Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1977

Volume II. Receptors — Birds

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

U.S. DEPARTMENT OF INTERIOR
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Outer Continental Shelf Environmental Assessment Program

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U.S. DEPARTMENT OF COMMERCE
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VOLUME II

RECEPTORS -- BIRDS

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ANNUAL REPORT

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

Paul D. Arneson
Alaska Department of Fish and Game
April 1, 1977

I. Summary

Coastal marine habitat is vital to millions of waterfowl, shorebirds and seabirds in Alaska. Until recently, little had been done to quantify bird usage of coastal habitats or to quantify the habitats themselves. An objective of this study was to determine seasonal distribution and abundance, critical areas, migratory routes and breeding locales for principal bird species in littoral and estuarine habitat in the Gulf of Alaska and Bristol Bay. Concurrently, coastal bird habitat was to be delineated.

Since the project's inception, 23 bird surveys and 15 mapping flights have been completed to meet these objectives. From four surveys conducted in Lower Cook Inlet, seasonal variation in species abundance was recorded. Year-to-year differences were noted for estuaries on the north side of the Alaska Peninsula from fall surveys in 1975 and 1976. Other surveys have been done during only one season or have given only partial coverage within subunits. Results of all surveys have been used to determine concentration areas of birds during the four seasons. Literature has also been searched for past records of important areas and from recent surveys and past records, "critical" areas have been selected for all subunits of the study area. These areas were selected on the basis of their importance to breeding, migrating or wintering birds. Some critical areas remain tentative until proven or refuted by future research.

Approximately 80 percent of the study area's coastal habitat has been aerially mapped. Amounts of coastal substrate have been summarized for the mapped areas. An interrelationship is suggested between bird use of habitats, frequency of occurrence of habitat types and varying susceptibility of habitats to oil pollution.

One of the most damaging effects of oil development to coastal birds will be from oil spills that damage them physically or reduce their food supply. Development of onshore terminal facilities may destroy bird habitat, and associated aircraft and ship traffic to and from onshore facilities may disturb feeding and breeding birds. Concentrations of birds at sites designated as "critical areas" in this report may be adversely affected by any one of these means. The Copper River Delta, for example, would be damaged most if oil washed up on the sand and mud flats, while colonies at the mouth of Resurrection Bay could be seriously affected by helicopter and tanker traffic near Barwell and Rugged Islands in summer. Cape Aklek and Unishagvak colonies, although not near lease areas, could be affected by having birds from the colony fouled by oil while on feeding sites. More must be learned about each concentration area before it can be decided how it could be impacted most by oil development.

II. Introduction

There are approximately 54,700 km of tidal coastline in Alaska with an associated 1,425,000 km^2 of outer continental shelf (Sowl and Bartonek 1974). This vast coastline and associated continental shelf provide abundant habitat to millions of seabirds, waterfowl, shorebirds, passerines and other birds at some stage of their life cycle. Sanger (1972) estimated that 51 million seabirds summer in subarctic Alaskan waters and Nisbet (1975) suggested a magnitude of 100 million birds for all Alaskan waters. Most of these breed on islands or other portions of coastline. According to Sanger (1972), who conducted pelagic boat surveys in the Gulf of Alaska, about 8 million seabirds also winter in Alaska. This estimate may increase when more information is obtained on nearshore wintering populations. Over 13 million waterfowl including 1 million geese, 12 million ducks, 70,000 swans and 150,000 cranes utilize Alaskan waters for breeding, migration staging or wintering (ADF&G 1975). An undetermined number of passerines, raptors and other birds use the littoral zone during some or all seasons of the year.

Most major waterfowl, shorebird and seabird habitats are known, but in most instances bird use or habitat diversity and size are not well quantified. Many areas of lesser importance to birds have not been identified. Because the State of Alaska's jurisdiction extends out three miles from the coast, and because this is the area most crucial to all breeding and many feeding marine birds, it is extremely important to fully assess the avifauna of the littoral and nearshore zone to determine which areas are more critical than others.

In order to evaluate coastal areas to determine which areas are most critical, it is necessary to synthesize existing literature and unpublished data on the distribution, abundance, behavior and food dependencies of birds associated with littoral and estuarine habitat within the study area. Since many areas have not been surveyed either in a particular season or in a quantitative manner, it is also necessary to conduct bird surveys to determine the seasonal density distribution, migratory routes, chronology of migrations, breeding locales and critical habitats for all bird species utilizing the littoral zone within the study area. Another objective of this project is to delineate and quantify bird habitats of the supratidal zone.

Many factors threaten Alaska's seabird populations, but developments by the petroleum industry including onshore and offshore drilling, pipelines, aircraft and ship transport and various associated activities, pose the greatest potential hazard to birds (King and Lensink 1971). Oil spills in marine waters directly affect many species of pelagic feeding and molting birds including shearwaters, fulmars, kittiwakes, phalaropes, gulls, alcids, cormorants and sea ducks (Bartonek et al. 1971). The mechanical effects of oil on bird plumage are well documented (see Vermeer and Vermeer 1974). Less obvious are the long-term effects on the ecosystem. Organisms lower on the food chain than birds may be affected less dramatically, but the long-term impact on the avifauna can be great. This may be especially true when oil is washed by tides or winds onto the productive littoral zone. Food organisms-both plant and animal-may be killed, thereby destroying extensive areas of feeding habitat for many ducks, geese and shorebirds (Vermeer and Vermeer 1975).

It is therefore essential to assess all coastline habitats for species composition and abundance of birds on a seasonal basis to determine use of the areas and then set priorities as to their importance to birds. This first assessment will be an extensive reconnaissance of the study area. Specific sites found to be more important than others will be studied intensively to determine why birds are attracted to them. More stringent restrictions on oil development could then be set for those areas determined to be most critical.

III. Current state of knowledge

A review of past information concerning bird use of coastal areas of southern Alaska was presented in last year's annual report for Research Unit #3/4 (Arneson 1976). Included were tables of data collected on prior waterfowl surveys in various parts of the study area. It was pointed out that, in general, very little baseline seasonal information on bird use of nearshore, intertidal and supratidal areas was available for most regions.

Since the writing of last year's summary, three additional non-OCSEAP related reports have been made available that concern bird use of nearshore waters within the study area. Dwyer et al. (1976) summarized data collected in winter and summer, 1972 and 1973, from Prince William Sound. They estimated over 300,000 birds inhabiting the Sound in winter. Approximately 40 birds/km^2 utilized shoreline habitats during that season while 20 birds/km^2 were found in open water habitats. The most common taxonomic groups at that season were diving and sea ducks, gulls and alcids with estimated populations of 129,000, 87,000 and 33,000, respectively. The most abundant species were glaucous-winged gulls(37,000), black-legged kittiwakes (34,000), goldeneyes (26,000), surf scoters (25,000), white-winged scoters (23,000) and marbled murrelets (22,000).

In summer, 70 and 30 birds/km^2 were found along shoreline and open water habitats, respectively. Dwyer et al. (1976) estimated a summer population of over 500,000 birds in the Sound. Sea ducks (52,000), gulls (220,000) and alcids (137,000) were again the most abundant groups, but the species composition and relative abundance did change. Black-legged kittiwakes were the most common summer resident (141,000) followed by marbled murrelets (140,000) glaucous-winged gulls (50,000), surf scoters (28,000) and mew gulls (20,000).

A survey of bird colonies on the south side of the Kenai Peninsula from Point Adam to Cape Resurrection was conducted by the National Park Service and U.S. Fish and Wildlife Service (USFWS) (Bailey 1976a). The Chiswell Islands were the most important colony both in abundance and species diversity. Eighteen species were observed around the islands, and 42 percent of the total birds including 59 percent of the breeding pairs recorded on the survey were found there. The next most significant areas were the Pye Islands and islands at the mouth of Resurrection Bay. Tufted puffins accounted for over half the breeding pairs on the survey, followed in descending order of abundance by black-legged kittiwakes, common murres, horned puffins and glaucous-winged gulls. A third report on the distribution, abundance, migration and breeding locations of marine birds in Lower Cook Inlet by David Erikson is presently being prepared. The project was funded by Alaska Department of Fish and Game (ADF&G), Marine and Coastal Habitat Management Section and coordinated with this project so comparable data were collected. Findings will be presented in the "Results and Discussion and Conclusion" sections of this report.

IV. Study Area

During FY 76 the study area for bird studies conducted by ADF&G, Anchorage included all coastline habitat from Cape Fairweather south of Yakutat to Cape Newenham in Bristol Bay. The area was divided into eight subunits: 1 - Northeast Gulf of Alaska, 2 - Prince William Sound, 3 - South Kenai Peninsula, 4 - Lower Cook Inlet, 5 - Kodiak Archipelago, 6 - South Alaska Peninsula, 7 - North Alaska Peninsula, 8 - North Bristol Bay (Figure 1).

A ninth subunit, Aleutian Shelf from Unimak Pass to Samalga Pass, was added in FY 77, and research this fiscal year will largely be confined to subunits 7, 8 and 9.

V. Methods

Aerial bird survey techniques remained the same as outlined in previous reports. Both twin-engine amphibious and single-engine aircraft were used depending on location of the survey and therefore on safety standards desired. Airspeed varied from 95 to 225 km/hour and altitude from 30 to 45 meters. Techniques varied with the type of habitat being surveyed, and normally two bird observers were used. While surveying straight beaches, the aircraft flew 100-200 meters seaward of the waterline. The shoreside observer enumerated all birds visible to the high water level, and the oceanside observer recorded all birds within 200 meters of the aircraft. Concentrations of birds outside this zone were also noted. In estuarine and coastal floodplain habitat a total count of birds was attempted. This entailed flying back and forth over the estuarine or supratidal zone at close enough intervals to get "total" coverage.

While flying over open water between islands or while purposely flying pelagic, nearshore transects, both observers recorded all birds within 100 or 200 meters of the aircraft. Poor observation conditions or faster flying aircraft caused the zone to be reduced to 100 meters.

A third technique was the experimental, random-stratified census of Kodiak Island. Preselected count units were surveyed in their entirety on eight habitat types.

When only one bird observer was present, either a fixed distance (100 or 200 meters) technique was used or the observer counted all birds within the zone from the aircraft to high tide line.

A requirement of the station designation scheme for this project was that units be easily identifiable at low altitudes while counting birds. Therefore, recognizable geographic features were used as starting and ending points and stations were of variable size. In most instances they did not exceed 16 kilometers in length.

All observations were recorded on cassette-type tape recorders. Information recorded included the following: bird identification to lowest taxon possible (order, family, genus, species), bird numbers, habitat type in which the bird was found and any other information possible including activity, sex, color phase and counting method. Weather observations

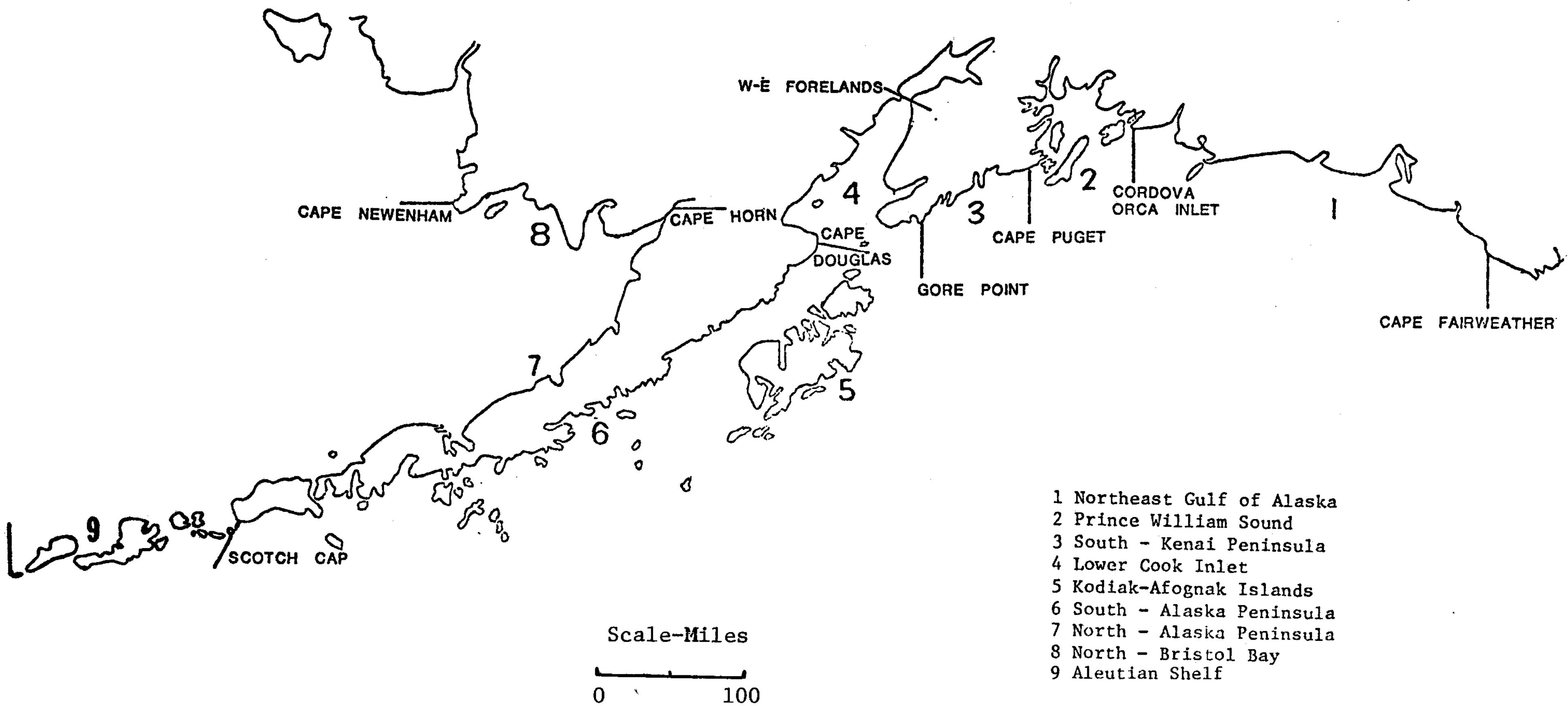

Figure 1. Study area with nine subunits for OCSEAP coastal marine bird project, Alaska Department of Fish and Game, Anchorage.

were recorded at the start of each flight and a coded survey conditions number was noted as often as conditions changed. Time was recorded at the start and end of each station.

Habitat mapping was conducted during snow-free months from both single- and twin-engine aircraft while flying at an altitude of 90-120 meters along the coastline. Information was color-coded onto USGS 1:63,360 or 1:250,000 maps using the scheme shown in Table 1.

Procurement and review of pertinent literature continued throughout the report period as historical information was located and recent literature published. Future reports will incorporate new information as it becomes available.

The order in which areas were selected for surveying was based largely upon presumed importance of the area to bird populations, vulnerability of the area to oil development and the proposed OCS planning schedule for oil lease sale areas. The amount of existing knowledge about certain areas and the extent of current research being conducted by other organizations or individuals also influenced which areas needed most research emphasis. For example, bird populations in Prince William Sound have been studied for the past several years by USFWS personnel because of the location of the terminus of the Alaska Pipeline at Valdez and future tanker traffic within the Sound. Therefore, I did not attempt to survey birds within that subunit.

VI. Results

Bird Surveys:

Since the project began in September 1975, a total of 23 bird surveys have been conducted. Of these, nine were classified "major" because they covered most of the subunit. Fourteen surveys were flown over only a small portion of the subunit, and were therefore termed partial. A summary of when and in what subunit the surveys were flown is shown in Table 2. Tracklines of where within each subunit surveys were flown are presented in Appendix A, Figures 1-15. Summaries of the number of species observed, total birds counted and number of stations surveyed for major and partial surveys are shown in Tables 3 and 4. A summary of five major surveys in four subunits by species group totals is listed in Table 5. Table 6 lists species group totals for four seasonal surveys in Lower Cook Inlet.

Data from 18 surveys are on computer tape, and information from the remaining five partial surveys is being transcribed. Unexpected delays in cleaning the tape of all errors has resulted in the lack of further computer analyses other than those presented. Information on habitat preference by birds was received too late for analysis. A compilation of the data is given in Appendices C, D and E. Analysis of bird densities along the coast will be available shortly.

Table 1. Color-coded habitat mapping system for coastal zone from Cape Fairweather to Cape Newenham.

Substrate: Color Code

Dk. Blue	Mud	
Yellow	Sand	
Red	Gravel	
Black	Rock	
Dk. Blue & Yellow	Mud and Sand	Many more combinations exist
Red & Yellow	Gravel with Sand	
Black & Red	Rock with Gravel (Rubble)	
Green	Vegetation - Mixed grasses, sedges, forbs	
Purple	Vegetation - Beach Rye	
Orange	Vegetation - Eelgrass	
Pink	Algae - Kelp	
Brown	Stormtide line	
Lt. Blue	Changed water course	

Slope of Bank

1	Flat	0-20°
2	Slight	20-40°
3	Moderate	40-60°
4	Steep	60-80°
5	Vertical	80-100°

Height of Bank

A	0-3 m	0-10 ft.
B	3-6 m	10-20 ft.
C	6-12 m	20-40 ft.
D	12-30 m	40-100 ft.
E	30+ m	100+ ft.

Table 2. Number of bird surveys by season and mapping flights completed from September, 1975 to March, 1977 by RU #3

	Number of Bird Surveys				No. of Mapping Flights	
Subunit	Winter	Spring	Summer	Fall	Major	Partial
1. Northeast Gulf of Ak.		1M	1P		1	1
2. Prince William Sound						2
3. Kenai Peninsula-South					2	
4. Lower Cook Inlet	1M,1P	1M,2P	1M,1P	1M,1P	1	1
5. Kodiak-Afognak Is.	1M*					1
6. Alaska Peninsula-South	2P			1P		2
7. Alaska Peninsula-North	2P		2P	2M	2	
8. Bristol Bay-North		1M			1	
9. Aleutian Shelf	1P					1
Total by classification	2M,6P	3M,2P	1M,4P	3M,2P	7	8
Overall Total		9M,14P			15	

M: Major P: Partial

*Random-stratified survey

Table 3. Number of species and individuals observed on aerial bird surveys (major) of five coastal regions of southern Alaska.

ID No.	Survey/Season/Date	No. of Species	No. of Additional Species Groups	Total No. of Species Identified (mimimum)	Total Birds Counted	No. of Stations Surveyed
7601	Alaska Peninsula-North Fall, Oct. 13-27, 1975	34	14	48	638,479*	201
7602	Lower Cook Inlet Winter, Feb. 9-18, 1976	20	11	31	23,138	141
7603	Kodiak, Winter Feb. 22 to Mar. 21, 1976	32	7	39	33,025	76
7604	Northeast Gulf of Alaska Spring, May 1-9, 1976	59	8	67	130,511	154
7605	Lower Cook Inlet Spring, May 3-7, 1976	41	7	48	115,292	164
7606	Bristol Bay-North Spring, May 17-20, 1976	56	7	63	45,865	110
7607	Lower Cook Inlet Summer, June 21-25, 1976	40	7	47	97,772	182
7701	Lower Cook Inlet Fall, Sept. 30-Oct. 2, 1976	38	7	45	55,682	178
7702	Alaska Peninsula-North Fall, Oct. 13-16, 1976	33	8	41	415,701	38

*Numbers of black brant included in total are likely in error. Total may be much less than 638,479.

Table 4. Number of species and individuals observed on aerial bird surveys (partial) of four coastal regions of southern Alaska.

ID No.	Survey/Season/Date	No. of Species Identified	No. of Species Group Identified	Minimum No. of Species Identified	Total Birds Counted	No. of Stations Surveyed
7601	Alaska Peninsula-South Fall, Oct. 13-27, 1975	25	7	32	36,459	14
7611	Lower Cook Inlet Winter, Mar. 5-6, 1976	7	5	12	611	5
7612	Lower Cook Inlet Winter, April 1, 1976	12	3	15	5,485	26
7613	Lower Cook Inlet Spring, May 10, 1976	13	13	26	993	8
7610	Alaska Peninsula-North Summer, June 16, 1976	2	7	9	1,282	7
7614	Lower Cook Inlet Summer, June 24, 1976	10	6	16	1,302	8
7608	Northeast Gulf of Alaska Summer, July 24, 1976	14	4	18	22,647	26
7609	Alaska Peninsula-North Summer, July 30-31, 1976	11	7	18	72,604	39
7615	Lower Cook Inlet Fall, Sept. 30, 1976	10	7	17	1,378	8

Table 5. Species composition and abundance of birds on littoral areas and nearshore water during major aerial surveys of four Alaskan regions.

Species Group	Survey Area and Dates Northeast Gulf Spring May 1-9, 1976	Kodiak* Winter Feb.-Mar., 1976	Ak. Peninsula-North Fall Oct. 13-27, 1975	Ak. Peninsula-North Fall Oct.13-16, 1976	Bristol Bay-North Spring May 17-20, 1976
Loons	529	1	72	66	409
Grebes	20	5	10	27	88
Tubenoses	0	0	82	0	0
Cormorants	485	963	1,255	38	1,628
Swans	13	0	43	171	64
Geese	1,729	131	420,026**	203,702	5,495
Dabblers	5,740	3,208	23,039	31,457	876
Divers	6,362	4,465	963	607	7,320
Sea Ducks	6,938	16,975	140,364	56,125	5,914
Mergansers	1,007	207	22	87	718
Eagles, Hawks, Falcons	185	163	30	29	11
Cranes	79	0	0	0	92
Small Shorebirds	18,828	779	21,682	45,294	1,627
Medium Shorebirds	13,062	177	211	20,580	2,098
Large Shorebirds	3,283	262	94	615	50
Mixed Shorebirds	23,556	125	3,823	3,558	791
Jaegers	114	0	0	2	20
Gulls	38,978	1,814	25,372	19,706	9,005
Terns	6,420	0	1	0	1,010
Alcids	3,687	2,936	239	7	8,533
Corvids	25	590	35	28	32
Fringillids	1	0	822	146	0

* random-stratified survey, only 29% of stations were sampled.
** Numbers of black brant at Izembek Lagoon included but may be overestimated.

Table 6. Species composition and abundance of birds on littoral areas and nearshore waters during four seasonal surveys of Lower Cook Inlet.

Species Group	Winter Feb.9-11 & 18, 1976	Spring May 3,4 & 7, 1976	Summer June 21-25,1976	Fall Sept.30-Oct.2,1976
	Season and Date of Survey			
Loons	64	81	102	76
Grebes	3	48	5	76
Tubenoses	0	0	1,006	3
Cormorants	458	1,198	1,765	2,799
Swans	0	29	44	0
Geese	0	6,808	52	2,659
Dabblers	1,502	7,196	2,291	13,109
Divers	3,073	13,249	1,056	1,103
Sea Ducks	10,178	19,229	29,463	10,618
Mergansers	253	717	184	291
Eagles, Hawks, Falcons	52	38	44	40
Cranes	0	215	13	0
Small Shorebirds	464	21,380	219	166
Medium Shorebirds	3,571	1,212	264	1,453
Large Shorebirds	1	61	33	1
Mixed Shorebirds	598	0	1	0
Jaegers	0	0	1	0
Gulls	1,432	42,197	55,288	22,373
Terns	0	15	366	0
Alcids	279	525	5,321	38
Corvids	779	117	52	706
Fringillids	0	0	4	3

Habitat Mapping:

In Appendix B, Figures 1-8 show portions of the coastline mapped thus far for this project. Amounts and percent composition of the various substrates of coastline that have been mapped are listed by subunit on Tables 7 and 8. Quantities of habitat on intertidal and supratidal areas for two subunits are shown on Table 9. Atlases of USGS 1:63,360 and 1:250,000 maps containing all habitat information collected to date from aerial reconnaissance have been completed and are available for perusal at ADF&G, Anchorage office. It has not yet been decided how the information will be reproduced. As additional information is collected in areas not previously mapped, it will be added to the atlases.

Table 9. Summaries of substrate and cover types on intertidal and supratidal areas in two subunits of the study area.

Substrate and Cover Types
(Area in Kilometers^2)

Subunit	Mud Flats	Sand Flats	Mud and Sand Flats	Mixed Forbs and Grasses	Beach Rye	Eelgrass*
Lower Cook Inlet	184	80	113	197	12	2
North-Bristol Bay	217	72	73	461	14	-

* Eelgrass was difficult to detect from the air. Much more is probably present.

Critical Areas:

Past and current information on bird distribution and abundance was analyzed to establish critical areas shown in Appendix A, Figures 1-15.

VII. and VIII. Discussion and Conclusions

Bird Surveys:

Until more specific computer analyses can be completed, only general statements can be made about results of coastal bird surveys conducted so far for this project. Species diversity was greatest for Northeast Gulf of Alaska and North Bristol Bay spring surveys. This may reflect the fact that birds were in bright spring plumage and in large concentrations which made them more easily identifiable. Birds that would otherwise be lumped into species group could be listed to species. This may have accounted in part for the high diversity. Another possible explanation was that a greater variety of preferred habitats in these subunits resulted in an actual increase in species diversity. Many species were also observed on a spring flight in Lower Cook Inlet and a fall flight along the North Alaska Peninsula. As expected fewest species were identified in winter surveys. Summer diversity was relatively low because many species using coastal habitat for spring migration travelled inland for breeding.

Table 7. Quantity of various substrate types along the coastline in the eight subunits of the study area, Cape Fairweather to Cape Newenham and percentage of coastline mapped in each subunit.

				Substrate composition of mapped shoreline (kilometers)							
Subunit	Mud	Mud & Sand	Sand	Gravel	Rock	Sand & Rock	Gravel & Rock	Sand & Gravel	Sand Gravel & Rock	Total Distance Mapped	Percent of Subunit Mapped
Northeast Gulf of Alaska	13*	--*	518	148	235	10	149	41	--	1114	98
Prince William Sound	29	--	83	387	591	3	194	16	--	1303	37
South-Kenai Peninsula	--	--	31	180	731	47	41	1	--	1031	89
Lower Cook Inlet	91	41	72	396	487	23	196	110	18	1434	95
Kodiak	5	--	79	491	859	21	296	62	3	1816	55
South-Alaska Peninsula	--	--	243	248	59	8	154	67	7	786	39
North-Alaska Peninsula	444	8	706	183	26	--	79	314	16	1776	99
North-Bristol Bay	283	11	404	14	86	27	68	40	4	937	99
Aleutain Shelf	--	--	74	292	679	77	242	19	--	1383	82

* Copper River Delta/Controller Bay not completely mapped. Values will be greater.

Table 8. Summary of substrate composition along mapped shoreline in eight subunits of the study area, Cape Fairweather to Cape Newenham.

	Substrate composition of mapped shoreline (percent)									
Subunit	Mud	Mud & Sand	Sand	Gravel	Rock	Sand & Rock	Gravel & Rock	Sand & Gravel	Sand Gravel & Rock	Percent of Subunit Mapped
Northeast Gulf of Alaska	1	--	46	13	21	1	13	4	--	98
Prince William Sound	2	--	6	30	45	Tr	15	1	--	37
South-Kenai Peninsula	--	--	3	17	71	5	4	Tr	--	89
Lower Cook Inlet	6	3	5	28	34	2	14	8	1	95
Kodiak	Tr	--	4	27	47	1	16	3	Tr	55
South-Alaska Peninsula	--	--	31	32	8	1	20	9	1	39
North-Alaska Peninsula	25	Tr	40	10	1	--	4	18	1	99
North-Bristol Bay	30	1	43	1	9	3	7	4	Tr	99
Aleutian Shelf	--	--	5	21	49	6	17	1	--	82

Surveys of Alaska Peninsula North in fall 1975 and 1976 had the highest totals of birds with an average of half a million birds counted. Flight routes were repeated intentionally to get year-to-year differences in species diversity and abundance. Several differences were evident although only the large estuaries were surveyed in October 1976. Shorebirds were three times more abundant in 1976 and were found in large numbers in most of the estuaries. Conversely, sea ducks were three times more abundant in 1975. This may have been due in part to their inhabiting outer coastal waters which were surveyed in 1975 but not 1976. Also, weather conditions may not have moved them south into the survey area by October 1976.

Snow and Canada geese were less abundant in the Ugashik-Cinder River/Hook Lagoon area in 1975 than in 1976. During the second year's survey Canadas were less abundant in Izembek Lagoon than they were the year before. In 1976, emperor geese appeared to be more abundant in Nelson Lagoon and farther north than at Izembek; in 1975, however, the emperors had moved farther down the Peninsula by mid-October. Black scoters continued to be the most abundant scoter and Steller's the most abundant eider. Dabbling ducks of all species were as abundant in 1976 as in 1975.

Differences of species composition among the various estuarine complexes were also apparent from these bird surveys. These differences were probably due to habitat preference based on an interplay of substrate cover and food source. Correlations between amounts of various habitats available and bird species composition on the estuaries, can be derived from analysis of aerial surveys. However, this information has not yet been compiled and analyzed for this project. Subtle differences, such as food availability within habitat types, could only be recognized by sampling and ground truth studies. This research needs to be conducted at specific sites.

Emperor geese and sea ducks were more commonly found at Nelson Lagoon, Seal Islands and Port Heiden. More Canada geese and dabblers were found in Ugashik-Cinder River/Hook Lagoon estuaries. Shorebirds were found in all areas, but most were in Nelson Lagoon and Cinder River/Hook Lagoon. Izembek-Moffet Lagoon contained the greatest diversity and abundance of bird species. Some species or subspecies of birds migrate across Bristol Bay and the Bering Sea, using Izembek as their only staging area before migration across the Gulf of Alaska to wintering areas.

An opportunity to observe seasonal changes of bird abundance and diversity was made available in Lower Cook Inlet through cooperation with the ADF&G, Marine and Coastal Habitat Management Section. Coastal bird surveys were conducted in all four seasons and migration patterns became evident. Results of the study are presently being summarized by David Erikson. A noteworthy finding was the change in scoter population size from winter to summer. Relatively large numbers wintered in the region, but the population increased as spring migrants arrived. The population peaked in summer when large rafts were found in several locations. The most abundant scoter in nearshore waters in all seasons was the surf scoter. Concentration areas for scoters were in Kachemak Bay, Iniskin-Iliamna-Oil Bays, and Akumwarvik Bay. An offshore wintering concentration of white-winged scoters was observed approximately five kilometers southwest of Bluff Point in Outer Kachemak Bay.

Bird-use patterns of areas in Lower Cook Inlet this year were similar to patterns reported in the past. Snow geese staged on flats of the Kenai and Kasilof Rivers in spring but bypassed the area in fall. Large numbers of scaup utilized nearshore waters in spring and goldeneyes, buffleheads and oldsquaws wintered in the region but departed for breeding grounds in summer. Shorebirds were most abundant during spring migration, but the largest concentration was observed several days after the spring survey. Warren Ballard, ADF&G Homer, estimated 1-2 million small shorebirds on Fox River Flats on May 11, 1976. Gulls were common in all seasons but most abundant in spring and summer with the arrival of breeding birds. Also, alcids were most plentiful at breeding sites in summer. Corvids frequently used coastal areas for foraging in winter but moved inland for nesting in summer.

The most abundant species groups using Lower Cook Inlet in winter were diving and sea ducks which comprised 57.3 percent of the total birds seen along the shoreline and in nearshore waters. A distant second in abundance were shorebirds (20 percent) followed by dabbling ducks and gulls with 6.5 and 6.2 percent, respectively. With the arrival of kittiwakes, gulls became the most prevalent bird in spring, comprising 36.3 percent of the total, followed by diving and sea ducks (28.2 percent) and shorebirds (19.6 percent). Gulls and diving/sea ducks remained the commonest species groups in summer with 56.5 and 31.2 percent of the total. A distant third were alcids with 5.4 percent. Most abundant in fall again were gulls (40.2 percent) followed by dabbling ducks (23.5 percent) and diving/sea ducks (21.0 percent).

Erikson (in prep.) also summarized the results of pelagic aerial surveys within Lower Cook Inlet. In winter, greatest densities of birds were found in Outer Kachemak Bay. An area centered 20 kilometers west of Point Bede contained the densest concentrations of birds in spring when alcids began migrating into the area. Summer concentrations were found both in Outer Kachemak Bay and a similar area off Point Bede but somewhat nearer shore. Shearwaters and fulmars comprised approximately 60 percent of the birds observed in the latter area. Densities in fall were again greatest in Outer Kachemak and the region off Point Bede mentioned for spring. Apparently incoming Gulf of Alaska water and outgoing Cook Inlet water causes food organisms to be concentrated in these areas where birds were most commonly seen.

Data from the other three major surveys have not been fully analyzed, but general areas of importance are explained later in this section. The spring survey of NEGOA (May 1-9, 1976) coincided with peak shorebird migration. It was after peak waterfowl movement but caught the beginning of the arctic tern migration. The total number of birds observed on the NEGOA flight was the third largest of all major surveys. As expected, the largest concentrations were observed on the Copper River Delta.

An attempt was made to catch the continuing spring migration by surveying North Bristol Bay the following week (May 17-20). Many waterfowl were still awaiting spring breakup by foraging in coastal waters of Bristol

Bay before moving farther north or inland. Many gulls were on breeding territories and alcids were at colony sites. The great species diversity for this area may be a result of the varied habitats from mud flats at the Kvichak River to rock cliffs at Cape Newenham. Surprisingly few shorebirds were observed, but it is not known at present whether this was a result of birds migrating overland or over water to breeding areas whether little habitat suitable for staging was available or whether we missed the peak of their migration.

Fewer species and lower numbers of birds were recorded during the winter survey of Kodiak because only a portion of the islands was surveyed in the stratified-random survey design. It is hoped that population totals, possibly by species, for eight designated habitat types will be compiled shortly for the entire archipelago. Wintering populations of diving and sea ducks were found throughout the islands but murres were more prevalent in Ugak and Kiliuda Bays. Mallards and other dabblers were common at stream mouths at heads of bays. Densities of most bird species appeared to be much lower on the forested Afognak-Shuyak portion of the archipelago.

Of the partial or minor surveys, the most noteworthy is the summer pelagic transects north of Unimak Island and Izembek National Wildlife Range. Large rafts of shearwaters were foraging several kilometers offshore, and 68,773 were estimated on 140 km^2 of transects. They comprised 95 percent of all birds observed on the survey. Next most abundant were murres with 2.6 percent of the total.

Pelagic surveys of Outer Kachemak and Kamishak Bays on 1 April 1976 revealed species composition differences between the two areas. Many more eiders were found in Kamishak than in Kachemak, but the reverse was true for scoters. Gulls were more common in Kamishak whereas alcids occurred more frequently in Outer Kachemak. Densities were three times greater in Outer Kachemak (60.9 vs 21.4 birds/km^2).

The value of the other partial surveys will be brought out when species abundance and diversity can be compared at specific stations or small geographic areas by season. As aircraft of opportunity become available along coastal and nearshore areas to bird observers, we will continue to take advantage of them in order to get as much bird distribution and abundance information as possible.

Several notable problems and biases arose when conducting aerial shoreline surveys that should be considered when analyzing the data. Most total figures in species lists from surveys probably represented minimum values or underestimates. There were differences between species as to how accurately birds were identified or their numbers were estimated. For example, counts of grebes should probably be higher in all cases. They appeared more frequently in ground and boat surveys, and it was assumed they dove at the approach of aircraft and remained under until the plane had passed. Also, in winter from a distance of 200 meters at 45 meters altitude, grebes resembled small alcids. Other species including cormorants, oldsquaws and common eiders dove in response to aircraft, making identification difficult.

Certain birds flush at the approach of aircraft and would be out of the transect zone when the observer arrived. Black brant were perhaps the most difficult to count because they flushed early and were often in tight, three dimensional masses. An over estimation of up to 100,000 brant was suspected for the October 1975 survey in Izembek. Many birds moved to other parts of the lagoon and may have been recounted. Birds such as rock sandpipers and sparrows would be easier to see and estimate if they were to fly, but they often remain on the ground and are not counted.

Size difference in shorebirds from small to medium and medium to large is not always easily discernible, and misinterpretations can result from improperly identifying flocks. Identification of the three scoter species may not always be possible, and extrapolating proportions of those identified to those unidentified may not always be valid.

For safety reasons, large colonies were often avoided, and numbers were too great to enumerate from the air. Therefore, some of the largest concentrations of birds were not recorded in shoreline surveys.

By pointing out the problems, I am not attempting to discredit shoreline bird surveys. On the contrary, I feel they are very useful. My intention is to suggest that total numbers recorded most likely represent underestimates and positive identification of certain species is not always possible. Unusual sightings and new distributional records should be admitted only if they were accurately verified. In many cases, analysis should be based on species groups rather than species.

There was insufficient time to analyze and discuss apparent habitat preferences of birds as depicted by compilations of bird observations on various water types, physiographic features and substrate types. Figures 1-9, Appendices C, D and E, quantify the relative use of these various habitat types according to aerial surveys conducted for this project.

Habitat Mapping:

Approximately 80 percent of the study area has been mapped. Mapping primarily included substrate at the high tide line and quantity of habitat types from high tide to storm tide levels. Aerial reconnaissance of this nature gave only basic information as to habitat types available to coastal marine birds. As yet no systematic ground truthing has been accomplished to supplement aerial mapping.

Vegetation of the supratidal region provided nesting cover and forage plants for several species of birds. Grasses, sedges and a variety of halophytic forbs formed the predominant cover on the coastal floodplain near rivers and in estuaries. A fringe of beach rye (*Elymus* spp.) was found on most sandspits and on long straight sandy beaches. In the latter case, the narrow fringe of beach rye could be measured only in terms of distance and not area. For example, the north side of the Alaska Peninsula has a 315-km wide fringe of beach rye. Many eelgrass beds were probably overlooked when mapping at high tide. Information on distribution of eelgrass and algae (kelp) will best be described by Zimmerman and Merrell (1976) and other RU #78/79 reports.

Diversity of substrate types is a likely index to bird species diversity. Homogenous coastlines will have fewer birds per unit distance. Almost half (46 percent) of the NEGOA coastline was sand and when correlations are made between habitat type and bird species present, they will probably show a preponderance of species like gulls and terns. These birds frequent sandy beaches more than other species. Prince William Sound has only been partially mapped but ratios of substrate type will probably be similar for the rest of the subunit. In the Sound 45 percent of the coast mapped so far was rock and 30 percent gravel. Seventy-one percent of the south side of the Kenai Peninsula was rock and that percentage may rise when mapping is completed. In Subunit 4, Lower Cook Inlet, composition of the shoreline was more varied as were substrates of the north sides of the Alaska Peninsula and Bristol Bay. Kodiak and the Aleutian Shelf contained mostly rock and gravel. Much sand and gravel was mapped on the south side of the Alaska Peninsula, but only 39 percent has been delineated. Values may change when mapping is completed.

Hayes et al. (in prep.) has devised a rating scheme for the susceptibility of various coastal habitats to oil impact. His information was based upon studies of oil spills in the Straits of Magellan and Spain and a literature review. His classification of susceptibility relates to longevity of oil in the environment which may have a direct bearing on its effect to food organisms of birds and to fouling of feathers. Coastal environments listed below are in decreasing order of their susceptibility to oil as designated by Hayes et al. (in prep.):

1. Protected estuarine salt marshes
2. Protected estuarine tidal flats
3. Sheltered rocky headlands
4. Gravel beaches
5. Mixed sand and gravel beaches
6. Impermeable muddy tidal flats (exposed to winds and currents)
7. Steeper, medium to course grained sand beaches
8. Flat, fine-grained sandy beaches
9. Eroding wave-cut platforms
10. Straight, rocky headlands

In his assessment of Lower Cook Inlet, Hayes et al. (in prep.) estimated that 41.5 percent of the coastline fell into the four most susceptible habitats, 13.4 percent into the three intermediate values and 45 percent into the four environments least susceptible to oil.

This rating scheme could be applied to all coastline within the study area when combined with the habitat delineation of RU #78/79 and this project (RU #3). With bird distribution and abundance known for these habitat types, a relative index could be derived for vulnerability of coastal marine birds to oil spills. The biological significance of oil spills in these various environments must be studied to determine the long-term effects on animal populations.

Critical Areas:

As a result of past and current bird surveys and literature searches, certain coastal areas were determined to be of primary or secondary importance to marine birds. In certain instances the judgment of importance may be only tentative until more observations can be made to verify the significance. One survey, in one area during one season, is insufficient to classify an area "critical" although many birds observed at that one time. Because there are many differences in species abundance within a given area according to year, season, time of day, weather and stage of tide, the regions must be looked at several times to "prioritize" the critical areas.

Problems arose in determining relative importance of the areas because a colony, for example, may be quite important to the ecosystem within a subunit but when compared to colonies in other subunits, it looks quite insignificant. In general, primary colonies are those containing over 100,000 birds and secondary colonies those over 10,000 but less than 100,000. Classification of migration and staging areas depended on their known or suspected values to birds within a subunit. The relative significance of the critical areas should be apparent from the text.

Subunit 1 - NEGOA:

[See Appendix A, Figure 1.]
The importance of the Copper River Delta to migrating and breeding birds is well known. It is a staging area for millions of shorebirds and hundreds of thousands of waterfowl plus a nesting area for almost 50,000 waterfowl and thousands of gulls. The world's population of dusky Canada geese (*Branta canadensis occidentalis*) nests in this region. Ducks and geese use mostly the vegetated areas nearest the saltwater edge, gulls nest on the sandy, barrier islands and shorebirds feed on the extensive mud flats. The 1964 earthquake uplifted mud flats approximately two meters, and resulting successional changes in vegetation have provided waterfowl - particularly dusky Canada goose goslings - with a heavily utilized food source. The area is flooded only on the highest tides. Both floodplains and intertidal areas on each side of the Copper River are important to migrating and summering birds.

Controller Bay is similar to Copper River Delta in habitat types and therefore attracts many migrating shorebirds and waterfowl. Orca Inlet provides extensive mud flats at low tide and is used largely by foraging shorebirds.

Several other areas are suspected of having moderate usage by migrating birds. Riou Bay on the southeast side of Icy Bay contained many sea ducks and various other birds in spring 1976. A colony of Aleutian and Arctic terns was found at the end of Riou Spit. The significance of this area to birds may be comparable to that of other areas east of Kayak Island but cannot compare to the Copper River Delta in total bird usage.

Similar situations are found on other portions of the coast from Cape Suckling to Fairweather-particularly in Yakutat Bay, Blacksand Island, and Dry Bay. At these locations bird concentrations are found during at least some migration periods, but in comparison to large staging areas they may appear insignificant. Summer and winter usage of this region is undocumented. Yakutat Bay and possibly Russell Fiord may contain concentrations of summering and wintering birds as well. Blacksand Island, near the confluence of the Situk-Ahrnklin Rivers and Seal Creek, were identified by Mickleson (1975) as an important migration area. Bird usage of Dry Bay may vary from year-to-year and the earthquake's uplift may have decreased its utility.

Middleton Island contains a large colony of black-legged kittiwakes, tufted puffins, common murres, pelagic cormorants and glaucous-winged gulls. Nearshore waters of the island provide resting and foraging areas.

Subunit 2 - Prince William Sound:

[See Appendix A, Figure 2.]
Prince William Sound is unique in its value to birds. The rocky, forested islands and fiords do not support large bird rookeries or staging areas. The two largest colonies are found on Wooded Islands and Boswell Rocks where the predominant species are tufted puffins and black-legged kittiwakes, respectively. The solitary nesting, marbled murrelet, is one of the most abundant species in the Sound, and likely nesting sites are in trees and in screes above timberline. No one area can be singled out as a concentration area for the murrelets. They normally are only in small groups or pairs and are well dispersed throughout the Sound. A concentration of 10,000 Kittlitz's murrelets, which probably nest on glacial moraines and talus slopes, was observed in Unakwik Inlet in July 1972 (Isleib and Kessel 1973). It is not known if concentrations of this magnitude occur often in the Sound and whether they reoccur in the same location.

Scoters as a species group are vulnerable to oil but do not occur in large concentrations in the Sound. Nevertheless small concentrations are found in many parts of the subunit in both summer and winter. Many white-winged scoters migrate inland during summer, but many non-breeding surf scoters are present in summer. Because several species have ubiquitous distribution within Prince William Sound and occur in large numbers, the entire inner portion of the Sound is somewhat critical. Quantities of spilled oil from tankers, fires or pipeline accidents could easily coat a large portion of the Sound. Because much of the habitat could be classified "sheltered rocky headlands" - third on the oil susceptibility scale - the oil could be devastating to large numbers of birds.

Subunit 3 - South Kenai Peninsula:

[See Appendix A, Figure 3.]
Bailey (1976a) completed an intensive survey of breeding sites within much of this subunit during summer 1976. A primary colony was documented on the Chiswell Islands and secondary colonies on the Pye Islands and at the mouth of Resurrection Bay. On the Chiswells, species in greatest

abundance were tufted puffins, black-legged kittiwakes and common murres. New colony records were discovered for rhinocerous auklets and fork-tailed storm-petrels. Tufted puffins, horned puffins, black-legged kittiwakes and glaucous-winged gulls were most common on the Pye Islands. A Kittlitz's murrelet egg was found on a grass-covered ledge of Outer Island. In Resurrection Bay, black-legged kittiwakes and common murres were the most numerous species, and the areas with the most birds in descending order of magnitude were Barwell Island, Cape Resurrection, Hive Island and Rugged Island. No other "critical" areas are documented for this subunit. Winter bird use of the area has not been evaluated.

The Chiswell Island-Cape Resurrection colonies would appear to be very near aircraft and tanker corridors if an oil/gas staging area were constructed in Seward for lease areas in the Gulf. Care should be taken to protect these colonies during critical breeding periods.

Subunit 4 - Lower Cook Inlet:

[See Appendix A, Figure 4.]
Largest concentrations of birds in Lower Cook Inlet are found in summer at colonies on the seven Barren Islands. Bailey (1976b) estimated a total of 205,000 tufted puffins, 91,000 common murres, 33,800 black-legged kittiwakes, 15,700 horned puffins and 5,200 glaucous-winged gulls on the islands. Parakeet auklets were found on five islands and a rhinocerous auklet colony was found on Sud Island. The critical area around the Barrens extends well away from shore due to feeding and resting birds. Foraging distances must be studied in greater detail to determine a safe "buffer zone" for the birds.

A secondary colony is located on the south and east end of Chisik Island and on adjacent Duck Island. Black-legged kittiwakes, common murres and horned and tufted puffins from this colony apparently forage to the south in Lower Cook Inlet. Snarski (1971) estimated a total of 78,525 birds on this colony over half of which were black-legged kittiwakes.

During migration there are several areas within Lower Cook Inlet important to staging birds. Fox River Flats at the head of Kachemak Bay is a known migration staging area for waterfowl and shorebirds. Because of the sighting of an estimated 1-2 million small shorebirds in this area in spring 1976, the value of these flats may be even greater. However, this heavy usage may not be a regularly occurring phenomenon and needs to be looked into further.

Moderate usage is made of the flats at the mouths of the Kenai and Kasilof Rivers in spring. Primary species using these areas for feeding and resting during spring migration are snow and Canada geese, cranes and dabbling ducks. In fall the area across the inlet at Bachatna Flats is used for staging waterfowl. Several other migration concentration areas were pointed out by Erikson (in prep.), but future studies would be necessary to determine if this usage is an annual occurrence.

In summer, large rafts of non-breeding scoters were noted in the Iliamna-Iniskin-Oil Bay region, in Akumwarvik Bay at the head of Kamishak Bay and also on the north side of inner Kachemak Bay. Flocks of several thousand common eiders were observed near Augustine Island in Kamishak Bay in spring, but large numbers were also observed in summer.

Concentrations of wintering birds were found in both inner and outer portions of Kachemak Bay. Perhaps the most significant were concentrations of scoters (mostly white-winged) that have been observed during at least three winters in outer Kachemak. A flock estimated at 10,000 was reported in 1968 near Dangerous Cape, we observed a flock of 10,000 white-winged scoters south of Bluff Point in 1976 and Sanger (pers. comm.) reported white-wingeds in a similar location in 1977. Murres were also common in outer Kachemak during winter. A variety of dabbling, diving and sea ducks were abundant in ice-free areas of inner Kachemak Bay in winter.

Subunit 5 - Kodiak Archipelago:

[See Appendix A, Figure 8.]
Over 200 colonies have been documented on the islands of Kodiak but only one was classified primary due to the 100,000 black-legged kittiwakes and other birds that were found there. This colony is in Boulder Bay at the mouth of Kiliuda Bay. Six colonies have been classified secondary for this report because they were estimated to contain over 10,000 birds by RU #338/343 (Lensink and Bartonek 1976). Three are located near the primary colony: one at Right Cape at the mouth of Kiliuda Bay and two in Sitkalidak Straits on Cathedral and Amee Islands. The latter is unique in that 5,000 Arctic terns and 3,000 Aleutian terns as well as 2,500 tufted puffins were found there. Three other coastal areas have concentrations of over 10,000 breeding birds. Cape Chiniak and adjacent islands, the Triplet Islands in Marmot Bay and the Noisy Islands of the outermost tip of Uganik Island. The most common species at these sites are tufted puffins, black-legged kittiwakes and the aforementioned terns.

Most habitat on Kodiak is unsuitable as staging areas for migrating geese, dabbling ducks and shorebirds. Possible sites are lagoons on the south end of the island particularly those on the Trinity Islands, but no one has looked at the area during migration. If other areas critical to migrating birds are present on the Archipelago, they are as yet unidentified.

Because bays are relatively ice-free in winter, several species utilize Kodiak as wintering grounds. Diving and sea ducks, in particular, are found well-distributed throughout the islands. Many are observed in Chiniak Bay from the road system at Kodiak and this may well be one of the densest wintering populations on Kodiak. Further research is needed to substantiate this. Many murres, crested auklets and sea ducks have been sighted in Uyak Bay in the past, and therefore, it has been designated a winter concentration area. Similarly, concentrations of murres were observed feeding in Kiliuda and Ugak Bays during last winter's survey. Whether these bays have continued year-to-year use remains to be verified.

An area on Kodiak which possibly has the densest bird populations in all seasons is Whale Passage between Kizhuyak Bay and Kupreanof Straits. Apparently, food organisms are made available by tidal currents, and many species use this 10 km^2 area. Last winter 215 birds/km^2 consisting mostly of sea ducks were found there. In other winters, thousands of crested auklets have been observed feeding there. During summer, species composition within the Passage consists of those breeding on nearby colonies and non-breeding summer residents.

Subunit 6 - South Alaska Peninsula:

[See Appendix A, Figure 11.]
The many islands and rock cliffs of the south side of the Alaska Peninsula support more large sea bird colonies within the study area. Sixteen colonies have been documented as having over 100,000 total birds and 30 have over 10,000 birds. At the north end of the subunit there are primary colonies at Cape Aklek and Cape Unalishagvak each containing over 200,000 murres. Nearby are two secondary colonies containing 10,000 or more tufted puffins.

From Ashiak Island near Agripina Bay to Ugaiushak Island south of Cape Kuyuyukak, seven secondary colonies are recognized. Species composition depends on the physiography at the site, but the most common species are tufted and horned puffins, black-legged kittiwakes, murres, glaucous-winged gulls and pigeon guillemots.

Within the Semidi Island group nine primary colonies are designated. Totals for the Archipelago include: 386,000 northern fulmars, 420,000 black-legged kittiwakes, 1,554,000 murres and 80,000 tufted puffins. Obviously, oil development or spills in the vicinity of these islands would have devastating effects on large numbers of birds.

One major and four secondary colonies are found in the vicinity of Mitrofania Island. Species composition for these five colonies include 11,200 glaucous-winged gulls, 26,500 black-legged kittiwakes, 210,000 murres, 4,000 pigeon guillemots, 38,000 horned puffins and 85,000 tufted puffins. The largest colony is Spitz Island with 200,000 murres and other colonies are on Mitrofania, Brother, Chiachi and Pinusuk Islands.

Another critical area is the Shumagin Archipelago because of its three primary and ten secondary colonies. The three largest colonies are on Karpa Island, Big Koniuji Island and Castle Rocks with total numbers of 263,000, 203,000 and 119,000 birds, respectively. Species composition of birds in this area resembles that of previously mentioned colonies except that moderate numbers of parakeet and crested auklets are also found there.

The last concentration of bird colonies on South Alaska Peninsula is south of Deer Island on small islands of the Sandman Reefs where six secondary colonies are located and at Amagat Island at the mouth of Morzhovoi Bay where a major colony is found. The most abundant species at these colonies are horned and tufted puffins - birds highly susceptible to oil contamination because they spend a large portion of their time on water.

During migration two areas can be classified critical due to large numbers of birds utilizing them. Morzhovoi and Cold Bays and in particular Big, Middle and Kinzarof Lagoons had large numbers of staging black brant, Canada geese, emperor geese and other waterfowl during the past two fall surveys. Also, in October 1976 tens of thousands of shearwaters were feeding throughout Morzhovoi Bay. Shearwater use may be irregular, but there is traditional waterfowl use of the areas.

In winter, both of the previously mentioned bays are suspected of having substantial sea duck concentrations particularly in mild winters. During the only other quantitative waterfowl survey of South Alaska Peninsula in winter, concentrations were found in Kujulik Bay and the Sanak Islands. The report of that survey (Havens 1970) suggested both these areas plus Morzhovoi Bay as key waterfowl winter habitat.

Another secondary colony is located at Bird Island south of Otter Cove on Unimak Island. Murres are the predominant species.

More quantitative surveys need to be done in order to fully assess the value of this subunit to marine birds. Due to the vastness of coastline and inclement weather in this region, it is difficult to evaluate the area by aircraft.

Subunit 7 - North Alaska Peninsula:

[See Appendix A, Figure 11.]
The only substantial colony within this subunit is on the north end of Amak Island and on two small islands north of Amak. Six seabird species were reported as present, but no quantitative estimate was given (Lensink and Bartonek 1976). The value of estuaries on North Alaska Peninsula is so well-known that further explanation is unnecessary. Those worthy of critical area status are : Ugashik, Cinder River/Hook Lagoon, Port Heiden, Seal Islands, Nelson Lagoon/Mud Bay, and Izembek/Moffet Lagoons. These areas are essential for staging to a variety of birds in both spring and fall migrations.

Another area of great importance to migrating birds is Bechevin Bay at the end of the Peninsula. Both St. Catherine Cove and Hook Bay were supporting large numbers of black brant, Canada and emperor geese, other waterfowl and larids when they were surveyed in fall 1975 and 1976. Urilia Bay on Unimak Island is suspected of supporting large numbers of migrating birds, but this area has not been surveyed during this study.

During moderate to severe winters much of this area is frozen and would not support large numbers of birds. However, tidal currents through False Pass maintain open water and therefore the Bechevin area is suspected of having considerable bird usage. In mild winters such as 1976-1977 waterfowl, sea ducks and emperor geese utilized bays and estuaries as far north as Egegik (possibly farther but no other areas were searched).

Subunit 8 - North Bristol Bay:

[See Appendix A, Figure 12.]
Seabird colonies on cliffs of Cape Newenham constitute one of the largest concentrations in the North Pacific (King and Lensink 1971). Species composition totals of the one major and five secondary colonies included: 309,110 murres; 71,460 black-legged kittiwakes; 5,000 tufted puffins;

790 cormorants, 500 glaucous-winged gulls and 252 horned puffins. Nearby Cape Pierce and Shaiak Island colonies add 139,498 birds to the total, most of which are murres and kittiwakes.

Walrus Islands are another area of prime importance to birds, supporting three primary and two secondary seabird colonies. The largest is on North Twin where an estimated 521,000 murres reside in summer. South Twin has an additional 500,000 murres. Other common species are black-legged kittiwakes, tufted puffins and cormorants. Because the combined total in a relatively small area is over 1.5 million birds, this critical breeding area should be safeguarded as much as possible from oil and gas development.

From a survey done last spring two areas were judged important migration staging areas and several others are possibly important. Large numbers of sea and diving ducks, particularly scaup, were rafting in salt water of Nushagak Bay while they waited for breeding areas to thaw. Over 2,000 scaup were seen on Flounder Flats. Additional waterfowl and larids were at the mouths of Nushagak, Wood, Snake and Igushik Rivers. Several thousand black brant and other waterfowl were found staging in Nanvak Bay also. Many birds were found in Kulukak Bay especially at the floodplain of the Kanik River and at Osviak Bay. These areas would have to be looked at more frequently to determine the degree of bird usage. Past fall surveys indicated both Nanvak Bay and Kanik River as staging areas, but no fall surveys have been conducted by this principal investigator.

During severe winters this area is frozen so there would be minimal bird usage. It is not known what birds would be present in mild winters but I suspect that some sea duck concentrations may inhabit the area. However, no areas could be classified critical winter habitat.

Subunit 9 - Aleutian Shelf:

[See Appendix A, Figure 13.]
Emphasis of OCSEAP projects has just recently been shifted into this subunit, and therefore current information is sketchy. An estimated 375,000 tufted puffins breed on Kaligagan Island, 100,000 on Rootok Island, 100,000 on the Baby Islands and 50,000 on Avatanak Island. Bogoslof Island is another important colony with 15 nesting species including red-legged kittiwakes and fork-tailed storm-petrels (Byrd and Divoky 1975). The most easterly colonies of whiskered auklets are found in this subunit. Other significant colonies may be found when future searches are made.

During migration, passes between islands may contain substantial concentrations of birds. Unimak Pass is a known migration corridor, but the same may be said for Akutan, Umnak and Samalga Passes. These areas may also be important summer and winter feeding areas. During this winter's survey, rafts of crested auklets and murres were observed in both Akutan and Unimak Passes.

Samalga Island is an area deserving special mention. During two recent flights to the island (in October 1976 and March 1977) by the principal investigator, large numbers of birds were present. In winter large numbers of geese, dabbling ducks, sea ducks and shorebirds were recorded. A fox was sighted on the island, likely precluding breeding concentrations, but the area should be given "critical" status if the observed concentrations are recurring.

IX. Needs for Further Study

It was proposed that all coastal marine bird habitat from Cape Fairweather to Cape Newenham during the period from September, 1975 to the present be delineated. Concurrently, bird usage of coastal environments was to be documented, preferably for all four seasons. Because lack of time and money and inclement weather precluded the realization of all the objectives, it is suggested that coastal bird surveys be continued. Much good information on "critical" areas for coastal marine birds can be derived from baseline aerial reconnaissance, but surveys must be conducted in all seasons and if possible during the same season on successive years. Bird use of a region in many cases would vary from year-to-year, but this may not alter its status as "critical."

With delays in OCS lease sales, perhaps more coastal bird surveys could be conducted in the Gulf of Alaska (currently the project is restricted to Bristol Bay and Aleutian Shelf lease areas) to get additional information prior to the sales. Areas classified as "tentatively critical" now could either be taken off the list or reclassified as "positively critical." Simultaneously, coastal habitat delineation not previously done could then be completed.

Coastal bird surveys completed to date have not been standardized for time of day; tide level or weather conditions. Because birds' behavioral responses to these factors vary, bird distribution and use of habitats as depicted by aerial surveys may be biased. Therefore, it is suggested that a small study area be selected that has a wide variety of bird habitats, a large species diversity and different bird uses (i.e. feeding, nesting, roosting). Preferably the area should have no logistics problems to hinder research. Boats and aircraft should be readily available.

Kachemak Bay is an area that fulfills most of these requirements. Besides convenient aircraft and boats, several vantage points for ground observation are accessible; two moderately sized colonies are present in the bay; it is used by migrating shorebirds and waterfowl; and it has substantial winter and summer use by non-breeding birds. The area has a sandspit, mud flats, coastal floodplain, lagoons, bays, fiords and rocky coast.

Together with the bird distribution study, food habits work could be done to determine what prey species are available and utilized by birds. An attempt could be made to determine foraging distances from colonies. It may also be an area to determine effects of human disturbance to colonies.

Another possible study site would be the Port Moller estuarine complex. A wide variety of habitats and birds are present, but logistics support would be less convenient.

Aerial reconnaissance and mapping of the supratidal zone (from high tide to storm tide levels) have not been sufficient to characterize vegetation and bird use of the region. Ground truth studies could be initiated to determine how the different subunits differ in plant species composition and bird use of this zone.

Gaps in knowledge of species composition and abundance are apparent for colonies on the Walrus Islands in Bristol Bay and the Fox and Krenitzin Islands in the Aleutian Shelf lease area. Both areas could be used to monitor effects of oil and gas development if population dynamics studies were initiated soon. Other colony complexes worthy of population dynamics work are those near Cape Aklek-Unalishagvak and Mitrofania Island. Because of its proximity to potential lease areas and large numbers of birds found there, Middleton Island is a logical choice for intensive colony work.

The NEGOA synthesis meeting pointed out two things that possibly warrant further bird work. One, the gyre northwest of Kayak Island, should be looked at more closely for feeding habits of birds and general bird use in the area. Oceanographers' drogues also went into Prince William Sound, and more intensive work should therefore be conducted in that subunit. Murrelets, both marbled and Kittlitz's, are one of the most abundant birds in the Sound, and ornithologists know very little about them. Studies to determine abundance, distribution and breeding biology (if possible) seem warranted. A starting point would be Unakwik Bay where 10,000 Kittlitz's murrelets were observed in 1972.

X. Summary of 2nd Quarter Operations

A. Aircraft activities

1. Field trip schedule: From February 28 to March 4, 1977 shoreline surveys were conducted using a Peninsula Airways Grumman Widgeon.
   In conjunction with a marine mammals survey, nearshore bird surveys were conducted from a Peninsula Airways Grumman Widgeon on March 16-18, 1977.

2. Scientific party: For the first survey Paul Arneson and David McDonald, ADF&G, Anchorage did the bird censusing. On the second survey only one bird observer, Paul Arneson, ADF&G, Anchorage was present.

3. Methods: Standard shoreline survey methods as reported in previous quarterly and annual reports were utilized on the first survey. Bird observers looked out both sides of the aircraft. Only one observer was present on the second survey, and he either looked out a fixed distance of 200 meters while doing open water transects or counted birds in nearshore waters and on the beach while flying the coastline.

4. Localities: See Appendix A, Figures 14 and 15 for tracklines of surveys.

5. Data collected: During the February 28-March 4 survey approximately 2635 kilometers of shoreline were surveyed for birds. Data for the survey are presently being transcribed from cassette tapes and have not been analyzed. About 2375 kilometers of shoreline and open water were surveyed on March 16-18, and none of the data for that survey have been transcribed.

6. Milestone chart: See Table 10 for update of data submission.

B. Problems

The most frustrating problem has been delays in getting data analyzed because of computer programming problems. This has been the major cause of slippages in the data submission schedule. Much time has been spent correcting and recorrecting errors on printouts and we have been unable to devote necessary time for important analyses. Various other factors including preparations for and attendance at synthesis meetings, untimely illness of the programmer, and additional, unscheduled field trips have caused further delays.

As mentioned in the previous quarterly report, cutbacks in operational funds together with increased costs curtailed some planned surveys. Fortunately, logistics will be provided by OCSEAP for a survey of Bristol Bay in the spring. Perhaps other unforseen aircraft of opportunity will be available at other times of year whereby bird observers could use the aircraft for portions of the time or sit in an unoccupied seat to get at least partial but important bird information. This may include aircraft off NOAA vessels in the vicinity in summer or from work being done by other PI's in the same area (e.g. NMFS marine mammal flights in the Krenitzin and Fox Islands.)

Scientific data collection in Alaska has the unavoidable setback that time, money and patience run out when inclement weather delays successful completion of a scheduled survey. Important information is often lost in such situations.

C. Funds expended:

Salaries	$ 9,234
Per Diem/Travel	1,030
Contractual Services (Air Charter)	4,600
Commodities	268
Equipment	0
Total	$15,132

Milestone Chart

TABLE 10.

Project Research Unit #3 P.I. Paul D. Arneson Date FY '77

MAJOR MILESTONES	QUARTERS 1 O	N	D	2 J	F	M	3 A	M	J	4 J	A	S
Bristol Bay-North Aerial Bird Surveys △								△			?	
Alaska Peninsula-North Aerial Bird Surveys △	▲					▲		△			?	
Aleutian Shelf Aerial Bird Surveys △					▲	▲				△	△	
Bristol Bay-North Habitat Mapping ○								○				
Alaska Peninsula-North Habitat Mapping ○	●											
32 Aleutian Shelf Habitat Mapping ○	●										?	
Quarterly Reports □			■			■			□			
Annual Report □						■						
Final Reports □										—	—	□
Supplemental Bird Surveys ⬡						⬢			⬡	⬡		

Milestones △ Planned

▲ Completed

XI. Literature Cited

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APPENDIX A

Tracklines of aerial bird surveys conducted by Alaska Department of Fish and Game, Anchorage. Study area includes coastline from Cape Fairweather to Cape Newenham. Known or suspected critical areas for migrating, breeding or wintering birds are designated.

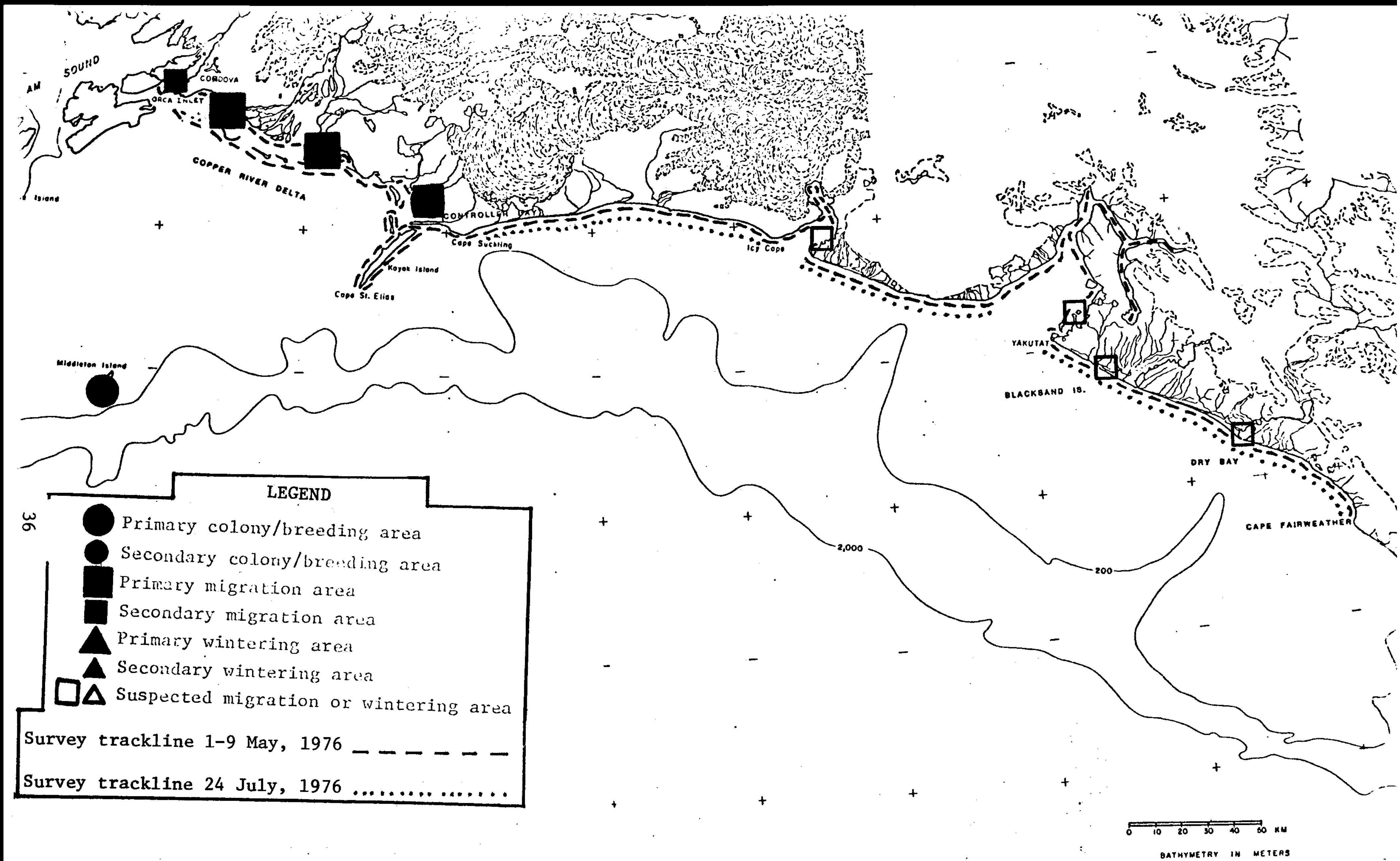


Figure 1. Tracklines of aerial bird surveys in Northeast Gulf of Alaska. Symbols denote known or suspected critical areas for birds.

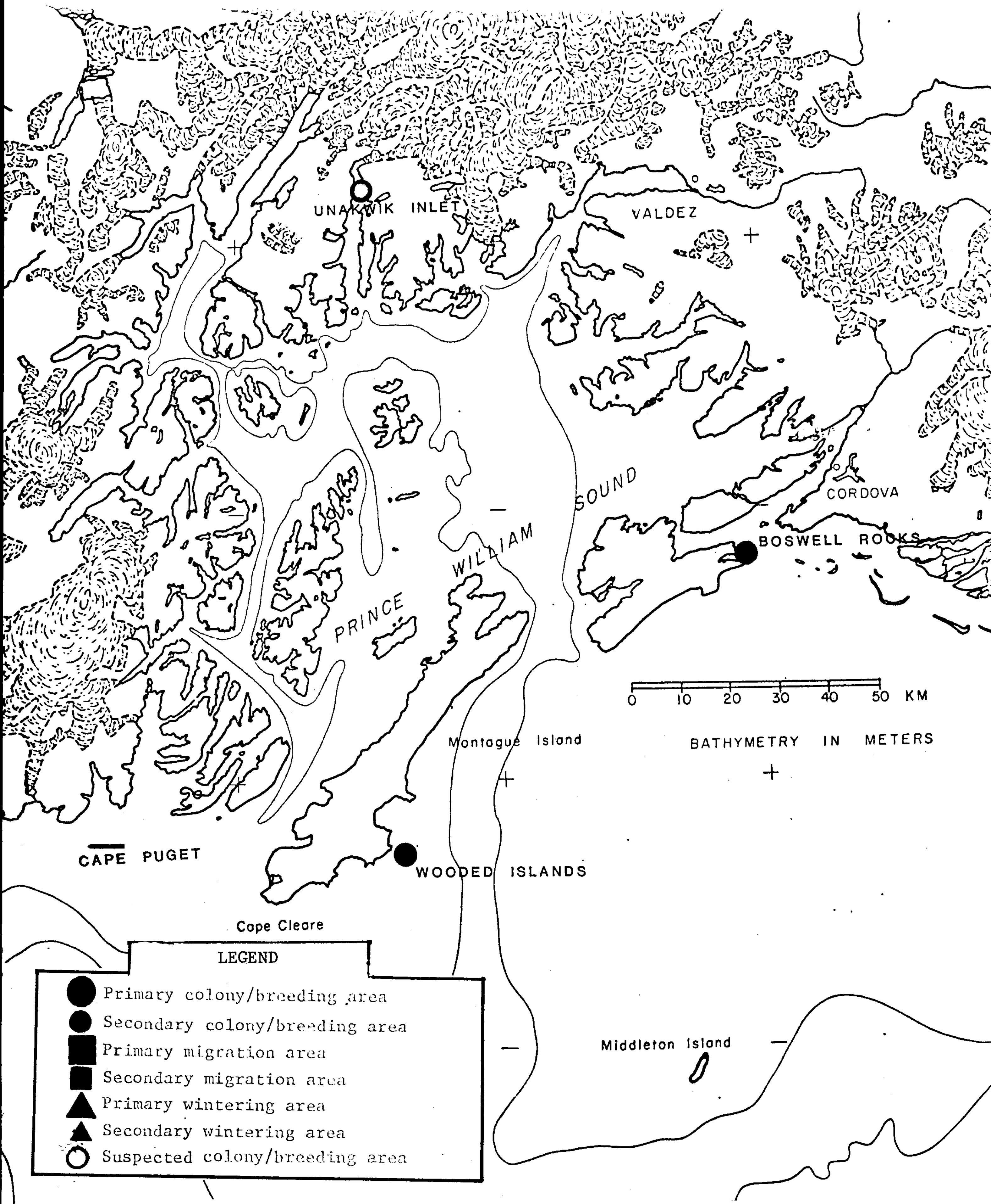


Figure 2. Known or suspected critical areas for birds of Prince William Sound. No aerial surveys conducted in this subunit.

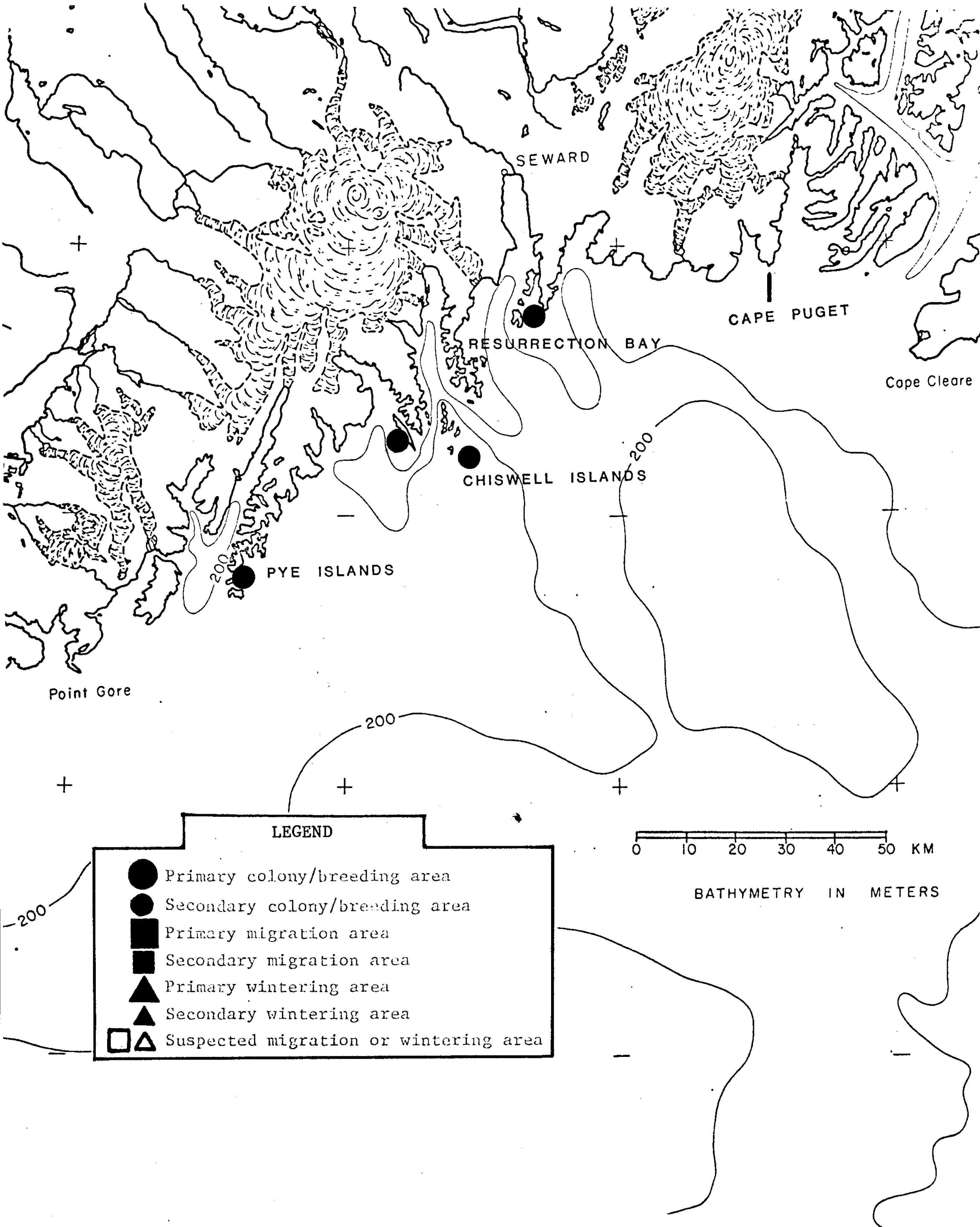


Figure 3. Known critical areas for birds of Kenai Peninsula - South. No aerial surveys conducted in this subunit.

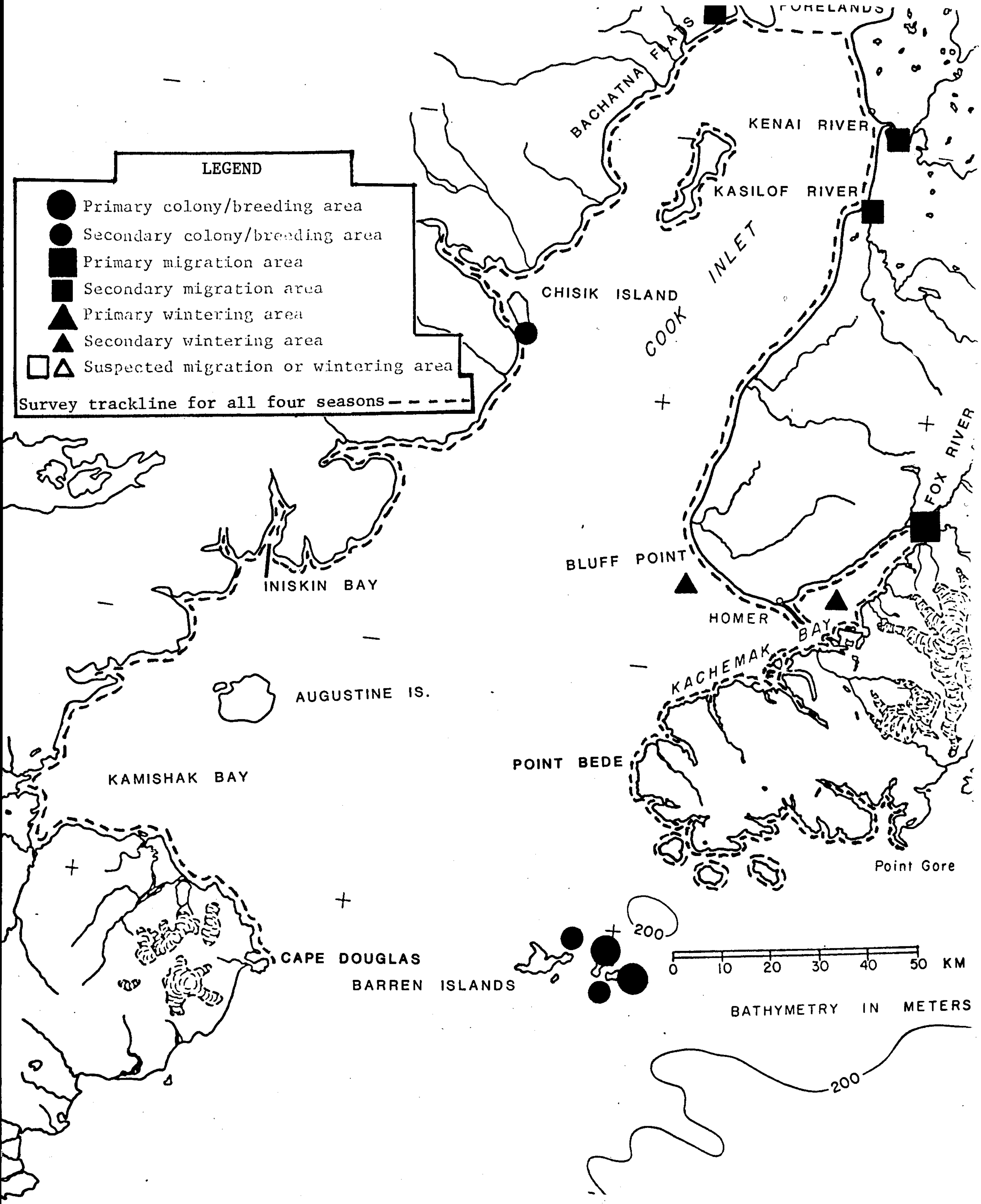


Figure 4. Trackline of aerial bird surveys flown in all four seasons in Lower Cook Inlet. Symbols denote known critical areas for birds.

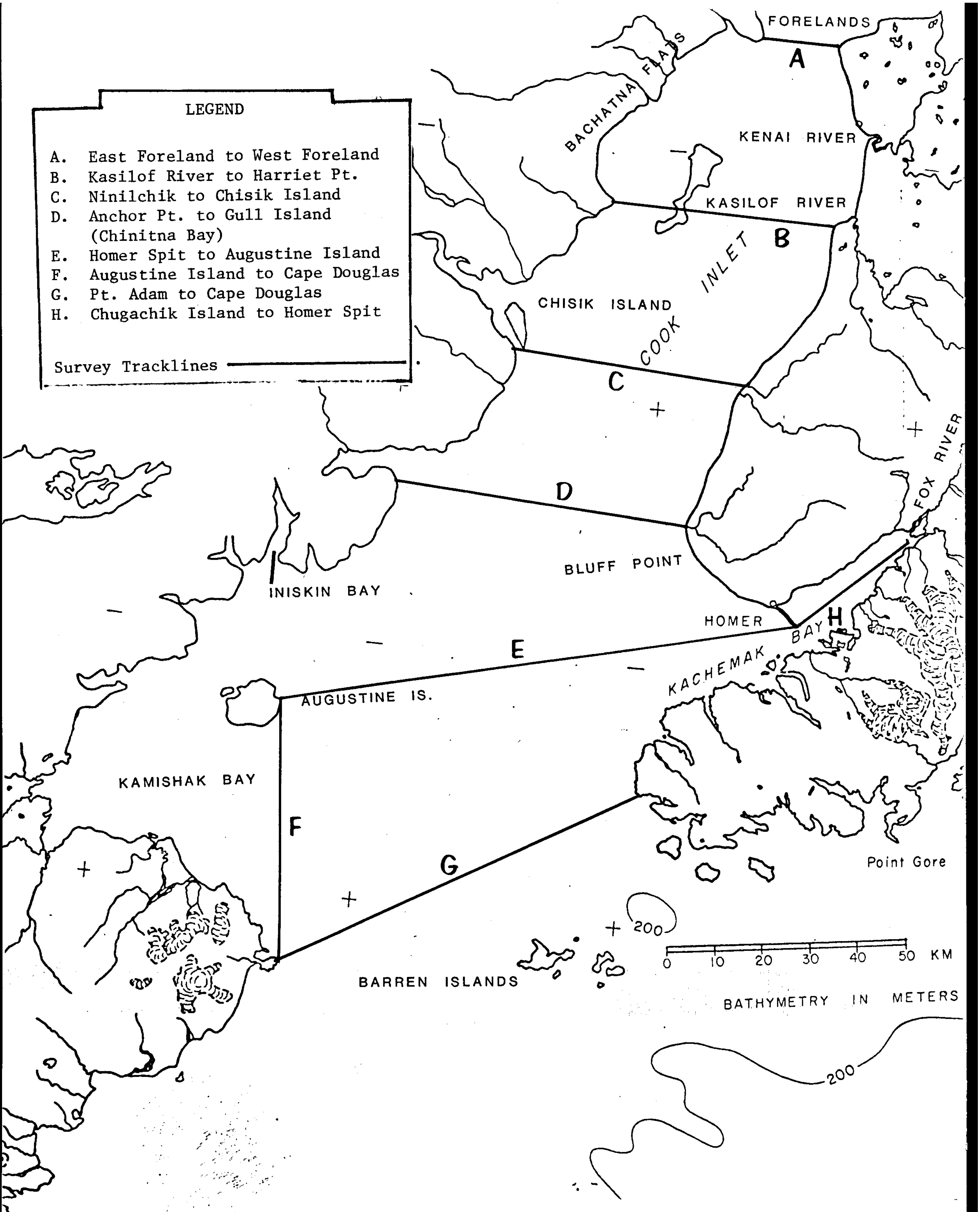


Figure 5. Trackline of pelagic aerial bird surveys flown in all four seasons in Lower Cook Inlet.

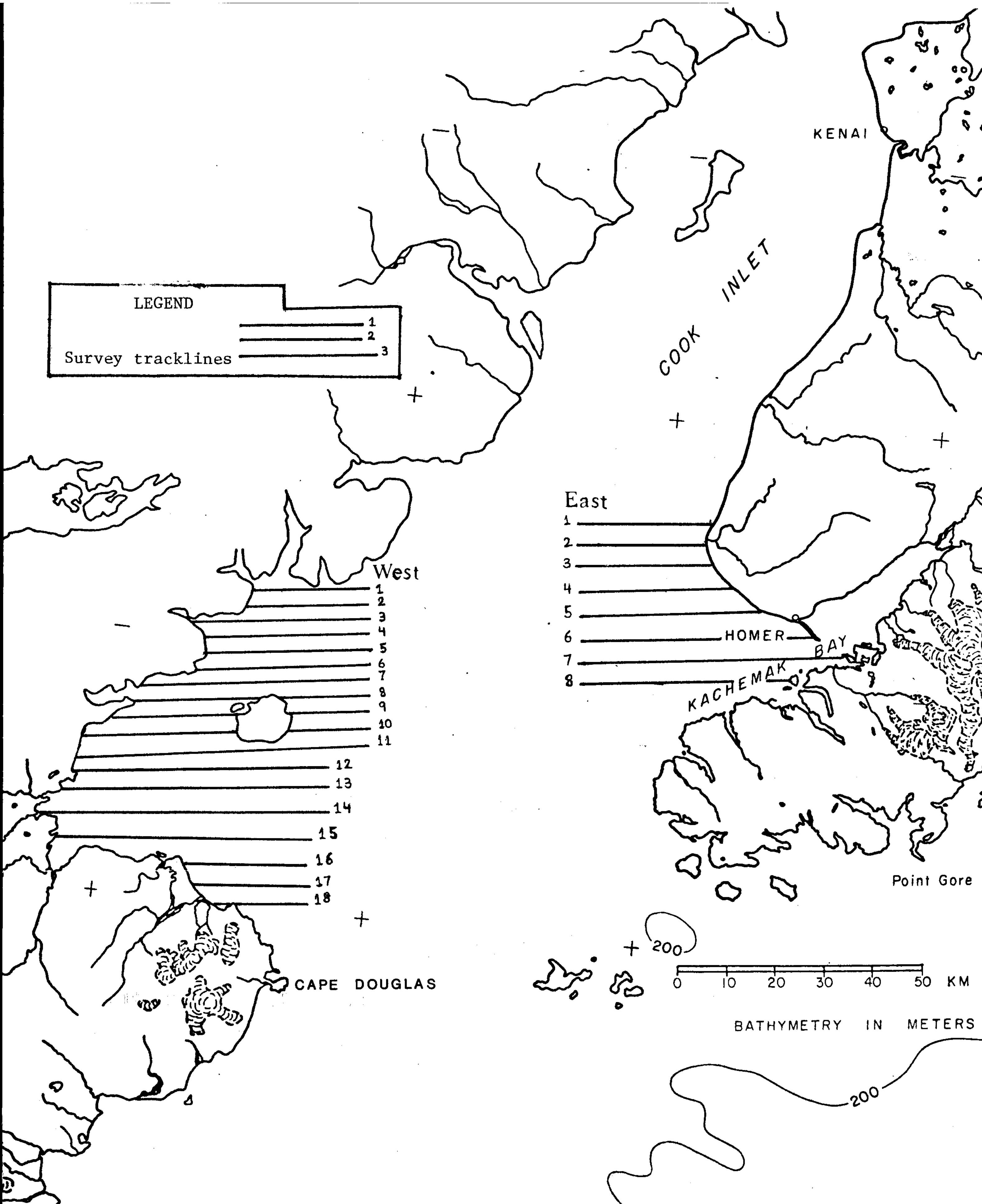


Figure 6. Trackline of pelagic aerial bird survey in Lower Cook Inlet, 1 April, 1976.

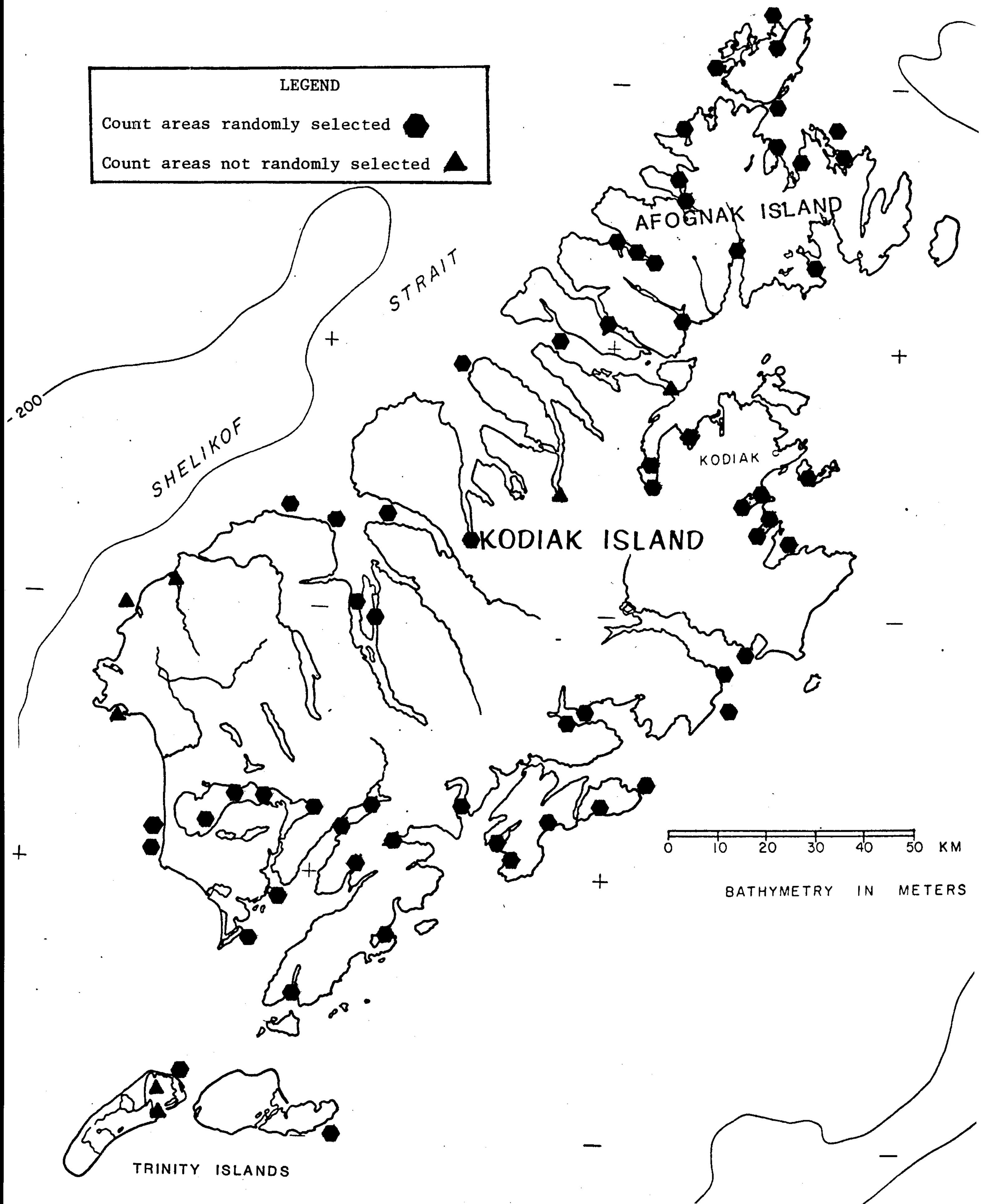


Figure 7. Count areas sampled during aerial bird surveys in Kodiak Archipelago February and March 1976. A stratified-random scheme was used.

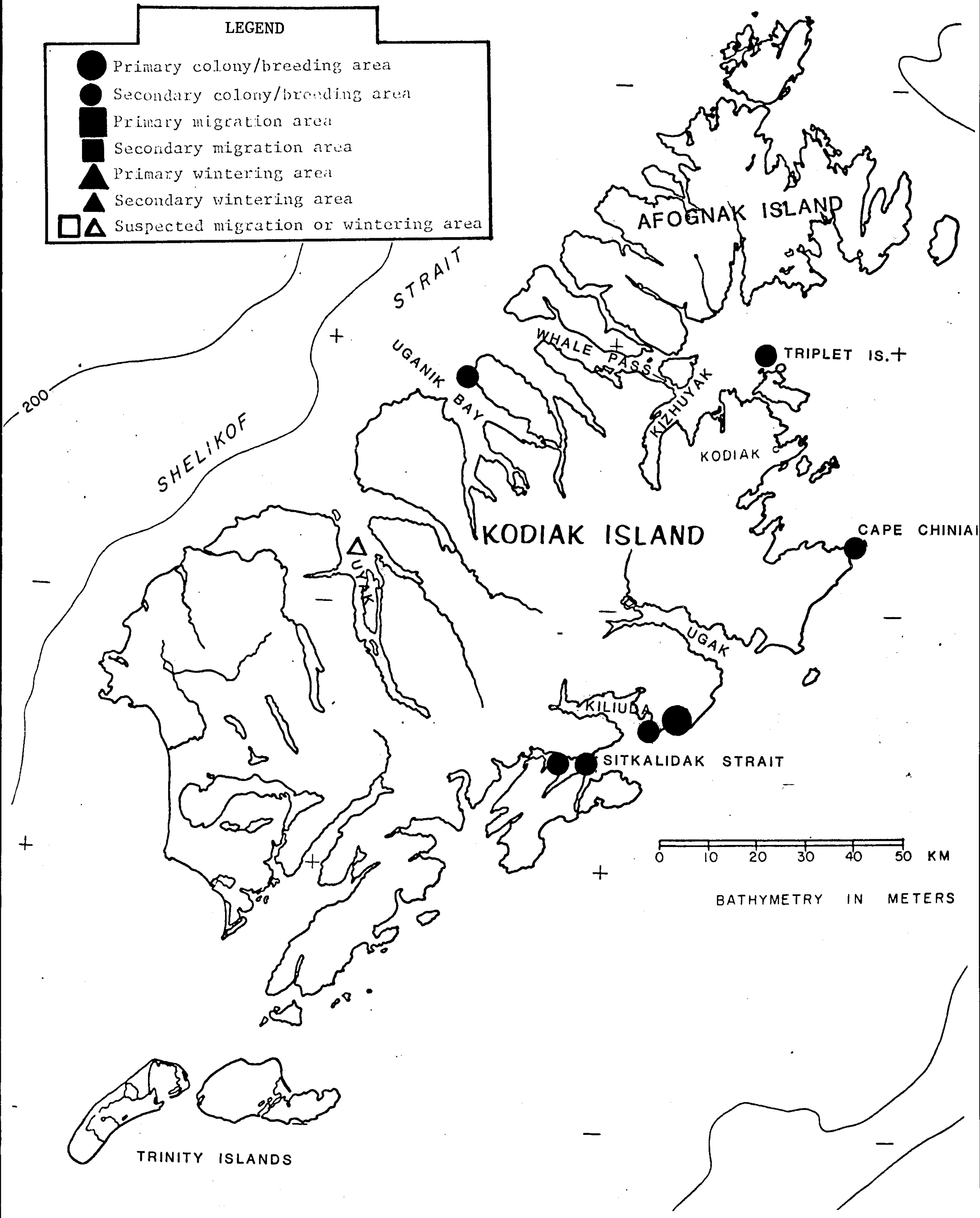


Figure 8. Known or suspected critical areas for birds of Kodiak Archipelago.

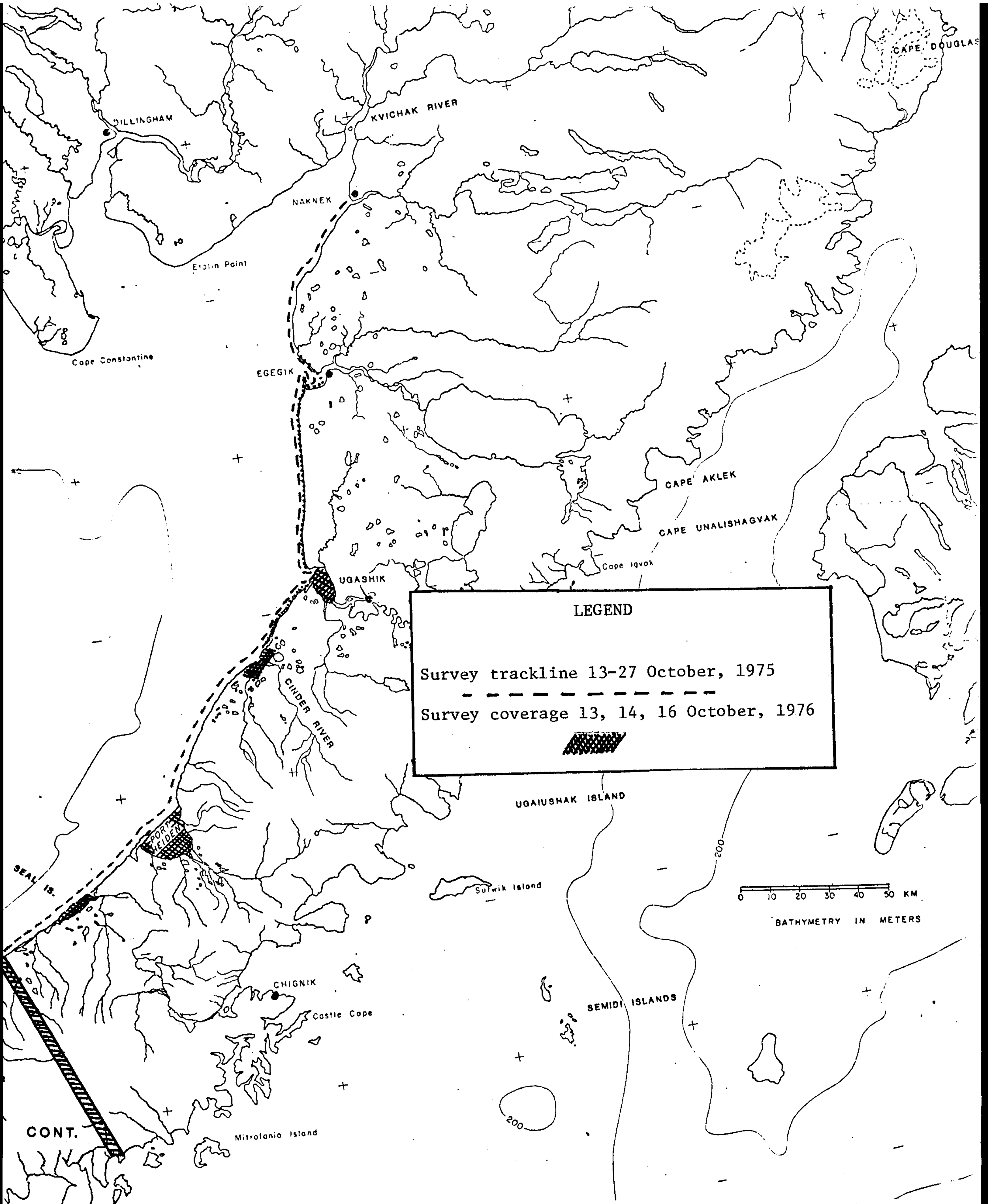


Figure 9. Tracklines of aerial bird surveys on Alaska Peninsula - North. No aerial surveys conducted on Alaska Peninsula - South.

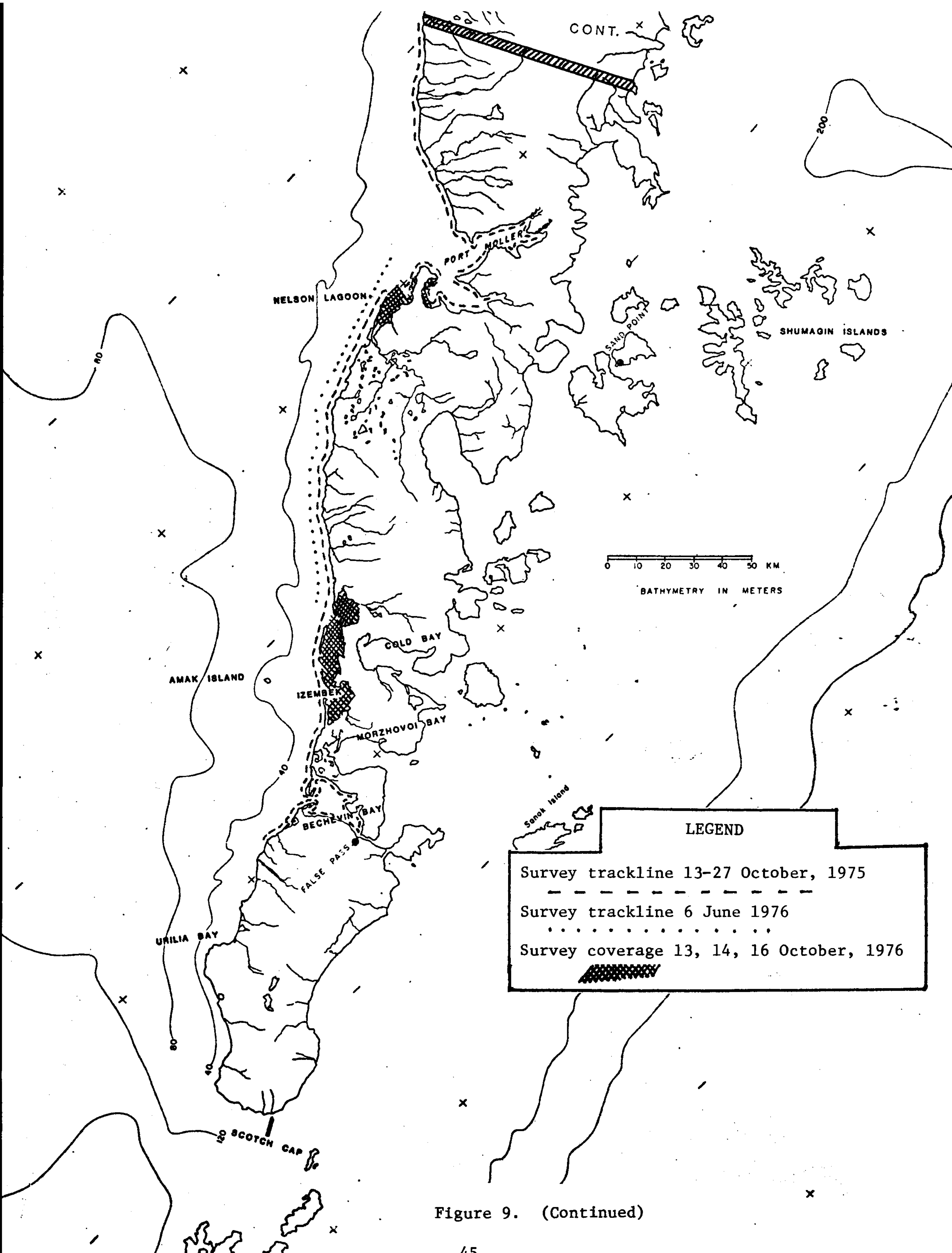


Figure 9. (Continued)

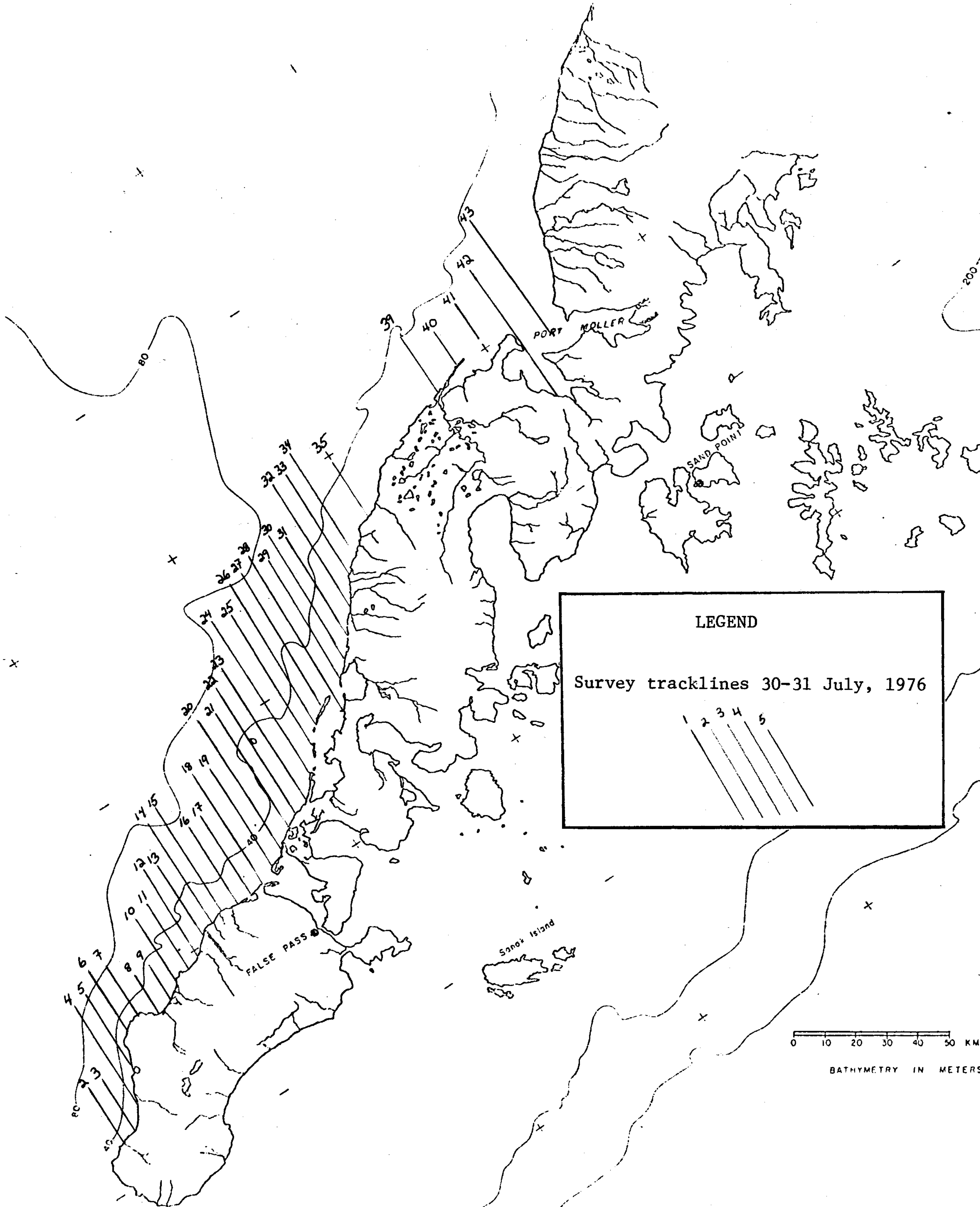


Figure 10. Tracklines of pelagic aerial bird surveys on Alaska Peninsula - North 30-31 July, 1976.

