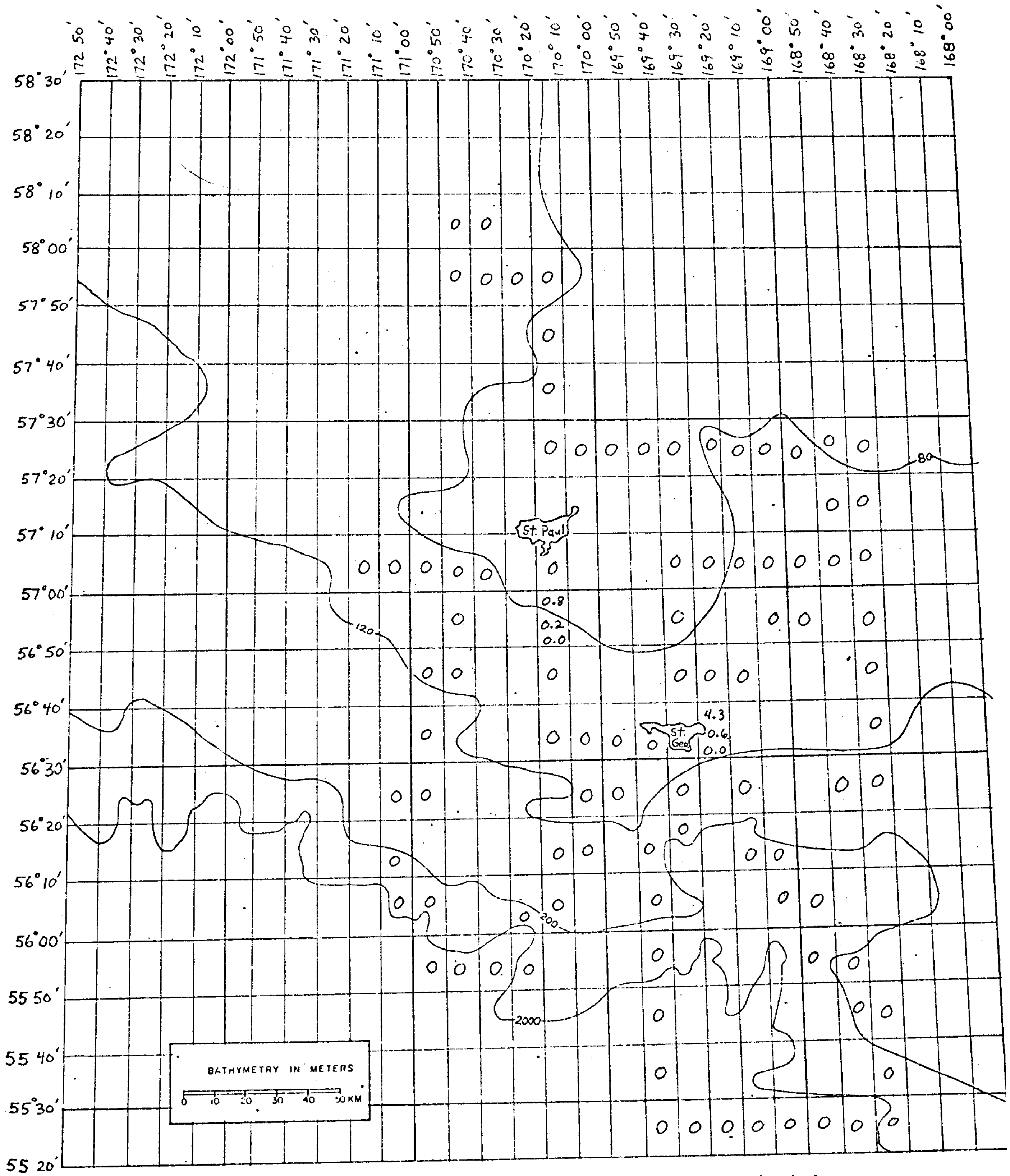
Appendix Figure 13. Northern Fulmar - numbers of flocks flying in indicated directions at times (BDT) specified at top of 10' x 10' block, 7-11 July 1977.



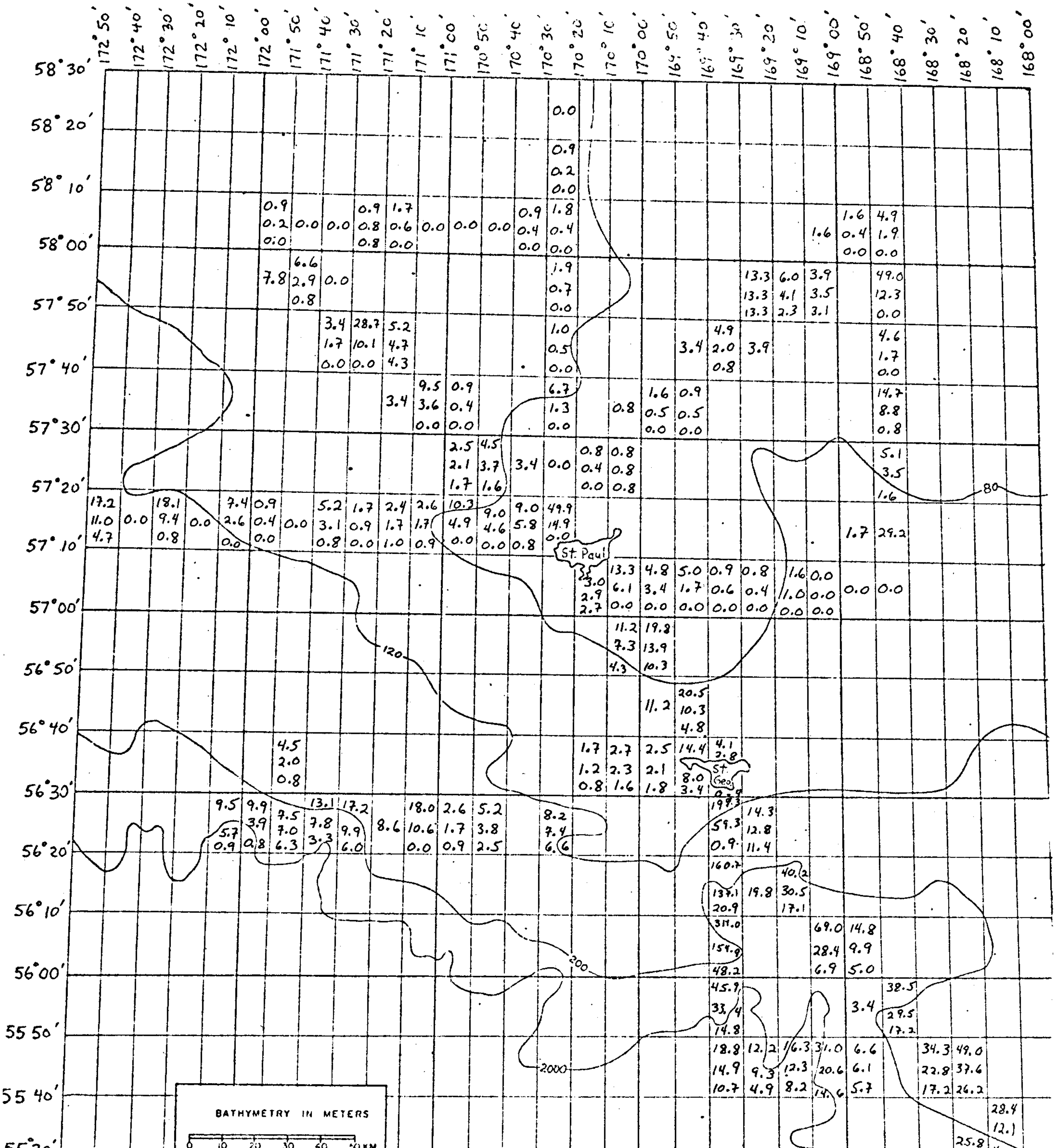
Appendix Figure 14. Northern Fulmar - numbers of flocks flying in indicated directions at times (BDT) specified at top of 10' x 10' block, 1-5 August 1977.



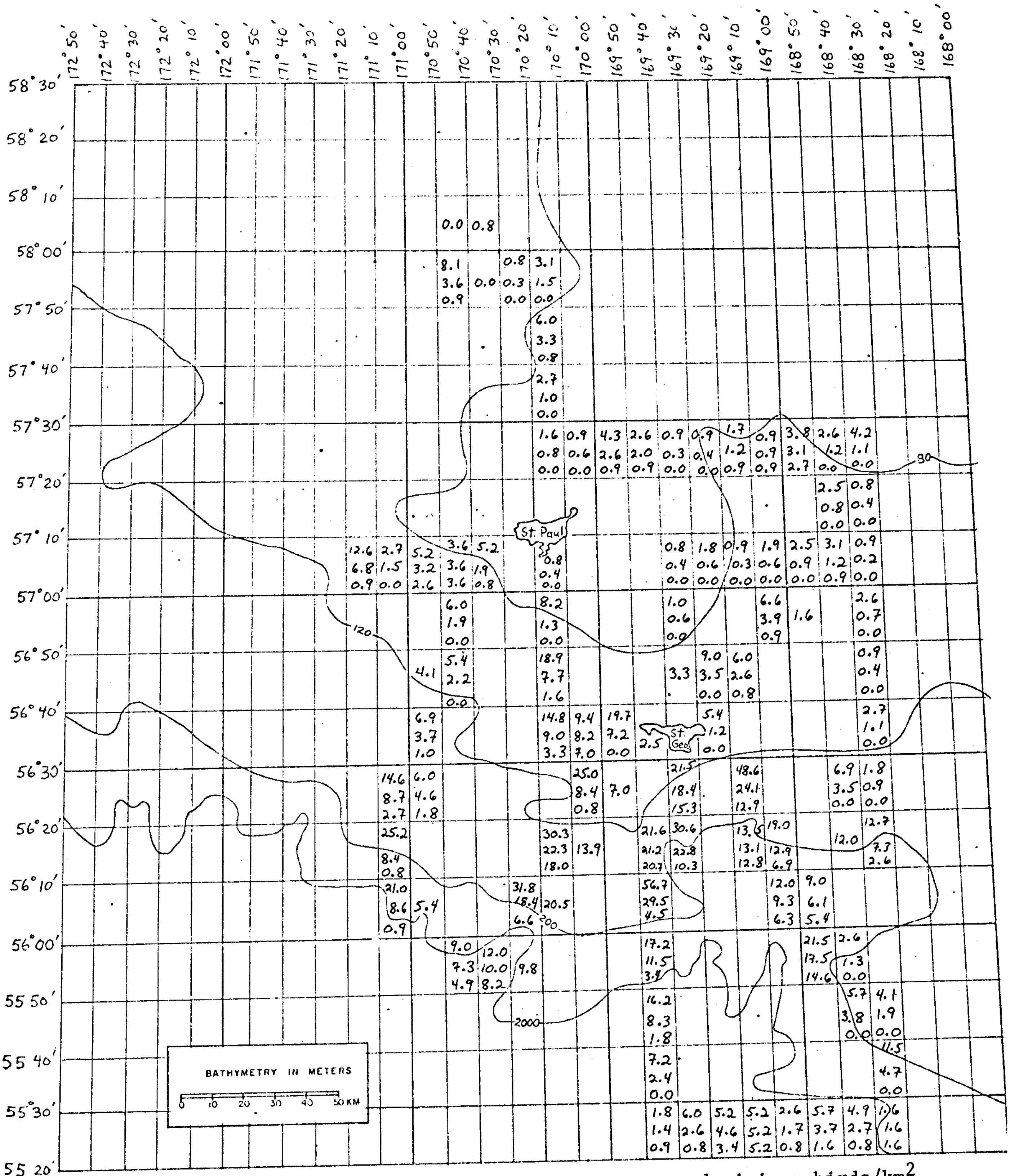
Appendix Figure 15. Red-faced Cormorant - maximum, mean and minimum birds/km^2 for all ship transects within each 10' x 10' block, 7-11 July 1977.



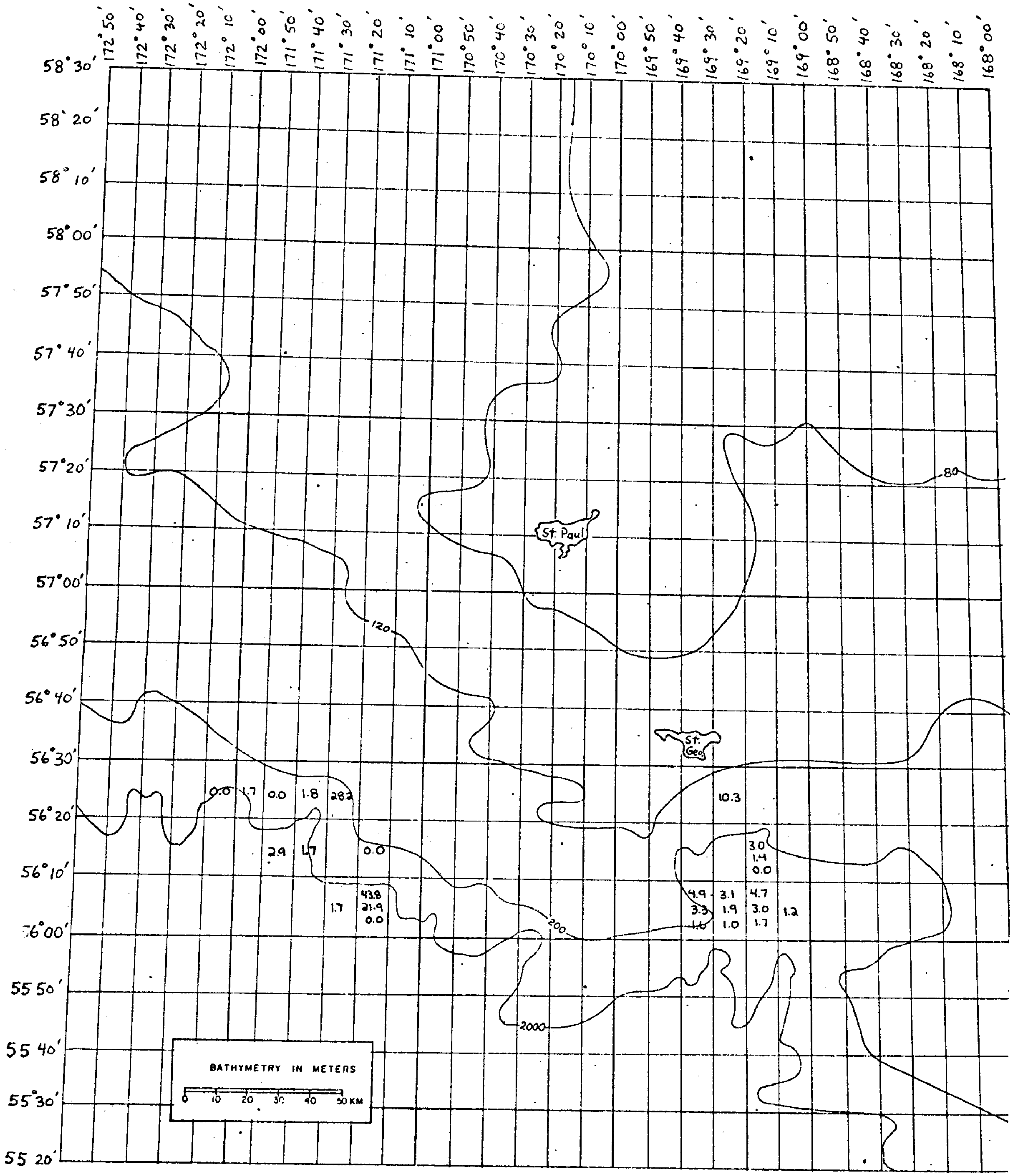
Appendix Figure 16. Red-faced Cormorant - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.



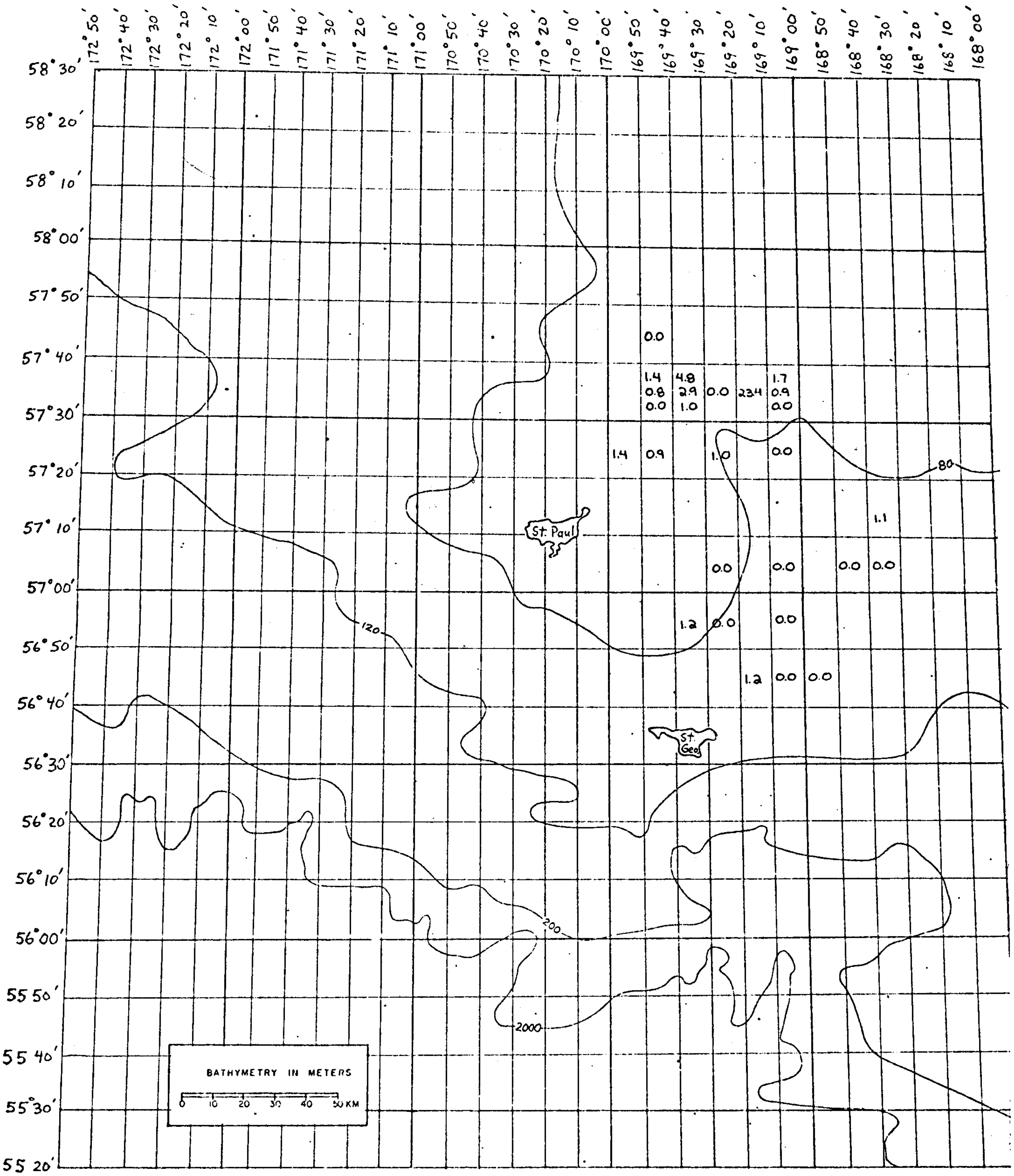
Appendix Figure 17. All kittiwakes - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block. 7-11 July 1977.



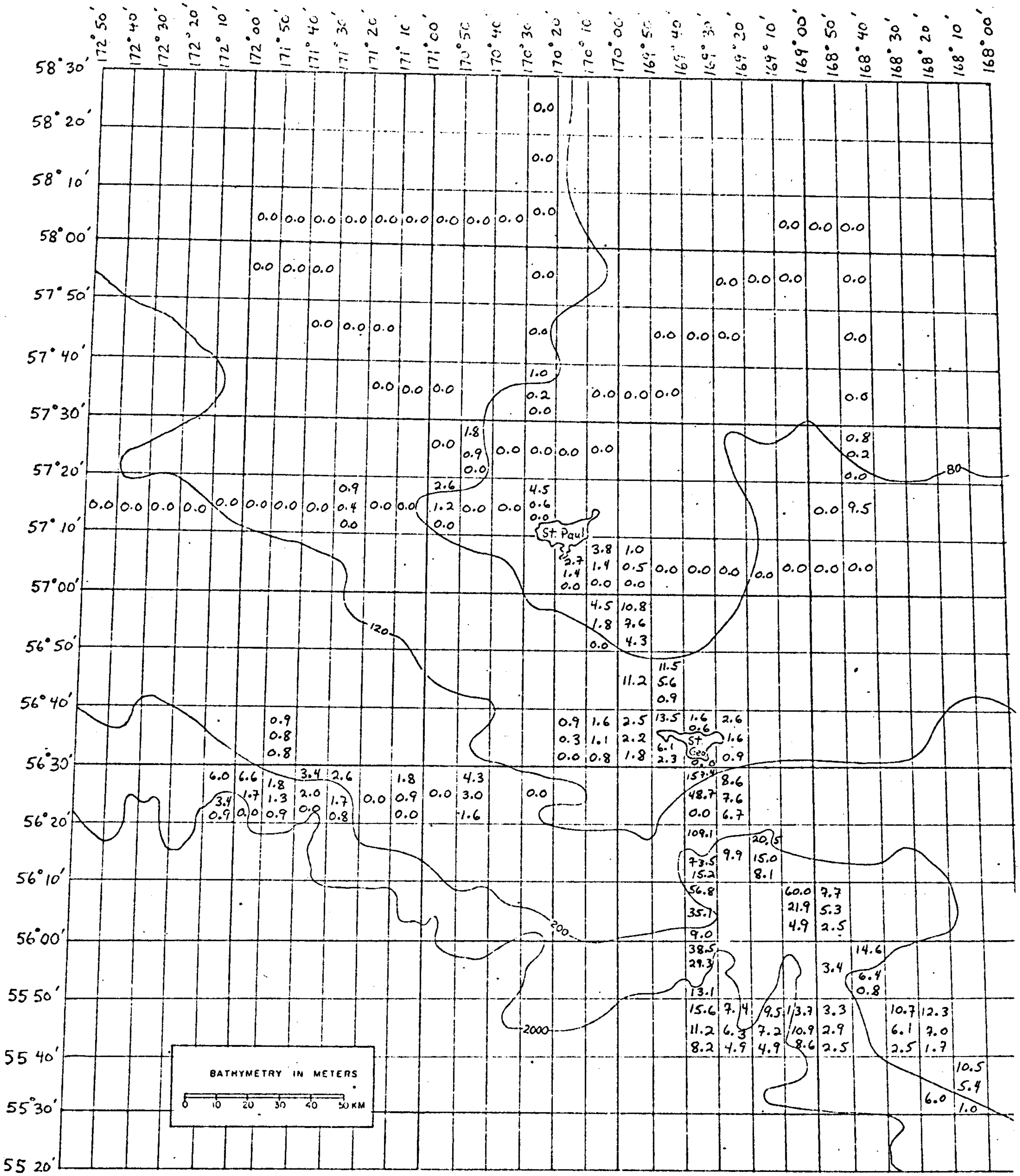
Appendix Figure 18. All kittiwakes - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.



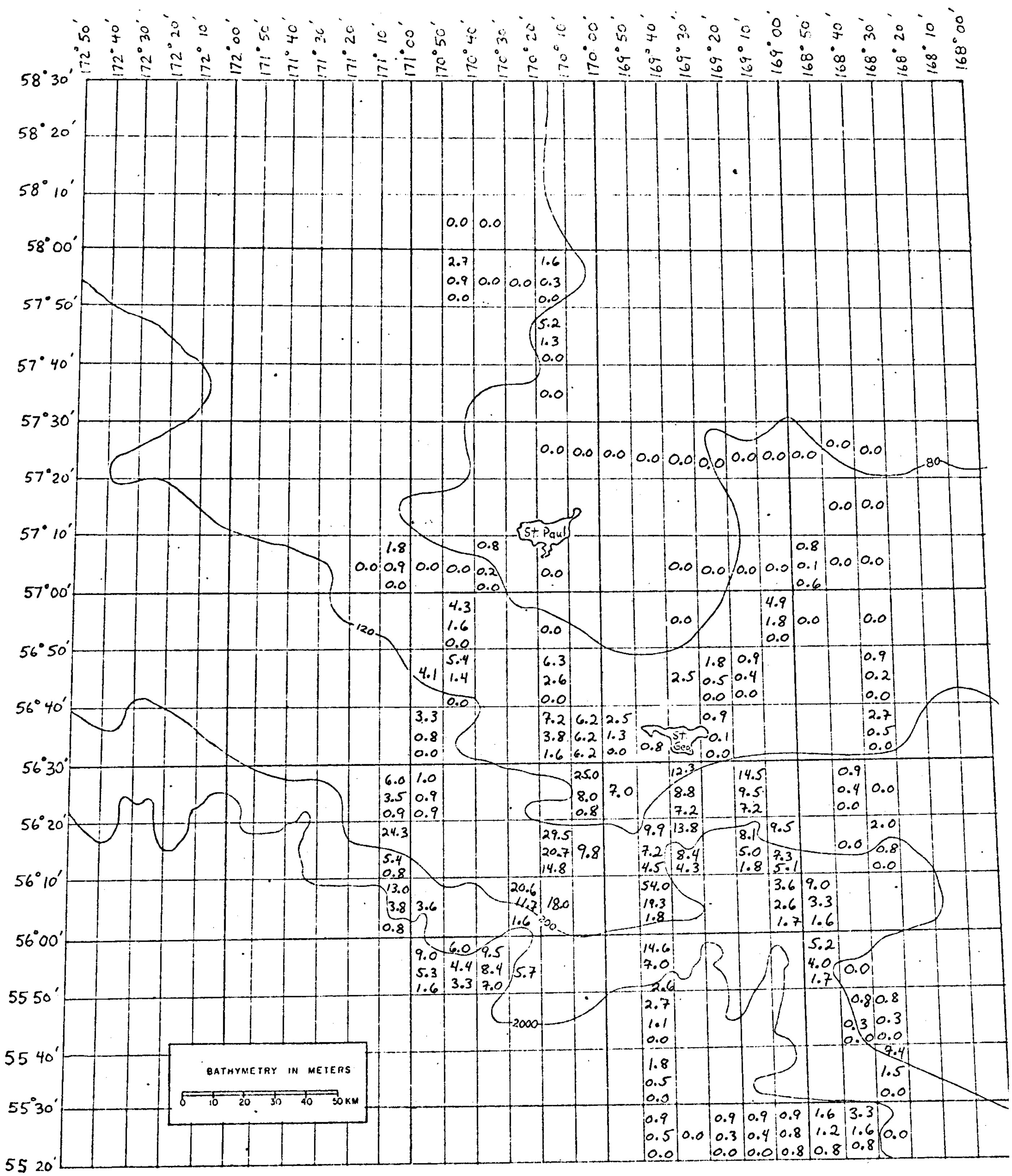
Appendix Figure 19. All kittiwakes - maximum, mean, and minimum birds/km^2 for all analyzed helicopter transects within each 10' x 10' block, 7-11 July 1977.



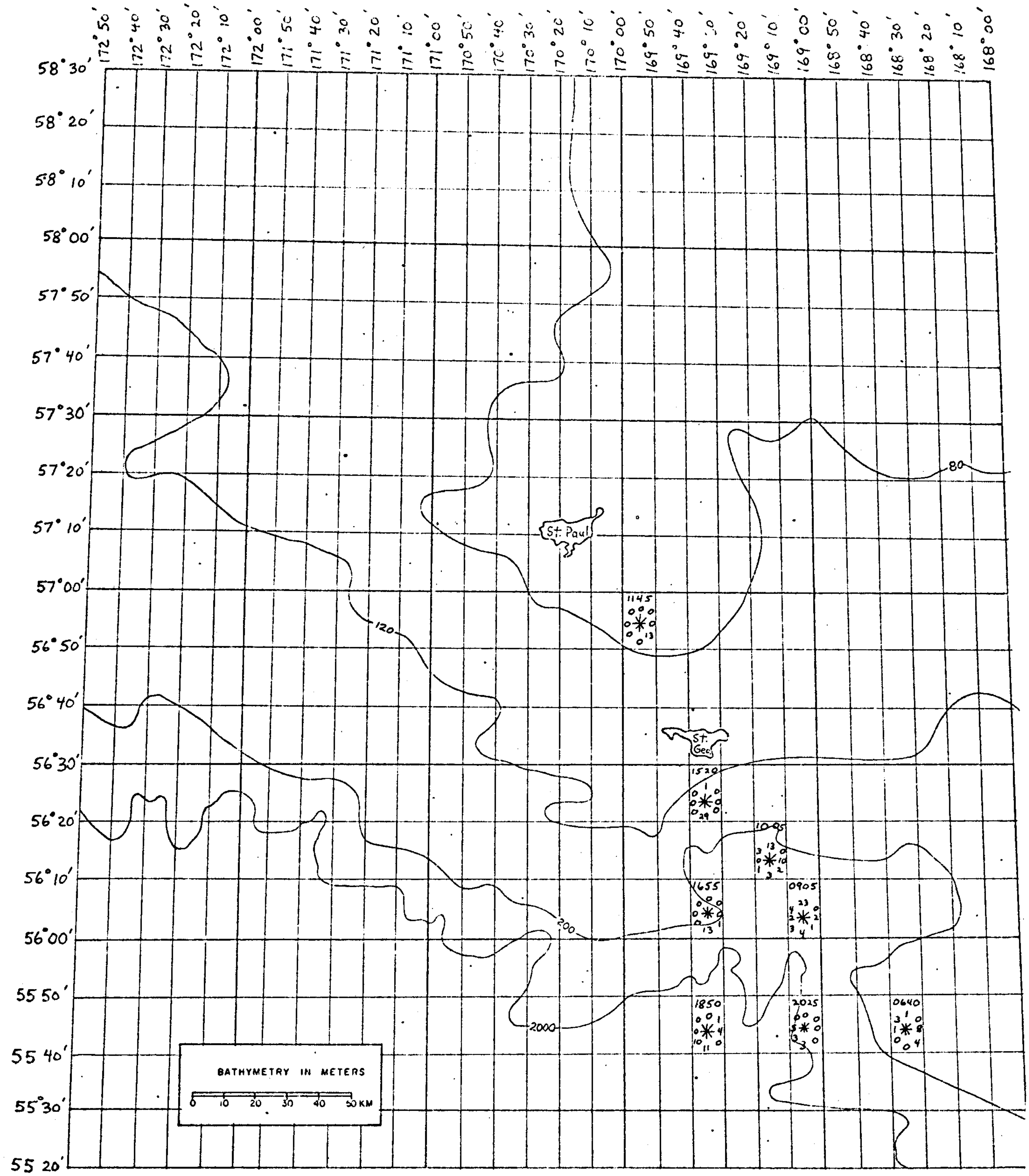
Appendix Figure 20. All kittiwakes - maximum, mean, and minimum birds/km^2 for all analyzed helicopter transects within each 10' x 10' block, 1-5 August 1977.