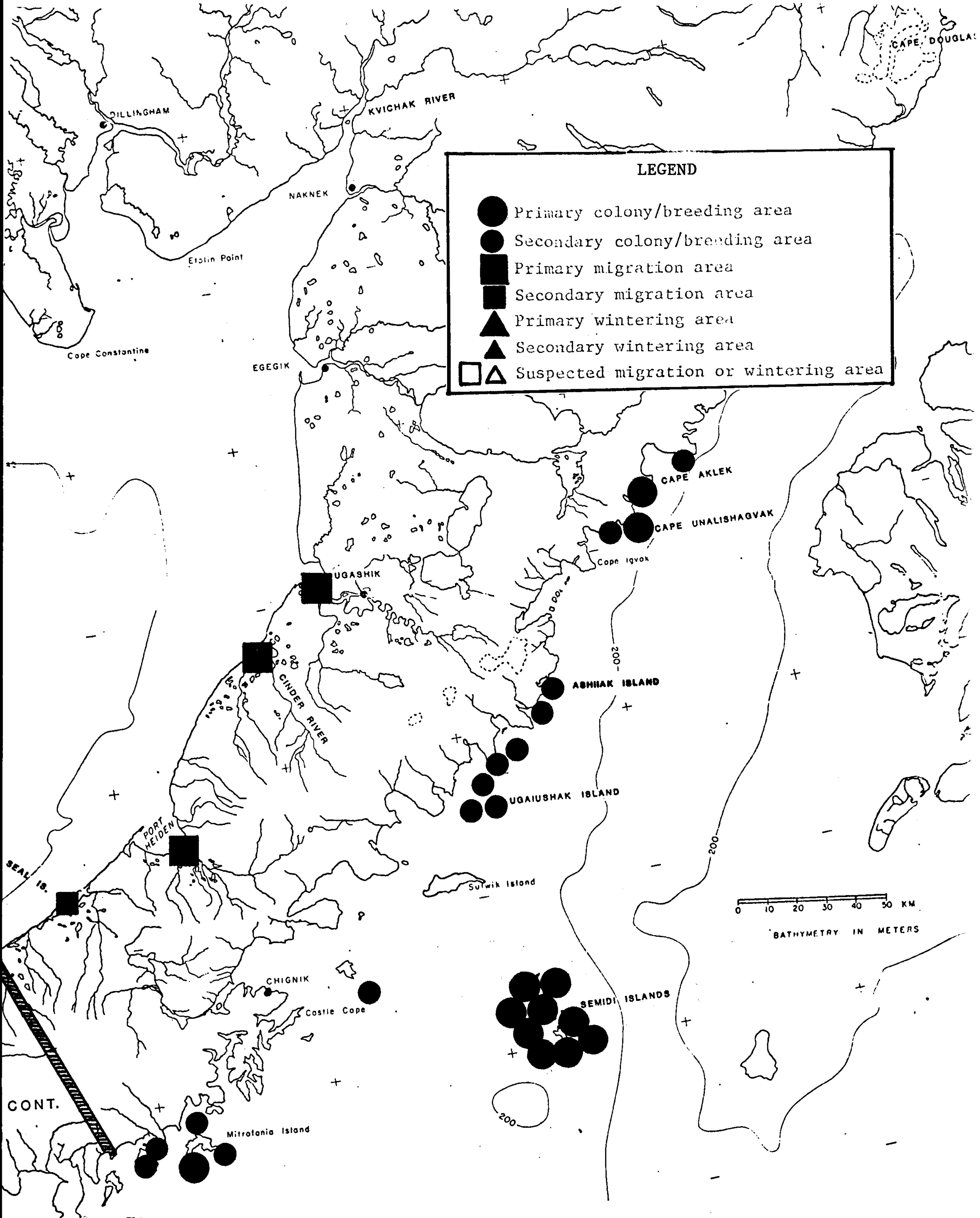


Figure 11. Known or suspected critical areas for birds of Alaska Peninsula - North and South.

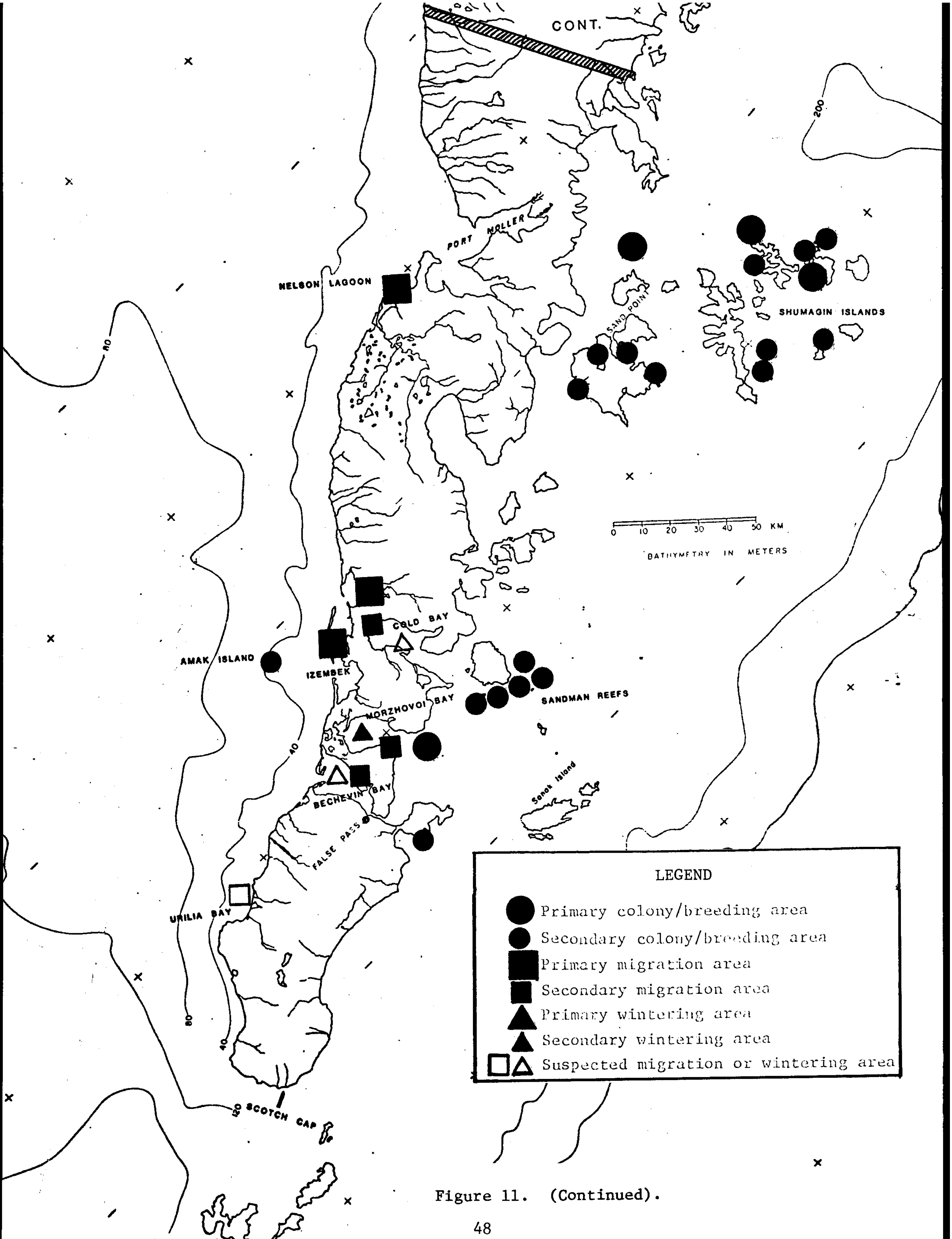


Figure 11. (Continued).

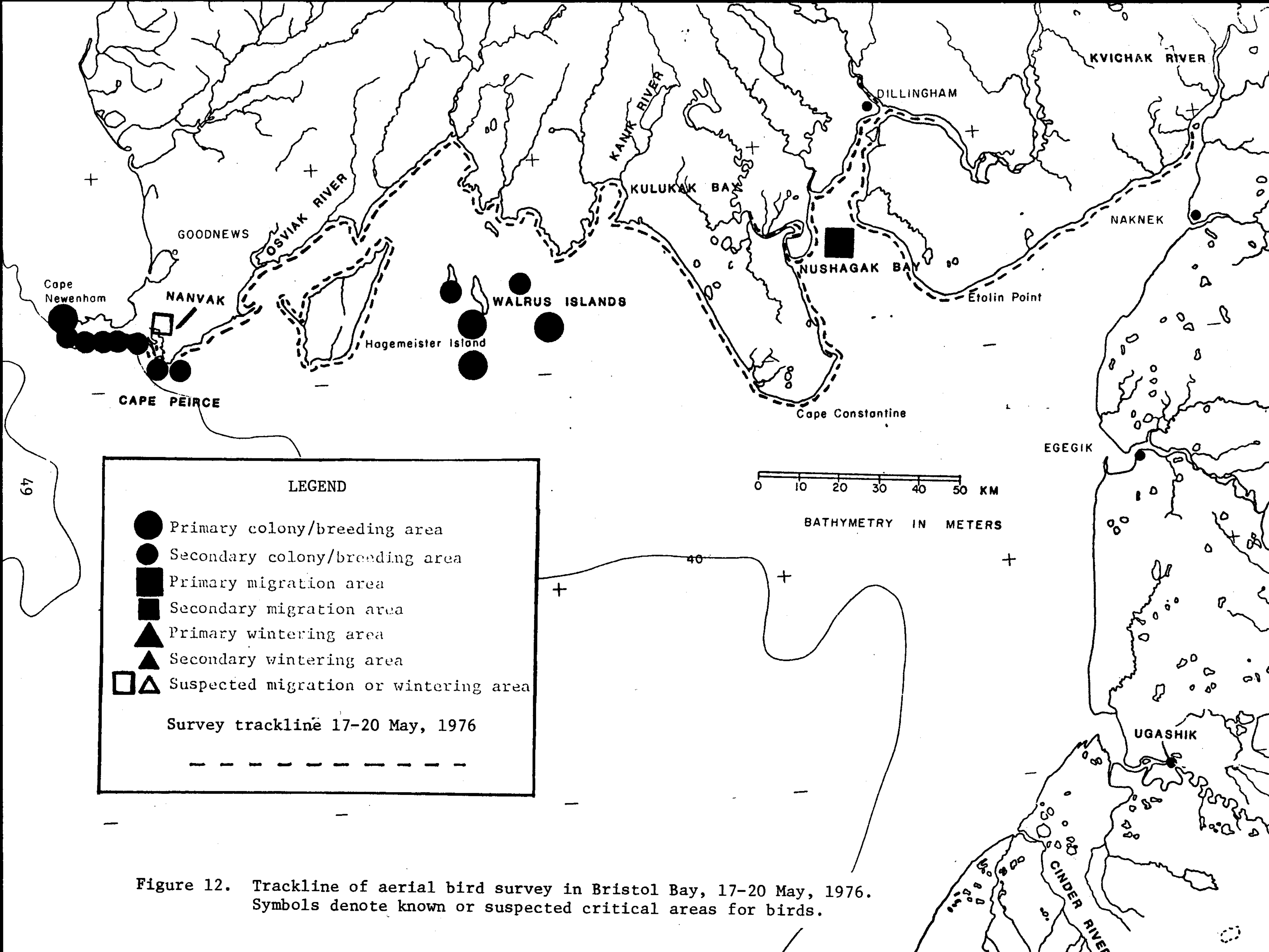


Figure 12. Trackline of aerial bird survey in Bristol Bay, 17-20 May, 1976. Symbols denote known or suspected critical areas for birds.

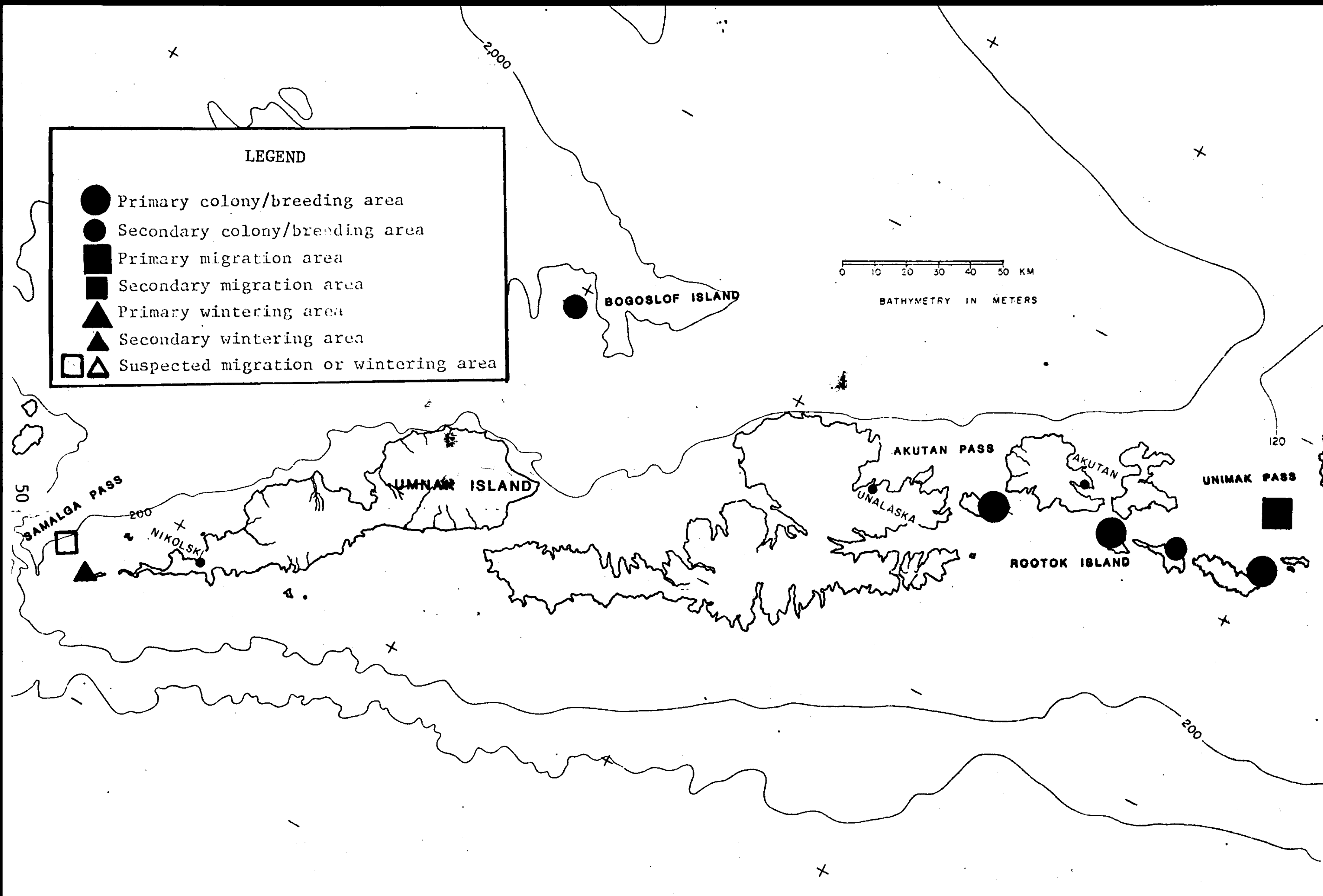


Figure 13. Known or suspected critical areas for birds of Aleutian Shelf. No aerial surveys conducted in this subunit.

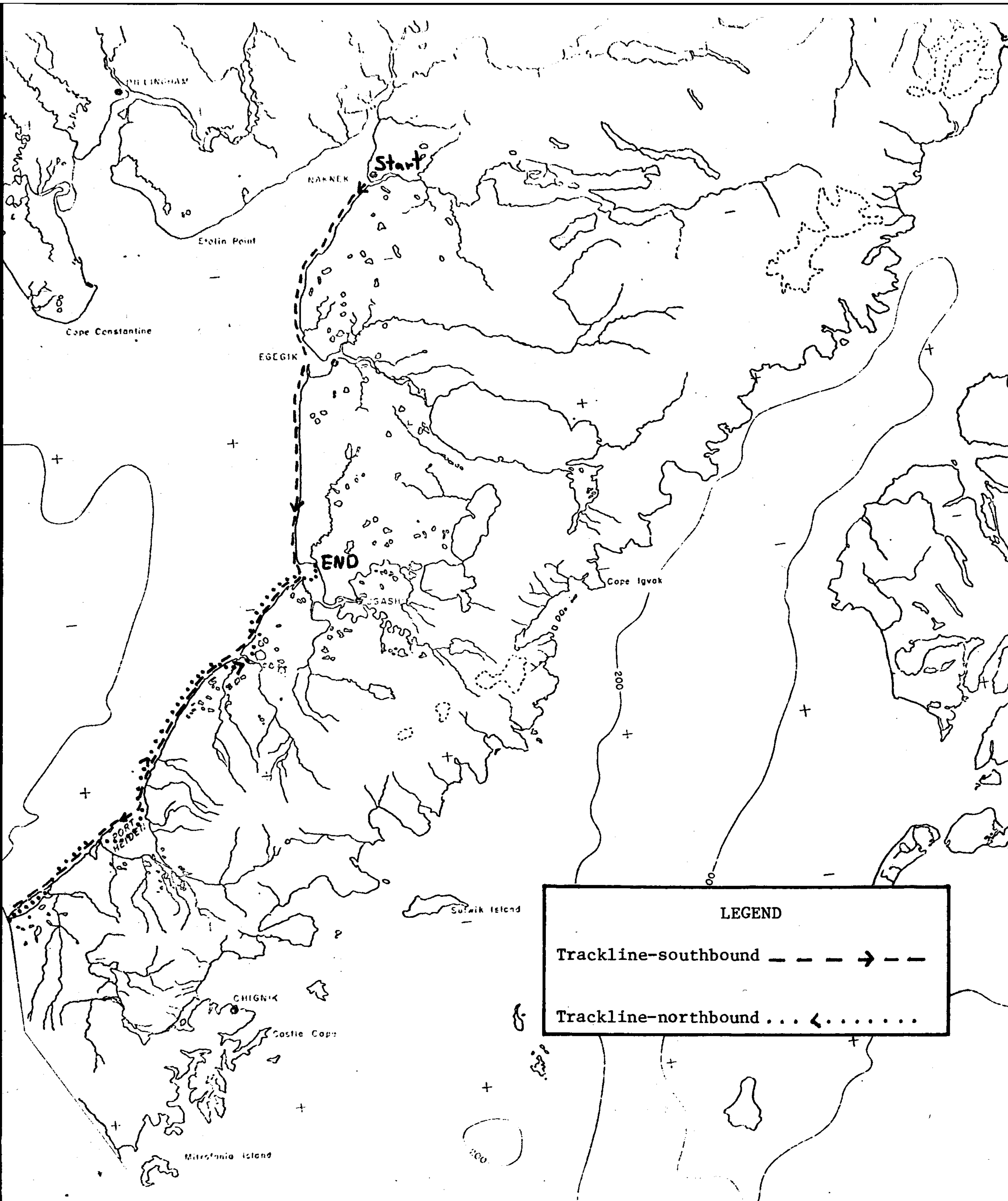


Figure 14. Tracklines of aerial bird survey on Alaska Peninsula-North, 28 February-4 March, 1977

0 10 20 30 40 50 KM

BATHYMETRY IN METERS

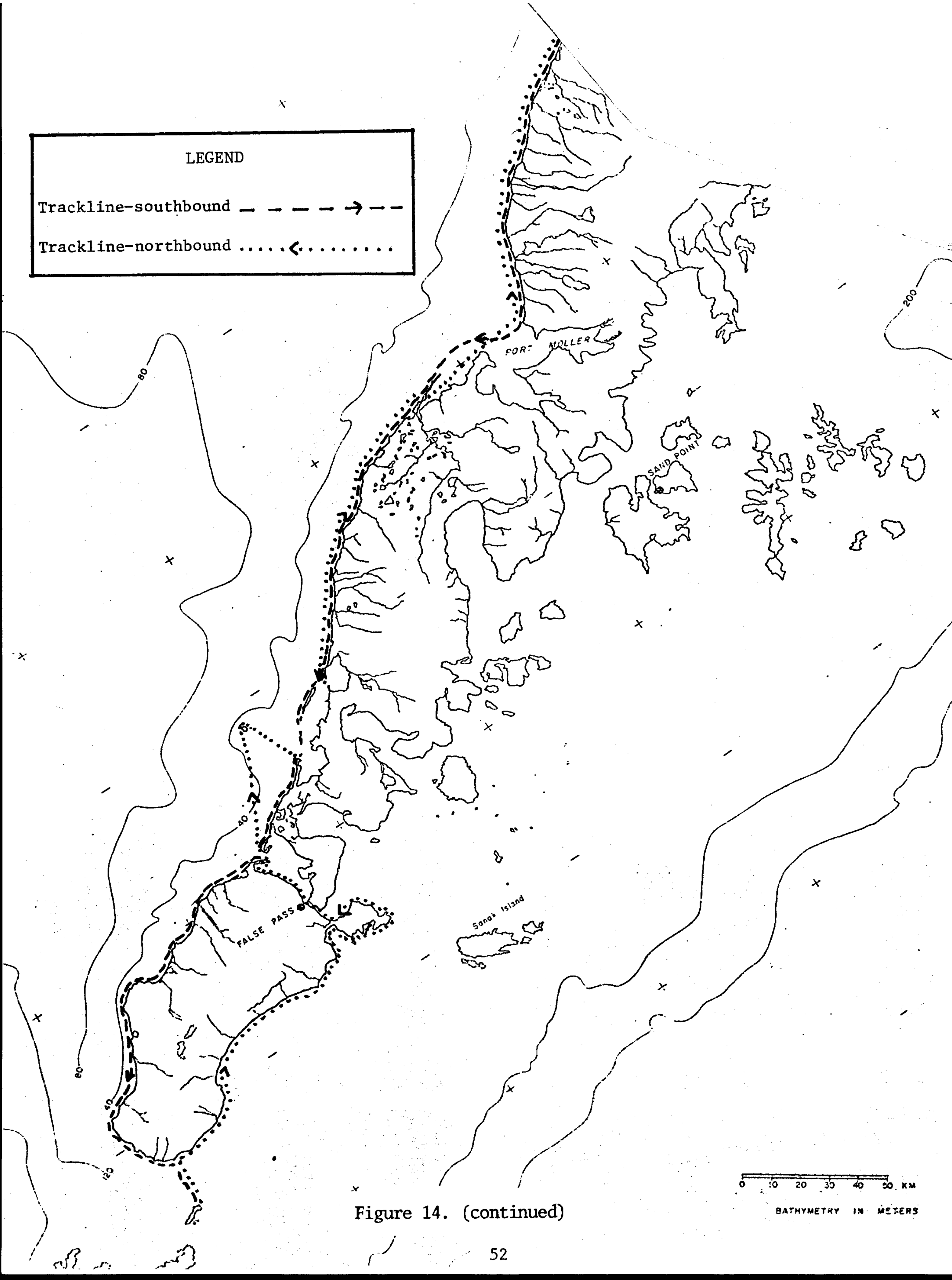
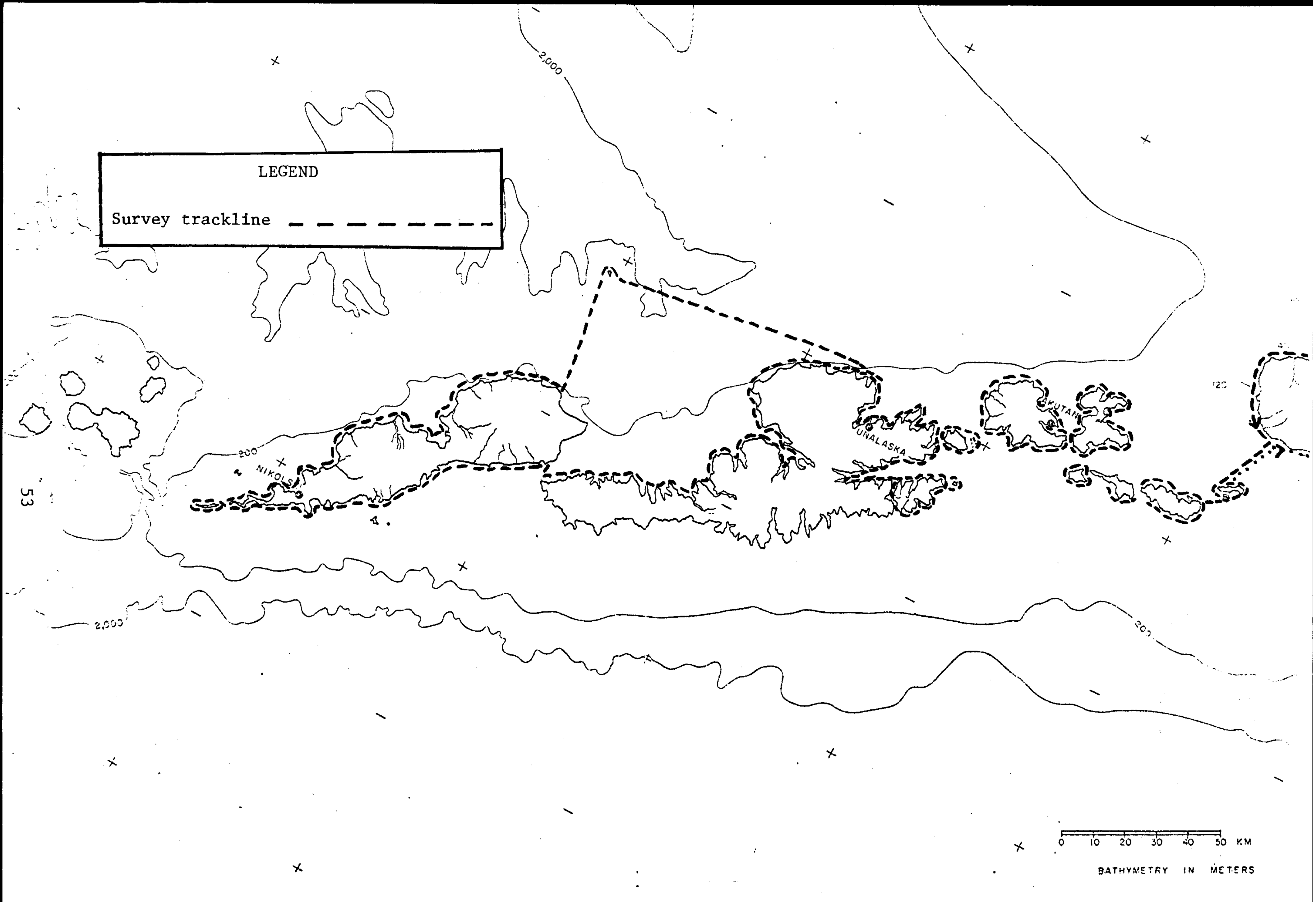


Figure 14. (continued)



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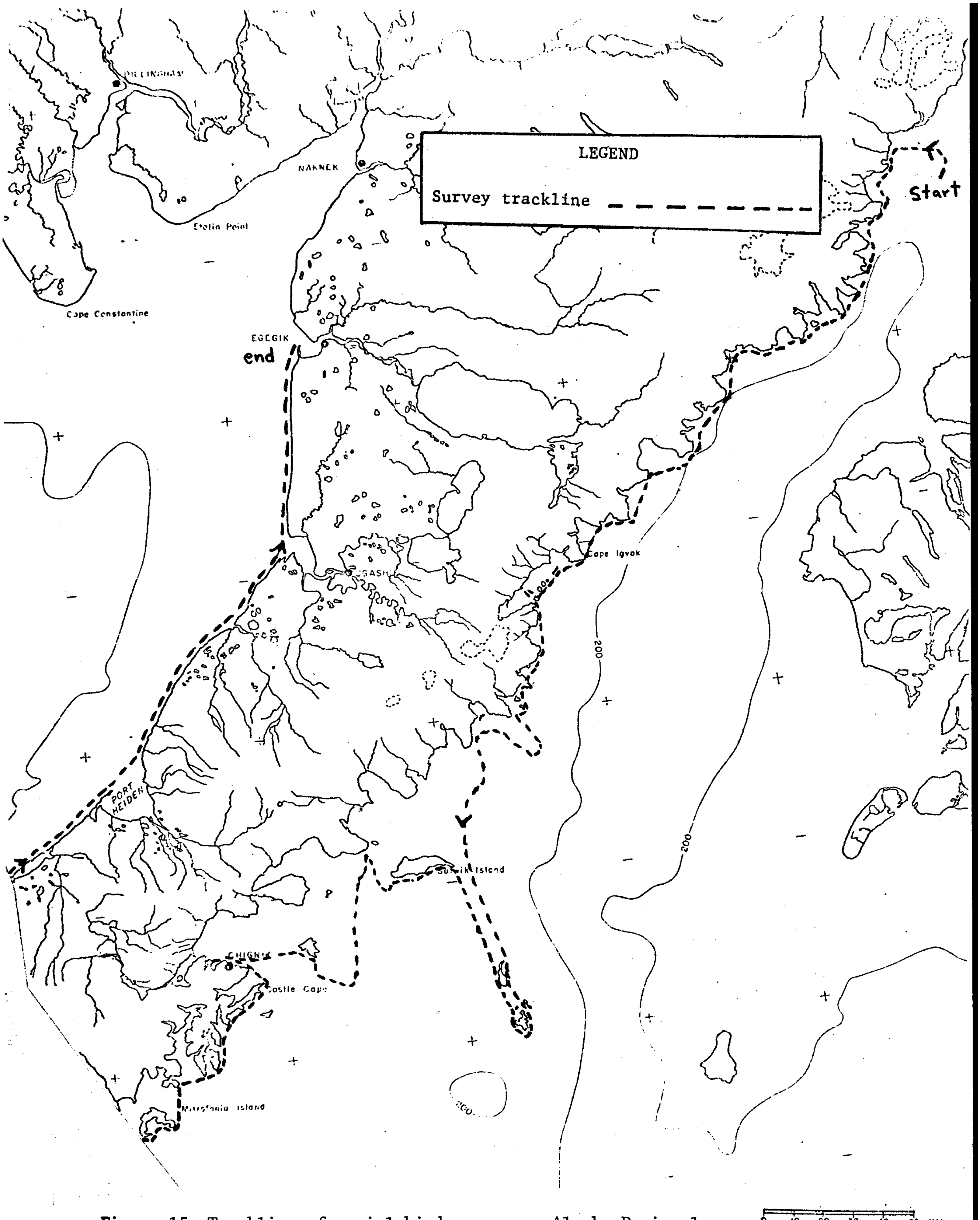

Figure 15. Trackline of aerial bird survey on Alaska Peninsula-South, 16-18 March, 1977

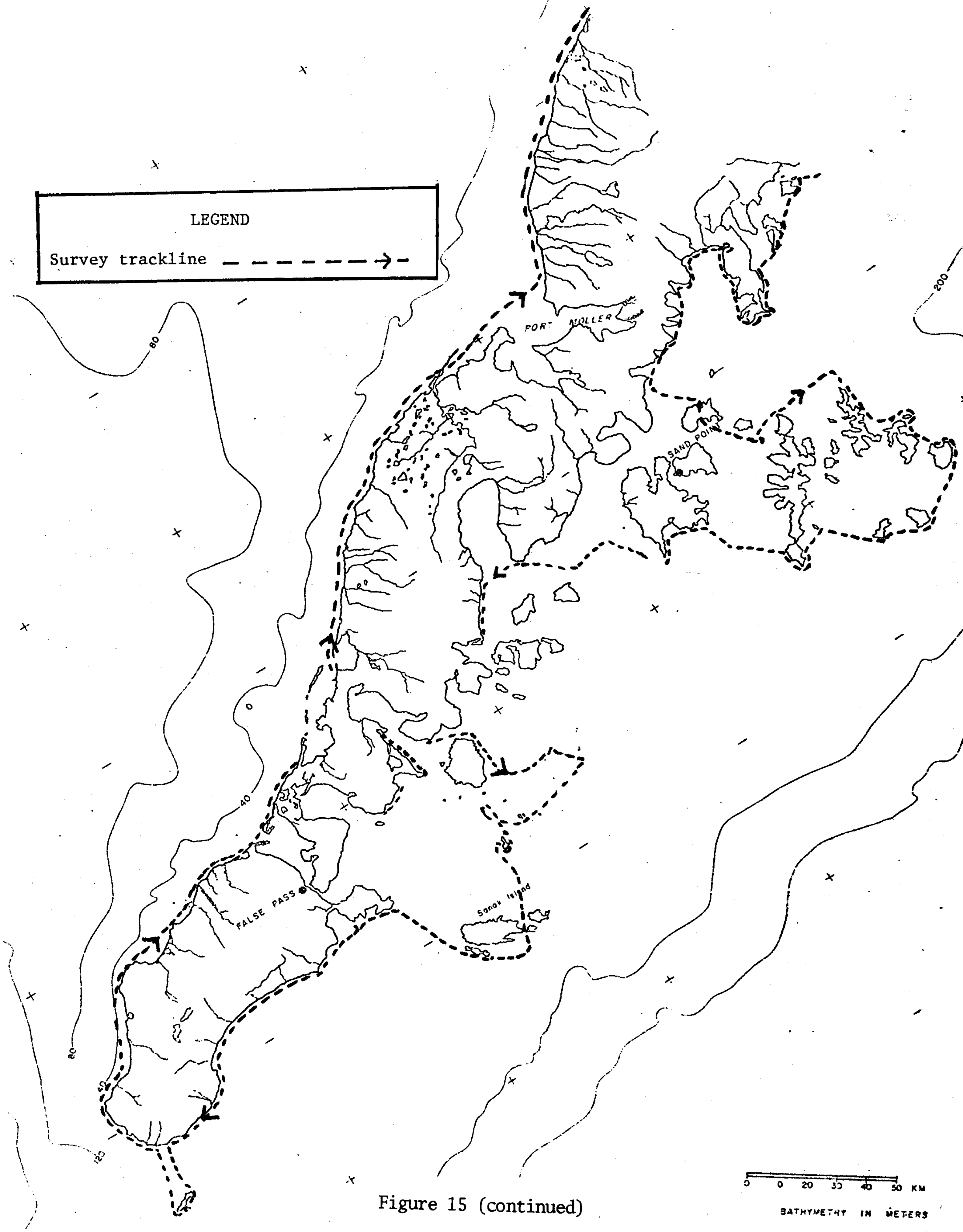

Figure 15 (continued)

APPENDIX B

Habitat mapping coverage for nine subunits within the study area. Information from mapped areas is available at Alaska Department of Fish and Game, Anchorage.

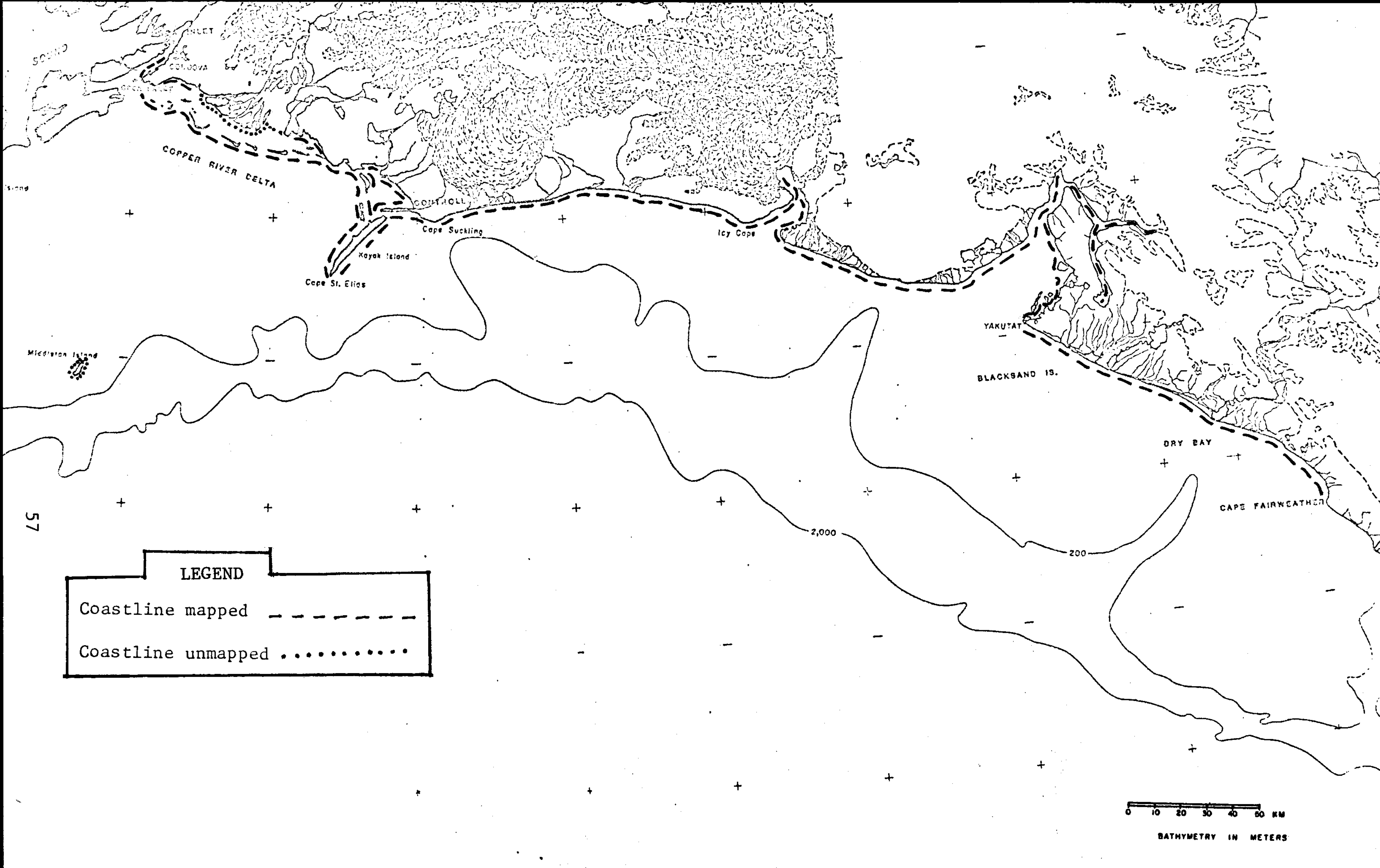

Figure 1. Habitat mapping coverage of Northeast Gulf of Alaska.

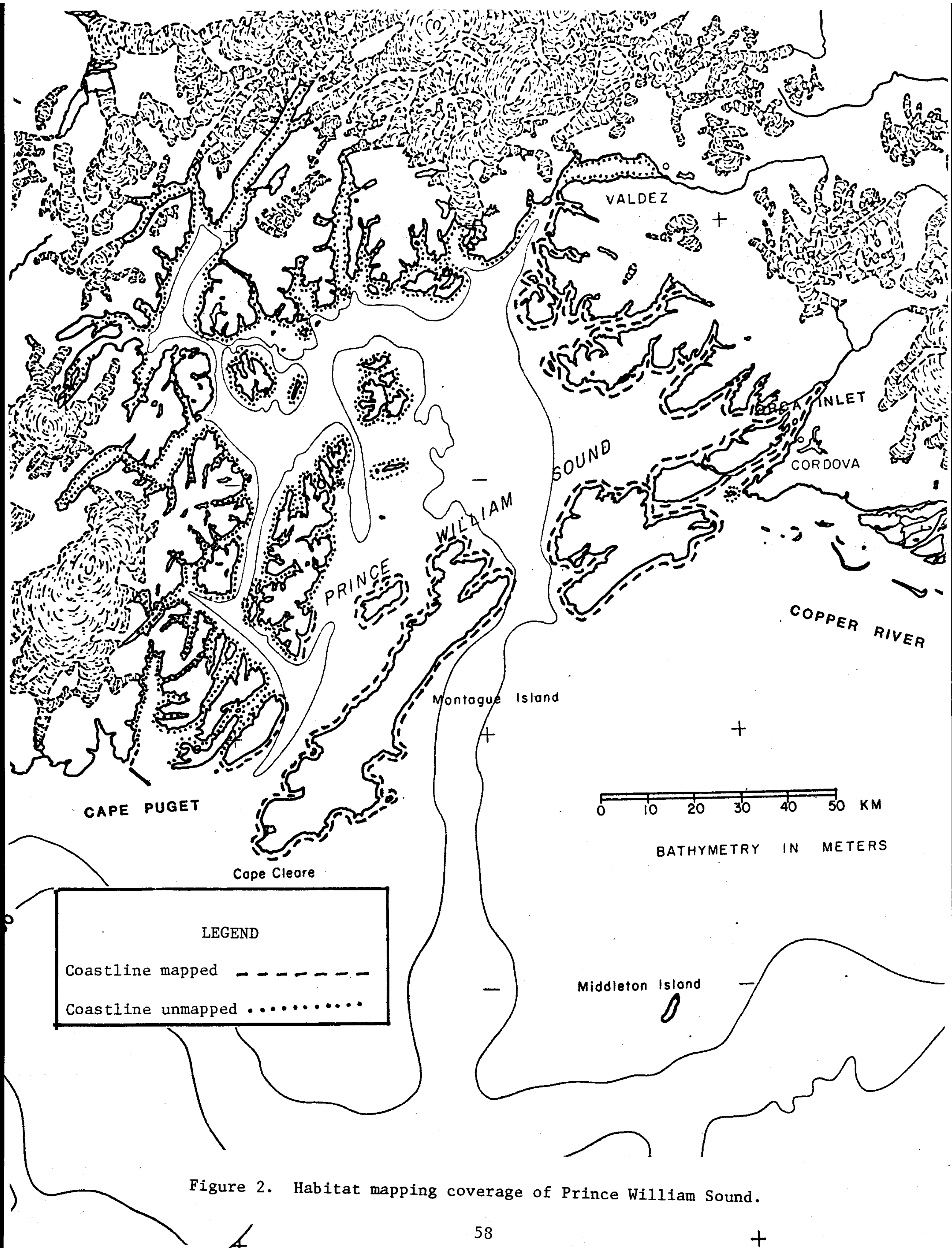

Figure 2. Habitat mapping coverage of Prince William Sound.

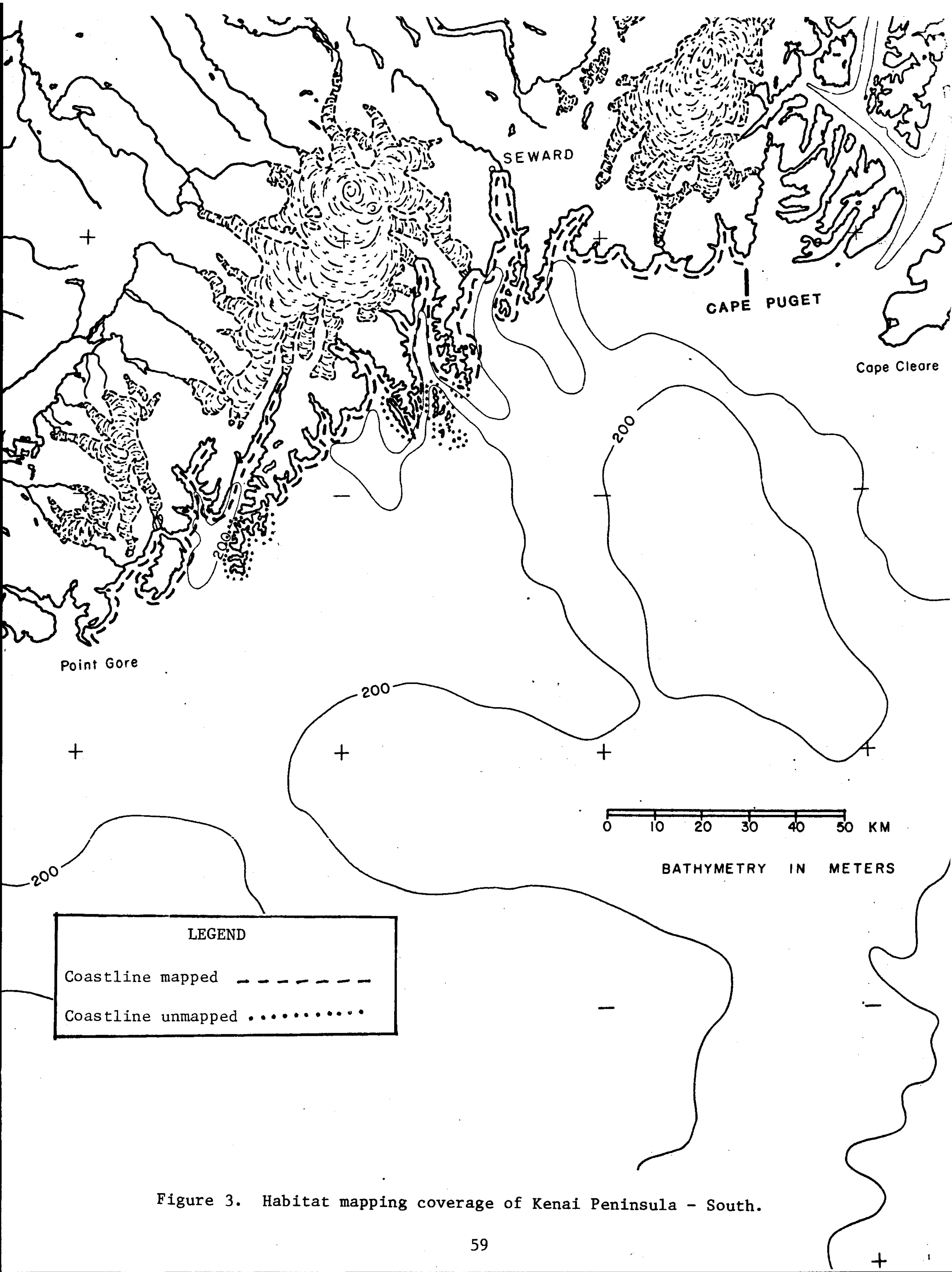

Figure 3. Habitat mapping coverage of Kenai Peninsula - South.

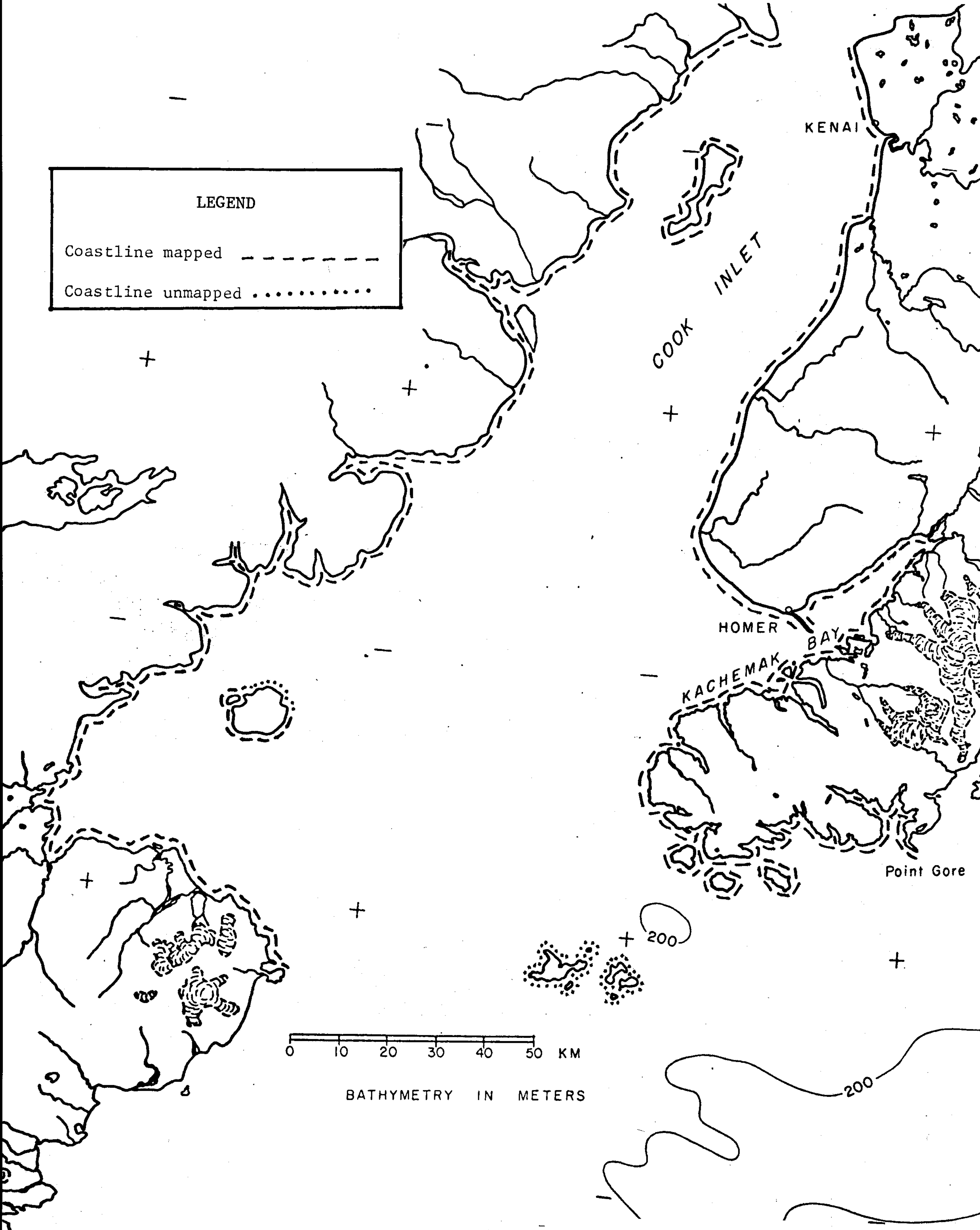

Figure 4. Habitat mapping coverage of Lower Cook Inlet.

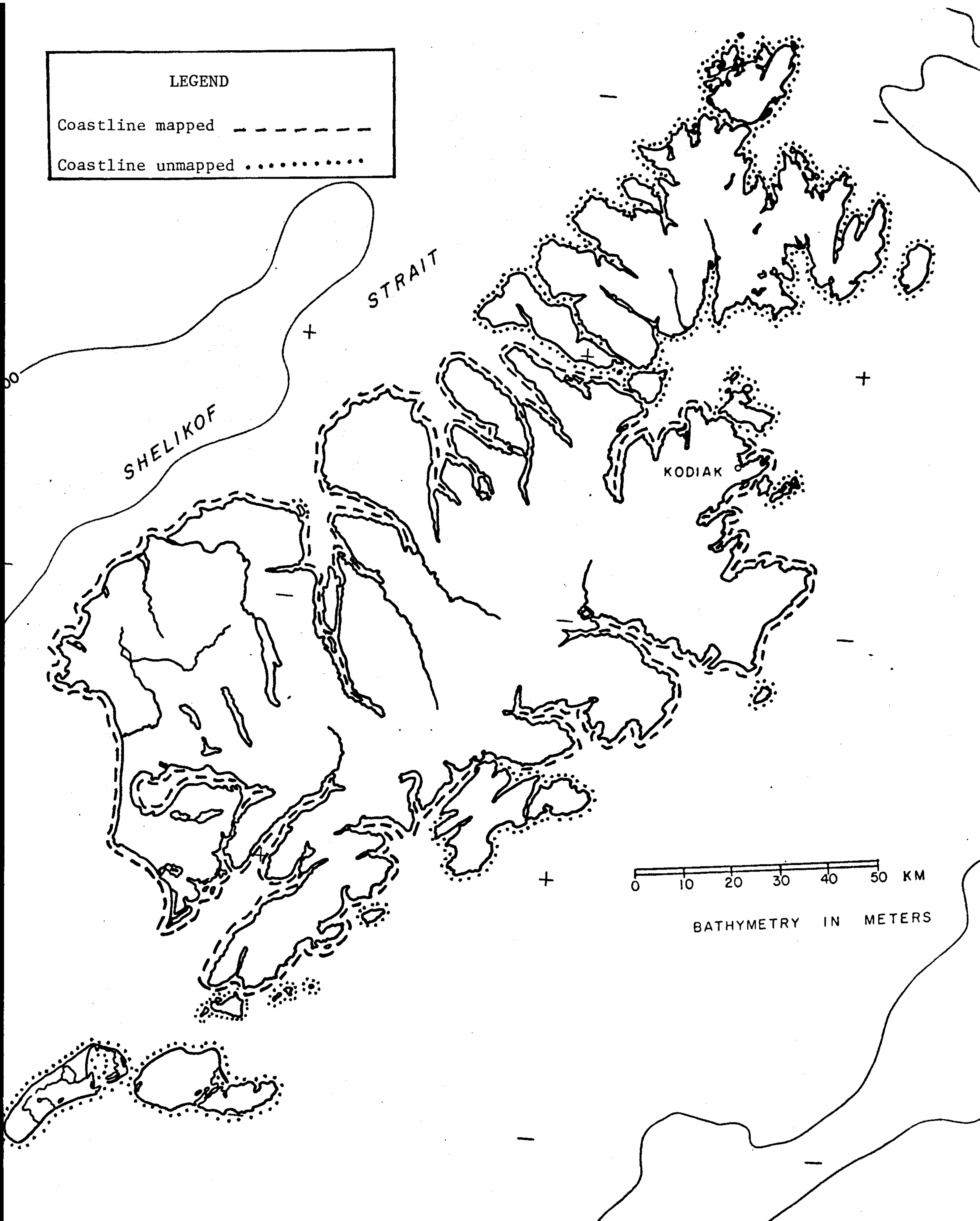

Figure 5. Habitat mapping coverage of Kodiak Archipelago.

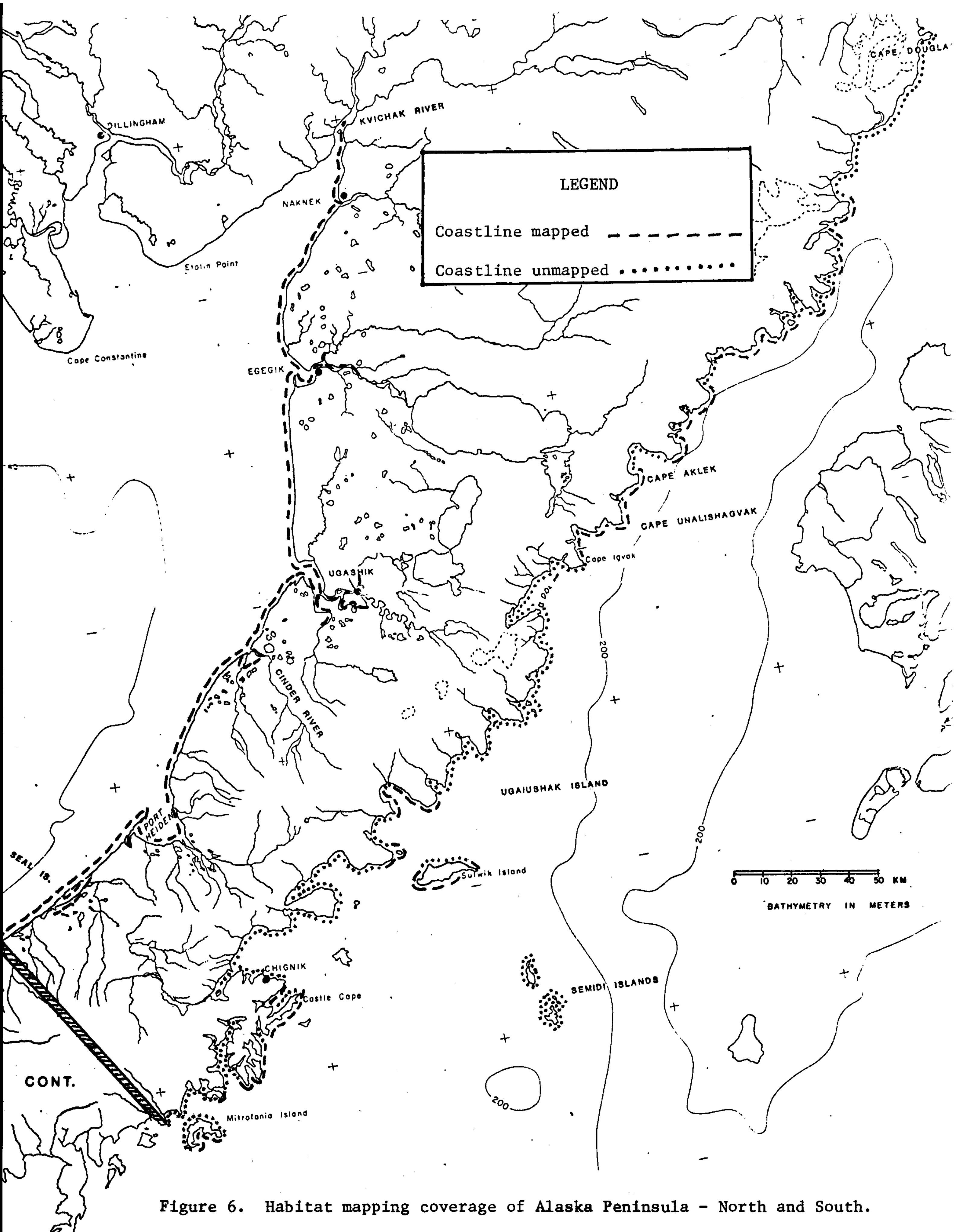

Figure 6. Habitat mapping coverage of Alaska Peninsula - North and South.

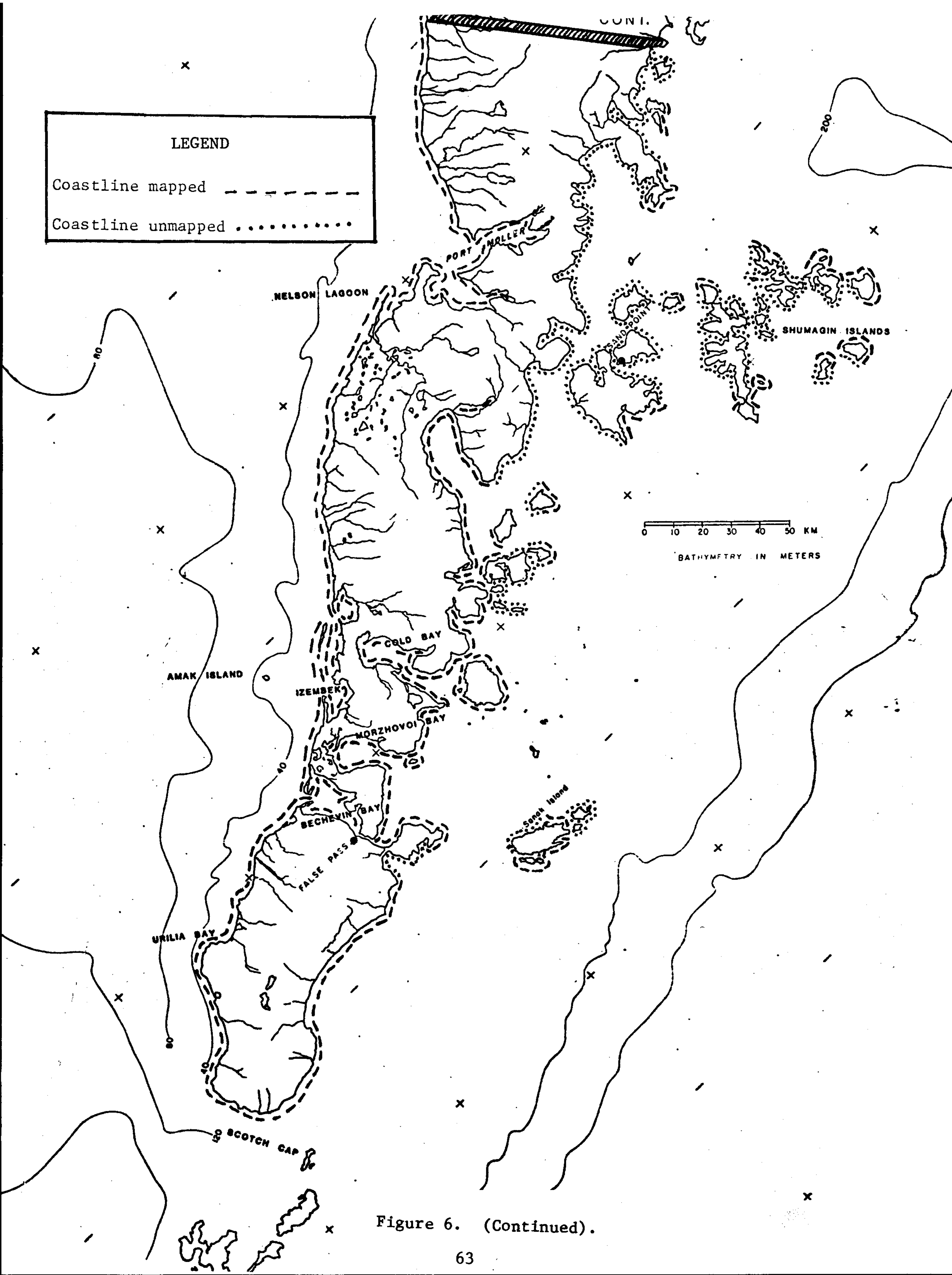

Figure 6. (Continued).

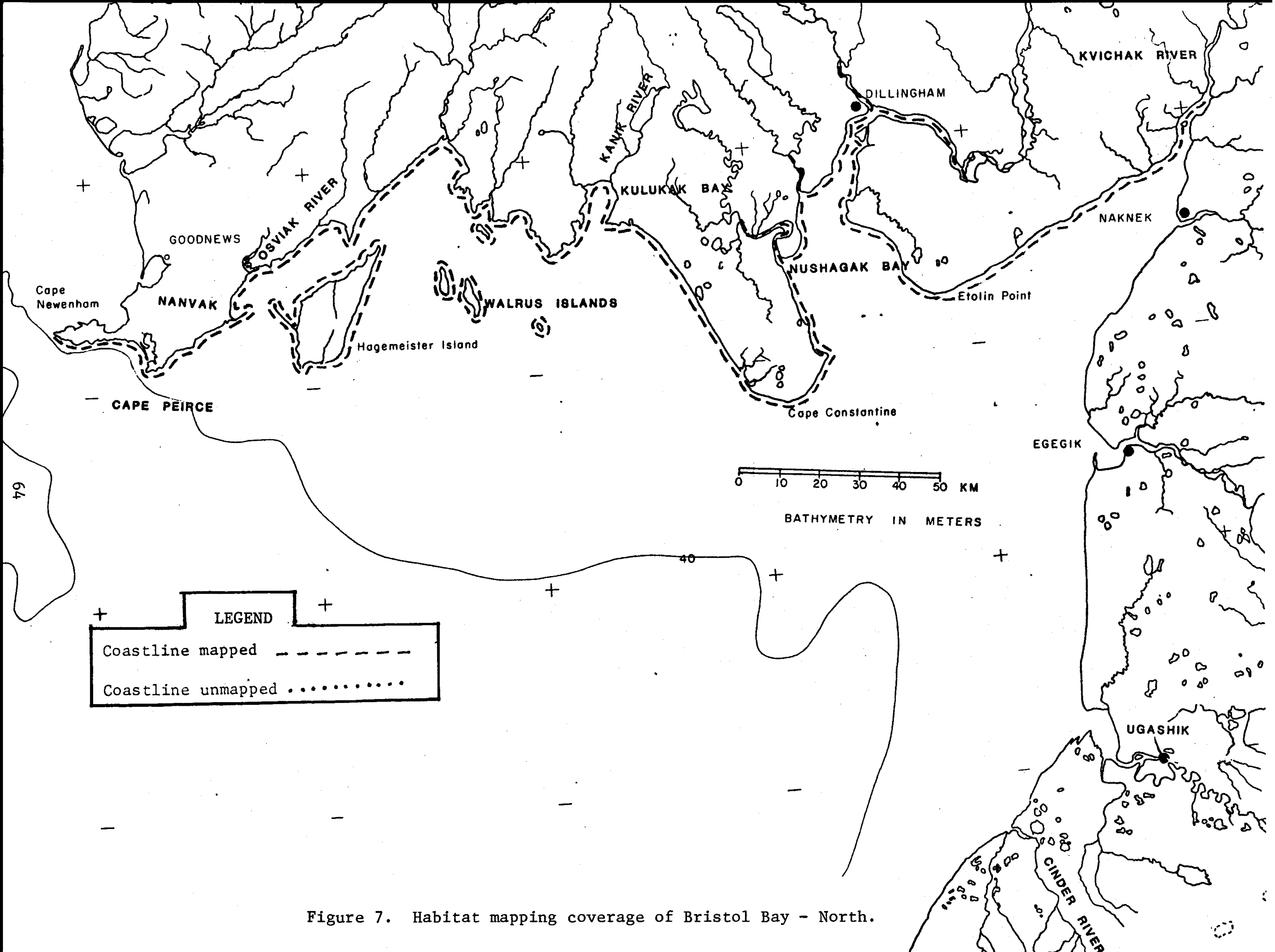

Figure 7. Habitat mapping coverage of Bristol Bay - North.

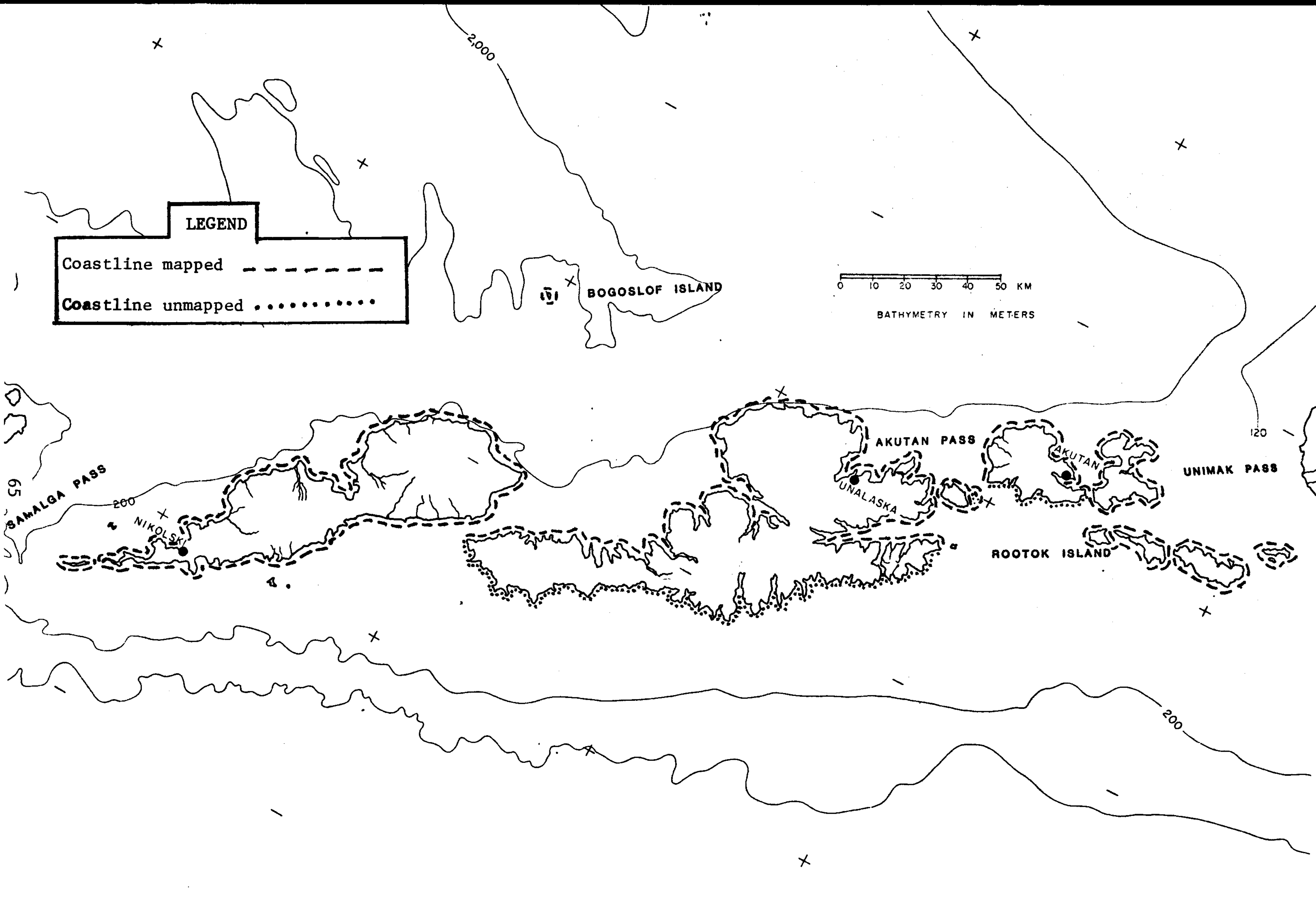

Figure 8. Habitat mapping coverage of Aleutian Shelf.

APPENDIX C

Aerial survey bird observations by water type. Compilation of nine major surveys in five subunits of the study area.

Table 1. Aerial survey bird observations by water type for Northeast Gulf of Alaska, 1-9 May 1976 (ID No. FG7604).

WATER TYPES

Species Group	Bay	Lagoon	Embayment	Fjord	Unprotected Shoreline	Brackish Pond or Lake	Fresh Water Pond or Lake	Lotic Environment	TOTAL
Loons	211		144	12	156				523
Grebes	12		1	5	2				20
Tubenoses									
Cormorants	270		40	8	167				485
Swans	4		6	3					13
Geese	157		1006	4	559				1726
Dabblers	1825		2866	470	447	12			5620
Divers	2279		1501	2006	236	12			6034
Sea Ducks	3787		498	1615	1315				7215
Mergansers	112		562	43	98				815
Eagles, etc.	26		48	6	105				185
Cranes					79				79
Sm. Shorebi.	3007		14,530	49	795				18,381
Med. Shore.	4329		7566	24	1052				12,971
Lg. Shorebi.	2567		625	6	59				3257
Mx. Shorebi.	10,780		11,978	155	643				23,556
Jaegers	31		55	20	8				114
Gulls	5987		5378	1593	25,982		25		38,965
Terns	1718		2085	131	2477				6411
Alcids	8			17	3662				3687
Corvids	10		7	1	7				25
Fringillids			1						1
OtherPasser.	6		52		6				64
TOTAL	37,126		48,949	6168	37,855	24	25		

Table 2. Aerial survey bird observations by water type for Lower Cook Inlet, 9-18 February 1976 (ID. No. FG7602).

WATER TYPES

Species Group	Bay	Lagoon	Embayment	Fjord	Unprotected Shoreline	Brackish Pond or Lake	Fresh Water Pond or Lake	Lotic Environment	TOTAL
Loons	29	3		12	20				64
Grebes	2				1				3
Tubenoses									
Cormorants	138	4		8	308				458
Swans									
Geese									
Dabblers	1325	159		18					1502
Divers	2369	267	227	116	73	12			3064
Sea Ducks	5691	45	119	272	3268			125	9520
Mergansers	156	65	19	2	11				253
Eagles,etc.	37	3		2	10				52
Cranes									
Sm.Shorebi.	305	2			157				464
Med.Shore.	3527				49				3576
Lg.Shorebi.	1								1
Mx.Shorebi.	495				103				598
Jaegers									
Gulls	100	36		1	1295				1432
Terns									
Alcids	107	21		87	64				279
Corvids	562				217				779
Fringillids									
OtherPasser.	1				25				26
TOTAL	14,845	605	365	518	5601	12		125	

Table 3. Aerial survey bird observations by water type for Lower Cook Inlet, 3-7 May 1976 (ID No. FG7605).

Species Group	WATER TYPES: Bay	Lagoon	Embayment	Fjord	Unprotected Shoreline	Brackish Pond or Lake	Fresh Water Pond or Lake	Lotic Environment	TOTAL
Loons	37	1	2	1	33	2		5	81
Grebes	16	10	5	1	16				48
Tubenoses									
Cormorants	505	20	3	4	666				1198
Swans	2							27	29
Geese	1161	1			630	4747		270	6809
Dabblers	1314	281	563		429	3639	2	968	7196
Divers	10,593	619	19	94	995	1		929	13,250
Sea Ducks	10440	373	10	94	8047			265	19,229
Mergansers	305	257	3	10	91			50	716
Eagles,etc.	16	4			14	1		3	38
Cranes					2	65		148	215
Sm.Shorebi.	13,698	220			7326	71		65	21,380
Med.Shore.	879	38			287	8			1212
Lg.Shorebi.	18				38			5	61
Mx.Shorebi.									
Jaegers									
Gulls	8385	996	65	5	31,737	421		588	42197
Terns					7	8			15
Alcids	96	28		1	398			2	525
Corvids	34	65		9	9				117
Fringillids									
OtherPasser.	1								1
TOTAL	47,500	2913	670	219	50,725	8963	2	3325	

Table 4. Aerial survey bird observations by water type for Lower Cook Inlet, 21-25 June 1976 (ID No. FG7607).

Species Group	WATER TYPES: Bay	Lagoon	Embayment	Fjord	Unprotected Shoreline	Brackish Pond or Lake	Fresh Water Pond or Lake	Lotic Environment	TOTAL
Loons	14	1		3	77	3		7	105
Grebes	2				3				5
Tubenoses	1				1005				1006
Cormorants	156				1602			3	1761
Swans	2				40			2	45
Geese	9				38			5	52
Dabblers	705		49		478	266	65	728	2291
Divers	818	2			182	1		53	1056
Sea Ducks	18,716	517	59	21	10,061			87	29,461
Mergansers	33	2	9		60			5	109
Eagles, etc.	18	4			20			2	44
Cranes			5		1	1		6	13
Sm. Shorebi.	97		3		93	20		6	219
Med. Shore.	38		26		164	17		19	264
Lg. Shorebi.	20				11			2	33
Mx. Shorebi.								1	1
Jaegers					1				1
Gulls	14,835	138	231		34,861	4		4755	54,824
Terns	110		46		177	3		29	365
Alcids	57	31		10	5223				
Corvids	26	2	7	8	5			3	5321
Fringillids	2		2						4
OtherPasser.	7	1	2		7			23	40
TOTAL	35666	698	439	42	54109	315	65	5736	

Table 5. Aerial survey bird observations by water type for Lower Cook Inlet, 30 September-2 October 1976 (ID No. FG7701).

WATER TYPES

Species Group	Bay	Lagoon	Embayment	Fjord	Unprotected Shoreline	Brackish Pond or Lake	Fresh Water Pond or Lake	Lotic Environment	TOTAL
Loons	9	1		1	65			1	77
Grebes	44				31				75
Tubenoses	1			1	1				3
Cormorants	803	129		75	1792				2799
Swans									
Geese	369				132			2158	2659
Dabblers	7150	1806		208	2859	157	9	924	13,113
Divers	789	63			210	6		35	1103
Sea Ducks	5361	801		273	4150			33	10,618
Mergansers	49	43		44	30			125	291
Eagles,etc.	20	3		2	14			1	40
Cranes									
Sm.Shorebi.	16				150				166
Med.Shore.	1289	11		22	52	45		35	1454
Lg.Shorebi.									
Mx.Shorebi.									
Jaegers									
Gulls	8331	3346		373	9416			907	22,373
Terns									
Alcids	11			7	20				38
Corvids	351	139		43	172			1	706
Fringillids	2				1				3
OtherPasser.									
TOTAL	24,595	6342		1049	19,095	208	9	4220	

Table 6. Aerial survey bird observations by water type for Kodiak Archipelago, 22 February-24 March 1976 (ID No. FG7603).

WATER TYPES

Species Group	Bay	Lagoon	Embayment	Fjord	Unprotected Shoreline	Brackish Pond or Lake	Fresh Water Pond or Lake	Lotic Environment	TOTAL
Loons	88				8				96
Grebes	5								5
Tubenoses									
Cormorants	834	12			117				963
Swans									
Geese	79	30			22				131
Dabblers	2156	366	686						3208
Divers	4053	308	97		7				4465
Sea Ducks	14,765	765	198		1247				16,975
Mergansers	191	9			7				207
Eagles,etc.	109	11	1		42				163
Cranes									
Sm.Shorebi.	419	25			335				779
Med.Shore	176				1				177
Lg.Shorebi.	222				40				262
Mx.Shorebi.	125								125
Jaegers									
Gulls	1088	393	17		316				1814
Terns									
Alcids	2931				6				2937
Corvids	526	37	1		26				590
Fringillids									
OtherPasser.	12	12							24
TOTAL	27,779	1968	1000		2174				

Table 7. Aerial survey bird observations by water type for Alaska Peninsula-North, 13-27 October 1975 (ID No. FG7601).*

WATER TYPES

Species Group	Bay	Lagoon	Embayment	Fjord	Unprotected Shoreline	Brackish Pond or Lake	Fresh Water Pond or Lake	Lotic Environment	TOTAL
Loons	55	1	3		71				130
Grebes	9	3				1			13
Tubenoses	81				1				82
Cormorants	1128	2			542			1	1673
Swans	2		23		8			8	41
Geese	375,855	34,495	34,672		3936			767	449,725
Dabblers	11,750	2104	7972		556	321	1300	893	24,896
Divers	655	547	108		52	30	89	46	1527
Sea Ducks	84,427	11,468	19,495		24,932	6		40	140,368
Mergansers	16	3	8		13			8	48
Eagles,etc.	16	12	6		19			2	55
Cranes									
Sm.Shorebi.	1304	2528	16,818		893			271	21,814
Med.Shore.			68		143			1	212
Lg.Shorebi.	15		27		70			1	113
Mx.Shorebi.	1100	33	2053		658			4	3848
Jaegers									
Gulls	12,798	1489	4089		9156	20		56	27,608
Terns			1						1
Alcids	201	6	2		37				246
Corvids	11	7	4		18			3	43
Fringillids	361		83		378				822
OtherPasser.	24	30	64		170			4	292
TOTAL	489,808	52,728	85,496		41,653	378	1389	2105	

*Needs corrections. Water types misinterpreted by transcriber.

Table 8. Aerial survey bird observation by water type for Alaska Peninsula-North, 13-16 October 1976 (ID No. FG7702).

WATER TYPES

Species Group	Bay	Lagoon	Embayment	Fjord	Unprotected Shoreline	Brackish Pond or Lake	Fresh Water Pond or Lake	Lotic Environment	TOTAL
Loons		8	41		16			1	66
Grebes		6	18		3	1			28
Tubenoses									
Cormorants		26	12						38
Swans			73			94	4		171
Geese	232	136,825	64,210		616	959		860	203,702
Dabblers		4736	20,493			5114	387	727	31,457
Divers		9	224			110	440	158	941
Sea Ducks	3039	19,138	64,347		261	1		158	86,944
Mergansers		1						86	87
Eagles, etc.		8	18					3	24
Cranes									
Sm. Shorebi.		1367	40,462		3,303			162	45,294
Med. Shore.		10,517	10,004		12	17		37	20,587
Lg. Shorebi.			561			2		45	608
Mx. Shorebi.			3247		8			303	3558
Jaegers			2						2
Gulls	18	3942	14,279		751	63	21	638	19,712
Terns									
Alcids		1	6						7
Corvids		13	11		3	1			28
Fringillids		39	81		25			1	146
OtherPasser.		81	123			1			205
TOTAL	3289	176,717	218,212		4998	6363	852	3179	

Table 9. Aerial survey bird observation by water type for Bristol Bay-North, 17-20 May 1976 (ID No. FG7606).

WATER TYPE

Species Group	Bay	Lagoon	Embayment	Fjord	Unprotected Shoreline	Brackish Pond or Lake	Fresh Water Pond or Lake	Lotic Environment	TOTAL
Loons	77	1	4		238	65		21	406
Grebes	15				57			16	88
Tubenoses									
Cormorants	114		26		1480			8	1628
Swans	12		3		1	30		18	64
Geese	4404	4	715		118	21		191	5453
Dabblers	338	2	6			254		206	806
Divers	768	29	16		3820	554	2	1498	6687
Sea Ducks	658	143	5		4919	67		81	5873
Mergansers	67	6	18		316	110		180	697
Eagles,etc.					5			6	11
Cranes	11		12		4	9		46	82
Sm.Shorebi.	490	6	29		649	152		254	1580
Med.Shore.	901	52	86		755	45		176	2060
Lg.Shorebi.	26	2	1		7	1		5	42
Mx.Shorebi.	392		5		347	3		44	791
Jaegers	1				3	2		11	17
Gulls	1901	109	414		4503	229	25	1268	8449
Terns	99	126	78		573	18		97	991
Alcids	78				8455				8533
Corvids	2	1			19			2	24
Fringillids									
OtherPasser.	9		2		8	6		12	37
TOTAL	9705	481	1420		26,277	1556	27	4140	

APPENDIX D

Aerial survey bird observations by physiographic feature. Compilation of nine major surveys in five subunits of the study area.

Table 1. Aerial survey bird observations by physiographic feature for Northeast Gulf of Alaska, 1-9 May 1976 (ID No. FG7604).

PHYSIOGRAPHIC FEATURE

Species Group	Beach	Coastal Floodplain	Intertidal Area	Tide Upwelling	Sandspit	Barrier Island	Other Island	River Delta	Stream Delta	Cliff	Manmade Structure	River Bank
Loons	294		21		16	28	9	146	9			
Grebes	8		4				1	5	2			
Tubenoses												
Cormorants	126		45		10		263	41				
Swans	7							6				
Geese	289		48		35	127	82	1113	30			
Dabblers	762		398		68	7	261	3049	1075			
Divers	2781		683		32	2	808	1991	45			
Sea Ducks	4655		734		60	8	1260	520	51			
Mergansers	108		13		29		36	617	12			
Eagles,etc.	110		4		4	7	8	47	4		1	
Cranes						79						
Sm.Shorebi.	1371		637		59		1281	14,603	366			
Med.Shore.	2309		1029		8		1565	7823	22			
Lg.Shorebi.	769		1				1830	654	2			
Mx.Shorebi.	738		10,225		150		50	12,118	275			
Jaegers	35				2			62	13			
Gulls	15,133		1879		407	3866	12,608	3920	1127			
Terns	2447		51		278	1	276	2384	974			
Alcids	421		3				3263					
Corvids	10				3		2	8	2			
Fringillids						1						
OtherPasser.	6		4				8	46				
TOTAL	32,379		15,779		1161	4126	27,743	49,153	4009		1	

Table 2. Aerial survey bird observations by physiographic feature for Lower Cook Inlet, 9-18 February 1976 (ID No. FG7602).

PHYSIOGRAPHIC FEATURE

Species Group	Beach	Coastal Floodplain	Intertidal Area	Tide Upwelling	Sandspit	Barrier Island	Other Island	River Delta	Stream Delta	Cliff	Manmade Structure	River Bank
Loons	59							5				
Grebes	3											
Tubenoses												
Cormorants	293				3		162					
Swans												
Geese												
Dabblers	277				1111			114				
Divers	1759		219		288		124	655	28			
Sea Ducks	6827		98		1606		741	443		463		
Mergansers	190		1				2	24	36			
Eagles, etc.	30		8		5		5	2		2		
Cranes												
Sm. Shorebi.	71		247		145		1					
Med. Shore.	3530				6		40					
Lg. Shorebi.	1											
Mx. Shorebi.	95		380		35		3	85				
Jaegers												
Gulls	793		8		602		5	30		4		
Terns												
Alcids	243						3	141		29		
Corvids	306		162		69		170	71		1		
Fringillids												
OtherPasser.	1						25		1			
TOTAL	14,478		1123		3870		1281	1423	65	499		

Table 3. Aerial survey bird observations by physiographic feature for Lower Cook Inlet, 3-7 May 1976 (ID No. FG7605).

Species Group	PHYSIOGRAPHIC FEATURE											
	Beach	Coastal Floodplain	Intertidal Area	Saltchuck	Sandspit	Barrier Island	Other Island	River Delta	Stream Delta	Cliff	Manmade Structure	River Bank
Loons	64		12		2		1	2				
Grebes	36		1				7			4		
Tubenoses												
Cormorants	248	1	87		31		207	1		622		
Swans	2							27				
Geese	152	4600	66		2		1046	943				
Dabblers	846	2517	1619	76			1148	771	139			80
Divers	2329	137	9671		507		263	170	133	39		
Sea Ducks	7951	144	7314		949		2332	167	7	333		32
Mergansers	269	49	313				14	54	3	12		
Eagles,etc.	15	3	12				5		1	1		1
Cranes	2	45					20	148				
Sm.Shorebi.	575	4058	14,733		200		1534	105	110			65
Med.Shore.	63		155		800		192			2		
Lg.Shorebi.	17		36				2			1		5
Mx.Shorebi.												
Jaegers												
Gulls	4827	569	3816	18	1001		25,958	1251	335	4002	369	3
Terns		8	7									
Alcids	185		4		1		265			70		
Corvids	78		36				2			1		
Fringillids												
OtherPasser.												
TOTAL	17,569	12,131	37,882	94	3493		32,996	3639	728	5087	369	186

Table 4. Aerial survey bird observations by physiographic feature for Lower Cook Inlet, 21-25 June 1976 (ID No. FG7607).

PHYSIOGRAPHIC FEATURE

Species Group	Beach	Coastal Floodplain	Intertidal Area	Tide Upwelling	Sandspit	Barrier Island	Other Island	River Delta	Stream Delta	Cliff	Manmade Structure	River Bank
Loons	34	3	6				2	50				7
Grebes	2						3					
Tubenoses	2						1004					
Cormorants	536		91		8		1091	30		8		1
Swans		2	42									
Geese		15	27				5	5				
Dabblers	138	958	870				164	85				76
Divers	455	54	468				79					
Sea Ducks	19,611		6857		193		2762					40
Mergansers	18	1	83					12	2			4
Eagles, etc.		3	8				10	5				
Cranes		6					5	1				1
Sm. Shorebi.	95	29	5				3	87				
Med. Shore.	1	41	133		16		3	70				
Lg. Shorebi.	18	1					8	6				
Mx. Shorebi.		1										
Jaegers	1											
Gulls	19,711	835	9467		1619		17,182	6182	35	179	3	63
Terns	144	66	9		6		113	28				
Alcids	170				1		515					
Corvids	31				1		2	4				
Fringillids	2						2	1				
OtherPasser.	3	6					3	1				
TOTAL	40,972	2021	18,066		1844		27,556	6567	37	187	3	192

Table 5. Aerial survey bird observations by physiographic feature for Lower Cook Inlet, 30 September-2 October 1976 (ID No. FG7701).

PHYSIOGRAPHIC FEATURE

Species Group	Beach	Coastal Floodplain	Intertidal Area	Tide Upwelling	Sandspit	Barrier Island	Other Island	River Delta	Stream Delta	Cliff	Manmade Structure	River Bank
oons	63						8	1	4			
rebes	60		7		2		7					
ubenoses	3											
ormorants	699		129		5		1921		27	18		
wans												
eese	4		2142				132	365				16
abblers	4391	60	4957		45		12	3136	245			263
ivers	754		215		24		15	67	28			
ea Ducks	8614		1185		127		671		16			5
ergansers	83		65					113				10
agles,etc.	21		5		1		10	3				
ranes												
.Shorebi.	92						74					
ed.Shore.	1314	3	13		15		29	80				
g.Shorebi.												
x.Shorebi.												
aegers												
ulls	10,300		6780		921		2047	1847	333		99	46
erns												
lcids	25						13					
orvids	391	1	139				162		12			1
ringillids	2						1					
therPasser.												
TOTAL	26786	64	15637		1140		5102	5612	665	18	99	341

Table 6. Aerial survey bird observations by physiographic feature for Kodiak Archipelago, 22 February-24 March 1976 (ID No. FG7603).

PHYSIOGRAPHIC FEATURE

Species Group	Beach	Coastal Floodplain	Intertidal Area	Tide Upwelling	Sandspit	Barrier Island	Other Island	River Delta	Stream Delta	Cliff	Manmade Structure	River Bank
Loons	95						1					
Grebes	5											
Tubenoses												
Cormorants	719		12	134			92				6	
Swans												
Geese	101		30									
Dabblers	2078		247		43			671	169			
Divers	3971		283	7	17		55	97	35			
Sea Ducks	10,921		594	1903			452	198				
Mergansers	194		4	8					1			
Eagles,etc.	100		7		1		23	1		31		
Cranes												
Sm.Shorebi.	754		25									
Med.Shore.	121			6			50					
Lg.Shorebi.	62						200					
Mx.Shorebi.	125											
Jaegers												
Gulls	1479		106	73	22		113	17	4			
Terns												
Alcids	2896			37			3					
Corvids	506		7	5			19	1	50	1	1	
Fringillids												
OtherPasser.	23						1					
TOTAL	24,150		1315	2173	83		1009	985	259	32	7	

Table 7. Aerial survey bird observations by physiographic feature for Alaska Peninsula-North, 13-27 October 1975 (ID No. FG7601).*

PHYSIOGRAPHIC FEATURE

Species Group	Beach	Coastal Floodplain	Intertidal Area	Tide Upwelling	Sandspit	Barrier Island	Other Island	River Delta	Stream Delta	Cliff	Manmade Structure	River Bar
Loons	122		2			1		3				
Grebes	6	1					4					
Tubenoses	75		3				4					
Cormorants	1663		7			2		1				
Swans	16	8						31				
Geese	402,061	12	7083		792	2796	595	34,911				
Dabblers	13,790	1765	142					9199				
Divers	1042	101	225					154				
Sea Ducks	96,930	18	8434		81	11,256	3513	19,165				
Mergansers	27	8						13				
Eagles, etc.	42		5					8				
Cranes												
Sm. Shorebi.	1919	277	303		2	2448	118	16,747				
Med. Shore.	21	1						190				
Lg. Shorebi.	35	50						28				
Mx. Shorebi.	1179	612						2057				
Jaegers												
Gulls	16,406	331	3455		1047	837	399	4065				
Terns								1				
Alcids	182		35			1	6	2				
Corvids	34						2	7				
Fringillids	358	41	320				20	83				
OtherPasser.	161	22				30	20	59				
TOTAL	536,069	3247	20,014		1922	17,374	4681	86,724				

*Needs corrections. Physiographic features misinterpreted by transcriber.

Table 8. Aerial survey bird observations by physiographic feature for Alaska Peninsula-North, 13-16 October 1976 (ID No. FG7702).

PHYSIOGRAPHIC FEATURE

Species Group	Beach	Coastal Floodplain	Intertidal Area	Tide Upwelling	Sandspit	Barrier Island	Other Island	River Delta	Stream Delta	Cliff	Manmade Structure	River Bank
...ors	12		36					14				
...ebes	3	1	17			2		5				
...henoses												
...rmorants			26	4				12				
...ans		24						143				
...ese	1355	12,790	40,510		1858	9366	11,339	26,099				260
...bblers		3761	6416				6485	14,163	130			115
...vers	2	20	201					343				
...a Ducks	3202	3	48,142		429	5551	42	29,575				
...rgansers			1					86				
...gles, etc.	3	2	6		5		2	9		1		1
...ranes												
...r. Shorebi.		570	15,422		3678	3495	8010	14,034				85
...d. Shore.		1853	8,069		13	2366	2629	5623				34
.... Shorebi.					20			588				
... Shorebi.			8			1200	1500	550				300
...gers								2				
...lls	652	289	5272		3272	1891	4669	3069	478			61
...erns												
...cids			6					1				
...vids	3	1	11		2	1		10				
...ingillids	25	37				54	25	5				
...rPasser.		140	8				50	7				
TOTAL	5257	19,491	224,151	4	9277	23,926	34,751	94,288	608	1		856

Table 9. Aerial survey bird observations by physiographic feature for Bristol Bay-North, 17-20 May 1976 (ID No. FG7606).

Species Group	Beach	Coastal Floodplain	Intertidal Area	Tide Upwelling	Sandspit	Barrier Island	Other Island	River Delta	Stream Delta	Cliff	Manmade Structure	River Bank
Loons	293	79	16		1			4				10
Grebes	68	2	1		1					2		14
Tubenoses												
Cormorants	1384	4	11		10		137	26		51		5
Swans		45	6					2				11
Geese	3512	252	985		5		8	677				23
Dabblers	40	649	46				43	3				60
Divers	2071	1656	2286				17	32	12			1150
Sea Ducks	4490	99	764		112		90	39		244		62
Mergansers	369	141	31					18				158
Eagles,etc.	3	3	1					2				2
Cranes	2	61	9				3	15				2
Sm.Shorebi.	411	522	500		35		74	5				26
Med.Shore.	1289	573	136		4		39	7				5
Lg.Shorebi.	19	12	5				9	1				1
Mx.Shorebi.	631	10	2				100	5				43
Jaegers	2	12					1					5
Gulls	4120	1707	1196		141		465	82	169	314	17	729
Terns	447	158	274		43			36	9			41
Alcids	434		18		236		5879			1966		
Corvids	20	9	2									1
Fringillids												
OtherPasser.	6	30	5									
TOTAL	19,611	5994	6294		588		6865	954	190	2577	17	2348

APPENDIX E

Aerial survey bird observations by substrate type. Compilation of nine major surveys in five subunits of the study area.

Table 1. Aerial survey bird observations by substrate type for Northeast Gulf of Alaska, 1-9 May 1976 (ID No. FG7604).

SUBSTRATE TYPE

pecies roup	Mud	Sand	Gravel	Rock	Mud & Sand	Sand & Gravel	Sand, Gravel & Rock	Water	Land Ice	Sea Ice
ons								523		
ebes								20		
benoges										
rmorants				150				335		
ans	2							11		
ese	647	49		18			190	625		
bblers	391	33		10		24		4106	5	3
ivers	27			7				6308		
a Ducks		20						7268		
rgansers				1				814		
gles, etc.	21	106	4	7		6		12	7	
kanes								79		
.Shorebi.	14,890	1599		35	145	300	23	857	65	
ed.Shore.	10,041	615		1581	25	6		272	26	
.Shorebi.	2099	98		700	2			43		
x.Shorebi.	21,148	283					600	1280		
aegers	27	10	2			9		25	2	2
ulls	4218	12,147	298	7267	1	723	241	10,377	49	42
erns	852	2589	4	3	30	357		1485	40	
lcids								3687		
orvids	2	7		6				3		
ringillids		1								
therPasser.	30	5		1		5		18		2
TOTAL	54,395	17,562	308	9786	203	1430	1054	38,148	194	49

Table 2. Aerial survey bird observations by substrate type for Lower Cook Inlet, 9-18 February 1976 (ID No. FG7602).

SUBSTRATE TYPE

Species Group	Mud	Sand	Gravel	Rock	Mud & Sand	Sand & Gravel	Sand, Gravel & Rock	Water	Land Ice	Sea Ice
Loons								64		
Grebes								3		
Tubenoses										
Cormorants				65				393		
Swans										
Geese										
Dabblers	60							1442		
Divers	138			3				2371		57
Sea Ducks			5	20				9946		207
Mergansers		1						226		24
Eagles, etc.	2		8	6				1	1	
Cranes										
Sm. Shorebi.	127		20	1						
Med. Shore.	3281		4	17						
Lg. Shorebi.										
Mx. Shorebi.	180		35	30				87	200	
Jaegers										
Gulls				3	5	15		963	7	8
Terns										
Alcids								274		
Corvids	2		3	6				2	7	
Fringillids										
Other Passer.				25				1		
TOTAL	3790	1	75	176	5	15		[illegible]	215	296

Table 3. Aerial survey bird observations by substrate type for Lower Cook Inlet 3-7 May 1976 (ID No. FG7605).

Species Group	SUBSTRATE TYPE Mud	Sand	Gravel	Rock	Mud & Sand	Sand & Gravel	Sand, Gravel & Rock	Water	Land Ice	Sea Ice
Loons								75		
Grebes								48		
Tubenoses										
Cormorants				474				473		
Swans					27			2		
Geese	3193			530	1682	675		153		
Dabblers	615			10	662	5		4574		
Divers				100				13,129		
Sea Ducks			15	43		1232		17,834		
Mergansers				4		53		654		
Eagles, etc.	5		2	3	1	3	1	4		
Cranes					193			2		
Sm. Shorebi.	17,314		40	50	425	1438		40		
Med. Shore.	138			184	810	16		18		
Lg. Shorebi.	41			14				1		
Mx. Shorebi.										
Jaegers										
Gulls	1497	923	1575	658	820	888	40	2585	8	
Terns	10							5		
Alcids				41				484		
Corvids			26	1		8	14	7		
Fringillids										
Other Passer.										
TOTAL	22,813	923	1658	2112	4620	4313	55	40,088	8	

Table 4. Aerial survey bird observations by substrate type for Lower Cook Inlet, 21-25 June 1976 (ID No. FG7607).

SUBSTRATE TYPE

Species Group	Mud	Sand	Gravel	Rock	Mud & Sand	Sand & Gravel	Sand, Gravel & Rock	Water	Land Ice	Sea Ice
Loons								102		
Grebes								5		
Tubenoses								1006		
Cormorants	13			848				904		
Swans	2							42		
Geese								47		
Dabblers	437							1841		
Divers	53							1003		
Sea Ducks		32	40	28			64	28,409		
Mergansers	2							169		
Eagles, etc.	3		4	6		1	1			
Cranes	6							1		
Sm. Shorebi.	38							20		
Med. Shore.	68				4			127		
Lg. Shorebi.	4		10	13						
Mx. Shorebi.	1									
Jaegers										
Gulls	8091	8119	3790	10,303	35	61	409	1953		
Terns	94							46		
Alcids				264				5042		
Corvids	3			1						
Fringillids	3									
Other Passer.										
TOTAL	8818	8151	3844	11,463	39	62	474	40,717		

Table 5. Aerial survey bird observations by substrate type for Lower Cook Inlet, 30 September-2 October 1976 (ID No. FG7701).

SUBSTRATE TYPE

Species Group	Mud	Sand	Gravel	Rock	Mud & Sand	Sand & Gravel	Sand, Gravel & Rock	Water	Land Ice	Sea Ice
Loons								76		
Grebes				1				75		
Tubenoses								3		
Cormorants		2	1	1734				1062		
Swans										
Geese	2523			132				4		
Dabblers	2480		40	83				10,218		
Divers		15	28					1058		
Sea Ducks		44		11				9565		
Mergansers	2							289		
Eagles,etc.	8	4	2	10				3		
Cranes										
Sm.Shorebi.	91	55		8				12		
Med.Shore.	99	3	1200	112				23		
Lg.Shorebi.										
Mx.Shorebi.										
Jaegers										
Gulls	9889	920	2840	1798		262		4572		53
Terns										
Alcids				1				38		
Corvids				295				131		
Fringillids				2				1		
OtherPasser.										
TOTAL	15,092	1043	4141	4187		262		27,130		53

Table 6. Aerial survey bird observations by substrate type for Kodiak Archipelago, 22 February-24 March 1976 (ID No. FG7603).

SUBSTRATE TYPE

Species Group	Mud	Sand	Gravel	Rock	Mud & Sand	Sand & Gravel	Sand, Gravel & Rock	Water	Land Ice	Sea Ice
Loons								96		
Grebes								5		
Tubenoses										
Cormorants				65				892		
Swans										
Geese								131		
Dabblers								3339		
Divers								4465		
Sea Ducks								16,975		
Mergansers								205		
Eagles,etc.		3	2	30		4		5	4	3
Cranes										
Sm.Shorebi.		309		5				148		
Med.Shore.				56			120			
Lg.Shorebi.				262						
Mx.Shorebi.										
Jaegers										
Gulls	1	54		2		4		961	140	
Terns										
Alcids								2936		
Corvids				4				75		
Fringillids										
OtherPasser.			10							
TOTAL	1	366	12	424		8	120	30,233	144	3

Table 7. Aerial survey bird observations by substrate type for Alaska Peninsula-North, 13-27 October 1975 (ID No. FG7601).

SUBSTRATE TYPE

Species Group	Mud	Sand	Gravel	Rock	Mud & Sand	Sand & Gravel	Sand, Gravel & Rock	Water	Land Ice	Sea Ice
Loons								130		
Grebes								13		
Tubenoses								69		
Cormorants				60				763		
Swans	26							26		
Geese	24,810	1022						62,201		
Dabblers	7,908	52						6879		
Divers	22							1505		
Sea Ducks	240	625						120,650		
Mergansers								43		
Eagles,etc.	3	2						1		
Cranes										
Sm.Shorebi.	17,382	23						161		
Med.Shore.	71							2		
Lg.Shorebi.	77							1		
Mx.Shorebi.	2994									
Jaegers										
Gulls	1316	227						1790		
Terns								1		
Alcids	23							222		
Corvids	3	8						3		
Fringillids	46	171								
OtherPasser.	20	12						125	1	
TOTAL	55,001	2142		60				194,585	1	

Table 8. Aerial survey bird observations by substrate type for Alaska Peninsula-North, 13-16 October 1976 (ID No. FG7702).

SUBSTRATE TYPE

Species Group	Mud	Sand	Gravel	Rock	Mud & Sand	Sand & Gravel	Sand, Gravel & Rock	Water	Land Ice	Sea Ice
Loons	4							62		
Grebes								28		
Tubenoses										
Cormorants								38		
Swans	2							169		
Geese	51,135	24,672			468			127,388		
Dabblers	7408	6450	35		90			17,264		
Divers								941		
Sea Ducks		567						86,377		
Mergansers								87		
Eagles, etc.	12	14						2		
Cranes										
Sm. Shorebi.	29,592	15,605			8			89		
Med. Shore.	12,783	6507	4		315			678		
Lg. Shorebi.	586	20						2		
Mx. Shorebi.	858	1200	1500							
Jaegers								2		
Gulls	3466	10,243	89	243	431	30		5067		
Terns										
Alcids								7		
Corvids	14	5						9		
Fringillids	41	104						1		
Other Passer.	146	50			8			1		
TOTAL	106,047	65,437	1628	243	1320	30		238,212		

Table 9. Aerial survey bird observations by substrate type for Bristol Bay-North, 17-20 May 1976 (ID No. FG7606).