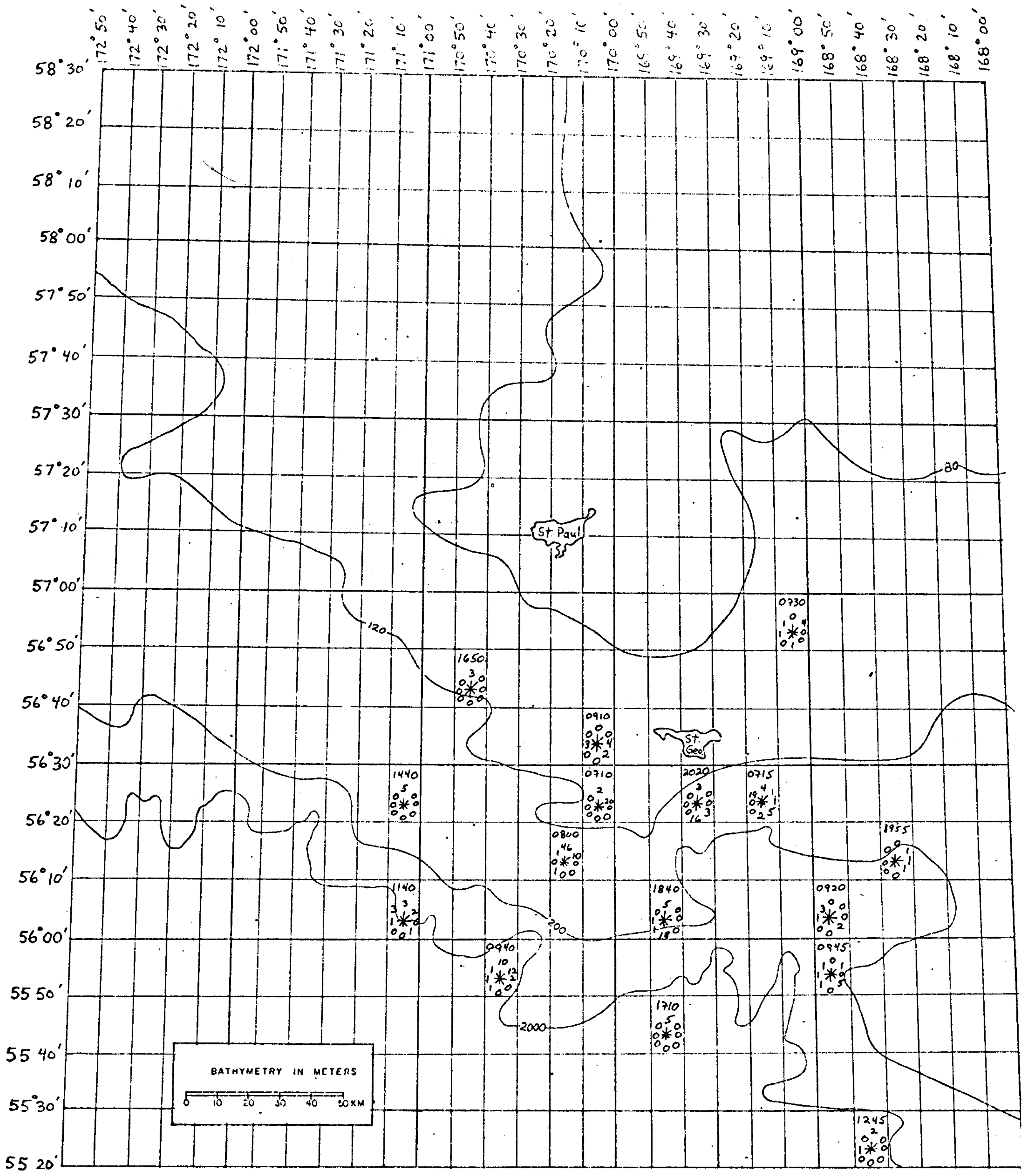
Appendix Figure 21. Red-legged Kittiwake - maximum, mean, and minimum birds/km² for all ship transects within each 10' x 10' block, 7-11 July 1977.



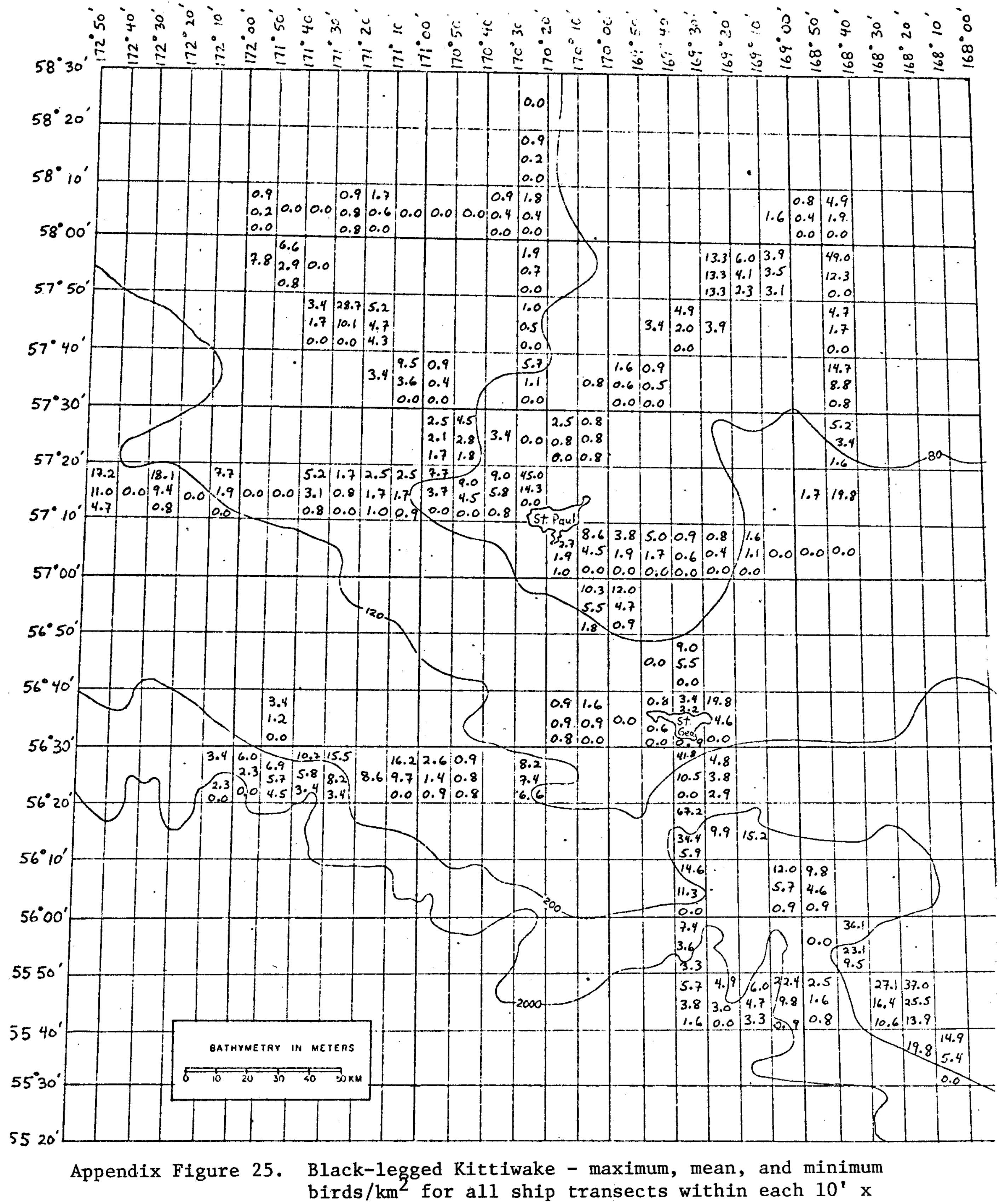
Appendix Figure 22. Red-legged Kittiwake - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.



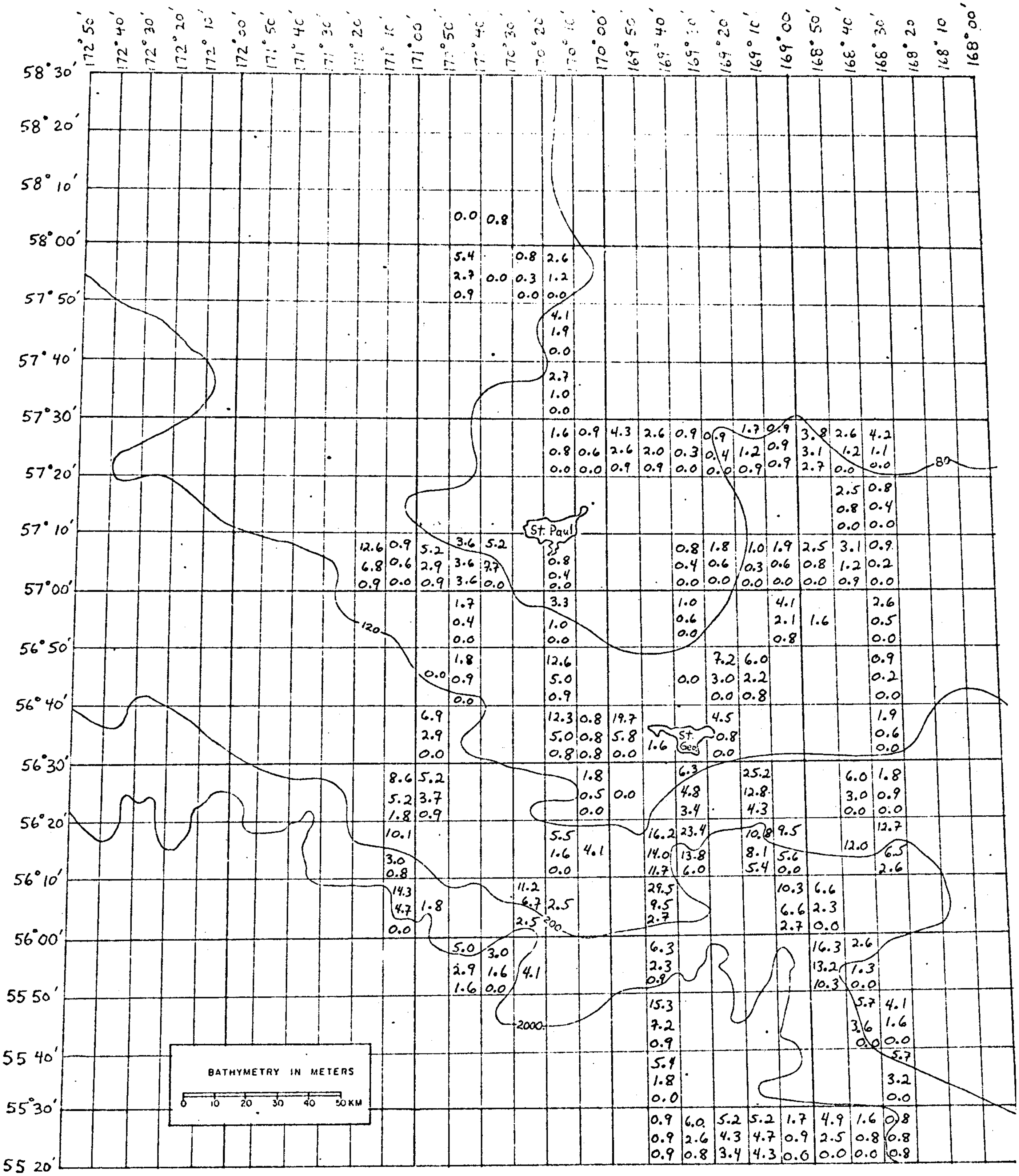
Appendix Figure 23. Red-legged Kittiwake - number of flocks flying in indicated directions at times (BDT) specified at top of 10' x 10' block, 7-11 July 1977.



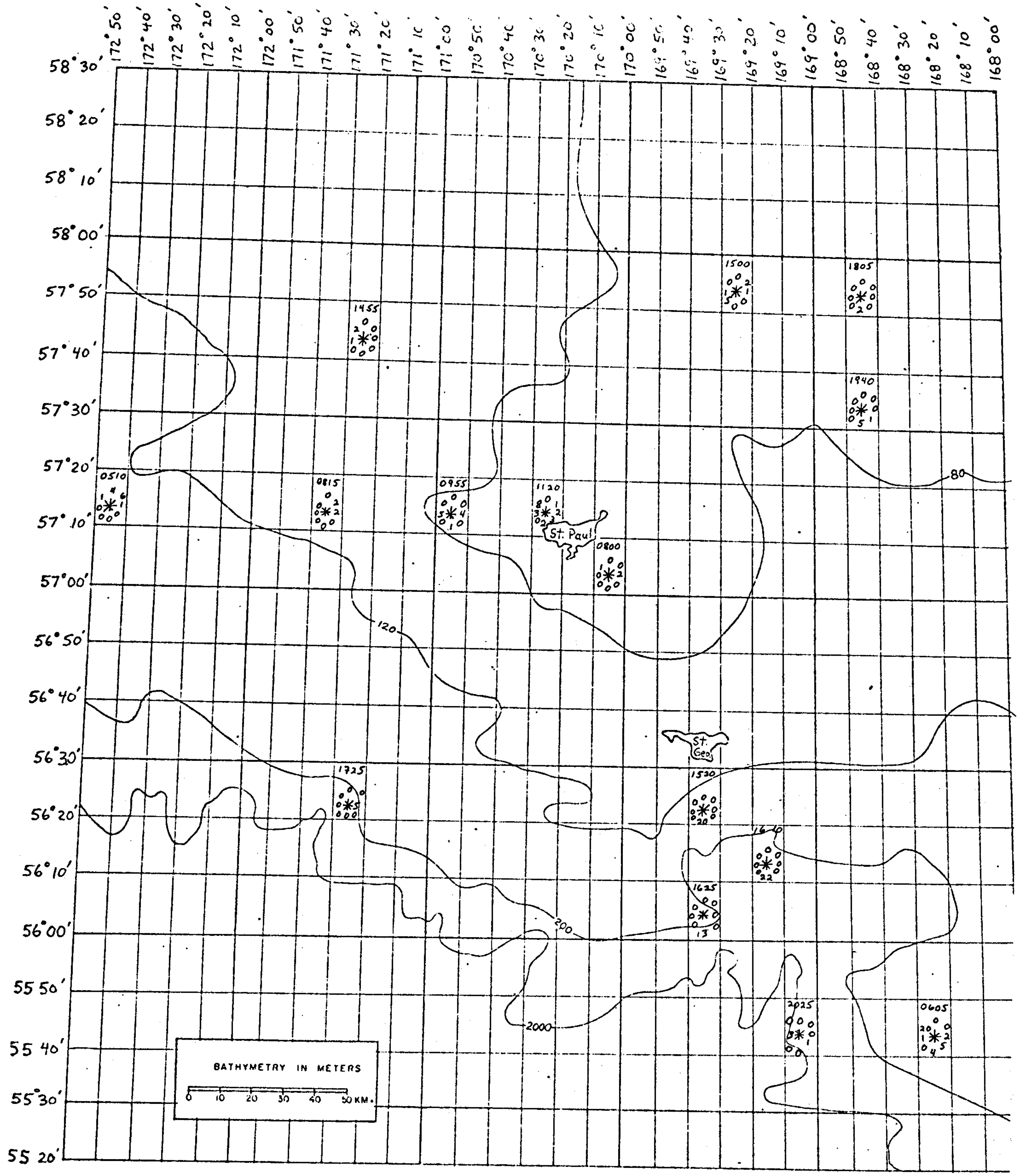
Appendix Figure 24. Red-legged Kittiwake - number of flocks flying in indicated directions at times (BDT) specified at top of 10' x 10' block, 1-5 August 1977.



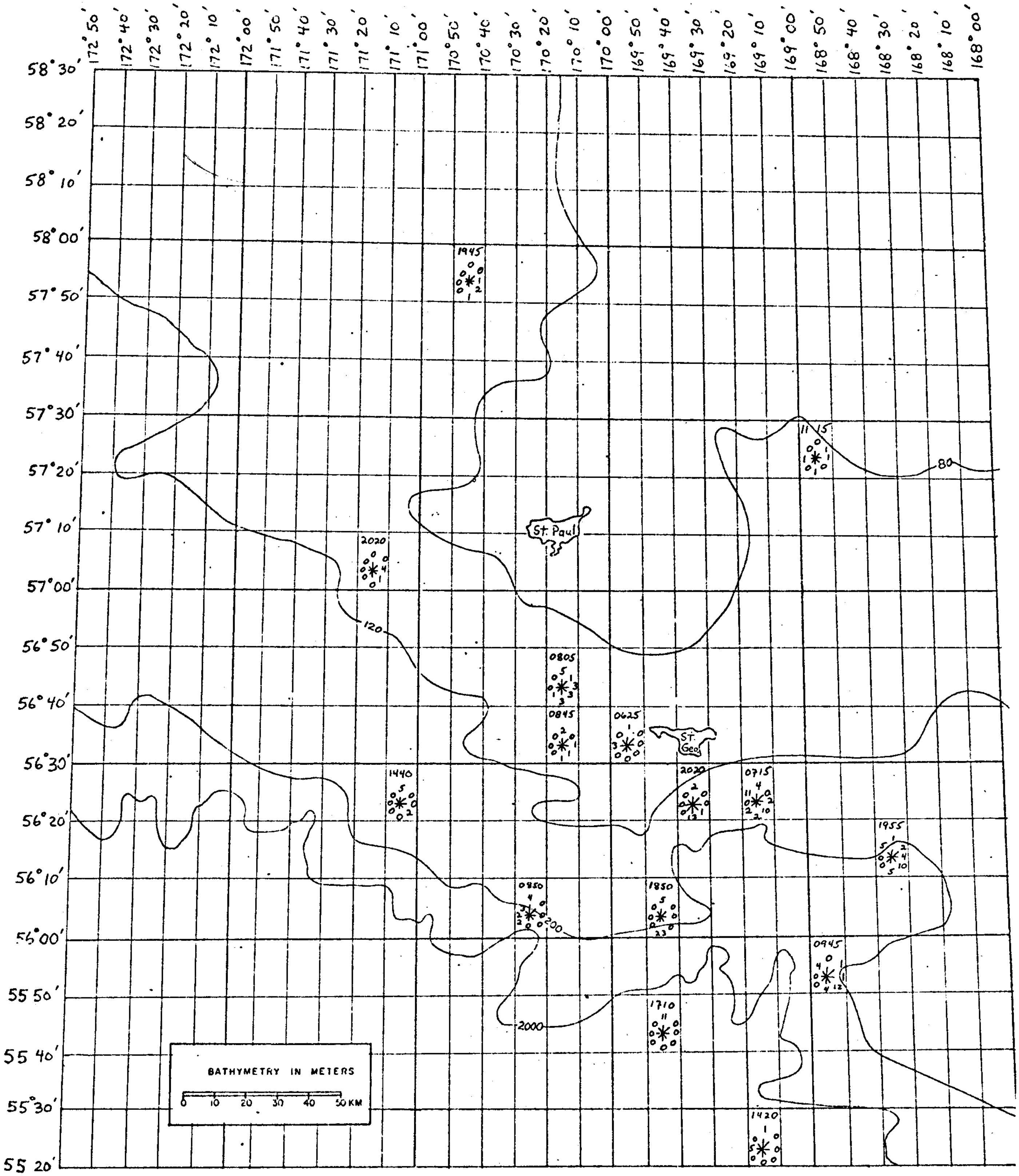
Appendix Figure 25. Black-legged Kittiwake - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 7-11 July 1977.



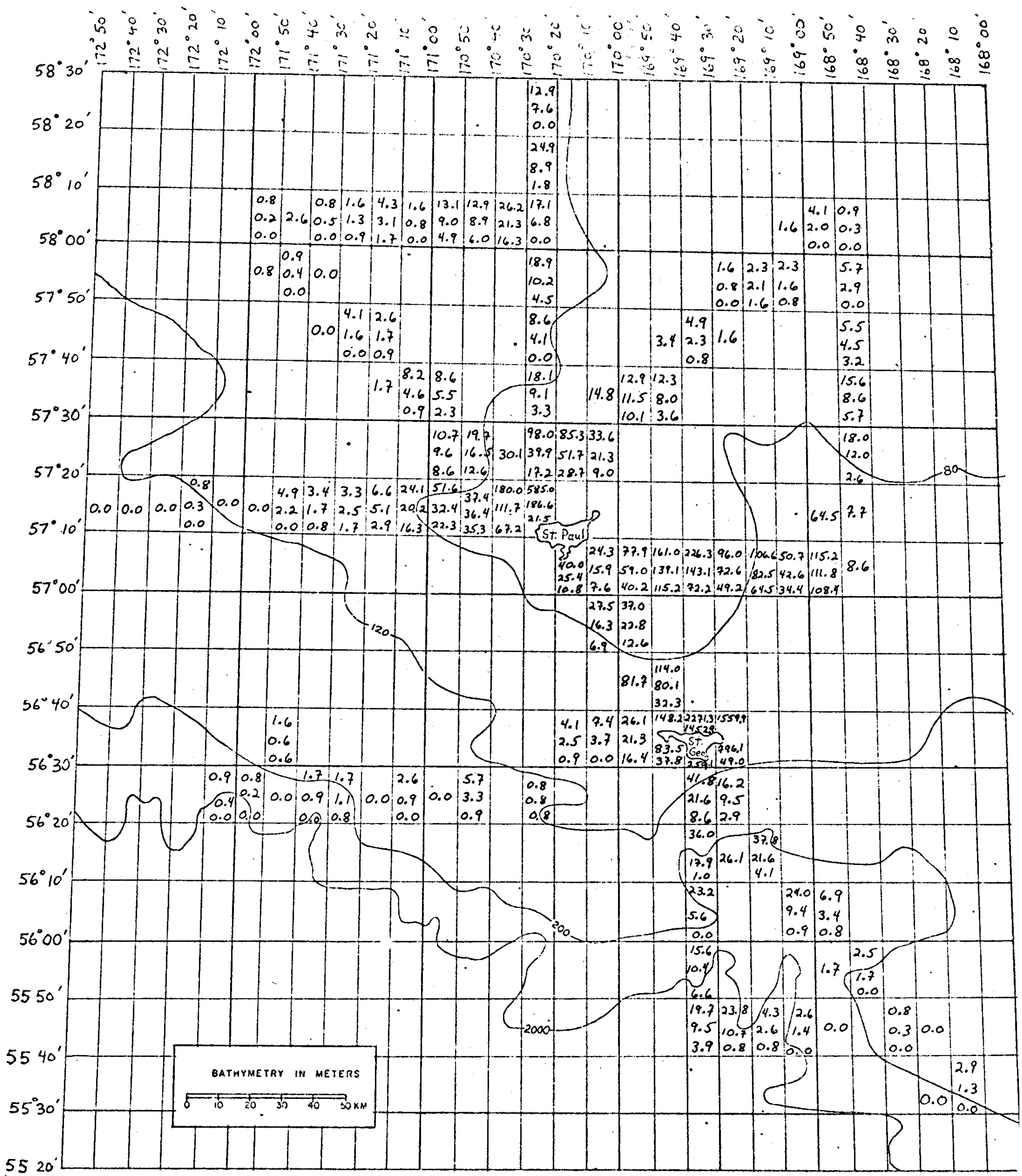
Appendix Figure 26. Black-legged Kittiwake - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.



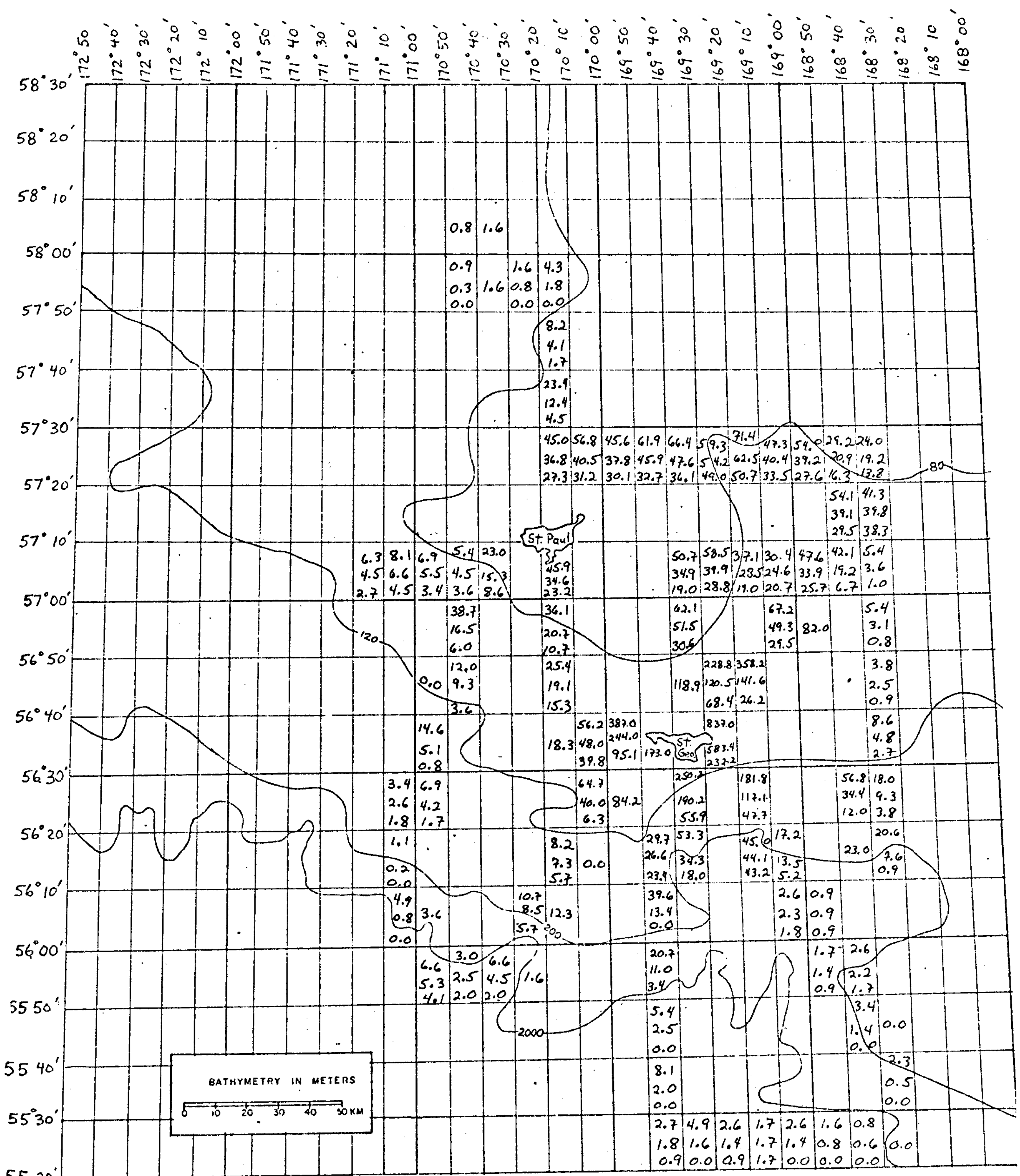
Appendix Figure 27. Black-legged Kittiwake - number of flocks flying in indicated directions at times (BDT) specified at top of 10' x 10' block, 7-11 July 1977.



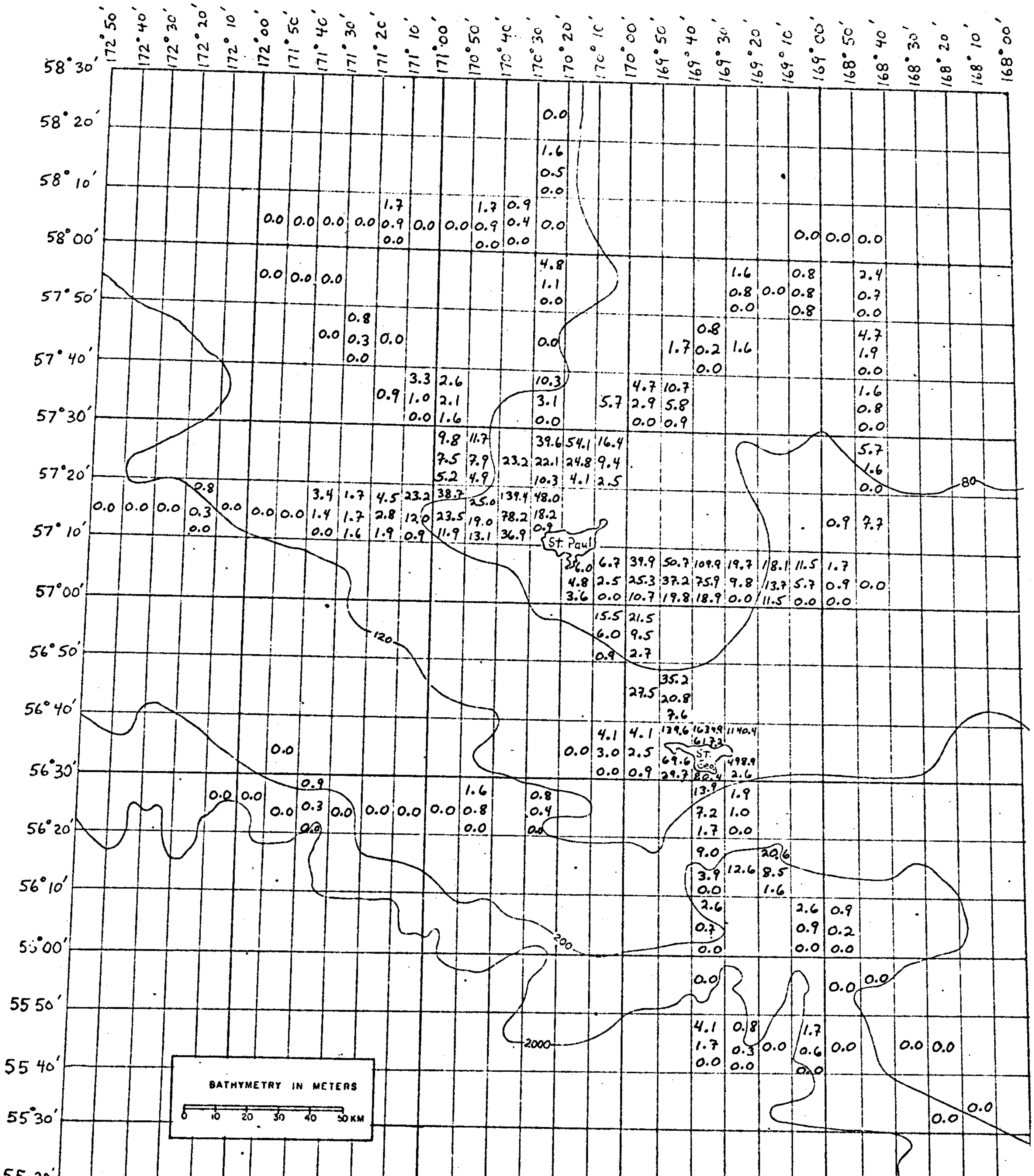
Appendix Figure 28. Black-legged Kittiwake - number of flocks flying indicated directions at times (BDT) specified at top of 10' x 10' block, 1-5 August 1977.