SUBSTRATE TYPE

ecies oup	Mud	Sand	Gravel	Rock	Mud & Sand	Sand & Gravel	Sand, Gravel & Rock	Water	Land Ice	Sea Ice	
ons		3		2				404			
ebes								88			
benoses											
rmorants	8	18	35	332				1183	24	2	
ans	14							49			
ese	84	5		3				4363			
bblers	117							742	17		
vers	58	2129				80		5040	1	10	
a Ducks	47	359		6				5481			
rgansers	8	6	22	4				581			
gles, etc.	1					1	2	2	1		
anes	28	2						52			
.Shorebi.	880	88	40	102		2	32	377			
d.Shore.	489	170	227	596			2	124	4	1	
.Shorebi.	23		1			18		3	15		
.Shorebi.	49	17		305		20		4			
egers	3			1				10			
lls	1280	1843	169	345		5	109	1358	126	676	
rns	100	139	10					91	9		
cids		56		1548				6810			
rvids	2	3						1	1		
ingillids											
herPasser.	9								4		
TOTAL	3730	4838	504	3244		126	145	26,102	202	689	

Final Report

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A Census of Seabirds on the Pribilof Islands

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ABSTRACT

A census of seabirds nesting on the Pribilof Islands, principally St. George Island, was undertaken in the summers of 1975 and 1976. Ledge-nesting species were estimated from cliff photographs by means of a stratified sampling technique, the counts being adjusted with correction factors for variation in daily and hourly ledge attendance for counts of thick-billed murres.

Crevice-nesting species on cliffs of St. George were estimated by using species-proportion figures based on counts of 63 reference ledges. Quadrat and flight counts were used to estimate the least auklets at a large inland colony. Census work on Walrus Island was omitted due to the absence of nesting birds on the former, where sealions have taken over the flatrocks, and Otter Island where the small number of birds did not encourage an investment of the manpower we had available. Order-of-magnitude estimates for St. Paul were obtained by using St. George overall densities.

It was concluded that the numbers breeding on St. George in 1976 involved 1.5 million thick-billed murres; 250,000 least auklets exclusive of beach-boulder nesters that could not be satisfactorily censused; 220,000 red-legged kittiwakes; 190,000 common murres; 150,000 parakeet auklets; 72,000 black-legged kittiwakes; 70,000 fulmars; 28,000 horned puffins; 28,000 crested auklets; 6,000 tufted puffins; and 5,000 red-faced cormorants. The least auklet numbers were probably down from those witnessed by previous ornithologists. The red-legged kittiwakes here appear to have their main stronghold in the North Pacific. Exploitation of St. George's seabirds by local Aleut people in 1975-76 was trivial. An important threat to the reproductive success of the ledge-nesting

birds will occur if St. George is ever used as a sea- or airport petroleum development. The total population, on the order of 2.5 million nesting birds on this 19.9-by-8-km island, would appear to make it the largest seabird colony in the Northern Hemisphere.

The total number of seabirds nesting on St. Paul was on the order of a quarter of a million. The total on Otter Island was reported to be very small, numbering in the low thousands.

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INTRODUCTION

General Nature and Scope of Study

No systematic census or population estimates of the seabirds of the Pribilofs has ever been attempted, although for almost a century ornithologists have reported their numbers as in the "millions." The project reported here will provide enumerational data on what supposedly is the largest aggregate of colonial birds anywhere in North America, as a baseline on which to estimate any subsequent effects and environmental impact of petroleum exploration and development on the birdlife of this part of the Bering Sea.

Estimating large numbers of colonial seabirds is a problem with several unique difficulties. The most obvious of these being (1) the number of birds present on the cliff is in a constant state of flux due to arriving and departing birds. The pattern of this fluctuation varies among species with the hour of the day and the date during the breeding season. (2) Several species nest underground, and their numbers have to be estimated indirectly, i.e., by counts of birds present on the surface or by flight counts of arrivals and/or departures. (3) Large numbers of nonbreeding birds of some species are present in the colonies.

We have attempted to account for these difficulties on a species by species basis, the amount of effort expended on any given species being roughly commensurate with its importance, numerically, in the Pribilof ecosystem. In this regard, we have calculated the numbers and productivity of thick-billed murres (1,500,000) with more consideration than those of tufted puffins (6,000).

Abbreviations of species names in our report are given in Table 1.

TABLE 1. ABBREVIATIONS USED IN TABLES AND GRAPHS IN THIS REPORT

ABBREVIATION	SPECIES	SPECIES CODE[a/]
Tables		
BI	Black-legged kittiwake incubating	8810060301
BK	Black-legged kittiwake	8810060301
BN	Black-legged kittiwake nest	8810060301
CA	Crested auklet	8810070801
CM	Common murre	8810070101
CN	Red-faced cormorant nest	8804010104
DF	Dark-phase fulmar	88030202010002
F	Fulmar	8803020201
HP	Horned puffin	8810071001
LA	Least auklet	8810070802
LF	Light phase fulmar	88030202010001
PA	Parakeet auklet	8810070701
RC	Red-faced cormorant	8804010104
RI	Red-legged kittiwake incubating	8810060302
RK	Red-legged kittiwake	8810060302
RN	Red-legged kittiwake nest	8810060302
TM[b/]	Thick-billed murre	8810070102
TP	Tufted puffin	8810071101
UK	Unidentified kittiwake	8810060300
UM	Unidentified murre	8810070100
Graphs and Tables		
MC	Murie Cove	
PP	Pinnacle Point	
RFC	Rosy Finch Cove	

a/ as used in magnetic tape supplied to NOAA with this report.

b/ % TM = percentage of maximum number of thick-billed murres present on cliff at this time.

Max TM = maximum number of thick-billed murres present on cliff during the day.

Specific Objectives

The primary task of this study is to define a major biological population which is subject to potential impact by petroleum exploration and development in the Bering Sea. The particular objectives of the project are twofold:

(a) to obtain close estimates, for as many species as is practical within the time framework of this study, of the breeding seabirds on the Pribilof Islands, and

(b) to explore the possibilites of obtaining refined estimates of those additional nesting populations that do not readily lend themselves to conventional census techniques.

Relevance to Problems of Petroleum Development

Seabirds, because of their large numbers and high visibility, are valuable indicators of the health of a marine ecosystem. Because of their importance in the ecosystem, and their high vulnerability to oil, their numbers are a natural index to the effect of oil on the biology of the area. Birds will be among the first species to be affected by oil pollution, and the techniques to monitor their numbers are now being developed. A repeatable census technique or techniques for colonial seabirds is essential to understanding the effects of oil and gas development on the outer continental shelf.

STUDY AREA

The study area comprises the islands St. Paul, St. George, Otter, and Walrus. With the exception of Walrus Id., a low, flat rock, the islands are surrounded by cliffs of varying heights. Bird colonies are found on all cliff areas around the islands, among talus slopes at the bases of the cliffs (and in one case inland), and among beach boulders. The largest areas for nesting, and the greatest avian populations, occur on the cliffs of St. George. St. Paul is considerably less populated, and Otter has the fewest nesting birds of the three islands. Although large populations of nesting murres were reported in the past on Walrus, there are none nesting there presently due to the establishment of a rookery there by Stellar's sea lions (Hunt pers. comm.).

In 1975 and 1976 we concentrated our census work on St. George. St. Paul was intensely surveyed over a 5-day period in 1976. Otter and Walrus, being difficult to approach and less significant in terms of total bird numbers, were not visited.

St. George is composed primarily of basaltic lava and is older than St. Paul (Hopkins 1975). St. George is encircled by 48,700 meters of cliff. Of these cliffs, 33,500 meters are over 61 meters high (200 ft.), 14,400 are over 122 meters high (400 ft.), 5,300 are over 183 meters high (600 ft.), and 4,200 are over 244 meters high (800 ft). The highest cliffs are 308 m high (1,012 ft.) (Table 2). We estimated total cliff area at 3,537,550 m^2 (Table 3) not including low cliffs less than 5m high.

St. Paul is lower and more weathered than St. George. Much of the island is composed of sand and sand dunes, and beaches are more prevalent. The cliffs of St. Paul are mainly restricted to the West and South sides of the island. There are 11,400 meters of cliff, 2,450 of which are over 61 meters high. The highest cliffs are 116 meters (379 ft.) (Table 2). We estimated total cliff area at 454,975 m^2 (Table 3) not including low

TABLE 2. PRIBILOF CLIFFS DIVIDED INTO 61-M. STRATA

St. George Cliffs Divided Into 61-meter Strata

Lengths estimated from photographs

Strata	Length in Meters
Stratum 1 0 to 61 m in height	
All cliffs over 7.62 m high	48,700
Stratum 2 61 m to 122 m in height	
Ledge 48 to N Sealion Point	1,800
Shag Rock Cove	400
Black Cliffs-Umanagula-Red Bluffs	13,200
Rush Pt.-Staraya Artel (minus Needle Point Gap)	18,100
Total	33,500
Stratum 3 122 m to 183 m in height	
Rush Pt. N-Suskarlogh Pt.	5,900
Needle Rock environs	1,500
High Bluffs	6,200
First Bluff	800
Total	14,400
Stratum 4 183 m to 244 m in height	
High Bluffs	5,300
Stratum 5 244 m and above	
High Bluffs	4,200

St. Paul Cliffs Divided Into 61-meter Strata

Lengths estimated from maps

Strata	Length in Meters
Stratum 1 0 to 61 m in height	
All cliffs over 7.62 m high	11,400
Stratum 2 61 m to 116 m in height	
Einahnuhto Bluffs	2,450

TABLE 3

ESTIMATES OF TOTAL CLIFF AREA

St. George

	Cliff Area	% of Total
Stratum 1 48,700 m x 34 m	1,625,200 m^2	46%
Stratum 2 33,500 m x 30.5 m	1,021,750 m^2	29%
Stratum 3 14,400 m x 30.5 m	439,200 m^2	12%
Stratum 4 5,300 m x 61 m	323,300 m^2	9%
Stratum 5 4,200 m x 30.5 m	128,100 m^2	4%
Total	3,537,550 m^2	

St. Paul

Stratum 1 11,400 m x 34 m	387,600 m^2	85%
Stratum 2 2,450 m x 27.5 m	67,375 m^2	15%
Total	454,975 m^2	

cliffs less than 5 m high.

The weather on the Pribilofs during the breeding season is changeable and patchy from hour to hour across the islands. Fog and wind predominate, and rain is frequent. In 1975 there was almost constant rain and fog early in the season (June). In 1976 the weather was fine and clear generally until late July when the rain began and continued through August. The lee side of an island was generally clearer. The only weather pattern we found to be ubiquitous was a steady rain with no wind. This occurs in a thick fog.

SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

The seabirds nesting on the Pribilofs consist of six species that nest on cliff ledges:

thick-billed murre (*Uria lomvia*)
common murre (*U. aalge*)
black-legged kittiwake (*Rissa tridactyla*)
red-legged kittiwake (*R. brevirostris*)
fulmar (*Fulmarus glacialis*), and
red-faced cormorant (*Phalacrocorax urile*);

and five species that nest underground:

parakeet auklet (*Cyclorrhynchus psittacula*)
crested auklet (*Aethia cristatella*)
least auklet (*A. pusilla*)
horned puffin (*Fratercula corniculata*), and
tufted puffin (*Lunda cirrhata*).

Ledge-nesting species.—The conventional method of counting cliff-nesting birds on islands has been to photograph the birds from aircraft (Nettleship 1975). There has been some conjecture as to how to interpret these data, since under various conditions a pair may be represented by more, or less, than two birds. In censusing murres, the Canadian Wildlife Service tries to photograph murres before the nonbreeders arrive (late June or early

July in eastern Canada) and at the same date and hour each year. (Nettleship, pers. comm.). In this approach, the Canadians assume each bird equals one pair. The bias in this assumption may be cancelled out in year-to-year comparisons, but the potential bias remains real in single-year data.

To understand this potential bias and to be able to correct for it, we undertook daily ledge-attendance counts of major species at given study ledges as often as possible throughout the season. These counts were made at various parts of the island from first light (about 0400 local time) until dark (about 2230) in 1976. A complete count of the ledge was made every 30 minutes. Locations of these ledges are given in Table 4 and Fig. 1. Ledges 53, 57 and 21, 22, 23 were used.

In 1976, during the latter half of incubation of thick-billed murres (the predominant species), two complete sets of photos of the St. George cliffs were taken; one set on 7 and 15 July, the other on 29 July. Sections of the higher cliffs were photographed again on 5 and 6 August. This phase of the project was dependent on perfect weather.
Even on clear days, portions of the higher cliffs usually were clouded. Photos were taken on Tri-X 220 film using a Pentax 607 camera with 105-mm lens and UV filter. We were unable to use slower film because of general overcast conditions and deep shadows on the North-facing cliffs. A 13-ft. inflatable Avon boat with 25-HP Evinrude engine was used as a photographic platform.

In order to determine the relative proportions of the various species on ledges, we arbitrarily divided the cliff areas into five different strata. Stratum 1 includes all cliff areas 0 - 61m high; stratum 2, 61-122 m high; stratum 3, 122-183 m high, stratum 4, 183-244 m high; and

TABLE 4

St. George Id. Study Areas

REFERENCE LEDGES NORTH	COORDINATES
ROSY FINCH COVE MAIN LEDGES LEDGE 57 ST GEORGE	563609N1693524W
ROSY FINCH COVE LOITERING LEDGE LEDGE 57 ST GEORGE	563610N1693524W
ROSY FINCH COVE BK LEDGE LEDGE 57 ST GEORGE	563609N1693526W
FIRST BLUFF AREA A LEDGE 1 ST GEORGE	563614N1693710W
FIRST BLUFF AREA B LEDGE 1 ST GEORGE	563614N1693711W
FIRST BLUFF WEST CM LEDGE LEDGE 2 ST GEORGE	563621N1693743W
FIRST BLUFF WEST AS A REFERENCE LEDGE	563620N1693743W
EAST GAP PUFFERY LEDGE 39	563612N1693751W
WEST GAP LEDGE 600 LEDGE 40 ST GEORGE	563610N1693848W
LEDGE 41 ST GEORGE	563611N1693909W
LEDGE 42 ST GEORGE	563610N1693950W
EAST FACE OF PROMONTORY LEDGE 43 ST GEORGE	563612N1694003W
WEST FACE OF PROMONTORY LEDGE 44 ST GEORGE	563612N1694004W
LEDGE 54 ST GEORGE HIGH BLUFFS WEST	563612N1694024W
LEDGE 55 ST GEORGE	563613N1694033W

BEACH SECTIONS NORTH	
VILLAGE CLIFFS	563612N1693242W563608N1693248W
VILLAGE TO NORTH HAULING GROUND	563608N1693248W563606N1693320W
VILLAGE EAST	563612N1693151W563525N1693115W
VILLAGE WEST CLIFFS	563612N1693601W563606N1693500W

INTERIOR LEAST AUKLET COLONY	
ULAKAIA RIDGE COLONY - RANDOM QUADRATS LEDGE 56	563530N1693245W
ULAKAIA COLONY - 175 M. PERMANENT QUADRAT	563518N1693224W
ULAKAIA COLONY - 450 M. PERMANENT QUADRAT	563516N1693236W
ULAKAIA COLONY - 750 M. PERMANENT QUADRAT	563514N1693248W
LA FLIGHT OVER AIRSTRIP	563606N1693300W

REFERENCE LEDGES EAST	
PINNACLE POINT LEDGE 53 ST GEORGE	563552N1692802W
TOLSTOI NORTH LEDGE 45 ST GEORGE	563545N1692741W
TOLSTOI SOUTH LEDGE 46 ST GEORGE	563540N1692740W
LEDGE 47 ST GEORGE	563536N1692745W
LEDGE 48 ST GEORGE	563530N1692754W
LEDGE 49 ST GEORGE	563524N1692809W
LEDGE 50 ST GEORGE	563522N1692812W
LEDGE 51 ST GEORGE	563517N1692819W
LEDGE 52 ST GEORGE	563513N1692830W

ST. GEORGE ID. STUDY AREAS (CONTINUED)

REFERENCE LEDGES	COORDINATES
SOUTHWEST	
MURIE COVE UPPER LEDGE LEDGE 22 ST GEORGE	563250N1693913W
MURIE COVE LOWER LEDGE LEDGE 21 ST GEORGE	563250N1693914W
MURIE COVE FULMAR LEDGE LEDGE 23 ST GEORGE	563251N1693915W
LEDGE 30 ST GEORGE	563222N1693806W
LEDGE 31 ST GEORGE	563218N1693751W
LEDGE 32 ST GEORGE	563218N1693749W
LEDGE 33 ST GEORGE MARVIN GARDENS	563217N1693714W
LEDGE 34 ST GEORGE UMANANGULA WATERFALL SOUTH	563215N1693706W
LEDGE 35 ST GEORGE	563210N1693621W
LEDGE 36 ST GEORGE	563203N1693455W
LEDGE 37 ST GEORGE	563159N1693434W
LEDGE 38 ST GEORGE	563158N1693412W
LEDGE 24 ST GEORGE FLYING BUTTRESS CAPE	563236N1693848W
LEDGE 25 ST GEORGE	563232N1693833W
LEDGE 26 ST GEORGE	563231N1693832W
LEDGE 27 ST GEORGE	563225N1693817W
LEDGE 28 ST GEORGE	563223N1693813W
LEDGE 29 ST GEORGE	563222N1693811W

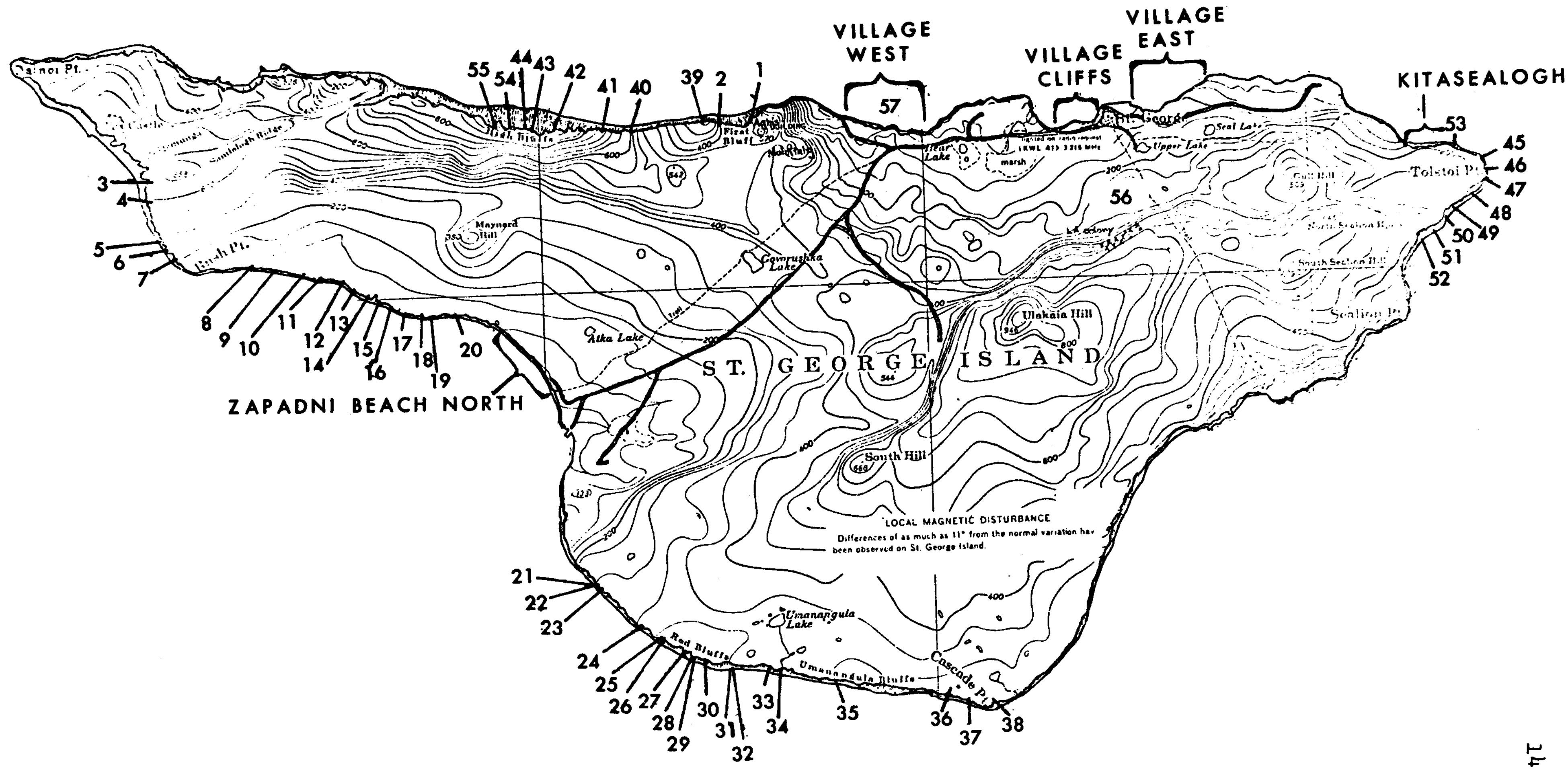
BEACH SECTION	
WEST	
ZAPADNI BEACH CLIFFS	563420N1693958W563448N1694042W

REFERENCE LEDGES	
WEST	
LEDGE 20 ST GEORGE	563452N1694112W
LEDGE 19 ST GEORGE	563452N1694124W
LEDGE 18 ST GEORGE	563452N1694133W
LEDGE 17 ST GEORGE	563454N1694143W
LEDGE 16 ST GEORGE	563457N1694200W
LEDGE 15 ST GEORGE	563458N1694207W
LEDGE 14 ST GEORGE	563502N1694216W
LEDGE 13 ST GEORGE	563504N1694228W
LEDGE 12 ST GEORGE	563507N1694233W
LEDGE 11 ST GEORGE	563510N1694248W
LEDGE 10 ST GEORGE	563510N1694300W
LEDGE 9 ST GEORGE	563512N1694318W
LEDGE 8 ST GEORGE	563514N1694340W
LEDGE 7 ST GEORGE	563520N1694448W
LEDGE 6 ST GEORGE	563524N1694453W
LEDGE 5 ST GEORGE	563526N1694455W
LEDGE 4 ST GEORGE	563546N1694508W
LEDGE 3 ST GEORGE	563552N1694510W

FIG. 1

St. George Id. Study Areas

The small x marks at 56 denote the least auklet quadrat locations studied on Ulakaia Ridge.



stratum 5, 244-308 m high. Only strata 1 and 2 occur on St. Paul. We then established reference ledges in the various strata and permanently recorded them with photographs and/or numbered metal tags; 63 such areas were set up on St. George and 35 on St. Paul (Fig. 2). Because of limited vantage points with views of the cliffs, random locations are an impossibility. We therefore tried to set up reference ledges at every vantage point we encountered where there was a section of nesting cliff that could be defined. Definitions were made by taking polaroid photos in the field which were then marked with permanent ink. These were later transferred to high-quality photos taken at the same time with the Pentax 607 or a 35-mm camera. We placed numbered metal tags at the spot where the observer stood. Coordinates for St. Paul study areas are given in Table 5.

These reference ledges are valuable for providing future indices of population change. A set of photos of these ledges accompanies the data tape. One reference ledge consists of an observation point where least auklet flights can be counted, and one is a vantage point for the entire inland least auklet colony where fixed and random quadrat counts were made.

To provide a random sample of the cliff-nesting population, we located sample points around the island on a set of contact prints of the cliff areas. Random number tables were used; 100 samples were taken in rough proportion to the amount of total cliff area represented by each stratum. Thus stratum 1, 46% of total cliff area, had 46 samples taken; 900-m^2 samples were taken using the random point as the lower left-hand corner. If part of the quadrat was above cliff level or overlapping the line delimiting two strata, the quadrat was moved up or down accordingly. If a quadrat overlapped a cliff top and a stratum line, it was extended to the right until the edge of the photograph was reached and then left. 900-m^2 was estimated using the height (from

FIG. 2

St. Paul Id. Study Areas

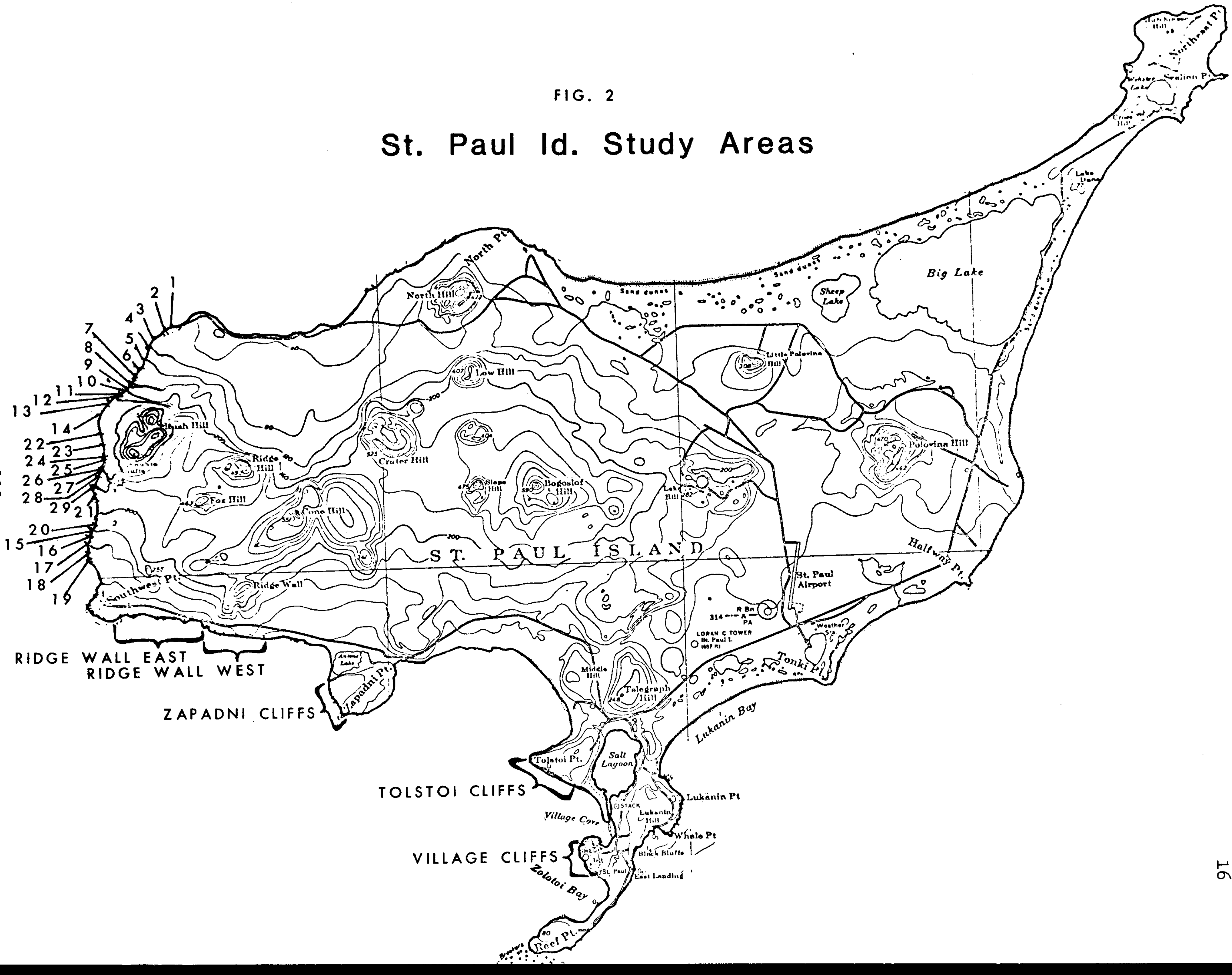


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TABLE 5

St. Paul Id. Study Areas

REFERENCE LEDGES WEST	COORDINATES
LEDGE 1 ST PAUL	571218N1702336W
LEDGE 2 SW ST PAUL	571216N1702344W
LEDGE 3 ST PAUL	571215N1702348W
LEDGE 4 ST PAUL	571209N1702351W
LEDGE 5 NE ST PAUL	571202N1702357W
LEDGE 5 SW ST PAUL	571200N1702358W
LEDGE 6 ST PAUL	571158N1702400W
LEDGE 2 NE ST PAUL	571217N1702342W
LEDGE 7 ST PAUL	571155N1702403W
LEDGE 8 ST PAUL	571115N1702406W
LEDGE 9 ST PAUL	571147N1702412W
LEDGE 10 ST PAUL	571146N1702413W
LEDGE 11 ST PAUL	571143N1702422W
LEDGE 12 ST PAUL	571142N1702427W
LEDGE 13 ST PAUL	571136N1702436W
LEDGE 14 ST PAUL	571129N1702445W
LEDGE 15 ST PAUL	571027N1702451W
LEDGE 16 ST PAUL	571023N1702454W
LEDGE 17 ST PAUL	571018N1702457W
LEDGE 18 ST PAUL	571015N1702457W
LEDGE 19 ST PAUL	571013N1702457W
LEDGE 20 ST PAUL	571029N1702450W
LEDGE 21 ST PAUL	571043N1702448W
LEDGE 22 ST PAUL	571121N1702443W
LEDGE 23 ST PAUL	571114N1702442W
LEDGE 24 ST PAUL	571108N1702441W
LEDGE 25 ST PAUL	571106N1702441W
LEDGE 26 ST PAUL	571103N1702442W
LEDGE 27 ST PAUL	571102N1702442W
LEDGE 28 ST PAUL	571057N1702445W
LEDGE 29 ST PAUL	571051N1702450W

BEACH SECTIONS

SOUTHWEST AND SOUTH

RIDGE WALL CLIFFS WEST END ST PAUL	570939N1702430W570932N1702306W
RIDGE WALL CLIFFS EAST END ST PAUL	570932N1702306W570923N1702206W
ZAPADNI CLIFFS ST PAUL	570900N1702100W570842N1702043W
TOLSTOI CLIFFS ST PAUL	570815N1701744W570800N1701654W
VILLAGE CLIFFS ST PAUL	570726N1701650W570709N1701636W

maps) of vertical cliffs as a reference. Photographic roll numbers on St. George Id. are given in Figs. 3-7. In counting birds, 11-in. by 14-in. enlargements were used.

Burrow- and crevice-nesting species.--A sampling scheme for censusing talus nesters has been worked out on St. Lawrence Island by Bédard (1969) whose technique was to lay out quadrats 14.2 by 14.2 m, the observer stationing himself 40 or more meters away between 5 and 8 AM during the few days preceding laying (and coinciding with minimum daily attendance of immature birds in the colony and maximum activity of breeding birds on the surface of the slope). This involves making tallies every 30 minutes during the 3-hr. period on three successive days. This procedure further involves (1) ignoring the highest count in each series in order to correct for abnormal values resulting from disturbance and (2) averaging the 2nd-, 3rd-, and 4th-highest census figures for each quadrat.

We employed a modification of this technique in 1976 with the inland least auklet colony on Ulakaia Ridge. We set up a grid system on the hillside 1100 m by 100 m, and laid out three 10-m^2 quadrats at the 175-, 450-, and 750-m points. These were counted every 30 minutes for two all-day counts, and one count at peak attendance from 1030 to 1500 local time. We averaged the 2nd-, 3rd-, and 4th-highest figures for each quadrat.

We also used the grid system as a reference to estimate 10-m^2 areas in the telescope field, and took four series of random 10-m^2 quadrats by locating a random point on 15X and zooming down to around 60X to count the area. These were done at times of peak attendance on the colony surface, between the 200- and 900-m grid points. Because both fixed- and random-quadrat counts required perfectly clear weather, a few false starts resulted. We had extremely good fortune with the weather, however, on the days we chose.

FIG. 3

ROLL NUMBERS OF PHOTOS TAKEN 7 JULY 1976 1315 - 1528 LOCAL TIME

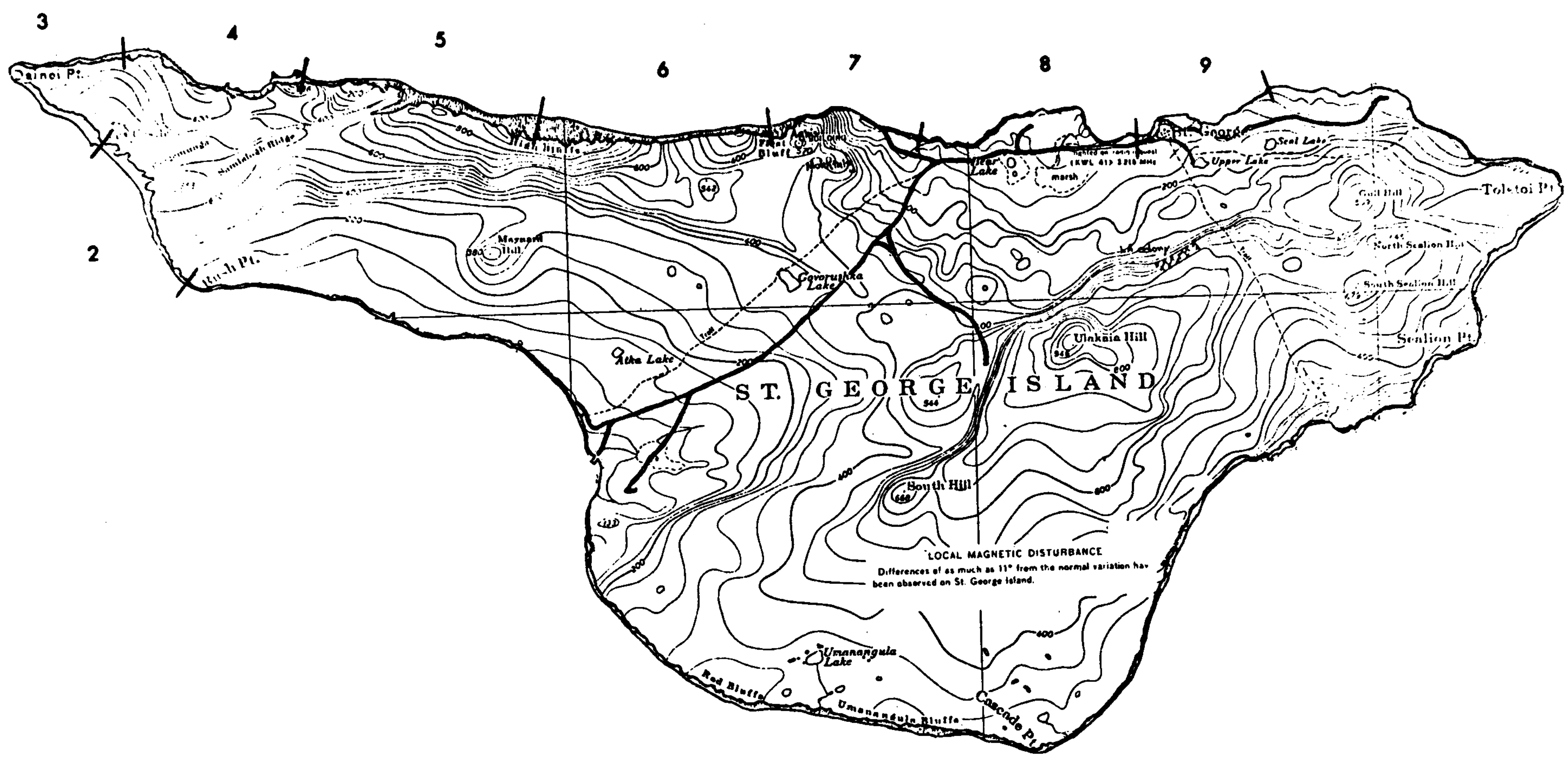


FIG. 4

ROLL NUMBERS OF PHOTOS TAKEN 15 JULY 1976 1430 - 1845 LOCAL TIME

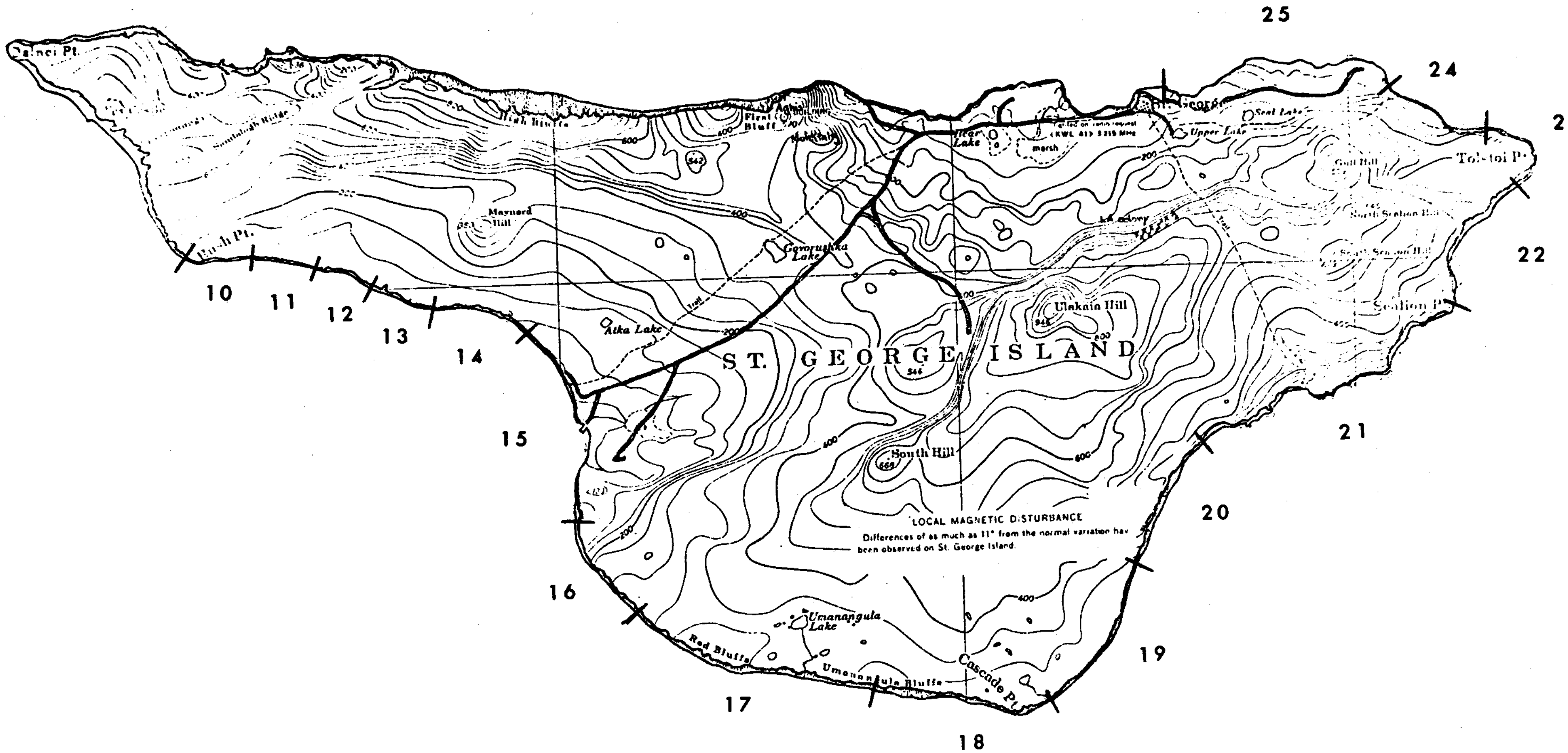


FIG. 5

ROLL NUMBERS OF PHOTOS TAKEN 29 JULY 1976 1230 - 1850 LOCAL TIME

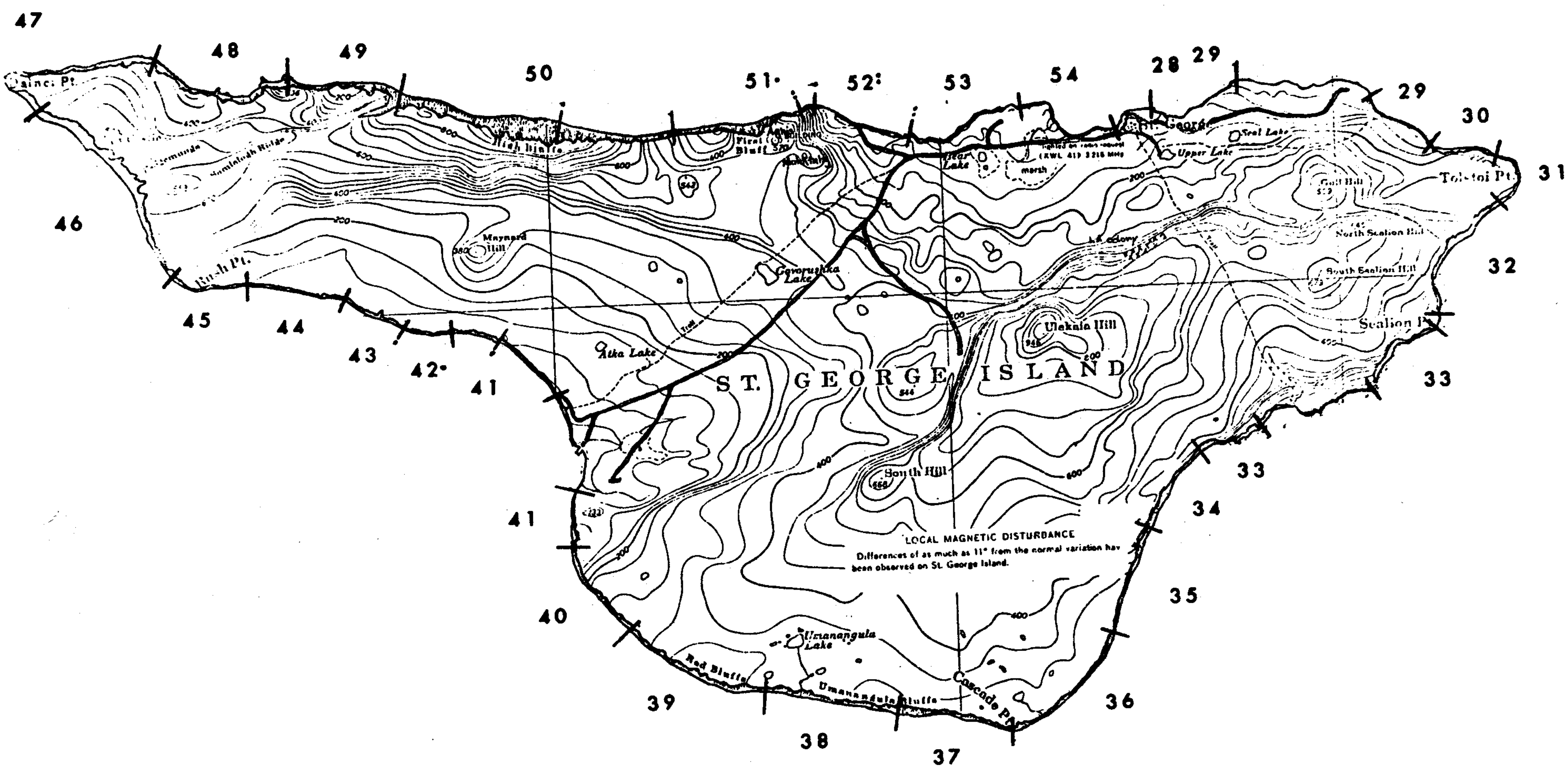


FIG. 6

ROLL NUMBERS OF PHOTOS TAKEN 5 AUG. 1976 1015 - 1100 LOCAL TIME

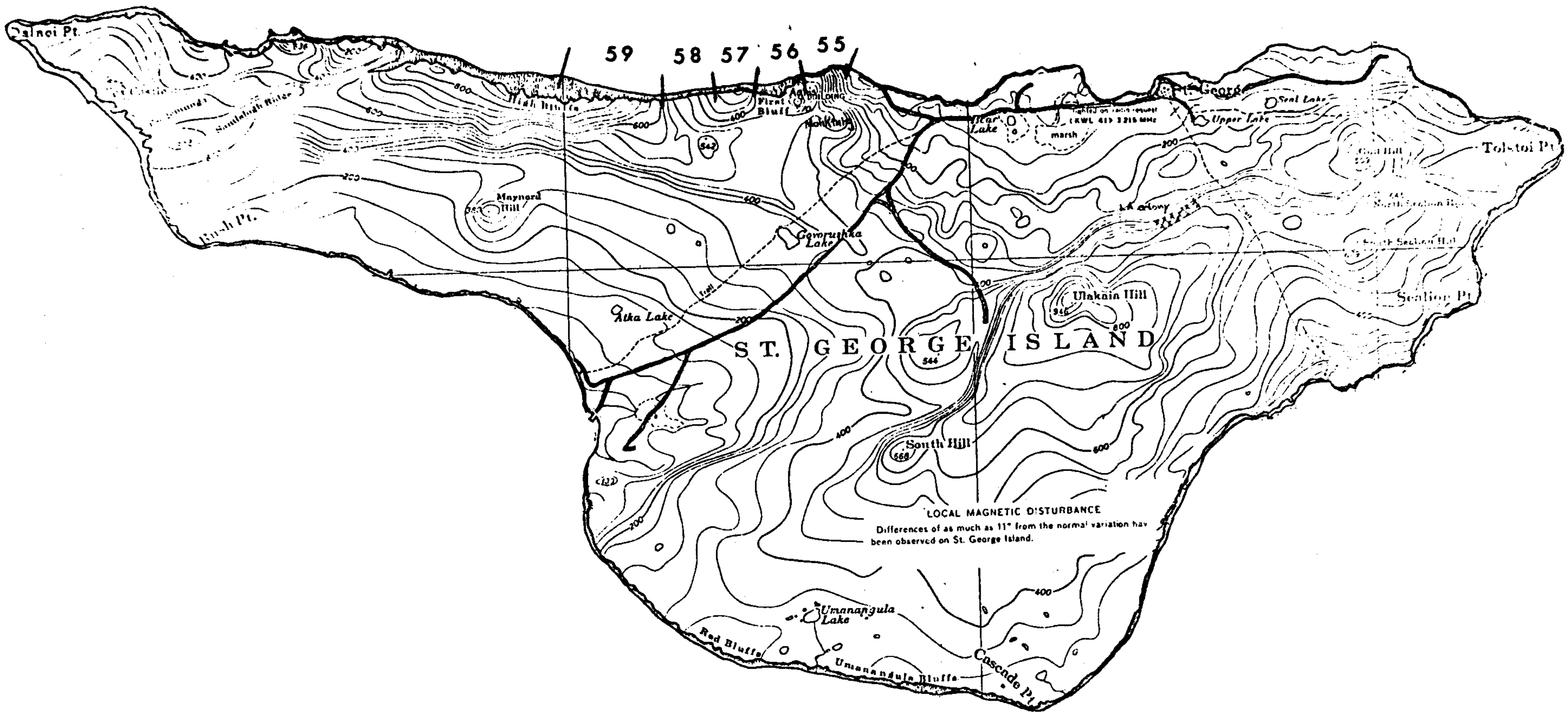
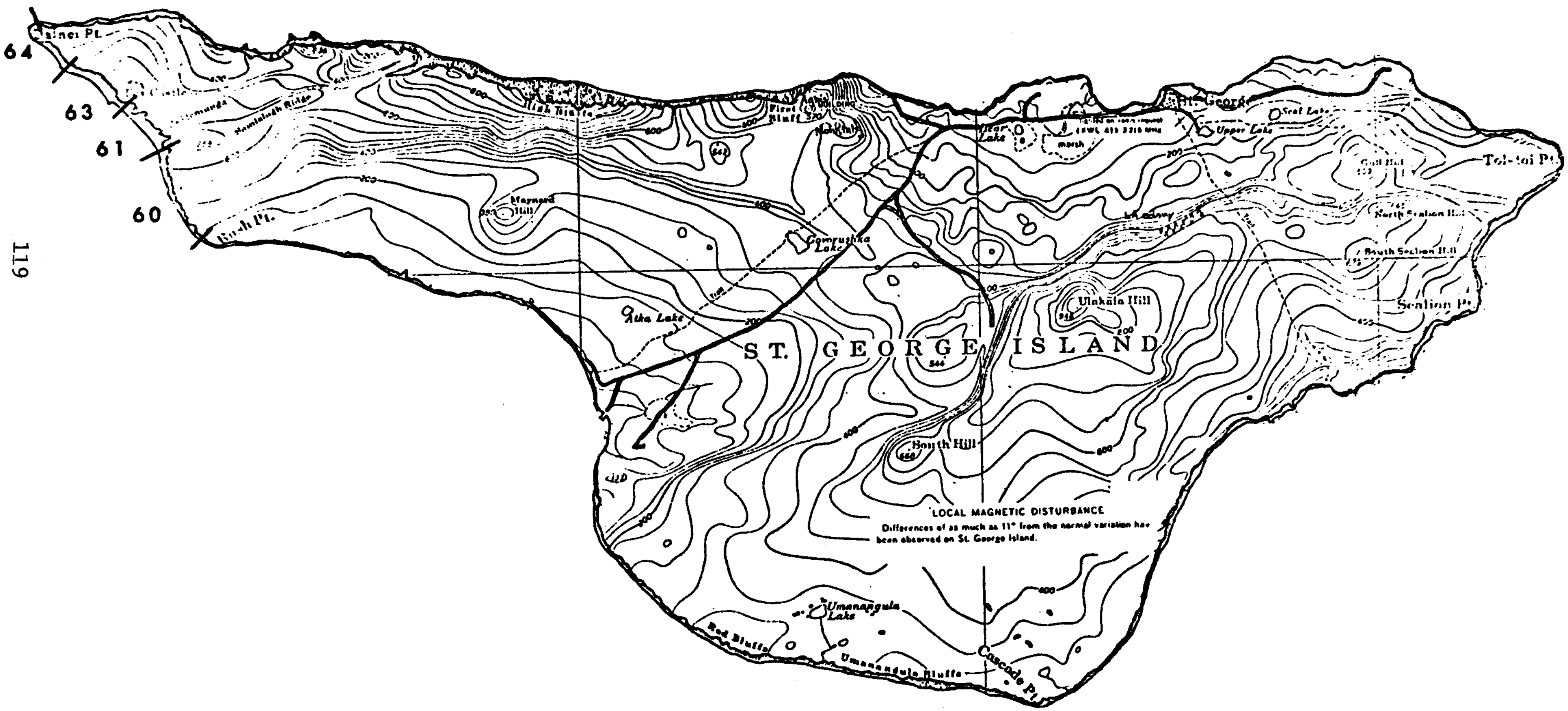


FIG. 7

ROLL NUMBERS OF PHOTOS TAKEN 6 AUG. 1976 1915 - 1950 LOCAL TIME



All the least auklets flying in to the colony can be observed as they pass over the road and airstrip west of the village. Seven 24-hour counts were made during the season by counting every other 10 minutes.

Birds were estimated in groups of 10 or in groups of 100 when larger numbers passed. A similar all-day-count was made from the inland vantage point of birds leaving the colony.

Two large colonies of crested, parakeet, and least auklets were located in talus slopes at the base of cliffs at the Northwestern end of the island. Because landing by boat was extremely difficult and time and weather limiting, we photographed these in color with the Pentax 607 and made counts from the photos.

Approximations of the numbers of burrow- and crevice-nesters on the cliff faces were made using the species proportions we obtained from our reference ledges. Only those counts made at times of the day when auklets should have been in attendance are valid, although this greatly reduces the sample size on St. George. On St. Paul, all reference counts were made at times when auklets were in attendance.

RESULTS

In 1975 a 3-man party consisting of J. J. Hickey, F. L. Craighead, and R. C. Squibb reached St. George Island on 21 June. Fifteen reference cliffs were set up, all-day flight counts were carried out of least auklets (flying west of the village into their colony On Ulakaia Ridge) and murres (flying east to west off Staraya Artel), and an aerial survey of the cliffs that resulted in 306 positive prints was carried out on 1 August by J. G. Bartonek of the U.S. Fish and Wildlife Service. Hickey left St. George on 14 July, Craighead on 8 August, and Squibb on 13 August. Frequent almost daily fogs were found to preclude the possibility of planning satisfactory aerial surveys of the ledge-nesting species, and plans were therefore inaugurated to photograph the cliffs from a boat in 1976.

In 1976 the field season began on St. George when Craighead arrived on 5 May. At this time the island was about 80% snow covered, with cornices and ice clinging to the North and West-facing cliffs.

The prevailing winter winds had piled drifts on the Western, lee, side of the island from Zapadni Bay NW to Dalnoi Point. In early May, both red- and black-legged kittiwakes, common murres, fulmars, cormorants, and least auklets were seen. Thick-billed murres were first seen on cliffs on 10 May (on North slopes, 17 May). Horned and tufted puffins were first seen on 18 May. Parakeet and crested auklets were not seen until 25 May, but we assume they arrived at roughly the same time as least auklets. They were seen offshore on 20 May. According to St. George Aleuts, it was an unusually late spring. The pack ice left in the last days of April, and the final thaw was about 27 May. There were still large patches of snow on the least auklet colony at Ulakaia Ridge well after egg-laying. Snowdrifts persisted throughout the summer on the Western side of the island.

Ron Squibb and John Cary arrived on 2 June, and the field work began in earnest. Three study ledges were selected on different parts of the island where the major species (thick-billed and common murres, red- and black-legged kittiwakes, and fulmars) were represeented. We tried to do daily ledge-attendance counts at one of these areas every other day. A flight count of least auklets and a quadrat count were done on days after a circuit of ledges had been completed. The weather was exceptionally good during June, and we managed to do an all-day count at each of these sites every 10 days to two weeks. We divided these counts into 3 shifts with a different man taking the early shift each time. Besides giving everyone an equal chance for the easy counts, this should have dampened any effects of individual bias. In between days of attendance counts we gridded the hillside at Ulakaia, visited reference ledges, coded and consolidated data, and otherwise waited for calm seas and a clear day to photograph the cliffs.

Cary left St. George on 16 July with the first full set of cliff photographs. On the same day, Squibb and Craighead flew to St. Paul to try to photograph the cliffs there using George Hunt's Zodiac. Unfortunately, the weather turned bad and remained bad--rough seas and fog--until 22 July when we returned to St. George. We were able to establish counts of 35 reference ledges on St. Paul which we permanently recorded as on St. George.

We continued daily ledge attendance counts and flight counts on St. George on a reduced scale with only two men, and again photographed the cliffs on a near-perfect day. The majority of St. George reference ledges were set up at this time. Craighead left on 11 August and Squibb left on 18 August.

Photographic Sample Counts

Murres, kittiwakes, and light-phase fulmars were counted from photographs with the results seen in Tables 6 and 7.

Daily Attendance

Daily attendance counts were made regularly at three sites: ledge 57 (Rosy Finch Cove), ledge 53 (Pinnacle Point) and ledges 21, 22, 23 (Murie Cove). Counts were made of birds present on a given cliff area every 30 minutes from first light until dark whenever possible. Attendance counts of shorter periods were made at ledges 1, 2, and 25. Counts were also made of least auklets on the surface of the colony in 3 fixed 100-m^2 quadrats at site 56 (Ulakaia Ridge), and of least auklets flying into and from the colony.

TABLE 6

St. George Island
1976

Numbers of Birds Counted in 900m^2 Random
Quadrats Sampled from Photographs

Stratum 1				Stratum 2			
Sample No.	Murres	Kittiwakes	Fulmars	Sample No.	Murres	Kittiwakes	Fulmars
26	98	91	0	23	339	68	42
18	94	99	51	25	670	115	18
16	22	10	0	19	11	32	0
15	408	17	7	11	0	0	0
14	47	4	0	6	7	18	0
13	0	0	0	5	445[a]	238[a]	42[a]
12	26	4	5	90	113	73	9
10	206[a]	113[a]	55[a]	92	121	16	0
8	0	21	0	85	35	6	66
7	251	48	2	28	77	56	60
4	59[a]	5[a]	1[a]	29	795	37	93
2	72	0	0	32	156	87	0
1	386[a]	1[a]	56[a]	33	135	8	4
38	103	35	86	36	48	3	0
80	107	28	67	37	235	11	2
95	237	17	22	43	1,187	178	41
93	33	9	0	45	892	215	58
87	0	4	0	48	313	9	3
71	46	11	73	49	488	11	23
56	56	68	5	51	176	33	1
30	251	4	50	54	537	49	37
31	305	71	55	59	0	0	0
34	24	28	0	62	67	14	8
35	226	72	11	68	420	95	37
40	188	35	19	69	208	51	3
41	0	0	0	73	247	90	17
47	341	64	2	96	0	5	0
20	0	0	0	101	353	23	48
50	457	35	13	98	424	32	0
52	156	21	27	39	32	5	25
53	318	2	25	27	135	49	1
55	177	8	21	9	297	157	25
57	45	4	0				
58	106	18	33				
61	238	38	129				
65	144	53	58				
64	387	44	23				
66	192	44	39				
67	5	35	0				
75	68	32	26				
81	254	59	0				
82	106	16	0				
99	280	114	49				
100	396	57	14				
42	0	0	0				
102	0	0	0				

(Table continued on next page)

TABLE 6 (con't.)

St. George Island
1976

Numbers of Birds Counted in 900m² Random Quadrats Sampled from Photographs (continued)

Stratum 3				Stratum 4				Stratum 5			
Sample No.	Murres	Kittiwakes	Fulmars	Sample No.	Murres	Kittiwakes	Fulmars	Sample No.	Murres	Kittiwakes	Fulmars
24	0	12	0	17	0	0	0	22	64	250	0
3	726	118	66	94	17	88	0	84	85	537	0
83	768	21	184	91	92	81	0	17	17	785	0
72	149	158	72	21	21[a]	339[a]	2[a]	78	25	466	2
76	184	49	124	74	133	220	0				
88	152	0	212	77	20	176	0				
89	221	163	0								
44	359	182	0								
46	91	91	12								
60	457	130	8								
63	162	18	1								
79	10	33	0								
70	112	70	0								
97	242	37	10								

$$\frac{91{,}800\text{m}^2 \text{ sampled}}{3{,}537{,}550\text{m}^2 \text{ total area}} = 2.5\% \text{ of total cliff area sampled}$$

a/ The figure cited is a mean of two counts by different observers.

Table 7

St. George Island 1976

Mean Number of Birds per 900m^2 Photo Quadrat

	Stratum 1			Stratum 2			Stratum 3			Stratum 4			Stratum 5		
	Murres	Kitti-wakes	Fulmars	Murres	Kitti-wakes	Fulmars	Murres	Kitti-wakes	Fulmars	Murres	Kitti-wakes	Fulmars	Murres	Kitti-wakes	Fulmars
mean	150.32	31.20	22.26	280.09	55.75	20.72	259.5	77.28	49.21	47.16	150.66	.3	47.75	509.5	.5
standard deviation	134.51	31.60	29.12	288.22	63.35	24.79	239.48	62.52	73.44	52.79	120.33	.82	32.22	220.5	1
standard error of mean	19.8	4.65	4.29	50.95	11.20	4.38	64.00	16.71	19.63	21.55	49.13	.3	16.11	110.26	.5
number of sample counts	46			32			14			6			4		
$s_{\bar{x}}$ as % of $\bar{x}$	13.17	14.90	19.27	18.19	20.08	21.14	24.66	21.62	39.89	45.70	32.61	--	33.74	21.64	--

Thick-billed Murres.--Thirteen all-day attendance counts and three shorter counts were made of thick-billed murres. Twelve all-day counts can be grouped in 4 clusters (Figs. 8-11) representing before egg-laying, egg-laying, incubation, and hatching periods. We ran correlation matrices of these curves (1) between each successive curve at a given site to demonstrate seasonal variation in ledge attendance and (2) between the three sites in a given cluster to demonstrate congruency of the curves or synchrony of behavior. The matrices between successive curves at a given site are shown in Table 8.

Only two ledges, 21 and 22, were used for calculating correlation coefficients at Murie Cove throughout the season. A third ledge, 23, was included in the count on 25 June and is included in the graphs.

The matrices among all three sites at a given time in the breeding season are shown in Table 9.

Common Murre.--Four all-day attendance counts and 3 counts over shorter periods were made on common murres. An example of curve produced is included (Fig. 12).

Red-legged Kittiwake.-- Five all-day counts, and 1 count over a shorter period were made of red-legged kittiwakes. An example of a curve produced is included (Fig. 13). Earlier in the breeding season these curves were flatter with less fluctuation in numbers present. During the times we photographed the cliffs, red-legged kittiwake numbers remained fairly constant at maximum levels.

Black-legged Kittiwake.--Six all-day attendance counts, and 1 count over a shorter period were made of black-legged kittiwakes. An example of a

FIG. 8

15 JUNE TO 19 JUNE, THICK-BILLED MURRE ATTENDANCE BEFORE EGG-LAYING

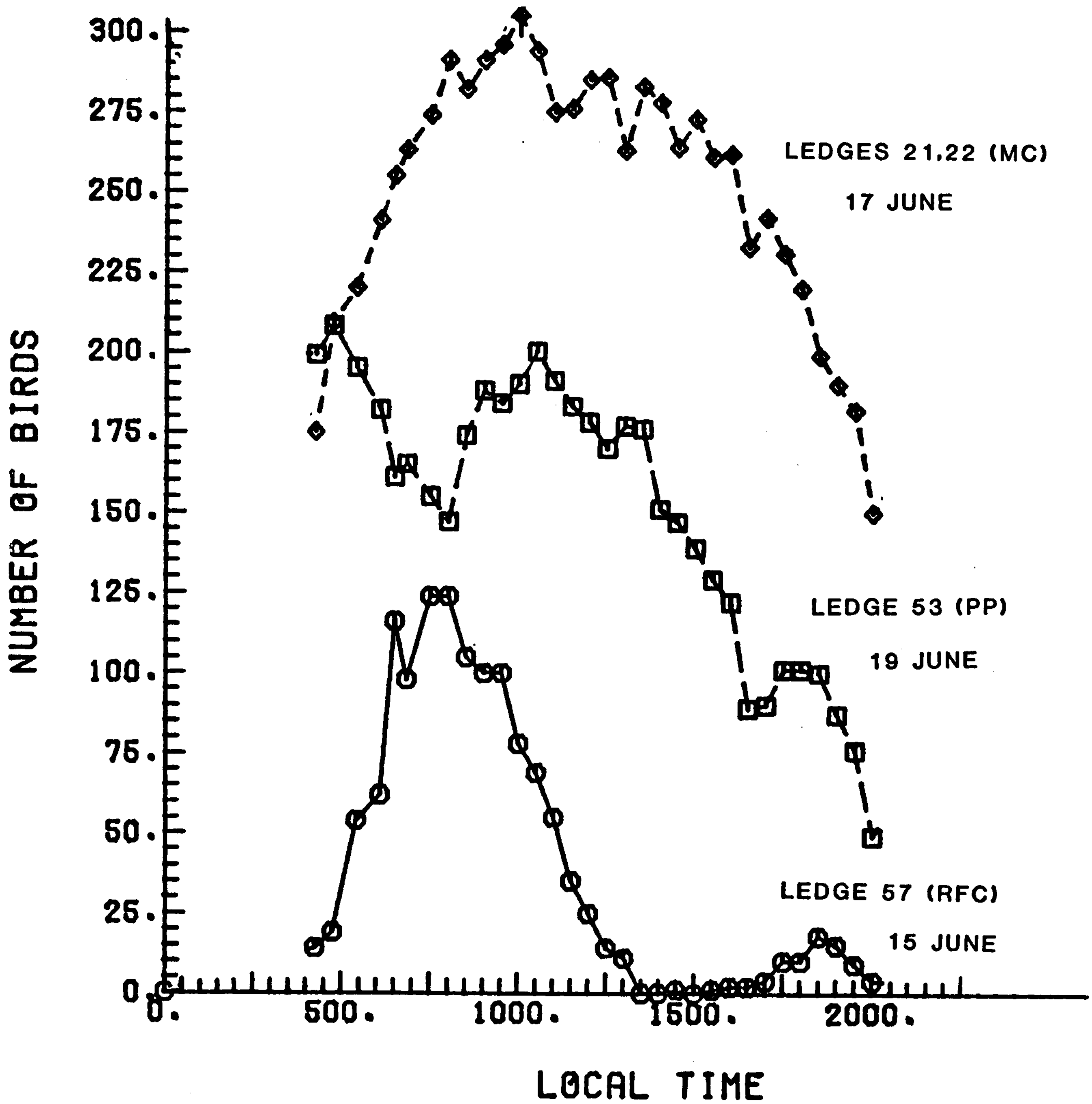


FIG. 9

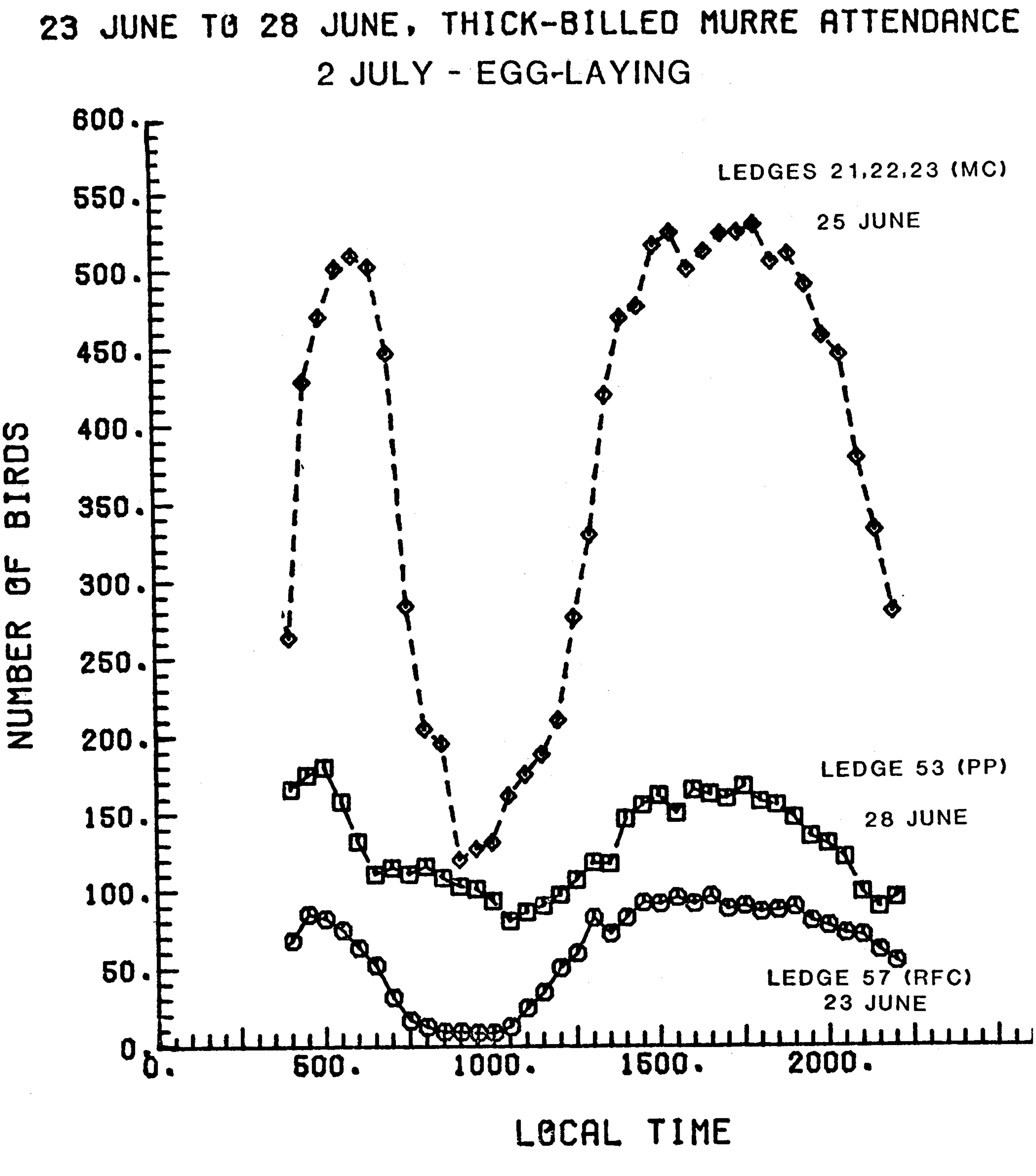

23 JUNE TO 28 JUNE, THICK-BILLED MURRE ATTENDANCE
2 JULY - EGG-LAYING
NUMBER OF BIRDS
0
50.
100.
150.
200.
250.
300.
350.
400.
450.
500.
550.
600.
0.
500.
1000.
1500.
2000.
LOCAL TIME
LEDGES 21,22,23 (MC)
25 JUNE
LEDGE 53 (PP)
28 JUNE
LEDGE 57 (RFC)
23 JUNE

FIG. 10

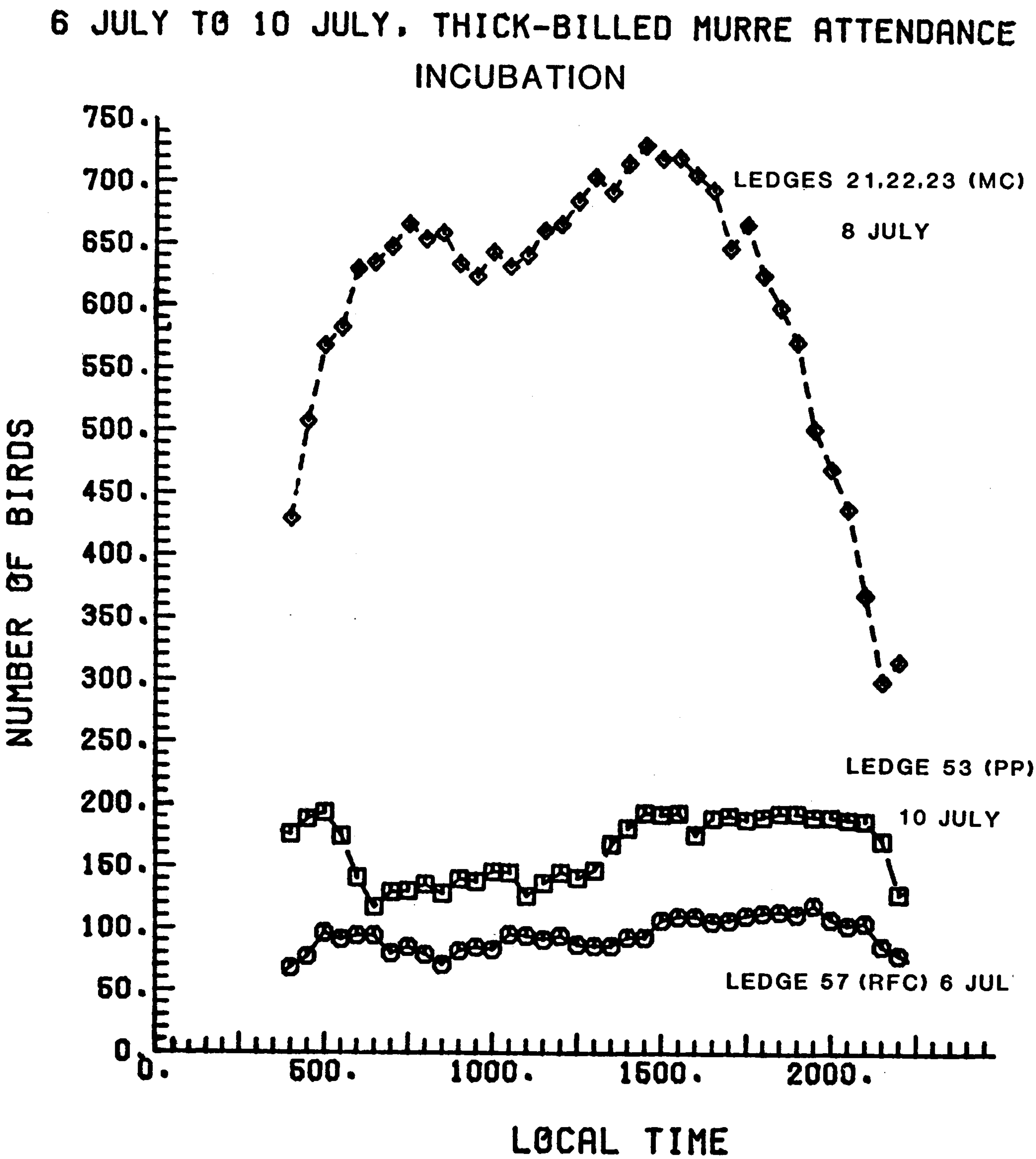

6 JULY TO 10 JULY, THICK-BILLED MURRE ATTENDANCE
INCUBATION
NUMBER OF BIRDS
LOCAL TIME
LEDGES 21,22,23 (MC)
8 JULY
LEDGE 53 (PP)
10 JULY
LEDGE 57 (RFC) 6 JUL
750.
700.
650.
600.
550.
500.
450.
400.
350.
300.
250.
200.
150.
100.
50.
0
0.
500.
1000.
1500.
2000.

FIG. 11

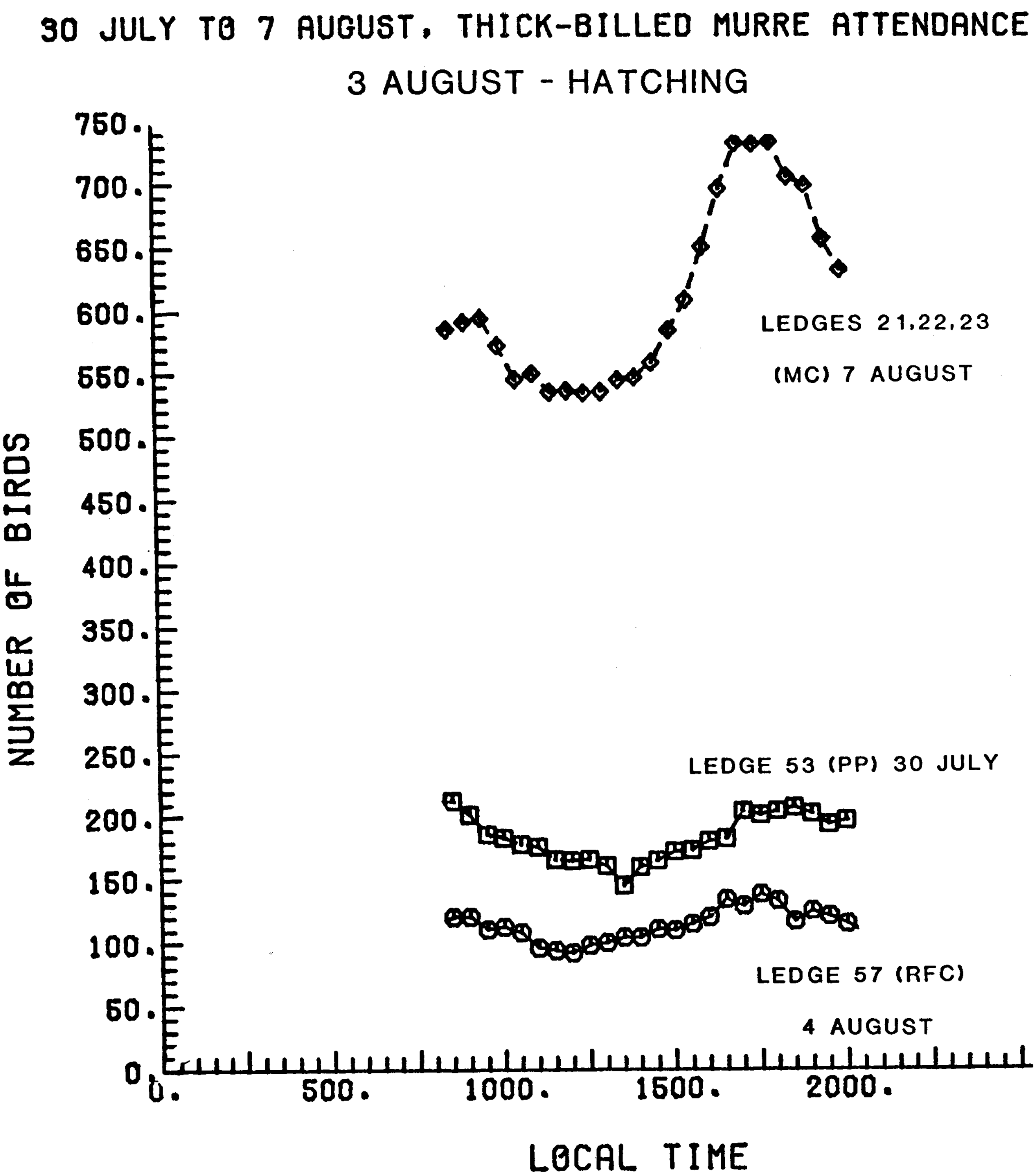

30 JULY TO 7 AUGUST, THICK-BILLED MURRE ATTENDANCE
3 AUGUST - HATCHING
NUMBER OF BIRDS
LOCAL TIME
LEDGES 21,22,23
(MC) 7 AUGUST
LEDGE 53 (PP) 30 JULY
LEDGE 57 (RFC)
4 AUGUST
750.
700.
650.
600.
550.
500.
450.
400.
350.
300.
250.
200.
150.
100.
50.
0
0.
500.
1000.
1500.
2000.

TABLE 8. SEASONAL VARIATION CORRELATIONS
Thick-billed Murres

Site Date	Ledge 57--Rosy Finch Cove (RFC) 1 RFC 615	2 RFC 623	3 RFC 706	4 RFC 804
1. RFC 615	1.000			
2. RFC 623	-.937	1.000		
3. RFC 706	-.662	.732	1.000	
4. RFC 804	-.093	.349	.498	1.000

No. of observations - 24

Site Date	Ledge 56--Pinnacle Point (PP) 1 PP 619	2 PP 628	3 PP 710	4 PP 730
1. PP 619	1.000			
2. PP 628	-.769	1.000		
3. PP 710	-.843	.898	1.000	
4. PP 730	-.487	.246	.189	1.000

No. of observations - 24

Site Date	Ledges 21,22--Murie Cove (MC) 1 MC 617	2 MC 625	3 MC 708	4 MC 807
1. MC 617	1.000			
2. MC 625	-.693	1.000		
3. MC 708	.805	-.211	1.000	
4. MC 807	-.563	.539	-.407	1.000

No. of observations - 24

TABLE 9. ISLAND-WIDE SYNCHRONY CORRELATIONS
Thick-billed Murres

15 to 19 June (Number of observations—32)

	1 RFC	2 MC	3 PP
1. RFC	1.000		
2. MC	.397	1.000	
3. PP	-.120	.440	1.000

23 to 28 June (Number of observations—32)

	1 RFC	2 MC	3 PP
1. RFC	1.000		
2. MC	.863	1.000	
3. PP	.765	.752	1.000

6 to 10 July (Number of observations— 37)

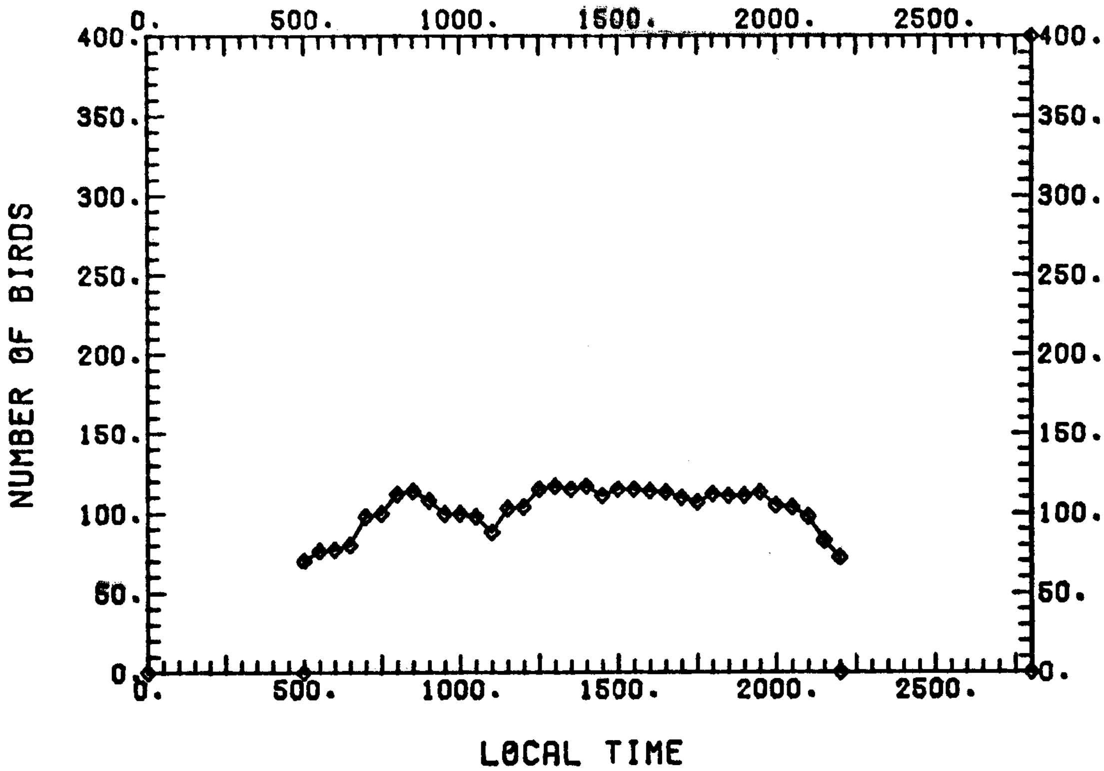
	1 RFC	2 MC	3 PP
1. RFC	1.000		
2. MC	.097	1.000	
3. PP	.640	-.132	1.000

30 July to 7 August (Number of observations— 37)

	1 RFC	2 MC	3 PP
1. RFC	1.000		
2. MC	.889	1.000	
3. PP	.736	.738	1.000

FIG. 12

4 AUGUST, COMMON MURRE ATTENDANCE, ROSY FINCH COVE 1976



curve produced is included (Fig. 14). During the times we photographed the cliffs, black-legged kittiwake numbers remained fairly constant at maximum levels.

Fulmar.-- Seven all-day attendance counts and two counts over shorter periods were made for fulmars. An example of a curve produced is included (Fig. 15). Earlier in the breeding season these curves were flatter. During the times we photographed the cliffs, fulmar numbers remained fairly constant at maximum levels.

Red-faced Cormorant.--Five all-day attendance counts were made for red-faced cormorants. An example of a curve produced is included (Fig. 16).

FIG. 13

30 JULY, RED-LEGGED KITTIWAKE ATTENDANCE, PINNACLE POINT 1976

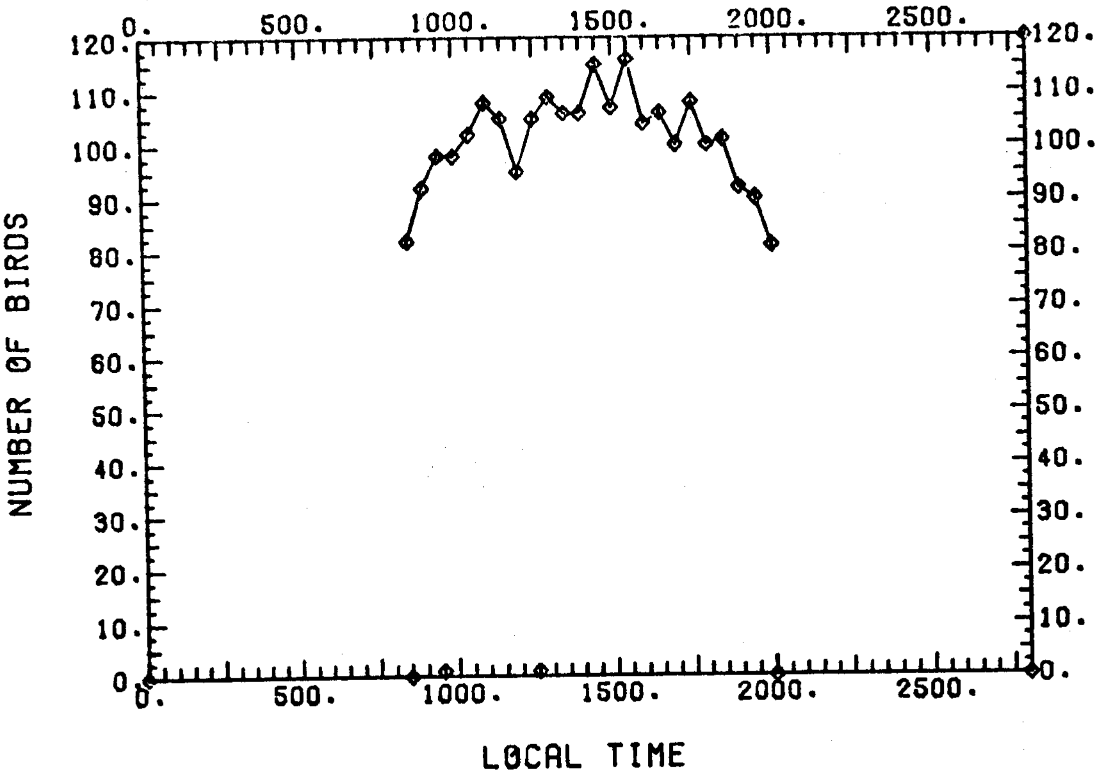


FIG. 14

30 JULY, BLACK-LEGGED KITTIWAKE ATTENDANCE, PINNACLE POINT 1976

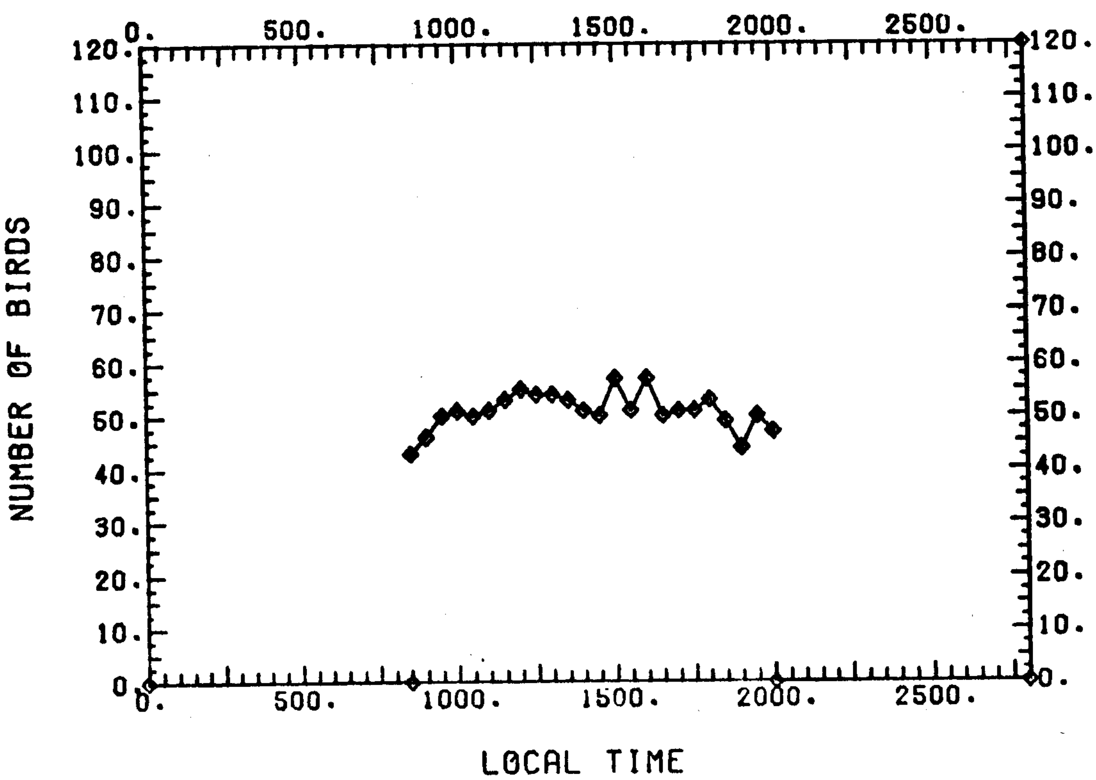


FIG. 15

7 AUGUST, FULMAR ATTENDANCE, MURIE COVE 'FULMAR' 1976

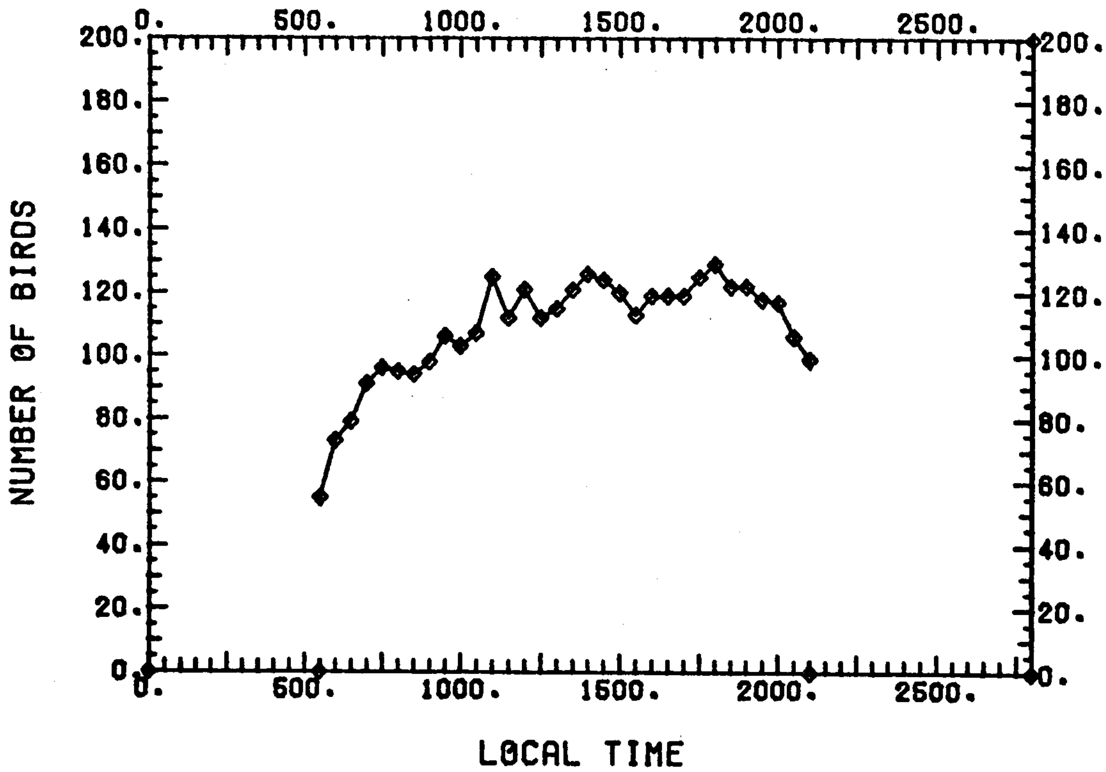
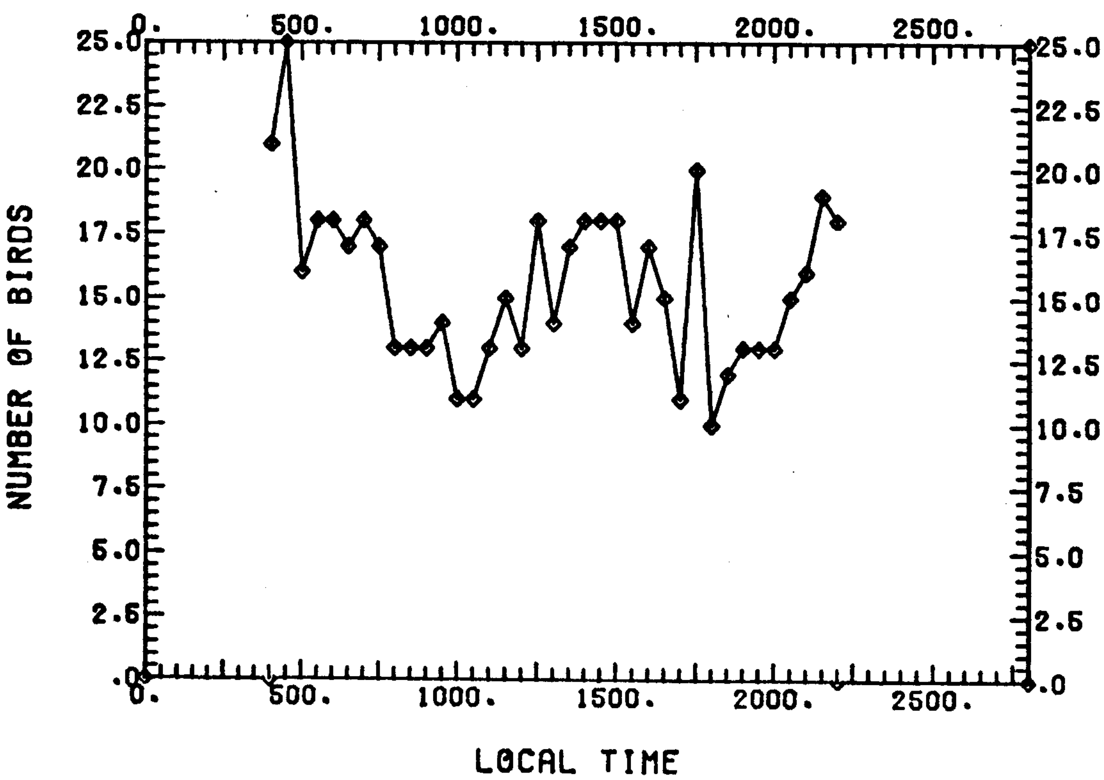


FIG. 16

28 JUNE, RED-FACED CORMORANT ATTENDANCE, PINNACLE POINT 1976



Parakeet Auklet.--Nine all-day attendance counts and one count over a shorter period of time were made of parakeet auklets. An example of a curve produced is included (Fig. 17).

Crested Auklet.--One attendance count for part of a day was made of crested auklets. This curve is included (Fig. 18).

Least Auklet.--Seven 24-hr. flight counts were made throughout the season of least auklets flying inland to the Ulakaia Ridge Colony. One count of birds flying seaward was made. Examples of these curves are included (Figs. 19-22). Three all-day fixed quadrat counts and two counts over a shorter time were made on the surface of the Ulakaia colony. Four counts of random quadrats on the colony surface were made.

Horned Puffin.--Three all-day attendance counts and one count over a shorter period were made of horned puffins. The curve produced by the shorter period count is included (Fig. 23).

Tufted Puffin.--One count during part of a day was made of tufted puffins. The curve produced is included (Fig. 24).

FIG. 17

4 AUGUST, PARAKEET AUKLET ATTENDANCE, ROSY FINCH COVE 1976

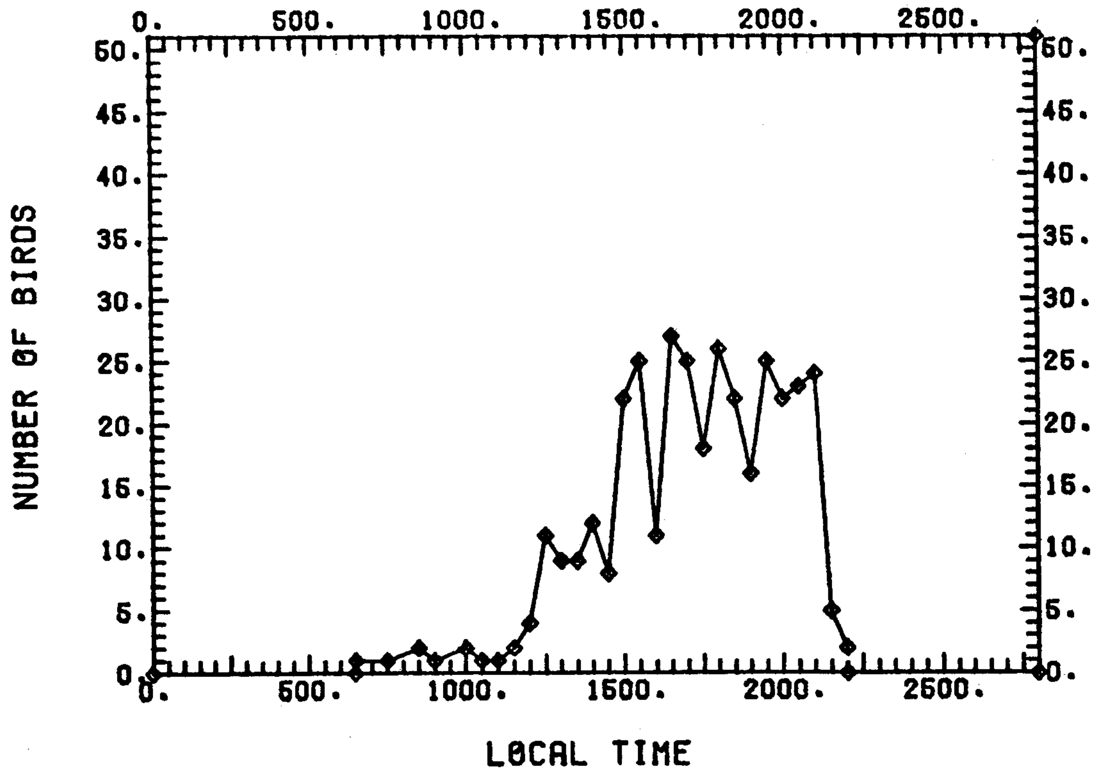


FIG. 18

23 JULY, CRESTED AUKLET ATTENDANCE, LEDGE 25 1976

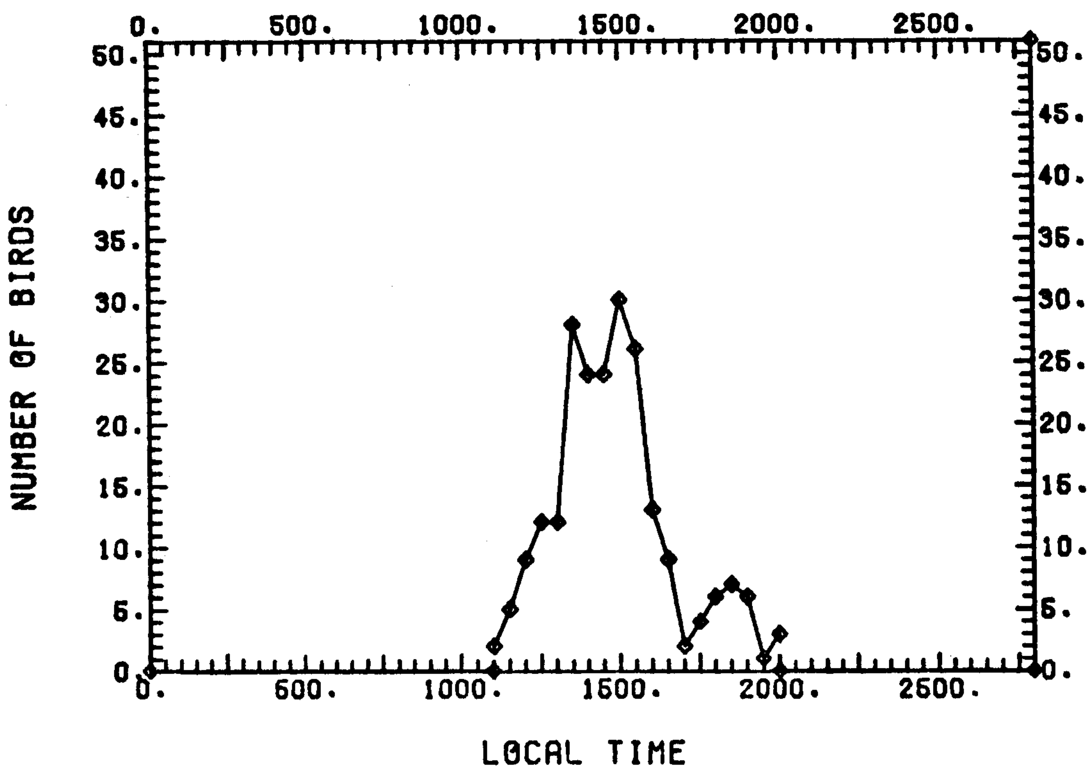


FIG. 19

1976

13 JUNE, LEAST AUKLET FLIGHT COUNT FROM SEA TO COLONY

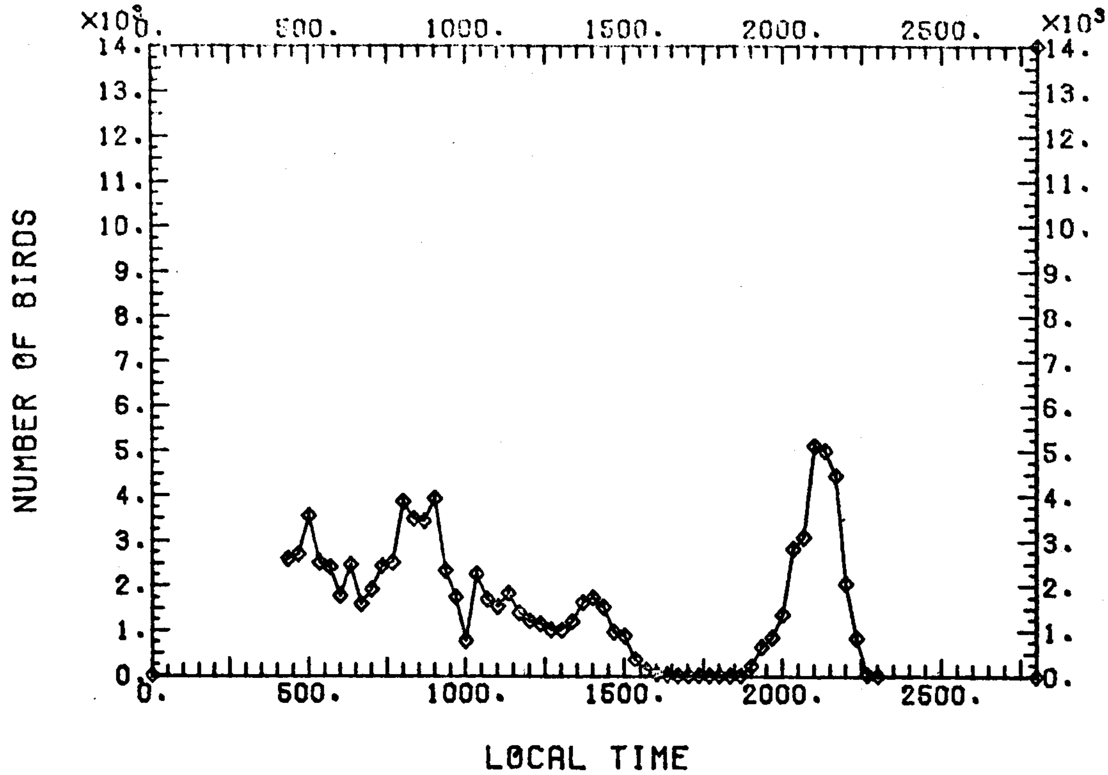


FIG. 20

1 JULY(LATE PM), 2 JULY, LEAST AUKLET FLIGHT COUNT FROM SEA

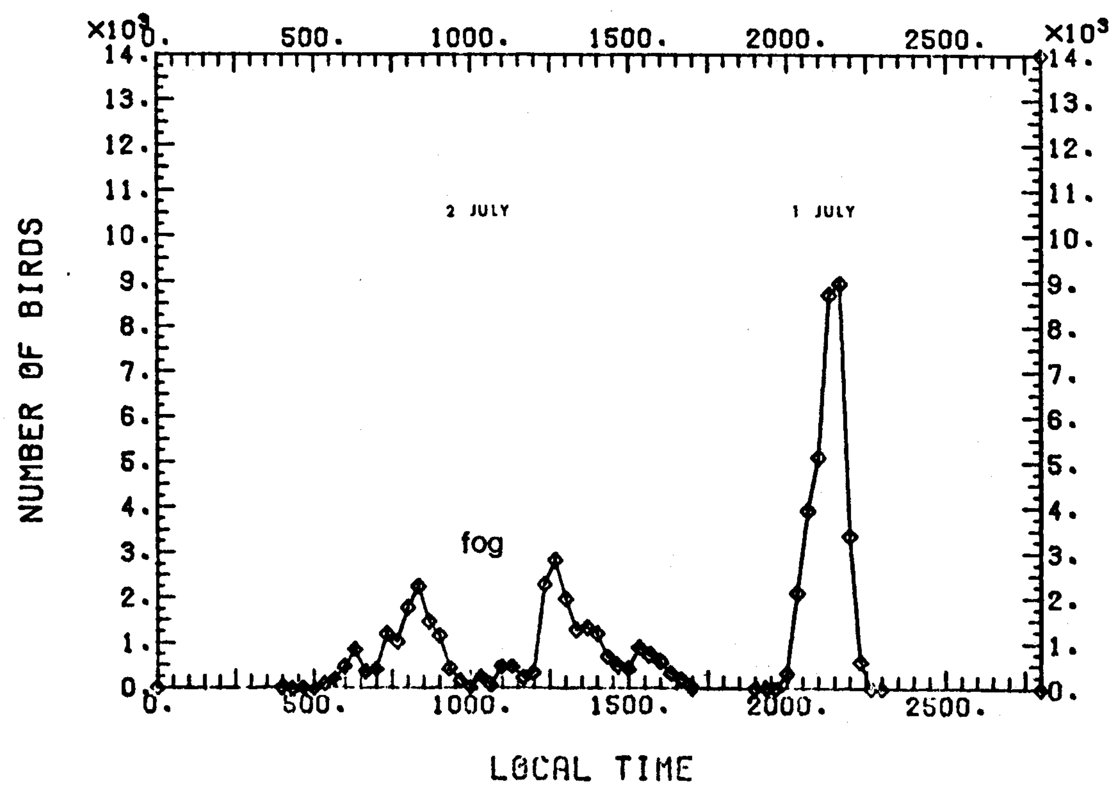


FIG. 21

1976

5 JULY, LEAST AUKLET FLIGHT COUNT FROM SEA TO COLONY

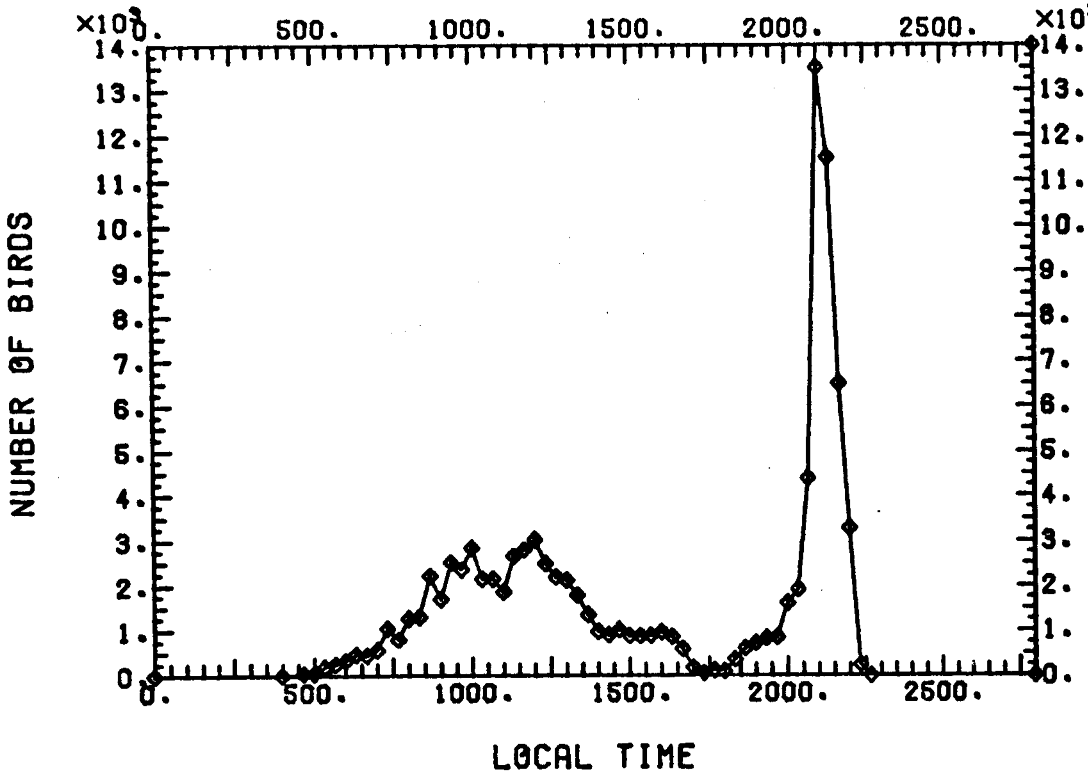


FIG. 22

1 JULY, LEAST AUKLET FLIGHT COUNT FROM COLONY TO SEA

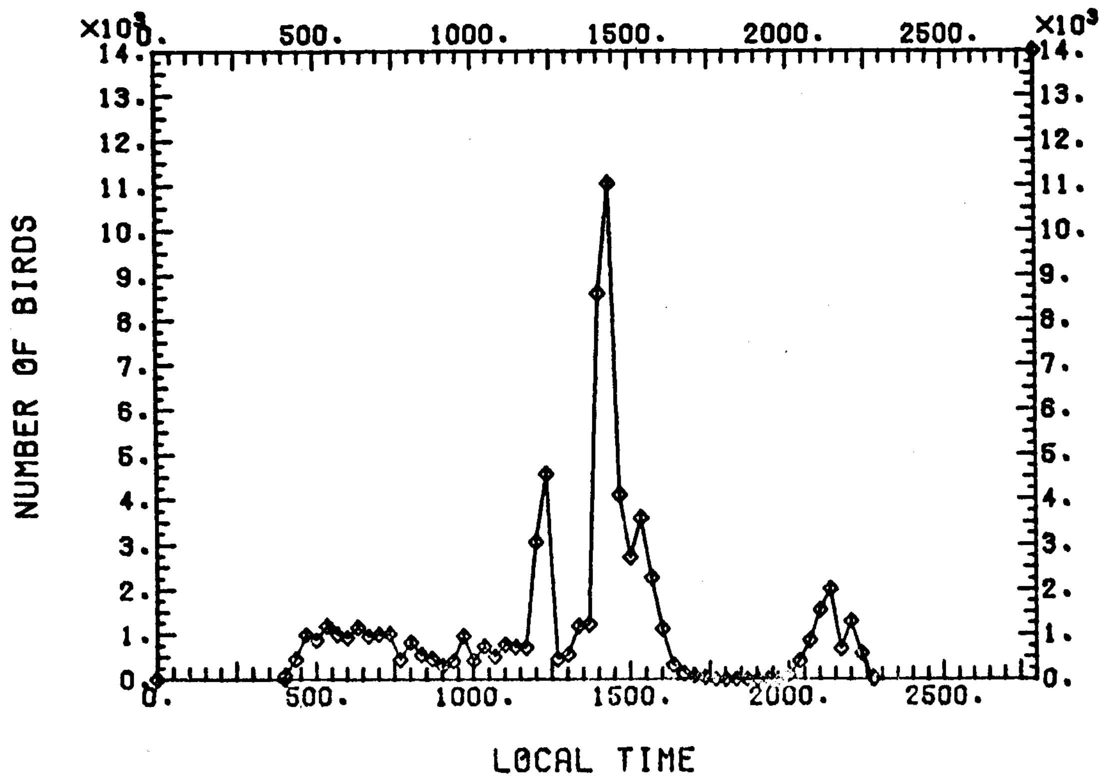


FIG. 23

23 JULY, HORNED PUFFIN ATTENDANCE, LEDGE 25 1976

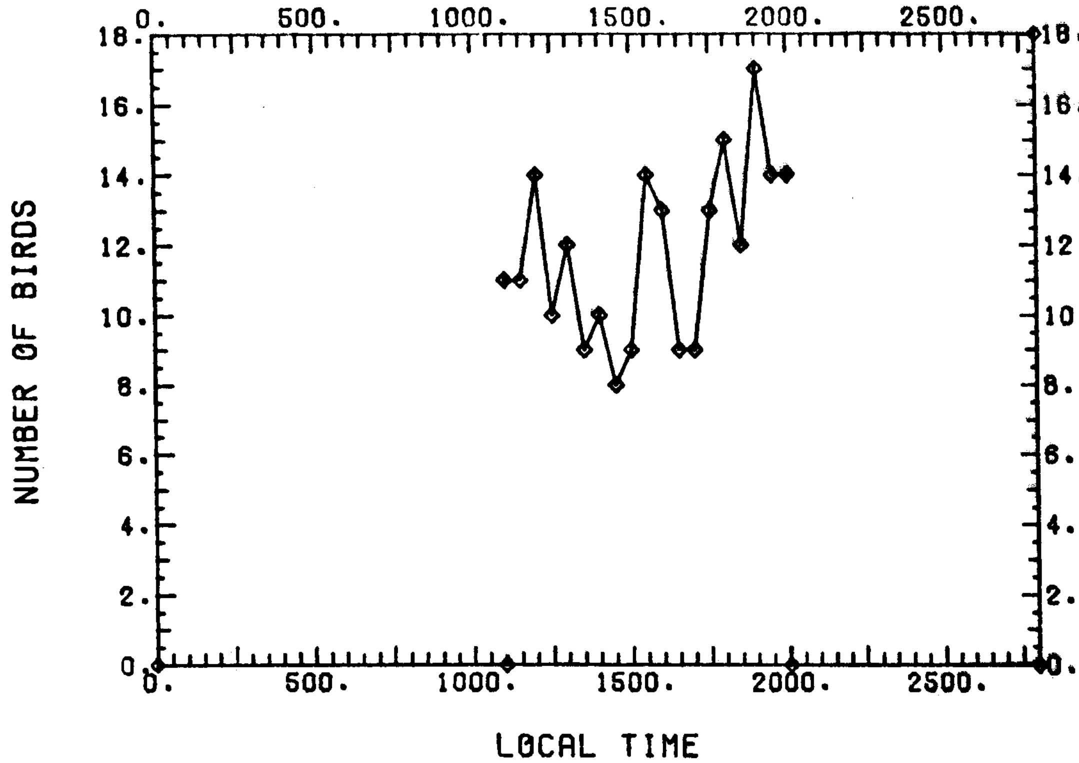
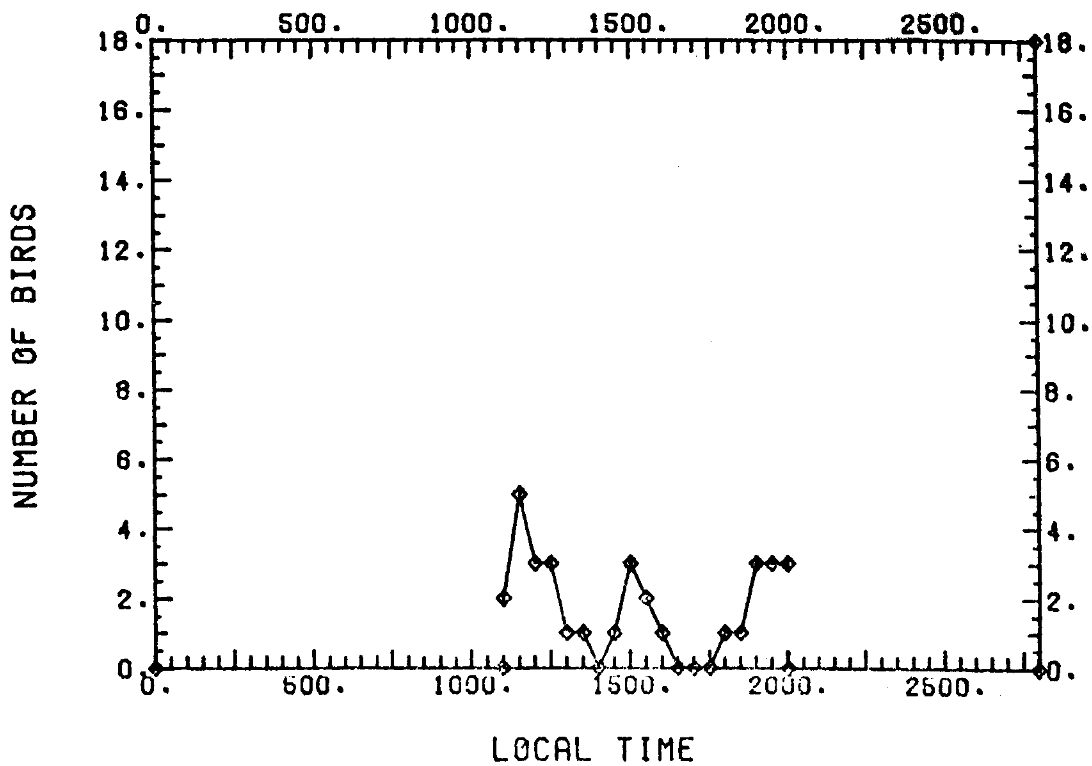


FIG. 24

23 JULY, TUFTED PUFFIN ATTENDANCE, LEDGE 25 1976



Reference-Ledge Counts

We carried out 89 ledge counts of 42,766 birds on St. George (Table 10) and two partial ledge counts that concentrated on cormorants only. Below 800 ft. the commonest species was the thick-billed murre; above 800 ft, the red-legged kittiwake. We found it impractical to census ledges of known equal size. Counts between 1200 and 1500 hr (Table 10) are referred to later in this report as Partial Reference Counts.

On St. Paul, we counted 23,123 birds on 40 ledges (Table 11).

The proportions of species in each stratum were calculated from the reference ledge counts on St. George and St. Paul. For St. George, one set of figures was derived by using all reference counts (Table 12), and another set was derived by using only counts made from 1200 to 1500 hours (Table 13). On St. Paul all counts were made from 1200 to 1500 hours resulting in one set of species-proportion figures (Table 14).

Quadrat Counts and Flight Estimates

The least auklet population on Ulakaia Ridge was estimated by using three methods; counts of fixed quadrats located in the center of the colony (Table 15), counts of randomized telescope quadrats (Table 16), and by flight-count data (Table 17). The area of the colony was estimated, and the number of birds on the surface of the colony was calculated (Table 18).

Productivity Counts

Productivity was estimated for murres (Table 19) and for fulmars (Table 20) at various sites on St. George Island. Murre ledges were visited, and the birds were flushed. Fulmar ledges were observed all day to note the number of chicks and eggs present.

TABLE 10

1976 Reference Ledge Counts St. George Island

Time	Location	TM	CM	BK	(nests)	incubating	RK	(nests)	incubating	PA	LA	CA	HP	TP	RC	(nests)	LF	(DF)	%TM	Max TM
Ledges 0-100 ft.																				
1050	19	91	16	26	24	22	0	0	0	6	0	0	0	0	2		10		76	120
*1445	9	295	0	38	25	23	7	3	2	23	2	0	3	0	1		24		81	364
1525	8	307	2	6	3	2	0	0	0	60	23	1	9	0	2		22		85	361
*1330	13	105	0	0	0	0	0	0	0	9	5	0	0	0	0		15		75	140
1035	20	58	0	0	0	0	0	0	0	4	1	0	0	0	0		0		79	73
1110	45	202	8	5	4	4	1	1	1	18	1	0	8	0	2	3	16	1	76	266
1140	46	184	0	31	23	19	7	1	1	11	0	0	0	0	3	3	0		75	245
*1215	47	156	3	20	9	7	1	0	0	14	3	0	2	0	0		28		75	208
*1255	48	237	2	17	11	8	6	2	1	11	2	0	0	0	13		10		75	316
*1345	49	31	0	21	8	5	59	31	26	0	0	0	0	0	0		0		76	41
*1400	50	119	3	5	4	4	4	3	3	4	0	0	0	0	0		0		76	157
1510	51	96	0	50	32	16	18	5	5	19	0	4	4	2	0		10		81	119
1540	52	52	0	103	79	52	15	7	5	0	0	0	0	0	4	5	4		89	58
1030	53	188	3	49	35	25	94	50	44	2	0	0	0	0	9	7	0		79	238
1150	16	169	0	5	4	3	0	0	0	7	12	0	2	0	0		0		75	225
*1210	15	193	0	6	4	4	0	0	0	14	10	0	2	0	0		27		75	257
*1250	14	177	28	34	17	14	17	7	4	15	13	2	3	0	0		12		75	236
1105	18	70	0	0	0	0	0	0	0	6	8	0	3	0	1		2		76	92
1130	17	148	6	8	6	3	0	0	0	12	13	0	2	0	0		11		75	197
*1345	12	180	22	4	0	0	1	0	0	11	0	0	0	0	0		5		76	237
*1400	11	115	52	8	6	6	0	0	0	1	1	0	1	0	0		0		76	151
*1420	10	348	15	2	1	1	7	4	3	22	9	0	4	0	0		36		78	446
1620	7 bottom	95	0	12	4	3	11	5	4	10	0	2	4	2	0		18		94	101
*1200	26	155	574	3	1	-	1	0	-	4	7	0	2	0	12		2		75	207
1925	38 bottom	181	0	1	1	-	1	0	-	0	0	0	2	0	0		1		72	251
*1230	Zapadni beach	675	23	46	21	13	45	13	5	115	8	0	15	2	18		4		75	900
1500-1630	Village E	1836	254	172	115	95	55	21	20	183	44	49	6	3	15	2	66	2	87	2110
*1230-1415	Village W	986	141	368	205	144	210	79	55	197	205	14	1	0	21	8	42		76	1297
1645	6 bottom	130	22	5	0	0	6	0	0	4	0	0	0	0	2		0		98	133
1630-1730	Village	730	41	358	234	165	293	50	41	103	3	0	23	4	10	3	0		97	753
	Unmarked																			
1505	ledges R557	143	0	0	0	0	0	0	0	9	3	0	0	0	0		33	1	81	177
1510	" "	133	67	0	0	0	0	0	0	5	1	0	0	0	1		0		81	164
1530	" "	158	14	2	1	1	0	0	0	25	3	9	1	1	0		4		85	186
*1320	ledges R556	225	0	0	0	0	0	0	0	12	21	1	0	0	0		8		75	300
*1350	" "	145	0	5	2	2	0	0	0	9	2	0	0	0	0		5		76	191
*1410	ledges R556	50	1	0	0	0	0	0	0	6	7	0	0	0	2		0		76	66
*1220	" R555	40	0	0	0	0	0	0	0	16	19	0	0	0	0		0		75	53
1005	" R553	50	0	5	3	3	0	0	0	0	1	0	0	0	1		0		81	62
1015	" "	10	0	1	0	0	0	0	0	1	2	1	0	0	0		0		79	13
1030	" "	69	0	8	6	5	0	0	0	2	1	0	0	0	3		10		79	87
1535	" R558	134	7	2	0	0	0	0	0	17	0	0	0	0	6		2		85	158
41 ledges Σn		9466	1304	1426 1422	888 886	649	859 857	282 282	220	987	430	83	97	14	128	31	427	4		11,756

(Table continued on next page)

TABLE 10

1976 Reference Ledge Counts St. George Island (continued)

Time	Location	TM	CM	BK	(nests)	incubating	RK	(nests)	incubating	PA	LA	CA	HP	TP	RC	(nests)	LF	(DF)	%TM	Max TM
Ledges 100-200 ft.																				
1625	24 middle	779	54	0	0	0	0	0	0	11	0	0	3	0	0		5		94	829
1620	7 top	414	21	0	0	0	2	1	1	57	7	10	32	0	0		74	1	94	440
1645	6 top	130	22	5	0	0	6	0	0	4	0	0	0	0	2		0		98	133
1520	32 lower	152	0	2	2	-	0	0	-	6	0	0	0	1	0		35		99	154
1730	35 lower	379	0	3	2	-	0	0	-	3	0	1	9	2	0		69		89	426
1900	37 lower	282	7	15	13	-	15	9	-	1	0	0	2	0	0		9		77	366
1925	38 middle	309	0	1	1	-	1	0	-	0	0	0	1	0	0		7		72	429
1545	Unmarked ledges R558	25	0	1	0	0	0	0	0	5	0	0	1	0	4	4	8	1	98	26
1644	" L608	103	0	0	0	0	0	0	0	0	0	0	0	0	0		1		73	111
9 ledges Σn		2573	104	27 6	18 0	0	24 8	10 1	1	87	7	11	48	3	6	4	208	2		2914
Ledges 200-300 ft.																				
1700	5	303	0	15	11	10	6	0	0	34	0	0	4	0	1		10		98	309
* 1400	22	174	0	0	0	0	6	3	3	1	0	0	0	0	0		0		98	176
* 1400	21	104	0	0	0	0	6	3	3	0	0	0	0	0	0		0		98	106
* 1400	23	268	0	1	1	0	14	5	4	3	0	0	0	0	0		126		98	273
1617	24 lower top	142	8	1	-	-	0	-	-	3	0	0	1	0	0		1		94	151
* 1215	25	857	83	25	19	-	3	0	-	60	122	16	9	1	0		51		95	902
* 1225	27	979	10	41	24	-	60	31		26	57	0	6	7	7	5	99		95	1031
* 1300	28	704	93	21	19	-	50	31	-	77	126	12	11	2	0		85	2	96	733
* 1320	29	592	21	12	9	-	18	9	-	61	76	26	14	3	0		40		97	610
* 1345	30	640	137	20	14	-	16	11	-	56	57	38	19	4	0		45		98	653
1514	31	210	38	0	0	-	0	0	-	11	2	15	6	3	0		3		99	212
1520	32 upper	219	55	1	1	-	0	0	-	10	0	24	2	0	0		9		99	221
1600	33	1202	2	18	13	-	475	285	-	16	0	0	2	0	0		47		98	1227
1730	35 top	303	0	24	19	-	3	2	-	0	0	0	0	0	0		39		89	340
1820	36	760	2	14	10	-	8	5	-	0	0	0	26	1	2	2	72		83	916
1850	37 top	387	8	7	4	-	27	9	-	0	0	0	0	0	0		8		77	503
1925	38 top	150	0	4	3	-	66	53	-	1	0	0	5	0	1		8		72	208
* 1350	39	530	89	57	33	20	67	29	23	43	0	0	54	2	0		80		76	697
1700	Unmarked ledges L608	707	0	0	0	-	20	0	0	33	3	3	1	0	1		6		93	760
* 1444	" L613	232	37	3	3	-	1	0	-	30	8	42	2	4	0		2		81	286
20 ledges Σn		9072	583	264 263 73	183 45	30	847 120	476 40	36	465	451	176	162	27	11	7	728	2		10,314

(Table continued on next page)

TABLE 10

1976 Reference Ledge Counts St. George Island (continued)

Time	Location	TM	CM	BK	(nests)	incubating	RK	(nests)	incubating	PA	LA	CA	HP	TP	RC (nests)	LF	(DF)	%TM	Max TM
Ledges 300-400 ft.																			
1605	24 top top	683	115	8	-	-	16	-	-	9	1	2	3	0	0	58		98	697
* 1445	2	466	100	3	0	0	22	13	12	6	0	0	2	0	0	4		81	575
1730	34	116	0	1	0	-	46	27	-	8	0	0	4	0	0	0		89	130
3 ledges Σn		1265	215	12 4 3	 0 0	 0	84 68 22	 40 13	 12	23	1	2	9	0	0	62	0		1402
Ledges 400-500 ft.																			
1730	4 lower	335	12	0	0	0	0	0	0	0	0	0	0	0	0	40		100	335
1820	3 far, lower	465	0	0	0	0	11	5	4	3	0	0	5	0	0	11		97	479
1300	1	320	0	19	15	12	132	73	61	8	2	0	1	0	0	2		75	427
3 ledges Σn		1120	12	19	15	12	143	78	65	11	2	0	6		0	53			1241
Ledges 500-600 ft.																			
1730	4 upper	88	0	2	2	2	63	30	26	0	0	0	0	0	0	14		100	88
1800	3 near	487	352	2	1	1	8	2	2	9	0	1	6	0	0	9	2	99	492
1645	40	113	0	17	9	9	169	89	77	0	0	0	0	0	0	0		98	115
3 ledges Σn		688	352	21	12	12	240	121	105	9	0	1	6	0	0	23	2		695
Ledges 600-700 ft.																			
1810	41 lower	516	19	22	17	15	132	86	74	0	0	0	0	0	0	0		99	521
1820	3 far top	764	112	-	-	-	-	-	-	33	0	0	-	-	-	-		97	788
2 ledges Σn		1280	131	22	17	15	132	86	74	33	0	0	0	0	0	0			1309
Ledges 700-800 ft.																			
1830	41 upper	1244	343	16	14	12	202	103	96	0	0	0	0	0	0	0		97	1282
1 ledge Σn		1244	343	16	14	12	202	103	96	0	0	0	0	0	0	0			1282
Ledges 800-900 ft.																			
1600	54 lower	79	0	0	0	0	99	42	34	1	0	0	0	0	0	0		89	89
1600	54 far right	122	0	0	0	0	86	39	34	0	0	0	0	0	0	0		89	137
1650	55	425	181	19	15	12	326	157	135	4	0	0	0	5	0	26		98	434
1450	42	185	1	4	1	0	362	159	141	0	0	0	0	0	0	0		81	228
4 ledges Σn		811	182	23	16	12	873	397	344	5	0	0	0	5	0	26			888
Ledges 900-1000 ft.																			
1435	43	196	0	21	14	14	580	314	260	3	0	0	0	0	0	0		78	251
1950	44	473	0	12	9	6	521	341	277	0	0	0	0	0	0	1		90	526
1600	54 upper	21	0	0	0	0	114	39	30	2	0	0	0	0	0	0		89	24
3 ledges Σn		690	0	33	23	20	1215	694	567	5	0	0	0	0	0	1			801

* asterisk indicates counts between 1200 and 1500 used in Partial Reference Counts to allow for small alcid attendance

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TABLE 11

1976 Reference Ledge Counts St. Paul Island

TABLE 11

1976 Reference Ledge Counts St. Paul Island

Time	Location	TM	CM	BK	(nests)	incubating	RK	(nests)	incubating	PA	LA	CA	HP	TP	RC	(nests)	LF (DF)
Ledges 0-100 ft.																	
1225	1	72	15	35	32	28	9	5	5	1	0	0	0	0	14	12	0
1255	2SW	26	2	26	12	10	0	0	0	16	11	0	1	0	4		0
1310	3	79	3	47	30	24	2	1	0	14	19	0	2	0	10	7	0
1345	4	100	0	15	7	6	0	0	0	5	4	0	0	0	1		2
1430	22 bottom	54	4	0	0	0	0	0	0	4	0	0	0	0	1	1	0
1130	17	88	21	24	19	14	1	1	0	5	0	0	5	0	1		0
1500-1700&																	
1000-1130	Ridge wall	2179	752	914	608	492	61	30	26	696	246	14	113	13	64	43	3
1030-1230	Zapadni	1952	558	720	539	462	15	9	8	322	135	12	29	5	48	19	2
	Σ	4550	1355	1781	1247	1036	88	46	39	1063	415	26	150	18	143	82	
Ledges 0-150 ft.																	
1330-1530	Tolstoi	1087	1085	338	206	186	0	0	0	444	828	311	29	37	11	1	0
	11 ledges Σn	5637	2440	2119	1453	1222	88	46	39	1507	1243	337	179	55	154	83	7
Ledges 100-200 ft.																	
1430	5SW	266	0	93	56	51	0	0	0	28	10	0	2	0	15	5	0
1405	5NE	120	1	14	3	8	0	0	0	5	1	0	0	0	3	2	0
1515	7 top CM	55	0	23	14	11	1	0	0	0	0	0	0	0	1		0
1515	7 ledge	87	256	24	20	19	0	0	0	7	0	0	0	0	1	1	0
1525	8	253	20	20	9	9	0	0	0	20	3	0	0	0	4	3	0
1545	9	133	104	94	72	50	5	3	2	16	0	0	5	2	1	1	2
1600	10	284	648	44	27	24	0	0	0	8	0	0	0	0	4	2	3
1100	19	181	131	52	32	28	0	0	0	11	12	0	1	0	1		2
1100	19	176	134	37	27	26	0	0	0	4	1	0	2	0	1		2
1115	18	254	192	40	22	17	3	1	1	3	0	0	0	0	8	5	0
1145	16	187	106	60	39	28	1	1	1	17	7	0	4	0	0		1
1200	15	206	11	50	36	31	2	0	0	2	0	0	5	0	7	2	4
1430	22 middle	337	2	19	12	9	2	1	0	26	3	0	5	0	0		3
1510	23 bottom	933	25	41	34	31	4	3	3	30	0	0	8	0	0		13
1220	20	37	0	15	13	13	0	0	0	0	0	0	1	0	0		1
	15 ledges Σn	3509	1630	626	416	355	18	9	7	177	37	0	33	1	46	21	31
Ledges 200-300 ft.																	
1245	21	137	2	24	14	10	1	1	0	25	15	3	5	0	0		7
1820	29	329	7	12	6	5	1	1	1	53	2	0	4	1	0		15
1625	11	40	0	21	18	13	0	0	0	5	0	0	1	0	0		0
1345	12	193	0	78	46	37	0	0	0	3	0	0	1	0	23	10	0
1355	13	110	0	40	26	23	1	0	0	13	0	0	0	0	2	2	0
1405		86	0	4	3	3	0	0	0	8	0	0	0	0	1	1	0
1415	14	369	184	20	11	8	6	2	2	15	0	0	3	1	3	1	2
1430	22 top	172	0	47	43	38	0	0	0	14	0	0	3	0	0		0
1510	23 top	140	0	39	28	25	7	2	2	12	0	0	3	0	2	2	4
	9 ledges Σn	1576	193	285	195	162	16	6	5	148	17	3	20	2	31	16	28
Ledges 300-400 ft.																	
1545	24	65	6	44	31	25	25	18	18	0	0	0	0	0	9	9	0
1605	25	87	0	41	27	21	3	1	1	0	0	0	0	0	0	0	0
1620	26	250	0	45	24	19	11	8	6	7	0	0	2	0	5	1	0
1645	27	13	0	25	13	11	25	20	19	0	0	0	0	0	0		0
1800	28	224	6	16	11	8	3	3	3	13	0	0	2	1	2	1	0
	5 ledges Σn	639	12	171	106	84	67	50	47	20	0	0	4	1	16	11	0

TABLE 12

Relative Proportions of Nesting Seabirds on Cliffs, St. George Id. 13 July - Aug. 5, 1976

counts made 1000-1930 hrs.

Stratum...........	1	1 Max*	2	2 Max*	3	3 Max*	4	4 Max*	5	5 Max*
Thick-billed Murre	0.6569	0.7008	0.7148	0.7396	0.6676	0.6827	0.7417	0.7469	0.3879	0.4163
Common Murre	.0768	.0672	.0518	.0504	.1344	.1283	.1393	.1366	.0470	.0449
Black-legged Kittiwake	.0793	.0693	.0191	.0174	.0148	.0141	.0112	.0110	.0145	.0138
Red-legged Kittiwake	.0482	.0421	.0644	.0588	.1414	.1350	.0981	.0963	.5397	.5147
Parakeet Auklet	.0586	.0513	.0337	.0308	.0074	.0071	.0097	.0095	.0026	.0025
Least Auklet	.0238	.0209	.0313	.0285	.0007	.0007	0	0	0	0
Crested Auklet	.0051	.0045	.0123	.0112	.0004	.0004	0	0	0	0
Horned Puffin	.0079	.0069	.0118	.0108	.0044	.0042	0	0	0	0
Tufted Puffin	.0009	.0008	.0119	.0017	0	0	0	0	.0013	.0012
Red-faced Cormorant	.0073	.0064	.0008	.0007	0	0	0	0	0	0
Light-phase Fulmar	.0346	.0303	.0546	.0499	.0281	.0268	0	0	.0069	.0067
Dark-phase Fulmar	.0003	.0003	.0001	.0001	.0007	.0007	0	0	0	0
Total Birds	18,325	20,956*	14,461	15,840*	2,708	2,836*	3,403	3,470*	3,869	4,057*

Max * extrapolations based on daily attendance maxima.

TABLE 13

St. George Island
1976
Relative Proportions of Nesting Seabirds on Cliffs

Using Partial Reference Counts

Adjusted For Auklet Attendance

(only counts between 1200-1500 hrs. included)

Stratum.....	1	1 Max*	2	2 Max*
Thick-billed Murre	0.5947	0.6584	0.6776	0.6970
Common Murre	.1213	.1022	.0696	.0657
Black-legged Kittiwake	.0810	.0682	.0224	.0211
Red-legged Kittiwake	.0503	.0423	.0321	.0303
Parakeet Auklet	.0678	.0571	.0442	.0417
Least Auklet	.0378	.0318	.0545	.0514
Crested Puffin	.0024	.0020	.0164	.0154
Horned Puffin	.0046	.0039	.0143	.0135
Tufted Puffin	.0003	.0002	.0028	.0026
Red-faced Cormorant	.0094	.0079	.0009	.0008
Light-phase Fulmar	.0306	.0258	.0650	.0613
Dark-phase Fulmar	.0000	.0000	.0002	.0002
Total Birds	7,120	8,455	8,185	8,681

Max* extrapolations based on daily attendance maxima.

TABLE 14

Relative Proportions of Nesting Seabirds on Cliffs

St. Paul Id.

17-21 July, 1976

counts made 1200-1500 hrs.

all auklets present

Stratum....	1	2
Thick-billed Murre	0.4602	0.6840
Common Murre	.2048	.0633
Black-legged Kittiwake	.1381	.1408
Red-legged Kittiwake	.0053	.0256
Parakeet Auklet	.0847	.0488
Least Auklet	.0644	.0053
Crested Auklet	.0169	.0009
Horned Puffin	.0107	.0074
Tufted Puffin	.0028	.0006
Red-faced Cormorant	.0101	.0145
Light-phase Fulmar	.0019	.0086
Dark-phase Fulmar	0	0
Total Birds	19,874	3,249

TABLE 15

St. George Island 1976

Counts of Fixed Quadrats Ulakaia Hill Least Auklet Colony

Date	Time	1st Highest Count Quadrat			2nd Highest Count Quadrat			3rd Highest Count Quadrat			4th Highest Count Quadrat			Mean of 2nd, 3rd, & 4th Highest Counts Quadrat		
		175	453	750	175	453	750	175	453	750	175	453	750	175	453	750
10 June	0900	38	53	27	28	49	12	24	26	11	--	--	--	26*	37.5*	11.5*
11 June	0430-0600	78	130	73	68	123	63	54	119	61	53	114	50	58.3	118.6	58
12 June		83	158	86	63	153	82	63	151	82	59	146	80	61.6	150	81.3
21 June		47	100	40	42	85	34	41	79	32	39	76	27	40.6	80	31
1 July		45	118	40	44	115	39	40	111	38	36	103	35	40	109.6	37.3
		Average of 2nd, 3rd, & 4th highest averages....												53.5	116.2	56.7
		Average of 2 counts immediately preceding laying....												59.95	134.3	69.65

*4th highest count disregarded

TABLE 16

St. George Island 1976

Counts of $100m^2$ Random Telescope Quadrats

Ulakaia Hill Least Auklet Colony

Date	Time Period	Number of Counts	Mean	Standard Deviation	Standard Error of Mean
12 June	0905-1207	59	28.3051	18.1680	2.373
21 June	1330-1502	35	24.7428	17.3414	2.9312
22 June	0915-1059	56	27.5	23.7869	3.1787
1 July	0942-1305	50	21.12	18.508	2.617

Grand mean of June counts = 25.6116 Least Auklets/$100m^2$

TABLE 17

St. George Island
1976

Least Auklet Estimates at Ulakaia Colony

Based on Evening Flight Counts During Incubation

1800 hrs until dark

Date	Least Auklet arriving	Least Auklet leaving
1 July	66,226	14,919
5 July	92,660	
Mean [a/]	79,443	

a/ 79,443 - 14,919 = 64,524 least auklets staying overnight at the colony. This in turn yields 129,048 breeding birds.

TABLE 18

St. George Island 1976

Estimates of Area of Ulakaia Least Auklet Colony

12 June	62,500 m^2
17 June	126,562.5 m^2
Mean	94,531.25 m^2

Estimates of Least Auklets on Colony Surface

Method	
Random Quadrats	94,531.25 m^2 X .256116 birds/m^2 = 24,211 birds Mean Density
Fixed Quadrats	94,531.25 m^2 X .794 birds/m^2 = 75,058 birds Peak Density

/

TABLE 19

Murre Productivity St. George Island 1976

Mid-afternoon, latter half of incubation period and early hatching period

Date/Time	TM	TM Eggs	TM Chicks	CM	CM Eggs	CM Chicks	Unidentified egg	Unidentified chick
31 July 1935	32			12			20	9
31 July 1500	3	1						
31 July 1500	25	11	9					
31 July 1505	21	9	7	24	6	6		
31 July 1500	55			14			35	14
1 Aug* 1700	95*			113*			90*	12*
29 July 1330	38	15	2					
29 July 1330	6	4	1					
9 July 1710	21	15						
9 July 1500	165	35						
9 July 1515	36	24						
Totals	497	114	19	163	6	6	145	35
Totals**	315	114	19	24	6	6		

* Egged on June 24 and 26 by Aleuts. All replacement eggs laid by August 1.

** Excluding the data of August 1.

TABLE 20

St. George Island
1976
Fulmar Productivity

All-day observations after mean hatching date

Date/ Area	No. of Chicks seen	No. of eggs	Maximum no. possible nest sites	Maximum no. adult birds	Nests/ Chick	Nests/eggs laid	Birds/ Chick	Birds/eggs laid
7 Aug Murie Cove	22	1	86	129	3.91	3.74	5.86	5.61
4 Aug Rosy Finch Cove	6	1	20	38	3.33	2.86	6.33	5.43
Mean					3.62	3.3	6.10	5.52

DISCUSSION

Estimates of Errors

Photographic Sample Counts.--At higher evelations and in poorer photographs it was difficult to distinguish murres and to discriminate between kittiwakes and fulmars. For this reason, the number of white birds (kittiwakes and light-phase fulmars) was calculated (Table 21, and Fig. 25) giving means with somewhat less variability. The number of photographic samples necessary to achieve a given confidence interval on the mean for counts of white birds is illustrated graphically in Fig. 26. We found similar results for murres. We sampled 2.5% of the total cliff area on St. George from 11 in. x 14 in. photograph enlargements.

TABLE 21

St. George Island 1976

Mean Number of White Birds per $900m^2$

Photo Quadrat

	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5
mean	53.54	76.47	133.64	151	510
standard deviation	48.50	76.21	87.03	120.96	220.39
Standard error of mean	7.15	13.47	23.26	49.38	110.19
number of sample counts	46	32	14	6	4
$s_{\bar{x}}$ as % of $\bar{x}$	13.35	17.61	17.40	32.70	21.61
C.I. on $\bar{x}$	28.6%	55%	103%	253%	701%
Stratum as a % of total area*	46%	29%	12%	9%	4%

* From Table 3.

Fig. 25

MEAN AND STANDARD ERROR OF PHOTO SAMPLE COUNTS

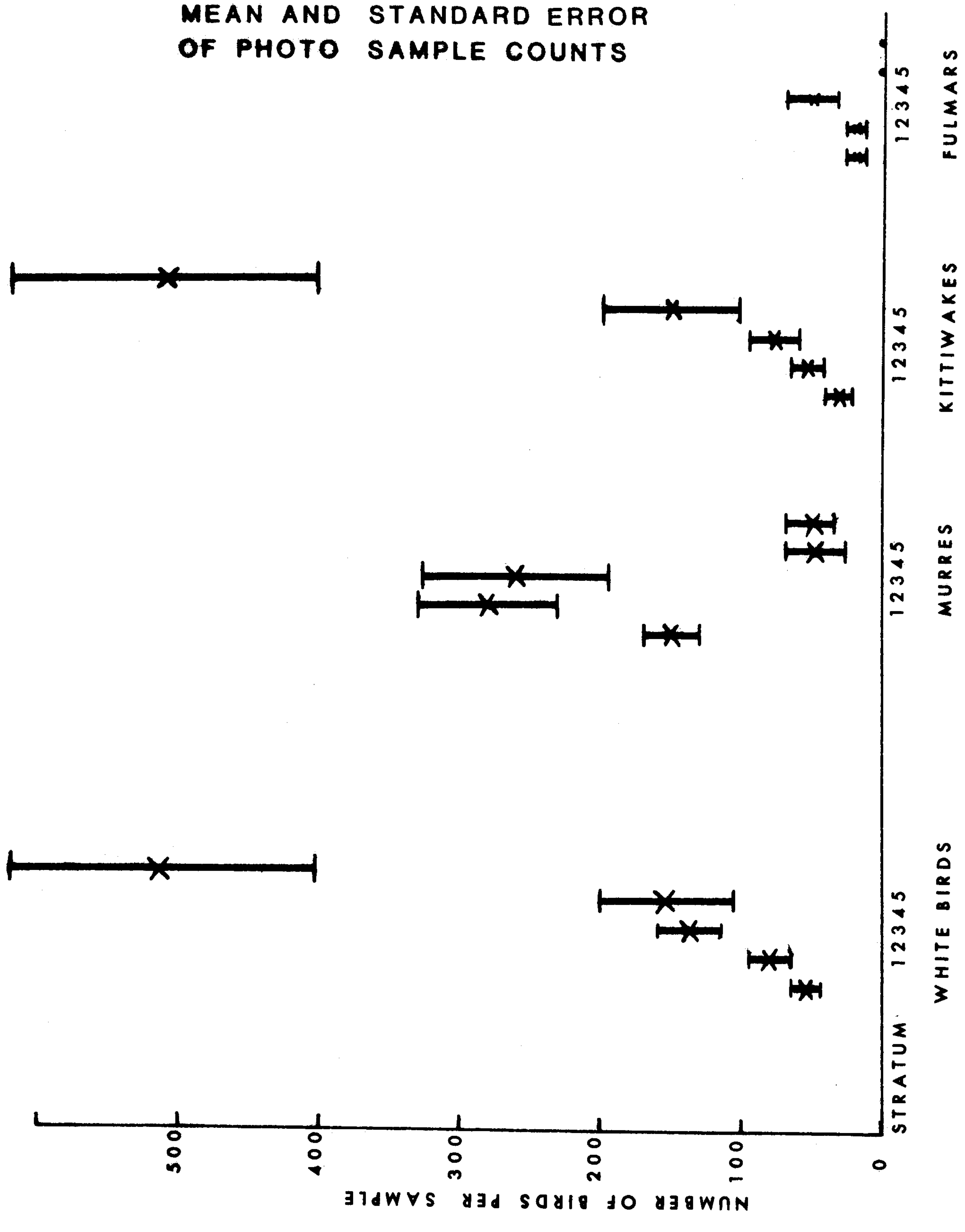
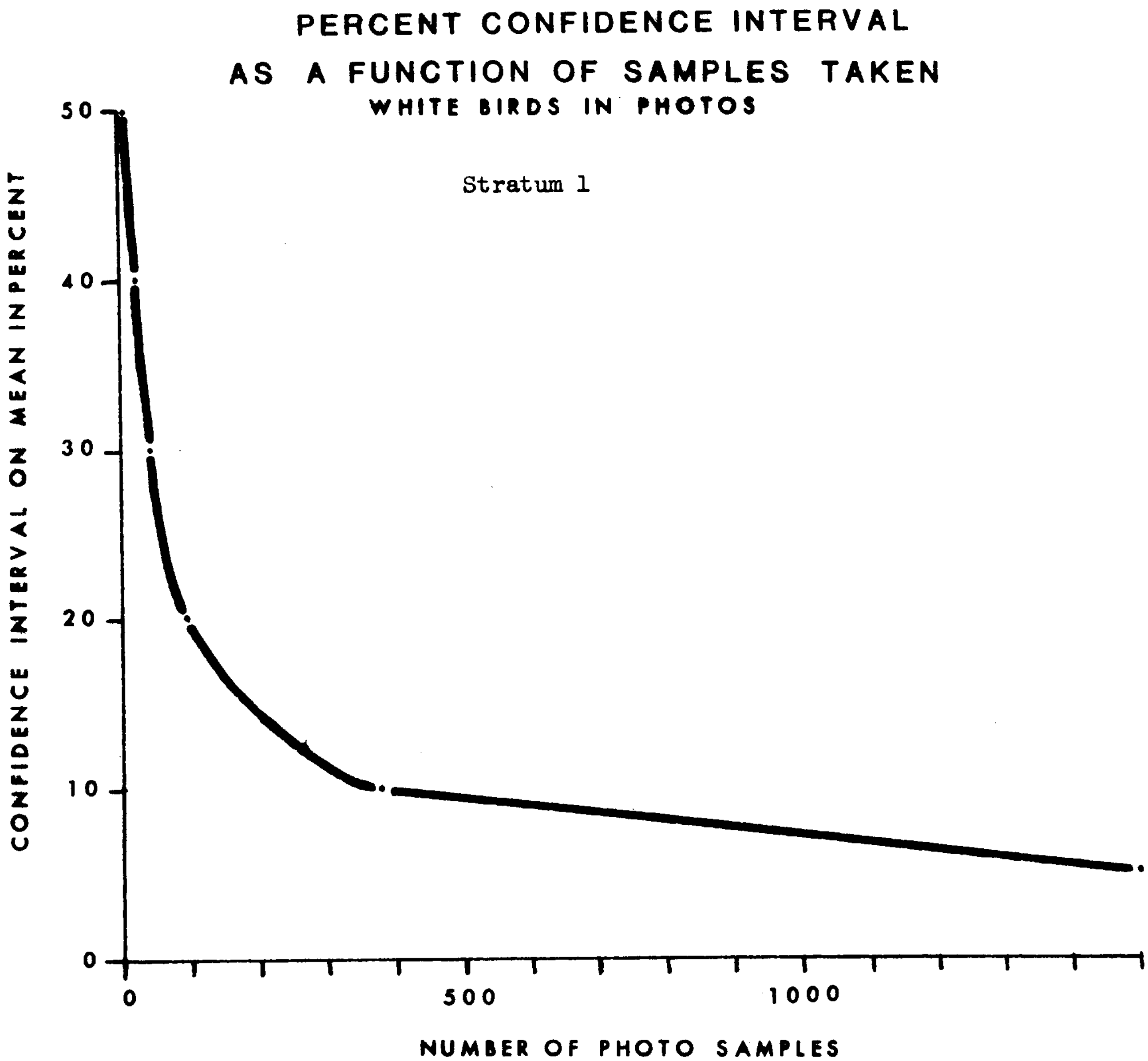


Fig. 26



The number of sample replications needed to obtain a given confidence interval on the mean was calculated using the formula

$$l = 2t_{\alpha}\,\hat{\sigma}/\sqrt{n}$$

l = confidence interval desired
n = number of samples.

Thus, for stratum 1 with 46 samples, we obtained about 29% confidence interval on the mean. For a 10% confidence interval, it would have been necessary to draw 376 samples.

We would expect standard deviation to reflect patchiness of habitat. With murres we would not expect s to change with height, and the fact that s changes with height (Fig. 25) indicates that it is a function of our method. The mean number of murres per 900-m^2 photo quadrat is best represented in the first three strata, the low numbers in the two higher strata are due mostly to the limitations of our photographic analysis. The much lower densities of murres at higher strata indicate that murres cannot be clearly counted in distant photographs.

For kittiwakes, the evidence of our reference counts and our photo counts indicate a real increase in density of kittiwakes with elevation. Likewise, with fulmars, there is evidence that density drops off sharply above stratum 3. We assumed that white birds could be seen and counted with consistent accuracy at all elevations; white fronts of murres could be distinguished from white birds at all but the highest elevations where the very narrow ledges seem to keep most murres facing inland. We used the density of white birds as an index to the numbers of other species. To do this, we determined the proportion of each species from our reference ledges on each stratum (Table 12-14) and extrapolated from the number of white birds to total number of birds present. Number of each species was calculated by taking the appropriate percentage of the total.

Since reference-ledge counts were made throughout the day on St. George, many of these were counted at times when small alcids (PA, LA, CA, HP, TP) were not present on the cliffs. To get a better estimate of the relative proportions of these small alcids, a subsample

TABLE 22

St. George Island

1976

Density Estimates Using Species Proportions From All Reference Counts Based on Number of White Birds in Sample

TABLE 22

St. George Island

1976

Density Estimates Using Species Proportions From All Reference Counts Based on Number of White Birds in Sample

Species	Stratum 1 16.21% (14.17%) White Birds		Stratum 2 13.83% (12.61%) White Birds		Stratum 3 18.43% (17.59%) White Birds		Stratum 4 10.93% (10.73%) White Birds		Stratum 5 56.11% (53.52%) White Birds	
	Birds in Sample	Birds/ 900m²	Birds in sample	Birds/ 900m²	Birds in sample	Birds/ 900m²	Birds in sample	Birds/ 900m²	Birds in sample	Birds/ 900m²
Thick-billed Murre	9,981 (12,167)	216.9 (264.5)	12,686 (14,352)	396.4 (448.5)	6,414 (6,873)	458.1 (490.9)	6,148 (6,307)	1,024.7 (1,051)	1,410 (1,587)	352.5 (396.7)
Common Murre	1,167 (1,168)	25.4 (25.4)	980 (978)	30.6 (30.6)	1,291 (1,292)	92.2 (92.3)	1,155 (1,153)	192.5 (192.2)	171 (171)	42.8 (42.8)
Black-legged Kittiwake	1,205 (1,205)	26.2 (26.2)	334 (338)	10.4 (10.6)	142 (142)	10.1 (10.1)	93 (93)	15.5 (15.5)	53 (53)	13.3 (13.3)
Red-legged Kittiwake	732 (732)	15.9 (15.9)	1,143 (1,141)	35.7 (35.7)	1,359 (1,359)	97.1 (97.1)	813 (813)	135.5 (135.5)	1,962 (1,962)	490.5 (490.5)
Parakeet Auklet	890 (892)	19.4 (19.4)	596 (598)	18.6 (18.7)	71 (72)	5.1 (5.1)	80 (80)	13.4 (13.4)	9 (10)	2.3 (2.4)
Least Auklet	362 (363)	7.9 (7.9)	550 (553)	17.2 (17.3)	7 (7)	.5 (.5)	0 (0)	0 (0)	0 (0)	0 (0)
Crested Auklet	77 (78)	1.7 (1.7)	214 (217)	6.7 (6.8)	4 (4)	.3 (.3)	0 (0)	0 (0)	0 (0)	0 (0)
Horned Puffin	120 (120)	2.6 (2.6)	209 (210)	6.5 (6.5)	42 (42)	3.0 (3.0)	0 (0)	0 (0)	0 (0)	0 (0)
Tufted Puffin	14 (14)	0.3 (0.3)	34 (33)	1.1 (1.0)	0 (0)	0 (0)	0 (0)	0 (0)	5 (5)	1.3 (1.3)
Red-faced Cormorant	111 (111)	2.4 (2.4)	14 (14)	.4 (.4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Fulmar	530 (532)	11.5 (11.5)	970 (970)	30. (30	277 (276)	19.8 (19.8)	0 (0)	0 (0)	25 (26)	6.3 (6.4)
Total Birds Extrapolated	15,194 (17,382)		17,693 (19,405)		9,609 (10,068)		8,289 (8,444)		3,635 (3,812)	

( ) parenthesis indicate figures derived using maximum number of thick-billed murres present during the day

TABLE 23

St. George Island
1976
Density Estimates Using Species Proportions from Partial Reference Counts Based on Number of White Birds in Sample

	Stratum 1. White Birds in sample 16.19% (13.63%)		Stratum 2. White Birds in sample 11.95% (11.27%)	
Species	Birds in sample	Birds/900m²	Birds in sample	Birds/900m²
Thick-billed Murre	9,047 (11,897)	196.7 (258.6)	13,874 (15,134)	433.6 (472.9)
Common Murre	1,846 (1,847)	40.1	1,423 (1,424)	44.5
Black-legged Kittiwake	1,232 (1,232)	26.8	458 (457)	14.3
Red-legged Kittiwake	765 (764)	16.6	656 (657)	20.5
Parakeet Auklet	1,031 (1,032)	22.4	904 (904)	28.3
Least Auklet	575 (575)	12.5	1,114 (1,114)	34.8
Crested Auklet	37 (36)	0.8	335 (334)	10.5
Horned Puffin	70 (70)	1.5	292 (293)	9.1
Tufted Puffin	5 (4)	.11	57 (56)	1.9
Red-faced Cormorant	143 (143)	3.1	18 (17)	.6
Fulmar	466 (466)	10.1	1,333 (1,333)	41.7
Total Birds Extrapolated	15,213 (18,070)		20,476 (21,713)	

( ) parentheses indicate figures derived using maximum numbers of thick-bille murres present during the day

TABLE 24

St. George Island
1976
Density Estimates for Stratum 4 Interpolating Species Proportions From Those of Strata 3 and 5
Based on Number of White Birds in Sample
37.27% (35.60%) White Birds

Species	Relative proportion	Birds in sample	Birds/900m^2
Thick-billed Murre	0.5277 (.5495)	1282 (1398)	213.7 (233.1)
Common Murre	.0907 (.0866)	220 (220)	36.7
Black-legged Kittiwake	.0146 (.0140)	35 (36)	5.9
Red-legged Kittiwake	.3406 (.3249)	828 (827)	137.9
Parakeet Auklet	.0050 (.0048)	12 (12)	2.0
Tufted Puffin	.0007 (.0006)	1.7 (1.7)	0.3
Fulmar	.0175 (.0171)	43 (44)	7
Total Birds Extrapolated		2430 (2545)	

( ) parentheses include figures derived using the daily maximum of thick-billed murres of reference ledges was used including only those counts made between 1200 and 1500 hours. This allows for the attendance of small alcids but substantially lowers the sample size. Only strata 1 and 2 could be treated this way.

Similarly, thick-billed murre attendance was taken into consideration. Daily attendance curves were smoothed out using a 3-point moving average, and each reference count was adjusted to account for the maximum number of murres. This generates a different set of species proportions (Tables 12-14) with a higher relative proportion of thick-billed murres. Two such 3-point moving average curves were used. One combined all curves from 30 July to 7 August (Fig. 11) for reference ledges counted late in the season. The other used the Murie Cove Ledges 21, 22, and 23 (Fig. 10) for reference ledges counted earlier (ledges 24-38).

Finally, the number of reference ledges in stratum 4 was small. This resulted in some inaccuracies. The relative proportion of red-legged kittiwakes was less than in stratum 3. Our field observations and photo analysis indicated that the density of red-legged kittiwakes increased dramatically with elevation. To arrive at closer estimates of species porportions for stratum 4, we interpolated intermediate values from strata 3 and 5 (Table 14). These manipulations resulted in several population estimates for each species. We will indicate which we feel to be most accurate.

Flight Counts.--Throughout the season we compared counts, two men each making an independent count and then comparing them for accuracy. Differences were on the order of five percent, but reaching up to 10 percent at peak times when several thousand birds passed within 10 minutes. Photos of flocks were taken to compare with our counts. Only small flocks could be photographed and counted well. Differences were less than 5 percent in flocks up to two or three hundred. Larger flocks are spread out over a wide area and could not be photographed.

Population Estimates

Density estimates are derived based on the number of white birds counted in photo quadrats. These are presented in Tables 22-24. Three sets of population estimates are derived; one from straight photo-quadrat counts (Table 25) and two others from the density estimates based upon the number of white birds counted in photo quadrats (Tables 26, 27).

To provide an order-of-magnitude estimate of St. Paul populations, we assumed that the total density of all birds was similar for strata 1 and 2 on both St. George and St. Paul. Extrapolations of total number of birds on St. Paul are presented in Table 28. Numbers of each species are derived from this total by using the species-proportion figures in Table 14. These numbers are presented in Table 29. These figures may be high, as Stratum 2 on St. Paul is near the top of the weathered bluffs and is consequently probably more heavily vegetated and less densely populated than on St. George.

TABLE 25
St. George Island 1976
Estimates of Total Birds on Cliffs From Numbers of Murres and White Birds Seen on Random Photo Quadrats

Stratum	Number of $900m^2$ areas in entire stratum	Murres/ $900m^2$	White Birds/ $900m^2$	Total Murres	Total white birds
1	1805	150.32	53.46	271,445	96,495
2	1135	280.09	76.47	317,980	86,793
3	488	259.5	126.38	126,635	61,673
4	359.2	47.16	150.96	16,940	54,225
5	142.33	47.75	510	6,796	72,588
Total				739,796	371,774

TABLE 26

St. George Island 1976

Estimates of Total Birds on Cliffs

Based on All Reference Counts

Species	Stratum 1 1805 (birds/ 900m²)	Stratum 2 1135 (birds/ 900m²)	Stratum 3 488 (birds/ 900m²)	Stratum 4 359 (birds/ 900m²)	Stratum 5 142 (birds/ 900m²)	Total
Thick-billed Murre [a/]	391,505 (477,423)	449,914 (509,048)	223,553 (239,559)	368,072 (377,519)	50,161 (56,450)	1,483,205 (1,659,999)
Common Murre	45,847	34,731	44,994	69,146	6,090	200,808
Black-legged Kittiwake	47,291	11,804	4,929	5,567	1,893	71,484
Red-legged Kittiwake	28,700	28,148	47,385	48,672	69,798	222,703
Parakeet Auklet	35,017	21,111	2,489	4,777	327	63,721
Least Auklet	14,260	19,522	244	0	0	34,026
Crested Auklet	3,069	7,605	146	0	0	10,820
Horned Puffin	4,695	7,378	1,464	0	0	13,537
Tufted Puffin	542	1,249	0	0	185	1,976
Red-faced Cormorant	4,332	454	0	0	0	4,786
Fulmar	20,758	34,050	9,662	0	896	65,366
Total Percent	596,016 27.4%	615,966 28.4%	334,866 15.4%	496,234 22.8%	129,350 6.0%	2,172,432 [b/] 100.0%

a/ parentheses include maximum number of thick-billed murres present during the day.   b/ (2,349,226)

TABLE 27

St. George Island
1976

Estimates of Total Birds on Cliffs Based on Partial Reference Counts for Strata 1 and 2 and Interpolated Reference Counts for Stratum 4

Species	Stratum 1 birds	Stratum 2 birds	Stratum 3[b/] birds	Stratum 4 birds	Stratum 5[b/] birds	Total
Thick-billed Murre[a/]	355,044 (466,773)	492,136 (536,742)	236,241 (239,559)	76,761 (83,730)	50,161 (56,450)	1,210,343 (1,383,254)
Common Murre	72,381	50,508	47,531	13,183	6,090	189,693
Black-legged Kittwake	48,374	16,231	5,222	2,119	1,893	73,839
Red-legged Kittiwake	29,963	23,268	50,020	49,534	69,798	222,583
Parakeet Auklet	40,432	32,121	2,636	718	327	76,234
Least Auklet	22,563	39,498	244	0	0	62,305
Crested Auklet	1,444	11,918	146	0	0	13,508
Horned Puffin	2,708	10,329	1,562	0	0	14,599
Tufted Puffin	199	2,157	0	108	185	2,649
Red-faced Cormorant	5,596	681	0	0	0	6,277
Fulmar	18,231	47,330	10,199	2,514	896	79,170
Total Percent	596,935 31%	726,177 37%	353,801 18%	144,937 7%	129,350 7%	1,951,200[c/] 100%

a/ parentheses include maximum number of thick-billed murres present during the day

b/ estimates based on all reference counts (Table 26).

c/ (2,124,111)

TABLE 28
St. Paul Estimates Based on Total Bird Densities on St. George

Stratum	Area (1,000 m^2) St. George	Area (1,000 m^2) St. Paul	Estimated Total No. St. George[a] All Species	Estimated Total No. St. George[a] Per m^2	Extrapolated No. for All Species on St. Paul
1	1,625	387.6	733,037	0.451	174,846
2	1,022	67.4	770,783	0.754	50,832
Total		455.0			225,678

a/ Based on partial reference counts involving maximum numbers of murres on cliffs (Table 27).

TABLE 29
Estimates of Species on St. Paul Directly Extrapolated
From Total Bird Densities on St. George and Not Rounded Off

Species	Stratum 1	Stratum 2	Total
Thick-billed murre	80,464	34,769	115,233
Common murre	35,808	3,218	39,026
Black-legged kittiwake	24,146	7,157	31,303
Red-legged kittiwake	927	1,301	2,228
Parakeet auklet	14,809	2,481	17,290
Least auklet	11,260	269	11,529
Crested auklet	2,955	46	3,001
Horned puffin	1,871	376	2,247
Tufted puffin	490	30	520
Red-faced cormorant	1,766	737	2,503
Light-phase fulmar	332	437	769
Dark-phase fulmar	0	0	0

Using the statistics generated from our photo-sample counts, we see that we are estimating the mean with one significant digit and may be close to two significant digits. Accuracy is worst at higher strata. If these figures are then used (i.e., white-bird counts) to extrapolate to numbers of other species, we lose control of the sampling errors involved. These extrapolations are based on counts of species on ledges of varying size so there is no way to calculate error. They are, however, based on large sample sizes on St. George Id.:18,325 birds counted in stratum 1; 14,461 in stratum 2; 2,708 in stratum 3; 3,403 in stratum 4; 3,869 in stratum 5 (Table 12). The sample size is reduced if we utilize only those counts from 1200-1500 when small alcids are present, 7,120 birds being counted in stratum 1 and 8,185 in stratum 2 (Table 13).

All things considered, we feel that we have an accuracy of one significant digit, and close to two with our extrapolated estimates. This is a considerable improvement over past population estimates by Gabrielson and Lincoln (1959) and Elliot (1884) who of course did not make serious attempts to determine numbers. This will enable us to detect a change in population of 50%. When one considers the possibly long lives of these seabirds, their reproductive strategies, and the probable year-to-year population fluctuations, a change of this magnitude may be close to a minimal amount that can be considered a real change in population size. A change on the order of 50% should be important enough to enable government officials to take action, generate interest and study, and bring a restraining order to any activities in the area that are environmentally degrading. If these techniques can demonstrate this change, they should be heeded.

The Species on St. George

Thick-billed murres.--Tuck (1960) found definite seasonal and daily variation in numbers of thick-billed murres on ledges at Cape Hay in 1957. Seasonally, the numbers of older breeding birds before egg-laying were increased by prospecting birds; after egg-laying, by inexperienced early prospectors beginning nesting; and then by late prospectors visiting the ledges after hatching. A breeding population of 80% of maximum occurred from the beginning of egg-laying until the late-nesting prospectors arrived. Daily variation in numbers changed during the season with a maximum number of birds present throughout the day early in the season (June 20 - egg-laying period).

A large daily fluctuation was found at the time of hatching (July 20) with a low in the afternoon and evening and a high in the morning hours. Four daily peaks were observed on August 18 at the time of sea-going of the young. Pennycuick (1956) at Spitzbergen and Uspenski (1956) at Novaya Zemlya found no such fluctuation. Swartz (1966) found a cycle of daily fluctuation at Cape Thompson after hatching in 1959 with one daily peak. Counts made during 8 days "seemed to indicate that curves of these diurnal patterns of cliff roosting tended to be nearly congruent."

Our data for thick-billed murres show marked seasonal and daily fluctuations in numbers. We made four groups of counts, a five-day circuit of the island visiting each of three ledge sites every other day, during the season. The three areas we chose for ledge attendance counts are on opposite sides of the island at places accessible by walks of an hour or less. If we compare the curves of attendance for Rosy Finch Cove (ledge 57), Murie Cove (Ledges 21, 22, 23) and Pinnacle Point (ledge 53) we find significant changes at each site during the season, and an expression of breeding synchronization between the three sites at certain periods during the breeding cycle.

Correlations of ledge attendance curves at each site throughout the season (Table 8) demonstrate the obvious fact that there is seasonal variation in ledge attendance.

Correlations between the three sites at four times during the breeding season (Table 9) demonstrate that thick-billed murre populations on all sides of the island are significantly identical, i.e., that ledge attendance behavior is highly synchronized, at the times immediately before egg-laying and at hatching, though not during the before egg-laying or incubation stages. This lack of synchrony could possibly be due to weather effects. Weather data were collected at all sites, and conditions were very similar at all three sites. During the counts at time of incubation, temperatures ranged from 4°C to 10°C and winds from 0 to 22 kt, the average at each site being about 6-10 kt. Correlating the curves with weather did not seem necessary. The weather was remarkedly consistent during this time of year. Although the Rosy Finch Cove site did have slightly higher temperatures and higher winds at certain times of the day, these were not extreme conditions. It may have been enough to change attendance behavior patterns however.

Pre-incubation temperatures during counts ranged from -2°C to 8°C with winds from 0 to 15 kt.

The weather varied more during counts that were synchronous: -1°C to 10°C with winds 0-26 kt during the egg-laying counts, so it seems unlikely that attendance behavior is sensitive to perturbations of this magnitude. Therefore, these differences--highly synchronized behavior at the times of egg-laying and hatching and less precise synchronization before egg-laying and hatching and during incubation--seem to be real differences.

The incubation curves were taken immediately after egg-laying. It is probable that some birds were still laying while others had begun incubating. These two overlapping phases of breeding behavior result in asynchronous graphs. Unfortunately, a series of curves at the height of incubation was not obtained as we went to St. Paul and had to wait for a return flight. We assume that behavior is synchronized during incubation. This is perhaps an expression in overall activity of what others have found with regard to timing of breeding on a more finely focused level of observation, i.e., actual time of egg-laying and of hatching.

Our findings on seasonal variation in general agree with those of Tuck. A continual high rate of occupancy was found early in the season before egg-laying (15-19 June). Tuck found that early in the breeding season (June 20) a maximum number of birds was present throughout the day. This was the egg-laying date, and two small peaks were observed. At this time on St. George, the birds had established a regular fluctuation, however, with two very large peaks. Two daily peaks were found at all other times up to a few weeks after hatching when the study was terminated. A low during the day was found which occurred later as the season progressed, and a low was found overnight. The fact that we found two peaks where Tuck and Swartz (although later in the season) found one may be due to continual daylight at those higher latitudes. The close congruence we found among study areas at the times of egg-laying and hatching seems to break down during the period of incubation. We feel this is due to an overlapping with egg-laying behavior. Counts later in incubation should be congruent.

Activity patterns appear unaltered by the fact of native egging at the Rosy Finch Cove site on 24 and 26 June, although total numbers may have dropped for a while as seen at our next count on 6 July. By the time of our next circuit and our count on 4 August, numbers were back to normal and many birds had re-layed. At the time that other sites had almost completed hatching, several eggs were still being incubated on the large ledge at Rosy Finch Cove, and some eggs appeared clean and newly laid. Only two egging attempts were made at this site, however, 70 eggs total being collected on 24 and 26 June. It is customary for Aleuts to visit ledges one to two weeks after the first collection to get the newly laid eggs, but this was not done at this site this year. Possibly, our interest in the proceedings made our Aleut friends wary, and they decided to "give the birds a rest" in case our reports would be unfavorable to them. At any rate, the native impact on the total population is negligable.

Population estimations of thick-billed murres are as follows: 739,796 murres (both CM and TM) are estimated from those seen in random black and white photo quadrats (Table 25). This does not take into account the fact that murres are very difficult to see against white backgrounds when they are facing seaward or against black backgrounds when facing landward. These counts should be close for strata 1 and 2. estimates based on white birds (Tables 26, 27) are higher. Some murres are undoubtedly counted as white birds in the two higher strata, 4 and 5.

When one uses all Reference Counts for proportions (Table 26), the murres counted in photos represent at maximum numbers:

247,015 thick-billed murres in stratum 1
298,901 thick-billed murres in stratum 2
106,373 thick-billed murres in stratum 3

and when Partial Reference Counts for proportions are used (Table 27):

233,443 thick-billed murres in stratum 1
289,362 thick-billed murres in stratum 2

This is contrasted with extrapolations based on the number of white birds by using all reference counts (Table 26):

477,423 thick-billed murres in stratum 1
509,048 thick-billed murres in stratum 2
239,559 thick-billed murres in stratum 3

and by using Partial Reference Counts (Table 27):

466,773 thick-billed murres in stratum 1
536,742 thick-billed murres in stratum 2
239,559 thick-billed murres in stratum 3

Our comparisons of a few photo counts with land counts are somewhat ambiguous (Table 30), but they indicate that not all murres are counted in photos. This makes sense. We feel the extrapolated numbers for murres are closer to the actual population, especially in the higher strata. Tuck (1960 p. 112) found that more birds tended to face the sea as the season progressed and loitering increased. We did not try to verify this. The majority of murres in our photographs were facing landward. Except in extremely dense concentrations with lots of guano, the backgrounds of the photos are dark basaltic lava in areas where murres (particularly thick-billed murres) are nesting. In distant photos and on the higher cliff strata, fewer and fewer murres can be distinguished as shown by comparison of photo counts with known reference ledges (Table 30).

Photo counts of white birds (kittiwakes and fulmars) are probably more consistently accurate as distance from the camera increases. If we accept the number of white birds as correct and use this number to extrapolate to the total number of birds by using the species proportions derived from our reference ledges, we arrive at the following figures:

(a) 1,483,205 thick-billed murres if all reference ledge counts are used, not allowing for daily fluctuations in numbers;

(b) 1,210,343 thick-billed murres if we use only partial reference ledge counts and not allow for daily fluctuations;

(c) 1,659,999 thick-billed murres by including the maximum number present during the day--using all reference counts.

(d) 1,383,254 thick-billed murres by using partial reference counts including the maximum present during the day.

TABLE 30

St. George Island
1976
Comparison of Land Counts with Photo Counts

STRATUM 1						
Ledge 47	Photo	29 July 1300	Land	3 Aug 1215		
	M	146	TM	156	CM	3
	K	31	BK	20	RK	1
	F	45	F	28		
	HP	2	HP	2		
Ledge 53 Pinnacle Point	Photo	9 June 1030	Land	6 June 1245		
	M	37	TM	78	CM	1
	K	67	BK	16	RK	79
	RC	10	RC	17		
STRATUM 2						
Ledge 52	Photo	29 July 1330	Land	3 Aug 1540		
	M	47	TM	52		
	K	122	BK	103	RK	15
	F	4	F	4		
			RC	4		
Ledge 23 Murie Cove Fulmar	Photo	29 July 1510	Land	7 Aug 1500		
	M	293	TM	295		
	K	14	K	14		
	F	112	F	120		
Ledge 5	Photo	29 July 1600	Land	25 July 1700		
	M	290	TM	303		
	K	45	BK	15	RK	6
	F	29	F	10		
Ledge 33 Marvin Gardens	Photo	29 July 1450	Land	13 July 1600		
	M	799	TM	1202	CM	2
	K	484	BK	18	RK	475
	F	27	F	47		
Totals	M	1,552	M	2092		
	K	763	K	762		
	F	217	F	209		
	HP	2	HP	2		
	RC	10	RC	21		
	Total	2,544	Total	3086		

We place most confidence in the figures 1,383,254 and 1,659,999 as the total number of birds of breeding age utilizing nesting sites. This represents approximately 644,000 eggs successfully surviving until hatching.

Egg loss and replacement is a continual process that has been studied in some detail by Tuck, Swartz, and others. In addition to natural loss, there is man-caused loss by egging and by disturbance. On two occassions during 1976, aircraft passed close by (1,500 ft.) during our attendance counts, and a rough estimate of the number of birds frightened from the ledges was obtained. This is approximately 15%. At this distance, during incubation, only loitering birds were frightened, but at closer distances (observed but not quantified) aircraft noise can frighten all birds with subsequent great damage to eggs and birds. The incubating birds kick their eggs off their feet as they fly, and birds collide with one another and with falling eggs and rocks knocked from ledges.

Cliff-nesting birds on the Pribilofs are sensitive to the noise of rock falls, and a moderate rock fall can clear a nearby section of cliff in seconds. Rock falls are fairly frequent--4 were observed by us in the course of our work in 1976, 2 of them very close--and the aftermath of many others was observed on subsequent visits to sites. There has been therefore constant selection for panic behavior in birds in response to loud noise. The birds may be able to adjust to frequent loud noises resulting from oil development, etc., but it would require several disrupted seasons, and perhaps even generations.

<u>Common murres.</u>--Common murres are relatively inaccessible on St. George. Small ledges are found on the Village East and Village West cliffs and on First Bluff. The only ledge easily observed was at Rosy Finch Cove. Ledge 25, which we located later in the season has a good large sample, but it is farther away from the road (1.5 - 2 hrs walk).

The Rosy Finch Cove ledge was a favorite Aleut egging spot as we discovered later. Common murres and thick-billed murres nest in about equal numbers on a large flat ledge. Since the daily ledge-attendance patterns of thick-billed murres at this site paralleled those of other sites, perhaps we can assume that neither common or thick-billed murres were upset for long by egging activity. We found less daily fluctuation in numbers among common murres than among thick-billed murres (Fig. 12) but place little reliance on it because of our limited sample. George Hunt found similar daily changes among the two species on St. Paul. Because of this uncertainty, and the fact that common murres are only 4th in total numbers, we did not attempt to adjust their numbers to allow for daily fluctuations on a ledge-by-ledge basis as for thick-billed murres.

Using the counts of murres from photos, we find the following numbers of common murres. Based on proportions from all reference ledges, the maximum number is:

24,430 common murres in stratum 1
19,079 common murres in stratum 2
11,626 common murres in stratum 3

Based on proportions from partial reference ledges:

38,002 common murres in stratum 1
28,618 common murres in stratum 2

Again, the extrapolated figures are higher (Table 26, 27). As with thick-billed murres, we feel the extrapolated figures are more accurate.

A total of 189,693 common murres is estimated by using only partial ledge-attendance counts; 200,808 are estimated by using all reference ledge counts to determine the species proportion. Spring (1971) cites evidence that common murres tend to displace thick-billed murres on the wide flat ledges. This seems to be the case in the Pribilofs. All large flat ledges (free of sea lions as on Walrus Island) are jammed with common murres. Although thick-billed murres are found nesting with them on some of the smaller ledges, such as ledge 57, they tend to be excluded to the periphery or more uneven areas. The number of common murres on the Pribilofs seems to be limited only by nesting sites.

Red-legged kittiwakes.--Although the black-legged kittiwakes are increasing in numbers on St. Paul, this does not seem to be at the expense of the red-legged kittiwakes at this time. The data, however, are limited. Kenyon and Phillips (1969) data for red-legged kittiwakes compare with ours as follows:

area	no. of nests	
	1965	1976
Tolstoi	0	0
Zapadni	13	9
Ridge wall	33	30
Village	0	0

We find little appreciable change in 11 years.

From reference ledge counts on both islands, our averages were 1.7 birds per nest on St. Paul, and 2.0 birds per nest on St. George. At Pinnacle Point ledge St. George, a growing colony, we found an average over the entire day of 1.4 on 10 July 1976 and 1.8 on 30 July 1976. At Pinnacle Point there were 38 completed nests near time of hatching on 29 July 1975 and 56 completed nests on 30 July 1976. At First Bluff (ledge 1 St. George), red-legged kittiwakes decreased insignificantly from 43 nests in 1975 to 40 nests in 1976. Birds per nest were 1.1 at 1500 on 29 July 1975 as compared with 1.5 at 1300 on 29 July 1976.

At First Bluff (ledge 2 St. George), red-legged kittiwakes increased from 24 to 33 nests from 1975 to 1976. Birds per nest were 1.4 at 1500 on 29 July as compared with 1.7 at 1300 on 29 July 1976. There is more daily variation in average number of birds per nest than among black-legged kittiwakes so that determining a constant number (Coulson and White 1956) seems unfeasible; 1.7 - 2.00, our island-wide totals, are the best approximations.

Red-legged kittiwakes are third in total numbers on St. George. Their nesting density increases with altitude in an inverse relationship with black-legged kittiwake density. In the highest stratum they constitute over 50% of all nesters, outnumbering even the thick-billed murres. On St. Paul, there is also an increase in density with altitude which is not directly comparable with St. George because of the lower cliffs on St. Paul. The lower overall numbers on St. Paul may be due to a preference for the higher cliffs of St. George or competitive exclusion for nest sites at the lower strata. We estimate 222,703 red-legged kittiwakes on St. George using all reference ledges and 222,583 using partial-reference-ledge counts.

Red-legged kittiwakes on St. Paul number in the thousands. Since these birds are only reported to nest in small numbers in the Aleutians and on Copper Id. in the Commander group, the birds of St. George represent the bulk of the total world population of red-legged kittiwakes. The value of maintaining this population of a unique species should be carefully considered as regards oil-development activities.

Black-legged kittiwake.--Black-legged kittiwake numbers are reported by Coulson and White (1956) to average 1.2 birds per nest in the N. Atlantic. Coulson reports that the proportion of nonbreeding birds is greater in younger colonies. Our daily attendance curves show that the number of black-legged kittiwakes rises quickly in the morning and remains fairly constant throughout the day, dropping just before dark. The number of birds per nest at Pinnacle Point ledge averaged higher than Coulson's average at 1.5 on 10 July and 1.6 on 30 July 1976. Pinnacle Point seems to be a growing colony and therefore a young one (Coulson and White 1956). In 1975 near time of hatching on 29 July, there were 23 completed nests. In 1976 on 30 July, there were 31 completed nests.

On both islands, our island-wide averages of birds per nest were high; 1.457 on St. Paul and 1.56 on St. George based on reference ledge counts. Comparing our counts on St. Paul with Kenyon and Phillips (1965), we see that the black-legged kittiwake population has increased greatly in some areas:

area	no. of nests	
	1965	1976
Village	0	0
Tolstoi	249	206
Zapadni	463	539
Ridge wall (low bluffs)	221	608
Total	993	1,353

The high proportion of nonbreeding birds present may indicate that the colonies on both islands are still growing or it may be due to a regional difference in black-legged kittiwake populations. On the East Village Cliffs of St. George we found 1.4 birds/nest in a total of 108 nests on 11 July 1976. There was no change in number of nests between 1975 (110) and 1976 (108). There were 1.5 birds per nest on 11 July 1975.

Black-legged kittiwakes are about sixth in total numbers on St. George. Using all reference ledges for our species proportions, we estimate 71,484. Using only partial reference counts, we estimate 73,839.

Fulmar.--Fulmars are early breeders, being preceeded in breeding phenology only by the red-faced cormorant. They also, like the cormorant, invest more relative time in incubating and caring for young than the other birds of the Pribilof community. Nonbreeding birds characteristically occupy nest sites for several years before they begin breeding.

We made 9 all-day attendance counts of fulmars at two of our study sites. The Rosy Finch Cove site has a small population (maximum 38), and the Murie Cove site has a much larger population (maximum 129). Little daily and seasonal variation was noted. The numbers rise abruptly in the early morning, stay at the same level throughout the day, and drop rapidly just before dark. Any changes in the attendance behavior of breeding birds could presumably be masked by the large proportion of nonbreeders. Because of the inaccessibility of the ledges, we made no attempt to distinguish between individual breeding and nonbreeding birds, although we made rough estimates of productivity as the chicks grew large enough to be seen (Table 20).

We estimate 65,366 fulmars by using all reference-ledge counts as a basis for species proportions, and 79,170 by using partial-reference counts. Light-phase fulmars far outnumbered dark-phase fulmars in the ratio 153/1. George Hunt's group (pers. comm.) reported a greater proportion of dark-phase fulmars among those seen in feeding aggregations at sea around the islands.

Our productivity estimates result in calculations of about 12,000 chicks and 13,500 eggs laid (when one uses the mean of the two population estimates).

Red-faced cormorant.--Red-faced cormorants are year-round residents of the Pribilofs. Because they are present in relatively low numbers, followed only by tufted puffins, little time was spent studying them.

One study site at Pinnacle Point yielded data on daily attendance. We estimate 4,786 by using all reference-ledge counts, and 6,277 using partial-reference-ledge counts. They are confined to the two lower strata of cliffs and were not seen even loitering any higher than this.

Auklets.-- Parakeet auklets are fifth in numbers on the cliffs of St. George with least auklets second and crested auklets ninth. Least auklets are about fifth in total numbers when the inland colony at Ulakaia Hill is not included.

No satisfactory method was found to estimate the numbers of least auklets nesting among beach boulders around the perimeter of the island, but these additional birds should place them second in overall numbers. All three auklets were found nesting together in two large talus slopes on the Northwest end of the island where they were counted in our photographs. All three are diurnal (Sealy 1973, Bédard 1969), the congeneric least and crested auklets typically showing two peaks of attendance per day, and the parakeet only one.

Parakeet auklets.--Parakeet auklets were the most numerous crevice nesters on cliffs. They appeared to nest along borders between the solid rock of murre ledges and areas of vegetation. We have several good ledge-attendance counts (Fig. 14). Most show a single afternoon peak, but one on 7 Aug. at Murie Cove clearly shows two peaks. Hunt's counts from St. Paul show one peak. Parakeet auklets fed in large flocks with crested auklets and lesser numbers of least auklets within a kilometer of shore. We did not go farther from shore than this. The principal aggregations were always encountered during the day at the Northeast and Northwest points of the island. We estimate 63,721 parakeet auklets by using all reference ledges and 76,234 using partial reference counts. Parakeet auklets were found on all cliff areas of the island but were relatively scarce in the higher strata; 3,349 were counted on the surface of the two talus slopes. These numbers probably represent only one bird of each breeding pair.

Crested auklet.--Crested auklets prefer loose boulder rubble of a certain size for nesting (Bédard 1969). We found them in two large talus slopes (which we nicknamed Meditterranian and Baltic Avenue) on the Northwest side of St. George, and scattered along the cliffs in crevices and small piles of loose, fractured rock on ledges. Only one good attendance count was made of a single peak from 1100 to 2000 at ledge 25 St. George. Counts made by George Hunt's team on St. Paul on 19 and 26 July show only one peak from 0400 to 2200.

Crested auklets were seldom seen close to areas of human activities, but on the water they did not seem any more wary than the other auklets. We estimate 10,820 on the basis of all reference ledge counts, and 13,508 using partial reference counts. In addition, 760 were counted on the surface of the two large talus slopes. None were seen above stratum 3. These numbers probably represent only one bird of each breeding pair since both birds seldom loiter together during incubation.

Least auklets.--Least auklets or "choochkis" are the most amenable of the auklets to study because of the large inland colony on Ulakaia Hill. The effective nesting area extended for about 1,300 meters along the slope, and was 100-200 meters wide. We estimated the area at about 94,531 m^2 (Table 18). The slope is approximately 30 degrees. Least auklets arrived before any of the hillside was free of snow, and engaged in courtship activities above the nesting holes for increasingly longer periods during the day as the season progressed.

The birds fly inland along a slight ridge between the village and the airstrip in a corridor that varies with weather conditions. On clear days, all the auklets flying inland can be clearly seen and counted. Birds flying out to sea disperse in smaller flocks over a wider area, but can be counted on a good day from our observation point in front of the colony hillside.

Seven 24-hour inland-flight counts were made throughout the season (Figs. 19-21). One seaward count was made on a very clear day for comparison (Fig. 22). At the time of the counts made just before egg-laying, we examined the colony at mid-day when no birds were present on the surface, and found no evidence of any birds underground either. Thus the entire population seems to visit the colony at least twice a day at this time of year--once in the morning and once in the evening. The morning peak is much broader and consists of some birds making repeated trips. Birds were seen flying back out to sea and feeding in small flocks offshore at this time. Birds from these flocks would then join the main flight inland which proceeds Westward along the North coast to the bay just West of the village. In this bay the joiners would mingle with the larger flock and fly inland across the airstrip. Fewer birds fly out during the evening peak, and these birds were never seen to land near shore, or to join incoming flocks. The birds leaving in the evening drop low to the water and fly rapidly out of sight to the North.

We feel that the evening peak is largely composed on one bird of each breeding pair which, after egg-laying, spends the night ashore. If we subtract the birds that return to sea in the evening from this peak, we should have an accurate estimate of the number of breeding pairs.

This number can be compared to the figures derived from our colony quadrat counts; 108 counts of each of the three fixed quadrats were made during 5 days prior to and during egg-laying. The average of the 2nd-, 3rd-, and 4th-highest count for each day (Bédard 1969) gives a figure of 79.4 birds/100 m^2. In addition, 150 counts of randomly placed telescope quadrats give a mean density of 24.49 birds/100 m^2.

The fixed quadrat counts show a pattern of daily attendance at the colony surface that can be compared with the flight counts. They were located in high-density areas in the center of the colony. The random telescope quadrats give a mean density at the surface for the entire colony.

Eggs were found on the beaches on 12 June 1976 although none were found on the colony hillside at this time.

We estimate 34,026 on the cliffs using all reference-ledge counts, and 62,305 using partial-reference counts allowing for auklet attendance. These probably represent only one bird of each breeding pair. In addition we estimate a total of 129,048 breeding birds in the Ulakaia colony using flight-count data, and 1,609 birds on the two large talus slopes in the Northwest. None were seen above stratum 3.

If the flight counts are an accurate estimate, the random telescope counts represent about 1/4 of the total birds seen on the colony surface, and the fixed, central quadrats about 3/4 of the total.

Horned puffin.--Horned puffins are present in about the same numbers as the crested auklets. Daily attendance data was obtained at Murie Cove Fulmar Ledge and at Ledge 25. Samples are not large enough to show any definite trend except for a possible afternoon peak. They are present in the afternoon and evening. We estimate 13,537 by using all reference-ledge counts for species proportions, and 14,599 by using partial-reference counts allowing for auklet attendance. These numbers probably represent only one bird of each breeding pair since both birds are seldom seen loitering during incubation.

Tufted puffins.--Tufted puffins are the scarcest breeding seabirds on the Pribilofs(with the exception of the glacous-winged gull). This is near the northern limit of their breeding range. Very few attendance data were collected, although these birds also seem to be present on cliffs in the afternoon and evening. We estimate 1,976 puffins by using all reference ledge counts, and 2,649 when partial counts are used to allow for auklet attendance. Again, these numbers probably represent one bird of each breeding pair, since both birds seldom loiter together on the cliff during incubation.

CONCLUSIONS

The resulting numbers indicate that St. George Island has over 2 million birds and is one of the larger seabird colonies in the world and apparently the largest in the Northern Hemisphere. Krasovski (1937) estimated the murre population at Bezymyannaya Bay at 1,644,503 in two colonies (bazaars). To our knowledge, no other close estimates of colonies of this size have been made.

The major threats to these seabird populations posed by petroleum exploration will be disturbance of the ledge-nesting species by people or aircraft if St. George is ever used as a local or regional base of operations for petroleum drilling.

Considering all alternative estimates, we place the numbers of each species on St. George in 1976 at close to 2.5 million birds (Table 31).

If one may be permitted to extrapolate from these figures to St. Paul, the breeding birds on that island number about a quarter of a million (Table 32).

TABLE 31

Breeding Seabirds on St. George Id., 1976

Thick-billed murre	1,500,000
Least auklet	250,000[a/]
Red-legged kittiwake	220,000
Common murre	190,000
Parakeet auklet	150,000
Black-legged kittiwake	72,000
Fulmar	70,000
Horned puffin	28,000
Crested auklet	28,000
Red-faced cormorant	5,000
Tufted puffin	6,000
Total	2,519,000

a/ Exclusive of beach-boulder nesters.

TABLE 32

Crude Estimates of the Number of Breeding Seabirds on St. Paul Island, 1976

Thick-billed murre	110,000
Common murre	39,000
Parakeet auklet	34,000
Black-legged kittiwake	31,000
Least auklet	23,000[a/]
Crested auklet	6,000
Horned puffin	4,400
Red-faced cormorant	2,500
Red-legged kittiwake	2,200
Tufted puffin	1,000
Fulmar	700
Total	253,800

a/ Exclusive of beach-boulder nesters.

Perhaps the most feasible method of monitoring the Pribilof seabird populations in the future is by recounting our 63 reference ledges on St. George and the 35 on St. Paul. Photos of these sites accompany the data sets we have submitted to NOAA; additional sets are at (a) the Department of Wildlife Ecology, University of Wisconsin--Madison; (b) the Environmental Research Institute, Moose, Wyoming (Lance Craighead); and (c) with Dr. George Hunt, Department of Population and Environmental Biology, University of California Irvine. Any significant change in the populations on these reference ledges should reflect changes in the entire population.

One special reference site is the least auklet flight count that streams over the airstrip into the Ulakaia Hill colony. Evidence indicates that this population has declined steadily since the visit of Gabrielson in 1940. During a short visit to St. George, this flight could be counted during one day if no other ornithological work was possible. Such a count would give an index to the least auklet population although not to populations of other species.

Finally, in regard to the Aleut impact on local bird populations, we offer the opinion that in 1975-76 Aleuts had a negligible effect on all species on the Pribilofs. The birds primarily affected by hunting were the thick-billed murre and the red-legged kittiwake. Our friends on St. George estimated that a family ate around 800 birds in 1975 when ammunition was plentiful and around 300 birds in 1976 when it was expensive. About 20 such large families live on St. George.

Most hunting is done in May by wing shooting along the low cliffs and beaches. There is some crippling loss when this takes place. Birds are also shot on the water occasionally, from an outboard powered skiff. This is considerably more efficient, and we have seen 80 birds collected in about 2 hours. Wing shooting harvests mostly kittiwakes, while shooting from a boat harvests mostly murres. All birds shot are utilized.

Egg collecting as mentioned before is also negligible and affects only birds on the low, accessible cliffs or near cliff tops in what is probably marginal habitat.

Whatever disposition is made of the bird cliffs (wildlife refuge or sanctuary are possibilities), the Aleuts should certainly retain their traditional hunting and fowling rights; they will not damage the populations. The threat to cliff-nesting species, especially murres, from too-close aircraft is much greater.

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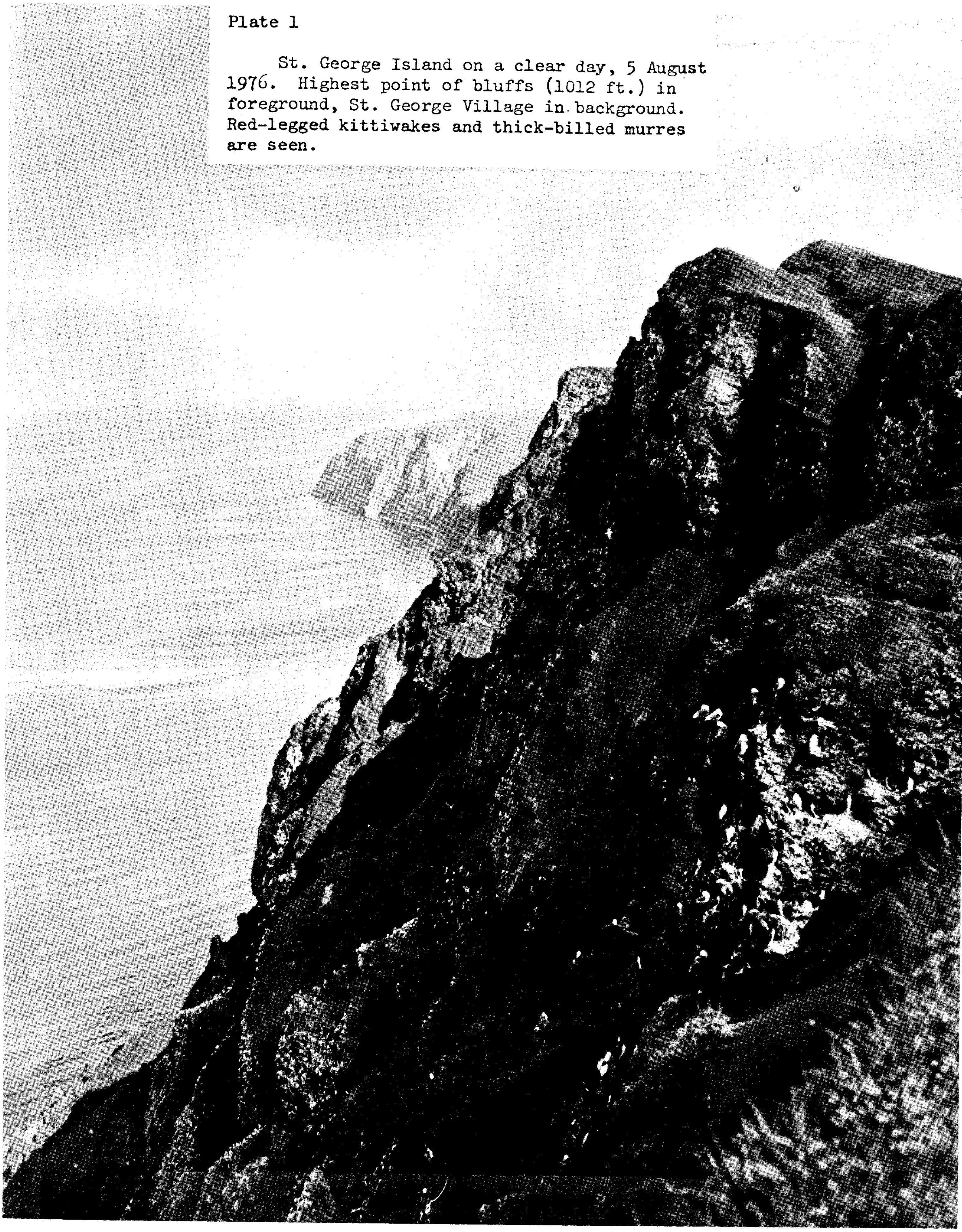


Plate 1

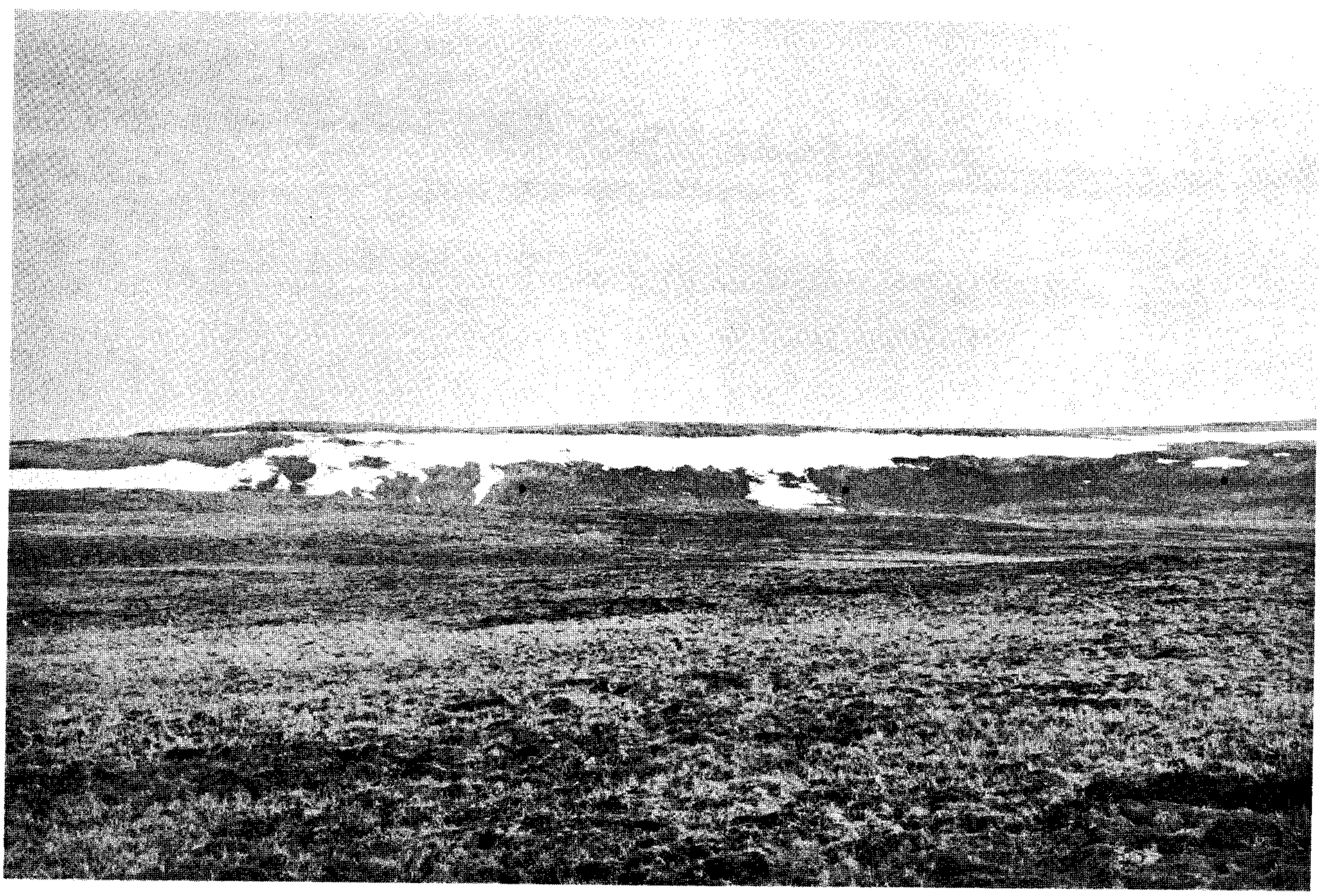
St. George Island on a clear day, 5 August 1976. Highest point of bluffs (1012 ft.) in foreground, St. George Village in background. Red-legged kittiwakes and thick-billed murres are seen.

Plate 2

St. George Island on a foggy day, June 1975. Zapadni beach, North end. R. Squibb (left) and L. Craighead counting birds on reference ledge. This is one of two short sandy beaches on the island.

Plate 3

St. George Id., Ulakaia Ridge least auklet colony (site 56) showing locations of fixed quadrats. l. to r. 175 m., 450 m., 750 m. 22 June 1976



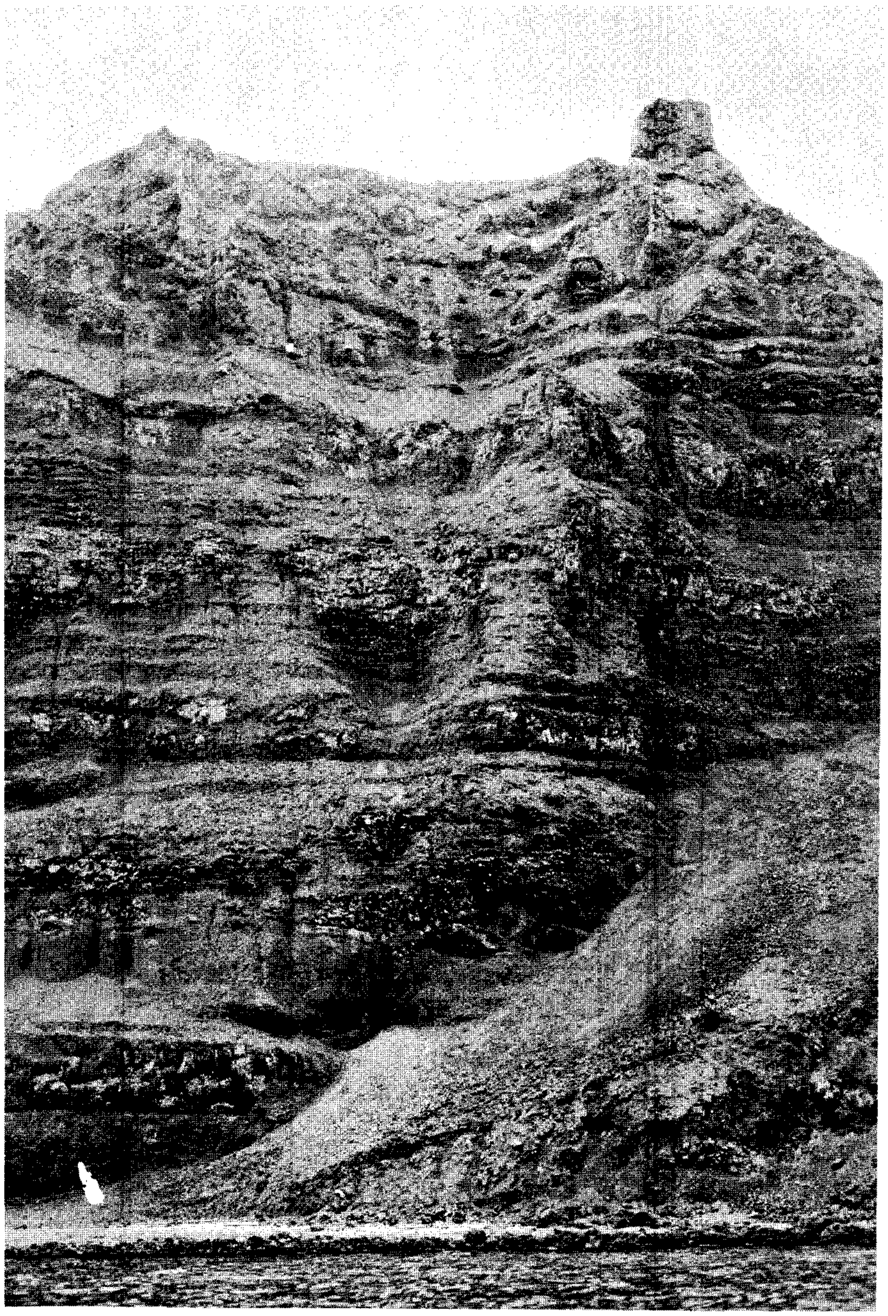


Plate 4

St. George Id., high bluffs, 5 Aug. 1976. Promontory Point on right.

Plate 5

St. George Id., Pinnacle Point (ledge 53) outlined, 29 July 1976. Daily ledge-attendance counts were carried out from the beach below this site.

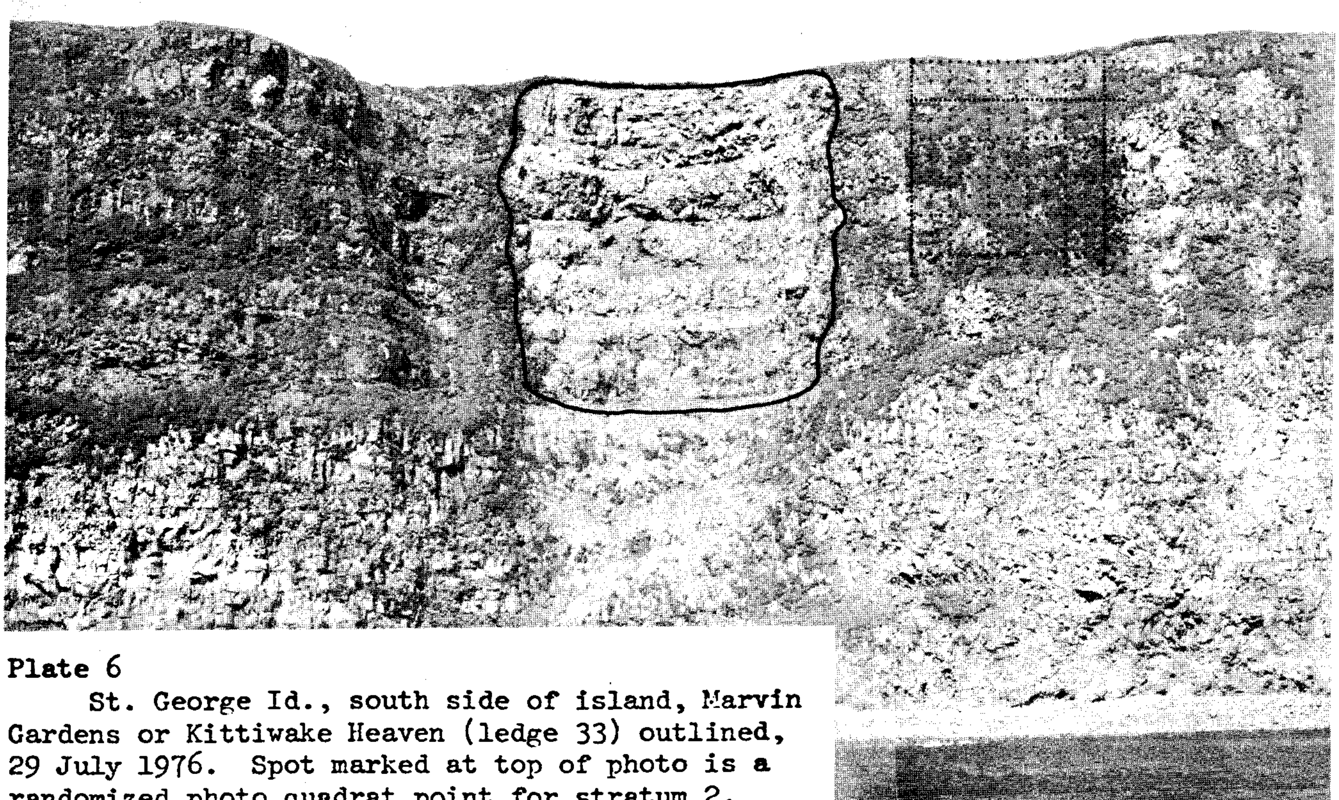


Plate 6

St. George Id., south side of island, Marvin Gardens or Kittiwake Heaven (ledge 33) outlined, 29 July 1976. Spot marked at top of photo is a randomized photo quadrat point for stratum 2. This was moved down to accomodate a 900 m^2 grid from 65 m above the beach to the cliff top (95 m in height), a sample from stratum 2. This grid is approximated by a small plastic overlay.