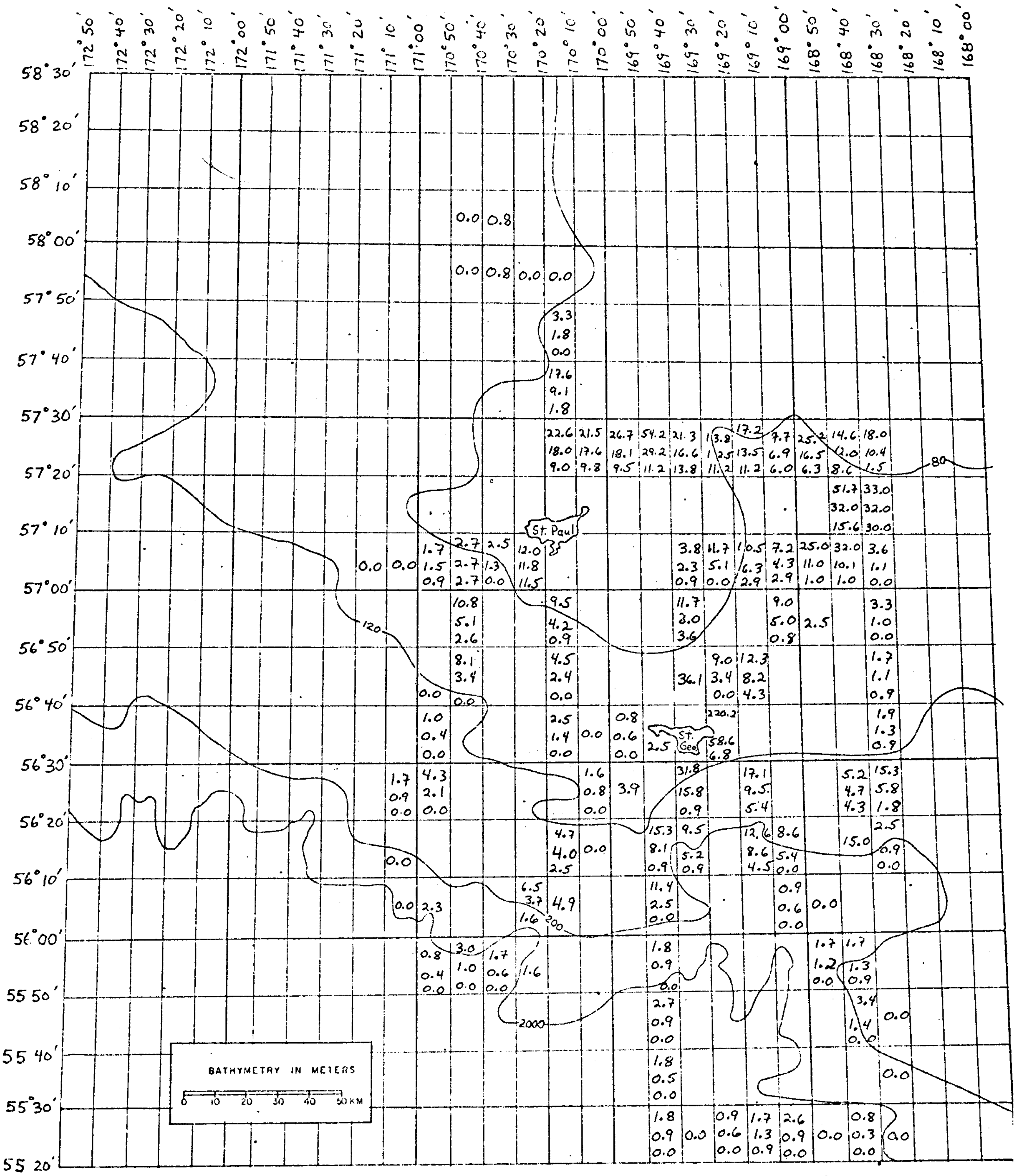
Appendix Figure 29. All murres - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 7-11 July 1977.



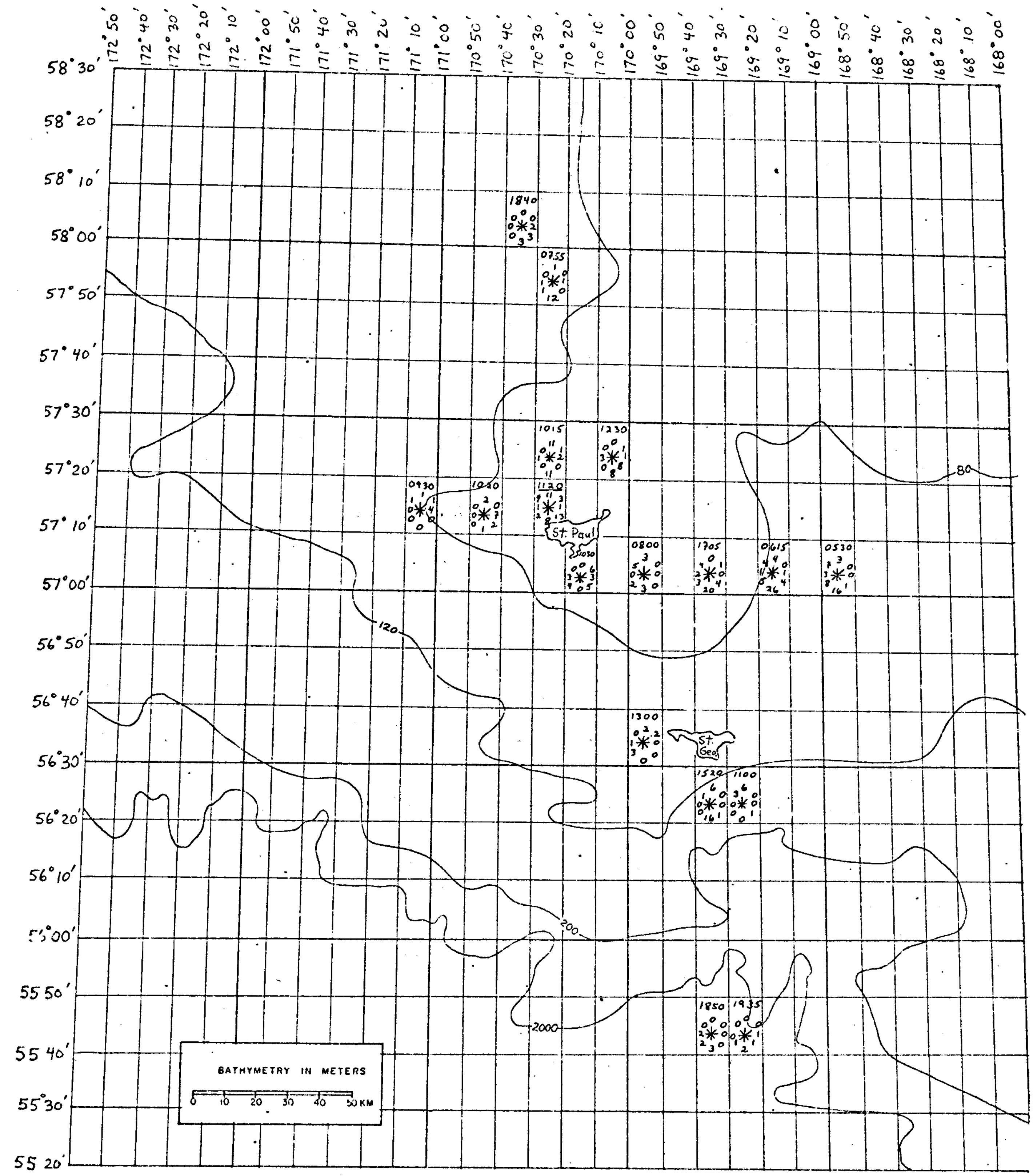
Appendix Figure 30 All murres - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.



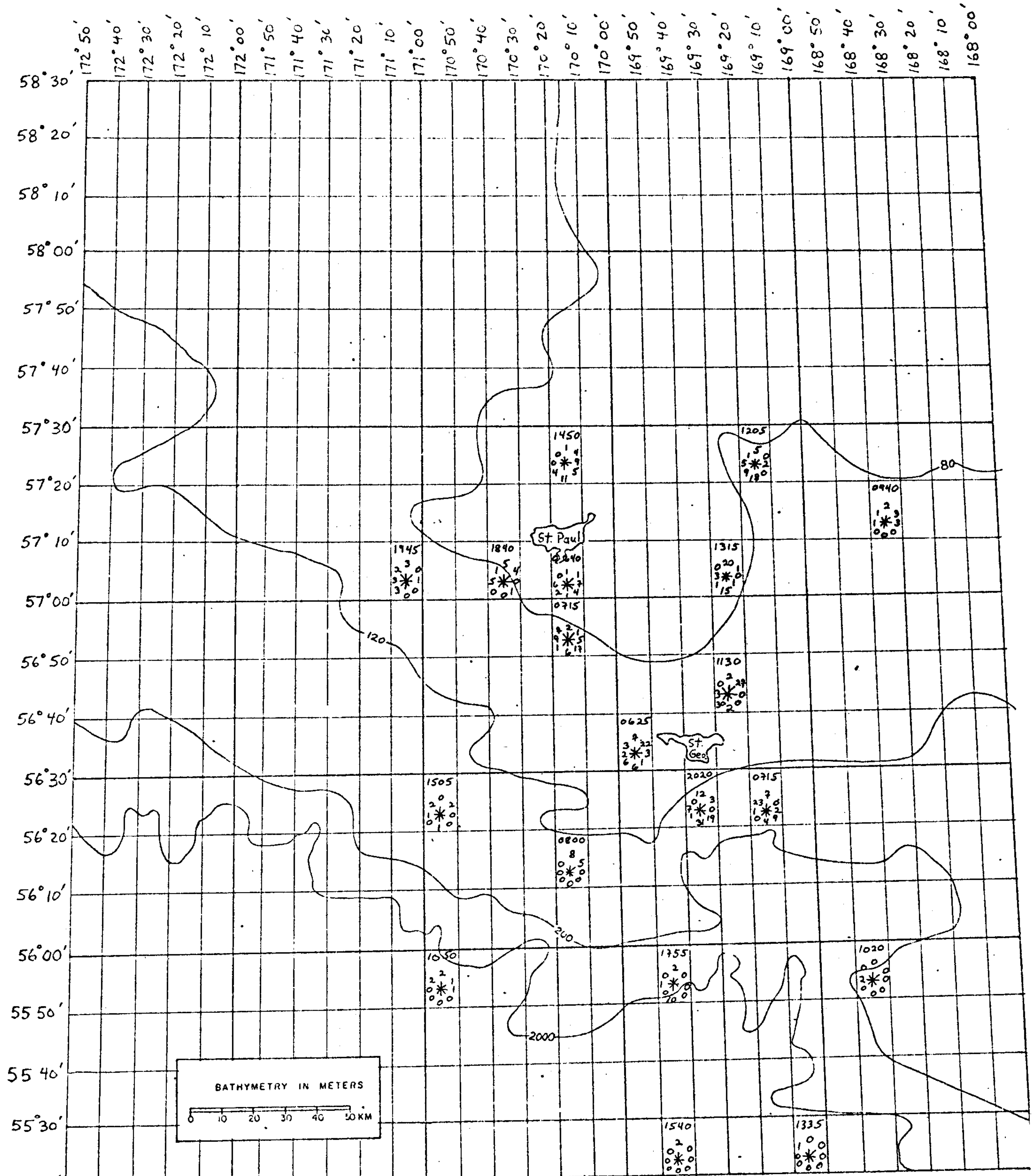
Appendix Figure 31. All murres on water - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 7-11 July 1977.



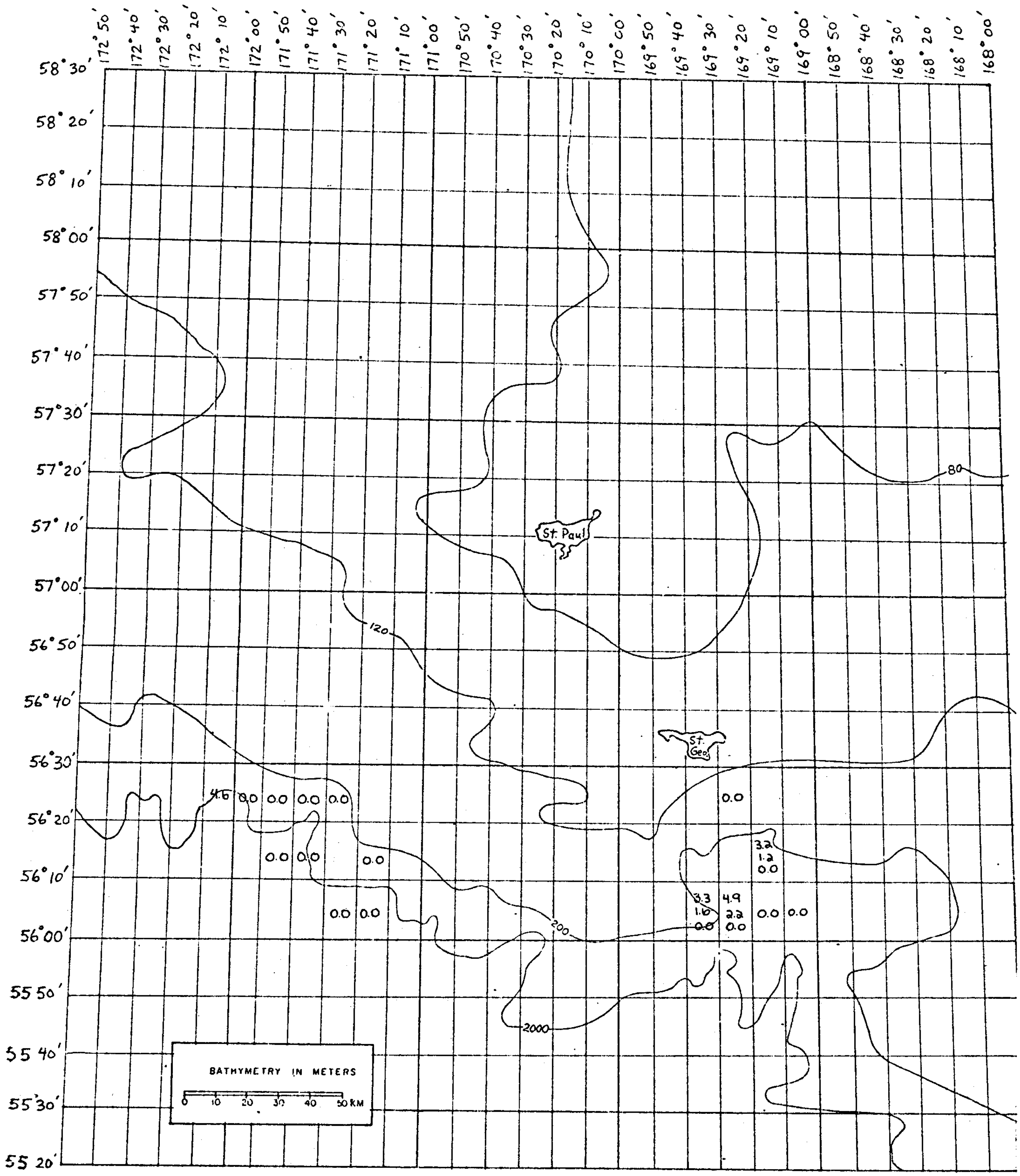
Appendix Figure 32. All murres on water - maximum, mean, and minimum birds/km² for all ship transects within each 10' x 10' block, 1-5 August 1977.



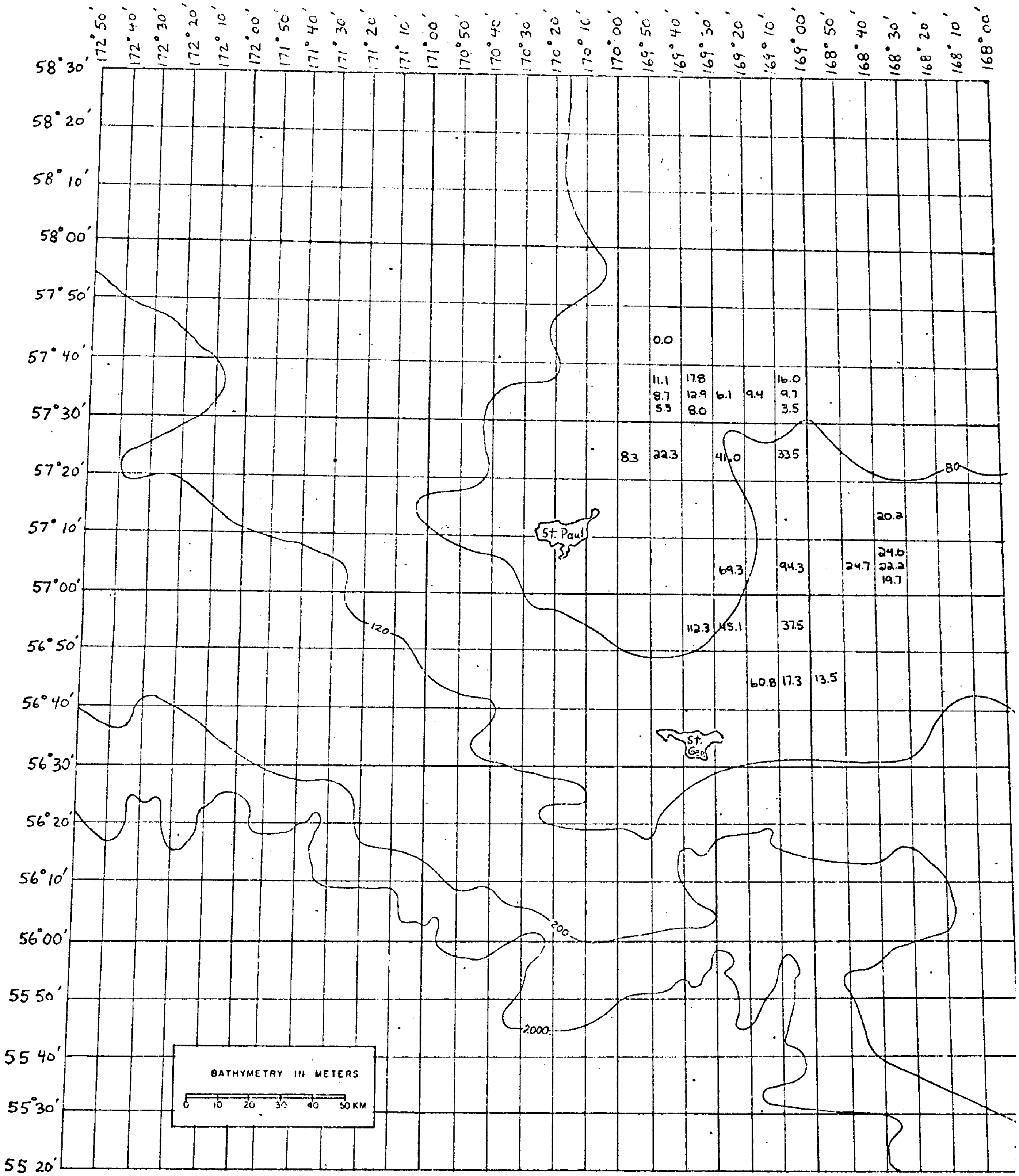
Appendix Figure 33. All murres - number of flocks flying in indicated directions at times (BDT) specified at top of 10' x 10' block, 7-11 July 1977.