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Reproductive Ecology, Foods, and Foraging Areas of Seabirds Nesting on The Pribilof Islands

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1 April 1977

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I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT.

The objective of the research detailed below was to obtain baseline data on the reproductive ecology of the eleven species of seabirds nesting on the Pribilof Islands of Alaska. To this end 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 and 1976 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. Little data was 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 and June and July 1976. On two occasions the effect of airplane movements close to seabird colonies were noted.

Because natural populations normally fluctuate from year to year in timing of breeding, reproductive success, growth rates and foods used, it is premature to draw conclusions as to what is "normal" for the seabird populations in the Pribilof Islands. Such conclusions can only be drawn after a three to five year study.

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 distruptions 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 ongoing 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 two seasons' field work conducted in the summers of 1975 and 1976. The purpose of this study was to obtain baseline 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 reproductive 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 ot 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 provide useful data for predicting the consequences of spills in general.

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. Milou 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.

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 sea-birds congregated into massive colonies are alcids. In fall and winter sea ducks may occur in vast numbers, 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 stucture, 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 both showed 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 of 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 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

The reproductive studies were conducted on St. Paul and St. George Islands in the Pribilof Islands, Alaska. The ten study sites on St. Paul and the one study site on St. George used in 1975 are marked on Figures 1 and 2, respectively. In Figure 1, the study areas between Southwest Point and Einahnuhto Bluffs are referred to as "Southwest Cliffs" in this study. Areas referred to as "Ridge Wall Cliffs" are coastal cliffs in the vicinity of Ridge Wall which itself is inland. In Figure 2, the 1975 Red-legged Kittiwake study area on St. George was located just east of the Staraya Artil Seal Rookery, which is not labeled on this map.

In 1976 eleven study sites in six different areas of St. Paul Island were used (Fig. 3), and three study sites on St. George (Fig. 4). Areas on St. Paul referred to as "Gun Emplacement", "Rush Gap" and "Rush South" located at or just north of the Einahnuhto Bluffs on the west end of the island.

Foraging areas at sea were studied on three cruises. Cruise tracks are presented in figures 5 - 7 in which the approximate ship's track and the number of separate segments per 10' x 10' grid block are presented. The study effort was concentrated in the immediate vicinity of the islands in order to examine if there was a clear spatial segregation of foraging effort by different species foraging 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.

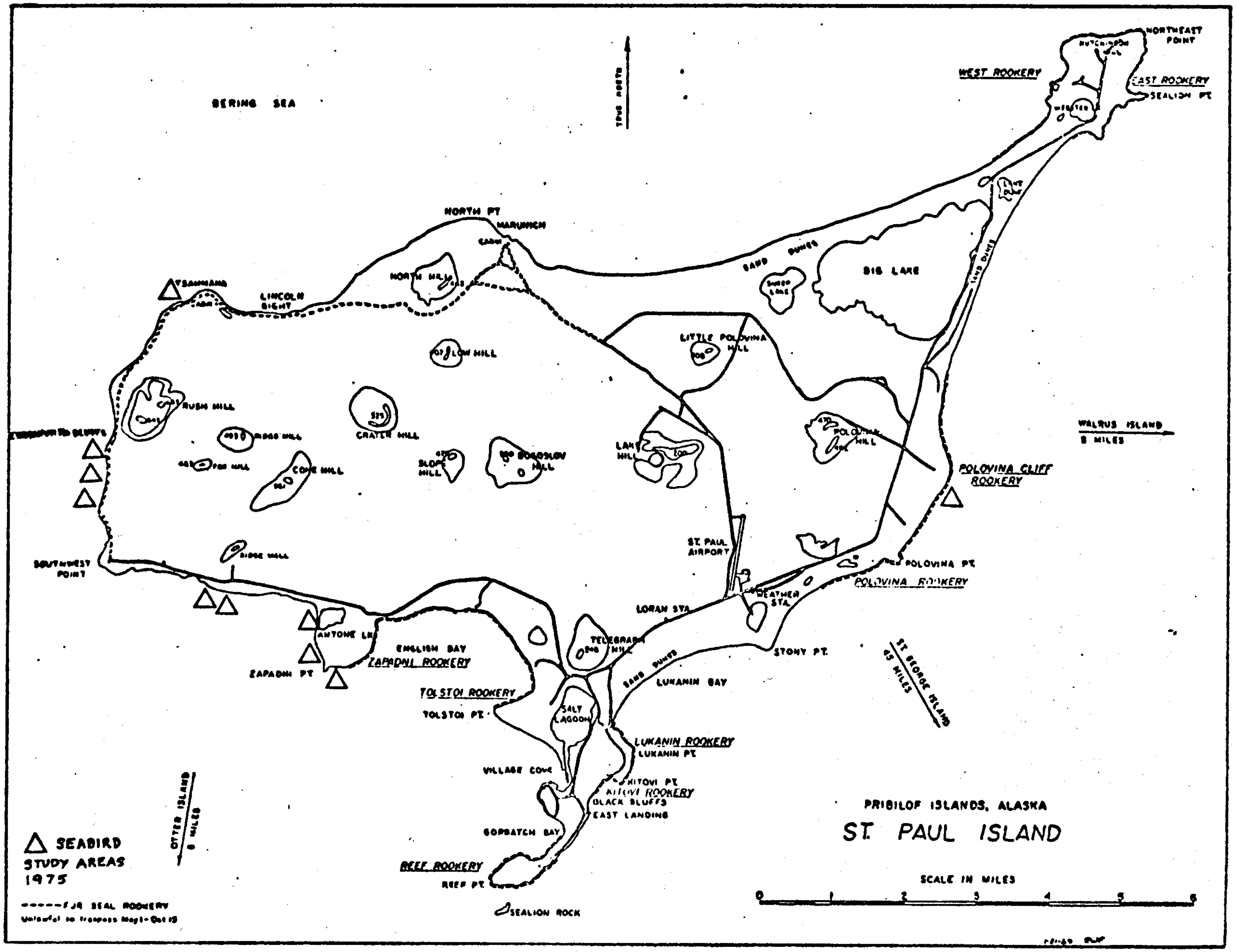

Fig.1. 1975 study sites, St. Paul Is.

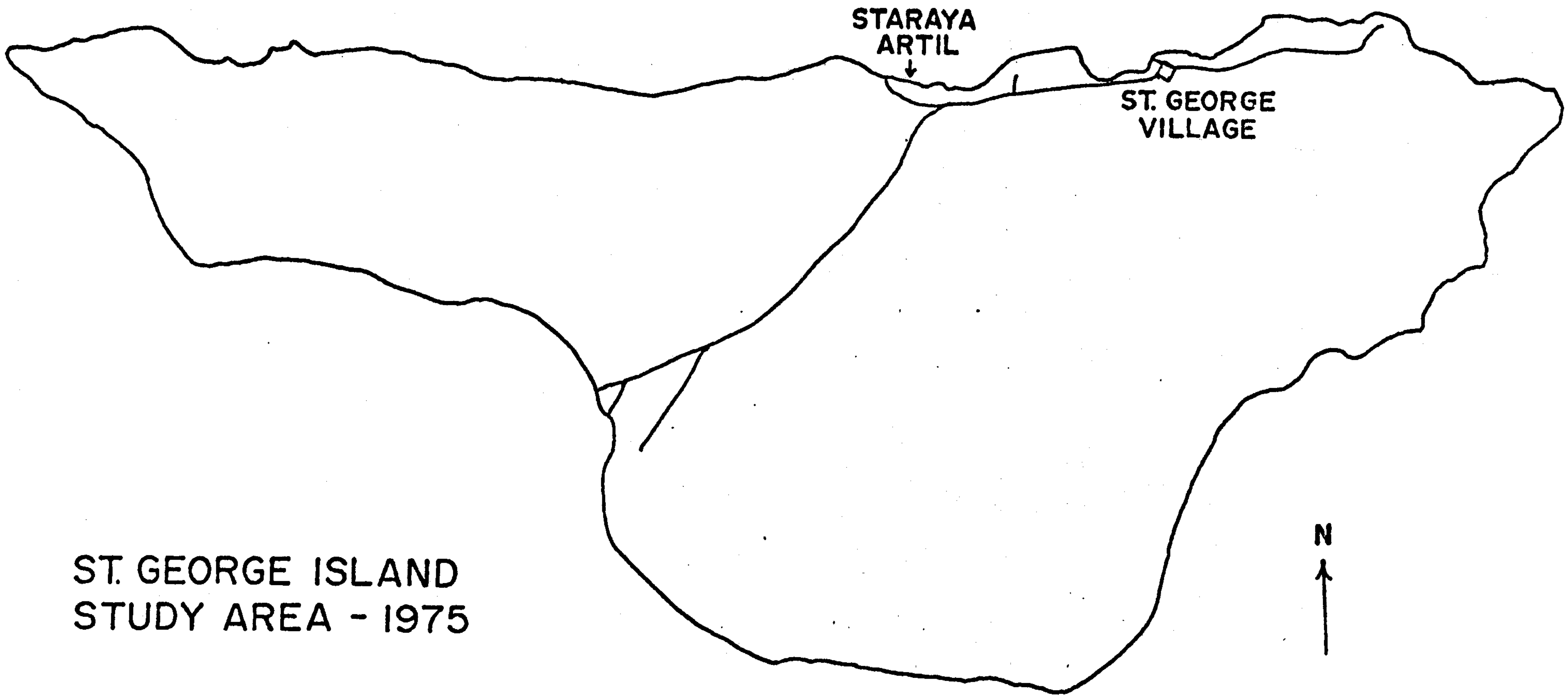

Fig.2. 1975 study site, St. George Is.

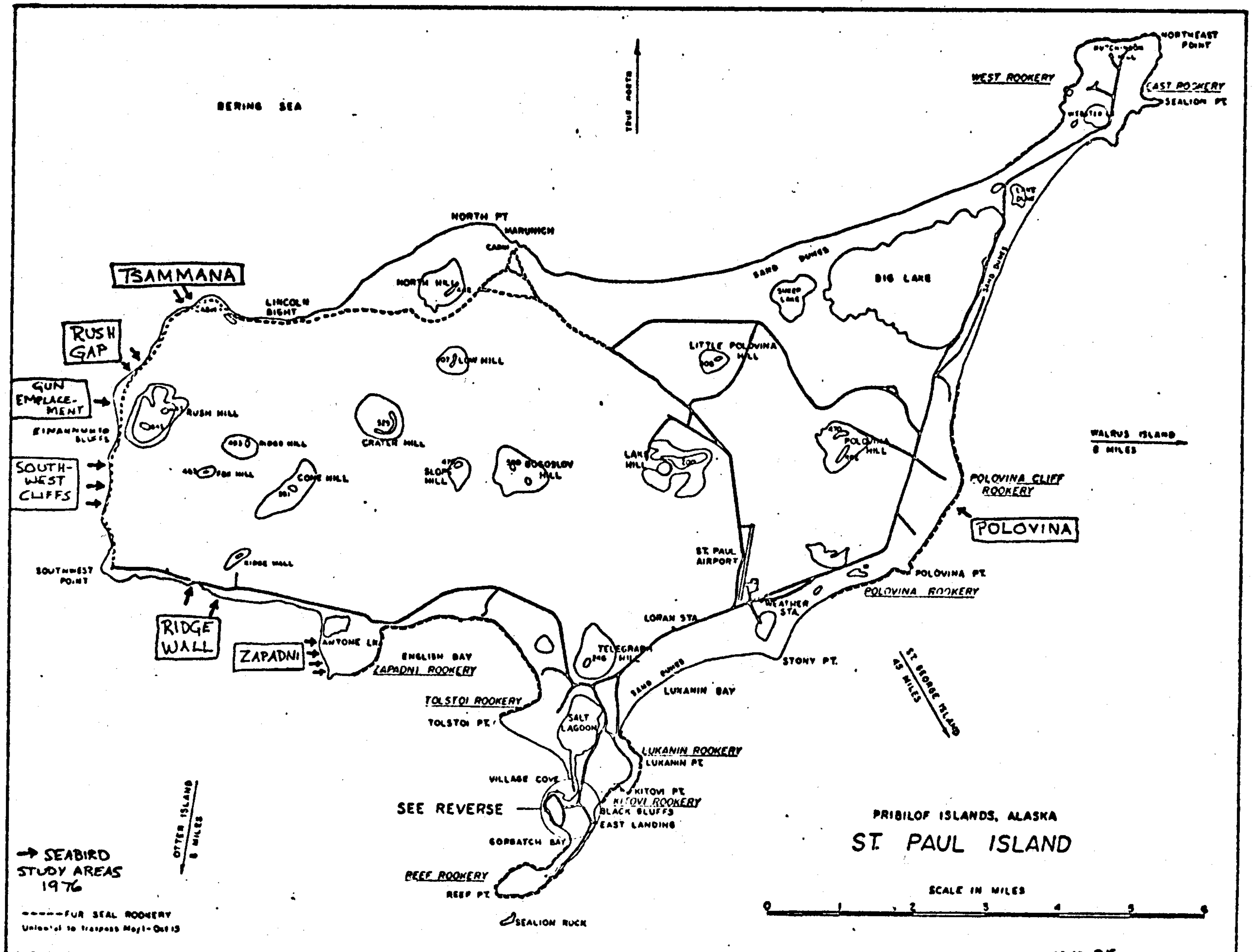

Fig. 3. 1976 study site, St. George Is.

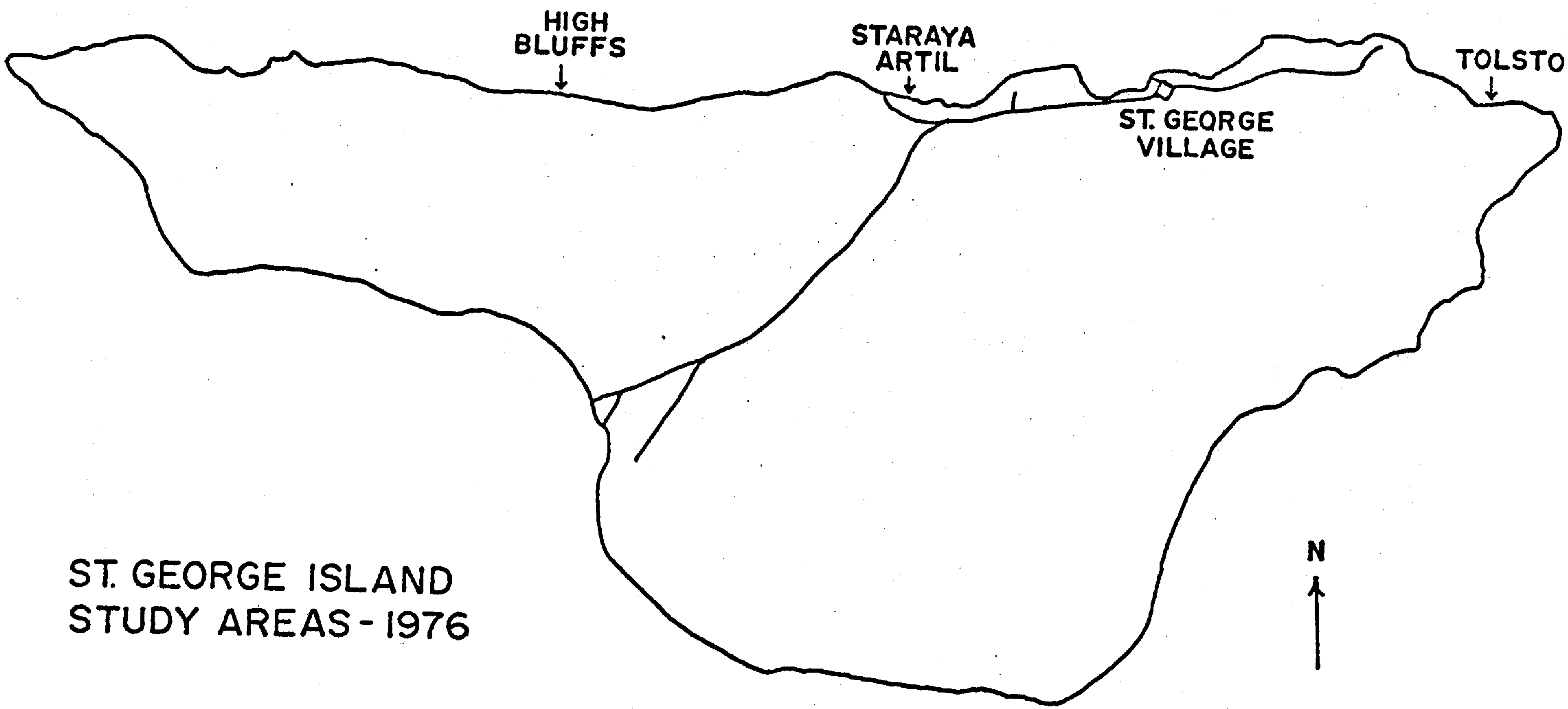

Fig. 4. 1976 study sites, St. George Is.

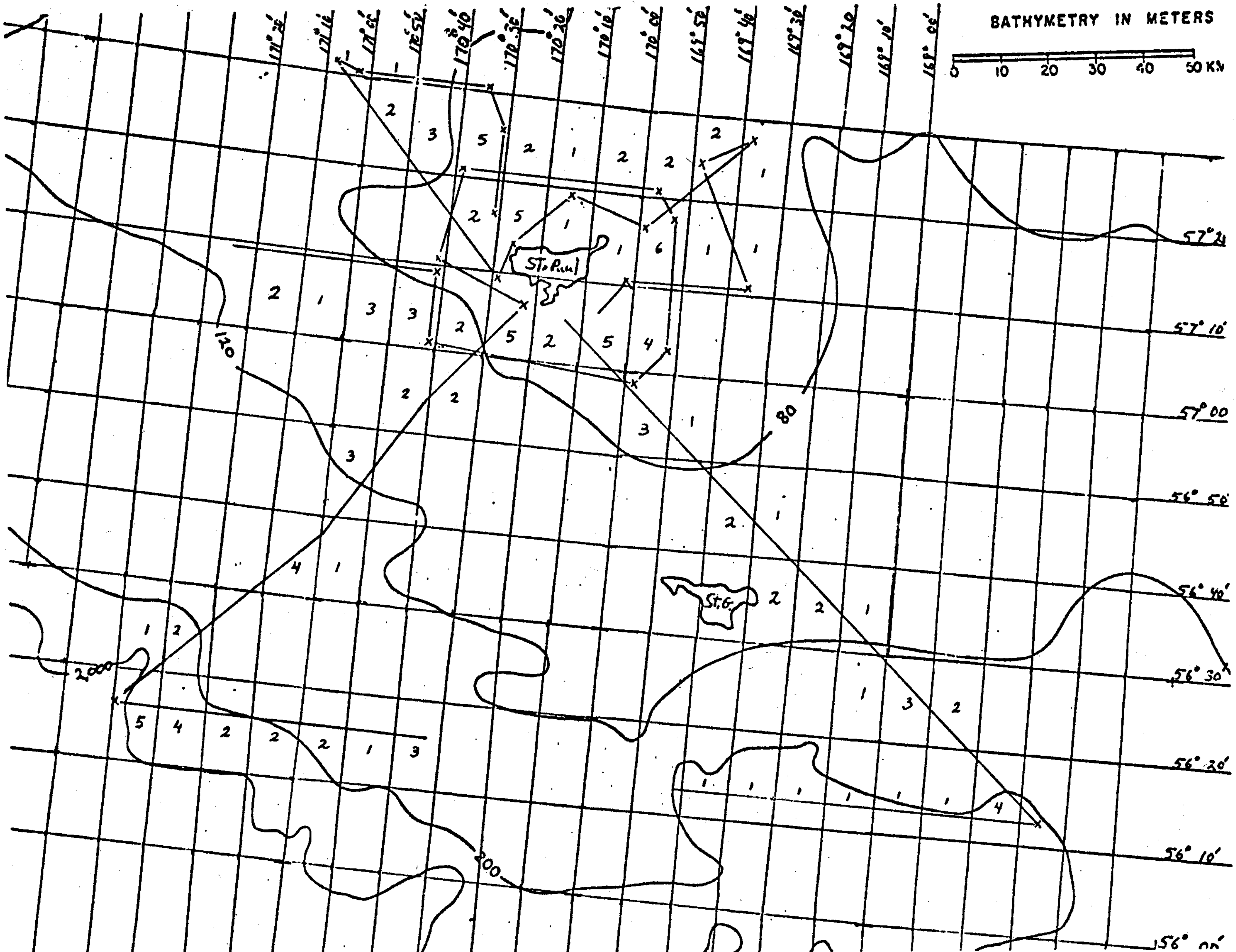

Fig. 5. Approximate cruise track of the R/V Discoverer, 21-24 August 1975. The number of transects run in each 10'x10' block is indicated.

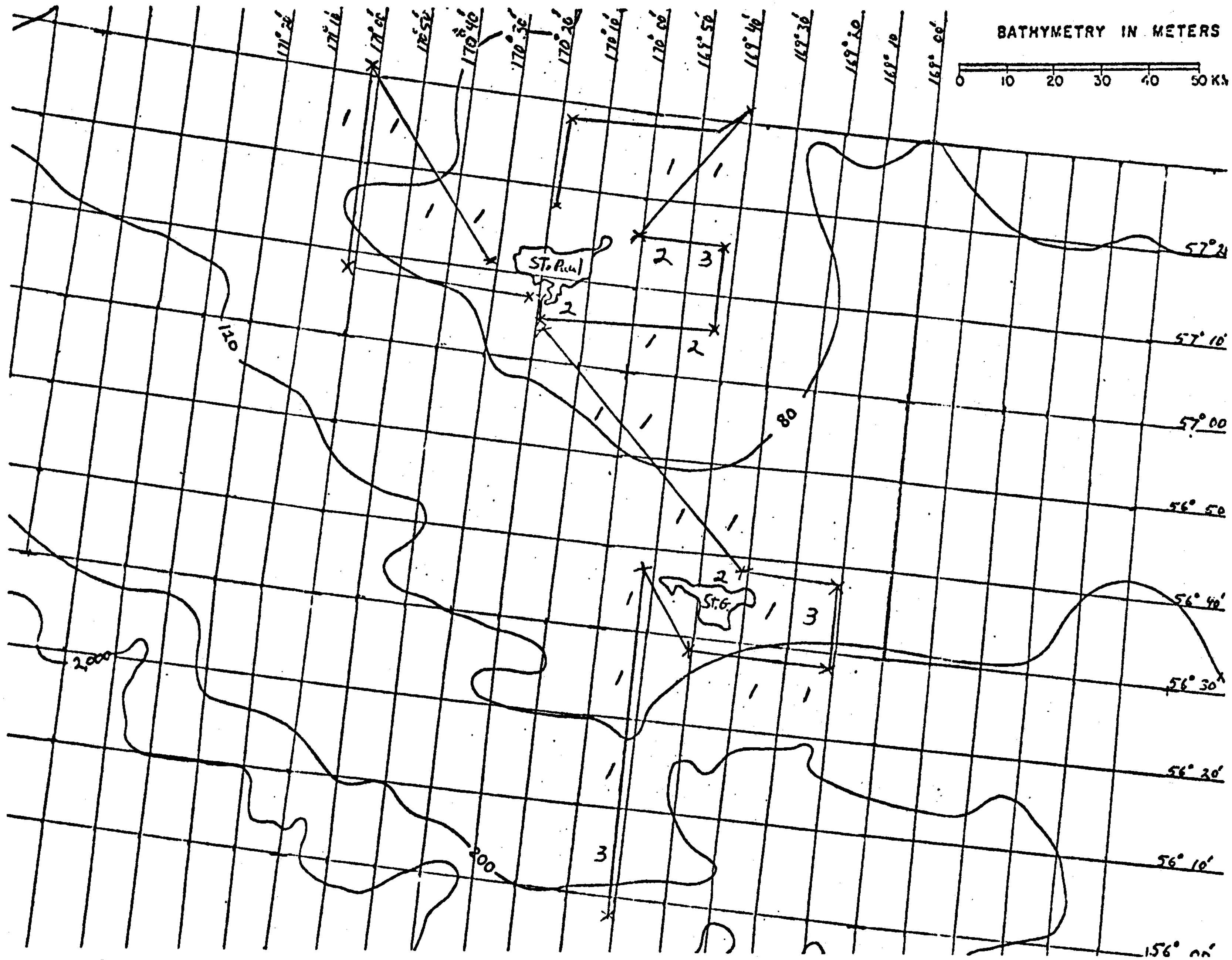

Fig. 6. Approximate cruise track of the R/V Moana Wave, 2-4 June 1976. The number of transects run in each 10'x10' block is indicated.

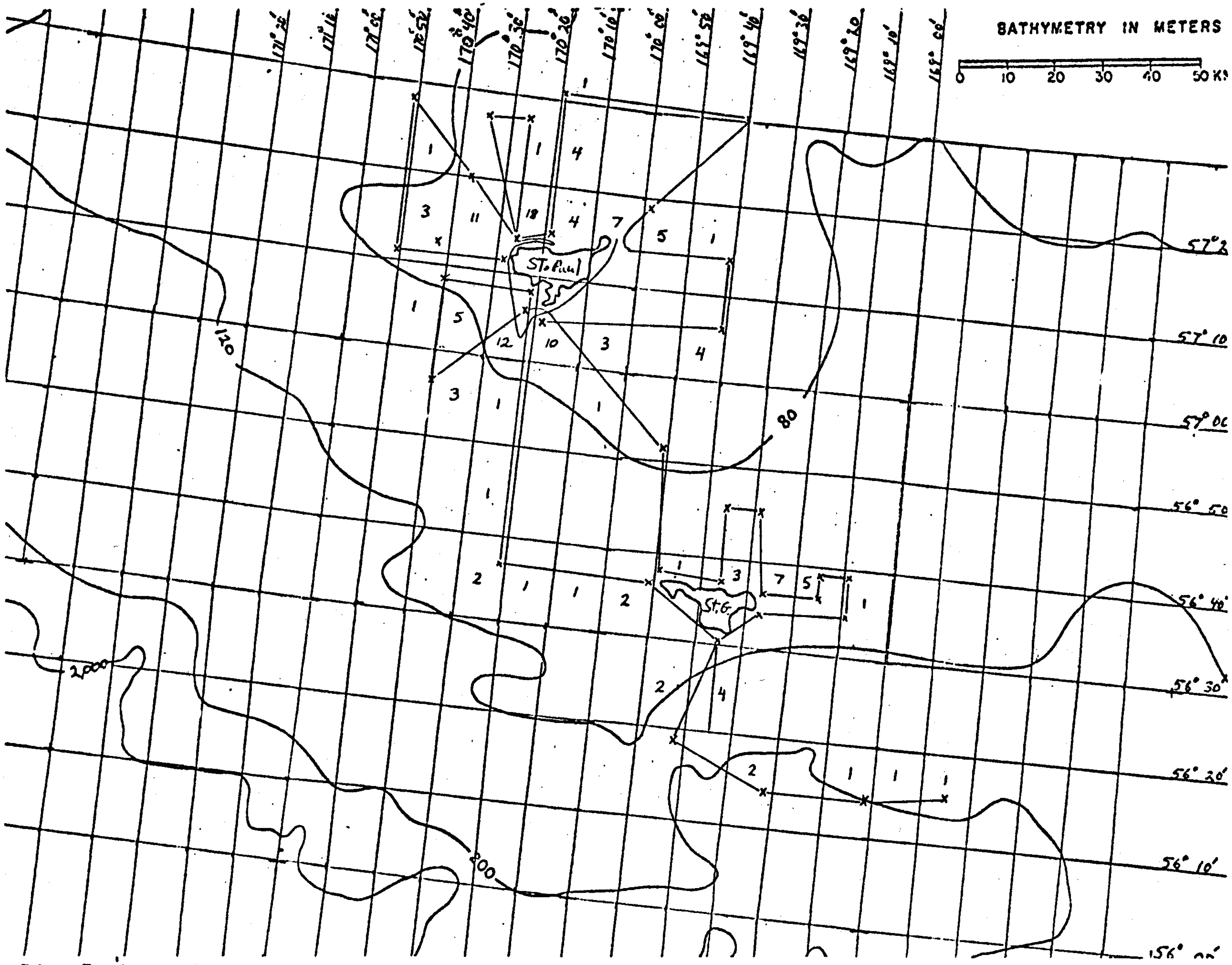

Fig. 7. Approximate cruise track of the R/V Moana Wave, 7-12 July 1976. The number of transects run in each 10'X10' block is indicated.

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 nest 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

Seabirds breeding on St. Paul Island either nest on cliff ledges or raise their young in holes and crevices in the cliffs or below ground among the rocks of boulder beaches. For those species which breed in the open (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).

Egg and chick counts for the Horned Puffin, for part of the Black-legged Kittiwake and Red-faced Cormorant samples on St. Paul Island and for all kittiwakes on St. George Island were made by using a ladder at the bottom of the cliff to reach into nests and nesting holes in the cliff. In 1976 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 the 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 the 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 eggs or chicks before they left their nesting ledges. However, some eggs were lost when the 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 not breeding. In 1976 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.

On St. George in 1976 there were no small Common Murre ledges easily observable from the cliff tops. At the Staraya Artil study site a small ledge was reachable by ladder, and reproductive success was assessed by climbing up to the site, which disturbed the adults and caused them to fly off. Thick-billed Murres were studied in the same fashion. However, disturbance at this site did not have the severe effects on hatching success as was found on St. Paul. Unfortunately, because the methods of disturbance were different on the two islands, the results from these sites may not be equivalent.

All probable nest sites located for Fulmars, 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 both summers accessible nests located in small holes in a cliff could be reached by using a ladder.

Data were taken 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 an hour and included Red-faced Cormorants and Red-legged Kittiwakes as well as small alcids. The 1976 data have been given to Dr. J. Hickey to include in his report on Pribilof Island Seabird Censuses, and will not be reported here.

3. Growth Rates

Growth rates of yound 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.

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

Information on foods were obtained in four ways: 1) adult birds were shot with a 16 gauge shot gun and their stomachs were removed and opened, 2) chick regurgitation was collected, 3) adult Least Auklets were captured in mist nets, and their regurgitation collected in 1975, 4) photographs were taken of birds (principally the Common and Thick-billed Murres) that held fish in their bills prior to feeding their young.

Birds of several species were collected once or twice each week for 3-4 hours per session. On the average, 10-15 birds were killed each week. The stomachs were removed from each bird for future content analysis. Each bird was skinned for use as a study skin or museum skeleton. The skinning process was quite time consuming, requiring 1/2 - 3/4 hours per bird. In 1976 approximately half of the birds shot were frozen after food was removed and were 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 soon 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.

Distribution of Foraging Seabirds

Three cruises were made to survey the distribution of foraging seabirds: 21-24 August 1975 on the Discoverer; and 2-4 June and 7-12 July 1976 on the Moana Wave. 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, while on the July 1976 cruise George Hunt and Zoe Eppley were aided by Doug Forsel of the U.S. Fish and Wildlife Service.

Observations were made almost continuously from dawn to dusk. When the ship was moving they were usually conducted by one observer who stood on the flying bridge (eye level 21 m above the water surface on the Discoverer, 10 m on the Moana Wave). The birds were recorded by numbers and location in one of three 100 meter segments parallel to the ship's course out to 300 meters from the ship. On the July 1976 cruise, one person recorded and either one or two made observations when bird densities were high. A course register and meterological log were kept during all observations.

In 1975 oceanographic stations were made at the completion of a two hour transect segment and in most cases, a Vertical Plankton Tow with a one meter net and a Tucker Trawl were made by other scientists on the ship. These plankton samples will be analyzed by Dr. Ted Cooney at the University of Alaska. During the oceanographic stations seabird observations were made from the middle of the flying bridge. The observer faced the bow of the ship and recorded birds by number and location in each of three concentric 100 meter wide semicircles around the ship's bow. Due to difficulty in interpreting these data, they have not been presented in this report.

During all transects and stations, care was taken to ensure that observations were of a natural situation and not of a situation influenced by the ship's presence in the water. Garbage and refuse was dumped only at the completion of the observations and a radar watch was kept for foreign and domestic fishing vessels within the radar range (50 nautical miles). Effort was made not to count circling or following birds more than once.

6. Survey of Otter and Walrus Islands

A brief survey of Otter and Walrus Islands (Figure 5) 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 1,00 feet out from the cliffs of Otter Island. Slides were taken using High-speed Ectachrome film in a Nikon camera with an 80-200 mm 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 Dough Causey and officals 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 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 m.p.h. directly at the cliff face 35 m above the highest point from a starting point 1000 m 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 1000 m, but at an altitude 100 m above the highest point of the cliff. Three passes were made at different sections of cliffs at airspeeds of 125 m.p.h., 105 m.p.h. and 90 m.p.h.

In the third set of trials, the aircraft was flown into the wind at an altitude 100 m 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 m.p.h., while one pass was at 110 m.p.h. and a fifth at 125 m.p.h. Again, no two passes were done in the same area of cliff.

VI. RESULTS

A. Data collected

Tables 1 and 2 indicated the dates on which reproductive data were collected for each species of each study site in 1975 and 1976 respectively. Included in these tables are days on which counts were made of breeding birds on the cliffs as well as days of nest checks and chick weighings.

Tables 3 and 4 provide a numerical summary of the different types of data gathered during the 1975 and 1976 seasons respectively.

TABLE 1. Work Schedule
Pribilof Islands 1975

June	Colony Work	Collecting of birds for food samples	Preparation of specimens and food samples	Motorcycle maintenance and repair	Other
7					GLH, MWH, LH, DS fly to Anchorage
8					In Anchorage, getting supplies
9					In Anchorage, getting supplies and permits
10					MWH, DS, LH, Max Thompson fly to St. Paul Is., move into House 103
11					explore for study sites
12					explore for study sites
13		X			no transportation
14					explore for study sites
15	X	X			
16	X	X			
17					GLH arrived, no transportation
18		X			explore for study sites
19	X	X			Max Thompson left
20					explore for study sites
21					review of progress to date
22	X	X			
23	X				
24	X				
25	X				
26		X	X		
27	X	X			
28	X		X		
29	X	X			
30	X				

TABLE 1 (continued)

July	Colony Work St. Paul	Colony Work St. George	Collecting of birds for food samples	Preparation of specimens and food samples	Motorcycle maintenance and repair	Other
1			X	X		
2	X					
3	X		X			Motorcycles arrived
4					X	
5	X					
6	X		X			
7	X		X		X	
8				X		
9	X					
10	X					GLH to St. George Is.
11			X	X		GLH at St. George Is.
12	X			X		GLH back from St. George
13						Data work, plan for Discoverer trip
14	X		X			
15	X					GLH left St. Paul
16	X					
17	X		X			
18	X			X		
19	X					
20						
21	X		X			
22	X			X		
23	X		X			
24	X	X	X			MWH to St. George Is.
25				X		MWH at St. George Is.
26	X		X		X	MWH at St. George Is.
27		X				MWH at St. George Is.
28	X		X			MWH at St. George Is.
29				X	X	MWH at St. George Is. DS-Photography
30	X	X	X			MWH at St. George Is.
31	X					MWH at St. George Is.

TABLE 1 (continued)

August	Colony Work St. Paul	Colony Work St. George	Collecting of birds for food samples	Preparation of specimens and food samples	Motorcycle maintenance and repair	Other
1				X		MWH at St. George Is.
2	X	X				MWH at St. George Is.
3						MWH at St. George Is.
4	X		X			MWH at St. George Is.
5		X				MWH at St. George Is.
6	X					MWH at St. George Is.
7	X		X			MWH at St. George Is.
8				X		MWH returned from St. George
9	X					Survey of Otter and Walrus Islands via Coast Guard helicopter
10	X	X**				
11	X					
12	X					Packing for move to Alaska Dormitory
13	X					Moved to Alaska Dormitory
14	X		X			Doug Causey arrived St. Paul
15				X	X	
16	X	X**				
17						
18	X					
19	X					DS and DC planning Discoverer trip
20	X	X**				DS and DC on Discoverer
21	X					DS and DC on Discoverer
22	X					DS and DC on Discoverer
23						DS and DC returned from Discoverer
24						
25	X	X**			X	
26					X	
27	X					
28	X				X	
29	X					
30	X	X**		X	X	
31					X	

** Work done by John Francis.

TABLE 1 (continued)

September	Colony Work St. Paul	Colony Work St. George	Collecting of birds for food samples	Preparation of specimens and food samples	Motorcycle maintenance and repair	Other
1	X					
2			X			MWH left St. Paul Is.
3		X**		X		
4	X					LH left St. Paul Is.
5	X				X	
6	X				X	
7						
8	X				X	
9						DS left St. Paul, only DC remaining
10	X				X	
11	X				X	
12	X				X	
13	X				X	
14					X	
15	X				X	
16	X				X	
17					X	
18	X				X	
19					X	
20					X	
21	X					
22					X	
23	X				X	
24					X	
25	X				X	
26					X	
27	X				X	
28						Storage of equipment and packing
29					X	Storage of equipment and packing
30					X	Doug Causey left St. Paul Is.

** Work done by John Francis.

TABLE 2. Work Schedule

Pribilof Islands 1976

May	Colony Work St. Paul	Colony Work St. George	Netting or collecting of birds for food samples	Preparation of specimens and food samples	Motorcycle maintenance and repair	Other
19						D. Causey arrives St. Paul, stays at Staff Quarters.
20						Relocation of equipment and unpacking.
21					X	D. Causey moves to Alaska Dorm.
22	X				X	
23	X					
24	X					
25	X					
26						
27					X	
28	X				X	
29	X					
30	X					
31	X				X	

TABLE 2 (continued)

June	Colony Work St. Paul	Colony Work St. George	Netting or collecting of birds for food samples	Preparation of specimens and food samples	Motorcycle maintenance and repair	Other
1						Made radio contact with R/V Moana Wave
2						D. Causey on R/V Moana Wave - at sea distribution of seabirds
3						D. Causey on R/V Moana Wave
4	X					D. Causey on R/V Moana Wave, returned to St. Paul
5						D. Causey moved to House103
6	X					
7	X				X	
8					X	
9	X				X	Made radio contact with R/V Surveyor
10						Helicopter survey of Otter and Walrus Islands
11					X	
12	X					Helicopter trip to Otter Island.
13						Coding data.
14	X				X	
15	X					D. Schwartz and Z. Eppley arrive St. Paul.
16					X	Coding data.
17	X					Z. Eppley and D. Schwartz instructed in use of Zodiac and motors.
18	X					
19	X					G. and M. Hunt arrive St. Paul.
20	X				X	
21	X		X			
22	X				X	
23	X		X			D. Schwartz developing prints for colony mapping.
24	X				X	Z. Eppley developing prints for colony mapping.
25	X					M. Hunt to St. George Island.
26	X	X	X			Coding of data (St. Paul).
27		X	X			
28		X	X			
29	X	X				Coding of data (St. Paul).
30	X	X	X			

TABLE 2 (continued)

July	Colony Work St. Paul	Colony Work St. George	Netting or collecting of birds for food samples	Preparation of specimens and food samples	Motorcycle maintenance and repair	Other
1		X				Photography of St. Paul bird cliffs by Zodiac
2	X					Coding of data (St. Paul).
3	X					Coding and analysis of data (St. Paul).
4	X	X				
5	X	X				Planning session for next Moana Wave cruise.
6	X	X				D. Causey left St. Paul Island.
7		X			X	M. Hunt returned to St. Paul Island. G. Hunt and Z. Eppley board R/V Moana Wave.
8	X					G. Hunt and Z. Eppley on R/V Moana Wave.
9	X			X		G. Hunt and Z. Eppley on R/V Moana Wave.
10		X	X			G. Hunt and Z. Eppley on R/V Moana Wave. B. Mayer arrives St. Paul. D. Schwartz developing photographs. Check of St. George study area by Hickey team.
11	X					G. Hunt and Z. Eppley on R/V Moana Wave.
12						G. Hunt and Z. Eppley return to St. Paul.
13	X					Revision of daily schedule.
14	X		X	X		
15	X					
16	X		X			Hickey team visiting from St. George.
17	X		X			Hickey team censusing and photographing cliffs.
18						
19	X		X			Hickey team censusing and photographing cliffs.
20	X					Hickey team censusing and photographing cliffs.
21			X			Hickey team censusing and photographing cliffs.
22	X					Hickey team returned to St. George.
23	X		X	X		
24	X		X			
25						
26	X				X	Photography of cliffs by Zodiac.
27	X				X	
28	X		X			
29	X		X		X	
30		X	X		X	Check of St. George study areas by Hickey team. Revision of daily schedule.
31	X					

TABLE 2 (continued)

August	Colony Work St. Paul	Colony Work St. George	Netting or collecting of birds for food samples	Preparation of specimens and food samples	Motorcycle maintenance and repair	Other
1	X					G. Hunt left St. Paul Island.
2	X					
3	X		X	X		
4	X					Summaries and coding of data.
5	X		X			Coding of data.
6	X					M. Hunt to St. George Island.
7	X	X				Coding of data (St. Paul).
8						Summaries of data (St. George).
9		X	X			Coding of data (St. Paul).
10	X					Coding of data (St. Paul).
11	X	X				
12		X				B. Mayer, Z. Eppley and D. Schwartz move from House 103 to Alaska Dorm on St. Paul.
13	X	X				
14	X	X	X	X		Coding of data (St. Paul).
15		X				Coding of data (St. Paul).
16	X					
17	X					Coding of data (St. Paul).
18	X					M. Hunt moved to Cottage C on St. George. B. Mayer to St. George.
19	X	X				B. Mayer returns to St. Paul.
20	X	X				Coding of data (St. Paul).
21	X		X			Data summaries and coding (St. Paul).
22						Coding of data (St. Paul).
23	X	X	X		X	
24	X	X				Finished coding 1975 data (St. Paul).
25	X					Data summaries (St. George).
26	X	X		X		
27	X	X		X		
28	X	X				
29						
30						Data summaries (St. George & St. Paul).
31	X	X				Coding data (St. Paul).

TABLE 2 (continued)

September	Colony Work St. Paul	Colony Work St. George	Netting or collecting of birds for food samples	Preparation of specimens and food samples	Motorcycle maintenance and repair	Other
1	X	X				Coding data (St. Paul).
2	X	X	X	X		
3	X	X				Data summaries (St. Paul).
4	X		X			Data summaries (St. George), coding (St. Paul).
5	X	X				
6	X	X				Data summaries (St. Paul).
7					X	Data summaries (St. George).
8				X		
9	X	X				Coding data, packing fieldequipment (St. Paul).
10	X	X			X	Data summaries (St. George & St. Paul).
11	X			X		Data summaries (St. Paul).
12				X	X	Data summaries (St. George).
13	X					Coding data (St. Paul).
14		X			X	Packing and cleaning field equipment (St. Paul).
15	X	X				Data summaries (St. Paul). D. Schwartz & Z. Eppley left St. Paul.
16	X	X				Data summaries (St. Paul).
17	X				X	Data summaries (St. Paul).
18	X				X	Data summaries (St. George).
19		X			X	Packing (St. Paul).
20	X	X			X	All motorcycles out of order. Rented another (St. Paul).
21	X				X	Packed field equipment (St. Paul).
22						B. Mayer left St. Paul. Data summaries (St. George).
23						
24		X				
25						Data summaries (St. George).
26		X				Data summaries (St. George).
27		X				Cleaning field equipment (St. George).
28						Packing and preparation of field equipment (St. George).
29						Packing.
30						M. Hunt left St. George Is.

TABLE 3

Types of Data Collected, Pribilof Islands 1975

1. Work on the Islands

Breeding Species	Number of Days of Observations at Study Sites: St. Paul Island: 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 4

Types of Data Collected, Pribilof Islands 1976

1. Work on the Islands

Number of Days of Observations at Study Sites

Breeding Species	St. Paul Island: Polovina	Zapadni	Ridge Wall	Southwest Cliffs	Gun Emplacement	Rush Gap	St. George Island: Tsammana	Staraya Artel	Tolstoi	High Bluffs	Number of nests observed: St. Paul	St. George	Number of chicks for growth data: St. Paul	St. George	Number of food samples collected: Both islands
Fulmar	-	-	-	16	-	18	-	-	-	-	23	-	-	-	-
Red-faced Cormorant	24	-	27	-	3[illegible]	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	51,544	241
July	4	146	6,057	567

B. Reproductive Success

1. Fulmar (Fulmarus glacialis)

Pairs of 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. All nest sites were inaccessible to researchers and observations were made from the cliff tops. 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 approximately 700 fulmars on St. Paul.

Two small study areas were chosen on St. Paul Is. in 1976 such that all birds were easily visible. These study areas consisted of areas of ledges rather than shallow caves, so that if a bird had a chick the chick would never be hidden from view. We hoped in choosing these areas to avoid the problems we had encountered in collecting data in 1975 when most nests studied were partially hidden. No fulmars were studied on St. George.

Only a small percentage of fulmars breeding on St. Paul actually build a nest. Since fulmars may spend several seasons visiting a nest site before actually breeding, 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. Until the chicks appear it is often very difficult to tell whether a fulmar that does not have a nest is incubating an egg.

Incubation time in fulmars is approximately 50-60 days and the chicks fledge in about two months. Although our observations of fulmars were not begun until 22 July, the first eggs must have been laid in 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.

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 about 2,500 adult Red-faced Cormorants on St. Paul, a figure which seems a bit high to us. They estimate about 5,000 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, personal communication), where they did not breed in either 1975 or 1976. 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 1976 the success of Red-faced Cormorants was followed at six study sites on St. Paul Island and one site on St. George Island. Although we do not have good data on the dates of egg-laying, we can extrapolate from the dates of chick hatching that egg laying must have begun in the last week of May and peaked in the first ten days of June. Hatching began in the last week of June and first week of July, and chicks fledged during the last two weeks of August. Cormorant chicks will stay in the area of the nest for one or two weeks after they can fly. Figure 8 shows the percentage of nests containing eggs and young at two sites on St. Paul and the one site on St. George Island. The timing of breeding of cormorants was similar on both islands in 1976 and on St. Paul similar in 1975 and 1976.

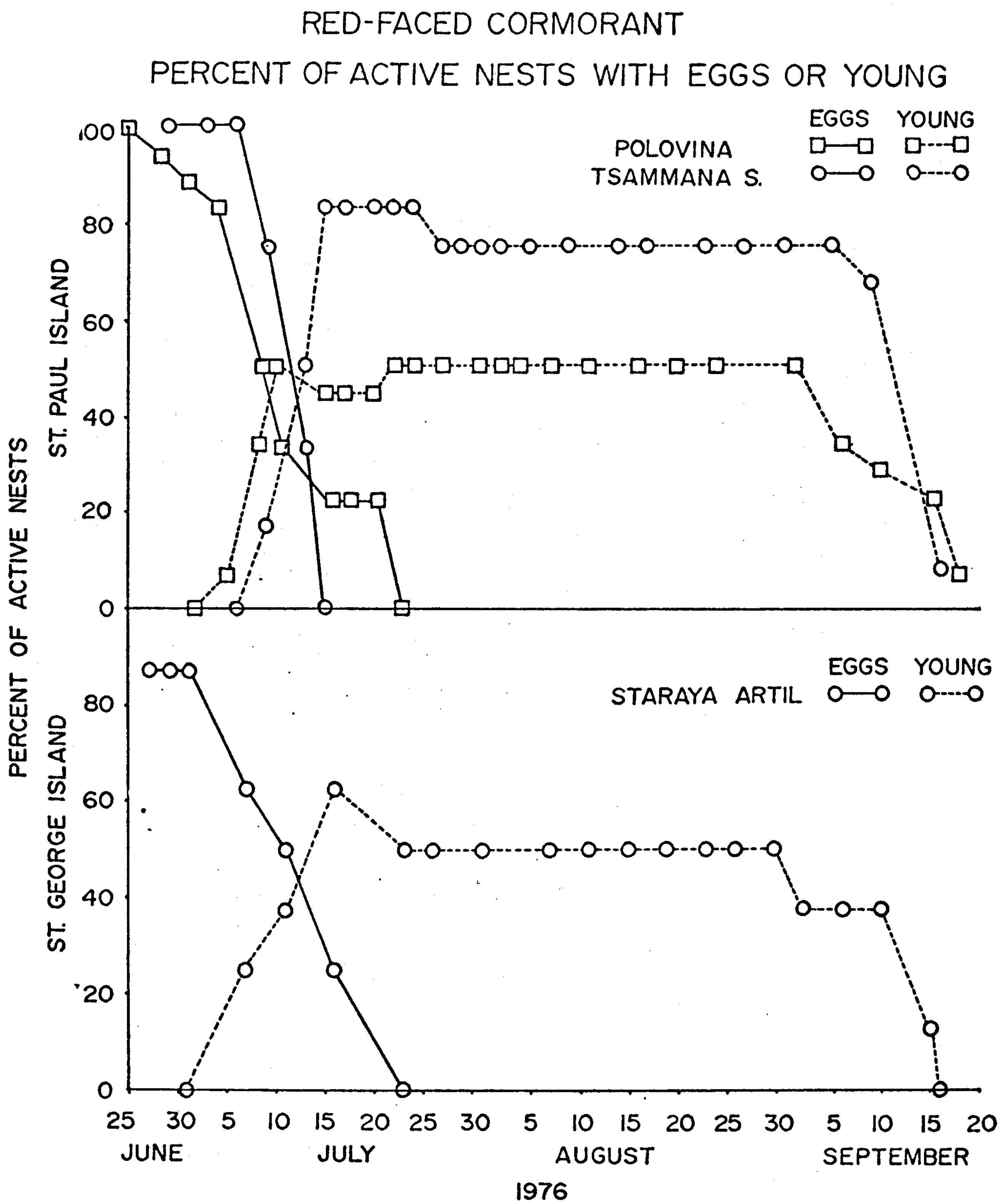

Fig. 8. Timing of breeding of Red-faced Cormorants, 1976

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.

Table 5 gives the reproductive success of 82 Red-faced Cormorant nests at the six sites at St. Paul. The data on hatching success are weak since the number of clutches of known size in 1976 is small and the fate of 15% of the eggs in those clutches is unknown.

The most important information is in the last two lines of the table. Average number of young fledged/nest was 1.52 for 79 nests which had been incubated. This yields approximately .53 chicks hatched/egg laid if the average clutch size of 2.89 egg/nest for 19 nests is representative.

Reproductive success in 1976 of cormorants at the Staraya Artil site on St. George Island is given in Table 6. Clutch size was known for all nests at this site. Overall reproductive success was 0.53 chicks fledged/egg laid, and 1.60 young fledged/nest.

Table 6 also gives a comparison of the reproductive success of cormorants on St. Paul in 1975 and 1976. Reproductive success was similar on both islands in 1976 and

TABLE 5

REPRODUCTIVE SUCCESS

RED-FACED CORMORANT - ST. PAUL ISLAND 1976

	Tsammana North	Tsammana South	Rush Gap	Gun Emplacement	Ridge Wall	Polovina	Total
Total nests	8	18	15	1	28	12	82
# incubated nests	8	17	14	1	28	11	79
# nests known clutch size	3	7	--	--	2	7	19
clutch size	3.0	1.23	--	--	3.0	1.73	2.89
% hatching success	0.0	4.8-14.3	--	--	66.7-100	47.4-68.4	25.5-40.0
total young seen	13	21	27	2	54	15	132
total young fledged	12	18	23	0	52	15	120
average young seen/incubated nest	1.63	1.23	1.93	2.00	1.93	1.36	1.67
average young fledged/ incubated nests	1.50	1.06	1.64	0.0	1.86	1.36	1.52
average young fledged/ total nests	1.50	1.00	1.53	0.0	1.86	1.25	1.46

TABLE 6

REPRODUCTIVE BIOLOGY

RED-FACED CORMORANT - PRIBILOF ISLANDS 1975 - 1976

	St. Paul 1975 (4 sites)	St. Paul 1976 (6 sites)	St. George 1976 (Staraya Artil)
Total nests studied	88	82	11
# incubated nests	79-81	79	10
average clutch size	3.00	2.89	3.00
% hatching success	38.4-44.4	25.5-40.0	56.7
# young fledged/ incubated nest	1.31-1.38	1.52	1.60
young fledged/ total nests	1.20-1.24	1.46	1.45
average growth rate (g/day gained)	61.8 ± 10.2	60.2 ± 14.7	48.5 ± 13.2
sample size - growth rates	8	17	11

slightly better on St. Paul in 1976 than in 1975.

Growth of chicks is also presented in Table 6. The 1976 data come from nests at the Polovina and Tsammana sites on St. Paul and Staraya Artil site at St. George. The average growth rates in the straight line portion of the growth curve were similar on St. Paul in both 1975 and 1976 and were lower on St. George in 1976.

3. Black-legged Kittiwake (Rissa tridactyla)

The Black-legged Kittiwake, unlike its congener the Red-legged Kittiwake, has a circum-polar and North Temperature distribution. Of the two species of kittiwakes, the Black-legged Kittiwake predominates on St. Paul Island while it is out-numbered by the Red-legged Kittiwake on St. George (about 31,000 Black-legged Kittiwakes 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.

Black-legged Kittiwake nests were chosen for study in 1976 in five areas of St. Paul Island, either because of their accessibility by ladder (Tsammana North) or because of their close proximity to nests of Red-legged Kittiwakes (Tsammana South, Rush Gap, Gun Emplacement and Ridge Wall) which, in a comparison of these two closely related species, would control for possible differences in environmental factors affecting their nesting success. On St. George Is. two sites were used, Staraya Artil and Tolstoi.

Black-legged Kittiwake nests at the five sites in 1976 were followed from prior to egg-laying in late June and early July until the chicks left the nests in September. Eggs are incubated for a month and chicks begin to fly at six weeks of age. The fledged young usually spend a week or ten days at the nest being fed by the parents before leaving the cliffs.

Of the five sites on St. Paul, data from Tsammana North are the most satisfactory because all nests could be reached with a ladder and we were able to obtain accurate counts of eggs and chicks at each visit. At the other St. Paul sites we watched from the cliff tops and were not always able to ascertain the number of eggs laid, but when the chicks grew large enough there was no problem in seeing them from a distance. At the two St. George sites nests were reached by ladder.

Reproductive success in 1976 of Black-legged Kittiwakes at the five St. Paul sites is presented in Table 7. Overall Clutch size ranged from 1-2 eggs per nest with a mean of 1.46. Hatching success in nests containing two eggs was often difficult to determine. In many cases we would find only one chick in a nest which at the last visit had had two eggs. The fate of the second egg was not known. Chicks fledged per nest at the different sites ranged from .33 to .71 with a mean of .53. Similar information from St. George Is. presented in Table 8. A comparison of the reproductive success of Black-legged Kittiwakes on both islands in 1976 and on St. Paul in 1975 is given in Table 9. Reproductive success was similar on St. Paul in both years, but higher on St. Geroge in 1976. It is likely that the figures from St. Paul in 1976 would have been higher had a rock slide at Tsammana North not destroyed 32 nests during the incubation period.

TABLE 7

REPRODUCTIVE SUCCESS

BLACK-LEGGED KITTIWAKES - ST. PAUL ISLAND 1976

	Tsammana North	Tsammana South	Rush Gap	Gun Emplacement	Ridge Wall	Total
# nests	69	20	18	13	35	155
# incubated nests	55	18	14	9	26	122
# nests with known clutch size	55	12	11	7	9	94
average clutch size	1.45	1.50	1.64	1.26	1.33	1.46
chicks hatched/ egg laid	.50-.55	.72-.83	.50-.83	.44-.55	.67-.92	.54-.66
chicks fledged/ chicks hatched	.59-.65	.60-.69	.69-1.00	.40-.50	.55-.75	.58-.70
chicks seen/ incubated nest	.73	1.00	.79	.77	.65	.76
chicks fledged/ incubated nest	.47	.61	.71	.33	.58	.53
chicks fledged/ egg laid (known clutch)	.33	.33	.50	.22	.58	.36
chicks fledged/ nest built	.38	.55	.56	.23	.43	.42

TABLE 8

REPRODUCTIVE SUCCESS

BLACK-LEGGED KITTIWAKES - ST. GEORGE ISLAND 1976

	Tolstoi	Staraya Artil	Total
# nests	16	20	36
# incubated nests	13	15	28
# nests known clutch size	7	15	22
average clutch size	1.29	1.50	1.36
chicks hatched/ egg laid	0.67-1.00	0.67-0.71	0.67-0.80
chicks fledged/ chicks hatched	0.67-1.00	0.73-0.79	0.71-0.85
chicks seen/ incubated nest	0.92	0.93	0.93
chicks fledged/ incubated nest	0.76	0.73	0.75
chicks fledged/ egg laid (known clutch)	0.67	0.52	0.57
chicks fledged/ nest built	0.63	0.55	0.58

TABLE 9

REPRODUCTIVE BIOLOGY

BLACK-LEGGED KITTIWAKE - PRIBILOF ISLANDS 1975-1976

	St. Paul 1975	St. Paul 1976	St. George 1976
Total nests studied	185	155	36
# nests known clutch size	87	94	22
average clutch size	1.44	1.46	1.36
chicks hatched/ egg laid	0.57-0.67	0.54-0.66	0.67-0.80
chicks fledged/ chicks hatched	0.57-0.68	0.58-0.70	0.71-0.85
chicks fledged/ egg laid	0.38	0.36	0.57
chicks fledged/ nest with eggs	0.54	0.53	0.75
chicks fledged/ total nests	0.44	0.42	0.58
average growth rate (g/day gained)	17.9 ± 3.4	12.8 ± 4.9	11.5 ± 2.6
# chicks with growth data	34	33	24

Growth rates of Black-legged Kittiwake chicks are presented at the bottom of Table 9. Chicks grew faster on St. Paul in 1975 than on either island in 1976.

While many Black-legged Kittiwake nests contained two eggs, no pair was able to raise two chicks to more than ten days old. In the nests in which we measured growth rates, the heavier, older chick was always the survivor. In three cases we observed the smaller chick being pecked continuously by its larger sibling, and in several other cases we found the smaller chick alive on the ground beneath its nest. It is very likely that the large chicks may try to force their smaller siblings out of the nest, where they will quickly become prey to foxes. In other parts of their range the Black-legged Kittiwake may lay up to three eggs and can fledge two or three young.

Figure 9 and Table 10 indicates the timing of the presence of eggs and chicks in Black-legged Kittiwake nests on the Pribilof Islands in 1975 and 1976. Birds on both islands in 1976 commenced breeding in the third week of June and the peak numbers of eggs and chicks occur in the same periods. In these graphs the data "calculated" on the basis of later hatching and chick data rather than "observed" resulted from the addition of nests to enlarge our sample on St. Paul after egg-laying had been completed, and a period of three weeks in July when no observers were present on St. George. Timing on St. Paul Island was about a week earlier in 1976 than 1975.

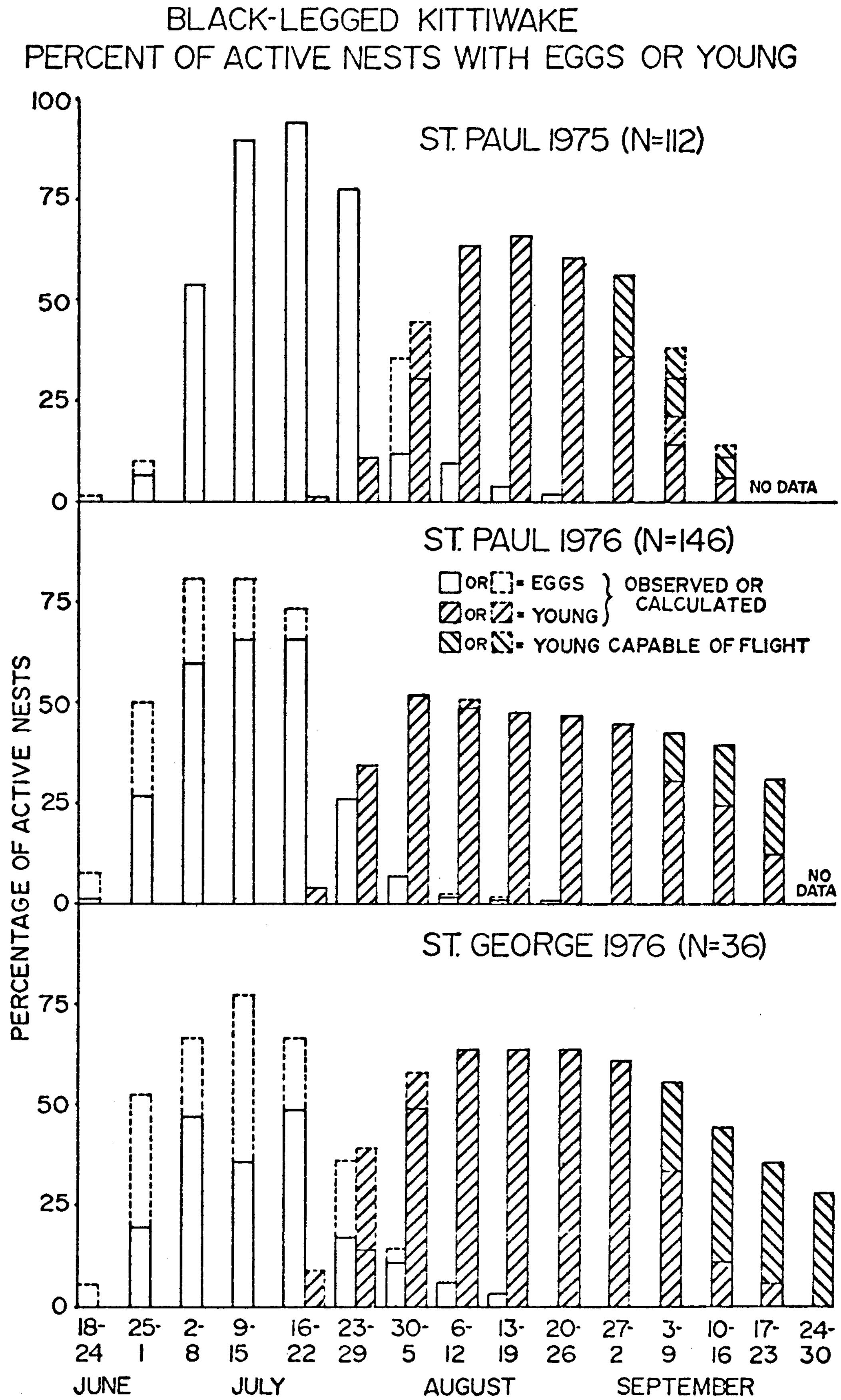

Fig. 9. Timing of breeding of Black-legged Kittiwakes 1975-1976

TABLE 10

MEAN LAYING AND HATCHING DATES

BLACK-LEGGED KITTIWAKE - PRIBILOF ISLANDS 1975-1976

		St. Paul Island - $\bar{X}$ ± S.D. (N)	St. George Island - $\bar{X}$ ± S.D. (N)
1975	Laying	5 July ± 4.4 (47)	-----
	Hatching	2 Aug. ± 4.7 (33)	-----
1976	Laying	29 June ± 3.9 (46)	1 July ± 6.6 (21)
	hatching	29 July ± 2.8 (23)	28 July ± 6.1 (17)

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 the 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. Four study sites on St. Paul were chosen in 1976 such that all nests could be viewed easily from the cliff top. Five nests in two of these areas were accessible by ladder.

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). Two study sites were used on St. George in in 1976 (Staraya Artil and Tolstoi), where nests of both species could be reached by ladder. These sites were monitored from the end of June until the end of September when the last chicks fledged. A third site (High Bluffs), where

Red-legged Kittiwakes were the only species breeding, was added in August. The inaccessible nests at this site were viewed from the cliff top (elevation 1,000 feet) and were used for measures of overall reproductive success only, since observations here were commenced after most eggs had hatched.

Unlike the Black-legged Kittiwake, the Red-legged Kittiwake lays only one egg. Reproductive success of Red-legged Kittiwakes at five sites on St. Paul and three sites on St. George in 1976 are given in Tables 11 and 12 respectively. Variation between study sites on each island was not large although overall reproduction was higher on St. Paul than on St. George. On both islands the survival of chicks that hatched was very high (94% on St. Paul, 91% on St. George), so that mortality that occurred between egg-laying and fledging happened mostly during the egg stage.

Table 13 presents a comparison of reproductive biology of Red-legged Kittiwakes on both islands in 1975 and 1976. Overall reproductive success was higher on St. Paul in 1976, when both hatching and fledging success were greater than in 1975. On St. George reproductive success was similar in both years to that on St. Paul in 1976.

Growth rates of chicks (Table 13) were similar on both islands in 1976 and on St. George Island in 1975.

Figure 10 indicates the timing of the presence of eggs and chicks in Red-legged Kittiwake nests on St. Paul and St. George Islands in 1976. In these graphs the data "calculated" on the basis of later hatching and chick data rather than "observed" resulted from the addition of nests

TABLE 11

REPRODUCTIVE SUCCESS

RED-LEGGED KITTIWAKES - ST. PAUL ISLAND 1976

	Tsammana South	Rush Gap	Rush South	Gun Emplacement	Ridge Wall	Total
# nests	9	13	11	24	18	75
# eggs laid	7	12	8	19	14	60
# chicks hatched	6	11	7	16	10	50
# chicks fledged	6	10	6	16	9	47
chicks hatched/ egg laid	0.86	0.92	0.87	0.84	0.71	0.83
chicks fledged/ chicks hatched	1.00	0.91	0.86	1.00	0.90	0.94
chicks fledged/ egg laid	0.86	0.83	0.75	0.84	0.64	0.78
chicks fledged/ nest built	0.67	0.77	0.55	0.67	0.50	0.63

TABLE 12

REPRODUCTIVE SUCCESS

RED-LEGGED KITTIWAKES - ST. GEORGE ISLAND 1976

	Tolstoi	Staraya Artil	High Bluffs	Total
# nests	35	30	24	89
# nests with eggs	26	18	--	44
# chicks hatched	20	14	--	34
% hatching success	76.9	77.8	--	77.3
# fledged	18	13	9	40
chicks fledged/ egg laid	0.69	0.72	--	0.70
chicks fledged/ nest built	0.51	0.43	0.38	0.45

TABLE 13

REPRODUCTIVE BIOLOGY

RED-LEGGED KITTIWAKE - PRIBILOF ISLANDS 1975 - 1976

	St. Paul 1975	St. Paul 1976	St. George 1975	St. George 1976
Total nests studied	51	75	28	89
# nests with eggs known	33	60	23	44
chicks hatched/ egg laid	0.55	0.83	0.83	0.77
chicks fledged/ chick hatched	0.83	0.94	0.84	0.91
chicks fledged/ egg laid	0.45	0.78	0.70	0.70
chicks fledged/ total nests	0.29	0.63	0.57	0.45
average growth rate (g/day gained)	--	13.1 ± 0.7	13.7 ± 3.7	12.4 ± 2.4
# chicks with growth data	--	5	18	32

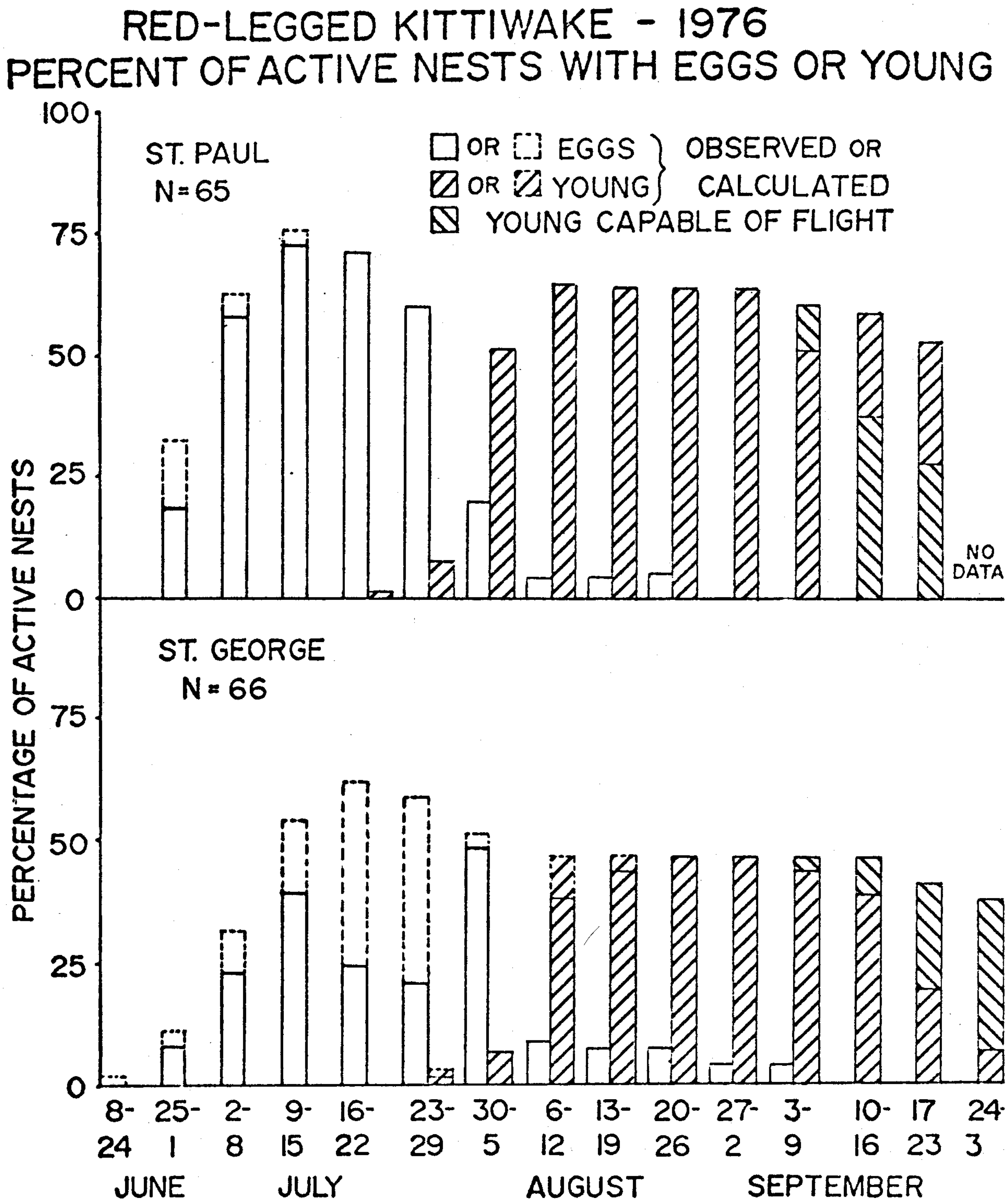

Fig. 10. Timing of breeding of Red-legged Kittiwakes, 1976

TABLE 14

MEAN LAYING AND HATCHING DATES

RED-LEGGED KITTIWAKE - PRIBILOF ISLANDS 1975-1976

		St. Paul Is. - $\bar{X} \pm$ S.D. (N)	St. George Is.- $\bar{X} \pm$ S.D. (N)
1975	Laying	6 July $\pm$ 2.0 (6)	----
	Hatching	31 July $\pm$ 0.0 (3)	1 Aug. $\pm$ 7.0 (19)
1976	Laying	3 July $\pm$ 4.5 (51)	7 July $\pm$ 6.0 (41)
	Hatching	31 July $\pm$ 4.7 (41)	5 Aug. $\pm$ 6.3 (35)

to enlarge our samples after egg-laying had been completed, and a period of three weeks when no observers were present on St. George. Mean laying and hatching dates are presented in Table 14. The Red-legs on St. George in 1976 nested slightly later on the average than these on St. Paul or those in the 1975 samples. While the earliest pairs to lay on St. George in 1976 did so earlier that those on St. Paul, the mean St. George dates are influenced by several nests in which chicks hatched in mid or late August. While timing of breeding of Black and Red-legged Kittiwakes was similar on St. Paul Island (Tables 10 and 14), in 1976 Red-legs nested later than Black-legs on St. George.

5. Common Murre (Uria aalge)

Most of the Common Murres nesting on the Pribilof Islands breed on wide ledges on which many birds of the same 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. No nest is built. The murres lay their single eggs on the bare rock and incubate by holding them on top of their feet against brood patch in the stomach area. Incubation lasts about a month. Chicks that "fledge" spend 2 1/2 - 3 weeks on the ledges before leaving to be fed at sea by the adults. During this short time on the cliffs their natal down is replaced by contour feathers, but chicks attain only about one-quarter of their adult weight before leaving the islands. The population numbers apporximately 190,000 individuals on St. George and 39,000 on St. Paul (Hickey and Craighead 1977).

Reproductive success of Common Murres on both islands in two years is presented in Table 15. Although our sample at the undisturbed site at St. Paul in 1976 is small, reproductive success was dramatically increased over the disturbed sites. Results from the St. George site are equivalent to the undisturbed site on St. Paul, although here too the sample is very small.

The presence of eggs and chicks at all 72 nest sites of Common Murres at St. Paul in 1976 is presented in Figure 11. The peak number of eggs was seen at about 7 July and the peak number of chicks from 5-15 August. The dip in the egg curve in mid July followed by a second peak a week later represents egg loss and relaying, which happens frequently due to other causes in addition to human disturbance. Although the sample from St. George Island in 1976 is very small, the peaks of egg and chick presence occur at the same time as on St. Paul. In 1975 the peak number of eggs occurred during the third week of July and the peak number of chicks during the last week of August (Fig. 12). However, this information, based on counts of a large ledge at Ridge Wall where individual nest sites were not differentiated, is not directly comparable to 1976 data. The data in 1975 were obtained after the area sustained heavy egg collecting by Aleuts on 29 June, and egg counts made after that date reflect many re-lays. Mean dates of laying and hatching on St. Paul in 1976 were 5 July ($\pm$ 7.9 days, N=83) and 29 July ($\pm$ 4.3 days, N=5) respectively. Mean hatching date on St. George in 1976 was 31 July ($\pm$ 3.0 days, N=9).

In 1975 we obtained no information on the growth of Common Murre chicks. In 1976 we obtained growth rates for seven chicks at a ledge at Zapadni Point on St. Paul and

TABLE 15

REPRODUCTIVE SUCCESS

COMMON MURRE - PRIBILOF ISLANDS 1975-1976

	St. Paul Island			St. George Island
	Disturbed 1975	Disturbed 1976	Undisturbed 1976	Disturbed 1976
# eggs laid	18	54	16	11
# chicks hatched	2	1	12	9
# chicks fledged	0	0	9	7
hatched/laid	.11	.02	.75	.82
fledged/hatched	0	0	.75	.78
fledged/laid	0	0	.56	.64

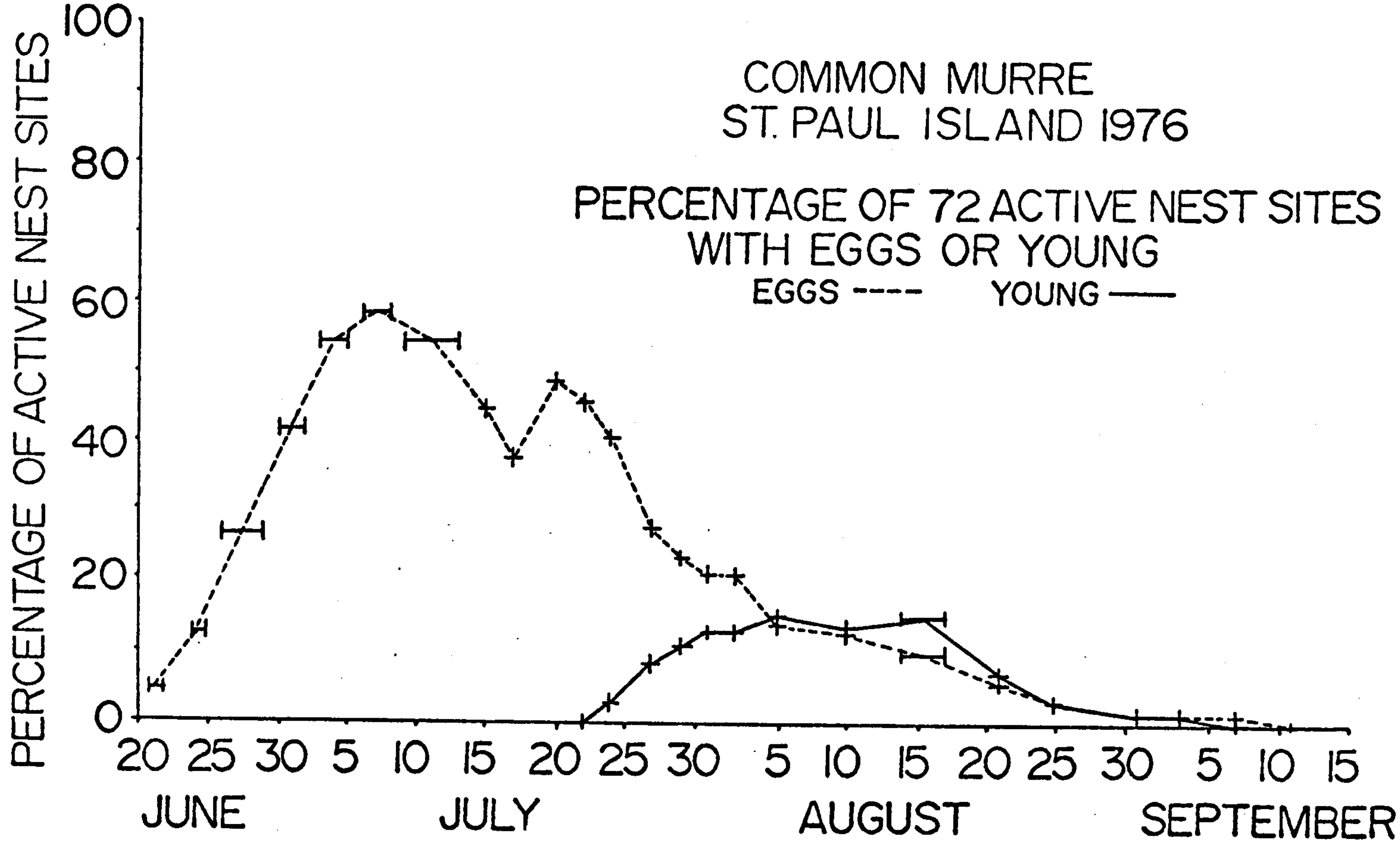

Fig. 11. Timing of breeding of Common Murres, 1976

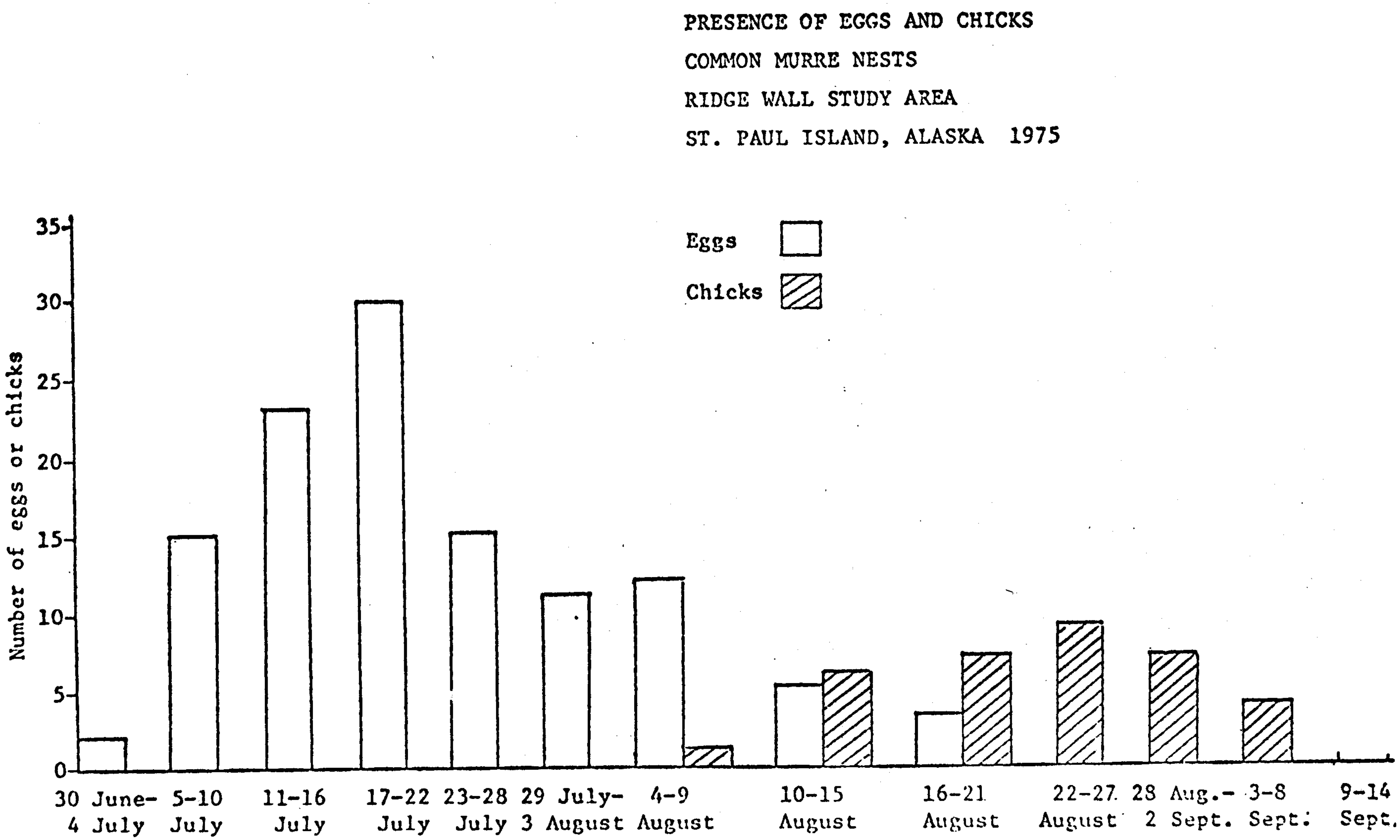

Fig. 12. Timing of breeding of Common Murres, 1975

TABLE 16

GROWTH RATES

COMMON MURRE CHICKS - PRIBILOF ISLANDS 1976

	St. Paul Is.	St. George Is.
# chicks	7	5
average g/day gained, first growing phase	6.78 ± 3.96	5.49 ± 4.21
# chicks not surviving	2	1
mean g/day gained, chicks not surviving	3.48 ± 3.92	-.55
# chicks surviving	5	4
mean g/day gained, first growing phase, surviving chicks	8.09 ± 3.47	7.00 + 2.91
mean "fledging" weight (g) surviving chicks	207.8 ± 18.8	176.8 ± 13.4

six chicks at the Staraya Artil site on St. George. In both cases the ledges were reached with a ladder, and chicks were marked with numbered plastic bandettes on one leg.

Growth rates of Common Murre chicks are presented in Table 16. Chicks grew slightly faster and "fledged" at a higher weight on St. Paul than on St. George, although the sample from each island is very small. Chicks that survived had much higher growth rates than those which died.

6. Thick-billed Murre (Uria lomvia)

The breeding biology of the Thick-billed Murre is similar to that of the Common Murre, one difference being the type of habitat where they choose to lay their eggs. Whereas the Common Murres cluster on large, broad ledges, Thick-bills tend to breed in linear formation on narrower ledges six inches to a foot wide. 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).

For studies of reproductive success (Polovina, Tsammana South, Ridge Wall and Southwest 1 and 2) five study sites were chosen on St. Paul in 1976 where Thick-billed Murres were scared away from the cliffs so observers could see eggs and chicks. In contrast to this method, four sites on Zapadni Point were chosen where the murres were not disturbed. At the Staraya Artil site on St. George, nests were checked by using a ladder.

Reproductive success of Thick-billed Murres on both islands and in two years is presented in Table 17. As in the case of the Common Murres (Table 15), on St. Paul hatching and

TABLE 17

REPRODUCTIVE SUCCESS

THICK-BILLED MURRE - PRIBILOF ISLANDS 1976

	St. Paul Island			St. George Island
	Disturbed 1975	Disturbed 1976	Undisturbed 1976	Disturbed 1976
# eggs laid	66	51	47	40
# chicks hatched	34	22	40	27
# chicks fledged	25	14	34	22
hatched/ laid	.51	.43	.85	.64
fledged/ hatched	.73	.64	.85	.81
fledged/ laid	.38	.27	.72	.55

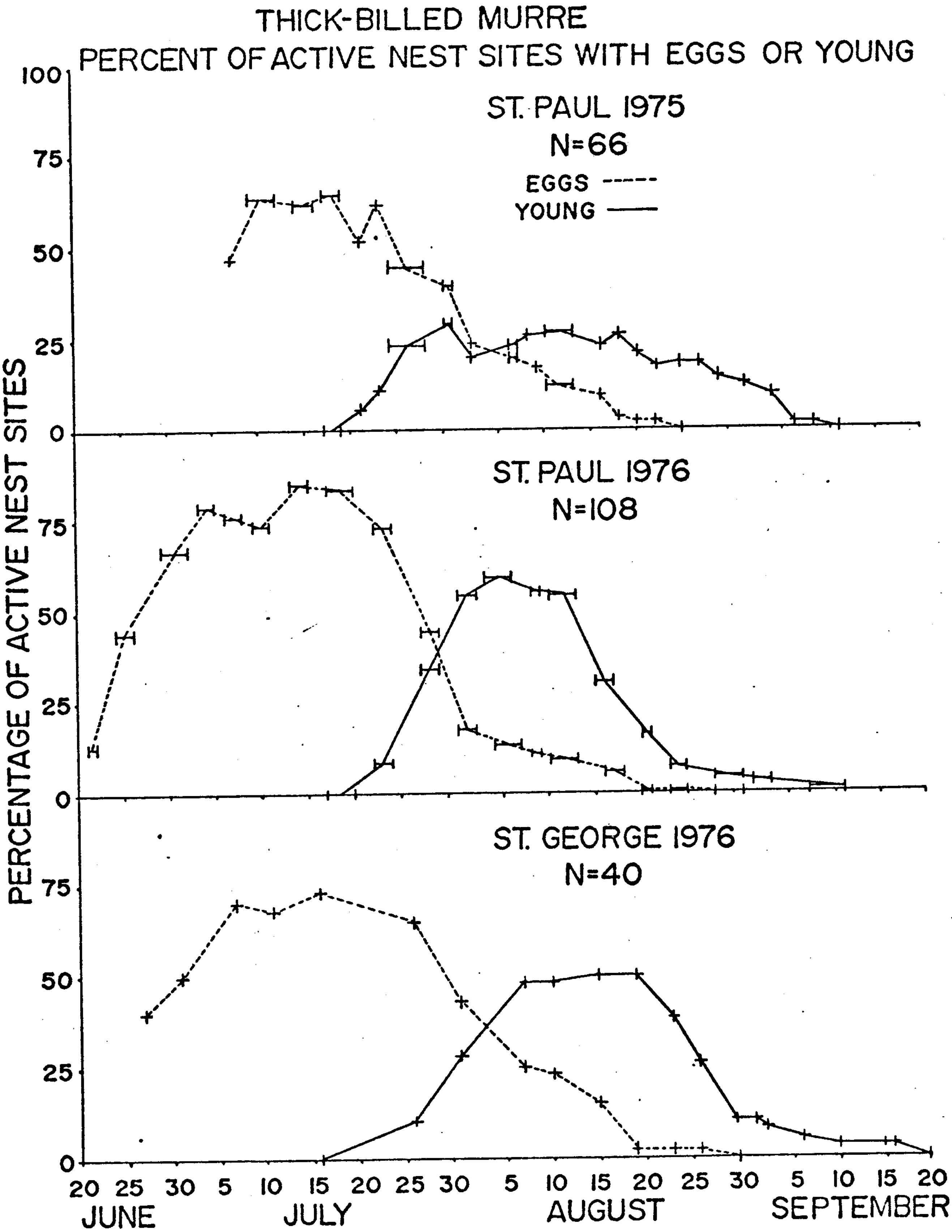

Fig. 13. Timing of breeding of Thick-billed Murres 1975 and 1976

TABLE 18

MEAN DATES OF LAYING AND HATCHING

THICK-BILLED MURRES - PRIBILOF ISLANDS - 1975-1976

		St. Paul Is. - $\bar{X} \pm$ S.D. (N)	St. George Is. - $\bar{X} \pm$ 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 Aug. ± 9.1 (26)

TABLE 19

GROWTH RATES

THICK-BILLED MURRE CHICKS - PRIBILOF ISLANDS 1975-1976

	St. Paul Island 1975	St. Paul Island 1976	St. George Island 1976
# chicks	7	16	24
average g/day gained, first growing phase	12.9 ± 5.5	11.7 ± 3.1	5.8 ± 3.0
# chicks not surviving	1	0	1
mean g/day gained, chicks not surviving	2.5	--	1.7
# chicks surviving	6	16	23
mean g/day gained, first growing phase, surviving chicks	14.6 ± 3.3	11.7 ± 3.1	6.0 ± 3.0
mean "fledging" weight (g), surviving chicks	215.0 ± 22.3	218.6 ± 28.8	147.8 ± 26.9

fledging success at the undisturbed site in 1976 was much higher than at the disturbed sites in 1975 or 1976. The techniques used to scare birds at the St. Paul disturbed sites depressed hatching success more than "fledging" success. At the site on St. George in 1976 where a ladder was used to reach the nests, hatching success was intermediate between those found between the disturbed and undisturbed sites on St. Paul, while "fledging" success was equivalent to that at the undisturbed site on St. Paul.

Figure 13 presents the timing of the presence of eggs and chicks at the individual nest sites of Thick-billed Murres on St. Paul in both years and on St. Paul in 1976. Table 18 presents the mean laying and hatching dates at Thick-billed Murre nest sites in the Pribilof Islands. The samples on St. Paul were equivalent in both years while Thick-bills on St. George were slightly later than those on St. Paul in 1976.

Growth of Thick-billed Murre chicks is given in Table 19. Chicks in our samples on St. Paul in both years grew faster and "fledged" at a higher weight than those sampled on St. George in 1976.

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).

A major effort in 1976 was made to locate Horned Puffin nests on St. Paul Island. In 1975 ten nests were located, one at Tsammana and nine at Ridge Wall. Location and periodic checking of the nests were accomplished using an extension ladder and often a flashlight. This work proved to be very time-consuming and yielded many fewer data points per unit of effort than did work with species that nest on the open cliff face. No accessible puffin nests were located in the St. George Is. study areas.

Assuming an average incubation period of 42 days (Sealy 1973), the Horned Puffin eggs on our 1976 sample were laid between 25 June and 25 July, with the peak of laying in the first week of July. Chicks hatched throughout the month of August, the last one hatching on 4 September. Puffin chicks fledge at about 40 days of age (Sealy 1973), and the last chick in our study areas should have fledged in mid-October. At the time of the last nest checks in mid September when the observers on St. Paul left the island, many chicks in our sample were still 2-4 weeks away from fledging. "Fledging" was assumed if chicks were still in the nest at the time of the last visit. Timing of breeding in 1975 was similar to 1976.

Reproductive success of Horned Puffins on St. Paul 1975 and 1976 is presented in Table 20. While hatching success was better in 1975 than 1976, overall reproductive success (chicks "fledged"/egg laid) may have been about the same in both years, assuming that chicks in 1975 that were not found in their nests at the end of the season had died and were not hiding out of reach in the back of their nest cracks.

TABLE 20

REPRODUCTIVE BIOLOGY

HORNED PUFFIN - ST. PAUL ISLAND

	1975	1976
# nests	11	27
# eggs laid	11	25
% of nests where hatching was known to have occurred	100	56
chicks fledged/ chicks hatched	.45 - 1.00	.79
chicks "fledged"/ egg laid	.45 - 1.00	.44
average growth rate g/day	11.1 $\pm$ 1.3	10.7 $\pm$ 3.7
# chicks for which growth rates obtained	8	10

Mean growth rates of Horned Puffin chicks in 1976 was similar to those found in 1975 (Table 20). Puffins hatch at a weight of about 50 grams and attain peak growth at about 30 - 35 days of age. In 1976 the mean growth rate of eight chicks still alive at the last visit was 12.0 g/day, while the average growth of two chicks which died or disappeared was 5.4 g/day.

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. No nest holes on St. Paul were accessible by ladder in either 1975 or 1976, and no nests were located in our study areas on St. George Island in 1976.

9. Crested Auklet (Aethia cristatella)

Crested Auklets are uncommon on St. Paul Island, the total population being estimated at approximately 6,000 birds (Hickey and Craighead 1977). On St. Lawrence Island, where this species breeds in huge numbers, nests are located between the large boulders of talus slopes. This type of habitat does not exist on St. Paul, and Crested Auklets must nest either in holes in the cliff or among the rocks of boulder beaches along with its smaller congener, the Least Auklet. No accessible nests were located in either year on St. Paul or in the St. George study sites in 1976.

Timing of breeding in this species is approximately the same as the Least and Parakeet Auklets. 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 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 may nest in the rocky rubble at the foot of the cliffs or in small holes in the cliff face. 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 each year.

However, we have considerable evidence for nesting phenology from the mist-netting of adult Least Auklets on the East Landing beach in 1976. 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, feathers begin growing in again in the brood patches of the adults. The first Least Auklets with brood patches beginning to grow in were netted on 10 July. Egg laying would then have commenced in the first two weeks of June. During the second half of July and the beginning of August we netted many adult Least Auklets which regurgitated food that they were bringing to their young. During this time chicks could be heard chirping among the rocks below the surface of the boulder beach. Chicks fledged at about a month of age. After the middle of August the underground chirping ceased and very few adults were seen on the island. However, in the nests we found in the cliff face, a chick nearly fully feathered was seen on 1 September 1975 and one ready to fledge was seen on 4 September 1976.

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. In 1975 we were unable to locate any possible nests on St. Paul until the end of the breeding season. 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, 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.

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. Unless the amount of field time devoted to this species were multiplied five or ten fold it is doubtful that we could obtain a larger sample in another season. 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 other species may prove to be better indicators for environmental quality than the Parakeet Auklet.

C. FOODS USED BY SEABIRDS:

Table 21 gives the overall use of foods in terms of the percentage of samples in which a particular food occurred for each species in 1975 and 1976. It is readily apparent from this table that fish are the most important source of food, followed by amphipods, euphausids and decapods. When the biomass of the various bird species is taken into account, foraging by Thick-billed Murres and possibly next by kittiwakes will have the greatest impact on the surrounding waters. These species are heavily reliant on fish and to a lesser extent on amphipods.

Tables 22 through 32 provide more detailed accounts of the foods found in individual bird species. The importance of various items is often hard to judge, because the percent of samples in which an item occurs may over-emphasize the importance of food types represented by traces of long-lasting indigestible hard-parts. On the other hand the importance of quickly digested items represented by only a trace of a hard-part may be underestimated as will be items that leave no hard-parts.

Red-faced Cormorants (Table 22) were found to take primarily bottom dwelling and shallow water fish, as well as a number of shrimp and crabs. A number of samples also contained molluscs, isopods and amphipods. However, it is unclear how many of these were primary foods of cormorants and how many represent prey items released from the stomachs of fish eaten by the cormorants. Although it is possible that cormorants would take small items while in pursuit of larger prey, it seems highly unlikely that such

TABLE 21

SUMMARY OF FOODS USED BY PRIBILOF ISLAND SEABIRDS

% SAMPLES CONTAINING FOOD TYPE

Species	# Samples with food		Mollusca		Cephalopoda		Isopoda		Copepoda		Cumacea		Amphipoda		Euphausiacea		Decapoda		Crustacean mush		Fish	
	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976
Fulmar	1	0	-	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red-faced Cormorant	38	65	7.9	7.7	-	-	-	3.1	-	-	-	-	36.8	33.8	2.6	-	65.8	53.8	-	-	92.1	95.4
Black-legged Kittiwake	120	86	0.8	-	0.8	4.7	-	-	-	-	-	-	15.0	23.3	5.0	16.3	5.0	2.3	-	-	94.1	77.9
Red-legged Kittiwake	12	97	16.7	-	-	6.2	-	-	-	-	0.8	-	16.7	22.7	-	3.1	-	11.3	-	-	83.3	95.9
Common Murre	24	36	-	-	-	-	-	-	-	-	-	-	-	8.3	-	-	8.3	-	8.3	-	91.7	100.0
Thick-billed Murre	20	31	-	-	-	3.2	-	-	-	-	-	-	5.0	9.7	-	6.5	10.0	3.2	-	-	90.0	80.6
Horned Puffin	2	11	-	-	-	-	-	-	-	-	-	-	-	36.4	-	-	-	18.2	-	-	100.0	100.0
Tufted Puffin	3	12	33.3	-	-	-	-	-	-	-	-	-	-	33.3	-	-	33.3	50.0	-	-	33.3	100.0
Parakeet Auklet	11	14	-	-	-	-	-	-	-	-	-	-	18.1	42.9	9.0	50.0	-	7.1	45.5	-	45.5	57.1
Crested Auklet	6	9	-	-	-	-	-	-	-	-	-	-	66.7	22.2	33.3	88.9	-	-	-	-	33.3	-
Least Auklet	56	37	12.5	56.8	-	-	-	2.7	41.1	100	1.8	29.7	51.8	72.8	16.1	24.3	1.8	-	25.0	-	16.1	10.8

TABLE 22 FOODS USED BY RED-FACED CORMORANTS

ST. PAUL ISLAND 1975 - 1976

	% Samples* 1975	% Samples* 1976	% Volume 1975	% Volume 1976
Sample size	38	65	1803ml	1783ml
Food Types				
Marine worm	2.6	0.0	0.1	0.0
Mollusca (not squid)	7.9	7.7	trace	trace
Isopoda	0.0	3.1	0.0	0.1
Amphipoda	36.8	33.8	4.2	2.2
Gammaridea	34.2	27.7	3.9	0.4
Hyperiida	2.6	3.1	0.2	0.1
Parathemisto libellula	2.6	1.5	0.2	0.1
Euphausiacea	2.6	0.0	trace	0.0
Decapoda	65.8	53.8	12.8	13.5
Shrimp	52.6	34.6	8.5	7.1
Lebbeus polaris	--	27.7	--	6.4
Lebbeus groenlandica	--	9.2	--	0.3
Argis crassa	--	7.7	--	0.4
Crab	52.6	35.4	3.7	3.7
Dematuras mandtii	--	18.5	--	1.3
Haplogaster spp.	--	6.2	--	1.4
All Fish	92.1	95.4	66.5	83.2
Ronquil Jordanii	--	1.5	--	0.4
Myoxocephalus	--	1.5	--	0.9

* % of Samples in which food types occurred

large birds would expend substantial amount of energy pursuing isopods or amphipods. Foods taken in 1975 and 1976 were generally similar and were present in roughly similar proportions.

Black-legged Kittiwake diets on St. Paul Island in 1975 and on St. Paul and St. George Islands in 1976 are given in Table 23 and 24 respectively. Between 1975 and 1976 on St. Paul there are considerable changes. Amphipods and euphausiids were of increased importance in 1976, while fish appeared to decline in importance. Until we have more fish otoliths and skeletal remains identified, it is impossible to say whether the apparent change in the species composition of fish taken is real.

In 1976 the Black-legged Kittiwakes on the two islands used generally the same classes of foods and in approxiamtely similar proportions. However, there are some interesting differences in the diets of the Black-legged Kittiwakes on the two islands. On St. George Island, greater amounts of cephalopods were taken, while on St. Paul Island more amphipods were used. Of the fish thus far identified, more caplin and gadids were taken by St. Paul Island birds, while more sandlance were used on St. George Island.

Red-legged Kittiwake diets for 1975 and 1976 are presented in Tables 25 and 26 respectively. In 1975 data from St. Paul Island and St. George Island were combined due to the very small number of samples obtained. When the two years are compared, cephalopods are seen to have been more important in 1975, while amphipods were more important in 1976. In 1976 there also appears to be an increase in the numbers of samples containing fish.

TABLE 23

FOODS USED BY BLACK-LEGGED KITTIWAKE

ST. PAUL ISLAND 1975

	% Sample	% Volume
Sample Size	120	1808ml
Food Types		
Mollusca (not squid)	0.8	trace
Cephalopoda	0.8	trace
Cumacea	0.8	trace
Amphipoda	15.0	3.1
Gammaridae	0.8	trace
Hyperiida	14.2	1.4
Parathemisto libellula	13.3	1.7
Euphausiacea	5.0	2.2
Thysanoessa raschii	1.7	0.5
Decapoda	5.0	0.1
Crab	5.0	0.1
Fish	94.1	94.7
Gadidae	3.3	trace
Mallotus villosus	0.8	trace

TABLE 24

FOODS USED BY BLACK-LEGGED KITTIWAKES

ST. GEORGE ISLAND AND ST. PAUL ISLAND 1976

	St. Paul % Sample	St. George % Sample	St. Paul % Volume	St. George % Volume
Sample size	56	30	557	260
Food Types				
Mollusca (not squid)	1.79	0.0	trace	0.0
Cephalopoda	1.79	10.0	trace	5.4
Amphipoda	28.6	13.3	2.3	2.0
Gammaridae	3.57	10.0	trace	trace
Hyperiida	21.4	10.0	trace	trace
Parathemisto libellula	17.6	6.7	2.0	1.9
Hyperoche medusarum	1.79	0.0	trace	0.0
Euphausiacea	16.1	16.7	11.1	5.0
Thysanoessa inermis	1.79	6.7	3.2	2.3
Thysanoessa longipes	1.79	0.0	3.1	0.0
Thysanoessa raschii	1.79	6.7	0.2	1.5
Thysanoessa spinifera	3.57	0.0	trace	0.0
Thysanoessa spp.	0.0	10.0	1.4	0.4
Decapoda	1.79	10.0	0.5	0.0
Shrimp	0.0	10.0	0.0	trace
Crab	1.79	0.0	0.5	0.0
All Fish	75.0	83.3	87.1	87.7
Larval Fish	1.79	13.3	trace	9.2
Mallotus villosus	35.7	6.7	31.6	4.6
Gadidae	35.7	10.0	32.9	11.5
Stichaeidae	1.79	0.0	1.3	0.0
Ammodytes hexapterus	3.57	10.0	1.3	2.3

TABLE 25

FOODS USED BY RED-LEGGED KITTIWAKES

PRIBILOF ISLANDS 1975

	% Sample	% Volume
Sample size	12	75ml
Food Types		
Cephalopoda	16.7	trace
Amphipoda	16.7	trace
Gammaridae	16.7	trace
Fish	83.3	100%
Gadidae	8.3	trace

TABLE 26

FOODS USED BY RED-LEGGED KITTIWAKES

ST. GEORGE AND ST. PAUL ISLANDS 1976

	St. George % Sample	St. Paul % Sample	St. George % Volume	St. Paul % Volume
Sample size	50	47	739ml	364ml
Food Types				
Cephalopoda	4.0	8.5	trace	1.4
Amphipoda	24.0	24.0	0.9	6.6
Gammaridea	12.0	2.1	0.8	trace
Hyperiida	8.0	21.3	0.1	6.6
Parathemisto libellula	2.0	19.1	trace	6.6
Hyperoche medusarum	8.0	0.0	0.1	0.0
Euphausiacea	0.0	6.4	0.0	0.6
Thysanoessa spinifera	0.0	2.1	0.0	0.6
Decapoda	14.0	8.5	0.8	0.3
Shrimp	10.0	2.1	0.7	0.3
Crab	4.0	6.4	0.1	trace
All Fish	100.0	91.5	98.2	90.4
Mallotus villosus	8.0	4.3	6.8	5.2
Gadidae	8.0	24.0	6.8	9.9

When the diets of Red-legged Kittiwakes on St. Paul and St. George Islands for 1976 are compared (Table 26), one can see that cephalopods and euphausiids were more important on St. Paul, while decapods and fish were somewhat more important on St. George. However, these differences are relatively small and may have little biological significance.

When the diets of the two species of Kittiwake are compared (data from both islands combined, Tables 27 and 28), it can be seen that the two kittiwakes have basically similar food habits. Red-legged Kittiwakes do take somewhat more squid and fish than do Black-legged Kittiwakes while the latter species takes more euphausiids and decapods than do Red-legged Kittiwakes. On the basis of the 1975 and 1976 data (Table 27 and 28), it also appears that the two kittiwakes tend to take different kinds of fish.