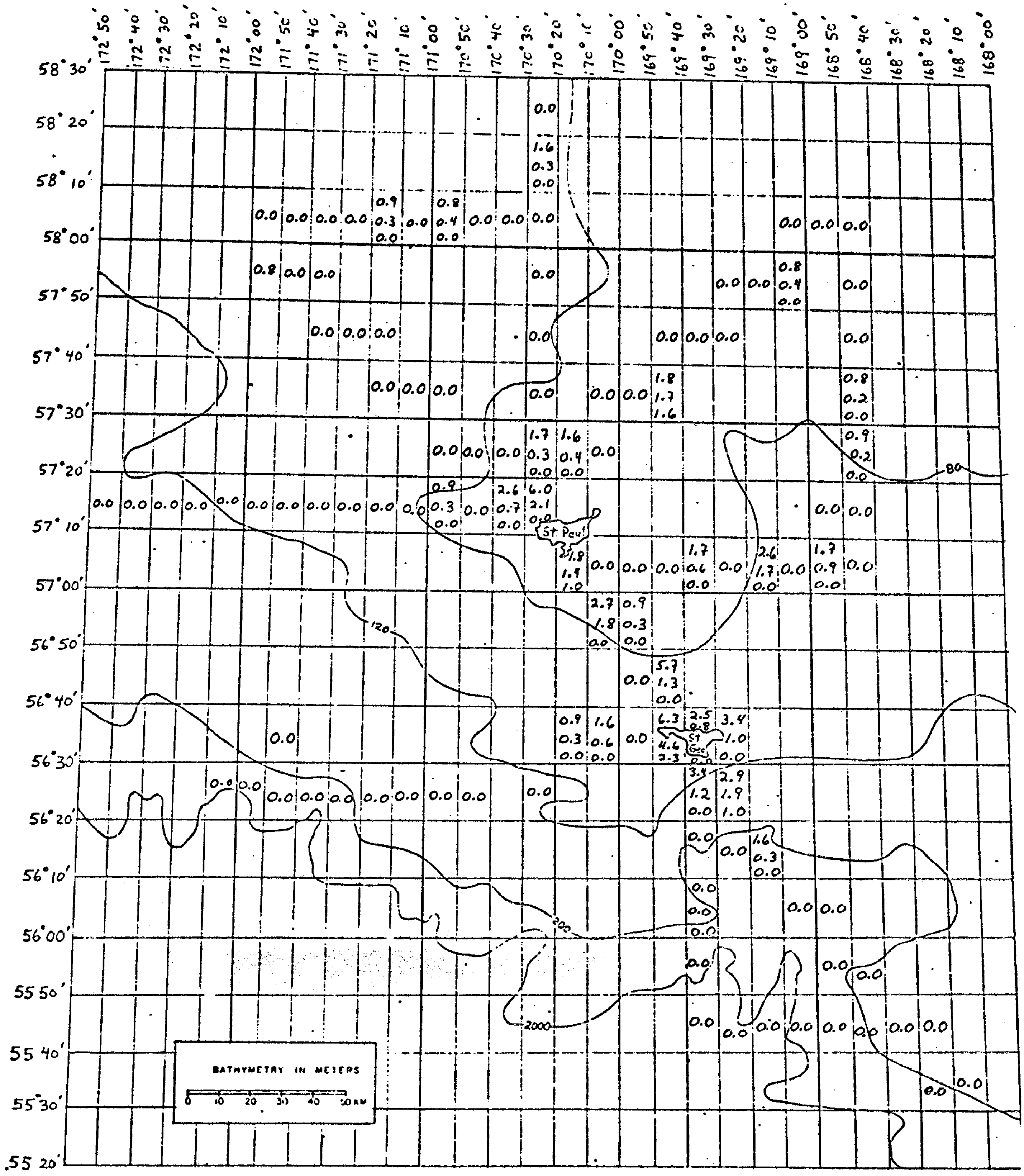
Appendix Figure 34. All murres - number of flocks flying in indicated directions at times (BDT) specified at top of 10' x 10' block, 1-5 August 1977.



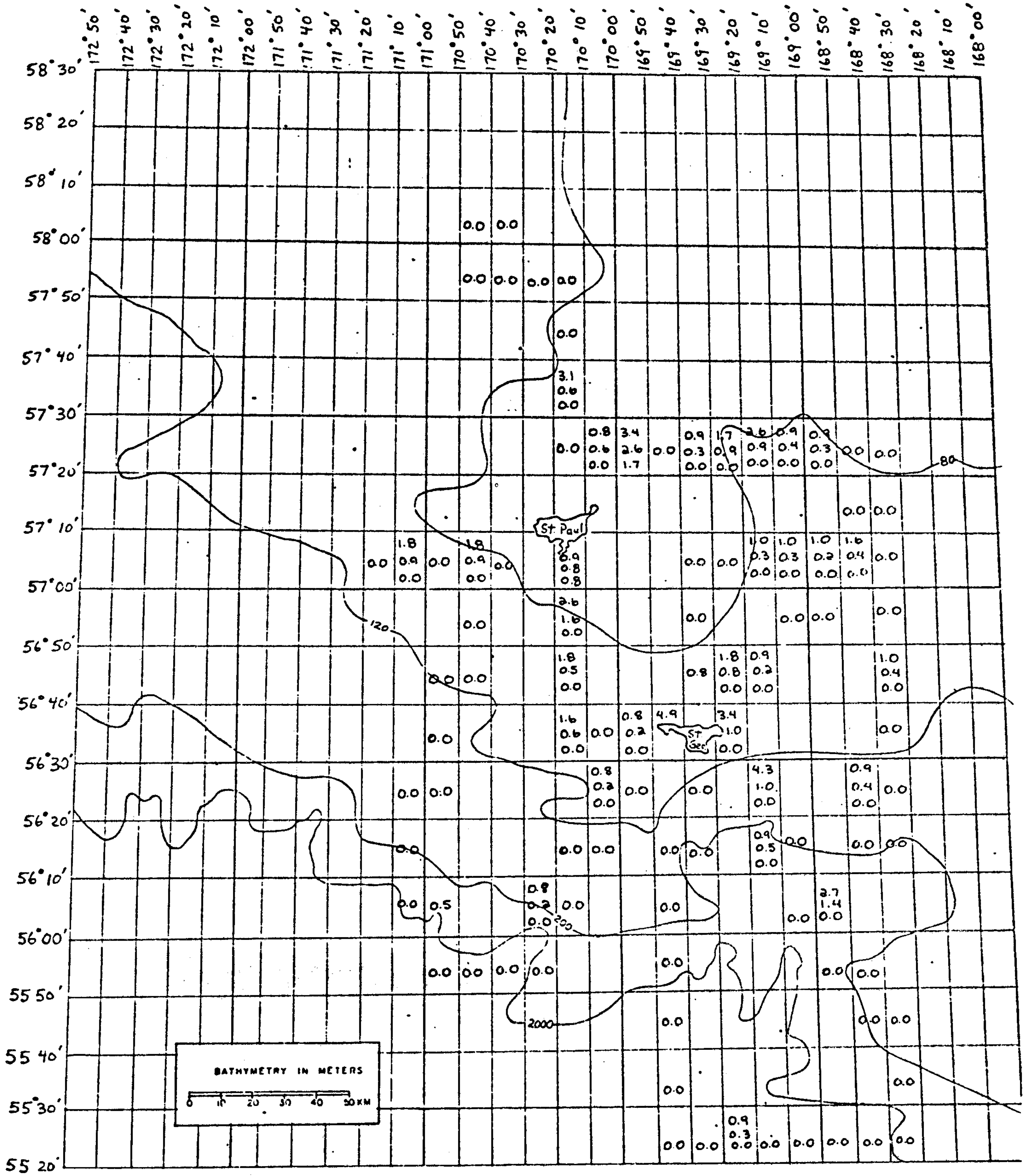
Appendix Figure 35. All murres - maximum, mean, and minimum birds/km^2 for all analyzed helicopter transects within each 10' x 10' block, 7-11 July 1977.



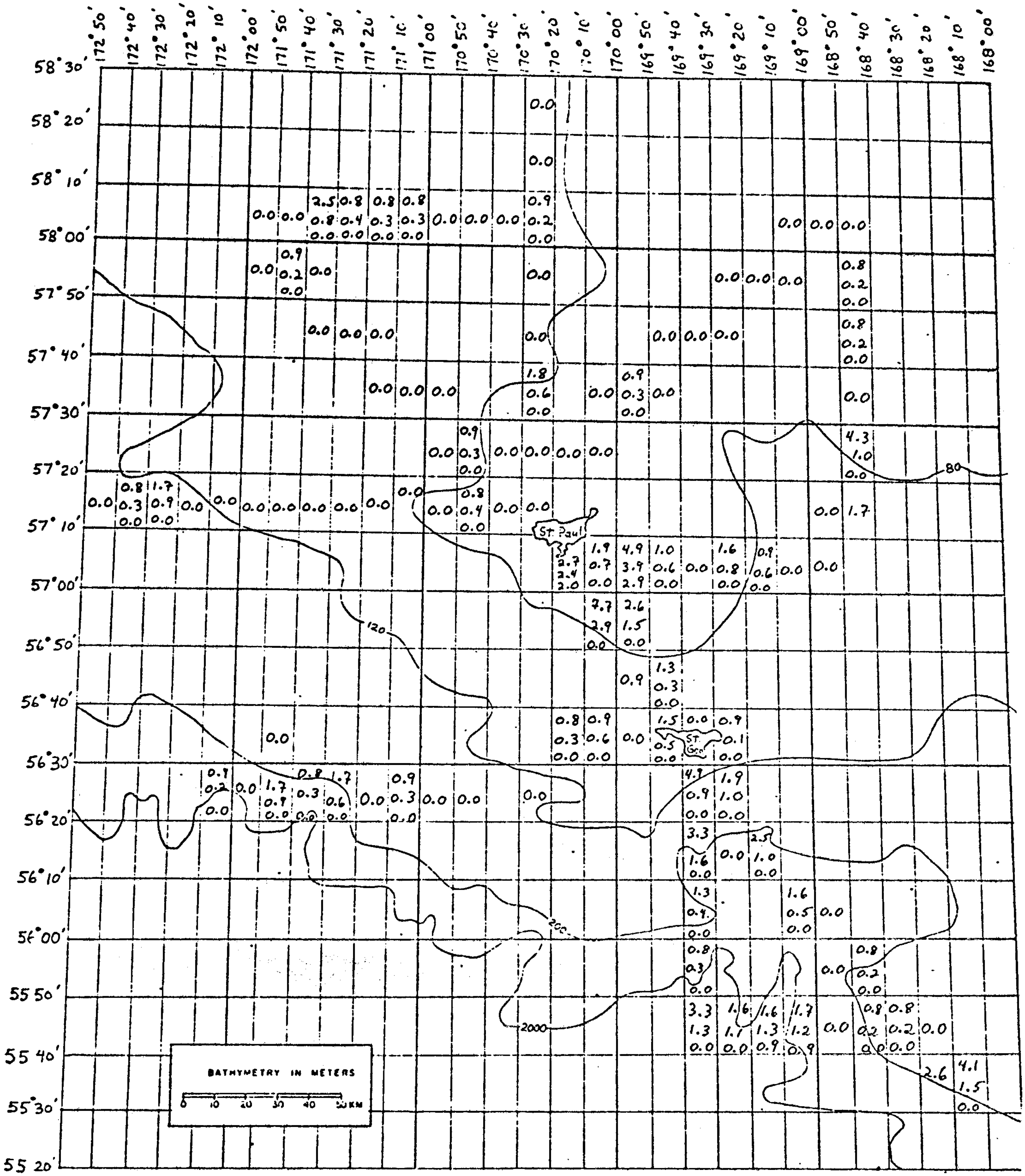
Appendix Figure 36. All murres - maximum, mean, and minimum birds/km^2 for all analyzed helicopter transects within each 10' x 10' block, 1-5 August 1977.



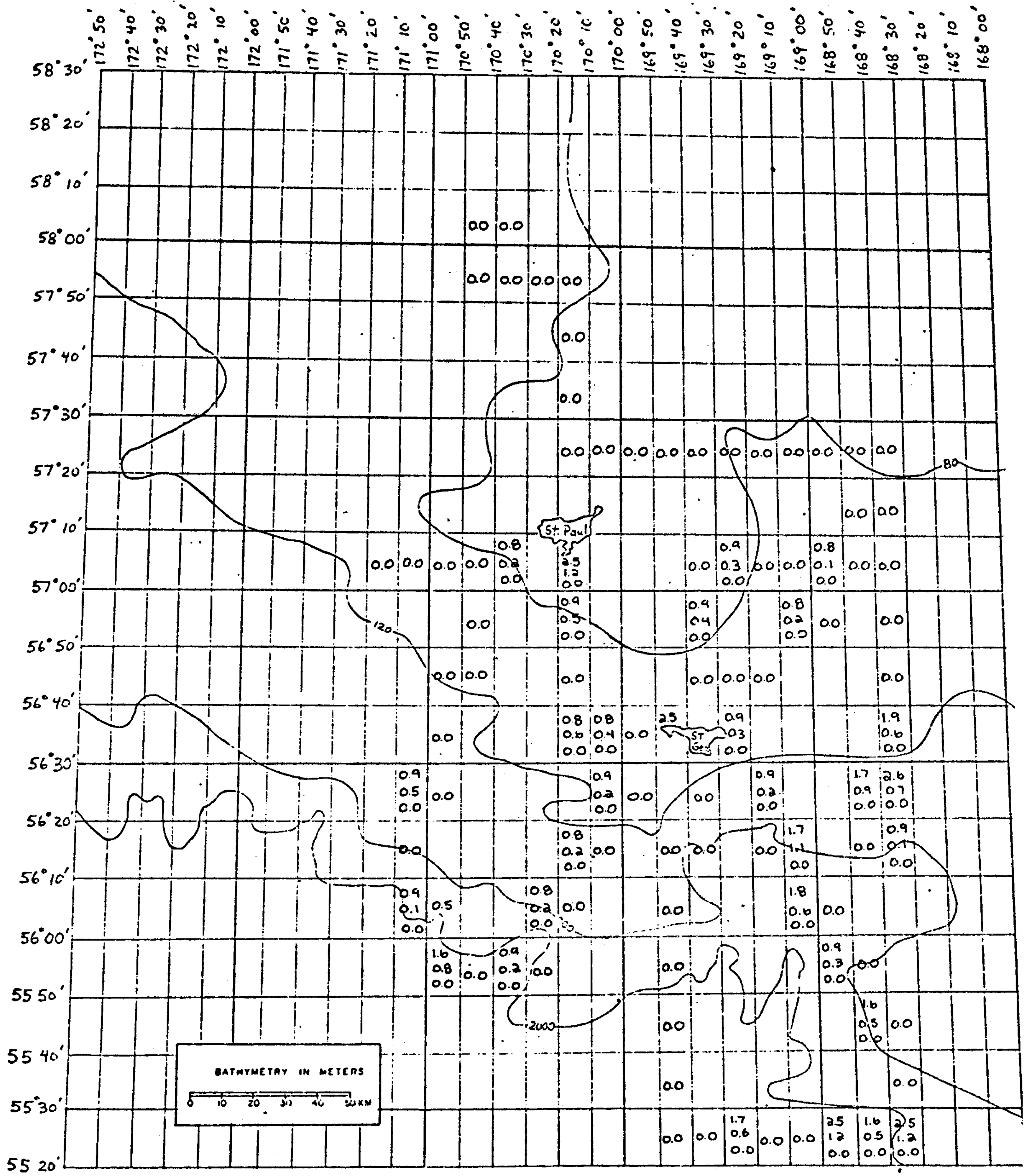
Appendix Figure 37. Horned Puffin - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 7-11 July 1977.