The diets of Common and Thick-billed Murres for 1975 and 1976 are presented in Table 29. Common Murres appeared more specialized on fish in both years, with Thick-billed Murres taking larger amounts of amphipods, euphausiids and decapods. Common Murres also appeared to take more gadids, while Thick-billed Murres took more Cottidae. It remains to be seen whether these differences will be repeated in a third year of study. Differences between the two years are modest. In 1976 both species took more amphipods and fewer decapods. In 1976 Common Murres took more fish and Thick-billed Murres less fish than in 1975.

Data on the food habits of Horned and Tufted Puffins for 1975 and 1976 are presented in Table 30. Given the small sample sizes,

TABLE 27

FOODS USED BY BLACK-LEGGED AND RED-LEGGED KITTIWAKES

PRIBILOF ISLANDS 1975

	Black-legged Kittiwake % Sample	Red-legged Kittiwake % Sample	Black-legged Kittiwake % Volume	Red-legged Kittiwake % 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
Gammaridae	0.8	16.7	trace	trace
Hyperiida	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 28

FOODS USED BY BLACK-LEGGED AND RED-LEGGED KITTIWAKES

PRIBILOF ISLANDS 1976

	Black-legged Kittiwake % Sample	Red-legged Kittiwake % Sample	Black-legged Kittiwake % Volume	Red-legged Kittiwake % Volume
Sample size	86	97	817ml	1103ml
Food Types				
Cephalopoda	4.7	6.2	trace	0.5
Amphipoda	23.3	23.0	2.0	trace
Gammaridae	3.5	7.2	trace	0.5
Hyperiida	17.4	14.4	trace	trace
Parathemisto libellula	12.0	10.4	2.0	2.2
Hyperoche medusarum	1.2	4.1	trace	trace
Euphausiacea	16.3	3.1	16.82	0.29
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
Crab	1.2	5.2	.40	.09
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
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 29

FOODS USED BY THICK-BILLED MURRES AND COMMON MURRES

PRIBILOF ISLANDS 1975 - 1976

	Common Murre % Sample		Thick-billed Murre % Sample		Common Murre % Volume		Thick-billed Murre % Volume	
	1975	1976	1975	1976	1975	1976	1975	1976
Sample size	24	36	20	31	69 ml	148 ml	18 ml	270 ml
Food Types								
Cephalopoda	0.0	0.0	0.0	3.2	0.0	0.0	0.0	trace
Amphipoda	0.0	8.3	5.0	10.0	0.0	2.0	trace	8.1
Hyperiida	0.0	0.0	5.0	10.0	0.0	0.0	trace	0.0
Parathemisto libellula	0.0	5.5	5.0	6.5	0.0	1.4	trace	8.1
Euphausiacea	0.0	0.0	0.0	6.5	0.0	0.0	0.0	5.2
Decapoda (crab)	8.3	0.0	0.0	3.2	trace	0.0	5.6	trace
Total Fish	91.7	100.0	90.0	80.6	98.6	97.9	88.9	72.6
Mallotus villosus	--	8.3	--	6.5	--	6.1	--	4.1
Gadidae•	29.2	41.7	25.0	19.4	trace	68.2	trace	17.0
Theragra chalcogramma	--	25.0	--	19.4	--	49.3	--	17.0
Stichaeidae	--	0.0	--	6.5	--	0.0	--	7.8
Cottidae	--	2.8	--	12.9	--	4.1	--	21.1
Unidentified crustacean and fish remains	8.3	2.8	0,0	9.7	trace	0.7	0.0	3.3

TABLE 30

FOODS USED BY HORNED PUFFINS AND TUFTED PUFFINS

ST. PAUL ISLAND, ALASKA 1975 - 1976

	Horned Puffin % Sample		Tufted Puffin % Sample		Horned Puffin % Volume		Tufted Puffin % Volume	
	1975	1976	1975	1976	1975	1976	1975	1976
Sample size	2	11	3	12	1ml	70ml	1ml	55ml
Food Types								
Mollusca (not squid)	0.0	0.0	3.33	0.0	0.0	0.0	trace	0.0
Amphipoda	0.0	36.4	0.0	33.3	0.0	27.1	0.0	9.1
Parathemisto libellula	0.0	18.2	0.0	16.7	0.0	24.3	0.0	5.5
Decapoda (crab)	0.0	18.2	33.3	50.0	0.0	trace	100	trace
All Fish	100.0	100.0	33.3	100.0	100.0	72.9	trace	61.8
Mallotus villosus	0.0	9.1	0.0	8.3	0.0	14.3	0.0	5.5
Gadidae	0.0	9.3	0.0	83.3	0.0	1.4	0.0	32.7
Larval Fish	0.0	9.1	0.0	0.0	0.0	5.7	0.0	0.0

it is premature to draw conclusions about the similarities or differences in their diets.

Foods used by Parakeet, Crested and Least Auklets in 1975 and 1976 are given in Tables 31 and 32 respectively. Since the number of samples from Parakeet and Crested Auklets is relatively small, comparisons between years are unwise for these species. In the case of the Least Auklets, there appear to be slight differences in the types of foods taken in 1975 and 1976. In 1976, Least Auklets took more gastropods, more copepods and fewer amphipods than in 1975.

The three species of auklets appear to have diets considerably different from one another. Least Auklets took primarily *Calanus* spp. and only trace amounts of other foods. In contrast, the other two species of auklets took no *Calanus*. Parakeet Auklets took mostly amphipods, euphausiids and fish, while Crested Auklets took amphipods and euphausiids and virtually no fish. Although the data are not presented here, the size ranges of foods taken by these auklets are largely non-overlapping.

TABLE 31

FOODS USED BY CRESTED AUKLETS
PARAKEET AUKLETS AND LEAST AUKLETS

PRIBILOF ISLANDS 1975

	Parakeet Auklet % Sample	Crested Auklet % Sample	Least Auklet % Sample	Parakeet Auklet % Volume	Crested Auklet % Volume	Least Auklet % No. of Prey Items
Sample size	11	6	56	40ml	57ml	5012
Food Types						
Mollusca (*Limacina helicina*)	0.0	0.0	12.5	0.0	0.0	0.6
Copepoda	0.0	0.0	41.1	0.0	0.0	93.7
Calanus spp.	0.0	0.0	42.9	0.0	0.0	93.7
C. marshallae or *C. glacialis*	0.0	0.0	30.4	0.0	0.0	90.1
C. cristatus	0.0	0.0	1.8	0.0	0.0	1.7
Cumacea	0.0	0.0	1.8	0.0	0.0	0.2
Amphipoda	18.1	66.7	51.8	2.5	73.7	9.7
Gammaridae	0.0	0.0	8.9	0.0	0.0	0.3
Hyperiida	9.0	66.7	35.7	2.5	73.7	4.6
Parathemisto libellula	9.0	66.7	35.7	2.5	73.7	4.5
Euphausiacea	9.0	33.3	16.1	2.5	26.3	0.4
Thysanoessa inermis	0.0	16.7	0.0	0.0	24.6	0.0
Thysanoessa raschii	0.0	0.0	5.4	0.0	0.0	0.2
Decapoda	0.0	0.0	5.4	0.0	0.0	trace
Crab	0.0	0.0	5.4	0.0	0.0	trace
Unidentified Crustacean remains	45.5	0.0	25.0	5.0	0.0	trace
Fish	45.5	33.3	16.1	87.5	1.8	trace

TABLE 32

FOODS USED BY PARAKEET AUKLETS,
CRESTED AUKLETS AND LEAST AUKLETS

ST. PAUL ISLAND 1976

	Parakeet Auklet % Sample	Crested Auklet % Sample	Least Auklet % Sample	Parakeet Auklet % Volume	Crested Auklet % Volume	Least Auklet % No. of Individuals
Sample size	14	9	37	119 ml	201 ml	13,576
Food Types						
Mollusca (not squid)	14.3	0.0	56.8	trace	0.0	1.7
Gastropoda (*Limacina helicina*)	0.0	0.0	56.8	0.0	0.0	1.7
Copepoda	0.0	0.0	100.0	0.0	0.0	90.2
Calanus spp.	0.0	0.0	100.0	0.0	0.0	trace
Calanus marshallae or *C. glacialis*	0.0	0.0	94.6	0.0	0.0	90.2
Calanus plumchrus	0.0	0.0	56.8	0.0	0.0	1.8
Calanus cristatus	0.0	0.0	56.8	0.0	0.0	1.3
Cumacea	0.0	0.0	29.7	0.0	0.0	1.4
Isopoda	0.0	0.0	2.7	0.0	0.0	trace
Amphipoda	42.9	22.2	72.8	5.9	trace	2.8
Gammaridae	0.0	0.0	13.5	0.0	0.0	2.7
Hyperiida	28.6	0.0	81.1	5.9	0.0	2.6
Parathemisto libellula	21.4	0.0	45.9	2.5	0.0	1.5
Hyperoche medusarum	0.0	0.0	35.1	0.0	0.0	1.1
Euphausiacea	50.0	88.9	24.3	53.8	99.5	0.2
Thysanoessa inermis	14.3	11.1	2.7	21.0	19.9	trace
Thysanoessa raschii	14.3	11.1	5.4	31.1	49.8	trace
Thysanoessa spinifera	0.0	0.0	5.4	0.0	0.0	trace
Thysanoessa spp.	0.0	22.9	0.0	0.0	14.4	0.0
Decapoda (crab)	7.1	0.0	0.0	0.8	0.0	0.0
All fish	57.1	0.0	10.8	40.3	0.0	0.2

DISTRIBUTION OF FORAGING SEABIRDS:

Approximately 85,595 seabirds of 23 different species were seen on 1,478 km of surveys during three cruises on 21-24 August 1975, 2-4 June 1976 and 7-12 July 1976. A total of 315 transects were made and for each the density of seabirds /km^2 was calculated. The mean of these densities was then calculated for all transects in each 10' x 10' grid block for each cruise. For the purpose of this analysis the three cruises will be used as measures of seabird distribution early in the breeding season before colony occupation is complete (2-4 June), during incubation (7-12 July) and during the chick stage (21-24 August), except for cormorants and the small auklets, some of which fledge their young before this date.

Figures 14, 15 and 16 show the mean densities of all species combined for each 10' x 10' block for the three cruises (see also Appendix I fig. 1, 2, and 3). Highest densities on all three cruises were found within 10 nautical miles of the islands and in the vicinity of 200 meter depth curve. Although many of the birds seen close to the islands were commuting to or from distant foraging grounds, immense flocks of murres were seen on the water near the east end of St. George Island on all three cruises, at the west end of St. George Island on the July cruise and near the west end of St. Paul Island in July. Murres were also found in modest numbers scattered throughout most of the study area. In general, storm-petrels were concentrated at the 200 meter curve, shearwaters occurred late in the summer in patchily distributed

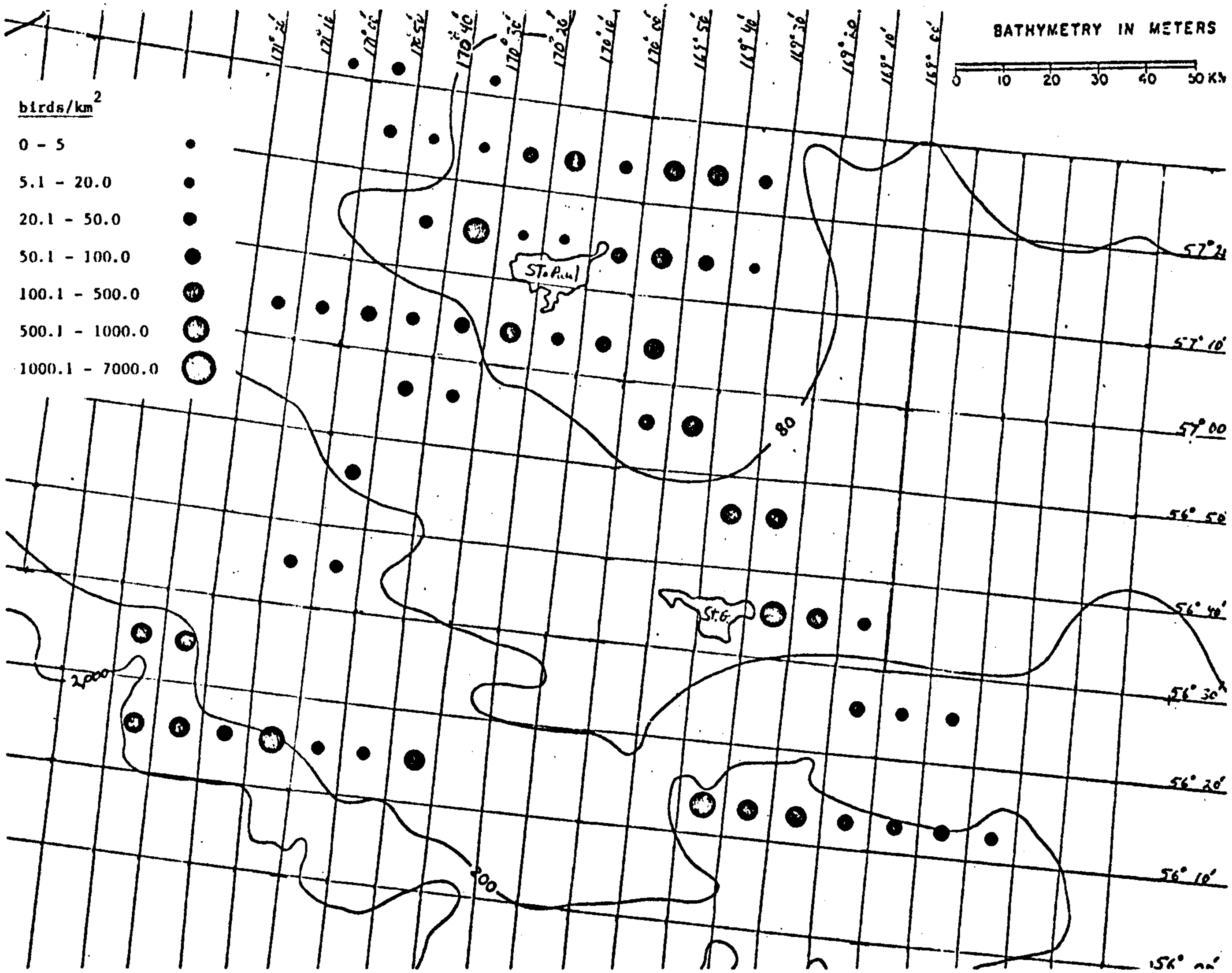

Fig. 14. Mean densities of all seabirds observed in each 10'x10' block. 21-24 August, 1975.

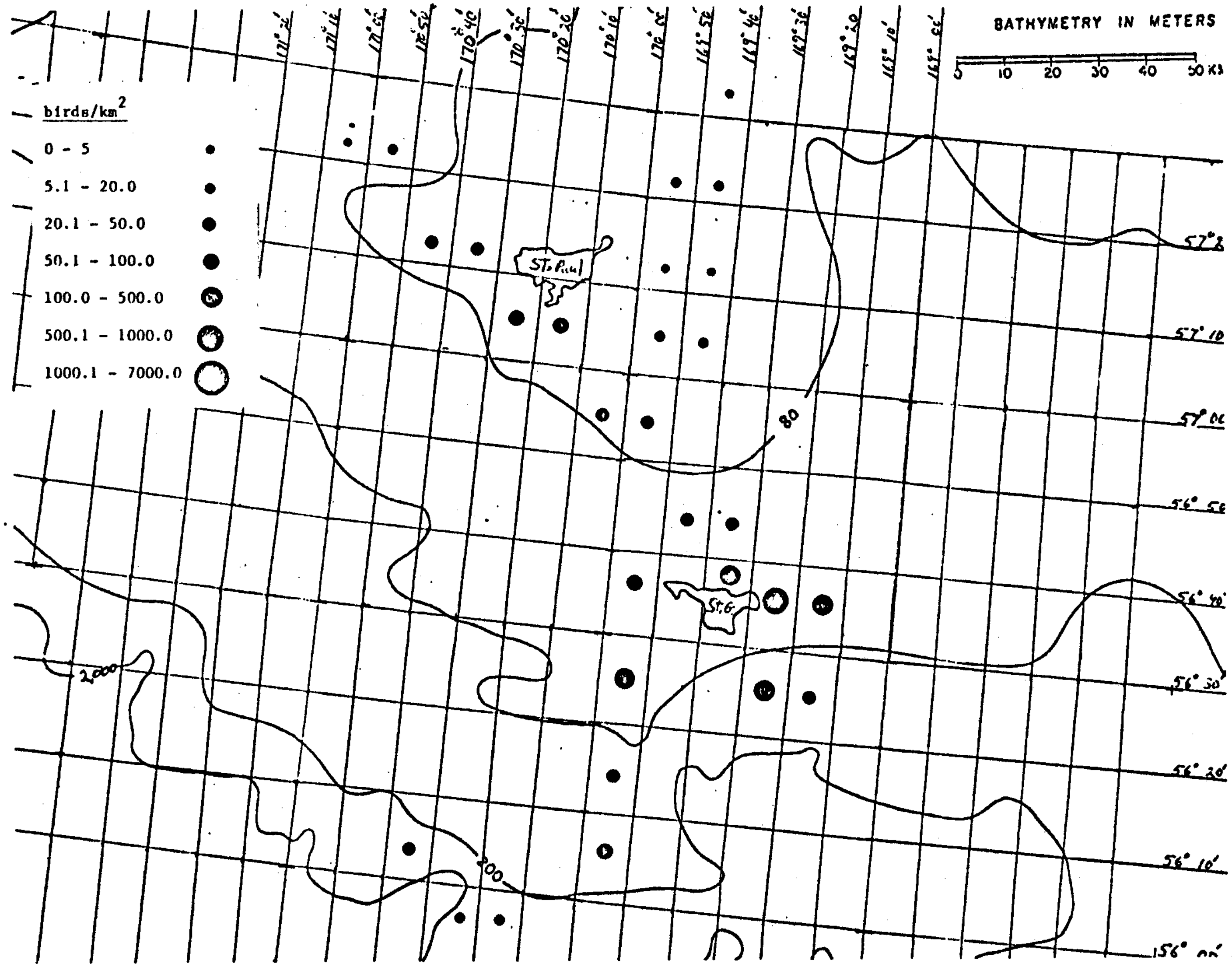

Fig. 15. Mean densities of all seabirds observed in each 10'x10' block. 2-4 June 1976.

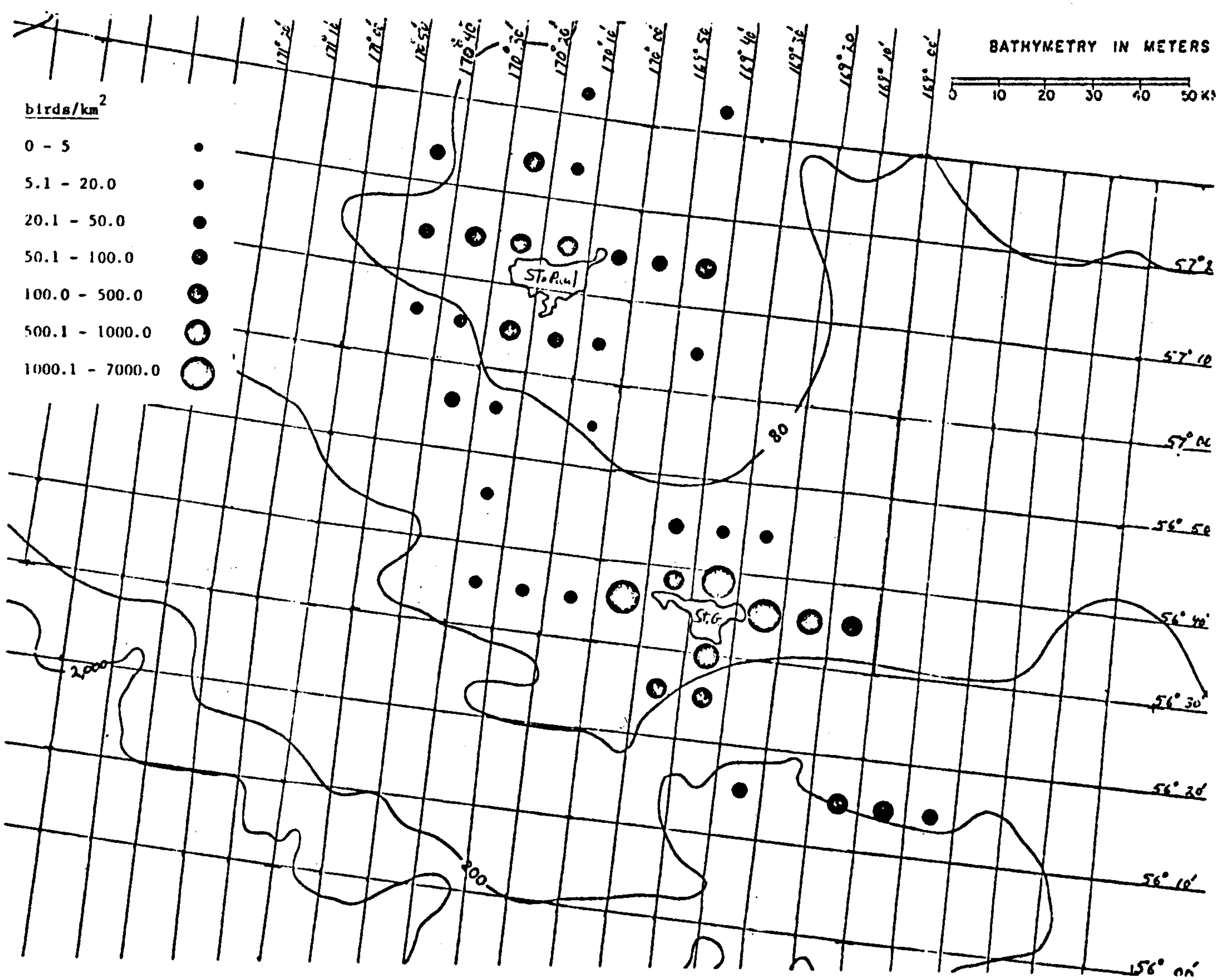

Fig. 16., Mean densities of all seabirds observed in each 10'x10' block. 7-12 July 1976.

flocks throughout the study area and fulmars were scattered throughout with some concentration near St. George Island. Four species, Red-faced Cormorants, and Least, Crested and Parakeet Auklets, were found primarily close to the islands. In contrast the two kittiwakes and two puffins were scattered in low densities throughout the study area.

Shearwaters and Storm-petrels were very scarce on the June and July cruises. In June only a single shearwater was sighted and storm-petrels occurred in only three transects. Likewise, in July shearwaters and storm-petrels were sighted on 19 and 14 of 146 transects respectively, with most storm-petrel sightings concentrated along the 200 meter curve southeast of St. George Island. In August, storm-petrels were still relatively scarce and were generally restricted in distribution to the southwest of St. George Island along the 200 meter curve (Appendix I Fig. 4). In contrast, in August large numbers of shearwaters were encountered almost everywhere during the cruise, (Appendix I Fig. 5). Large flocks were encountered near St. Paul Island and southwest of St. George Island in the same area which supported large storm-petrel populations. The large variations in shearwater numbers from transect to transect and 10' grid to 10' grid emphasize the patchy nature of their distribution. 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 foraging rest on the water and are sluggish, will be particularly vulnerable to oil spills in their vicinity.

Fulmars were seen in modest numbers on all three cruises (Appendix I Fig. 6, 7, and 9). In early June they were generally scarce and seen in low numbers throughout the cruise, the only notable concentration occurring south of St. George Island. By July, the numbers of Fulmars had increased significantly. They were encountered in moderately large numbers 8-15 km west of St. Paul Island and east and west of St. George Island. South of St. George Island large numbers were seen flying south in the evening to join an enormous flock several miles long which trailed out down-wind from a factory ship southeast of St. George Island. This ship may have been responsible for the large numbers of Fulmars seen along the 200 meter curve on the July cruise. In August, the number of Fulmars seen had dropped off dramatically and most observations were of birds in deep water around the 200 meter curve.

Flight directions of Fulmars in selected grids during the July cruise are given in Appendix I Fig. 8. Of greatest interest are the morning and evening flight patterns south of St. George Island. In the evening the preponderance of birds were moving south and southeast, away from the island and apparently commuting to join the flock of birds associated with the factory ship. Several days later in the morning, most Fulmars seen were flying north toward the St. George Island. Likewise slightly later in the morning the predominant 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 evenings to commence foraging and return in the early morning. How long they are away from the islands is not known. Figure 15 of Hickey and Craighead (1977) suggest that Fulmars leave St. George in the evening and return in the morning, a pattern consistant with our at-sea observations.

Red-faced Cormorants were generally restricted to the shallow waters in the immediate vicinity of the islands and their nearby reefs (Appendix I Figures 10, 11, and 12). In June, numbers at sea were scarce, while in July moderate densities were found close to the islands. In August, a few birds were seen away from the islands southeast of St. Paul Island. 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.

Kittiwakes were seen in relatively low numbers in early June (Appendix I Fig. 13) prior to the commencement of egg-laying and in moderate numbers on the July and August cruises (Appendix 1 Fig. 14, 15, and 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.

Although it was not always possible to distinguish the two species of kittiwakes, on all three cruises sightings of Red-legged

Kittiwakes were concentrated near, or south of St. George Island, where the major portion of the world's population of this species breeds. On the July cruise we were able to obtain reliable species identifications for most kittiwakes seen. Although there was a scattering of Red-legged Kittiwakes around St. Paul Island, most were seen south of St. George Island. On the evening of 8 July, 1976, large numbers of Red-legged Kittiwakes were observed flying due south from St. George (Appendix I Fig. 17). These birds were no longer seen in large numbers after we turned east along the 200 meter curve, and we suspect that 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. Red-legged Kittiwakes were relatively scarce north of St. George and when seen leaving their colonies on the north side of St. George they flew south over the island rather than going around it. Unlike the Black-legged Kittiwakes, Red-legged Kittiwakes were not seen in foraging flocks close to the islands.

Black-legged Kittiwake flight directions (Appendix I Fig. 18) were similar to those of Red-legged Kittiwakes south of St. George Island. Likewise, around St. Paul, Black-legged Kittiwakes were seen flying away from the island in the evenings. No strong trend of flight toward the islands was seen 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 through the day, and start to decrease in numbers on the cliffs in the evening.

Murres, the most abundant of the breeding seabirds of the Pribilof Islands, were also the most abundant bird at sea for all three 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 Pribilof Islands and most at-sea observations undoubtably are of Thick-bills.

On the June, 1976, cruise, the greatest concentrations of murres were found just north and east of St. George Island (Appendix I Fig. 19). To the north of St. George Island, most murres were commuters, while to the east of the island out to a reef about 9 nautical miles off-shore huge rafts of murres were found on the water. These birds appeared to be foraging. Moderately large numbers of murres were also seen south of St. George Island out to a distance of 30 nautical miles or more where birds concentrated near the 200 meter curve. Except for large numbers of murres foraging in the tide-rips of Otter Island, the numbers of murres sighted around St. Paul Island in June were small.

In July, the picture was generally similar to that found in June (Appendix I Fig. 20 and 21). Immense flocks of murres were found on the water at both the east and west ends of St. George Island and large numbers were seen flying east and west along the north and south sides of St. George. 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. Again, as in June, large numbers of murres were found foraging in the tide-rips south of Otter Island.

Somewhat surprisingly, a large percentage of murres seen up to 20 nautical miles from land were flying rather than on the water. This finding suggests that many murres may be foraging at considerable distances from the islands and that long (80-100 nautical mile) radial transects will be profitable in the coming field season.

Flight directions of murres in selected grids are shown in Appendix I Fig. 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. A similar but less clear trend toward an evening exodus and morning return seemed to hold in the vicinity of St. Paul Island. Again these at sea observations fit with our data on murre colony attendance obtained in 1975 (Hunt 1976, also Hickey and Craighead 1977, Fig 8). Ledge attendance was low in the early morning, rose throughout the day and dropped rapidly in the late afternoon and evening.

During the August, 1975, cruise, major concentrations of murres were found at the east end of St. George Island, along the 200 meter curve south of St. George Island and in somewhat smaller numbers northeast of St. Paul Island and near Walrus Island (Appendix I Fig. 22). In contrast relatively few murres were found to the southwest, away from the islands or to the northwest of St. Paul Island.

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 still more distant foraging grounds. It will be important to locate these foraging grounds and determine the density of murres using them.

Sightings of Horned and Tufted Puffins on the three cruises were sparse (Appendix 1 Fig. 2-29). In June, the few that were seen were mostly near St. George Island. In July, puffins of both species were more plentiful and scattered sightings were made at sea in addition to fairly consistant sightings of low numbers close to the islands and their associated ledges. The waters around St. Paul Island appeared to support slightly greater densities of puffins than St. George Island in July. In August, 1975, puffin sightings were less numerous than in July, and the majority were close to the islands. Although our sample size is small, it appears that sightings of puffins distant from land were more often of Tufted Puffins than Horned Puffins.

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 scattered flocks during the June cruise (Appendix I Fig. 30). Although a few flocks were seen well away from the islands, most were within 10 nautical miles of the islands where they nested. This close attachment to the islands was even more obvious during the July cruise (Appendix I Fig 31) when the auklets had eggs. Virtually all sightings were within 10 nautical miles of the islands, and most were closer. The greatest numbers were found east of St. George Island in an area of cold water, presumably an area of upwelling. It is of interest that it was a short way north of this area, in a region of slightly warmer water, that the large flocks of foraging murres were encountered.

If there was any spatial separation in the foraging areas used by the three species of auklets, it was not readily apparent from our data. In general, the numbers of Crested and Parakeet Auklets were too small to give a clear definition of their foraging ranges, and too little ship time was available to work out differences in distribution which might have required resolution within a zone two or three miles off the islands.

During the late August, 1975, cruise, auklets were generally scarce (Appendix I Fig. 32). At this time most sightings were at least moderately removed from the islands, although modest numbers were still to be found in the area to the east of St. George Island. This then represents a real change in distribution from that seen in mid July, and undoubtably reflects the dispersal of the auklets from their island nesting colonies.

E. 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.

F. EFFECTS OF HELICOPTER TRAFFIC ON CLIFF NESTING SEABIRDS

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 presumably also its output of noise, murres would leave when the helicopter was further away. Thus at an airspeed of 125 miles per hour, murres were departing the cliffs when the helicopter was judged to be 225-250 m away, but the birds allowed the helicopter to approach to 180-200 m 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 500 m and 350 m no birds left the cliff, at 200-250 m moderate numbers left the cliffs, and at 200 m and 150 m murres streamed from the cliffs in huge numbers.

VII. DISCUSSION

Ideally a baseline study of nesting seabirds should provide data on: 1) where and when birds are nesting, 2) what kinds of birds are present, 3) how many birds are present, 4) how successful they are in raising young, and 5) where they obtain food and what they eat. With this information available, it is possible to ascertain the populations at risk if an oil spill occurs in a given area, and the magnitude of the effects of the spill on nesting population size and reproductive success. Additionally, if long term banding data are available, it may be possible to construct life tables for species and to predict the ability of a species to recover from a disaster.

In the present coordinated studies of Pribilof Island seabirds, Dr. J. Hickey and his team on St. George have concentrated on problems 1, 2, and 3, while we have concentrated on problems 4 and 5 on St. Paul. With cooperation between the two groups, we feel it will be possible to get a clear overall picture of seabird numbers and reproductive ecology in the Pribilof Islands.

In our work on the Pribilofs we have attempted to develop an overall understanding of processes and principles which govern seabird reproductive success and foraging behavior. There are too many remote colonies of seabirds in Alaska for all to be accorded the degree of study needed to establish realistic baselines. Therefore, it is necessary to concentrate on a limited number of important areas, and attempt to develop an understanding of seabird ecology which can be extrapolated to other areas.

Predictions can then be made and tested, and if found reliable, used for estimating present baseline conditions, and also for advising government bodies on the sensitivity of areas to oil spills before lease sales are made.

The temporal distribution of nesting activities for seabirds on St. Paul Island in 1975 and 1976 is summarized in Fig.17. The Red-faced Cormorants are the first to commence nesting activities in May, and the puffins are the last to finish in mid October. Thus for at least six months, nesting activities will bind one or more species of seabirds to the vicinity of the island.

We have found that the spatial distribution of nesting activity for the 11 species of seabirds on St. Paul Island is determined by the availability of nesting sites on ledges and in holes in the vertical cliffs that border the island on the south and west sides. In addition, one of these species, the Least Auklet, also nests in large numbers on boulder beaches deep in holes between the rocks.

All seabird species on St. Paul were the potential prey of the Arctic Foxes which live by scavenging, catching birds and taking eggs. The foxes are small and agile and were often seen running easily up and down the crumbling cliffs where a person would soon perish. Consequently, the seabirds that bred successfully are those that nest in locations inaccessible to foxes and therefore also to ornithologists. Interestingly,

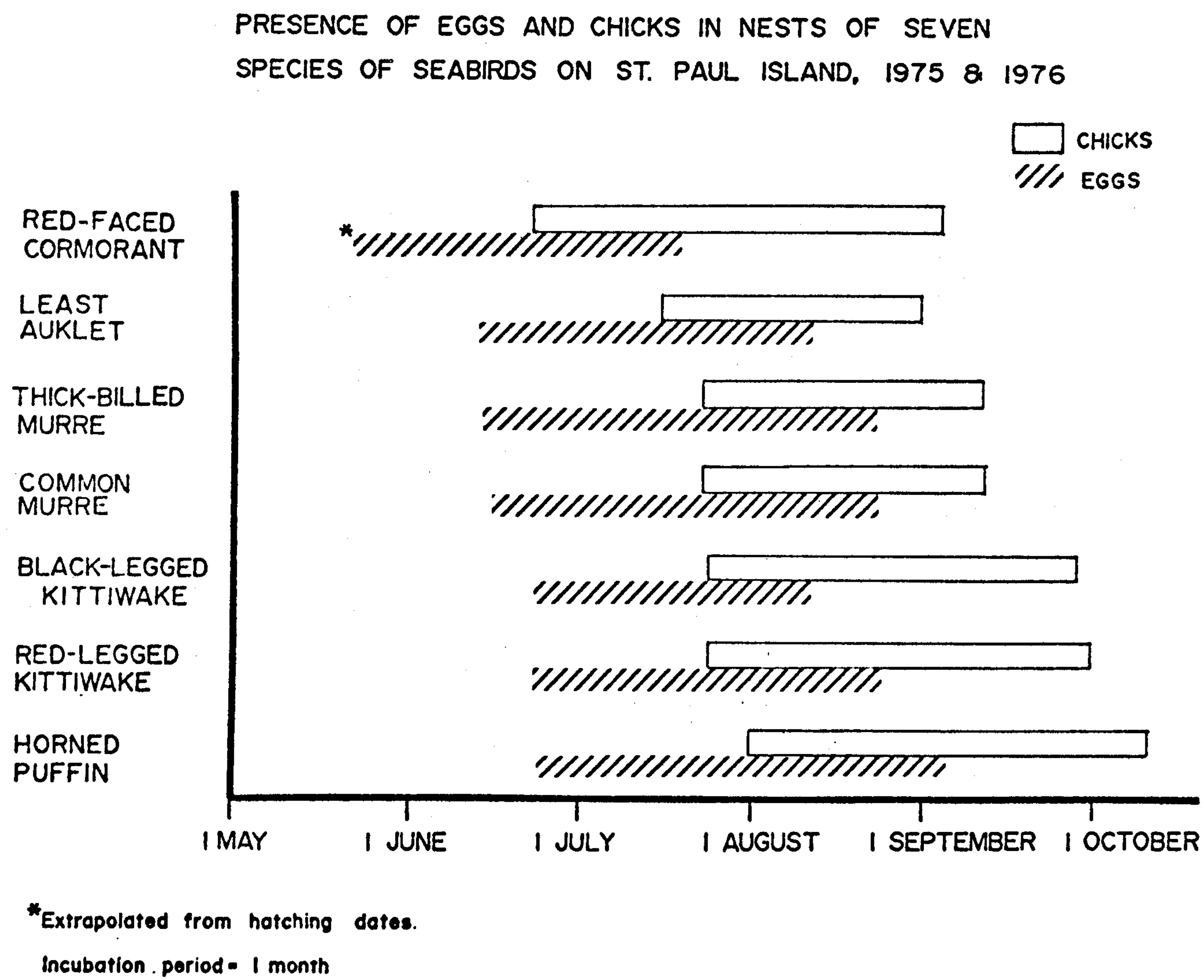

Fig. 17. Timing of breeding of seven species of seabirds, St. Paul Is. 1975-1976

introduced cats, while common in the villages, did not appear to be a major threat to the cliff nesting seabirds.

Because seabird nesting activity is restricted to areas free from fox predation, most bird nests will be relatively protected from terrestrial activity that might be related to resource development. People and their pets walking on the cliff tops will likely have minimal impact on nesting activity. They may cause some desertion of cliff-top nest sites, but as long as they do not deliberately try to scare the birds, impact from this source of disturbance should not be great.

The potential for disturbance by people walking on beaches or boating below nesting cliffs is greater. Birds usually are not flushed from nests by the presence of people on the beaches, but the potential for scaring large numbers of birds from their ledges with the concommitant loss of Murre eggs and chicks is great. Loud noises, rock throwing and gun shots can all cause mass flights. Most of the beaches below major bird cliffs of the Pribilofs are inaccessible from land, but the potential for disturbance by shooting from small boats is great.

Oil floating immediately off-shore would have a devastating effect on all of the seabirds, especially the alcids. Spilled oil washing ashore is generally a major threat only to 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 oil could possibly reach Least Auklet nest sites in the boulder beaches. Other species rarely land on the beaches, and so would presumably not be harmed by beach-cast oil.

Aside from massive oil spills in the vicinity of colonies, aircraft flying close to nesting cliffs probably pose the greatest threat to seabirds from petroleum exploration and development activities. Although we do not have extensive data on the effects of different kinds of aircraft, we do know that in 1975 aerial photography efforts by the United States Fish and Wildlife Service in their P2V Neptune aircraft resulted in massive departures from the cliffs and an apparently related diminuation of reproductive succcess in Murres. Also, our experiments with the relatively quiet NOAA Bell SU-I helicopter showed that helicopter flights within 250 meters of the cliffs would cause streams of Murres (preincubation phase) to leave the cliffs. As we get a clearer picture of distances at which aircraft will cause birds to fly, regulations to insure aircraft safety as well as undisturbed nesting areas should be set.

On the Pribilof Islands four species of seabirds are particularly appropriate for baseline study because of their large numbers, their rarity or their ease of study. Red-faced Cormorants are present in small numbers, can be censused accurately, and are amenable to precise study of reproductive biology. Black-legged Kittiwakes are numerous, easily studied, and there exists a broad published literature on their biology.

Additionally they are widespread in Alaska and are well studied by other OCSEAP investigators (see Appendix 2 for a partial compendium of 1976 Alaska work). Red-legged Kittiwakes that have the major portion of their entire population on St. George Island are relatively scarce on St. Paul Island and difficult to work with, but their world-wide rarity demands that their populations be monitored carefully. Finally, Thick-billed Murres as the most numerous of the seabirds of the Pribilofs deserve careful study as they would likely be heavily impacted by oil spill or disturbance.

The reproductive success of Red-faced Cormorants was similar in 1975 and 1976 on St. Paul and on St. George in 1976. For Red-faced Cormorants 1976 was a slightly better year, perhaps because late spring storms destroyed a number of low nests in 1975 on St. Paul. For Black-legged Kittiwakes, birds on St. George did slightly better than those on St. Paul. At present there is little additional data with which Pribilof Island Red-faced Cormorant can be compared, but more should soon be available through the OSEAP investigations.

When the reproductive success of Black-legged Kittiwakes on the Pribilofs in 1975 and 1976 is compared with that found elsewhere in Alaska (Appendix 2) or elsewhere in the world, we find that overall reproductive success in the Pribilofs is rather low. Clutch size of Black-legged Kittiwakes in the Pribilofs is 1.4 to 1.5 eggs per nest (Table 9), while Belopol'skii (1957) found a mean of 1.96, in the Berents Sea. Coulson (1966) gives means between 2.11 and 2.35 eggs per nest in Northumberland, England and Coulson and White found the clutch to vary from 1.83 for inexperienced females breeding for the first time to 2.33 for females breeding for the third year. Swartz (1966) found an average of 1.84 eggs per nest at Cape Thompson, Alaska. Elsewhere three egg clutches are not unusual, and even occasionally 4 egg clutches are found. We have never seen a clutch of greater than two eggs in the Pribilofs.

Black-legged Kittiwake chick production in the Pribilof Island also appears low (0.42-0.58 young per nest Table 9) when compared to other locales. In the Barents Sea Belopol'skii (1957) reports that there are often three nestlings and that occasionally the third chick fails to survive when there is a shortage of fish. Coulson (1966) found chick production in Northumberland, England, to vary from 0.92 to 1.72 young per nest depending on female breeding experience and past history, while Coulson and White (1958) found a variation in young fledged per nest from 0.66 young for birds nesting for the first time to 1.63 young per nest for kittiwakes breeding for at least the third time. Swartz (1966) at Cape Thompson found a fledging success of 1.22 per nest and 0.72 per nest for 1960 and 1961 respectively. However chick survival in the Pribilofs (.55-.85% of chicks, Table 9) is probably better than that found by Swartz (55%). Likewise, chick growth rates (11.5-17.9 g/day in the Pribilofs, Table 9) are comparable or better than those found by Belopol'skii, 1957, (9.6-11.0 g/day) or Coulson and White, 1958, (14.7-16.7 g/day).

It is possible that competition for food with the huge numbers of Murres in the Pribilofs results in the availability to lay clutches larger than two.

Belopol'skii 1957 believes that competition for food with Murres results in reduced kittiwake clutch size. When fish were scarce in 1942 and 1947 on Novaya Zemlya and kittiwakes had to switch from fish food to crustaceans, clutches were reduced from 3 to 2 eggs and in 30-40 percent of the nests only a single egg was found.

Although chick growth rates are comparable with other places, in the Pribilofs adults are providing for only one chick, while elsewhere adults are often providing for two chicks. In the Pribilofs invariably the second chick disappears within 10 days, often after being pecked by its sibling and possibly pushed from the nest. Significantly, the endemic Red-legged Kittiwake invariably lays but one egg.

If the hypothesis that the reduced clutch size of Black-legged Kittiwakes in the Pribilof Islands is the result of competition for fish food with Murres, then any disturbance which affected the availability of food to kittiwakes could endanger their populations by further reducing their reproductive output. Since we do not know either the annual rate of mortality or life-expectancy of Black-legged or Red-legged Kittiwakes in the Pribilof Islands, we cannot compute the net reproductive rate required to maintain these populations. However, Coulson and Wooler (1976) estimate that male and female Black-legged Kittiwakes in Northumberland, England have a life expectancy of 5.4 and 7.1 years respectively once they have began to breed at an age of 2-3 years. It is likely that a reduction in reproductive output in the Pribilofs could result in a population decline, a matter for serious concern particularly in the case of the Red-legged Kittiwake.

The comparison of the reproductive biology of the Red-legged Kittiwake with the Black-legged Kittiwake is of considerable interest. The Red-legged Kittiwakes produces but one egg, has about the same success in hatching this egg as Black-legged Kittiwakes have in hatching theirs (54-83% vs 54-80% respectively, Table 9 and 13), and has greater success in fledging those chicks that do hatch (83-94% vs 57-85% for Red-legged and Black-legged Kittiwakes respectively, Tables 9 and 13). The net result is that the Red-legged Kittiwake produces about as many if not more young per nest than do Black-legged Kittiwakes (0.50 young/nest vs 0.45 young/nest respectively for both years on both islands, Tables 9 and 13). This means that, in the Pribilof

Islands, Red-legged Kittiwakes manage to produce more young with less initial investment (1 egg vs. 2) than do the Black-legged Kittiwakes.

Thick-billed Murres are the most abundant of the nesting seabirds of the Pribilofs, numbering in excess of 1.6 million birds on the two islands. Due to differences in methods imposed by site-specific problems and the development of improved techniques, it is difficult to compare our results between years or islands, which most likely range between 0.4 and 0.7 (Table 17) young produced per egg laid. This is in the same range as that found by Tuck, 1961, (.4 young/pair at Cape Hay, 1957) in a study where he disturbed birds in the process of data gathering. Swartz (1966) states that egg mortality at Cape Thompson varied between 26.8% and 51.4% while egg losses in the Pribilofs varied between 15% and 57%. Swartz provides no data on chick mortality and a portion of the egg mortality reported by him was the result of Eskimo egg collecting.

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 can be calculated. In the Pribilofs we have found growth rates of chicks which survived to jumping from the cliffs varing from 6.0 g/day on St. George Island in 1976 to 14.6 g/day on St. Paul in 1975 (Table 18). In contrast Thick-billed Murre chicks which failed to survive had growth rates of 1.7-2.5 g/day. Apparently a wide range of growth rates is possible for chicks of this species before chick survival on the cliffs is affected (chick survival on St. Paul Island and St. George Island in 1976 were nearly identical despite the fact that growth rates on St. Paul Island were nearly double those on St. George Island). However, chicks with reduced growth rates may leave the cliffs at a lower weight and have reduced survival potential at sea.

The distribution of foraging seabirds at sea makes an important difference in the potential impact of an oil spill. If birds are widely dispersed at low densities an oil spill will have to cover a vast area before it will cause serious damage to seabird populations. On the other hand, if seabird densities are high or more particularly if birds are concentrated in extremely high densities over small areas of unusually rich foraging grounds, then even a small spill can have devastating effects. This will be especially true if the bird species is limited in dietary preferences and access to the preferred food is blocked.

The distribution of all birds taken together on the three cruises (Figs. 14, 15, and 16) show clearly that extremely high densities of birds frequently are encountered in the immediate vicinity of the Pribilof Islands. The major constituents of the concentrations are flocks of murres and auklets. While some of these may represent birds gathering on the water in "staging areas" prior to flying to their nests, in many cases birds were foraging. The flocks are not always encountered in the same place, perhaps due to changes in tides or upwelling, but they are of regular enough occurrence at the east and west ends of St. George Island and the west end of St. Paul Island so that one can predict major damage to Pribilof Island seabird populations should a spill occur near the island (within 10 miles).

Large concentrations of foraging birds may also be expected over the shelf-break (Fig. 16). While the densities of birds here are not quite as great as in the immediate vicinity of the islands, the areas covered by large numbers of birds are great, and therefore the number of birds at risk may be as great or greater than in the immediate vicinity of the islands. Clearly, great care should be exercised in the St. George Basin to avoid a spill, or cleanup spilled oil quickly.

Black-legged and Red-legged Kittiwakes are most abundant around St. George Island and south from there toward the deep ocean water. Shuntov (1974) states that Black-legged Kittiwake distribution is pretty evenly dense around the Pribilofs, while Red-legged Kittiwakes were more frequently found over ocean waters often in the central part of the Bering Sea. It is our impression also that Red-legged Kittiwakes may show a preference for foraging over deeper water.

Murres reach their highest densities on the water within one or two miles of the Pribilof Islands and their associated reefs (Appendix 1, Fig. 16, 17, 18, and 19). These are also the areas in which the small auklets are densest (Appendix 1,

Fig. 21, 22, and 23). However, murres are also widely dispersed further at sea and can be found in high densities near the shelf break (Appendix 1, Fig. 19), where the small auklets are generally not found. Thus, for these vulnerable groups of birds the water near the islands appears most critical in terms of oil pollutions, followed in importance by the waters over the shelf break.

A final point of interest in 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, I feel that it is almost impossible to determine population changes for their species without reasonalby 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 enviornment.

The possibility of an increase in the Black-legged Kittiwake population between 1954 and 1975-76, a period when Red-legged Kittiwake numbers have apparently not expanded (at least on St. Paul) is of considerable interest. 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 visa 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 Stellar's Sea Lions, first reported by Kenyon and Phillips (1965) as occurring in 1954, now being 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.

VIII. Conclusions

Given the need to obtain data over the course of several years prior to determining what is "normal", any conclusions at this point would be premature. We have, however, demonstrated the feasibility of obtaining accurate data on the timing of nesting, reproductive success, growth rates and foods of a wide variety of seabirds in a demanding environment. Gathered over a sufficient time base, these types of data can provide the information necessary to detect changes due to environmental perturbations.

In terms of immediate application of our observations to O.C.S. development, two findings may be of particular significance. First, the cliff nesting species, particularly murres, may be very sensitive to disturbance both by fixed wing aircraft and helicopters. Additional experimental study on this point is needed to determine the extent of the hazard and permissable distances of approach.

Secondly, from our three cruises, it appears that most of the birds nesting on St. Paul Island forage relatively close to the island. If subsequent cruises confirm this impression, then oil spilled within a zone 30-40 miles around a colony will create an extremely serious hazard to sea birds breeding on that colony. Note of this zone of extreme vulnerability of nesting birds to oil should be taken in any decisions concerning permits for drilling or transporting oil.

IX. Needs for further study

Additional required research falls into two categories, short term and long term studies. Needed long term (10-15 year duration) studies include banding programs to elucidate life-history information, and mortality and replacement rates. The results of such studies should be generalizable for whole species and could be conducted in different locations for different species, depending upon their accessibility. Species in the Pribilofs which could profitably be studied for life-history information would be the Black-legged and Red-legged Kittiwake and the Red-faced Cormorant. The life-history information is essential if the impact of an oil related disaster is to be assessed in terms of the ability of a population to recover.

A second long term study making use of banding would be to determine the frequency of movement of individuals of various species of seabirds between colonies. If a given colony is destroyed or partly destroyed, the repopulation of the area may depend as much or more on immigration of individuals from adjacent populations as from population growth generated within the remenants of the local population. At present there is very little information on the extent of interchange between colonies.

A number of short term studies are required which should be able to be completed within the 3-4 years remaining for the proposed baseline program. One such study would involve radio-tracking of birds on their foraging grounds. The present efforts, using large ships to conduct radial transects, is providing valuable information on the general distribution of birds in the vicinity of the Pribilof Island colonies. The implicit assumption is that the the birds seen are nesting on the nearby islands. To test that assumption it is necessary to track birds from their nests to the foraging ground.

A second short term study of value would involve determining the importance of the role of the apparent surplus of non-breeding Murres which occupy the nesting colonies. Dr. Drury and I have both noticed that for every egg on a given ledge there may be several adult murres present in addition to the pair which produced the egg. There are suggestions that some of these "extra" birds are in fact "helpers", which contribute food and perhaps protection to a chick of which they are not a parent. In order to determine the impact of a spill on the reproductive output of a colony, it will be important to know the extent to which these "extra" birds contribute to raising a chick. If "helpers" play a signigicant role in raising a chick, then the loss of even the "surplus" non-breeding birds could affect the reproductive output of a colony.

A final short-term study of great urgency is an investigation of the effects of aircraft disturbance on murres. With the likelihood of increased aircraft traffic with all phases of oil exploration and development, and with the use of aircraft for censusing birds or for estimating reproductive success as suggested by Dr. William Drury, it is essential that we determine the impact of aircraft operations near colonies. Observations of the effects of aircraft on seabirds should be gathered in carefully controlled experiments involving coordinated efforts between observers on the ground and in the plane.

X. Summary of 8th quarter operations

During the period 1 October 1976 - 1 April 1977 we have been operating on a reduced staff of the Principal Investigator (10%), two Assistant Specialists (one full time, the other 50% time for four months) and a lab helper (100%, 1 month). In this period we have worked up food samples to a first level of identification, completed analysis of 315 at-sea transects from three cruises and worked up the 1976 reproductive biology data from St. Paul and St. George Islands. With the exception of further refinement of the identification of food items used by seabirds and working up additional Black-legged Kittiwake and Least Auklet food samples, we have completed the reduction and presentation of the 1975 and 1976 field efforts. The remainder of the food samples will be worked up prior to the start of the 1977 field season, and identification of fish parts will be updated as information becomes available.

We are still behind in submitting our data for entry into the EDS computer bank. With the help of Mike Crane's office in Anchorage, we have now submitted almost all of our data for punching, and verification of print-out is in progress. It is expected that by the middle of May when we return to the field most if not all of our 1975 and 1976 data will have been submitted in the appropriate formats.

Planning for the 1977 field season is almost complete and most supplies and equipment are either already on St. Paul or awaiting shipment on the M/V Pribilof in Seattle. At present we forsee no major obstacles to completing the 1977 field season.

ACKNOWLEDGEMENTS

In this project we have often had to rely on the help of others to assist us in our work. We gratefully acknowledge the valuable assistance of the personnel in the Juneau NOAA-OCSEAP office for providing logistic and other help; Mike Crane for help with coding, punching and otherwise organizing us in the fine arts of A.D.P.; the personnel of the National Marine Fisheries Service, Pribilof Island Project for providing housing, transportation and permission to enter Fur Seal rookeries; the Aleut Communities on St. Paul and St. George Islands for permission to conduct this work, for transportation, and for various other help and support; the United States Coast Guard for maintainence expertise, logistic support on St. Paul and helicopter transport; the Officers and Crew of the Discoverer, Surveyor and Moana Wave; and numerous scientists on St. Paul and St. George for help and encouragement.

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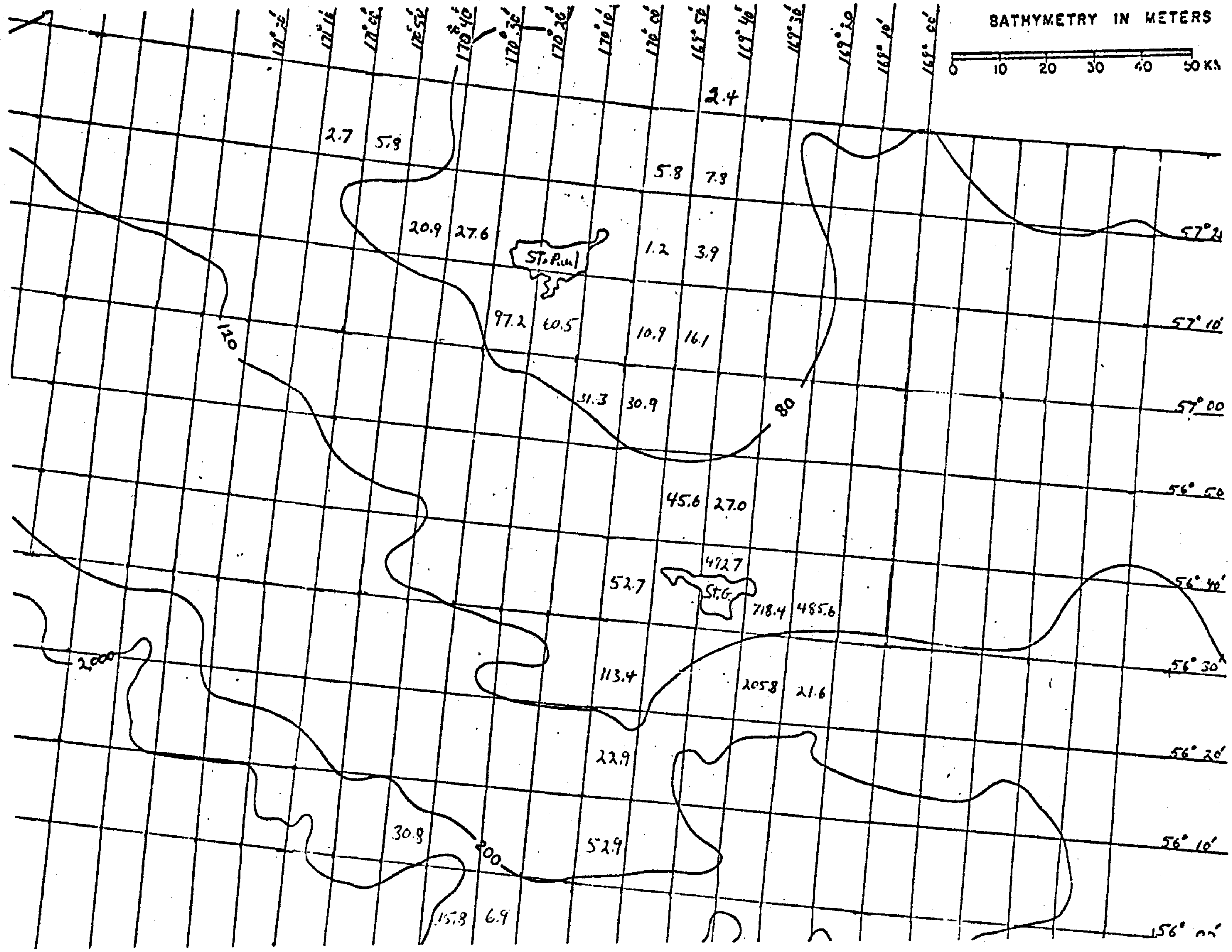
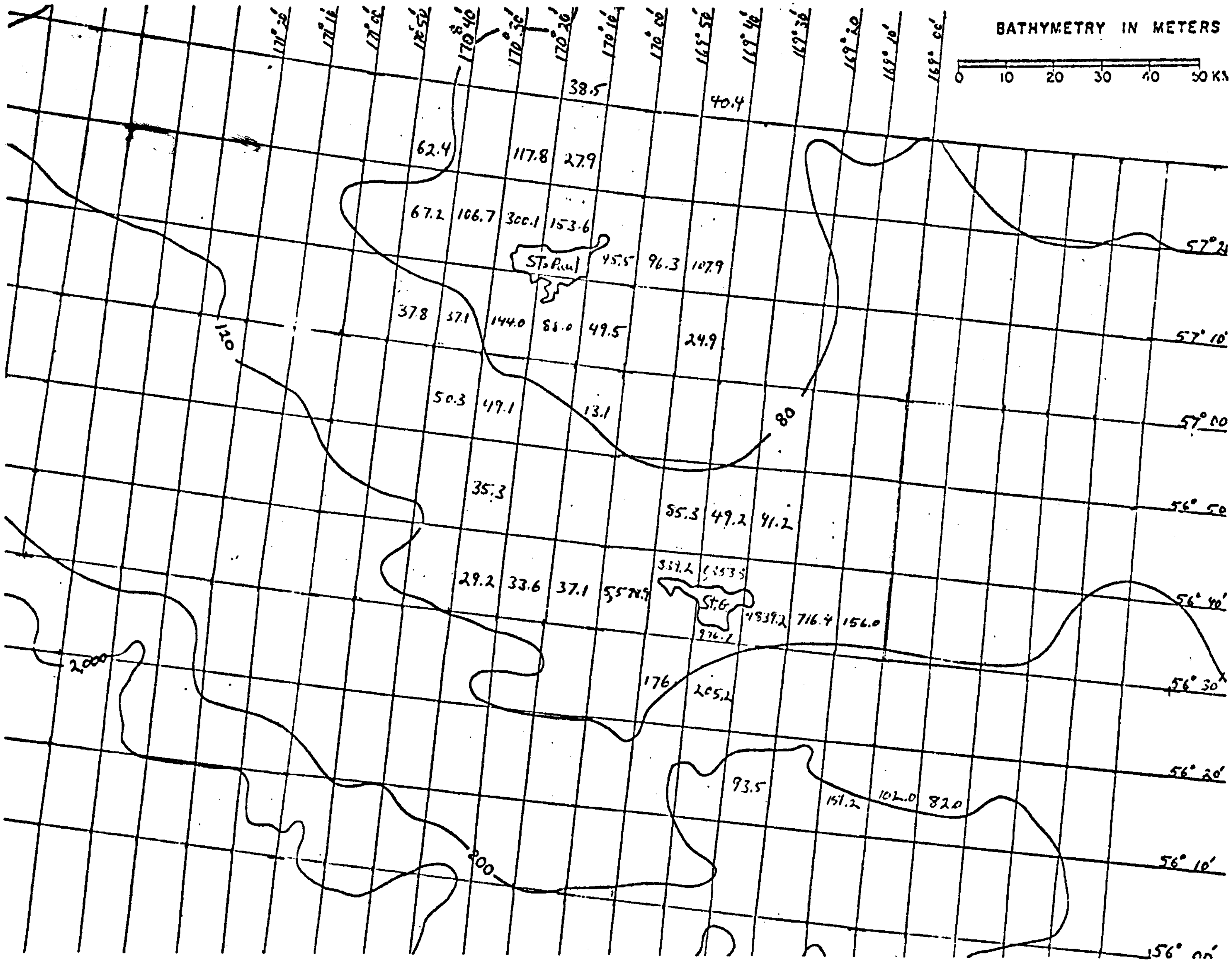
Appendix I.

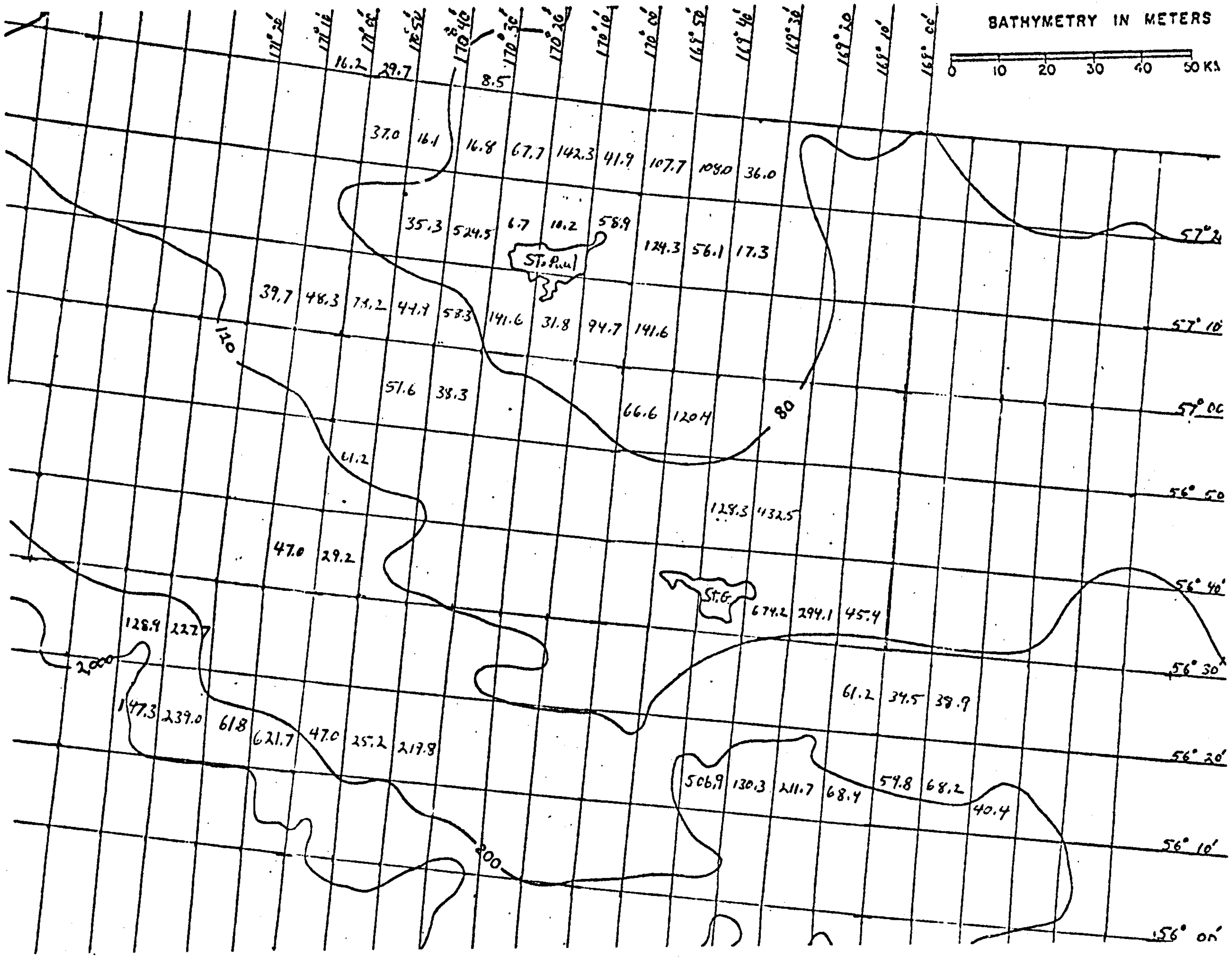
Figures 1-32 in Appendix I show densities of seabirds observed on the cruises of the R/V Discoverer (21-24 August, 1975) and the R/V Moana Wave (2-4 June and 7-12 July 1976).



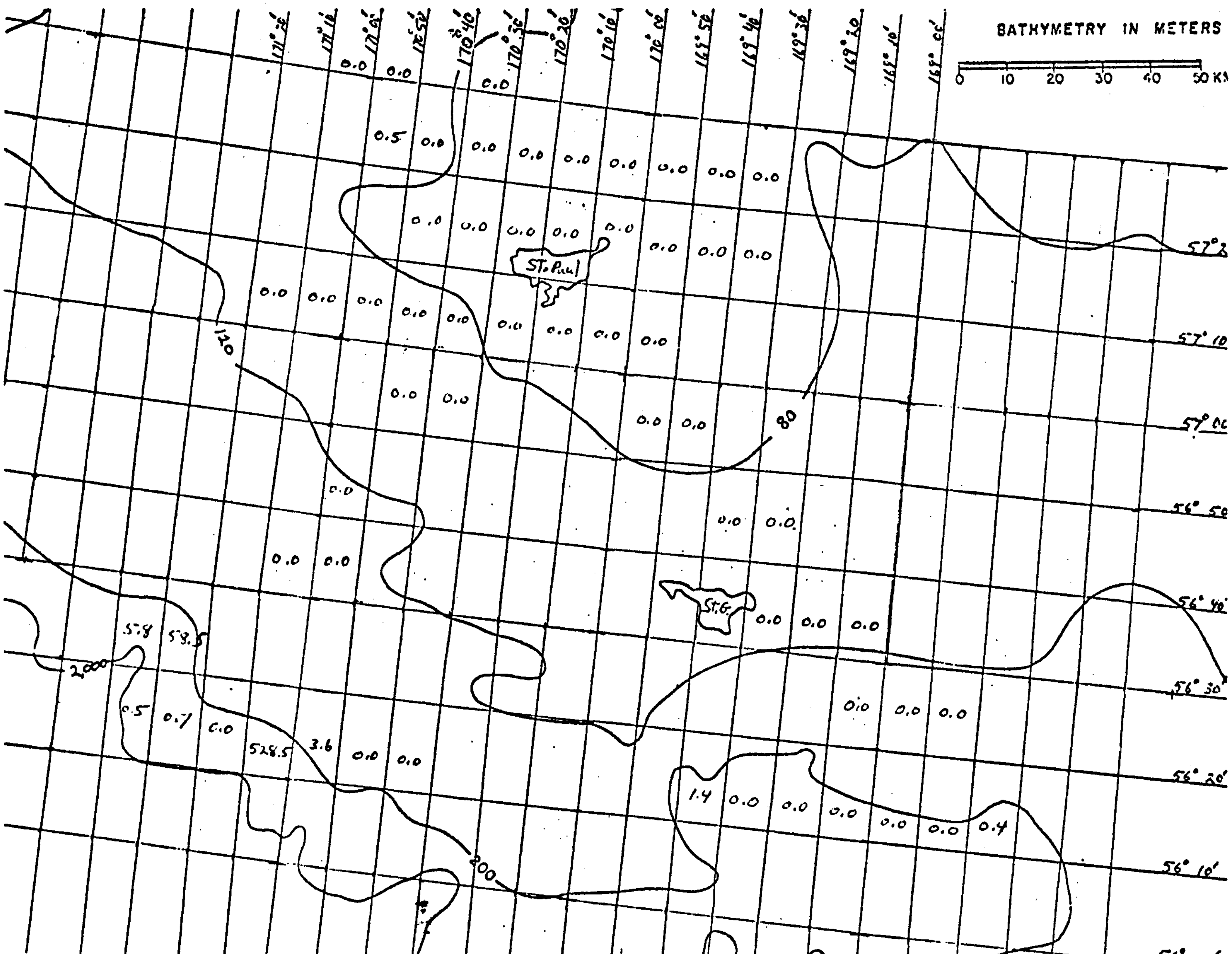
Appendix I. Fig. 1. All species combined - mean birds/km^2 for all transects within each 10'x10' block. 2-4 June 1976



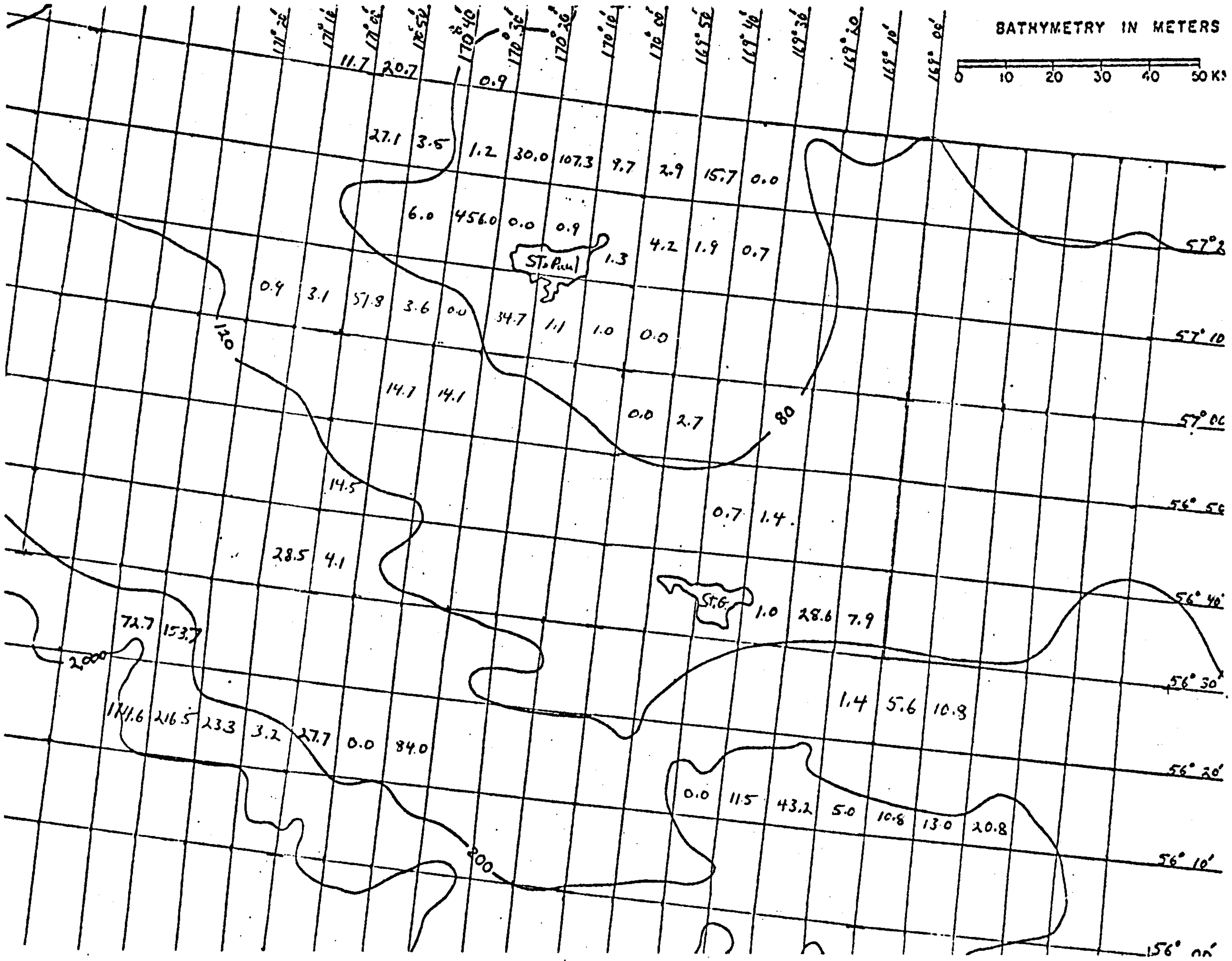
Appendix I. Fig. 2. All species combined - mean birds/km^2 for all transects within each 10'x10' block. 7-12 July 1976.



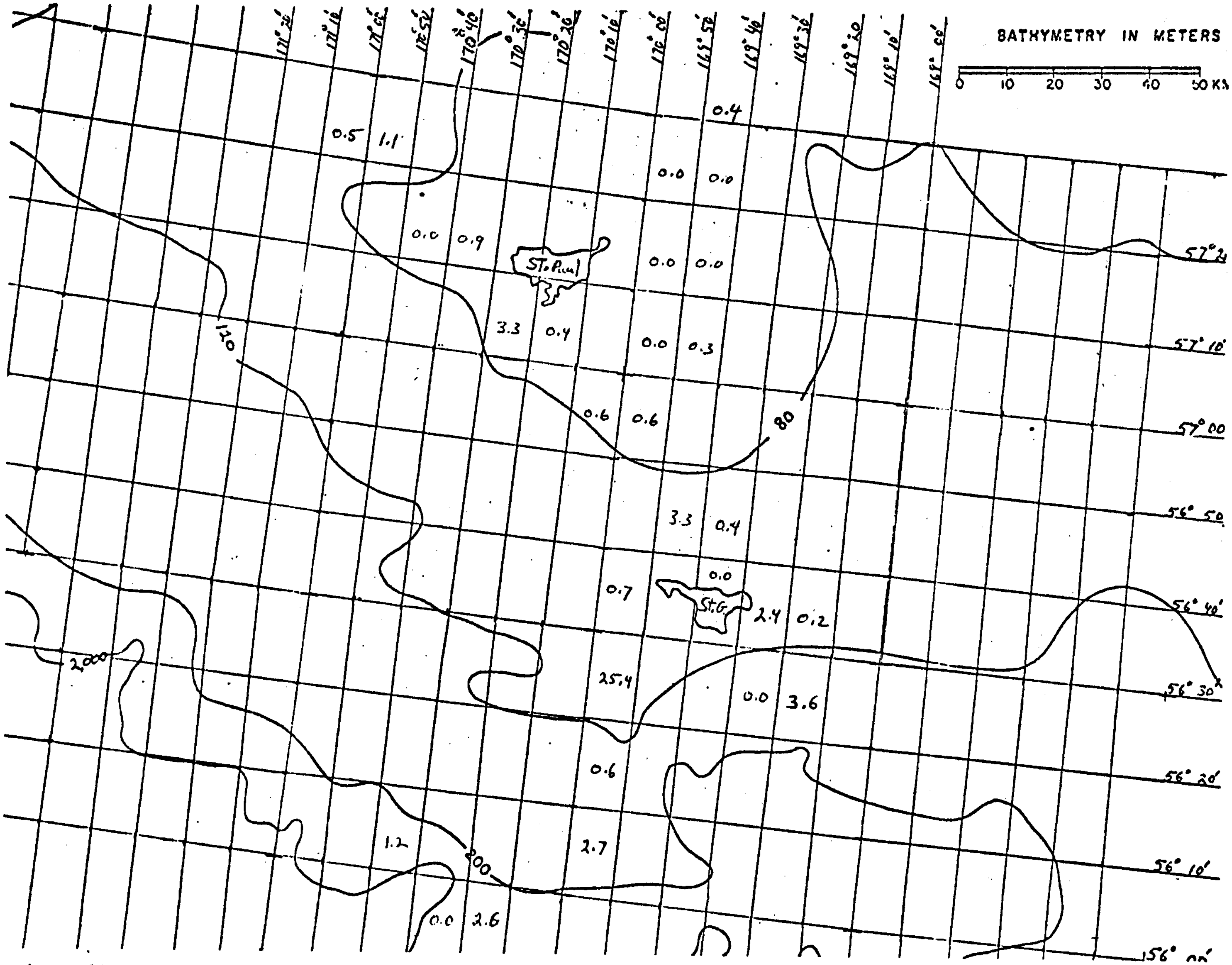
Appendix I. Fig. 3. All species combined - mean birds/km^2 for all transects within each 10'x10' block. 21-24 August 1975.



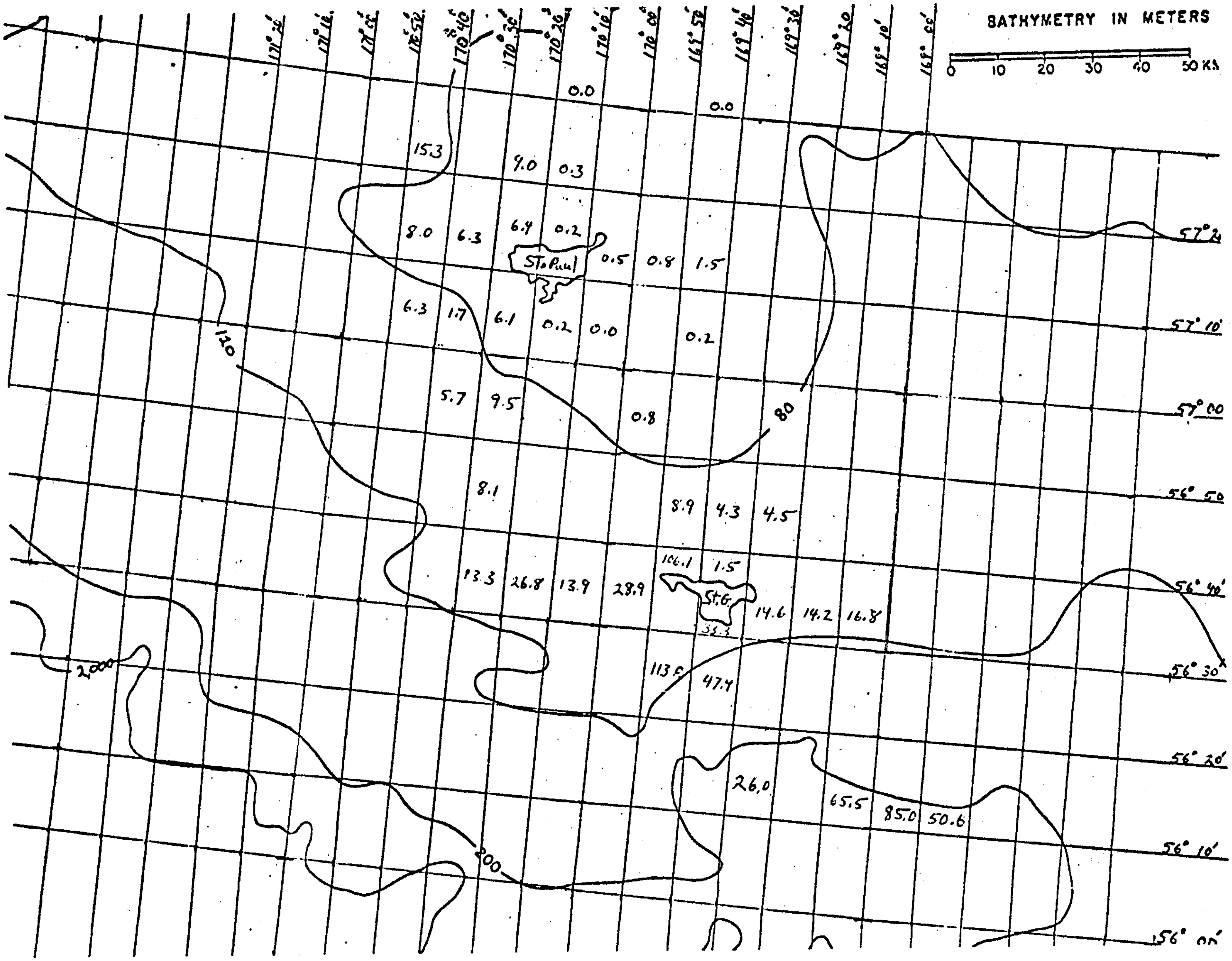
Appendix I. Fig. 4. Storm-Petrel- Mean birds/km^2 for all transects within each 10'x10' block.
21-24 August 1975



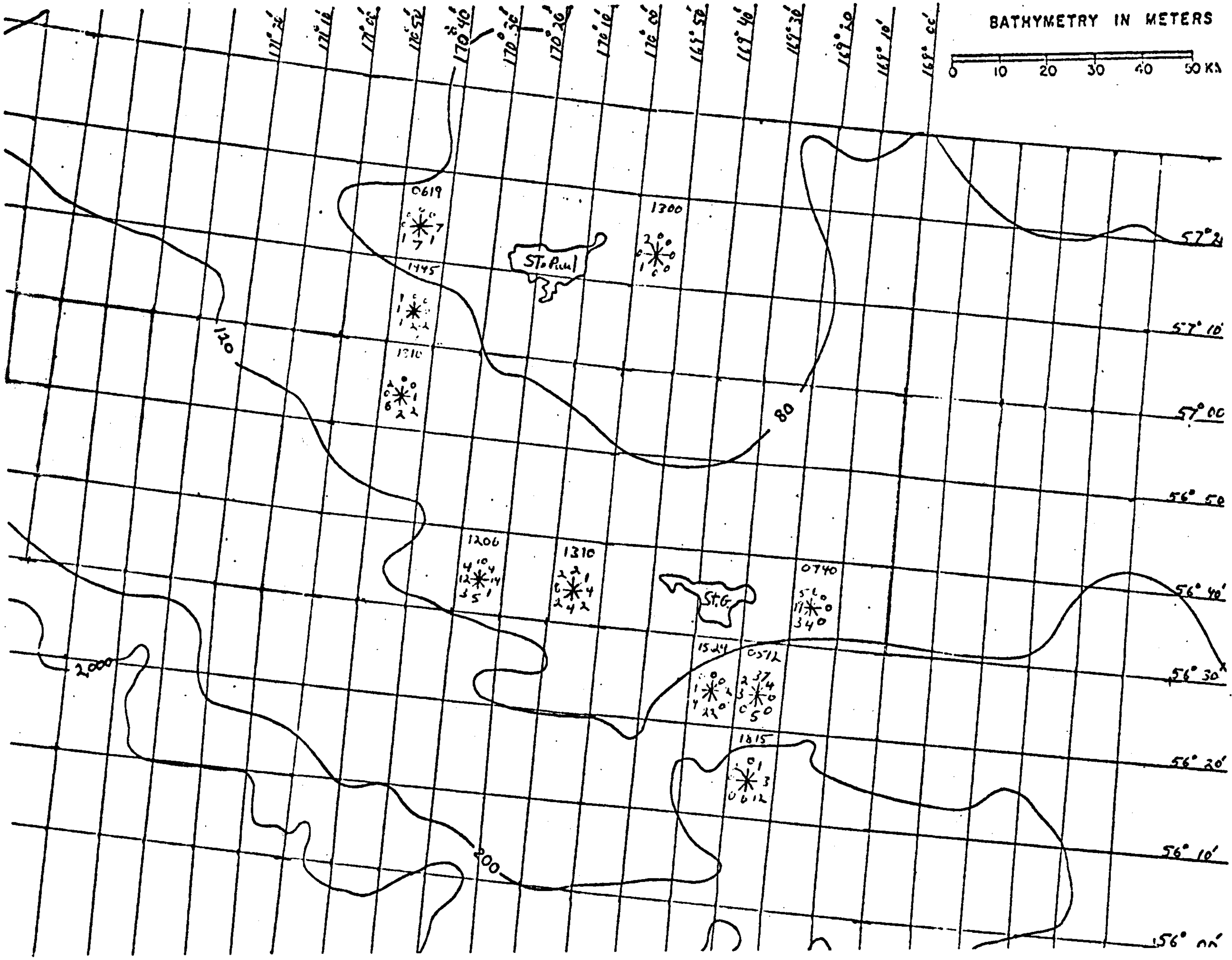
Appendix I. Fig. 5. Shearwaters - mean birds/km^2 for all transects within each 10'x10' block. 21-24 August 1975.



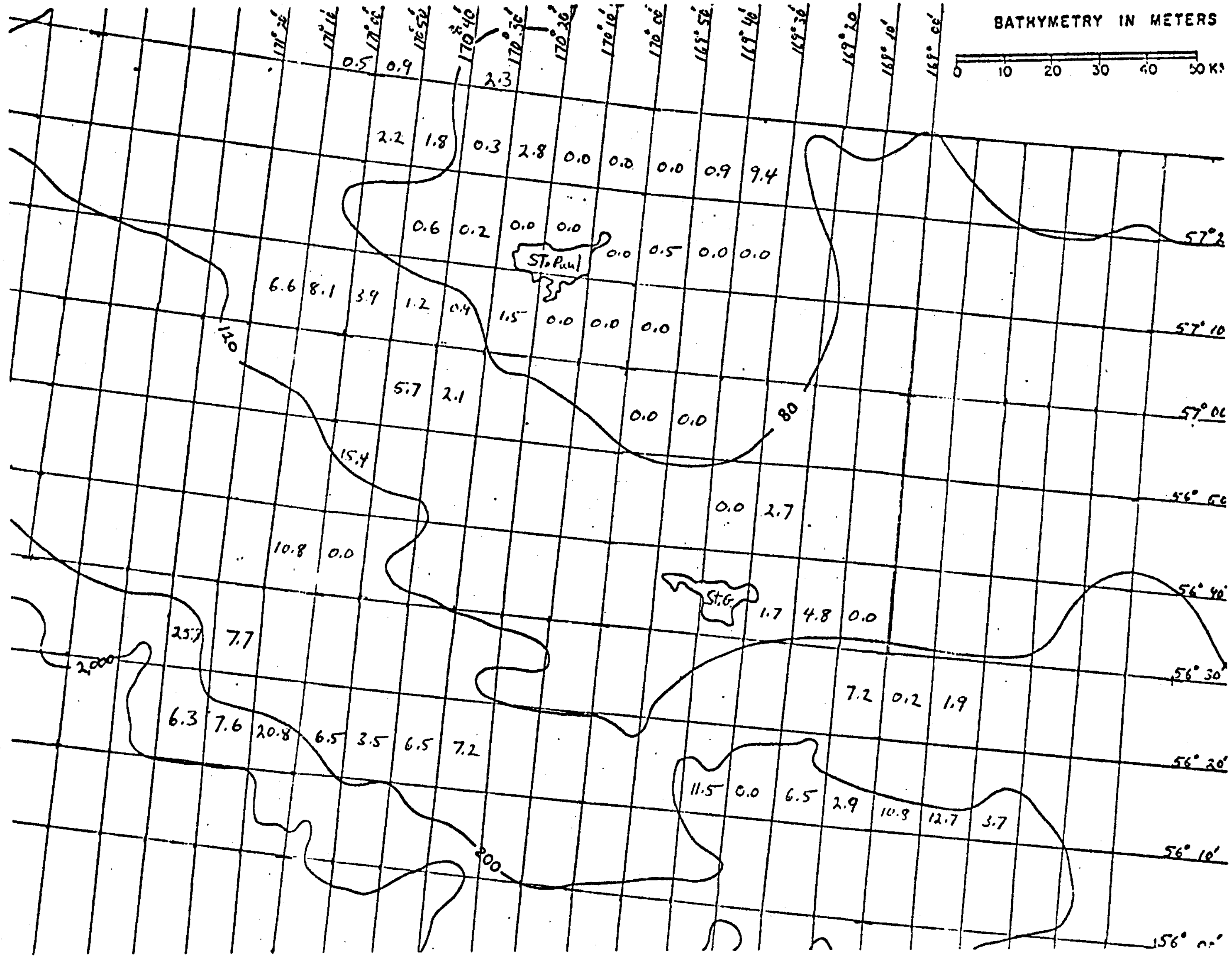
Appendix I. Fig. 6. Northern Fulmar- mean birds/km^2 for all transects within each 10'x10' block. 2-4 June 1976



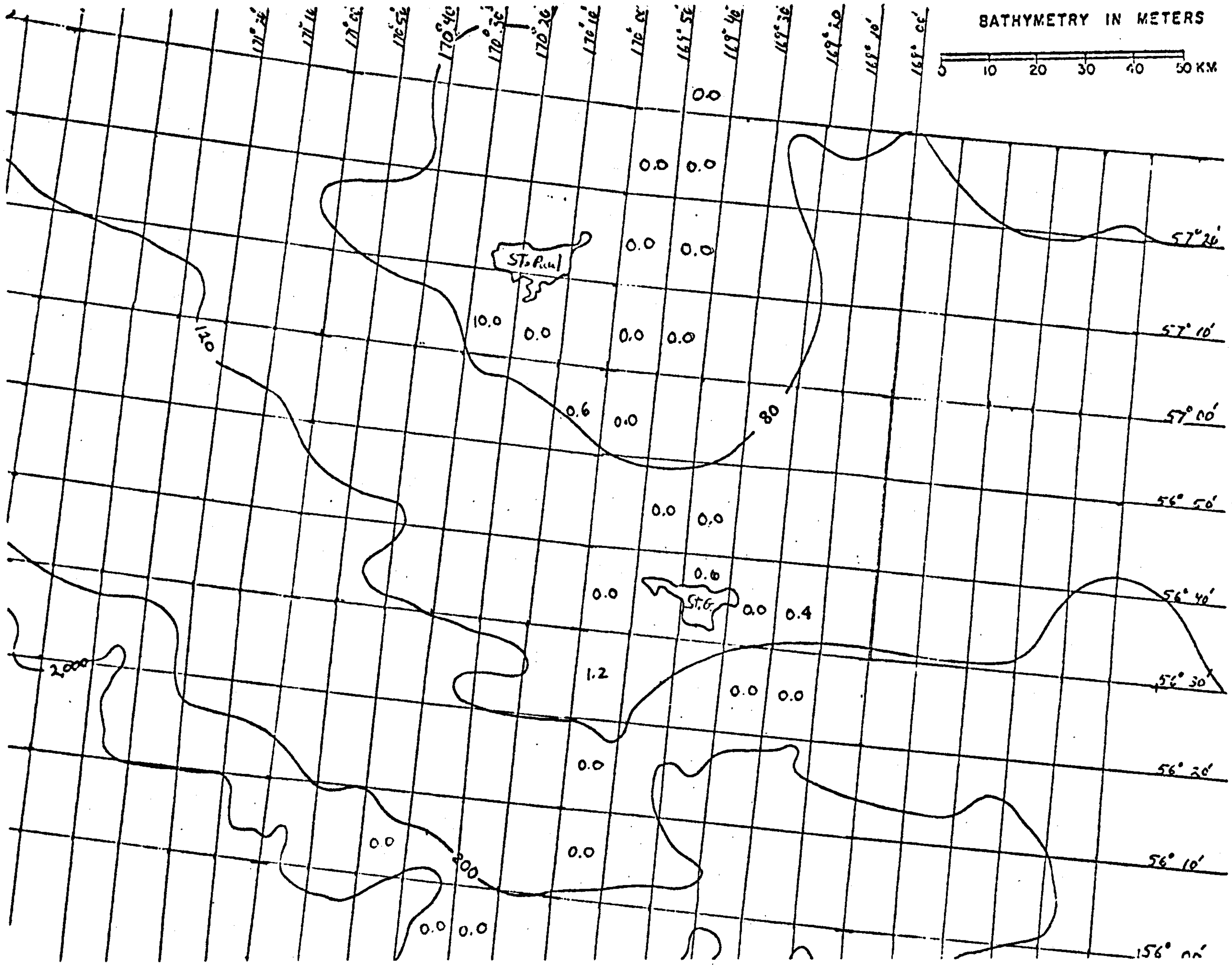
Appendix I. Fig. 7. Mean birds/km^2 for all transects within each 10'x10' block. 7-12 July 1976



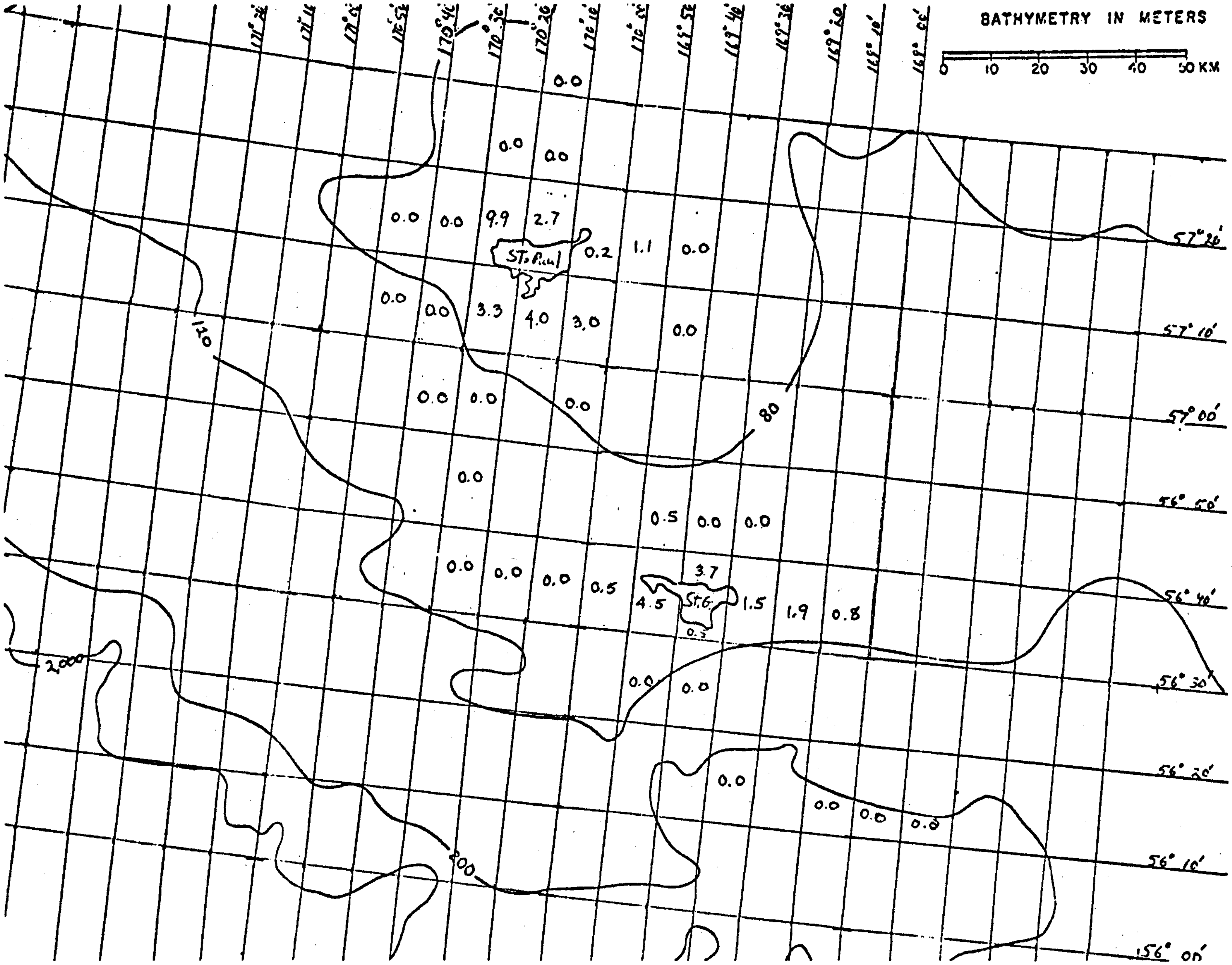
Appendix I. Fig. 8 Northern Fulmar - Number of flocks flying in indicated directions at times specified at top of 10'x10' block. 7-12 July 1976



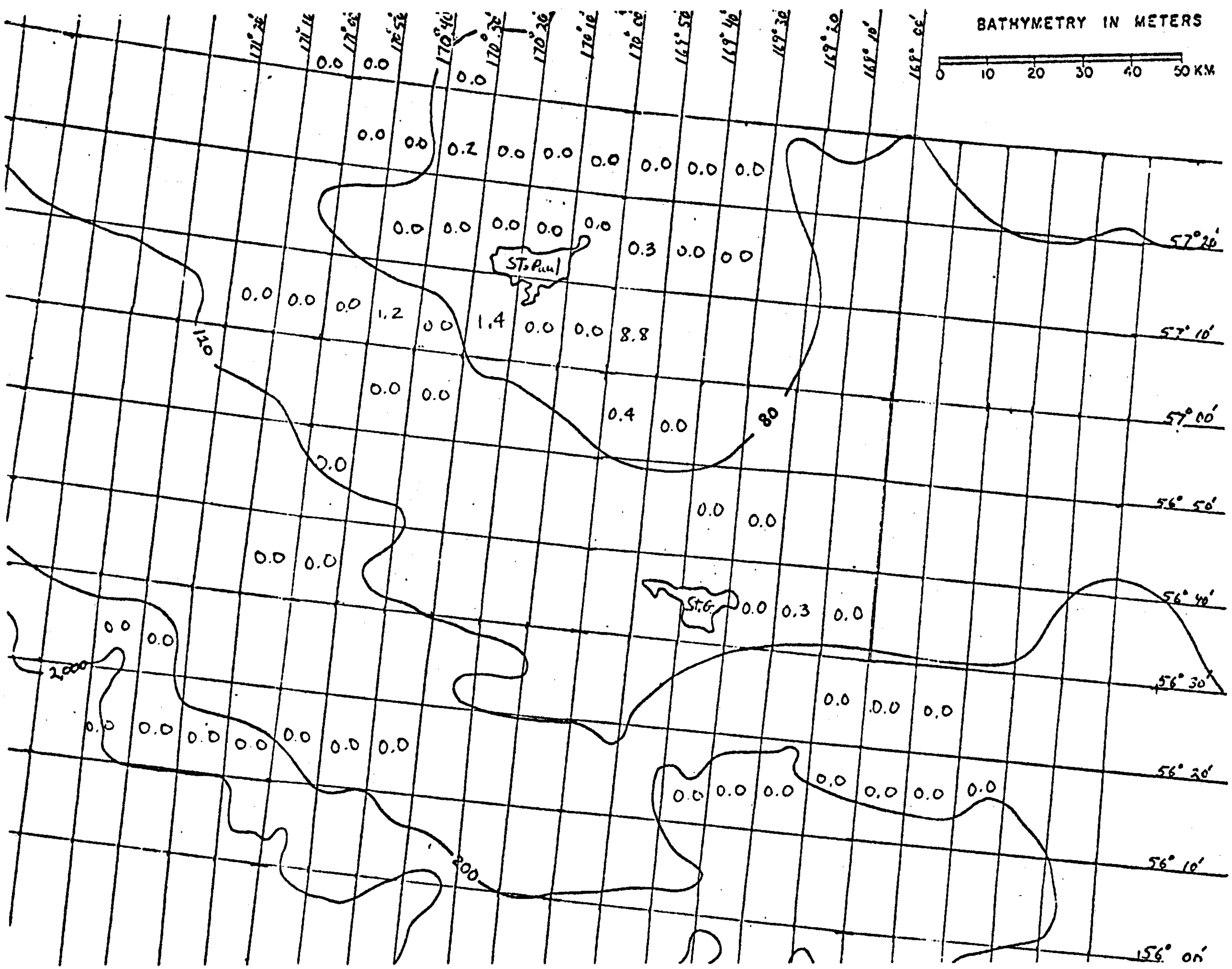
Appendix I. Fig. 9.
Northern Fulmar- mean birds/km^2 for all transects within each 10'x10' block. 21-24 August 1975.



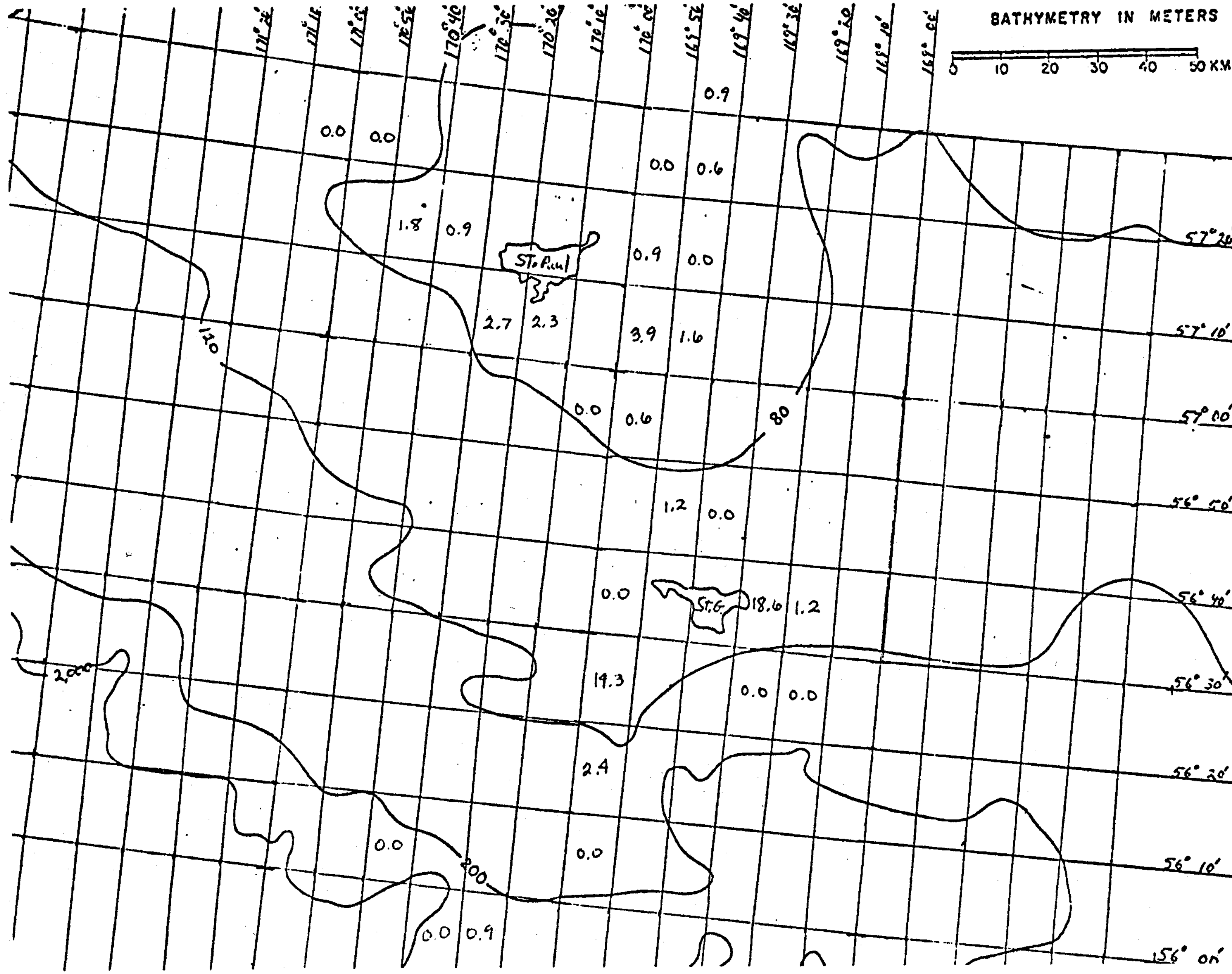
Appendix I. Fig. 10. Red-faced Cormorant - mean birds/km^2 for all transects within each 10'x10' block. 2-4 June 1976.



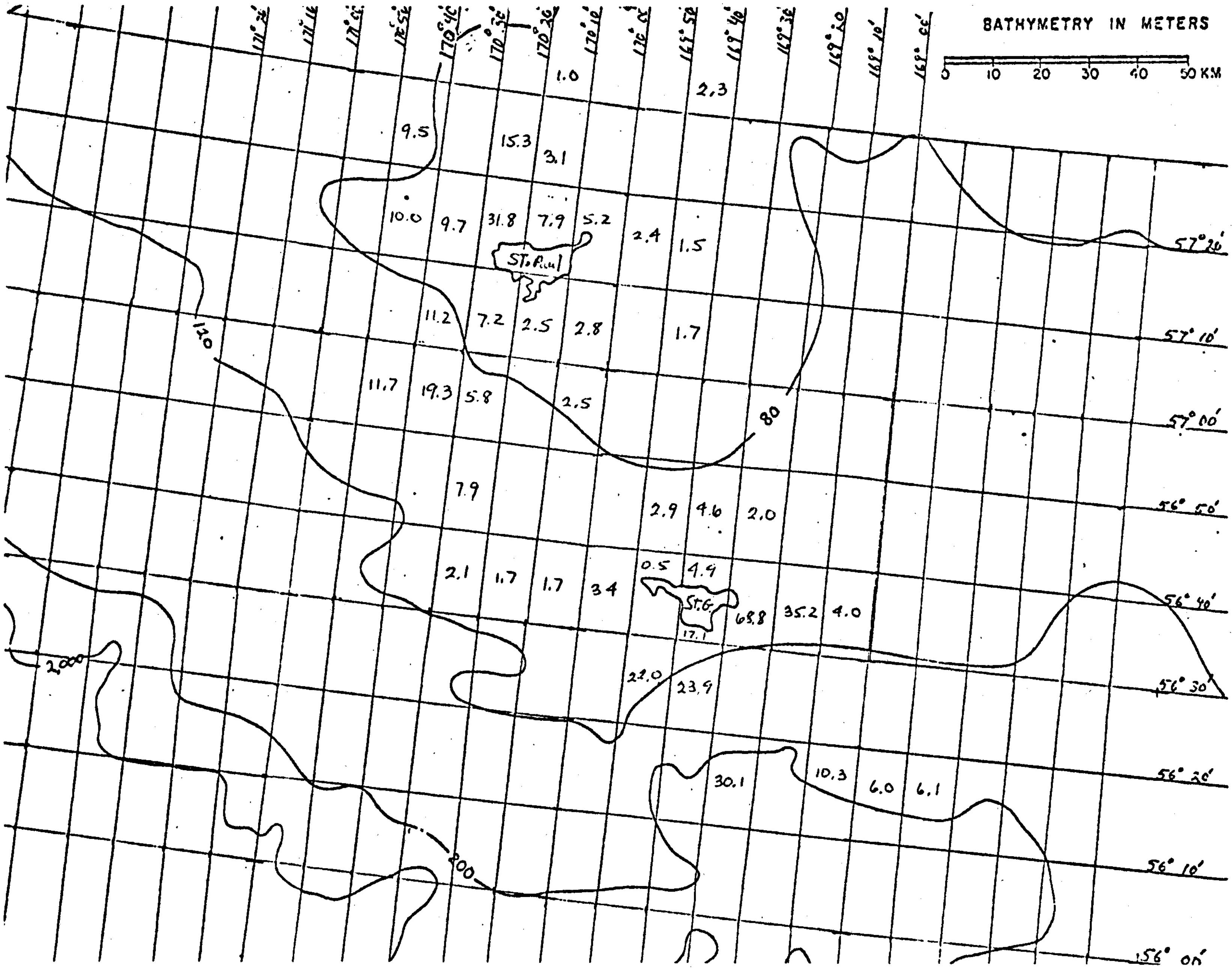
Appendix I. Fig. 11. Red-faced Cormorant - mean birds/km^2 for all transects within a 10'x10' block. 7-12 July 1976.



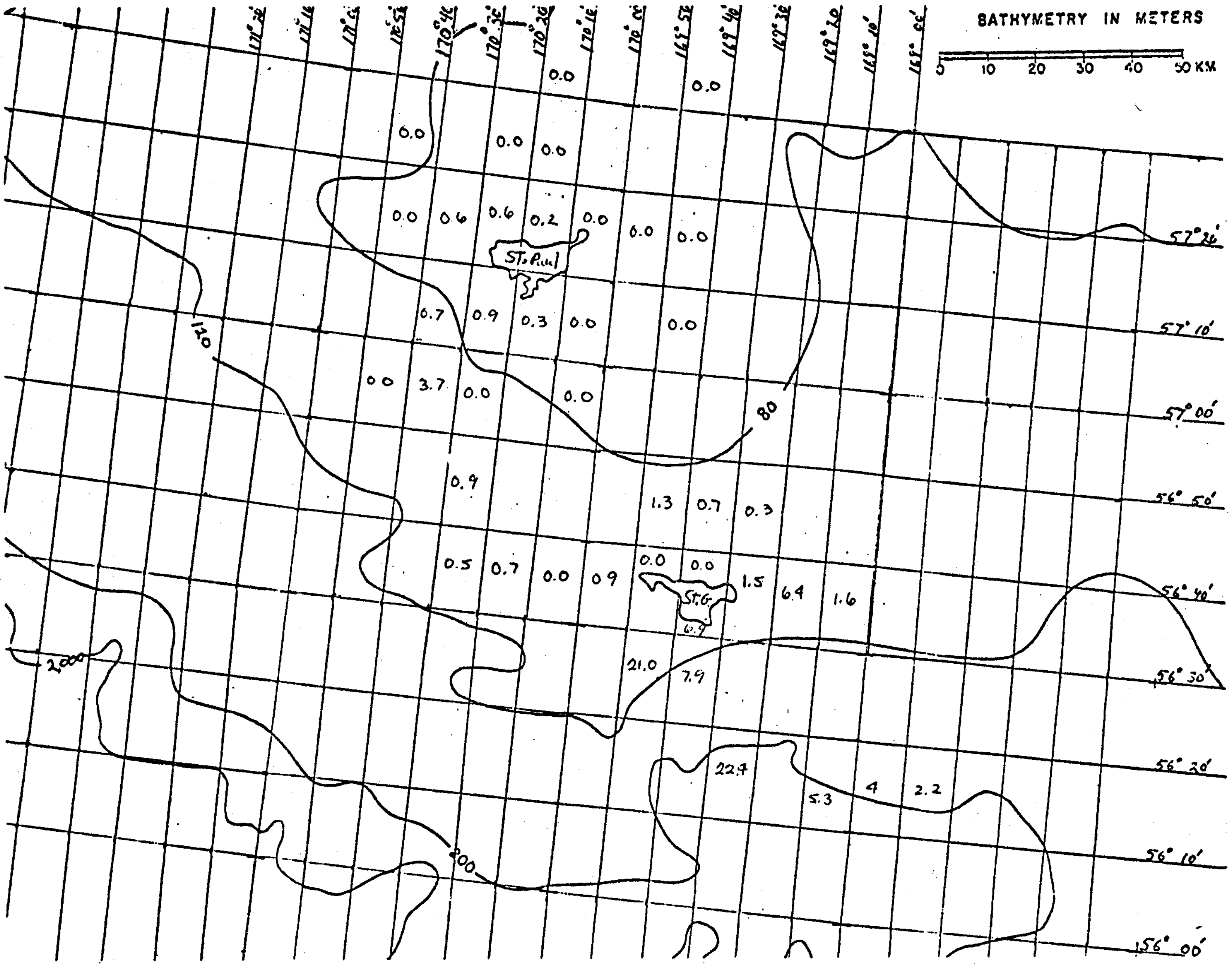
Appendix I. Fig. 12. Red-faced Cormorant - mean birds/km^2 for all transects within a 10'x10' block. 21-24 August 1975.



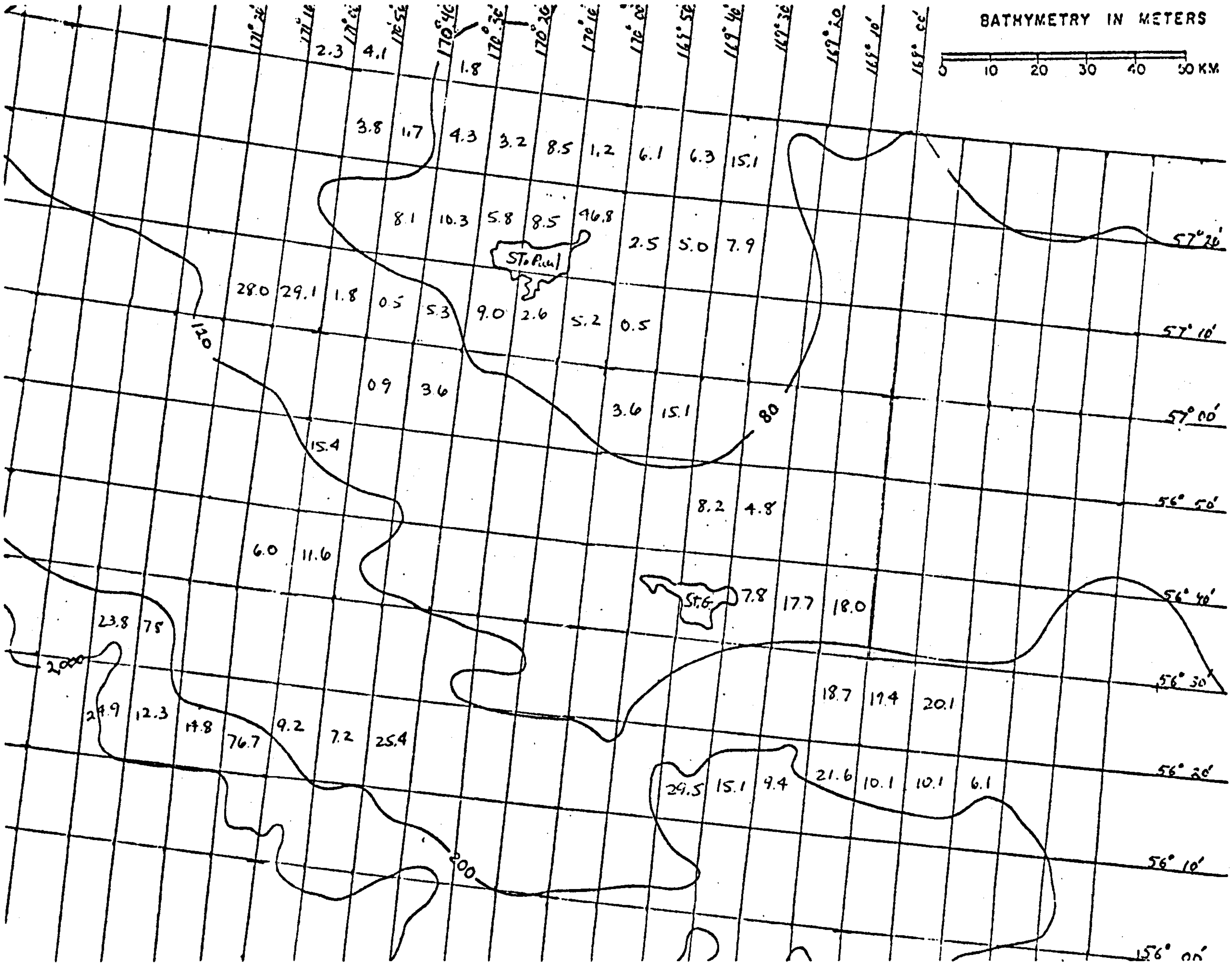
Appendix I. Fig. 13. Kittiwakes - mean birds/km^2 for all transects within each 10'x10' block. 2-4 June 1976.



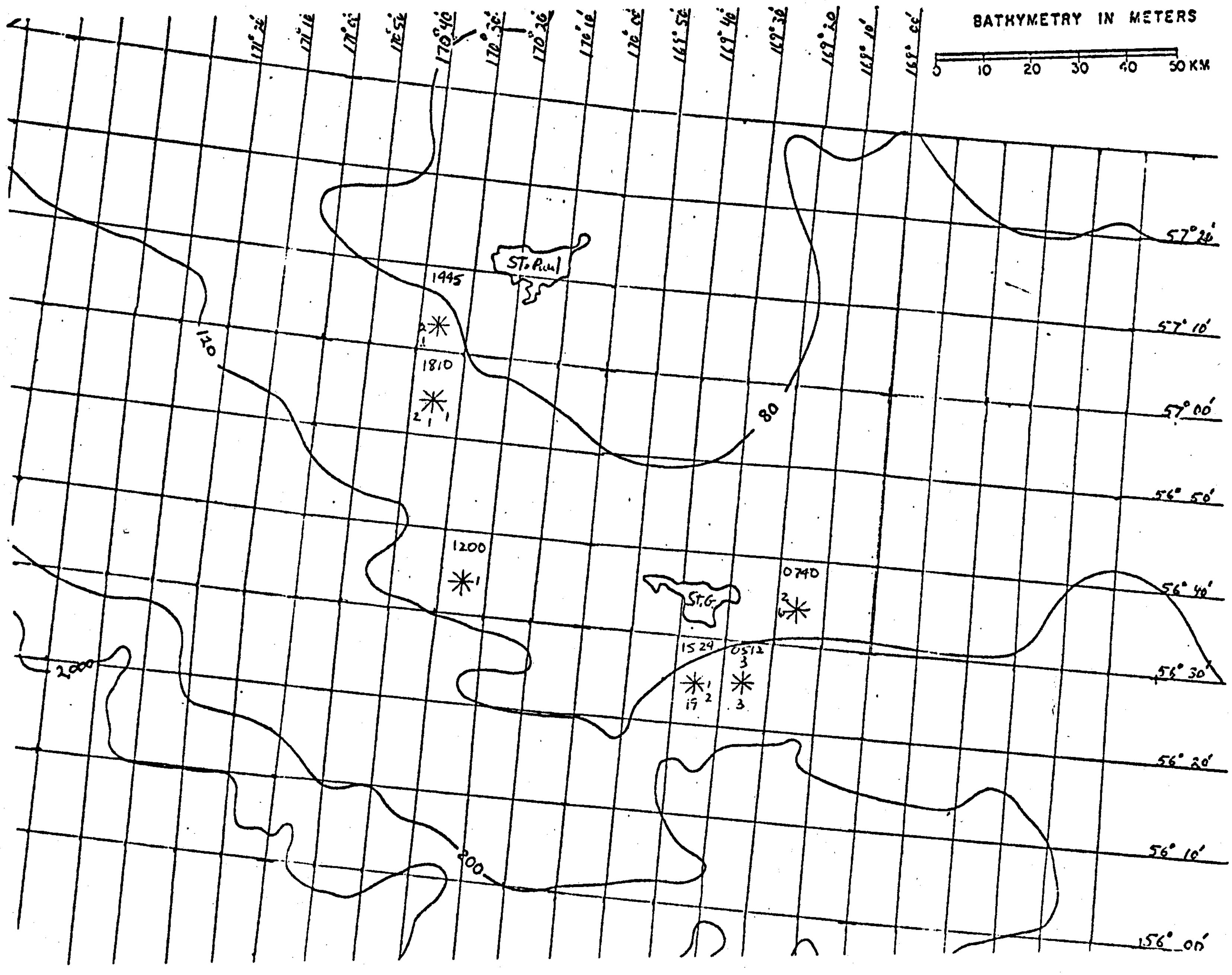
Appendix I. Fig. 14. All kittiwakes - mean birds/km^2 for all transects within each 10'x10' block. 7-12 July 1976.



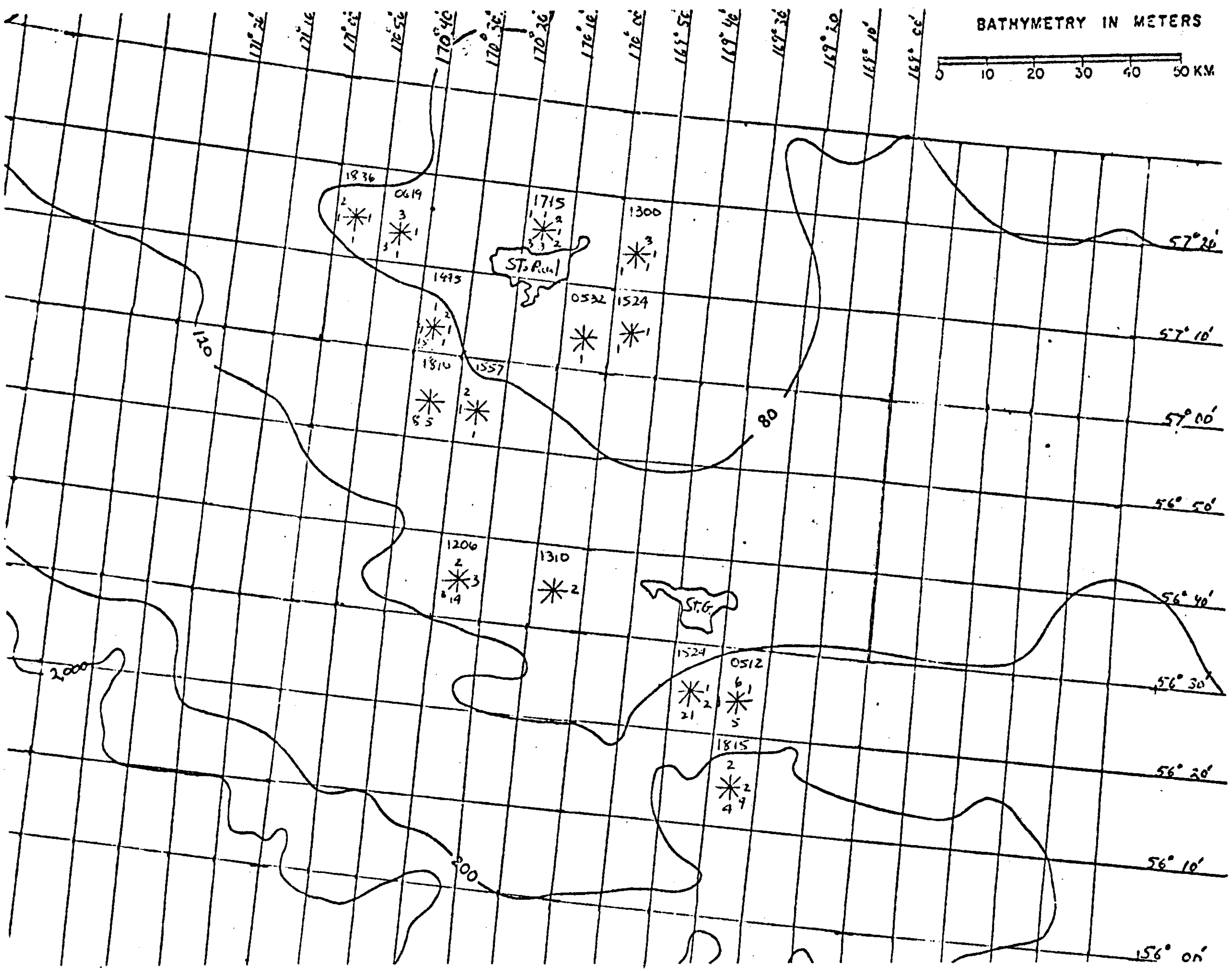
Appendix I. Fig. 15. Red-legged Kittiwake - mean birds/km^2 for all transects within each 10'x10' block. 7-12 July 1976.



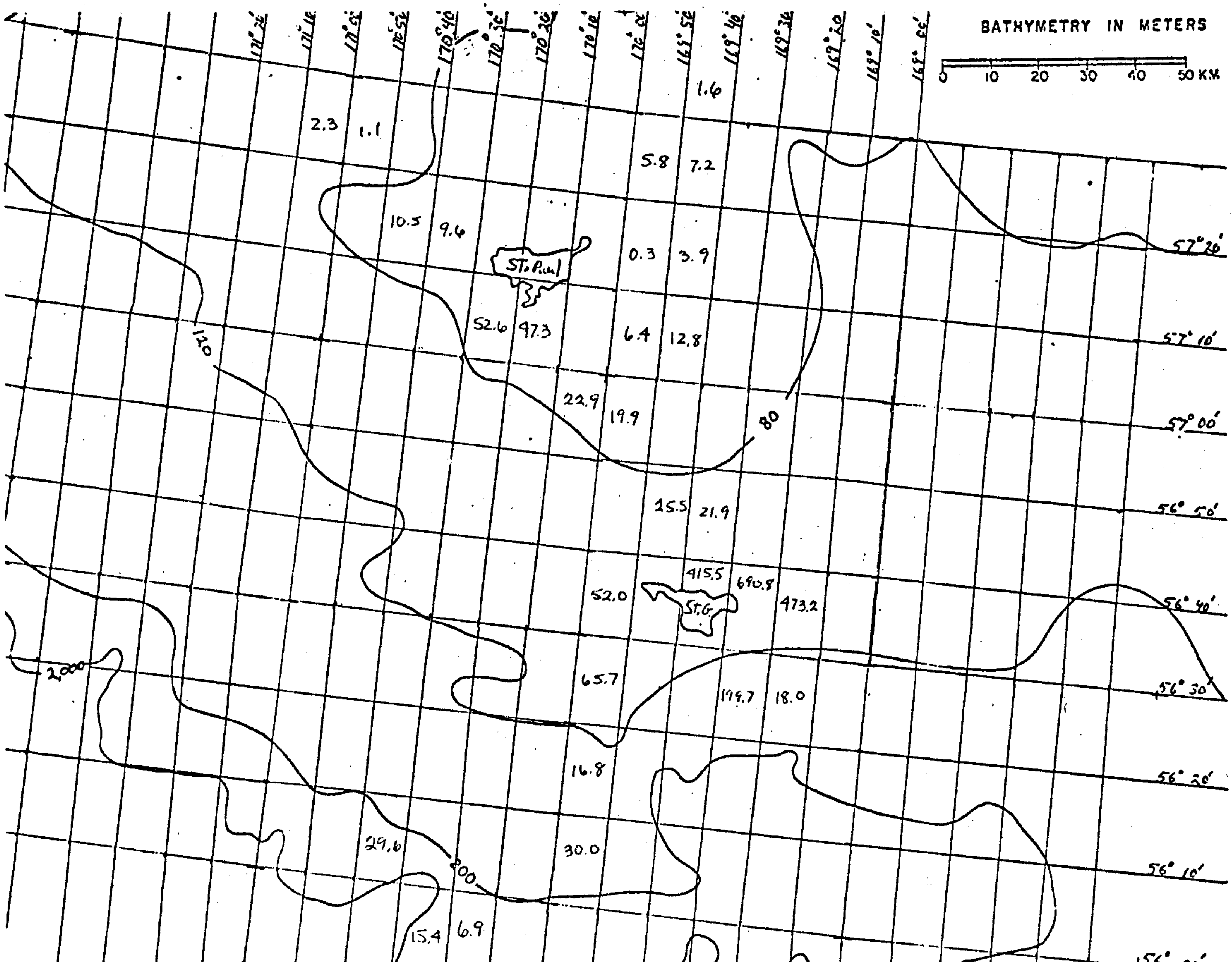
Appendix I. Fig. 16. All kittiwakes - mean birds/km^2 for all transects within each 10'x10' block. 21-24 August 1975.



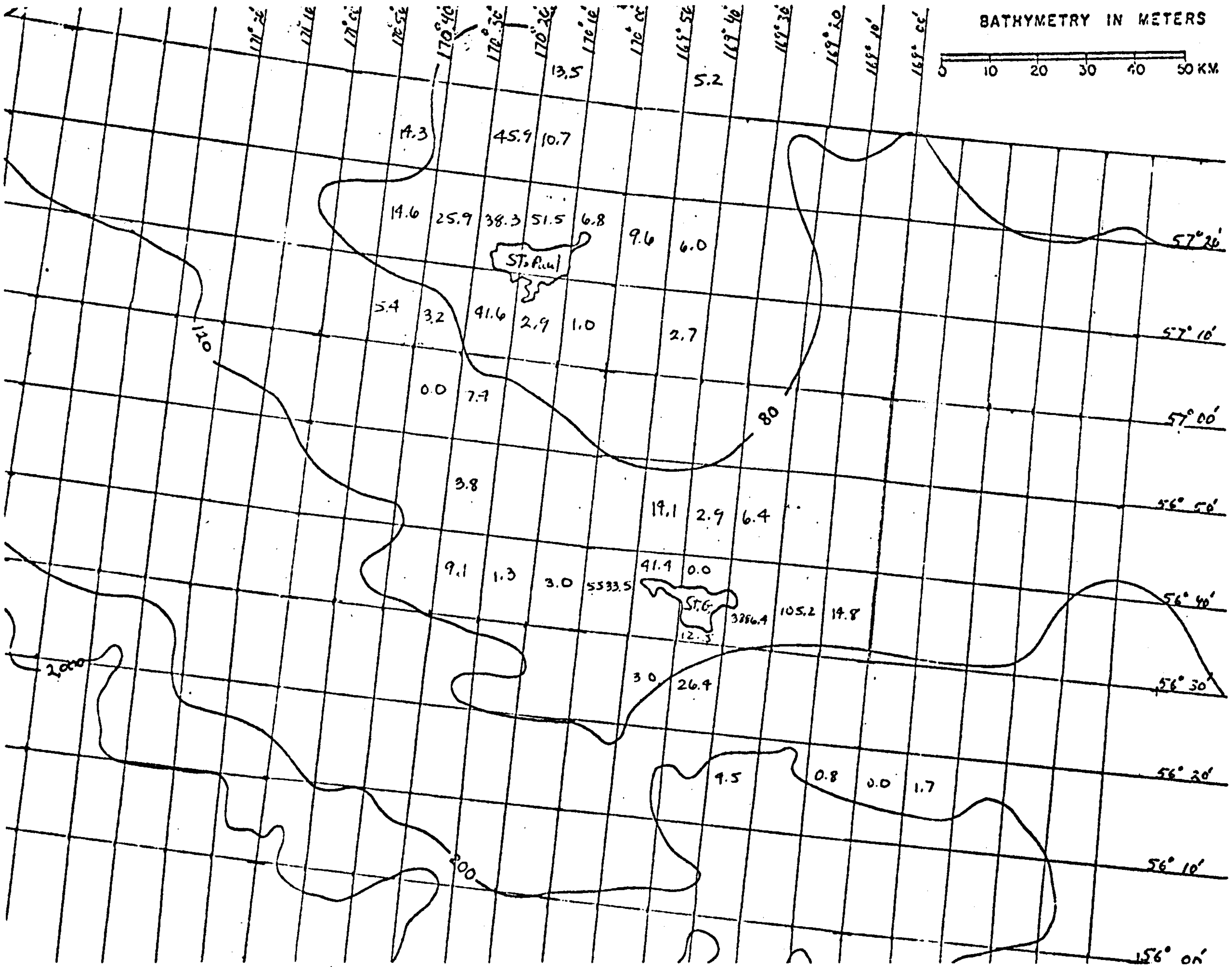
Appendix I. Fig. 17. Red-legged Kittiwake - Number of flocks flying in indicated directions at times specified at top of 10'x10' block. 7-12 July 1976.



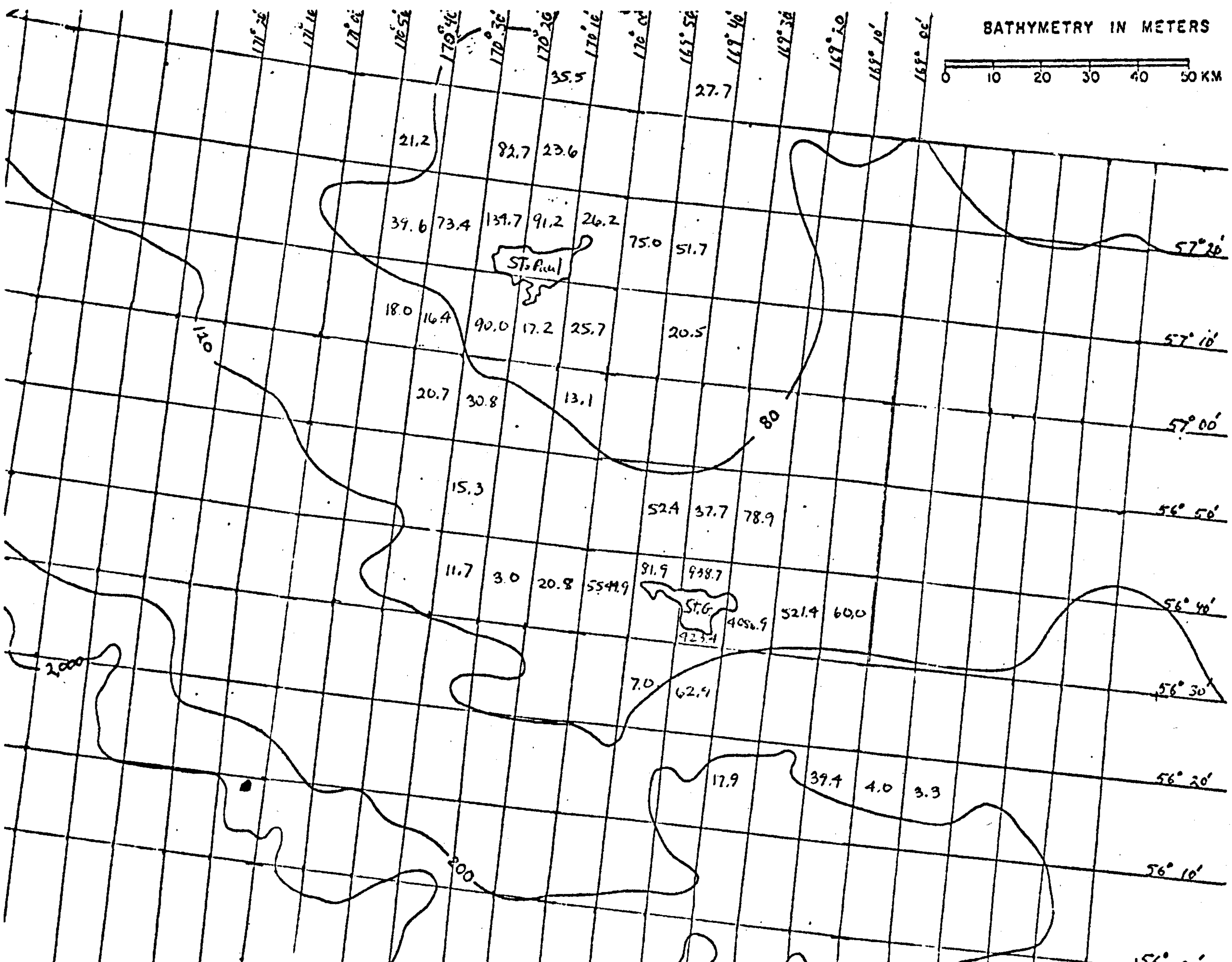
Appendix I. Fig. 18. Black-legged Kittiwake - Number of flocks flying in indicated directions at times specified at top of 10'x10' block. 7-12 July 1976.



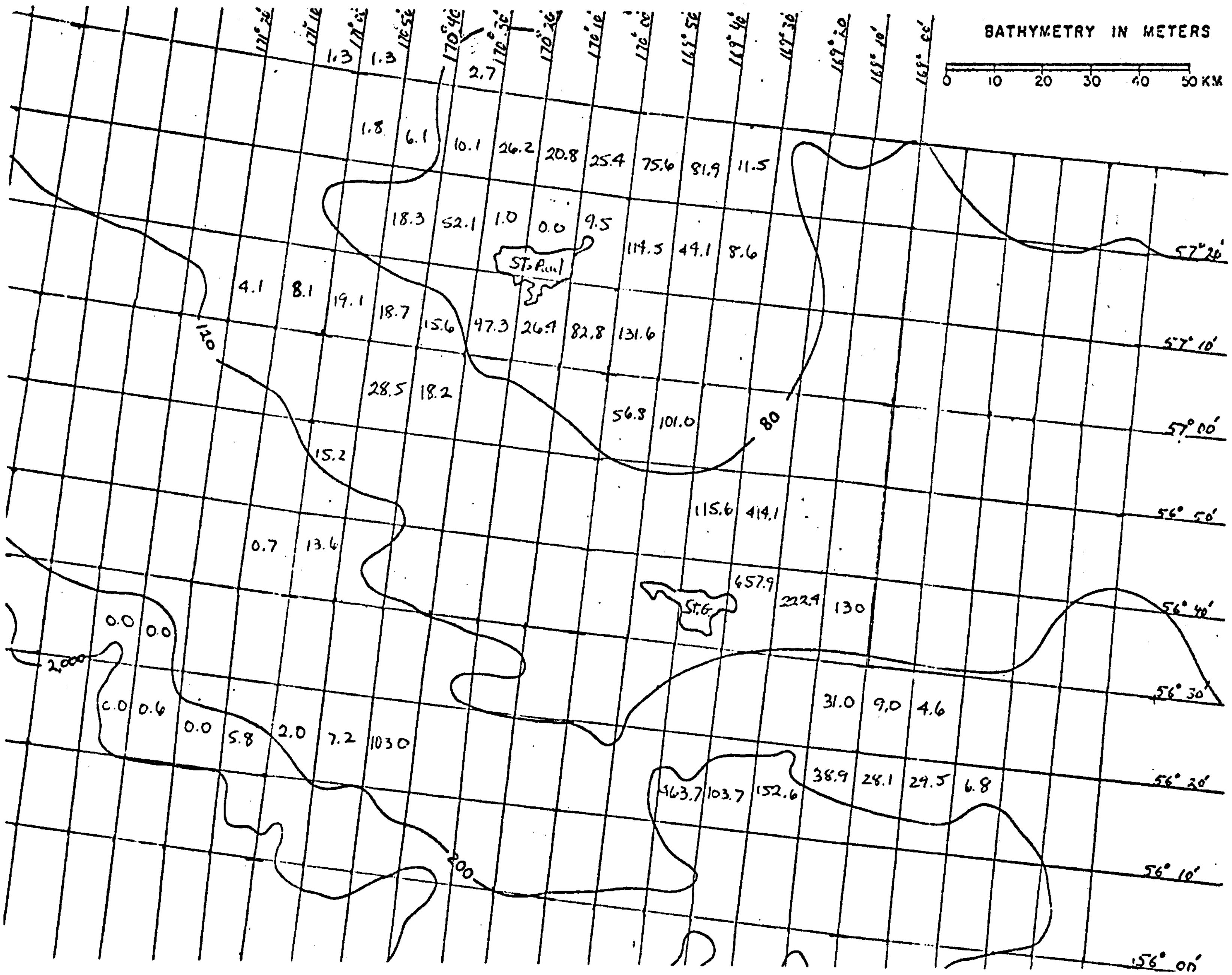
Appendix I. Fig. 19. All murres - mean birds/km^2 for all transects within each 10'x10' block. 2-4 June 1976.



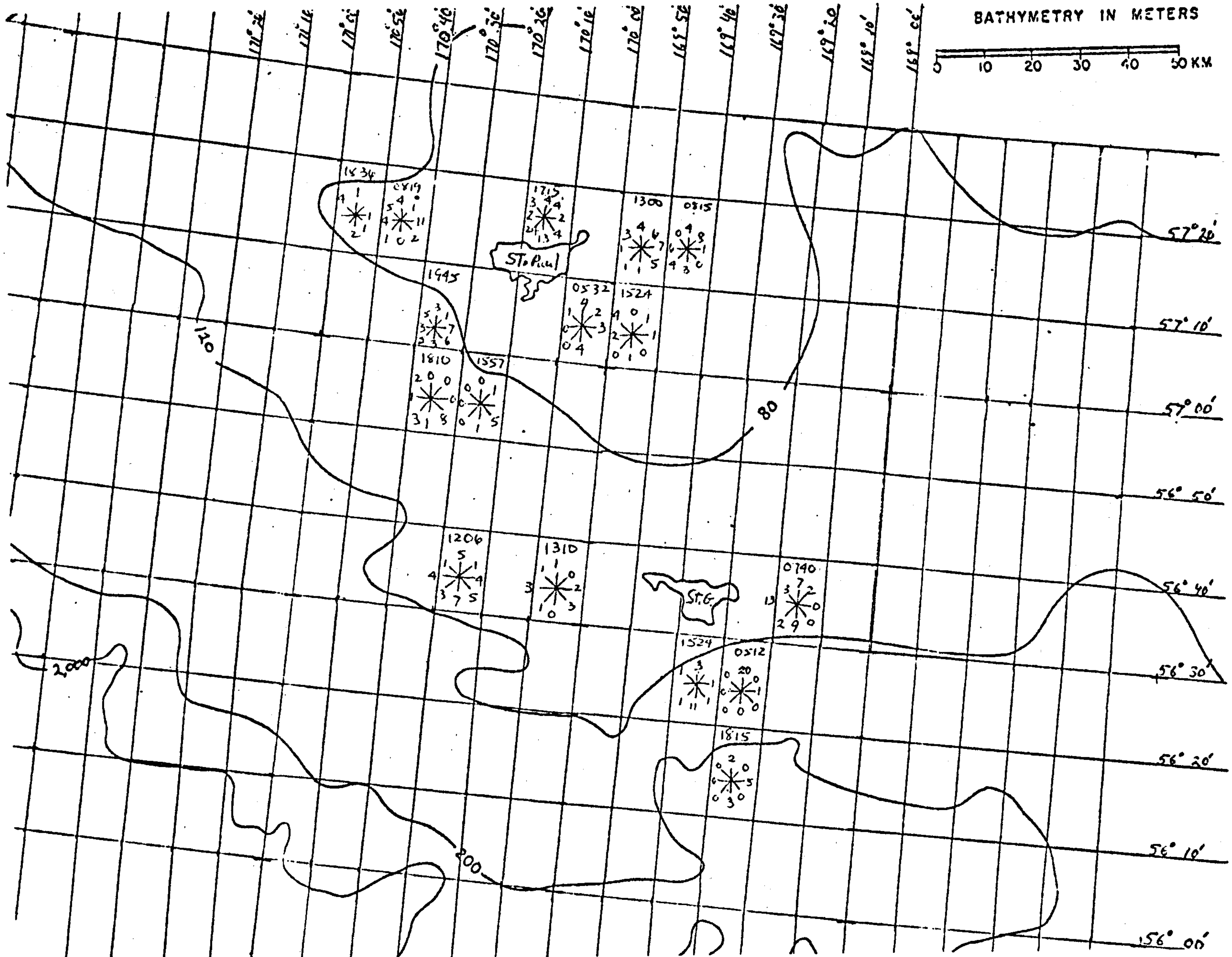
Appendix I. Fig. 20. All murres on water - mean birds/km^2 for all transects within each 10'x10' block. 7-12 July 1976.



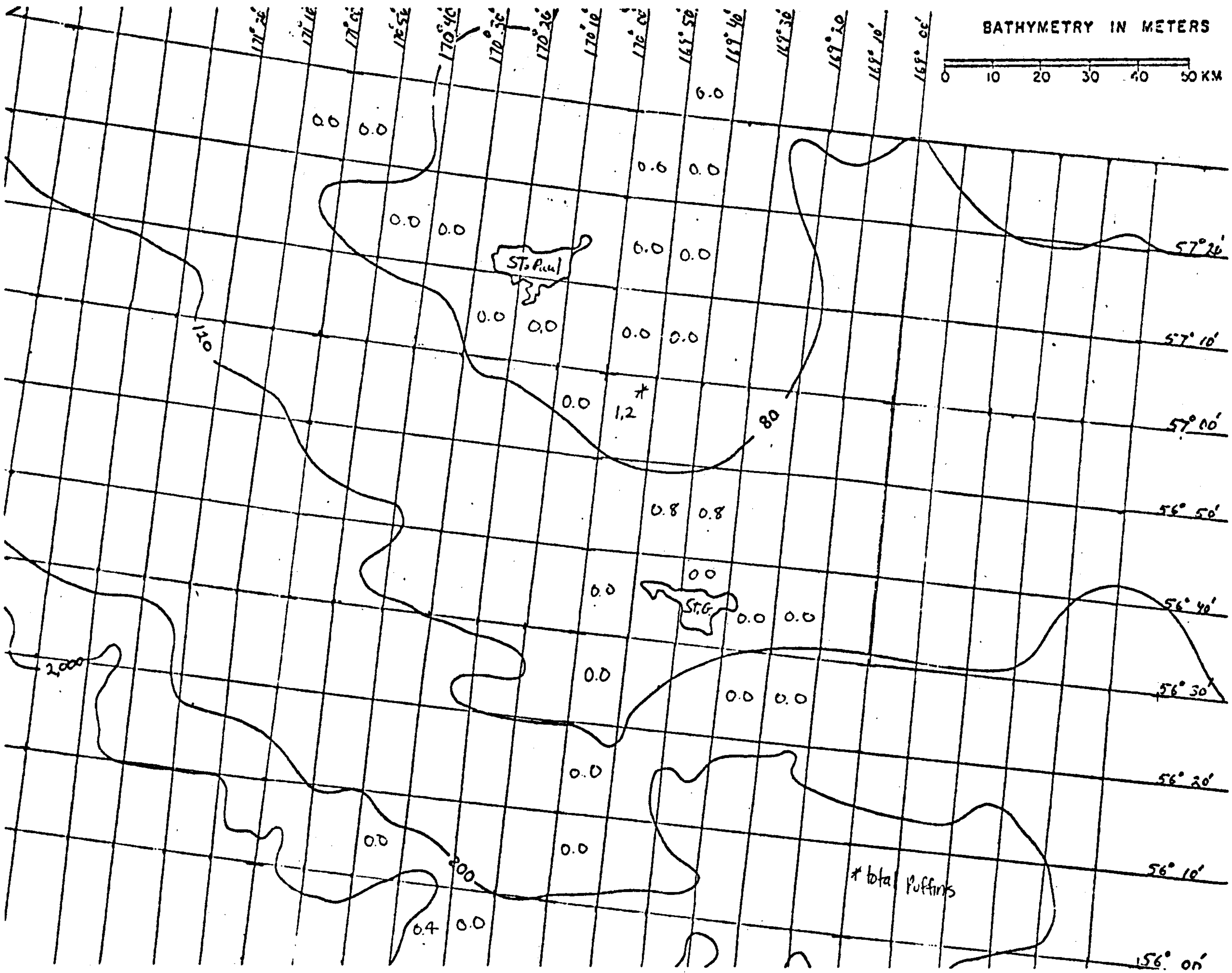
Appendix, I. Fig. 21. All murres - mean birds/km^2 for all transects within each 10'x10' block. 7-12 July 1976.



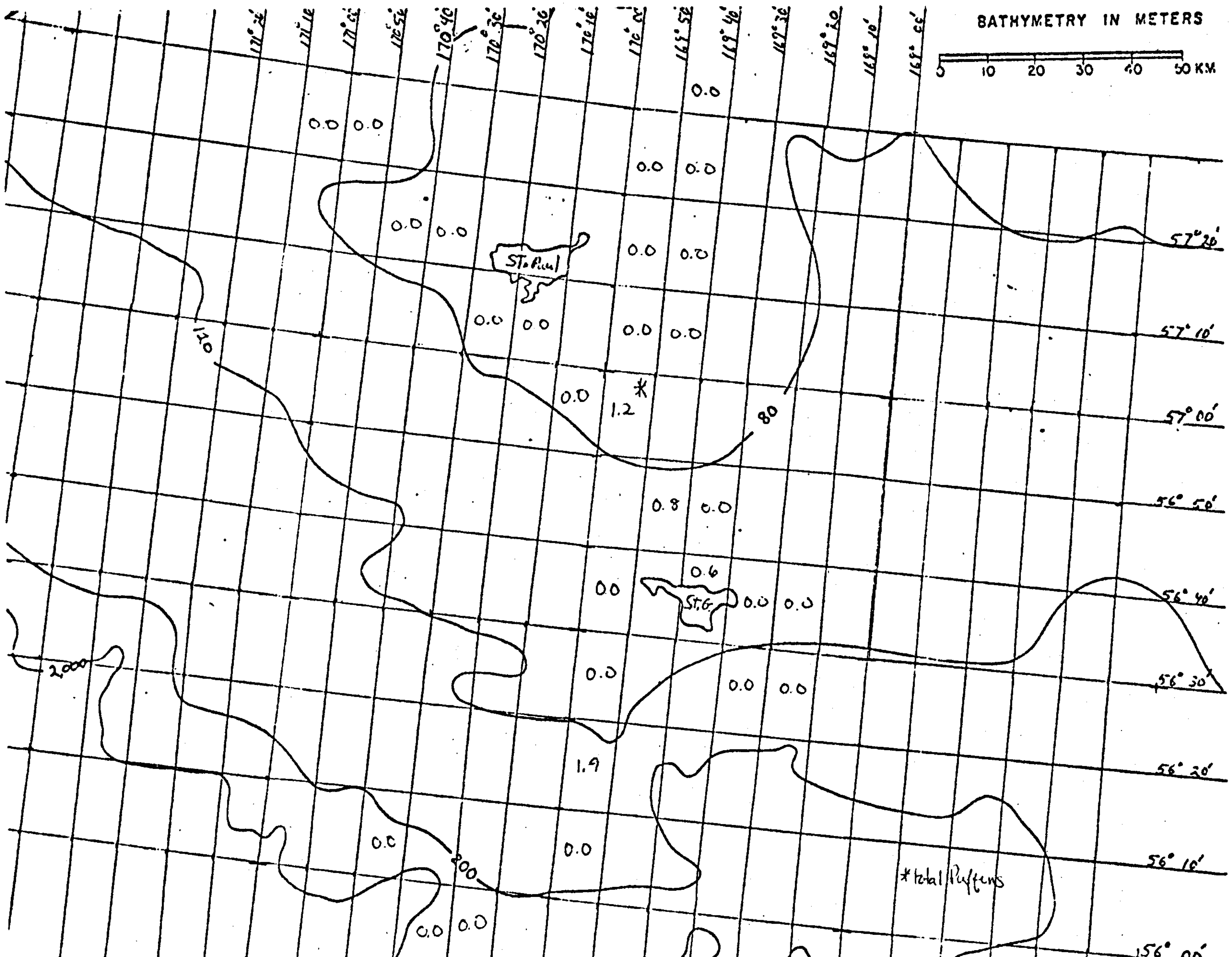
Appendix, I. Fig. 22. All murres - mean birds/km^2 for all transects within each 10'x10' block. 21-24 August 1975.



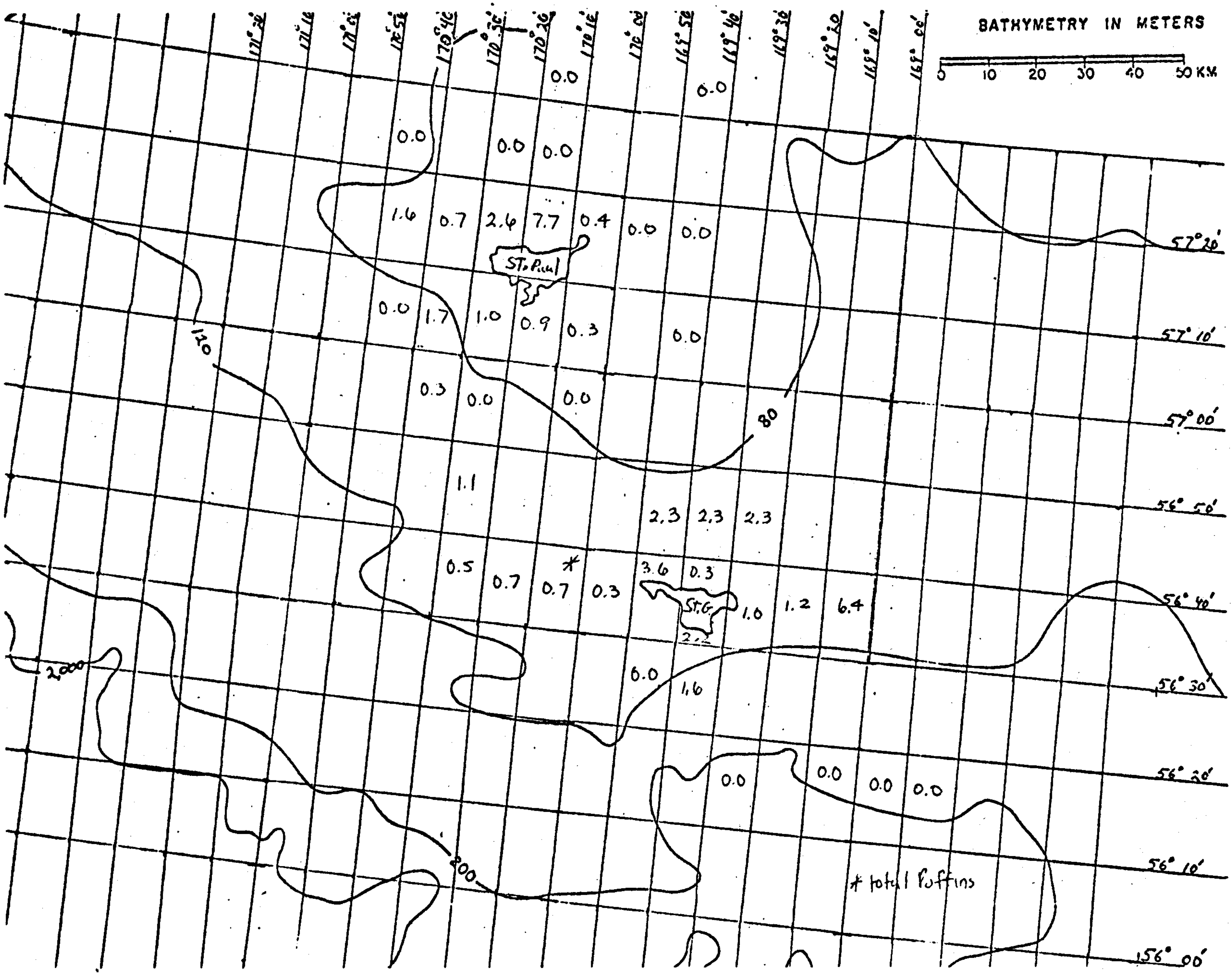
Appendix I. Fig. 23. All murres - Number of flocks flying in indicated directions at times specified at top of 10'x10' block. 7-12 July 1976.



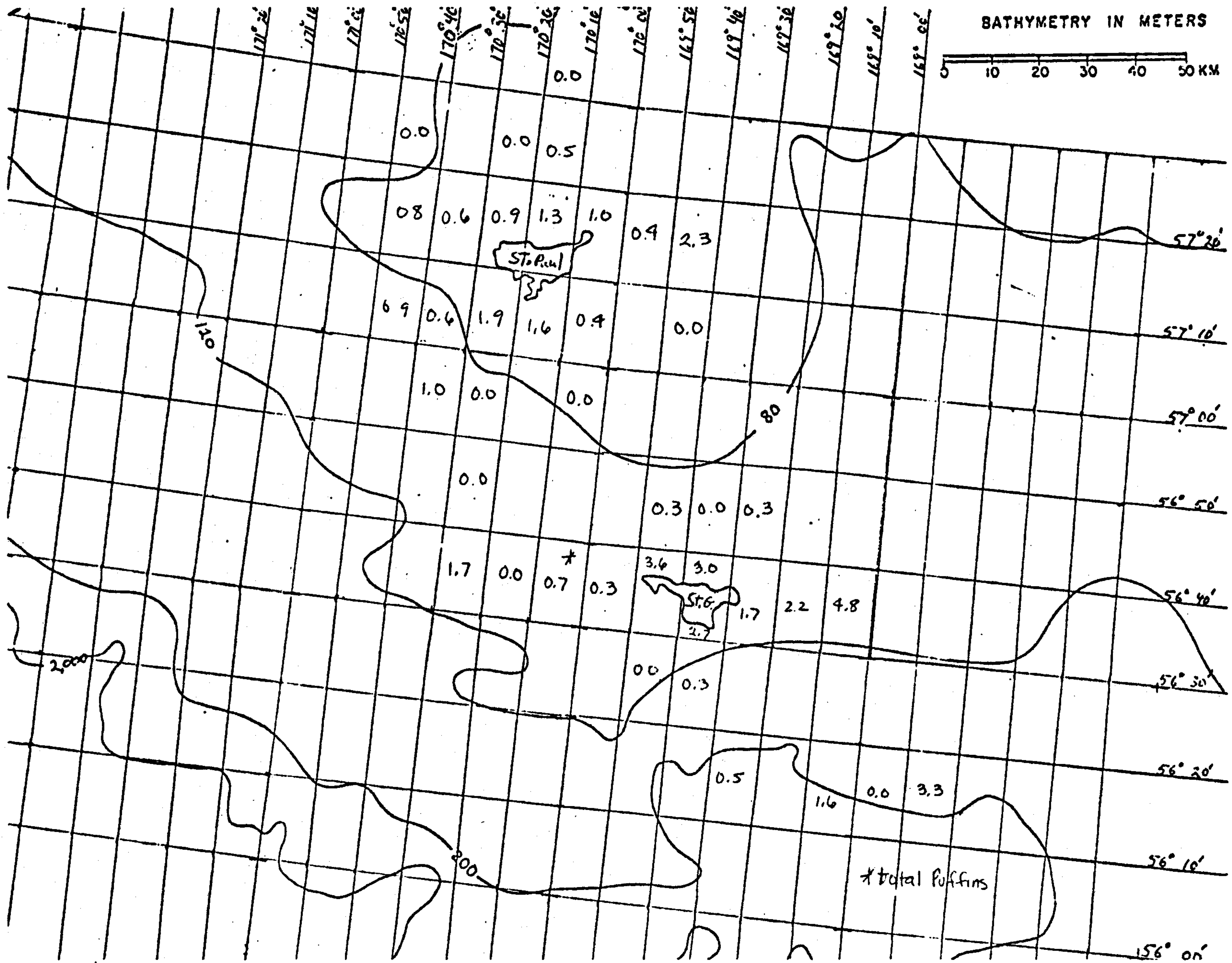
Appendix I. Fig. 24. Horned Puffin - mean birds/km^2 for all transects within each 10'x10' block. 2-4 June 1976.



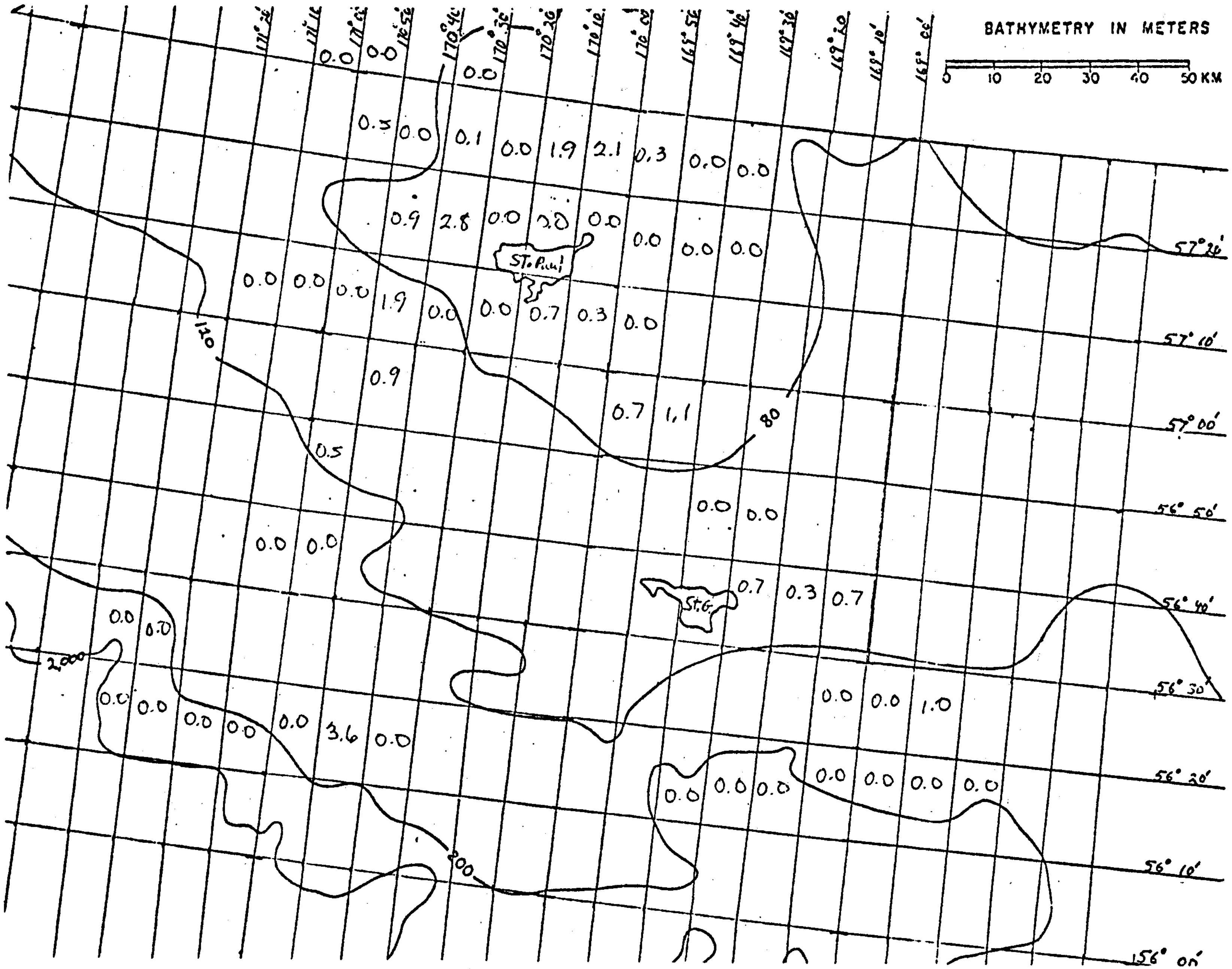
Appendix I. Fig. 25. Tufted Puffin - mean birds/km^2 for all transects within each 10'x10' block. 2-4 June 1976.



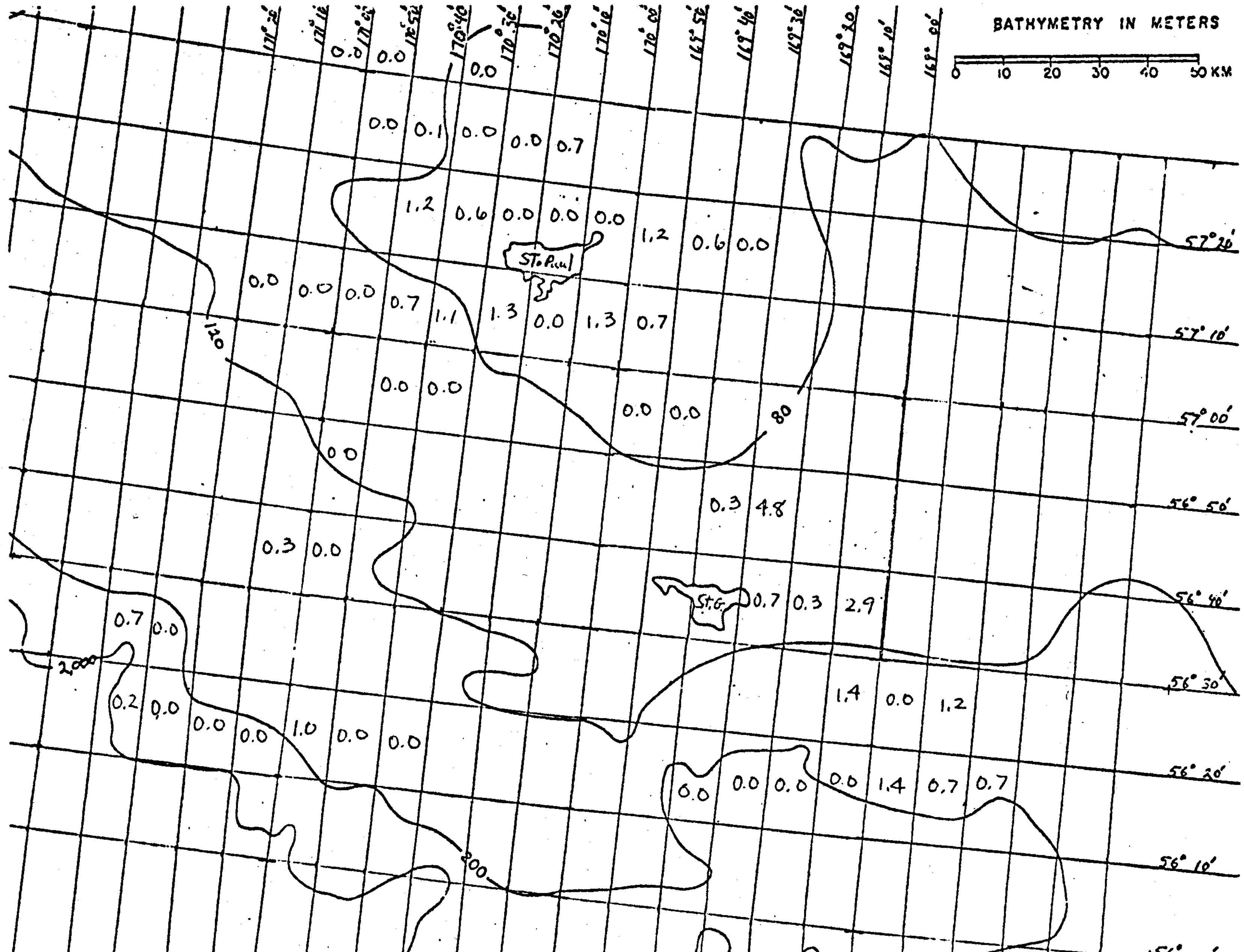
Appendix I. Fig. 26. Horned Puffin - mean birds/km^2 for all transects within each 10'x10' block. 7-12 July 1976.



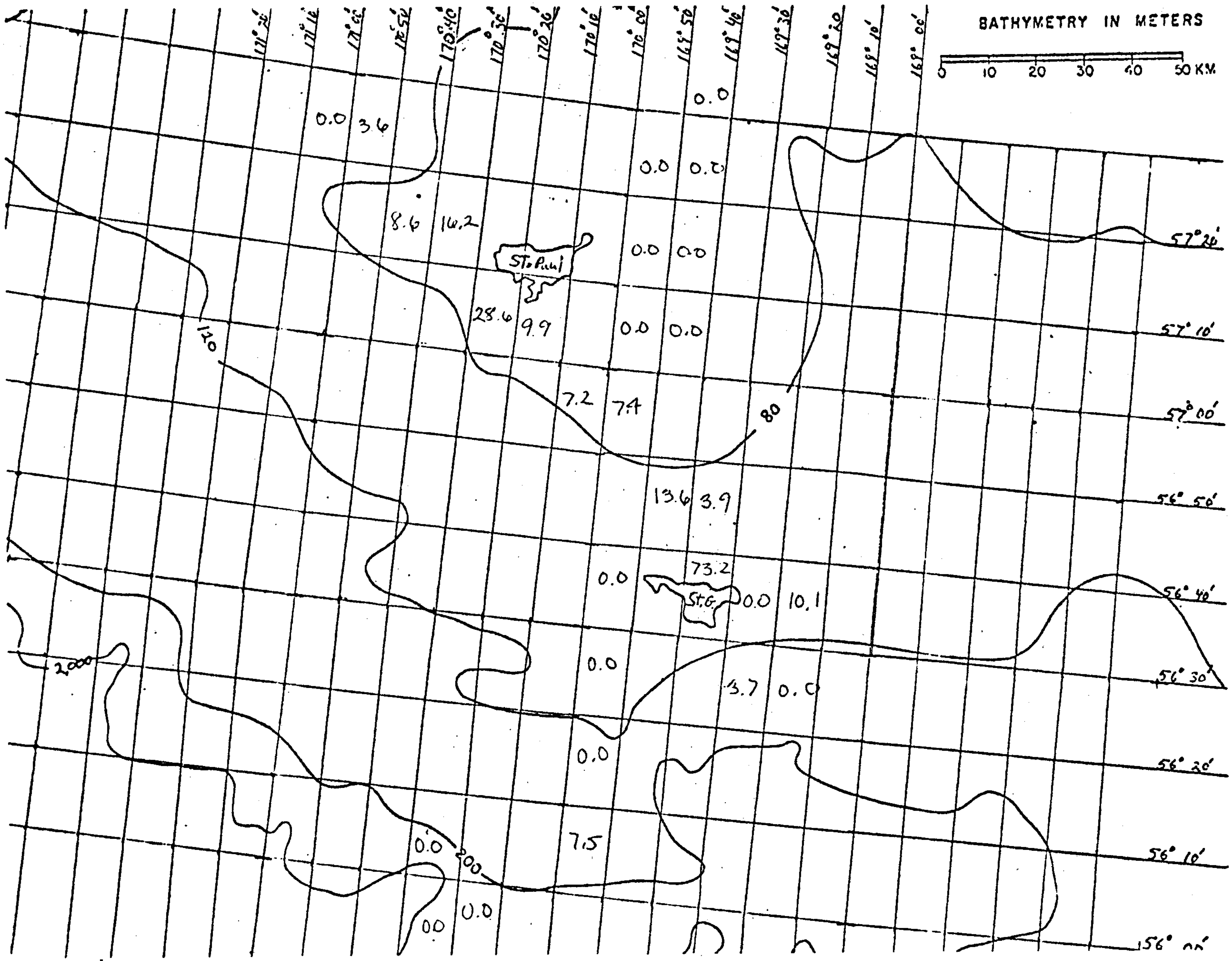
Appendix I. Fig. 27. Tufted Puffin - mean birds/km^2 for all transects within each 10'x10' block. 7-12 July 1976.



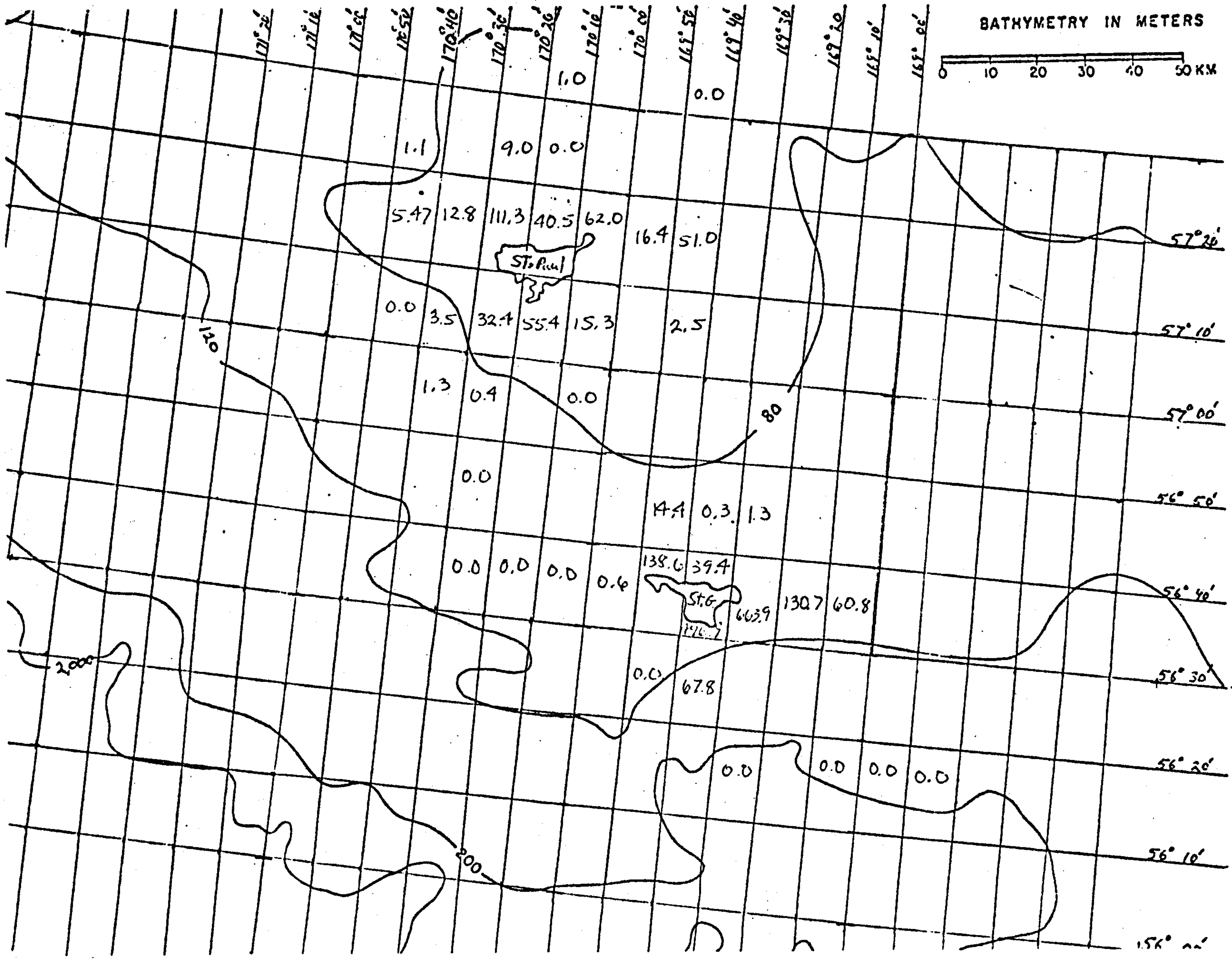
Appendix, I. Fig. 28. Horned Puffin - mean birds/km^2 for all transects within each 10'x10' block. 21-24 August 1975.



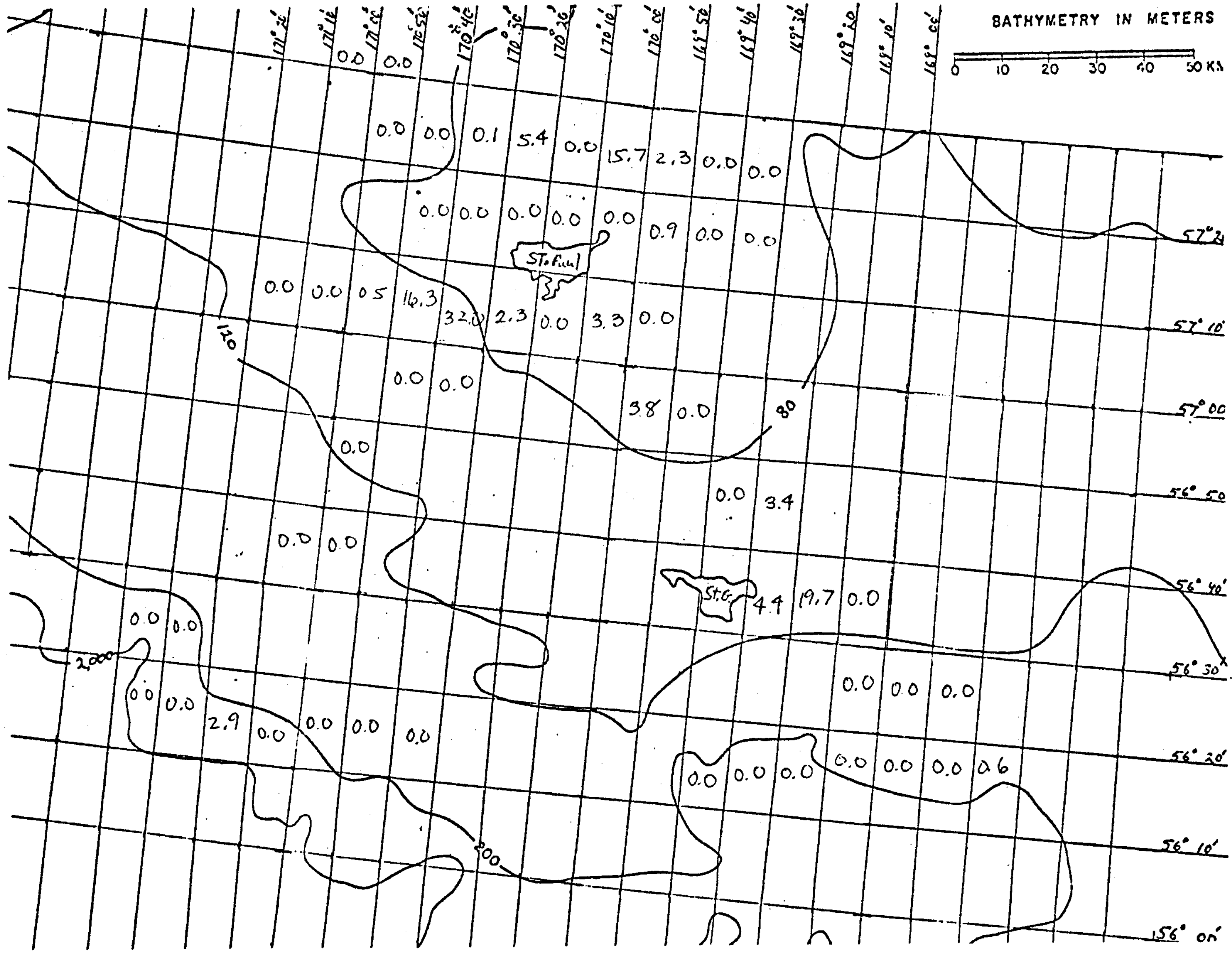
Appendix I. Fig. 29. Tufted Puffin - mean birds/km^2 for all transects within each 10'x10' block. 21-24 August 1975.



Appendix I. Fig. 30. All small auklets - mean birds/km^2 for all transects within each 10'x10' block. 2-4 June 1976.



Appendix I. Fig. 31. All auklets - mean birds/km^2 for all transects within each 10'x10' block. 7-12 July 1976.



Appendix I. Fig. 32. All auklets - mean birds/km^2 for all transects within each 10'x10' block. 21-24 August 1975.

XIV. Appendix II

A Report on the Reproductive Success of Black-legged Kittiwake (*Rissa tridactyla*) in Alaskan Waters 1976

Compiled by
George L. Hunt, Jr.

Introduction

Numerous observers around the coast of Alaska, under contract to NOAA-OCSEAP, reported various forms and degrees of reproductive failure in several colony-nesting species during 1976. In an effort to seek causal understanding of the phenomena, NOAA-OCSEAP convened a workshop of all bird investigators in October 1976 in Anchorage. As a result of this bringing together of an extensive overview out of multiple intensive site efforts, the Black-legged Kittiwake (*Rissa tridactyla pollicaris*) was selected for trial review because of its wide occurrence from Cape Lisburne in the Chukchi Sea, south to the southernmost OCSEAP sites in the Gulf of Alaska. I (George Hunt) have compiled information in the following text, with my tentative suggestion on the timing and nature of reproductive difficulties experienced by this species. Through this mechanism of pre-printing and limited distribution of the paper through NOAA-OCSEAP we are seeking to accomplish the following:

1. soliciting comments or alternative explanations for 1976 observations
2. emphasizing the need for many investigators to standardize observations on such widely occurring species
3. assessing the desirability and feasibility of compiling species accounts with relatively rapid turn-around time, to interpret apparent breeding anomalies in Alaskan marine species confronting offshore oil development.

Such species accounts depend on the good will and cooperation of the individual investigators, who must contribute their observations to a central compiler. Because all conclusions contained here in are tentative, permission to Cite this preliminary effort must be obtained from NOAA-OCSEAP.

Results and Discussion:

Chukchi and Northern Bering Sea

From Cape Lisburne in the north to St. Lawrence Island in the south there was an apparent general failure of Black-legged Kittiwake reproduction (Table 33). At Cape Lisburne, breeding progressed in many cases through nest construction, while at Cape Thompson very few breeding attempts progressed past site occupation, where only 15 nests with eggs or chicks were found by Springer. Alan Springer in 1976 located the first laid egg on 4 July. L. G. Swartz (1966) reported first eggs on 22 June, 21 June and 25 June for 1959, 1960 and 1961 respectively.

In Norton Sound, William Drury reported that reproductive effort "appeared normal well into egg-laying stage and then fell apart completely". Egg laying on Bluff Island occurred between 25 June and about 14 July, much the same time period when the reproductive efforts of Black-legged Kittiwakes on Cape Lisburne and Cape Thompson failed. In 1976, only 16-38% of the nests in the Norton Sound Colonies had adults incubating, while in 1975 on Bluff Island 70-80% of the nests were being incubated. Reproductive output in 1976 was reduced to 0.02 young/nest, in comparison to 0.34-0.50 young/nest in 1975.

At St. Lawrence Island, Gary Searing found that in 1976 the Black-legged Kittiwakes experienced reproductive failure after nests were built (Table 33). On this island they had an almost complete failure to lay eggs. Only two eggs and one fledgling were found. The first egg in 1976 was found on 29 June.

Springer's failure to observe kittiwakes copulating, the lack of brood patches on kittiwakes, the delay in nesting, and the lack of foraging flocks at Cape Lisburne and Cape Thompson all suggest that a scarcity of food was responsible for the reproductive failure. Drury also suggested that food may have been in short supply in 1976 near Bluff Island, although he also mentioned that a storm following a period of cold weather may have triggered breeding failure on King Island. On St. Lawrence Island, Searing found "normal" productivity for Murres (60%) at the same time as the kittiwakes failed. This result again suggests that failure of some aspect of the food chain peculiar to Black-legged Kittiwakes was the cause their low productivity rather than weather.

Eastern Bering Sea:

In contrast to the failures in the Chukchi and northern Bering Sea, Black-legged Kittiwakes on the Pribilof Islands and Cape Pierce enjoyed good reproductive success (Table 33). In the Pribilofs, egg laying of the Black-legged Kittiwakes was earlier in 1976 than 1975 (mean 29 June 1976 vs. 5 July 1975) on St. Paul (Hunt), and productivity in the two years similar (0.44 young/nest in 1975 vs. 0.42 young/nest in 1976). On Cape Pierce, nesting in 1976 was earlier than in the Pribilofs (mean 18 June, range 10 June - 2 July). While hatching success at Cape Pierce was lower than in the Pribilofs (45% vs. 54-80%), fledging success at the two areas was similar (Cape Pierce, 76%; Pribilofs, 58-85%). Thus, it appears the reproductive success of Black-legged Kittiwakes in the Eastern

Bering Sea was good and similar to 1975, at least in the Pribilofs.

Western Gulf of Alaska:

Ten different Black-legged Kittiwake colonies were checked in the Western Gulf of Alaska in 1976 (Table 33). These colonies were distributed from the Shumagins (Hall Is. off Big Koniuju Isl.) to the islands near Kodiak. Within this area reproductive success was variable. Matthew Dick reported apparently successful nesting on Viesoki Island and at least a good start for nesting kittiwakes in the Gibson Cove colony near Kodiak. Allen Moe reported good success at Cape Thompson, on Big Koniuji Island.

In other areas, reproductive success was low or nil. Avian predators (Bald Eagles, Ravens) were suspected as the cause of kittiwake reproductive failure on Hall Island (Moe), and at two study sites on Ugaiushak Island (Duff Wehle, Keven Powers and Eric Hoberg), where phenology was similar to that found by George Divoky in 1974 (egg laying started 21 June 1974; 20-23, 27 June 1976). On Ugaiushak in 1976 a bad storm also destroyed a number of nests.

It is not clear why a number of Black-legged Kittiwake colonies visited by Dick around Kodiak Island apparently failed. Colonies at Izhuit Bay and Marmot Island, near Afognak Island, apparently either failed to build nests or to lay eggs, as was also true for a colony in Uyak Bay on the West side of Kodiak Island.

The patchy distribution of successful and unsuccessful colonies in the vicinity of Kodiak Island is hard to explain. Failure to lay cannot be ascribed to bird predation, and the close proximity of successful and unsuccessful colonies (at least through egg-laying) makes it hard to postulate a failure of food resources, unless these resources are very patchy and colony foraging areas discreet. We have too little evidence in this case to determine the cause of failure.

The patchy distribution of successful and unsuccessful colonies in the Western Gulf of Aláska and variety of causes of failure requires that this region be accorded further thorough study. We need to know the distribution and abundance of food, the extent to which colonies partition these resources by foraging in limited, non-overlapping areas, and the extent to which avian predators or disturbance by aircraft may effect reproductive success at various stages of the breeding cycle.

Northern Gulf of Alaska:

Four islands, three at the southern edge of Prince William Sound and Middleton Island had kittiwake colonies which received study (Table 33). Avian predators (Bald Eagles, Glaucous-winged Gulls) destroyed virtually all eggs on South Island (Wooded Islands) and on Porpoise Rocks (Hinchinbrook Island). In contrast despite predation by Ravens, approximately 0.40 young/nest were produced on Wood Island and 0.8 young/active nest on Middleton Island (0.40 young/nest). The reproductive output on these last two islands is similar to that found in the Pribilofs and suggests that, without predation, nests on at least Wood Island could produce considerably more young than those on the Pribilofs.

Summary and Conclusions:

1) In the Chukchi Sea and Northern Bering Sea Black-legged Kittiwakes produced almost no young. Reproductive failure occurred early in the reproductive cycle, during or before eggs were laid. Fragmentary circumstantial evidence suggests that some food upon which the kittiwakes (but not Thick-billed Murres) depend was missing.

2) In the Southeaster Bering Sea, Black-legged Kittiwake reproductive success appeared "normal", although only two years data are available for determination of the "norm".

3) East of the Aleutians in the Gulf of Alaska, Black-legged Kittiwakes generally had poor reproductive success. While a few of the larger colonies managed to have an apparently successful season, on most colonies a large proportion of eggs or young were lost to avian predators, which apparently are not a major problem in the Bering Sea. A few colonies in the Gulf of Alaska apparently failed in the pre-egg or laying stage, suggesting that localized food shortages may have been a problem.

4) It is my impression that food or weather and not predators are the major factors in regulating Chukchi and Bering Sea Kittiwake reproduction and that avian predators nesting on (?)

wooded islands are the principal limiting agent of kittiwake reproduction in the Gulf of Alaska. There is also some evidence that, in the absence of avian predators, kittiwakes may have higher productivity in the Gulf (the Cape Thompson colony on Big Koniuji Island; Middleton Island) than in the Bering Sea. These very tentative ideas need to be checked thoroughly in future years. Oil development may affect predator numbers which in turn could alter reproductive success of kittiwakes.

5) In order to gain maximum information from the comparisons of simultaneous studies of seabirds in Alaska, we should agree on minimal data elements and reporting formats to facilitate analysis.

6) We need good information on normal food habits and food species densities in the vicinity of a number of colonies over a period of several years. Analysis of the 1976 season would have been greatly facilitated if we had had data on foods used and on food availability.

Persons Contributing Data Sheets

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Table 33. Black-legged Kittiwake breeding biology compilation, 1976.

Colony	location	colony size (number of individuals unless otherwise specified)	sample size (nests)	initiation of nest building	mean initiation of clutch	range clutch initiation	% hatch	% fledge	fledge per nest	Other data and comments	Investigator
Cape Lisburne		?	140	?	?	?	?	?	?	3 eggs (1 addled), 12 live chicks (7-15 days old), 8 dead chicks. 8 additional adults incubating	Springer
Cape Thompson		10,000-20,000			1st egg 4 July					only found 15 nests with eggs or chicks. 6 of these failed before hatching; most failed to build nests.	Springer
Bluff Island	75 miles E. of Nome	3,500-6,100	2,244			25 June-13 July			.02	normal well into incubation; then fell apart	Drury
Square Rock	78 miles E. of Nome	575	121						.02		Drury
Sledge Island	25 miles W. of Nome	1,300	204							4-15% of nests with incubating adults early August	Drury
King Island	80 miles W. of Nome	3,000-6,000	72							28% of nests with incubating adults mid August	Drury
Cape Denbeigh N	eastern Norton Sound	1,200	765							27% of nests with incubating adults mid August	Drury
Cape Denbeigh S	eastern Norton Sound	650	588							27% of nests with incubating adults mid August	Drury
Egg Island	eastern Norton Sound	525	92							38% of nests with incubating adults mid August	Drury
St. Lawrence Is.		2,100	50	8 June	29 June					almost no eggs laid (2 eggs, 1 fledgling found)	Searing
Cape Pierce	Cape Newenham Bristol Bay	20,000 pairs	106	1 June-5 Sept.	18 June		45.3	73.6		predation by Ravens caused losses throughout season	Peterson & Sigman
St. Paul Island	Pribilofs	31,000	46		29 June		54-66	58-70	.42	appeared to be a good year	Hunt
St. George Island	Pribilofs	72,000	21		1 July		67-80	75-85	.37	appeared to be a good year	Hunt
Hall Island	Shumagins	142 nests			last week of June	16 June-8 July		0		heavy predation of chicks, just after hatching, probably by Ravens	Moe
Cape Thompson	Big Koniuji Shumagins	7,904 nests	150		est. 11 June				.72		Moe
Chiniak Bay	Kodiak				June					reproduction believed successful	Dick
Viesoki Island	Kodiak		12							10 nests with eggs	Dick
Ishuit Bay	Afognak Is.	several thousand								no nests built by 9 July	Dick
Marmot Cape	Marmot Is.	few								apparently only a small portion of a large colony active	Dick
Uyak Bay	Kodiak	123 nests								only 7 with eggs or young	Dick
Gibson Cove	Kodiak	38+ nests								71% being incubated	Dick
Ugaiushak Is. 04	Kodiak Basin	7,500-10,000	60		25 June-2 July	20 June	17	3		failure at end of egg laying and early hatching-Storms and Ravens	Wehle, Powers, Hoberg
Ugaiushak Is. 05	Kodiak Basin	7,500-10,000	35			27 June-	0	0		failure at early stage of laying	Wehle, Powers, Hoberg
Wood Island	Montague Island	1,600	392			3 June-15 July			.40	Ravens took eggs by 1 August. 38 nests destroyed, 42 deserted, 46/2 chicks, 66/1 chick	Lehnhausen
South Island	Montague Island	100				3 June-15 July		0		Glaucous-winged Gull predation	Lehnhausen
Porpoise Rocks	Hinchinbrook Is.	992 pairs	200			7 - 14 June	1.9	86		predation by Bald Eagles and Glaucous-winged Gulls - commencement of hatching	Nysewander Knudtson
Middleton Is.	Gulf of Alaska	60,000							.8/active nest	50% of nests active	Howe & Frazer

QUARTERLY REPORT

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

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I. Task Objectives

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

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

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

II. Field Activities

A. Ship Schedule

22 October - 6 November	Moana Wave

B. Scientific Party

Wayne Hoffman	Oregon State University
Terence R. Wahl	Oregon State University

C. Methods

1. Distribution of Seabirds. Most of our distributional data have been collected in 15 minute and 30 minute transect counts, on a 90° quadrant from a moving ship, as described in our previous reports. However, on the Oct. 22 - Nov. 6 cruise, the last 5 days were spent in regions of consistantly very low bird densities, so all birds seen were recorded, and we searched either 180°

or 360° around the ship, depending on the light conditions. We searched continuously during daylight, while the ship was moving.

2. Transect method intercalibration. During the Oct. 22 - Nov. 6 cruise, transect data were collected simultaneously by Dr. Patrick Gould of the USFWS and ourselves, as a direct intercalibration test of the two methods. These transects will also be used to test the applicability of the Caughley and Goddard (J. Wildl. Mgt. 36:1972) method of density calculation from transect counts.

3. Transect method complexity. We used the Oct. 22 - Nov. 6 cruise to assess the difficulty of learning our transect method. Terry Wahl was familiar with many of the birds, but had not previously tried to use our transect method. His proficiency in transect counts was assessed to determine how long it would take to teach a novice the method.

4. Transect method applicability. Since the latter part of the Oct. 22 - Nov. 6 cruise was in subtropic waters we used the cruise to evaluate the applicability and efficiency of our transect method in oceanic areas other than the Alaskan waters.

D. Trackline See figure 1.

E. Data collected

47 transects (mostly 30 minutes in length), totalling 1430 minutes, were taken north of 41° N latitude. South of 41° N latitude, continuous daylight observations totalling 2760 minutes were conducted.

Data coded, keypunched, and transmitted to NODC on magnetic tape:

Transect Data Transmitted

File	Ident.	Cruise Dates	Vessel
1616	1	5/11/76 - 5/20/76	Discoverer
0622	1	8/23/76 - 9/3/76	Surveyor
0522	1	8/8/75 - 8/27/75	Surveyor
0531	1	9/4/75 - 9/12/75	Surveyor
2614	0	6/11/76 - 6/23/76	Miller Freeman
1614	0	4/13/76 - 5/10/76	Discoverer
0621	1	8/15/76 - 8/20/76	Surveyor

III. Results and Preliminary Interpretation

A. Bird distributions in the NEGOA. The maps in this section include preliminary analyses of the distribution of the principal pelagic species of the Northeastern Gulf of Alaska study area. More detailed analyses will be prepared in the future. These maps were also transmitted to NOAA, BLM, and SAI personnel at the Jan. 11-13 Anchorage working meeting on the NEGOA.

B. Feeding Flocks

Feeding flocks occur wherever schools of forage fishes or invertebrates (usually Euphausids) appear on the surface in the presence of the appropriate bird species.

Fish-based flocks. These flocks are nearly always located in shallow nearshore areas (20m-5km from shore). In the Gulf of Alaska and eastern Aleutians the fish species most frequently involved are sandlance, herring, and capelin and other smelt. The flocks are commonest in protected areas such as bays inlets and fjords, and in areas of bathymetric turbulence. The latter include areas just off headlands or points of land, passes between islands, and shoal areas. These areas usually contain localized "rips" and convergences, where water is sinking. Plankton are concentrated by the sinking water, and fish schools frequently feed in them. Bird flocks form over the fish schools, and while the fish schools are deeper below the surface, the birds frequently rest on the water in the convergence areas. Certain rip areas may apparently be used daily by the birds for periods of several months. The convergences are also characterized by collection and concentration of floating debris. Thus they are potentially areas of concentration for floating oil, and may form major hazards to the birds and their prey (see figure 13) by concentrating the oil in the favored feeding spots. These locations are especially important to marine birds in island groups such as the Semidis, the Shumagins, and the eastern Aleutians. In areas where the shorelines are less complex, or where currents are weaker, they are less frequent, but those that do occur are very heavily utilized. Sitkinak Pass and Ugak Island, off the southwest end, and off the southeast side, respectively, of Kodiak Island are good examples.

In the GOA and Eastern Aleutians, these flocks are generally initiated by Black-legged Kittiwakes or Glaucous-winged Gulls. The Kittiwakes and gulls will feed in flocks at any season of the year. Cormorants, Horned and Tufted Puffins, and murres are regular participants, and as many as 15 other species are at times associated with the flocks. The cormorants enter flocks most frequently during the nesting season, but also do so regularly the rest of the year. Murres and puffins use the flocks extensively during their incubation and nestling phases of the breeding season, but switch to a diet of invertebrates and ignore the flocks for the rest of the year. Sooty Shearwaters are common (at times abundant) participants from May through October. Sea lions, Harbor Seals, and Harbor Porpoises are frequently associated with the flocks.

Invertebrate-based flocks. The invertebrates involved are normally euphausids, but other pelagic crustaceans and perhaps Chaetognaths may occasionally be important. Schools of these active and abundant organisms are commonest in rips around passes (they seem to prefer areas with lower velocities than fish schools), on shallow banks such as Portlock Bank, and along the continental shelf margin. Sooty and Short-tailed shearwaters are the predominant species in these flocks, but kittiwakes, puffins, and auklets regularly take part. Baleen whales, especially Fin and Hump-backed Whales, often associate with the flocks.