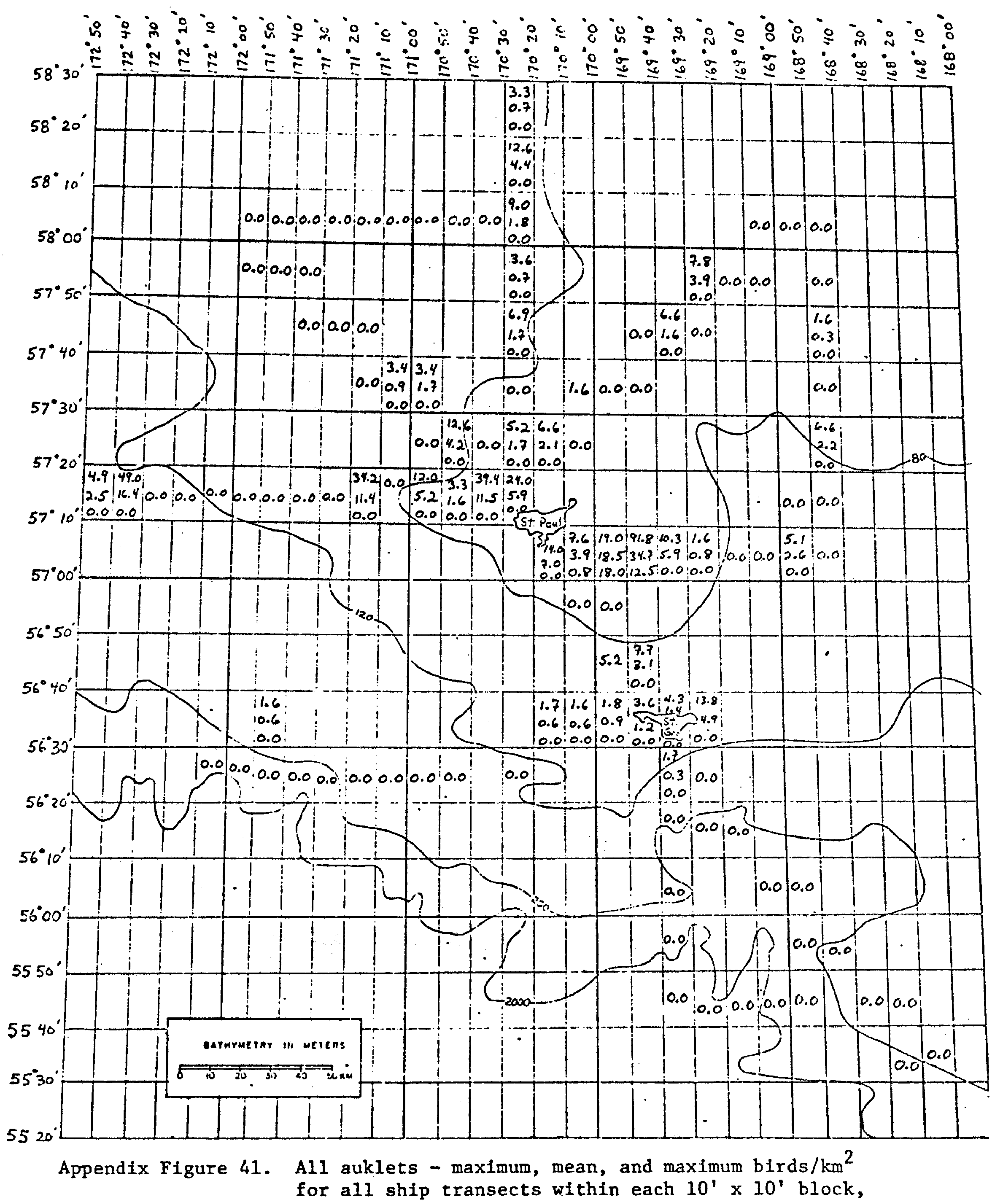
Appendix Figure 38. Horned Puffin - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.



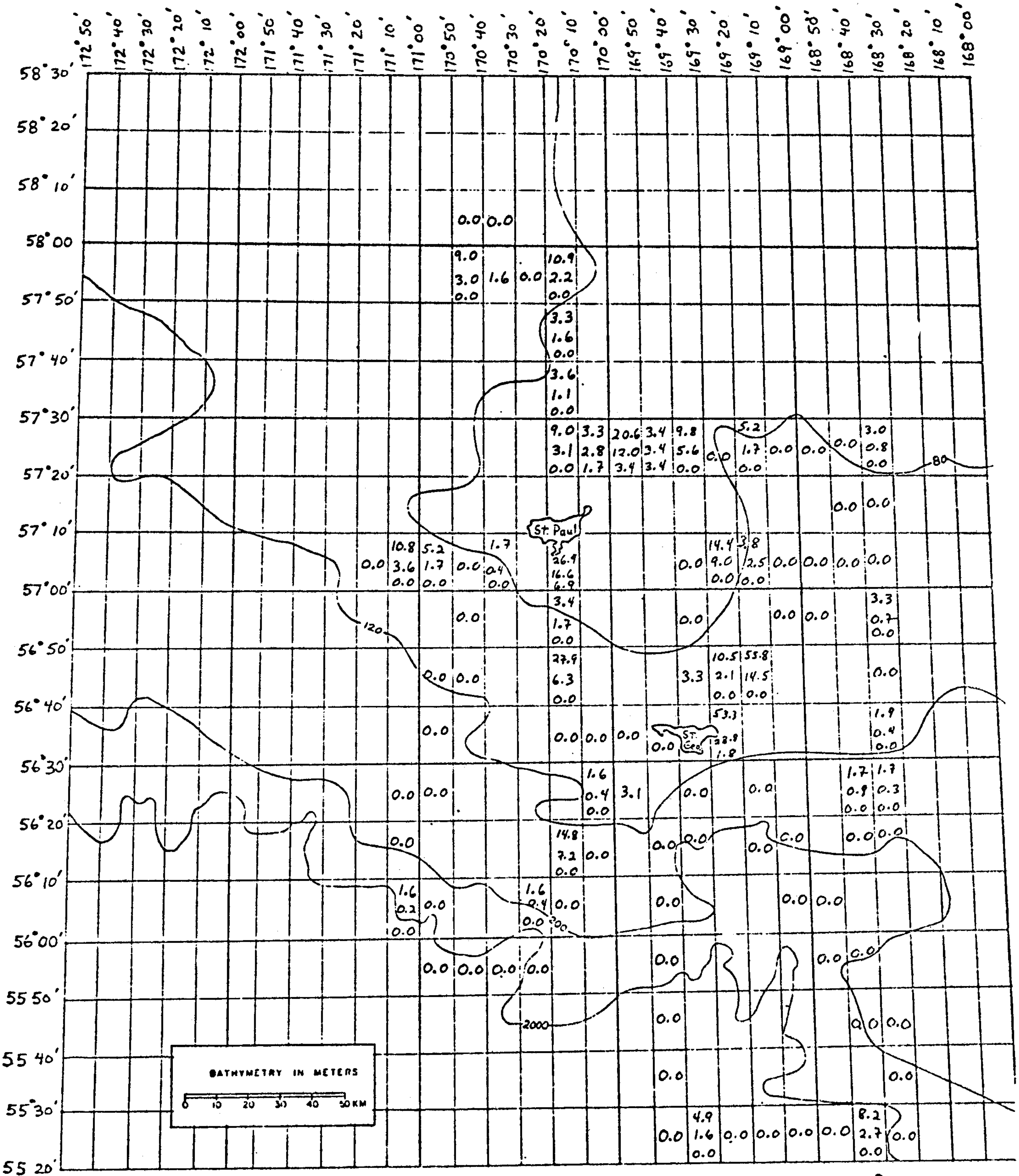
Appendix Figure 39. Tufted Puffin - maximum, mean, and minimum birds/km² for all ship transects within each 10' x 10' block, 7-11 July 1977.



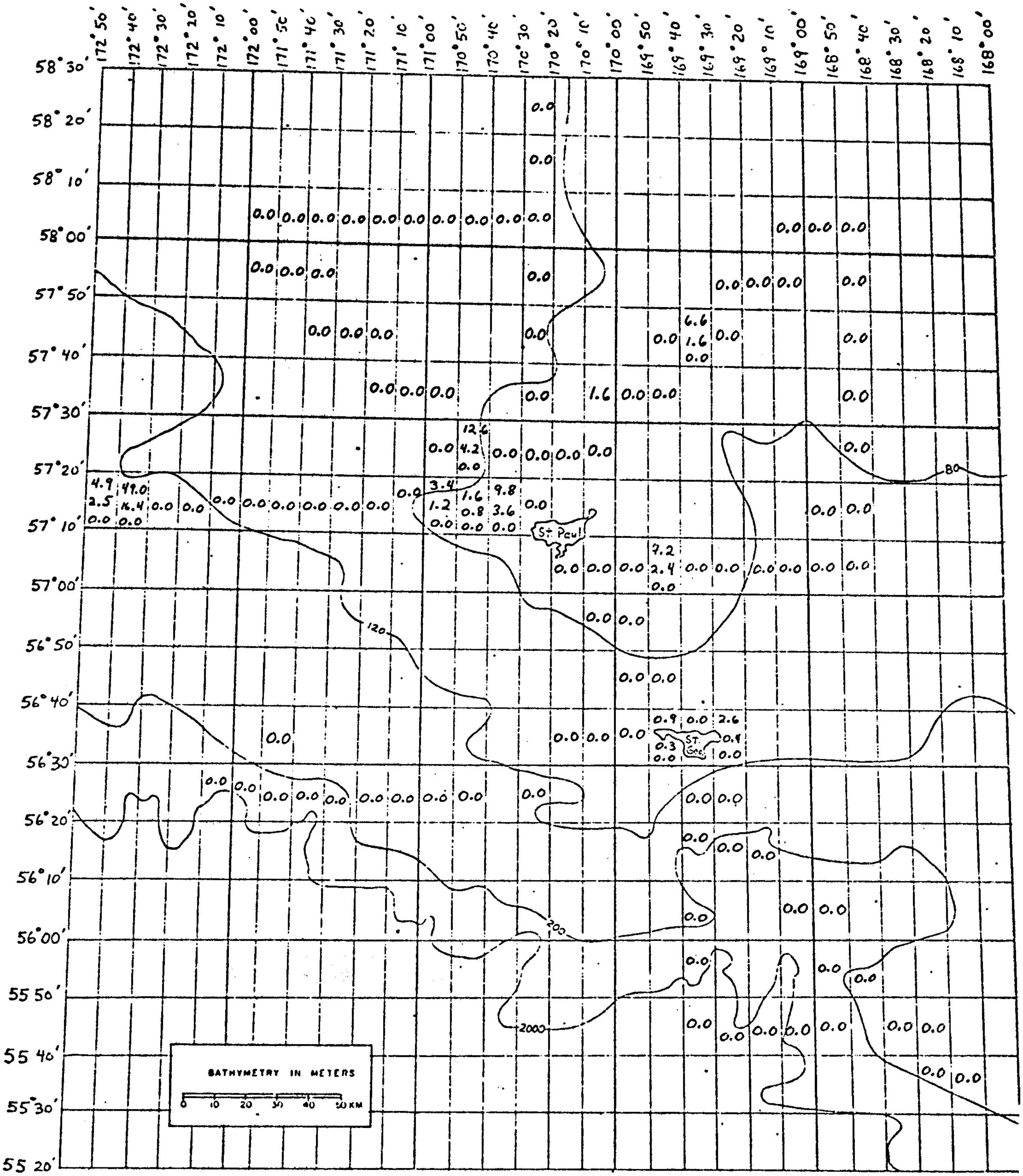
Appendix Figure 40. Tufted Puffin - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.



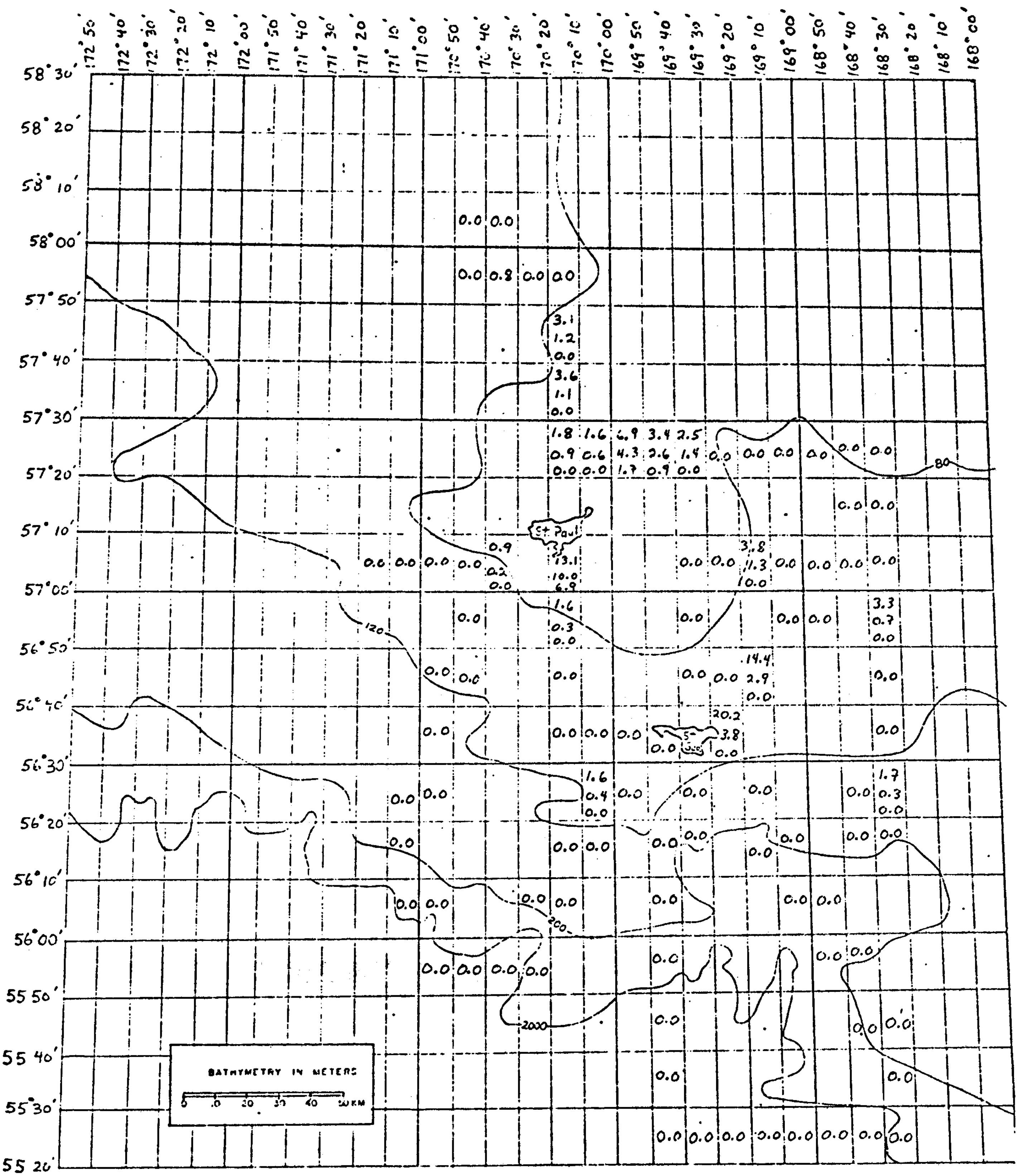
Appendix Figure 41. All auklets - maximum, mean, and maximum birds/km^2 for all ship transects within each 10' x 10' block, 7-11 July 1977.



Appendix Figure 42. All auklets - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.



Appendix Figure 43. Auklets on the water - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 7-11 July 1977.



Appendix Figure 44. Auklets on the water - maximum, mean, and minimum birds/km^2 for all ship transects within each 10' x 10' block, 1-5 August 1977.

Appendix II.

KITTIWAKE WORKSHOP

Held at P.S.G. Meeting, Victoria, B.C.

January 20, 1978

These observations and comments result from a workshop on geographical variation in the reproductive success of Black-legged Kittiwakes together with papers on the food, foraging patterns, winter activities and mortality of this species. The reports were part of the Pacific Seabird Group Meetings.

A. Black-legged Kittiwakes have a number of characteristics that make them more easily studied at their breeding sites than other cliff-, burrow-, or rubble-nesting species. Because they are relatively insensitive to the direct and catastrophic effects of oil spills, their numbers remain relatively constant and they are relatively inexpensive to monitor, they may therefore prove useful as an indicator of indirect effects.

As a result of the studies made in five regions (Cape Lisburne to St. Lawrence Island, the Southern Bering Sea, SWGOA, and NEGOA) over three years, we have identified the following kinds of information, not only as important for understanding the biology of Black-legged Kittiwakes, but also so that kittiwakes can be directly useful for environmental assessment by NOAA and BLM.

1. Reproductive Biology

a. There is a temporal gradient in clutch initiation that varies from the GOA regions to those of the Bering Straits and Norton Sound, with those in the north being initiated later. There is also apparently an historical change in phenology, at least at Cape Thompson, where, in the 1960's, clutches were initiated earlier than in the present studies (1975-1977).

b. There are also important and regular variations in the size of clutches and the percent of nests in which eggs are laid from one region to another, with smaller clutches being laid and fewer nests receiving eggs in the north than in the GOA. Again, historical information suggests that in the 1950's (Pribilofs) and 1060's (Cape Thompson) clutch size may have been larger than at present.

c. Important differences exist in the regularity of reproductive success in different geographic regions as well. These differences have, in the past three years, usually been expressed in the number of eggs hatching per nest, either because fewer eggs were laid or because eggs failed to hatch. In some regions there have been years of failure and years of good success (high productivity) in which some pairs even raise two chicks per nest. In other regions, reproductive success has been consistently moderate and no parents have been able to raise twins.

d. The reasons for reproductive failure have differed in different regions. In the north, particularly, absence of food has been suggested to be the primary influence, while in the GOA bird predators, perhaps taking advantage in changes in kittiwake behavior in response to shortages of food, are the proximate cause of reproductive failure.

Kittiwakes in other parts of their circumpolar range, e.g. the Northeast Atlantic, where this species is reproducing very well and the population is increasing, lay earlier and lay larger clutches than in Alaska. It is likely that timing of clutch initiation, clutch size and the percentage of nests receiving eggs all relate to the availability of food. The above results all suggest that Bering Sea and Bering Strait kittiwake populations may presently be subject to some stress due to food limitation.

2. The food used by Kittiwakes varies in conspicuous ways between regions. In the GOA kittiwakes depend heavily on Capelin, which seems to be a

dependable resource. This resource is augmented by Sand Launce.

In the southern Bering Sea kittiwakes use a diverse food supply without heavy dependance on a single species.

In the northern Bering Sea different colonies use different foods, and high levels of success between 1975 and 1977 have depended upon appearance of Sand Launce in the feeding range.

Kittiwakes are evidently opportunists in their feeding. They will become specialists if suitable prey is available. Whether a colony has a consistent or "boom/bust" economy seems to depend upon the kinds and numbers of small fish and crustacea and the phenology of those organisms in the surrounding area.

3. It is very important for future monitoring of populations, measuring impacts and predicting effects on populations, to know which colonies produce young at a rate higher than animal adult mortality so that they in effect export young. It is also important to identify those colonies which do not produce enough young to maintain the population, hence, those colonies which depend upon immigration of young. This information is needed to determine what colonies are critical and at what rate a population is able to increase. Future work should identify a) which colonies produce an excess of young and whether the fledging weights of those young are high enough to ensure post fledging survival. Any changes in rates are important to determine environmental effects on these bird populations. We also need to determine b) the degree of exchange of kittiwake chicks among colonies and regions, and c) the life-expectancy and total life-long production of young per kittiwake pair.

B. In order to identify which colonies are sources of young and which are sinks and why, in order to identify the relation of kinds and diversity of foods taken to constancy of reproductive success (i.e., the linkage of the kittiwake part of the ecosystem to the next level down in the system), and in order to make a predictive model of population structure locally and regionally, we recommend the following:

1. That a banding program be undertaken at several colonies which are dispersed among the regions. The purposes of a banding program are:

   a. To measure life expectancy and winter mortality by age groups in order to prepare a life table and hence predict rates and directions of population changes.

   b. To identify site tenacity and performance of individual birds and pairs.

   c. To identify which colonies produce an excess of young and the rates, directions and distances of exchange among colonies.

2. That studies of breeding biology be continued at several colonies which are dispersed among the regions. These studies are not needed every year, once an intensive study has first been made to establish the baseline, but should be repeated often enough to detect systematic shifts in breeding biology and populations.

   a. The studies should include close attention to details of phenology, clutch size, hatching rate, fledging rate, growth rate, and weight of chicks at fledging.

   b. The studies should also include foods used, patterns of foraging, and feeding behavior.

3. That studies be undertaken on the distribution, numbers, behavior, food, foraging patterns and feeding behavior of these birds on the wintering grounds.

This information should contribute answers to some additional important questions such as: Does the especially heavy competition for nest sites among kittiwakes indicate that sites would remain occupied even if an important percent of the population died? How readily would kittiwakes recover from a decline to reattain present or maximum numbers?

What are the behavioral implications of nesting failure when coupled with the heavy competition for nesting sites? Why, in terms both of natural selection and in terms of hormonal (physiological) effects, do birds persist so actively on the ledges after failing? What age groups are represented among the birds that occupy sites without building nests? What are their ages and weights relative to the weights of the birds which lay eggs and to those which build nests but do not lay eggs?

Appendix III.

KITTIWAKE WORKSHOP, P.S.G., JANUARY 1978

Results of the Working Group Meeting on Methodology:

1. What is the best measure of colony size?

The best measure of colony size was agreed to be total nests present. Also useful measures were total birds present and to a lesser extent, total pairs handling nesting material. Whenever possible, total nests and total birds should be recorded.

It was agreed that a nest shall be defined as a substantial mud platform with evidence of activity in the present season.

2. What are the best measures or presentation of phenology?

It was agreed that the best presentation format was the use of bar graphs showing dates of clutch initiation. Notes of laying of all eggs may also be useful to show, but graphs should be labeled as to whether they represent clutch initiation or laying of all eggs. So that all graphs can be more easily compared, it was agreed to use 4 day intervals with 1 May being day one.

3. What are the most useful measures of reproductive success?

It was agreed that a first priority is to give productivity in terms of chicks produced per nest (see definition of nest above). This type of information will allow at least a crude comparison between sites studied intensively and those checked only once or twice in a season.

Fledged birds were defined as fully feathered chicks (having fully developed tails and lacking down feathers on the nape). For kittiwakes these chicks had to be at least 40 days old. For murre chicks, "fledging" was defined as having survived to at least 15 days of age.

4. It was agreed that, whenever possible, mapping or photographing and following the fates of individual nests was the method of choice. At the

same time, since brief monitoring visits to a colony would not permit following individual nests, it was agreed that at sites where intensive studies are made, counts of cliff faces should be made for comparative purposes.

5. It was agreed that the most useful measure of growth would be grams gained/day. It was also agreed that it may be useful to have an age classification based on feather development. Furthermore, it was agreed that we should test whether feather development was age specific and independent of weight gain.

Kittiwake Age Stages

1. cannot stand
2. pin feathers on "hand"
3. dark tips on pins on "hand"
4. tail feathers bursting out
5. white inside black on tail
6. no down, except on nape

Murre Age Stages

1. cannot raise head
2. scaley feathers on head and neck
3. white on chin
4. white cheek, and stand separate from parent

6. Although not discussed at the meeting, it seems useful to list a possible minimum data set for both long-term and brief visits to a colony. Your comments will be useful.

Brief Visit:

1. date
2. time of day
3. for segment of cliff face
   a. total birds (ad., im.), excluding second birds of a pair, so that total birds equals total occupied sites
   b. total nests
4. nest contents for at least 50 nests (number of eggs and chicks)
5. chick ages by above classification
6. chick weights (20 is possible, band the chicks for reweighing if possible)
7. 20 samples of foods used (from chicks or shoot adults)
8. comments on causes of mortality if dead eggs or chicks are seen

Site Intensive Studies:

1. number of adults, immatures present
2. number of nests and total of regularly occupied sites
3. histogram of time of arrival, start of nest building, clutch initiation, hatching and fledging
4. distribution of clutch size
5. distribution of fledging brood size
6. growth rates of at least 20 chicks
7. food samples from pre-incubation, incubation and nestling stages
8. estimates of hatching success, fledging success and productivity from at least 100 nests spread among at least 5 different sub-areas
9. causing and timing of reproductive failures
10. variation in attendance by 24 hours
11. variation in attendance through the breeding season

Appendix IV.

WHY CONDUCT STUDIES OF SEABIRDS?

or

WHAT ECOLOGICAL STUDIES OF SEABIRDS OFFER OCSEAP

Value of Seabird Studies:

Seabirds are an extremely visible element of the marine ecosystem and are the center of attention for a large segment of the conservation-minded public. As such, when populations are fouled with oil, regardless of the long-term effect of the impact, oiled seabirds generate public outcry. For this reason, if no other, efforts to minimize impact are of value.

Seabirds may also occur in local concentrations involving millions of birds and thousands of metric tons of biomass in a relatively small area. Given that these birds probably consume on the order of 20 percent of their body weight daily, the destruction or removal of large segments of the bird population could alter the ecological situation that now exists in the ocean.

However, perhaps of greater long-term importance is the potential role seabirds may play as indicators of environmental quality. They are more conspicuous and also probably less expensive and easier to study and monitor than any other marine species. Thus, these birds, many of which are highly vulnerable to floating oil, should provide, through changes in numbers or distribution, indices of contamination. More importantly, as high order consumers at the top of the marine food chain, these birds may provide sensitive gauges of the functioning of the marine ecosystem. Since we do not have time or resources to study all areas or to study the biology of all species, we need to make generalizations from a few hopefully typical species. To this end we need to select "indicator" species and target areas for concentration of research effort.

Linkage Between Marine Birds and the Marine Ecosystem:

While it is clear that generalizations must be built on "indicator" species, we must nevertheless recognize that the use of certain species as indicators of "environmental quality" or "ecosystem health" depends upon the assumption that the linkage between these species and the ecosystem is deterministic. The closed system models used to relate the impact of events in an ecosystem to the components of that system assume direct, tight linkages between components. We need to learn what the linkages between seabirds and their food resources are, and we need to learn which of these linkages will be sensitive not only to the acute but also to the chronic impact of oil pollution.

In order to establish the strengths and limitations of the use of birds as indicators we need both long-term studies within regions and comparative studies between regions that relate food resource availability with the distribution, numbers and reproductive success of seabirds. Studies need to be long-term so that fluctuations in components of local resource bases can be correlated with changes in seabird ecology. Studies must also be conducted in the several OCS areas in Alaskan waters because the preliminary studies undertaken to date suggest that birds in these geographically widely separated regions depend upon strikingly different resource bases. Such information is of critical importance if mathematical ecosystem models are to be successfully used to predict the impact of spills.

Possible Indicator Species

In order to select indicator species it is necessary to ask first what it is we need to know about environmental change, and second which species will supply the answers, i.e. will it be affected and in what ways.

1. Direct effects of oil on the water:

In order to assess the impact and distribution of oil spills, especially small, chronic losses, we need to have an indicator species that is a) vulnerable to floating oil, that b) has a widespread distribution, and c) that occurs in numbers whose changes can be easily measured. Of the breeding seabirds most often encountered in Alaska, the puffins would seem to be a good candidate for this role; they nest in many small to moderate sized colonies well dispersed along most coasts. Murres are often too numerous to allow accurate counts of numbers and tend to be clumped in large colonies. Kittiwake numbers are less likely to be directly affected by spilled oil than alcids as the kittiwakes spend relatively little time on the surface of the water.

2. Assessment of local changes or "environmental stress" on food chains:

To the extent that oil development and its attendant activities may cause adverse impact on local food chains or other local ecosystems, it is necessary to have a species for which it is possible to monitor the effects of changes in food availability. This can be accomplished through knowledge of the reproductive ecology of a species, including such parameters as phenology, clutch size, growth of chicks and fledging success, all of which are sensitive to variations in the availability of energy resources to breeding adults. For an indicator species of this sort we choose the Black-legged Kittiwake because the reproductive biology of this species appears to be sensitive to local changes in food supply and because data on reproductive performance can be obtained with relative ease and considerable accuracy. Kittiwakes may therefore be useful as inexpensive yet accurate indicators. They have the further major advantage that there is considerable background information available for this species in Alaska and in other parts of its range. Because of their ease of study and their probable lack of direct sensitivity to spilled oil, kittiwakes are likely to be more useful for gathering information on indirect effects -- that is on the "quality" of the ecosystem -- than the alcids.

3. Assessment of spatial patterns of ecosystem productivity and health:

For the purposes of this sort of monitoring, we require a species that is sufficiently widespread and numerous, that is easily located, and for which major changes in numbers and distribution will be detectable. Also a species that is present for most of the year and does not gather in highly mobile, wandering flocks will be preferable to one that has a clumped and erratic distribution. Murres appear to be suitable for these functions. It is possible that, just as fishermen have for centuries used local concentrations of birds to locate fish, birds can be used as valuable indices of the distribution of commercial fish, benthos and other aspects of marine productivity relevant to OCSEAP.

Monitoring and Remote Sensing:

Given the vast areas of the Alaskan outer continental shelf potentially exposed to the impact of oil development and the immense cost of monitoring and assessing impact on the large and remote areas involved, it appears essential to develop means of remote sensing that will allow us to monitor not only environmental quality but also the abundance and distribution of pelagic birds. In the event of a spill, the latter information will be essential if deployment of clean up efforts and protection of marine birds is to be effective.

Except for areas close to shore (such as Kodiak or Nome) regular censusing from aircraft is not practical due to the difficulty of providing adequate year-round coverage. Two alternatives exist. One, the possibility of developing direct monitoring on concentrations of birds at sea using SEASAT radar, has yet to be tried. There is however the strong possibility that large flocks of birds, either flying or on the water, will give a radar signature different from that obtained from the ocean's surface. In the event that we are able to use remote radar sensing, we would have a powerful tool for predicting the impact of spills and assigning clean-up priorities.

A second alternative is to learn the relationships between features easily monitored by remote sensing systems (such as sea surface temperature and chlorophyl density), features assessible to other techniques (water depth, productivity) and seabird distribution. If these sorts of linkages between physical oceanograpny, biological oceanography, and bird numbers and distribution are adequately deveioped, again a prediction of the impact of any given spill may be possible. Linkages of these sorts will have to be developed for each of the OCS regions, as their oceanographic regimes may differ significantly. Either of these systems would have the added value that the remote sensing data obtained would be directly available to automatic data processing.

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