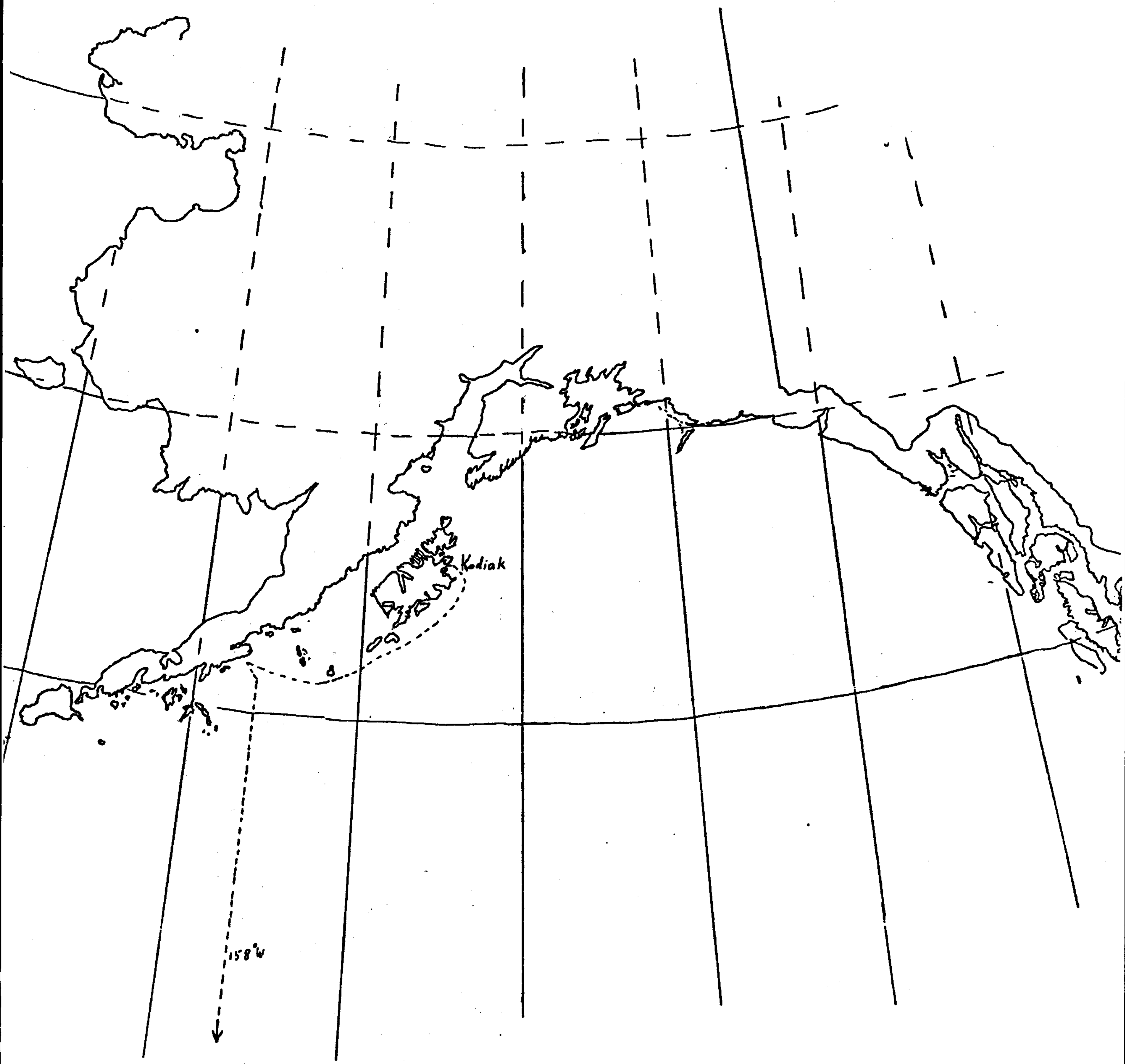


Figure 1. Moana Wave trackline, Oct. 22-Nov 6, 1976

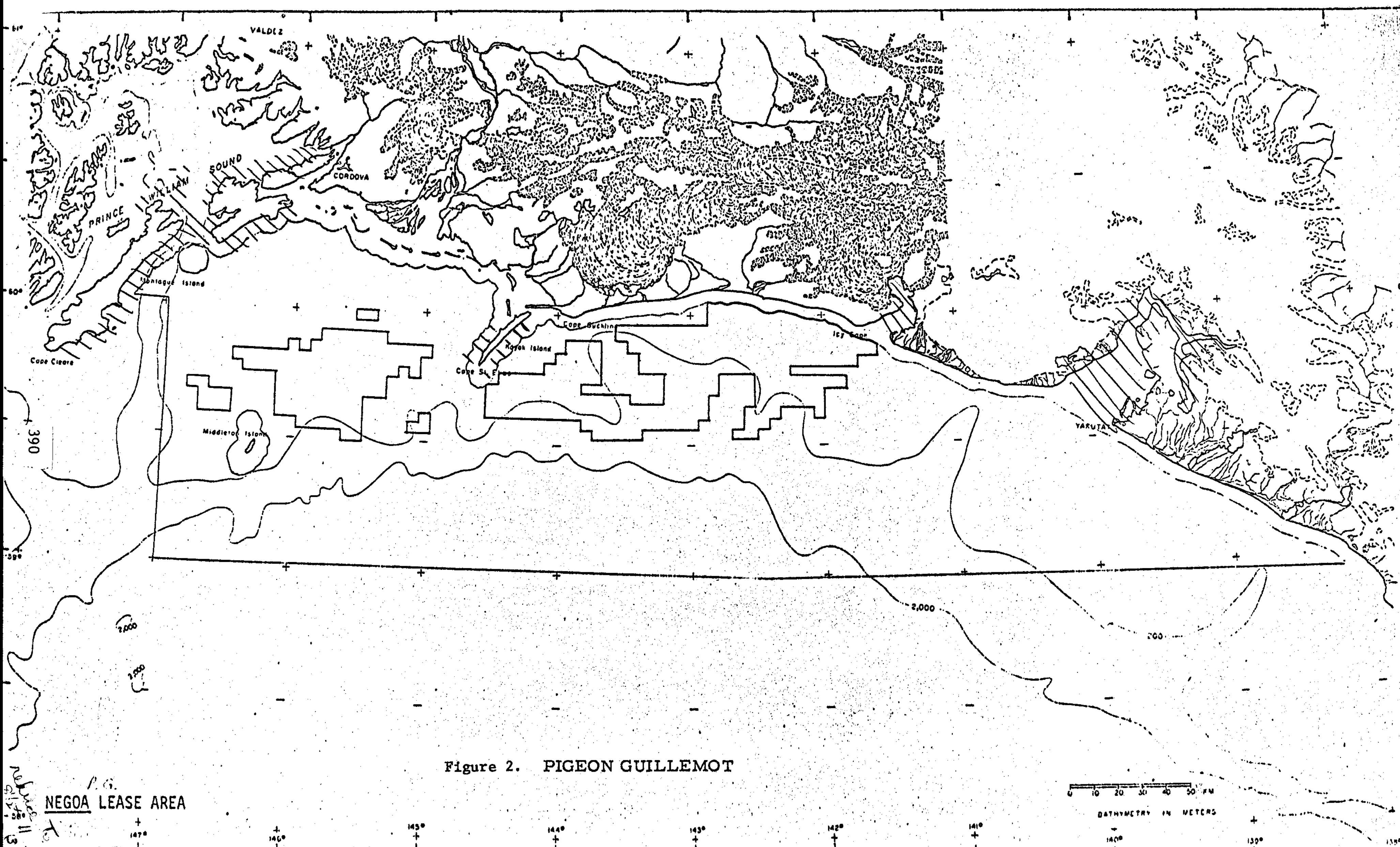


Figure 2. PIGEON GUILLEMOT

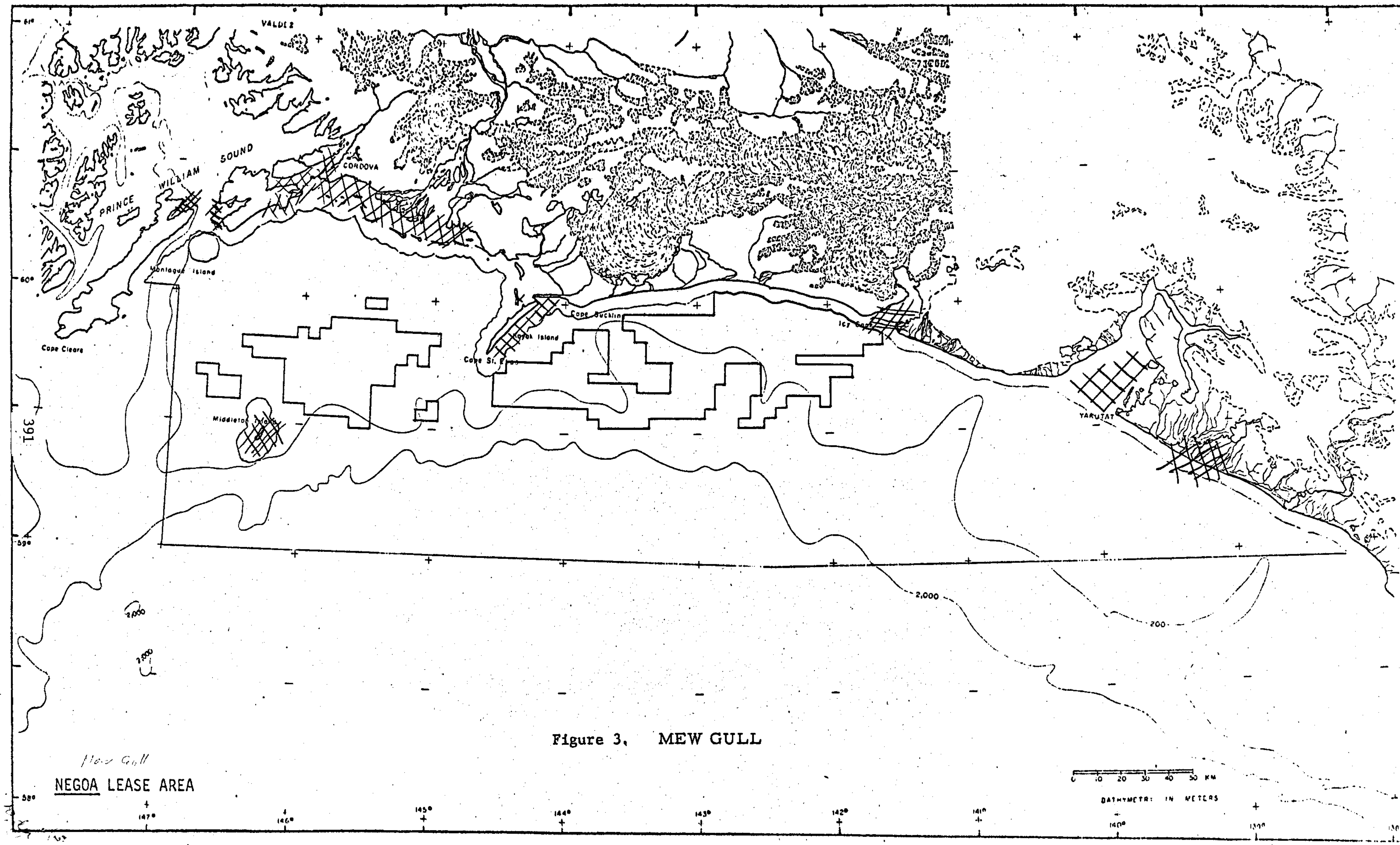


Figure 3. MEW GULL

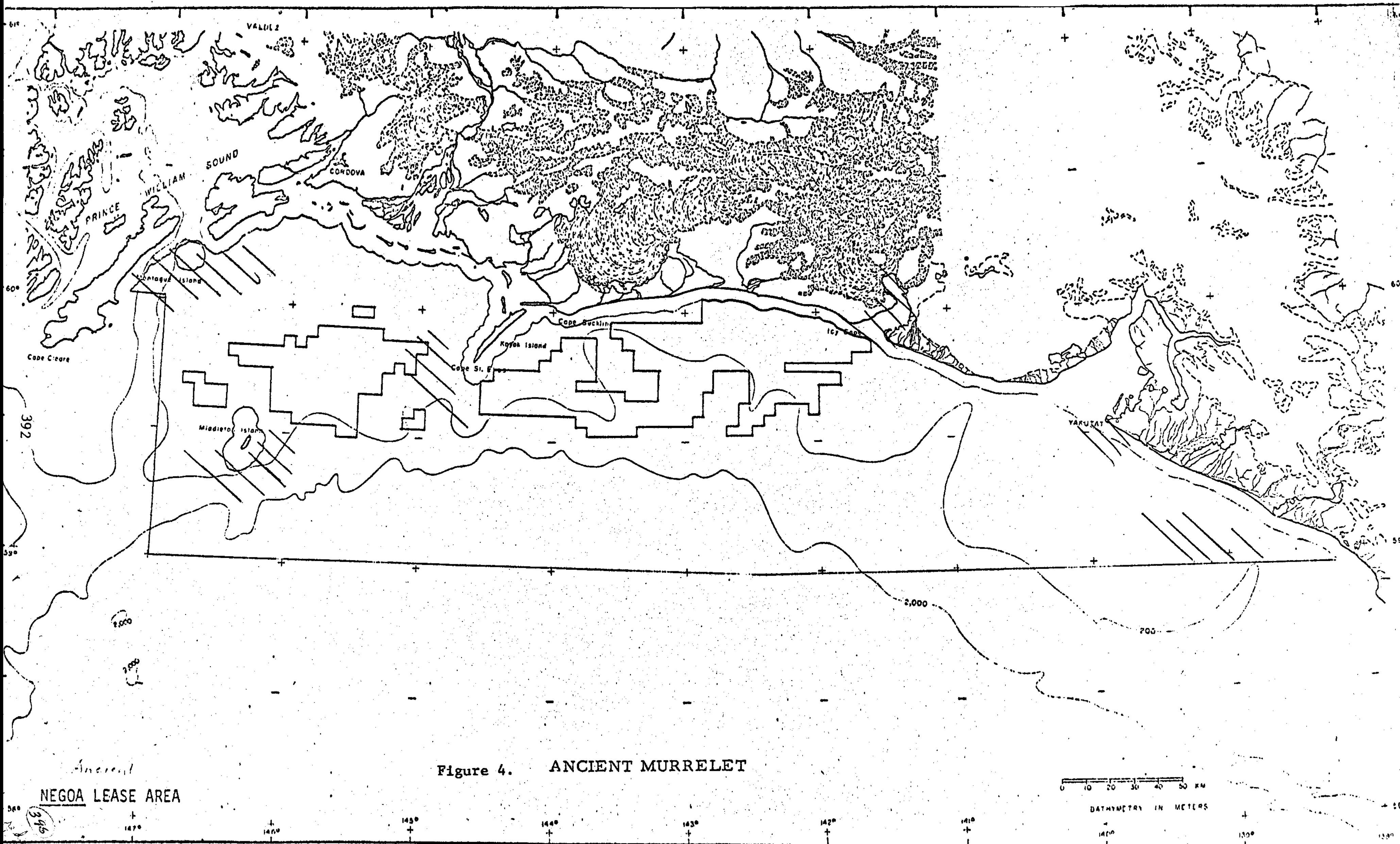


Figure 4. ANCIENT MURRELET

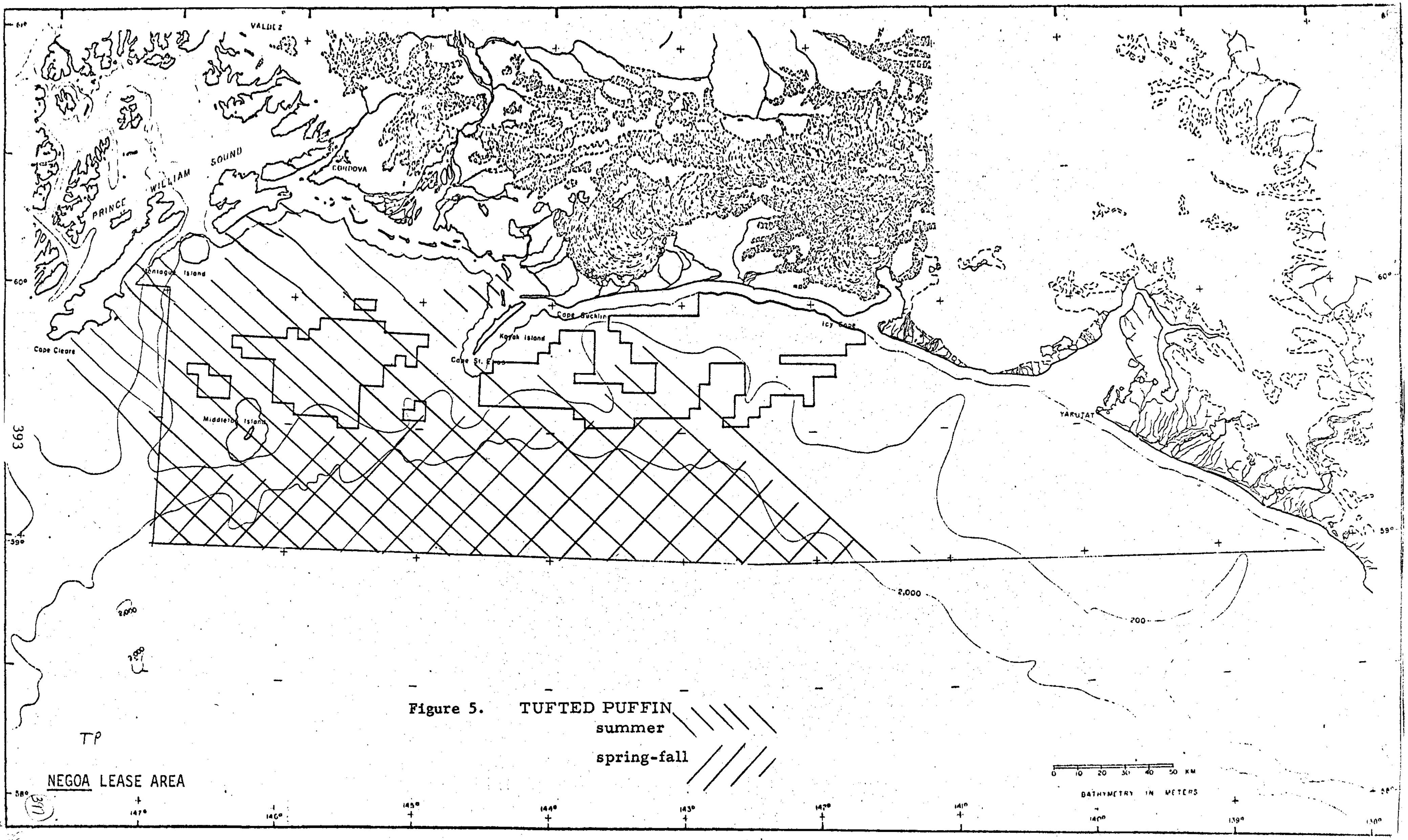


Figure 5. TUFTED PUFFIN
summer
spring-fall

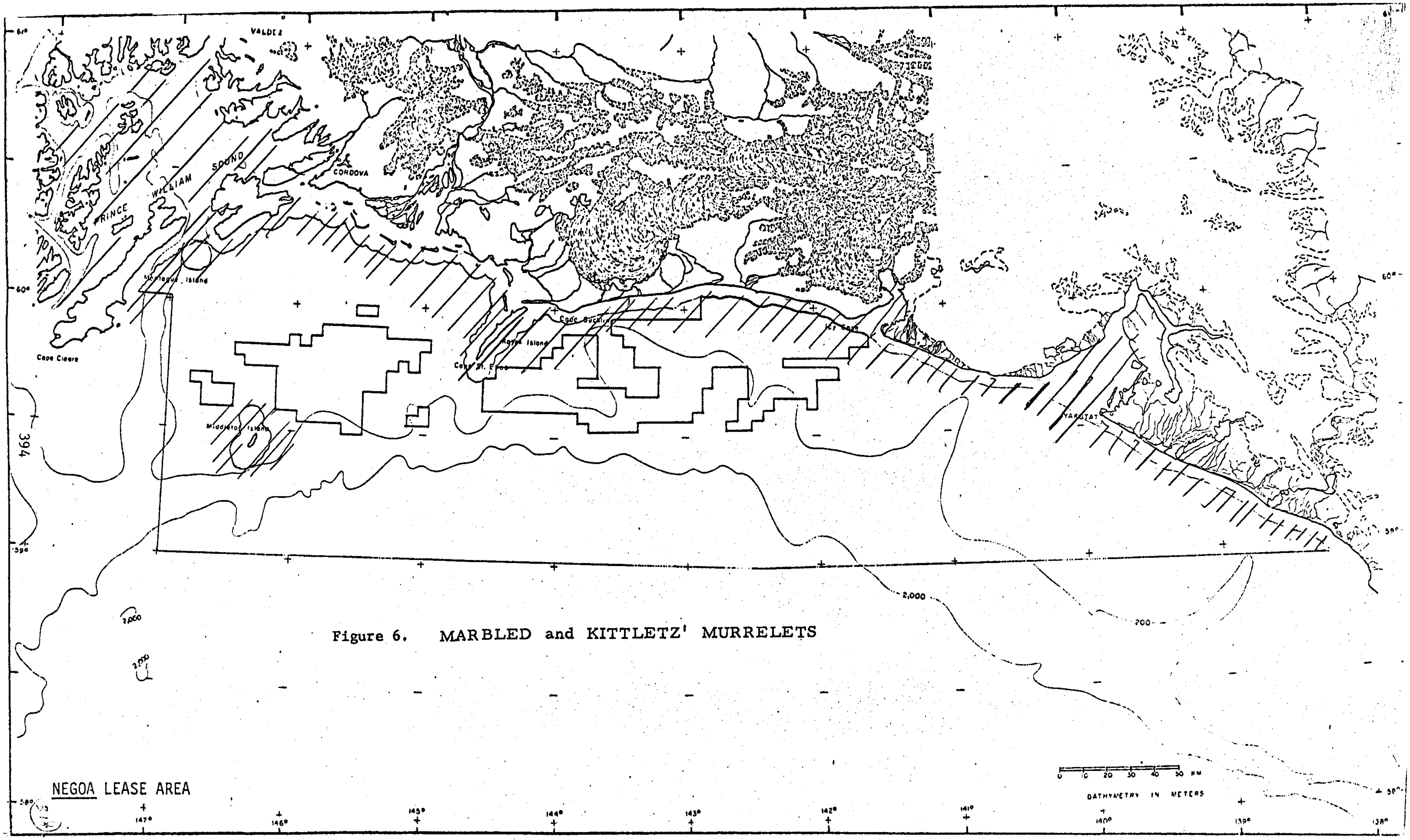


Figure 6. MARBLED and KITTLETZ' MURRELETS

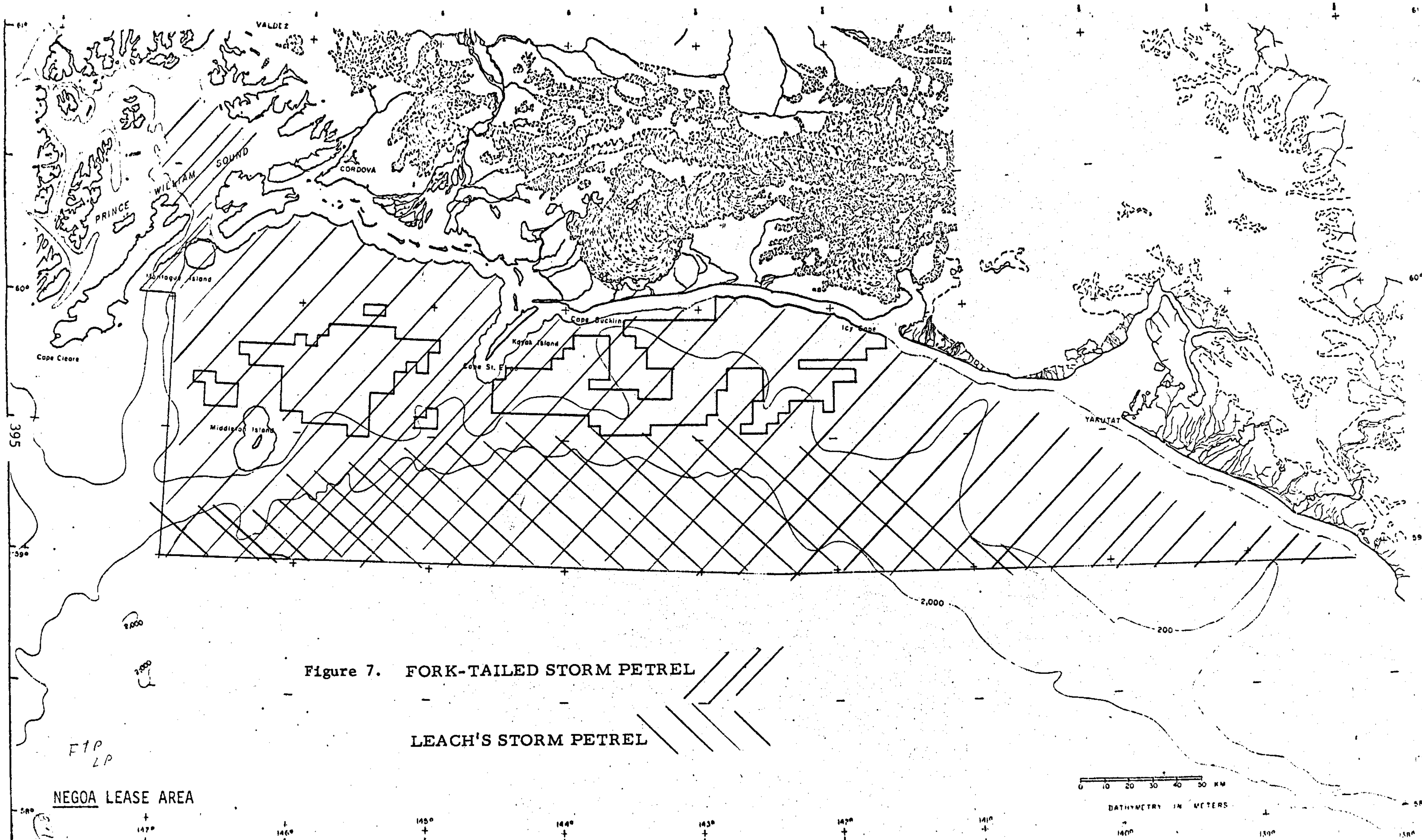


Figure 7. FORK-TAILED STORM PETREL

LEACH'S STORM PETREL

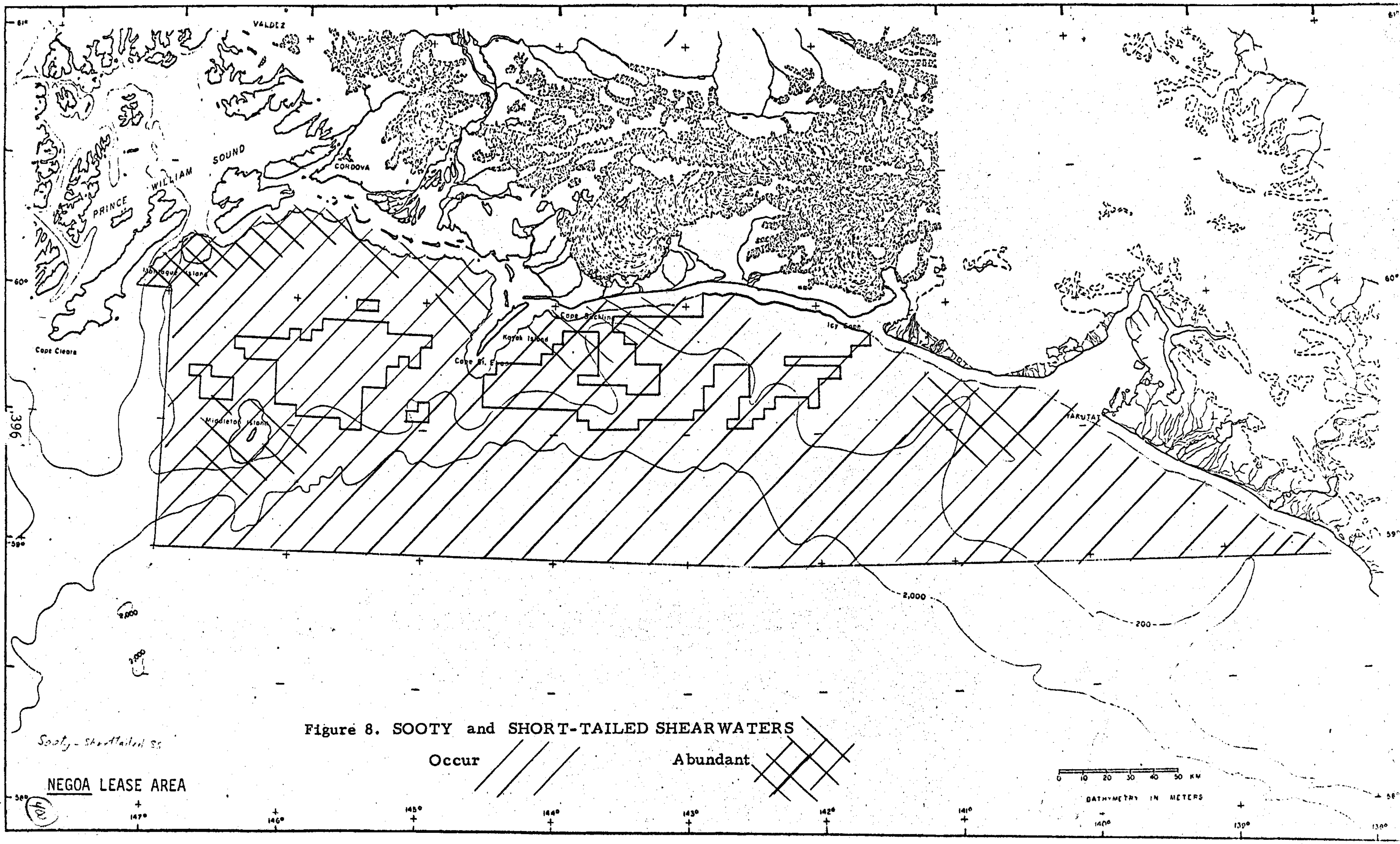


Figure 8. SOOTY and SHORT-TAILED SHEARWATERS

Occur

Abundant

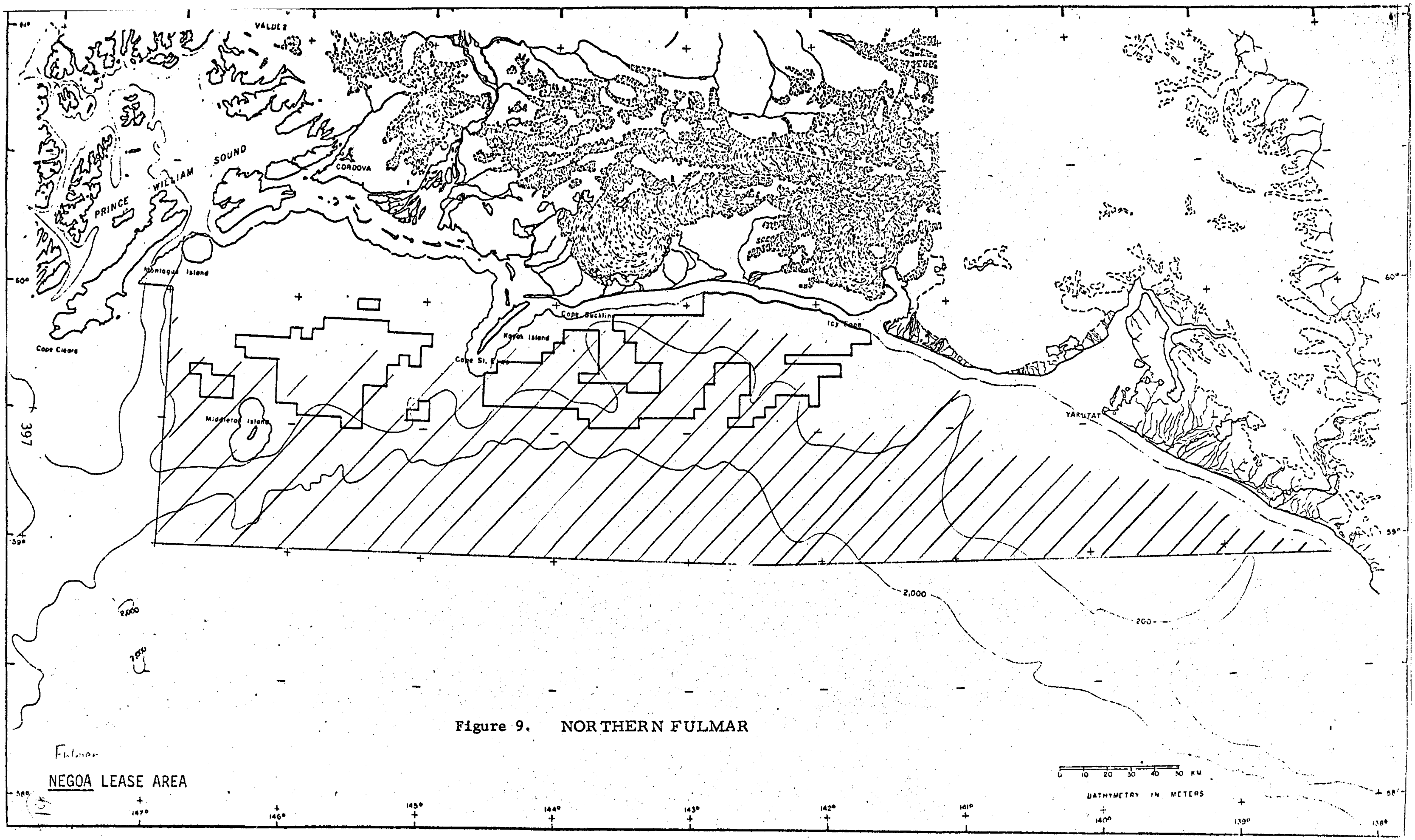


Figure 9. NORTHERN FULMAR

Fulmar

NEGOA LEASE AREA

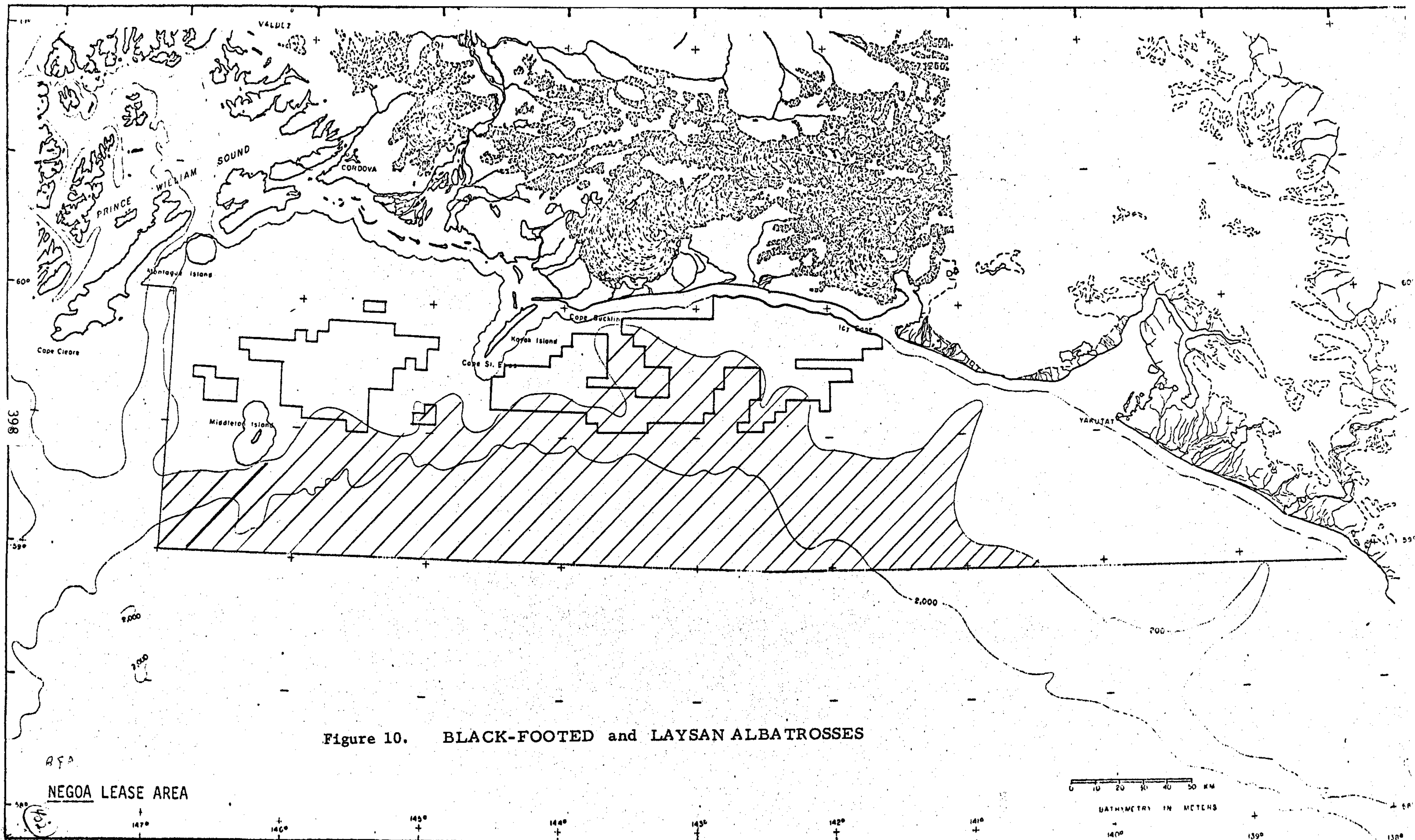
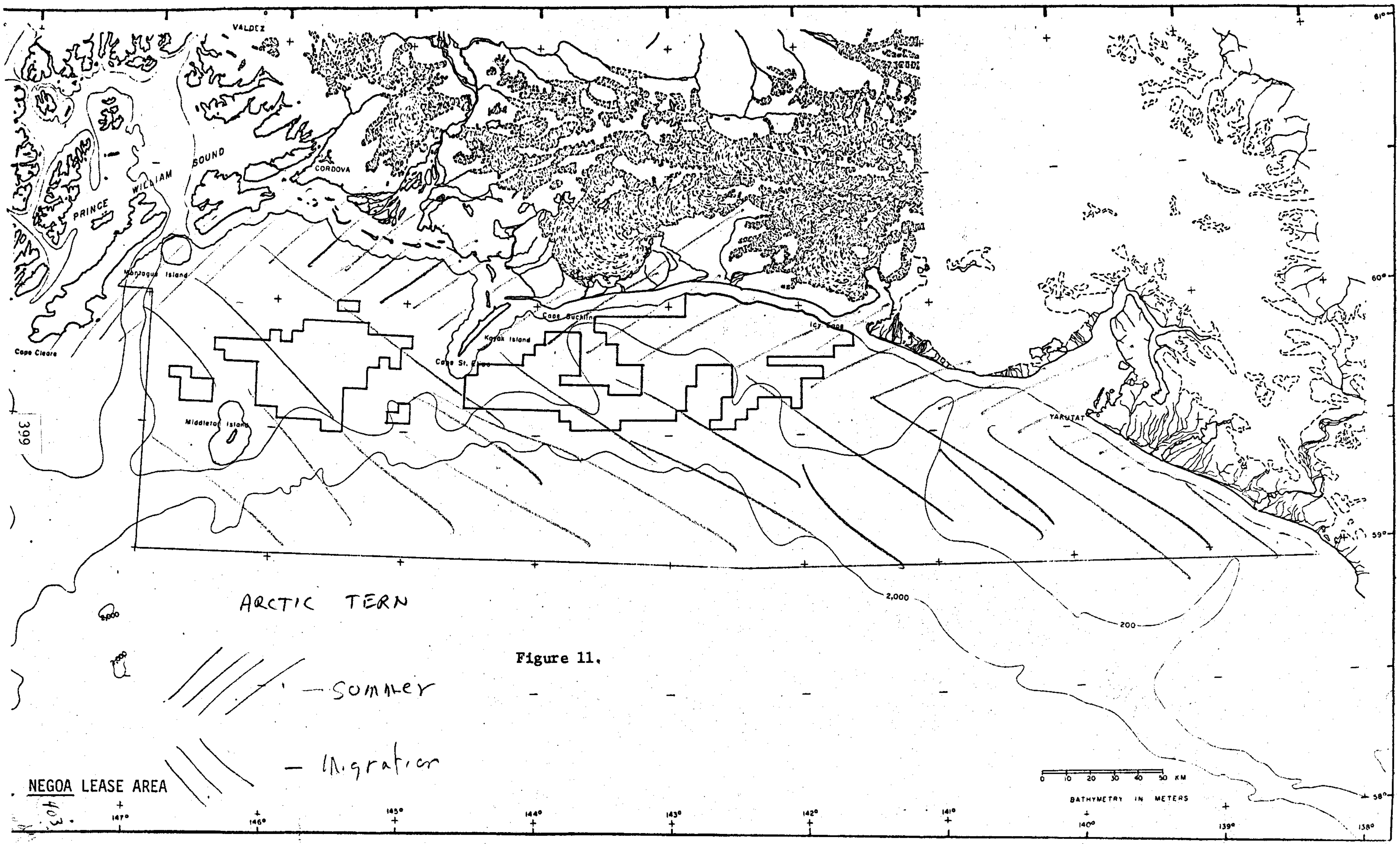


Figure 10. BLACK-FOOTED and LAYSAN ALBATROSSES

NEGOA LEASE AREA



VALDEZ
CORDOVA
PRINCE WILLIAM SOUND
Montague Island
Cape Cleare
Middleton Island
Cape St. Elias
Kayak Island
Icy Cape
YAKUTAT
2,000
200
ARCTIC TERN
— Summer
— Migration
NEGOA LEASE AREA
BATHYMETRY IN METERS
0 10 20 30 40 50 KM
147°
146°
145°
144°
143°
142°
141°
140°
139°
138°
61°
60°
59°
58°

Figure 11.

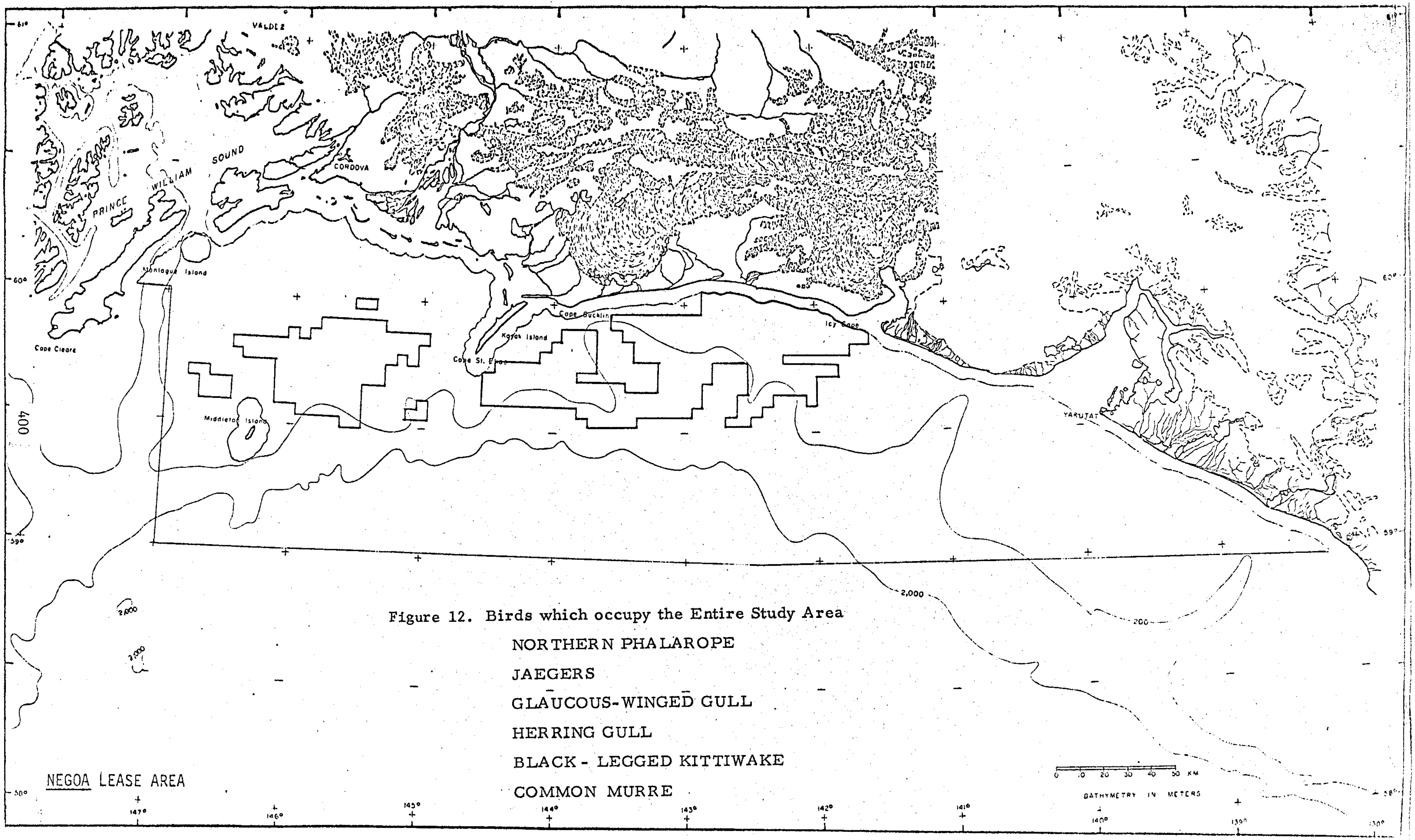


Figure 12. Birds which occupy the Entire Study Area

NORTHERN PHALAROPE

JAEGERS

GLAUCOUS-WINGED GULL

HERRING GULL

BLACK-LEGGED KITTIWAKE

COMMON MURRE

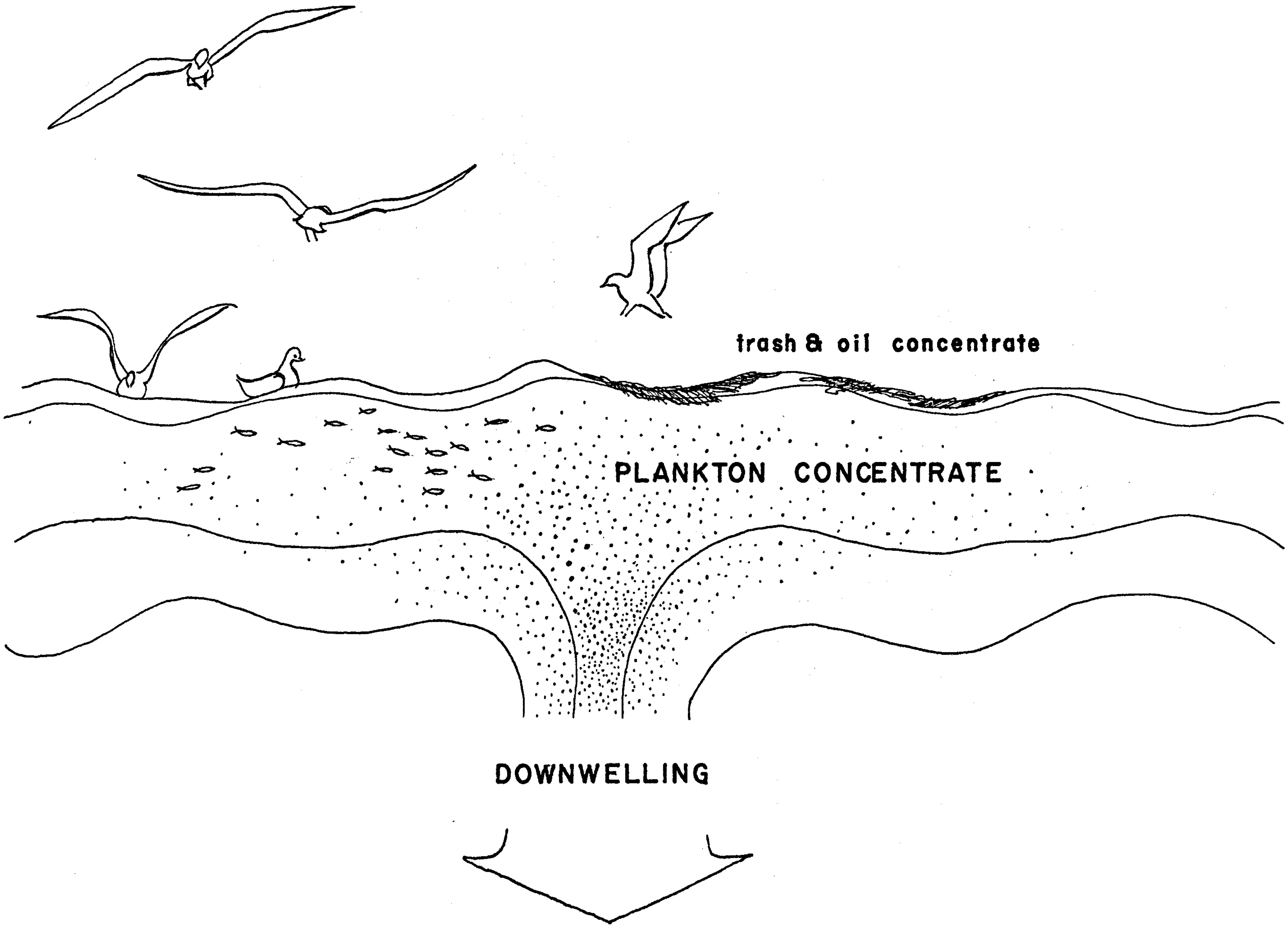


Figure 13.

Shorebird Dependence on Arctic Littoral Habitats

Annual Report, R. U. 172
April 1, 1977

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Table of Contents

I. Summary of Objectives, Conclusions and Implications

Shorebirds (sandpipers, plovers, and their relatives) are a major and important component of the Alaskan arctic avifauna. Prior to this study, shorebird work in the Arctic has concentrated on events on the tundra where these birds nest and has largely been confined to the brief breeding period. Very little information was available concerning the use of littoral zone (shoreline) areas by shorebirds within the Arctic. The first two seasons of work in this study have now begun to fill in this serious gap.

The ultimate objective of this study is the assessment of the degree and nature of dependence of each shorebird species on arctic habitats which are potentially susceptible to perturbation from offshore oil development activities. Within this general objective, we are attempting to identify critical habitats, critical time periods, and critical areas of the Beaufort and Chukchi coasts, and to estimate the relative susceptibilities of each shorebird species to potential disturbances. Quantitative data of four major categories are being gathered to meet these objectives:

1) Seasonal occurrence of shorebirds by species, age and sex in a variety of arctic littoral and near-littoral habitats. This receives major effort, consisting of repeated, intensive transect censuses of many habitats near Barrow, supplemented by less regular, more extensive observations there and at six other sites in the Beaufort and Chukchi. These censuses are continued throughout the entire period of shorebird presence in the Arctic and can be compared between seasons.

2) Trophic relationships of shorebirds and other species foraging in arctic littoral areas. Increased emphasis on this aspect of our study is required since we have identified major fluctuations in prey conditions between two seasons.

3) Description of habitats in the littoral and near-littoral areas and determination of foraging habitat preferences by species as these change through the season.

4) Other factors affecting the dependence of species on littoral areas including, for example, the length of use of littoral areas by individuals; the importance of this use in premigratory fat deposition; variation in weather patterns between years; and effects of wind conditions on zooplankton and phalarope distribution.

It must be stressed repeatedly that one of the most striking characteristics of the coastal tundra ecosystem is the pronounced annual variation in environmental conditions, causing significant fluctuations in the timing and magnitude of biological events from year to year. An analysis of seasonal variability in weather patterns at Barrow, utilizing weather records for 25 years, is included as an appendix.

Most of the conclusions presented in the first annual report are supported by this second season's data. However, many events did vary, with some species being considerably more or less common in this second season. In particular, we have identified extreme differences between 1975 and 1976 in zooplankton composition and densities and corresponding differences in the foraging behavior of some birds dependent upon this food source.

Population density and habitat use information for individual species are presented in Parts VI and VII (Results and Discussion). In general, four periods of shorebird littoral zone use, overlapping to some extent, can be recognized.

1) In spite of the very restricted littoral habitat availability in early June, some pre-breeding adults of several species forage along beaches or around saline pools or littoral stream slough edges. Throughout the nesting season, Semipalmated Sandpipers nesting on nearby tundra forage on exposed mudflats.

2) From late June through early July, a movement of non-breeding and post-breeding adults of several species occurs, with flocks and individuals utilizing habitats at the edges of small coastal lagoons and nearby brackish pools.

3) In late July and early August, adults of both sexes of most species are released from nesting duties as young birds fledge and become self-sufficient. These flocking adults, beginning their southward migration, move into littoral areas.

4) The phase of heaviest use of littoral areas in both years occurred during the entire month of August, stretching into September for some species. Juveniles left the tundra areas where they had fed before fledging and flocked in littoral habitats, beginning their southward movements independently of, and later than, the adults. A summary of the Barrow shorebird phenology, in 10 day intervals for both tundra and littoral zone, is included as an appendix to this report.

Types of littoral habitats used during this period varied considerably, including mudflats, inner lagoon margins, brackish pools and outer coast gravel shores. Foraging microhabitat data revealed two major habitat gradients: the first corresponded to the position of the foraging site with respect to the water line, while the second described changes in habitat relating to particle size of the substrate. Species using the littoral zone around Barrow responded differently to these gradients, in ways that probably affect their susceptibilities to oil damage.

Diets of shorebirds in the littoral zone varied, with oligochaetes and adults and larvae of chironomid flies comprising the major food source in fresh to brackish mudflat, lagoon edge, and saltmarsh pool areas. When outer coast shorelines open and shorebird use of these areas peaks in August and early September, several species of large marine zooplankton become the dominant food source for several shorebirds, gulls, and terns. Red Phalaropes also take zooplankton in brackish closed lagoons during this period.

The results of all bird stomach, zooplankton, and benthic samples are included in tables and appendices within this report. Conclusions from the data include these: no clear seasonal patterns in zooplankton communities emerged from the 1976 studies. Red Phalaropes select the larger species of zooplankton preferentially. Within one habitat, several shorebird species prey upon the same food source. In comparison with 1975, densities of marine zooplankton were strikingly lower in 1976. Mean densities of the three prey species taken most commonly by shorebirds were approximately 25 times greater in 1975. Diets of Red Phalaropes showed corresponding differences between summers, with copepods scarcer and amphipods more common in 1976. This change reflects an observed difference in foraging behavior: in contrast to the clear pattern of protected shore foraging in 1975, when plankton densities were high, phalaropes frequently foraged on windward shores in 1976, perhaps attracted by the amphipods released from the undersides of grounded pieces of ice. Red Phalaropes also spent more time roosting in 1976, possibly in response to the altered prey conditions.

The post-breeding season movements of adults and juveniles to littoral zone foraging areas precedes migration; it is therefore probable that this phase in the cycle of annual activities represents an important and possibly critical period of energy storage to meet the demands of migration. For inexperienced and presumably less efficient juveniles especially, a high level of energy reserve in the form of deposited fat may be a critical factor in determining survival during migration. Rates of fat deposition in juvenile shorebirds differed considerably between species in 1976, indicating differential utilization of available food resources. Between season comparisons for particular species will be possible in future seasons, and may show relationships to annual variation in food resources.

The color marking and release of 47 juvenile Red Phalaropes during August, 1976, was an initial effort toward determining the turnover rate of these shorebirds migrating through the Barrow area. The resighting results suggest that individuals remain in the Barrow area for only a few days; the high density of phalaropes along Barrow Spit throughout August and early September implies much larger numbers of individuals moving through, and therefore susceptible to a local disturbance such as an oil spill.

Drawing upon distributional information, seasonal habitat use information and studies of social organization, behavior, and trophic relationships, we have tentatively constructed two tables (19 and 20) indicating the relative susceptibilities of common Barrow shorebird species to disturbances associated with developments onshore and offshore.

In spite of year-to-year variation in timing or magnitude of movements of particular shorebird species and of differences in trophic conditions, the conclusion that the Barrow Spit area is heavily used by many shorebirds, gulls, and terns in late summer is supported by the data from both seasons of this study. From visits to other regions of the Beaufort and Chukchi coasts by personnel of this project, coupled with the extensive observations from ADF&G RU 3/4, several other critical areas have been tentatively identified as sustaining very high use by several species in late summer. These include the Plover Islands, the muddy sloughs near Lonely, salt marsh flats near Icy Cape, and the spit and islands around Peard Bay. However, coverage of the coast is still somewhat uneven and we do not yet know whether all of these high use areas remain constant over many seasons.

The implications for OCS oil development for some of these results are clear. If continued studies support the present identification of critical areas which are much more heavily used by birds in littoral areas than are other segments of the Arctic coast, then leasing and development should be planned so as to minimize the threat to these critical areas. From the detailed information developed showing seasonal habitat shifts and migratory movements in many shorebird species, we can identify periods of each season during which potential impacts on birds are highest. Coupled with other distributional information, assessments of relative susceptibilities of shorebird species mentioned above will indicate the danger to particular species populations from disturbances in an area.

The identification of certain littoral habitats as especially important is relative; it implies that other habitats are less well used by birds. In fact, our studies show that narrow mainland beaches backed by eroding tundra cliffs, a common land form on much of the arctic coast, receive much lower use by shorebirds than do barrier islands, spits, lagoon edges, mudflats, and salt marshes. Shorebird considerations therefore favor development on this common land form.

In the 1975 annual report, we suggested that construction activities on barrier islands or along shorelines may interfere with foraging by phalaropes, gulls, and terns by producing temporarily high turbidity in waters close to shore. Even without affecting the actual density of zooplankton, increased turbidity might reduce the foraging efficiency of these visual predators. It has not yet been possible to gather information to answer this question, but observation at construction sites in the Prudhoe Bay area may permit this in future seasons.

Alteration of shorelines through construction activities may actually increase densities of shorebirds, gulls, and terns foraging in these areas in August and September since islands and spits appear to be used more than mainland shores. This possible increase in shoreline habitat is a mixed blessing, however; birds might be attracted to precisely those areas where development activities and potential impacts are greatest.

The potential disturbance of birds through noise and activity associated with development is not considered serious in most areas for migrating shorebirds, gulls, and terns. Observations of non-nesting birds in these families indicate that they are not especially sensitive to noise disturbance. Activities in waterfowl staging areas or near nesting habitats could cause more serious problems in this respect.

Finally, the effect of any oil spillage could be quite serious, depending upon timing as well as magnitude of the spill and upon the dispersal behavior of oil under varying conditions of ice coverage. During open-water periods of August and September, oil carried to nearshore areas would probably cause extremely high mortality to juvenile Red Phalaropes and other swimming birds including gulls, waterfowl, and alcids. Immediate effects would not be so severe on most other species of shorebirds which walk along shores or on flats and wade in shallow water but do not usually swim. Any drastic reduction in prey densities of plankton or infaunal invertebrates in areas where these shorebirds feed would reduce the foraging efficiency and probably the survival of all these species, however. This effect would be extremely difficult to predict or to evaluate in the event of a spill since the range of "natural" variation is so poorly known.

During the synthesis meeting in Barrow in 1977, three major areas of information were identified as critical needs of the OCS studies:

1) We need more information, both extensive and intensive, on patterns of habitat use along both Chukchi and Beaufort coasts, and for several seasons at specific sites. Disagreements emerged on the importance of particular areas to observers familiar with events in those areas in different seasons. Variation between seasons is an important factor in the interpretation of all biological systems in the Arctic. Without a reasonable idea of the natural variation in particular processes, we will be unable to predict impacts or to evaluate impacts after they have occurred.

2) We need a considerably better understanding of the effects of disturbances on all species involved. We do not know how individual birds or migrating flocks will react to the presence of an oil slick, to increased turbidity or to increased noise disturbance, and in most cases we do not know how flexible species are with respect to habitat, prey base, or staging areas.

3) Emerging as probably the greatest need in both bird and mammal studies in the OCS Program is the question of trophic relationships. In order to assess the impact of a change in one component of the biological systems, we must understand the relationships between components. For most bird species, our information is fragmentary in time and space. We must know how diet varies with location, foraging habitat, and season for each species. We must then understand what factors contribute to variation in prey communities and how flexible predator species are with respect to this variation. In particular, the striking change in zooplankton composition and density along Barrow Spit between 1975 and 1976 indicates our lack of understanding of most components of the zooplankton community, apparently the major or only source of food for several species of shorebirds, gulls, and terns migrating along the arctic coast in late summer. The continuing emphasis in RU 172 discussed above is designed to meet these informational needs.

II. Introduction

Shorebirds (suborder Charadrii: sandpipers, plovers, and their close relatives) constitute a major and prominent segment of the Alaskan arctic avifauna, contributing nine regular and seven irregular breeders to the Barrow community (Pitelka, 1974). These, as well as several other shorebird species which do not breed locally, occur at Barrow and elsewhere along the arctic coast as migrants, wintering in temperate and tropical regions of both northern and southern hemispheres.

Prior to 1975, considerable effort had been expended on studies of the ecology of tundra nesting shorebirds near Barrow, Alaska (see Appendix A for references). These studies dealt almost exclusively with conditions on the upland tundra, primarily during the short arctic breeding season. It had been noted, at Barrow and elsewhere in the Arctic, that densities of several species of shorebirds increase near the shoreline as the summer progresses, resulting in a net increase in use of littoral habitats (Holmes, 1966; Bengtson, 1970). This movement begins with non-breeders and is augmented progressively by a shoreward movement of local and also inland birds, especially after the young have fledged. However, the importance of this habitat shift in the breeding cycle of arctic shorebirds had not been adequately evaluated.

This study is attempting to provide the detailed and quantitative information necessary to assess the dependence of shorebirds and other species on littoral habitats along the Alaskan arctic coast. We wish to determine the relative susceptibilities of different species to potential impacts of oil development, and to identify critical species, habitats, areas, and periods to aid in OCS development decisions. We are addressing several aspects of shorebird ecology essential to evaluating the significance of the littoral zone for shorebirds, gulls, and terns: seasonal occurrence of these birds by species, age, and sex, in different habitats; trophic relationships of shorebirds and other birds feeding in littoral habitats, and variability in the prey base; seasonal patterns of habitat availability and foraging habitat preferences; and behavioral patterns and other aspects of littoral zone use by shorebirds, gulls, and terns.

The relevance of this investigation to problems of OCS petroleum development is clear. To the extent that shorebirds and other birds utilize and depend upon shore and nearshore habitats, any perturbation of these habitats can affect them. Use of littoral habitats in the Arctic appears to be heaviest by juveniles moving from inland nesting areas to the coast in late summer, prior to their long-distance migrations. Since post-fledging mortality of juveniles is a significant factor in determining reproductive success, alteration of required habitat conditions for these birds could affect population levels over wide areas. Specific petroleum development implications arising from this study were discussed in Part I. Also, as discussed in Part I, the specific objectives of this study match very closely the principal informational needs identified at the Barrow synthesis meetings in the discussions of birds, plankton, critical areas, and critical biota.

III. Current state of knowledge

As already mentioned, prior to RU #172, no quantitative studies had concentrated on shorebird use of arctic littoral areas. Available information was rather sparse and general, usually gathered by observers in the course of other studies. Detailed information on breeding activities on the tundra is available for many species, however. A partial list of publications dealing with Alaskan arctic shorebird ecology, mostly done near Barrow, is appended. These studies provide a valuable basis for interpreting littoral zone and post-breeding activities of many shorebird species in the context of the entire summer reproductive cycle.

IV. Study area

The bulk of field activities took place near Barrow, Alaska (latitude 71° 17' North; Longitude 156° 46' West), utilizing logistic support provided by the Naval Arctic Research Laboratory (NARL). Within the coastal area extending 22 kilometers southwest and 6 kilometers southeast of Point Barrow, the northernmost point of land in Alaska, a variety of littoral and near littoral habitats are being studied. These include tundra-backed open lagoon beach (Elson Lagoon); open lagoon estuary (Central Marsh Slough); tundra-backed ocean beach (near Nunavak Bay); ocean estuary (Nunavak Bay); closed brackish lagoon (North Salt Lagoon) and peripheral estuary mudflats (Voth Creek, Middle Salt Lagoon); brackish storm-flood pools (Britton ponds and Barrow Spit ponds); and gravel spit beaches (Barrow Spit and Plover Spit: Chukchi, Beaufort, and Elson Lagoon shores).

Supplementary study areas, at Lonely near Pitt Point (latitude 70° 55' North, longitude 153° 15' West); Wainwright (latitude 70° 38' North, longitude 160° 02' West); Peard Bay (latitude 70° 49' North, longitude 158° 25' West); and Icy Cape (latitude 70° 18' North, longitude 161° 52' West) were visited in July and August 1976; and Cape Krusenstern (latitude 67° 08' North, longitude 163° 44' West) and Wales (latitude 65° 37' North, longitude 168° 08' West) were visited briefly in June, July and September.

V. Methods: data collection and analysis

For reasons discussed in the first annual report (Connors and Risebrough, 1976), the arctic littoral zone is considered to extend from lowest tide level up to the limits of the regions likely to be inundated by storms at least once every few years. Within this study, data were collected throughout this zone, on the tundra above this zone, and on the nearshore water areas beyond this zone. The discussion of methods will be divided into several sections corresponding to the principal classes of data gathered:

A. Shorebird seasonal habitat use. As described in Connors and Risebrough (1976),primary effort was focused on a permanent transect method. Transects were marked at 50 m intervals in littoral and in tundra areas. A listing of names and locations of transects is given in Table 1 and Figure 1. Upland transects are necessary for comparison with littoral

Table 1. Locality Codes for Transects and Sample Stations (see Figure 1).

Code	Transect or Station Name	Transect Length (m)	Transect Width (m)
AP	Airport	1000	50(200)
BD	Barrow Dump	2900	50(200)
BP	Britton Ponds	300	100
BS	Barrow Spit	1000	50(200)
BSS	Beaufort Sea Station		
CB	Cemetery Beach	1000	50(200)
CM	Central Marsh Slough	1000	50(200)
CSN	Chukchi Sea North	1000	50(200)
CSS	Chukchi Sea South	1000	50(200)
DM	Deadman	1000	50(200)
EL	Elson Lagoon	1000	50(200)
GF	Graveyard Flat	500	100
MSE	Middle Salt East	500	50(200)
MSW	Middle Salt West	500	50(200)
NB	Nunavak Bay	1000	50(200)
NSL-1	North Salt Lagoon-1	500	100
NSL-2	North Salt Lagoon-2	500	50(200)
NT	Nuwuk Tundra	500	100
PB	Plover Bight		
PP	Plover Point	1000	50(200)
PS	Plover Spit	1000	50(200)
RW	Rotten Walrus	1000	50(200)
T-1 through T-10	Tundra Transects 1-10	1000 each	100 each
TW	Top-of-the-World	1000	50(200)
VC	Voth Creek	500	100
WB	Whalebone Bight		
WS	Whalebone Spit	1000	50(200)

Totals: Tundra, 10 km x 100 m: 100 hectares
Littoral, 18.4 km x 50 m: 92 hectares
Littoral, 2.3 km x 100 m: 23 hectares

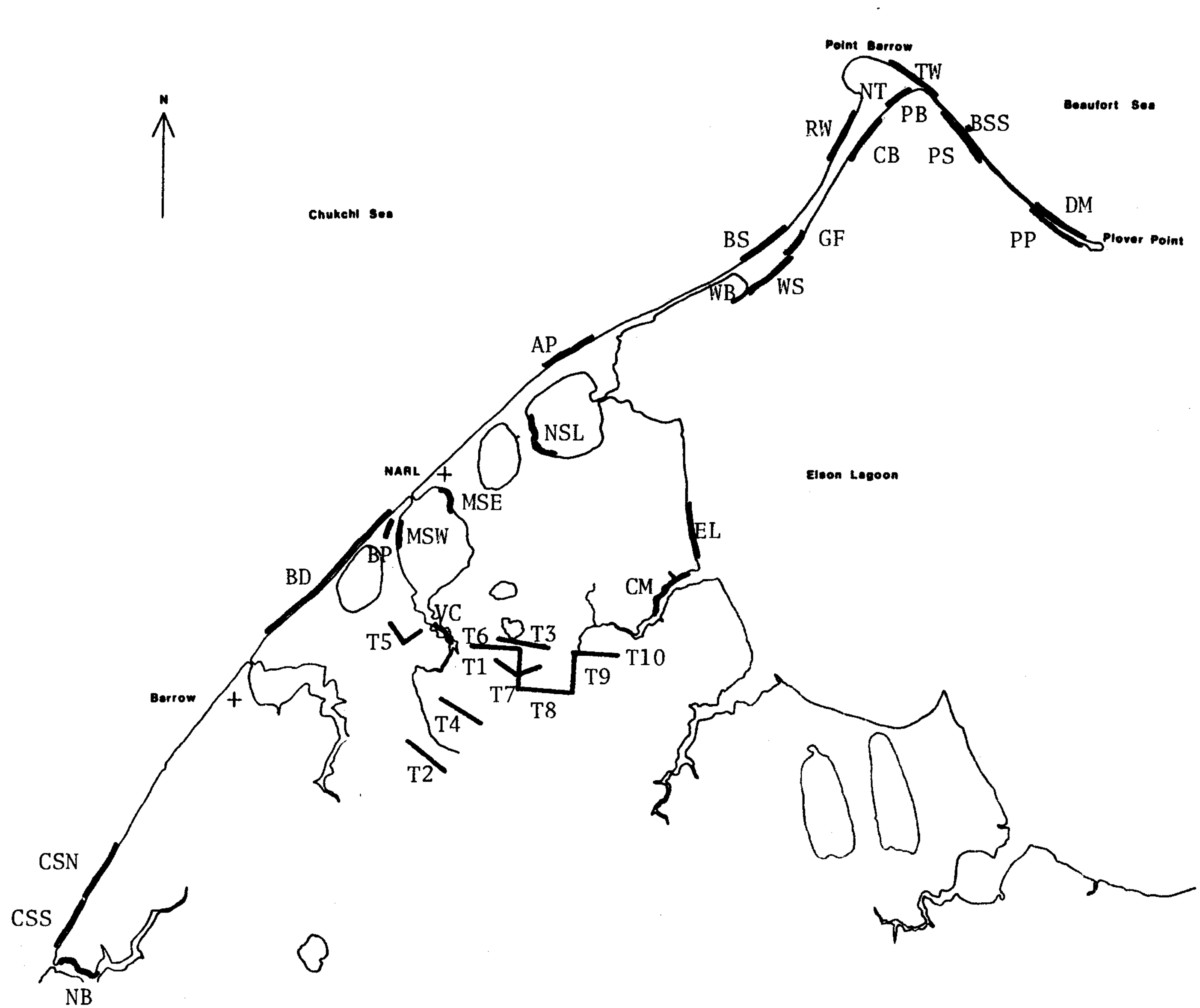


Figure 1. Locations of transects and sampling stations.

transects to assess seasonal changes in habitat use by birds. In narrow shoreline habitat areas, as along outer beach shores, stakes defined a single row of square census plots 50 meters on each side. In areas of more extensive, continuous habitat, such as mudflats or upland tundra, the stakes defined a double parallel row of 50 m plots. Total lengths of transects within single habitats ranged from .3 km to 2.9 km. Total area of littoral transects included 115 hectares in 20.7 km; total area of tundra transects included 100 hectares in 10 km. Transects were censused repeatedly and regularly at least once every five days, from June 6 to September 15. All birds within each census plot were recorded, as well as any birds within 200 m on the water side of shoreline transects. Passerine species were not included in littoral zone censuses during the breeding period but were counted in August and September, when flocks of Lapland Longspurs and Snow Buntings moved into littoral areas.

The method of permanent transects regularly censused provides data which are easily analyzed to record seasonal changes in population density, as illustrated in Part VI (Results). To obtain more extensive coverage of littoral areas near Barrow and at other study sites along the arctic coast and to increase the prospect of observing very transitory or localized phenomena, the transect method was supplemented with censuses recorded as numbers of species in a known or estimated length of shoreline or area of suitable habitat. This approach provides flexibility in treating all observations, and results can be used to explain and complement the transect results.

B. Trophic studies

Trophic studies of shorebirds using littoral habitats received increased emphasis in the second year of this study with collection of birds for stomach analysis being supplemented by more extensive collection of plankton and substrate samples. Collection methods (by shotgun followed by immediate injection of formalin fixative solution in the field) were described in Connors and Risebrough (1976). Most of the collected birds were subsequently prepared as museum specimens.

Plankton samples were taken with a floating net towed parallel to shore in shallow water. The cross section of the net opening was rectangular, 30 cm wide and supported by styrofoam floats to sample to a controlled depth of 14 cm. This net was designed to sample from the same fraction of the water column as do foraging phalaropes, gulls, and terns on gravel shores in August and September. The 87 cm length net tapered to a removable 8 oz glass bottle attached by a steel hose clamp. Net mesh size was 350 μ for all outer shoreline stations and 150 μ for Middle Salt Lagoon stations.

Tows were made by slowly pulling the floating plankton net parallel to shore for 15 m. The net operator walked along on shore leading the net by means of a 2 m pole and attached line. Tows were usually made between 1-1.5 m from shore in water of 15-30 cm depth. Replicates of 2 or 3 samples were collected 13 times to determine sample variance; otherwise, one per collection was taken. Towing speed was approximately .2 m per second. Experiments with milk added to the water showed that at this slow speed, no appreciable volume of water is pushed in front of the net. Total volume filtered per tow is therefore simply the cross section multiplied by the distance of the tow, which equals .63 cubic meters. Occasional observation of large zooplankton near the net did not demonstrate a serious problem due to escape responses but this remains a possibility. Plankton samples were preserved in 70% ethyl alcohol or 10% hexamine-buffered formalin solution. Plankton samples were collected synchronously with the collection of Red Phalaropes and also at four established stations (BSS, PS, WS, and BS) at least once every five days through August and early September.

Benthic samples were also taken synchronously with the collection of individuals foraging on mud, sand, or gravel substrates. Additional benthic samples were collected in other areas utilized by foraging shorebirds.

During subsequent laboratory analysis, contents of stomach and esophagus of each collected bird were treated separately. Prey items were identified to species whenever possible; mean length of common items in stomachs was measured or estimated by species; relative biomass of all prey types representing more than 5% of any stomach was estimated as a percent of the total mass of material within that stomach.

Plankton samples were counted and identified and average length of specimens recorded. For dense samples a dilution procedure was employed and only aliquots were counted.

Some benthic samples were separated by addition of saturated magnesium chloride solution in which prey items will float to the surface. This supernatent was then poured through a 150 μ screen. While this procedure does not remove all the organisms in the sample (largely due to the entrapment of specimens in debris and algae), the relative abundance of the organisms remaining in the sediment was the same as that of the organisms which were floated out. Other benthic organisms were examined directly without use of magnesium chloride.

Salinity samples were determined with an A&O TS meter and concentrimeter (Goldberg Refractometer).

C. Foraging microhabitat preferences

The likelihood that a bird will encounter spilled oil depends, to a great extent, upon its preferred microhabitat: the same physical transport systems important in generating and modifying local habitat conditions are also those involved in the movement of oil in littoral areas - currents, wave action, exposure, etc. In all shorebird communities that have been studied, species differ in their microhabitat use. If this generalization extends to the Beaufort and Chukchi coasts, then it implies that species' susceptibilities to oil spillage may vary in accord with their preferred microhabitats. It therefore becomes important to determine how each species responds to microhabitat in the littoral zone, in order to properly assess species susceptibility to oil damage.

In 1975 we began a program investigating this problem; results from the first field season are presented in last year's annual report. In 1976 we continued the study, modifying our sampling program as a consequence of the first year's experience. The following discussion describes our procedure and summarizes analyses which have been carried out to date.

Six variables (see Table 2) were measured at the foraging sites of individual shorebirds as they fed on our littoral zone transects in the Barrow area. A microhabitat ordination was then obtained using factor analysis: this multivariate technique reduces the dimensionality of the original data set to a series of factors, each of which represents an environmental gradient within the microhabitat. Mathematical criteria for extracting the factors involve their ability to reproduce the intercorrelations among the original variables. Each variable is considered to be composed of two components: that portion unique to the original variables, and that due to hypothetical factors - in our case the gradients - common to other variables and responsible for their intercorrelations. Factors extracted by this procedure may be thought of as "major influences acting on the system" (Wallace and Bader, 1967). The relative weighting of the original variables along each factor, i.e. their correlation coefficient with the factor, allow a biological interpretation of the underlying gradient being described: those weighting most heavily indicate the nature of the habitat variation produced along the gradient.

The ordination obtained through factor analysis summarizes natural patterns of variation in the microhabitat used by the shorebird community: it defines a habitat space with the gradients functioning as major axes. Different areas in the space correspond to different types of habitat. With this ordination, it is possible to ask how each species responds to habitat variation produced by the gradients: its habitat preferences can be described in terms of the frequency of use of different areas in habitat space.

D. Phalarope marking - resighting study

During August, juvenile Red Phalaropes were trapped, banded, color-marked, and released along Barrow Spit. Trapping was accomplished with a wire hoop approximately 1.2 m in diameter, covered with mist netting and attached to a modified rat trap spring. This trap was set at the water's edge and held with the hoop vertical by the operator, situated 10-20 m away. The trap was then released by the operator when a Red Phalarope moved into position in front of the net. Forty-eight juvenile Red Phalaropes were captured and banded in this way. Of this total, 47 birds were color-marked with quick drying paint on the wing stripe and upper breast areas. Two colors and three positions permitted identification of groups of birds marked on each of six days. Resightings were attempted during subsequent census periods. The intent of this effort was to determine whether individual juvenile Red Phalaropes remained in the Barrow area throughout the period of phalarope activity in August and September, or alternatively, whether individuals are continuously moving through the area. Tarsus length, wing cord length and weight of all trapped birds were measured to look for changes in fat deposition during this pre-migratory period.

Table 2. Foraging Microhabitat Variables

Variable Name	Description of Measurement
WATERDS	distance (cm) from the foraging point to the water line; positive distances are on land; negative in water.
DEPTH	depth of water (mm) at foraging point
GRNSIZE	modal size (mm) of substrate particles at foraging point. Variable entered as ($\log_{10}$GRNSIZE)
DISTALG	minimum distance (cm) from the foraging point to the nearest algal mass. Variable entered as $\log_{10}$(DISTALG +1). If no algae was apparent within 50 meters, DISTALG was set to 5000 cm. (=50 m.).
DISTVEG	minimum distance (cm) from the foraging point to the nearest vascular plant. Variable entered as in DISTALG.
BILLPEN	penetration depth (mm) of the bird's bill into the substrate. Recorded in the field as the proportion of the bill which entered the substrate and corrected subsequently using an average bill length for each species.

VI and VII. Results and discussion

These two sections are combined for convenience in presentation. Four categories of results will be treated.

A. Shorebird seasonal habitat use

A series of seasonal population plots for littoral and upland habitat transects are presented in Figures 2-25 for all common shorebird species. Data are presented as bar graphs with height of each bar equal to the recorded total population on all littoral or tundra transects during the census period. Length of each census period is five days and multiple counts for any transect within one period are averaged so that each total population number represents the mean population on all grouped transects within the period. Total area of littoral zone transects is 115 hectares in 20.7 km. Area of tundra transects is 100 hectares in 10 km. Note, however, that within the Barrow area, a greater proportion of total littoral habitat is represented on these transects than the proportion of total tundra habitat. In comparisons between these two broad habitat classifications, therefore, the relative use of tundra habitats may be underestimated.

All shorebird species recorded in littoral habitats are discussed in this section. Records of uncommon species refer only to littoral zone sightings. In most cases in which habitat use of a species did not differ between 1975 and 1976, an abbreviated status description is given. The reader is referred to more extensive comments in the first annual report (Connors and Risebrough, 1976).

1. Semipalmated Plover (*Charadrius semipalmatus*). As in 1975, an uncommon species seen only in littoral areas where a few pairs nested on gravel and near mud-bordered brackish pools around lagoons.

2. Golden Plover (*Pluvialis dominica*). Figure 2. Very common, breeding and migrating, but almost restricted to tundra habitats.

3. Black-bellied Plover (*Pluvialis squatarola*). Only a few individuals seen near Barrow in littoral areas. Much more common farther east along the Beaufort coast where this species occurs on mudflats during migration.

4. Ruddy Turnstone (*Arenaria interpres*). Figure 3, 4. Common breeder and migrant. Pattern similar to 1975. Adults nest on tundra during June and July, moving into littoral areas in late July and early August with juveniles. Adults migrate southward in early August, however. Juveniles continue to accumulate in littoral areas throughout August, staying until well into September, where they forage around brackish flood pools, on mud and gravel flats, and along gravel beaches where they take zooplankton washed up on the shore.

5. Curlew Sandpiper (*Calidris ferruginea*). Occasional breeder at Barrow, with two individuals seen in littoral areas in 1975 but none in 1976.

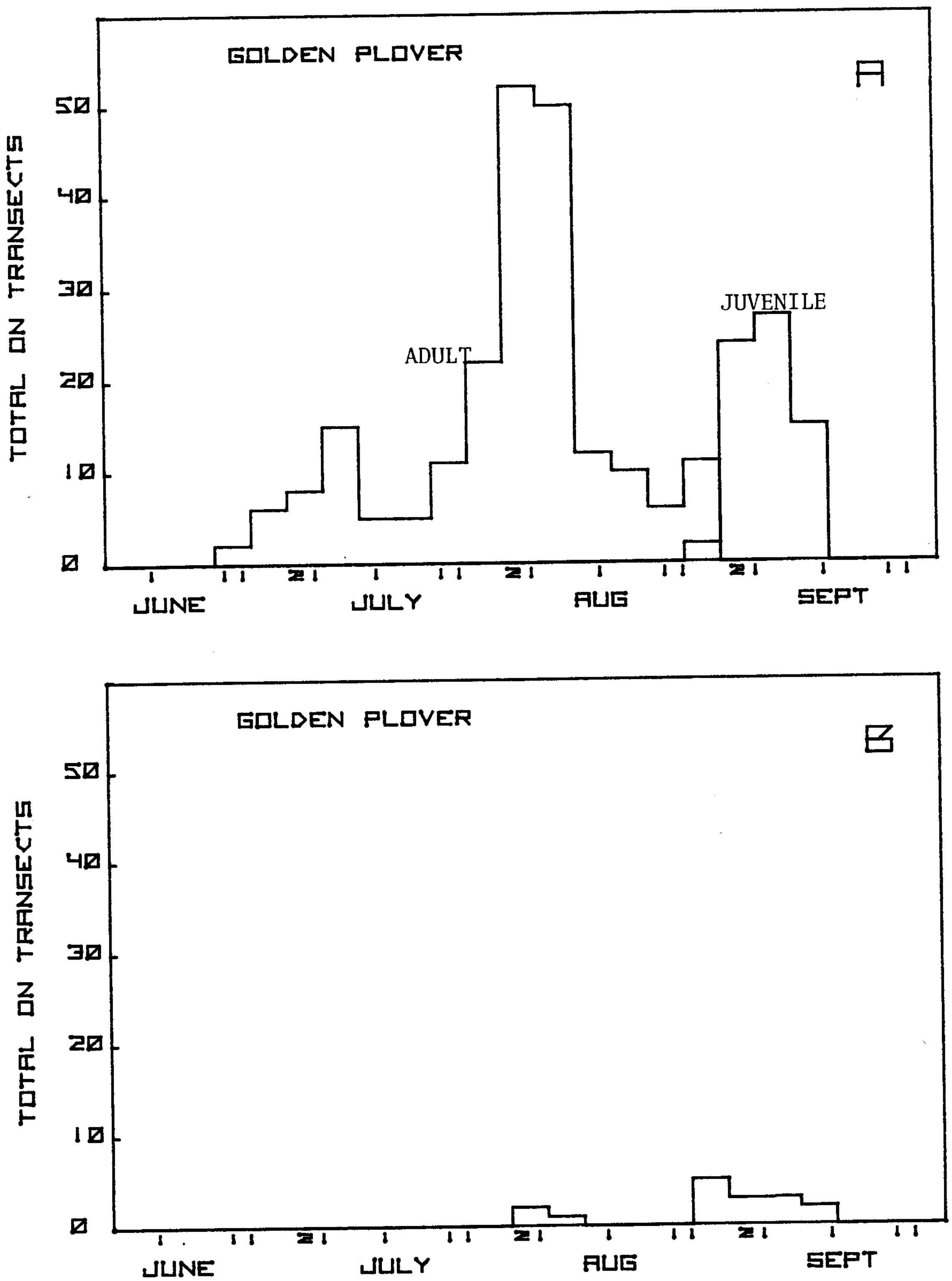


Figure 2. Seasonal population change. A. Tundra, adult and juvenile. B. Littoral, total.

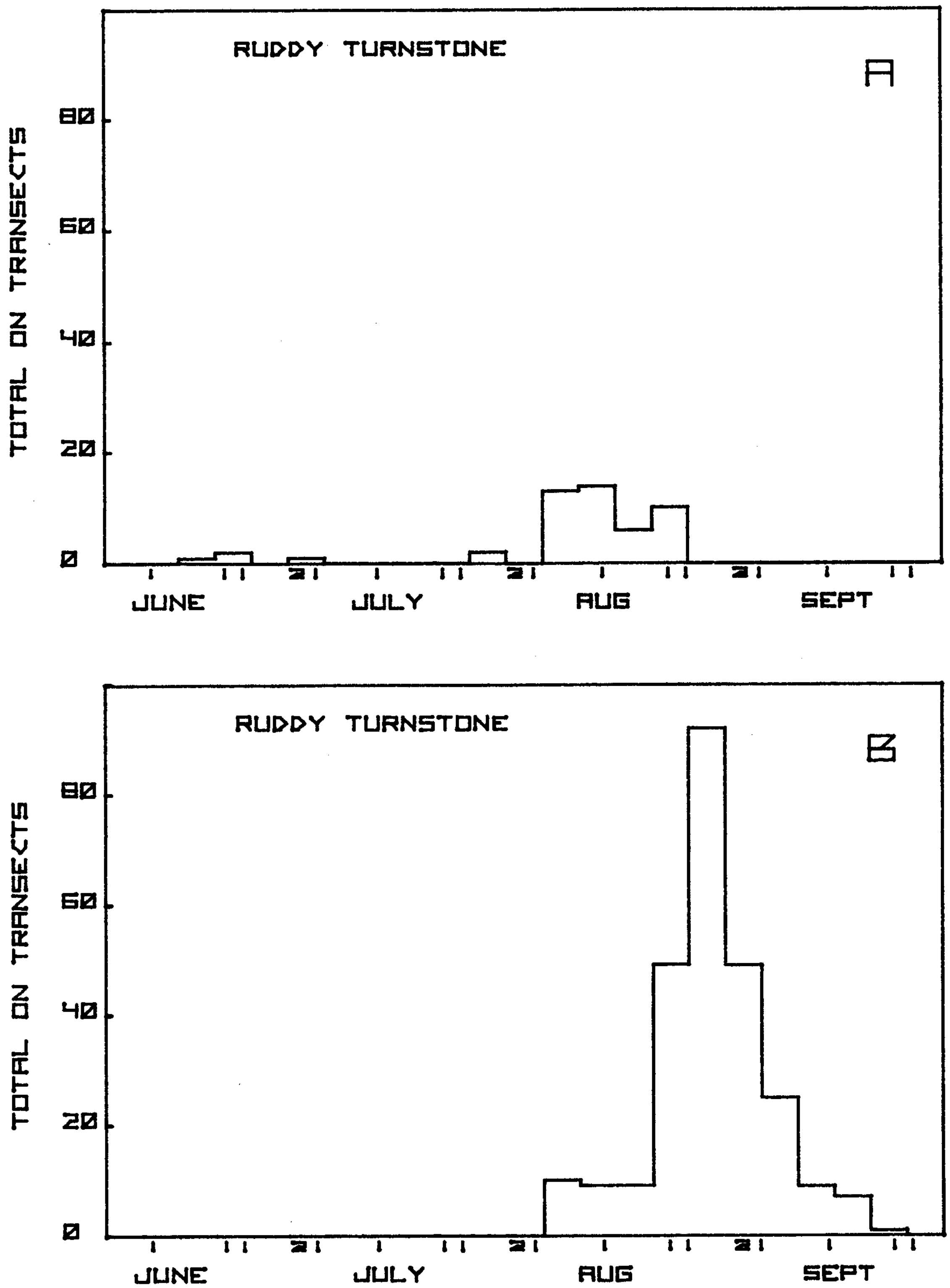


Figure 3. Seasonal population change. A. Littoral, adults.
B. Littoral, juveniles.

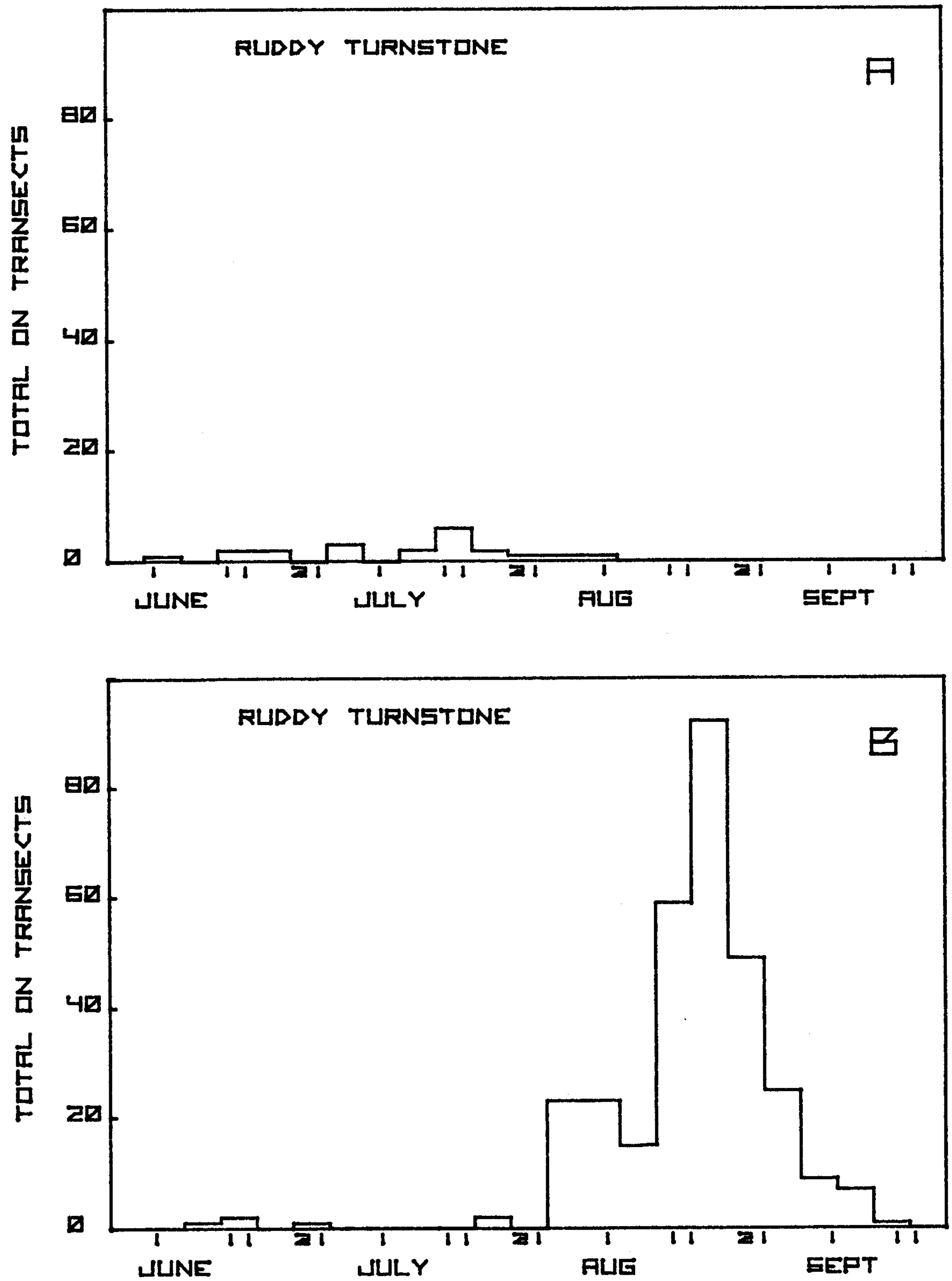


Figure 4. Seasonal population change. A. Tundra total.

B. Littoral total.

6. Semipalmated Sandpiper (Calidris pusilla). Figure 5, 6. This regular breeder at Barrow showed a very similar habitat use pattern in both years. Adults nest on tundra but usually forage on stream margins or littoral mudflat habitats adjacent to the nesting areas. Adults are therefore fairly common in littoral habitats throughout the early part of the season, in contrast to most of the Barrow sandpipers. The sudden and striking juvenile population peak occurred similarly in both years (August 3, 1975 and July 31, 1976). Juveniles suddenly appeared on most inner lagoon shores and mudflats and around brackish pools, but densities declined sharply within a few days. The peak was actually sharper than indicated in Figure 5B, since this is the average of one high count and one low count within the 5-day census period. The sudden movement of large numbers of juvenile Semipalmated Sandpipers to shorelines is apparently fairly widespread and synchronous in the Alaskan arctic. Similarly high densities were observed within two days of the Barrow peak at Prudhoe Bay in 1975 and at Wainwright and Icy Cape in 1976.

7. Western Sandpiper (Calidris mauri). Figure 7, 8. This species also showed a pattern very similar in both summers, with heaviest representation in littoral areas. Again, a movement of non-breeding adults passed through Barrow during late June and early July, foraging along inner lagoon edges and on mudflats. The second movement, consisting primarily of juveniles, arrived in early to middle August, with individuals remaining until early September. As in 1975, the migration peaks of these last two ecologically similar species exhibited almost no overlap in time.

8. Rufous-necked Sandpiper (Calidris ruficollis). In 1975, we located the first recorded nest of this Siberian species in North America east of Cape Prince of Wales. The nest was at Point Barrow on the NT transect. In 1976, an unaccompanied male displayed in this same area for several days in June. Two Rufous-necked Sandpipers were also seen foraging on mudflats on VC transect in late June.

9. White-rumped Sandpiper (Calidris fuscicollis). This species was rare in both seasons in littoral areas and on the tundra.

10. Baird Sandpiper (Calidris bairdii). Figure 9, 10. This species shows many contrasts to several of the other Calidris sandpipers. Baird Sandpipers are one of the most common shorebirds in most littoral habitats during June and July near Barrow. They nest frequently near lagoon edges, in salt marsh areas near brackish pools, and on or near gravel beaches. One nest was located in drift material 5 m from the edge of Elson Lagoon on the Barrow Spit beach. The young hatched out several hundred meters from the nearest small patch of tundra vegetation. Another brood was located on the flat portion of Point Barrow around Nuwuk Lake. These downy young, approximately one week old, were foraging directly on live zooplankton in the shallow water of a brackish flood pool. This species also nests commonly on coastal tundra in non-littoral areas. On our transects, however, densities were generally higher in littoral areas. A peak of presumably post-breeding adults occurs in late July, diminishing before the juveniles leave the area, as in many other species. However, the juvenile population movement does not show a large peak as in most

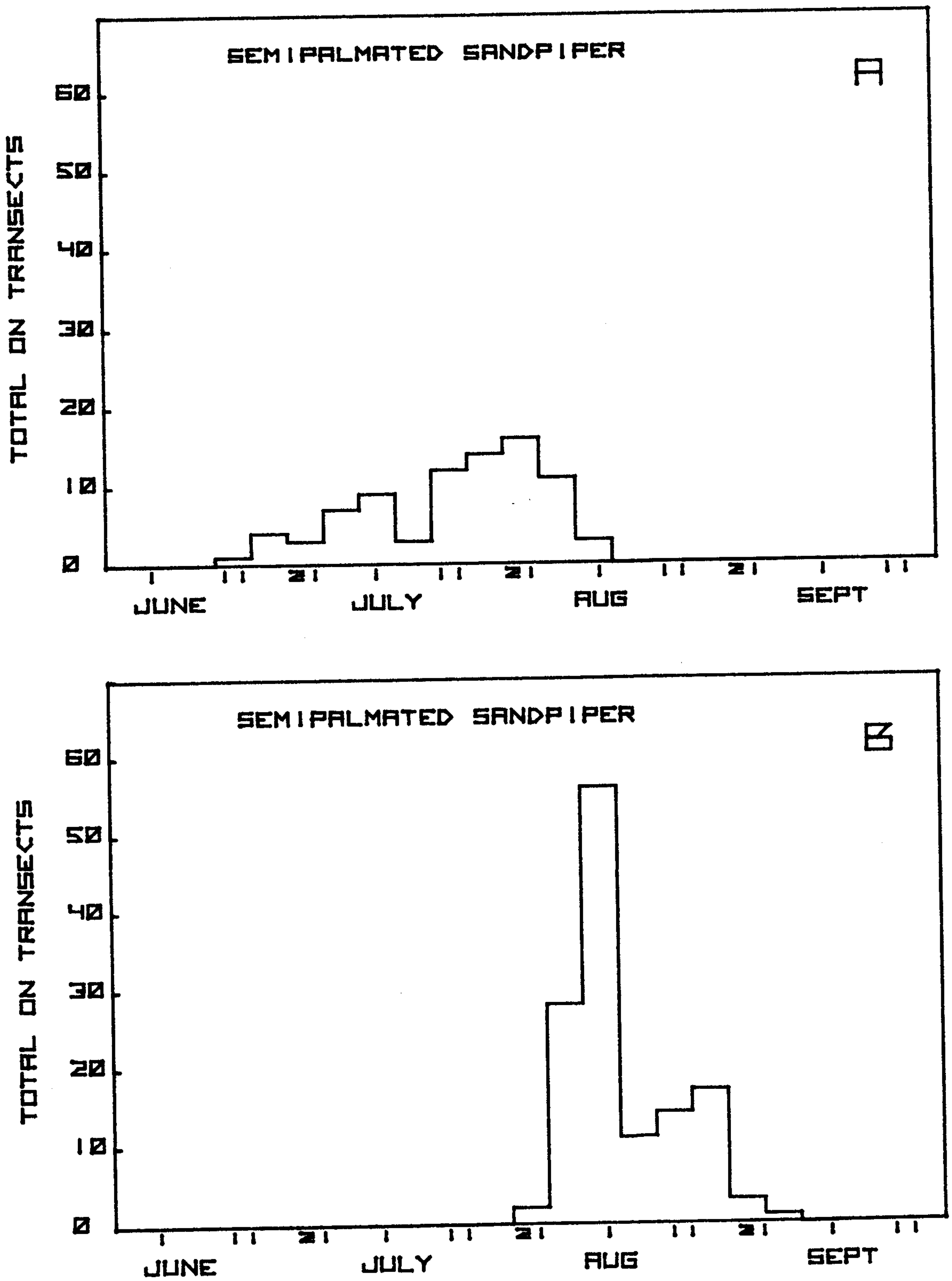


Figure 5. Seasonal population change. A. Littoral, adults.
B. Littoral, juveniles.

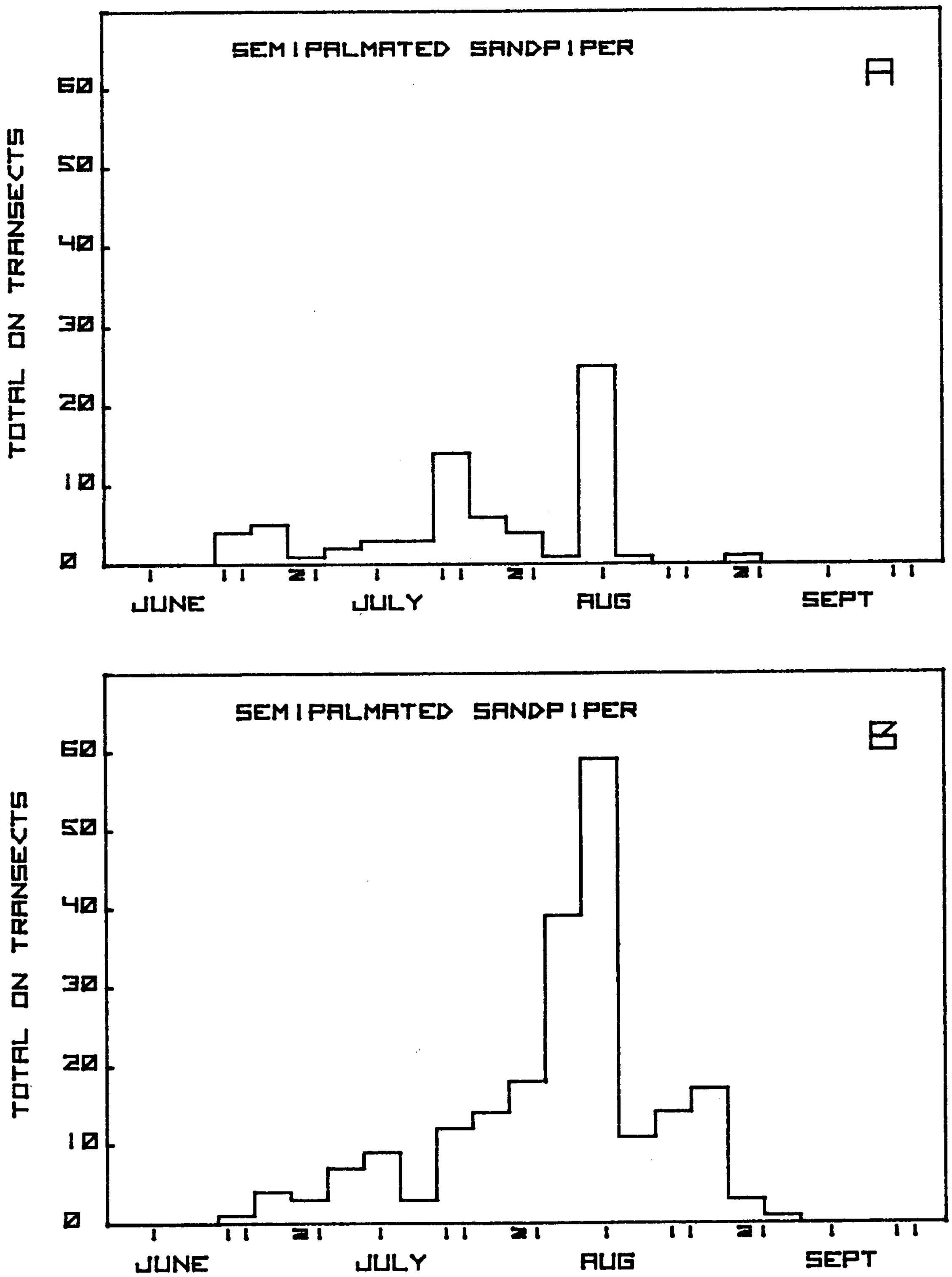
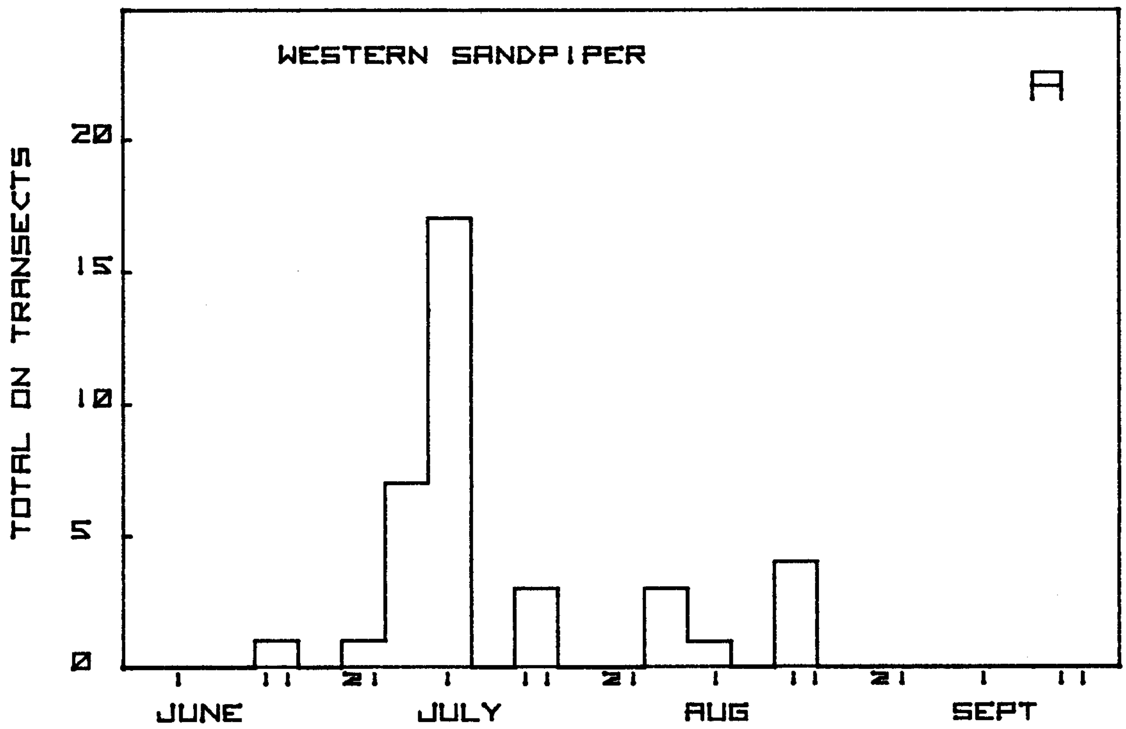


Figure 6. Seasonal population change. A. Tundra, total.

B. Littoral, total.



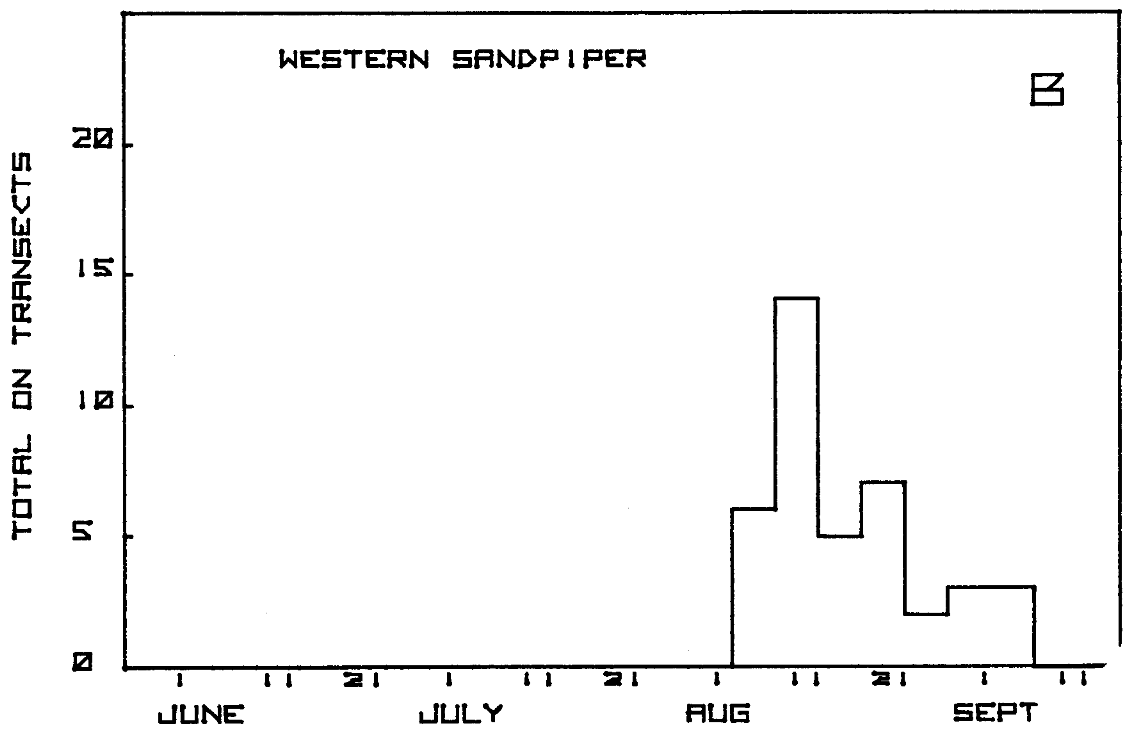


Figure 7. Seasonal population change. A. Littoral, adults.

B. Littoral, juveniles.

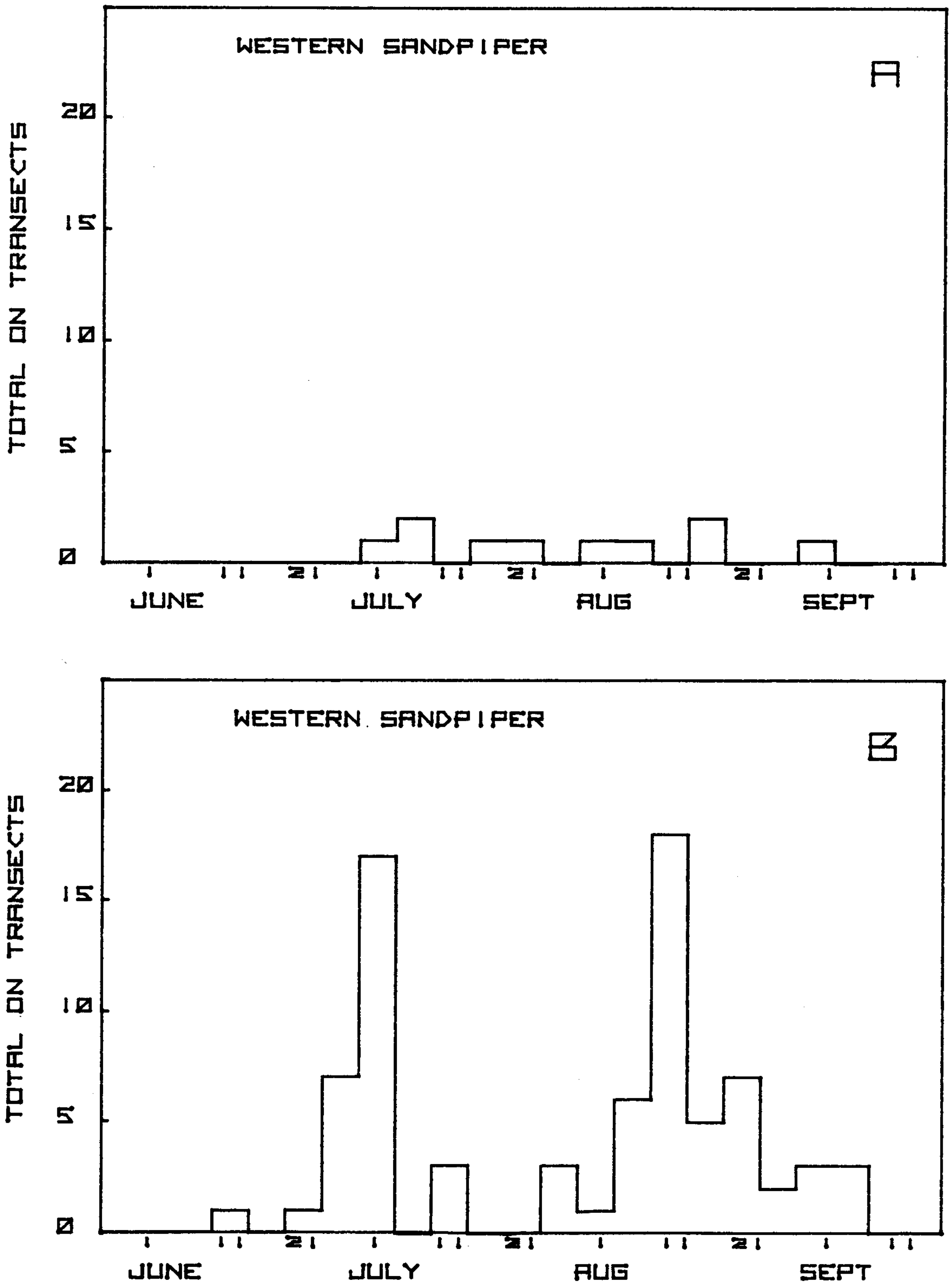


Figure 8. Seasonal population change. A. Tundra, total.
B. Littoral, total.

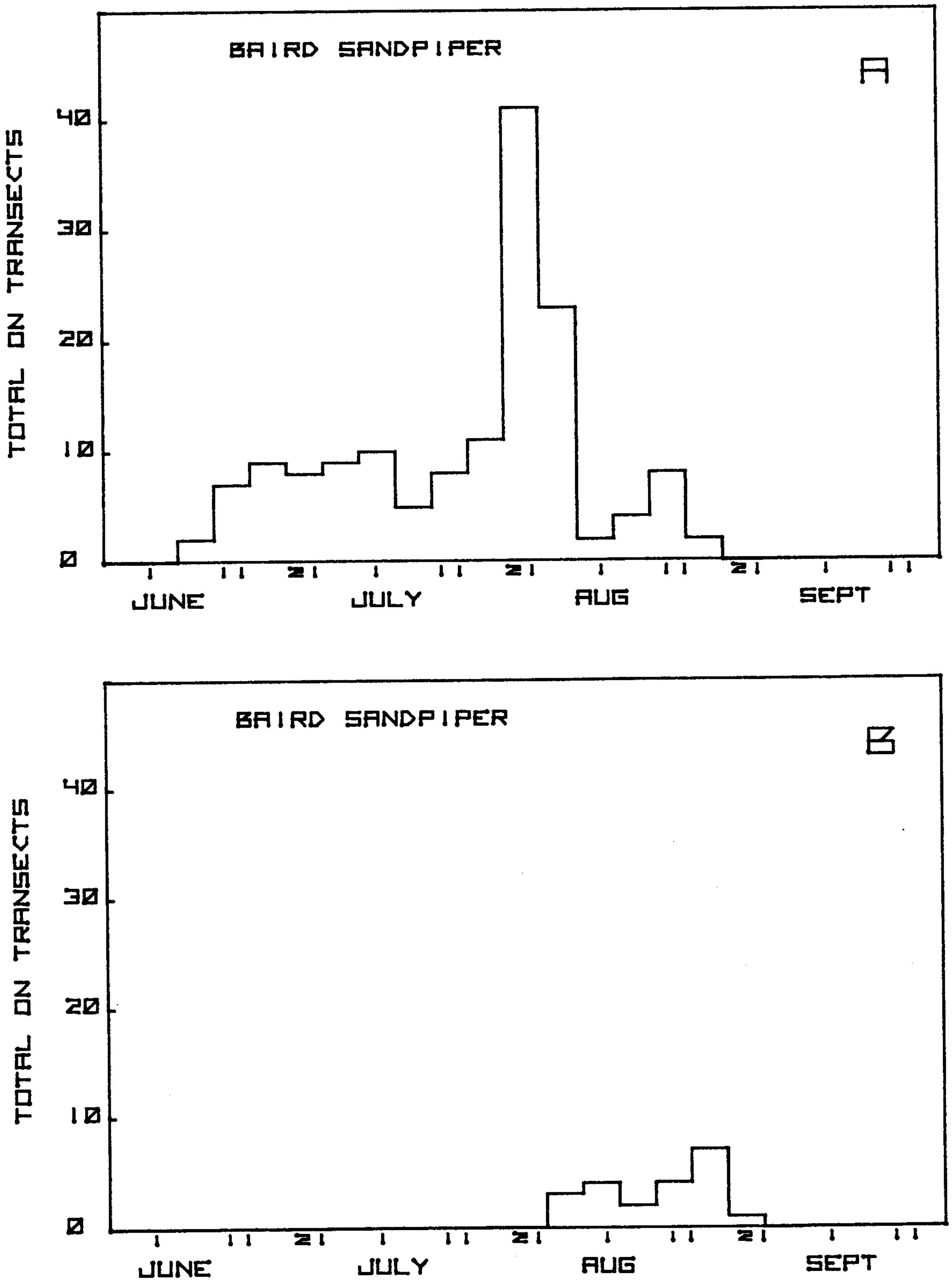
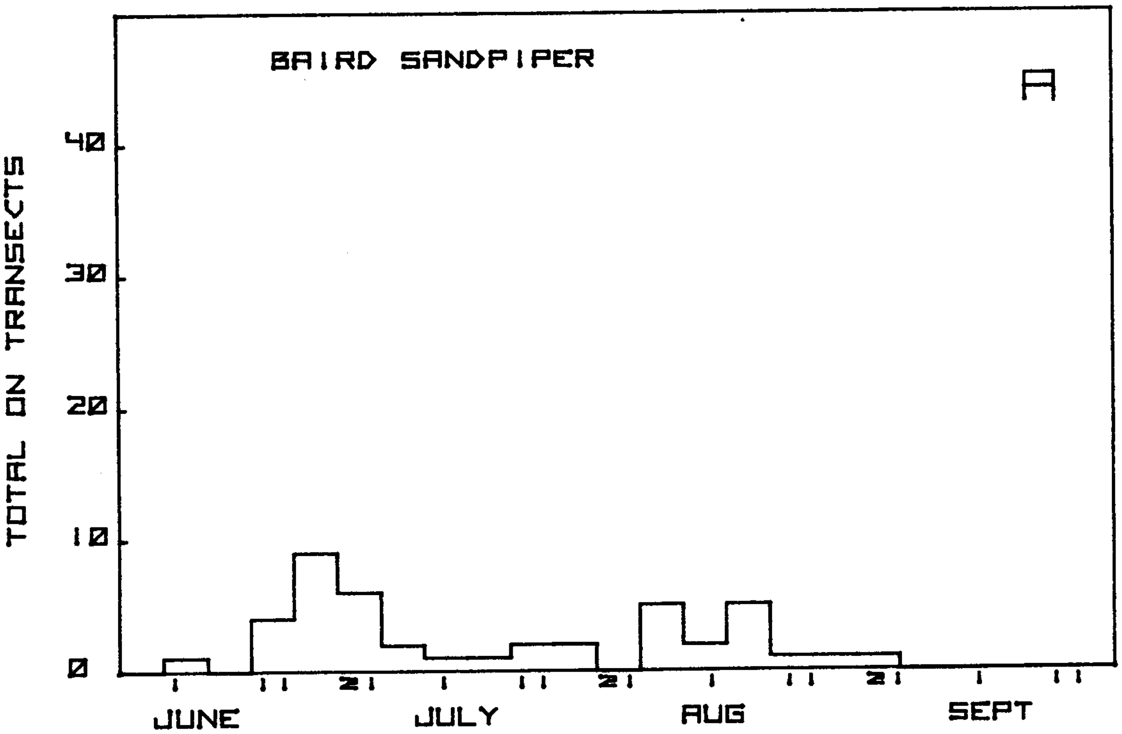


Figure 9. Seasonal population change. A. Littoral, adult. B. Littoral, juvenile.



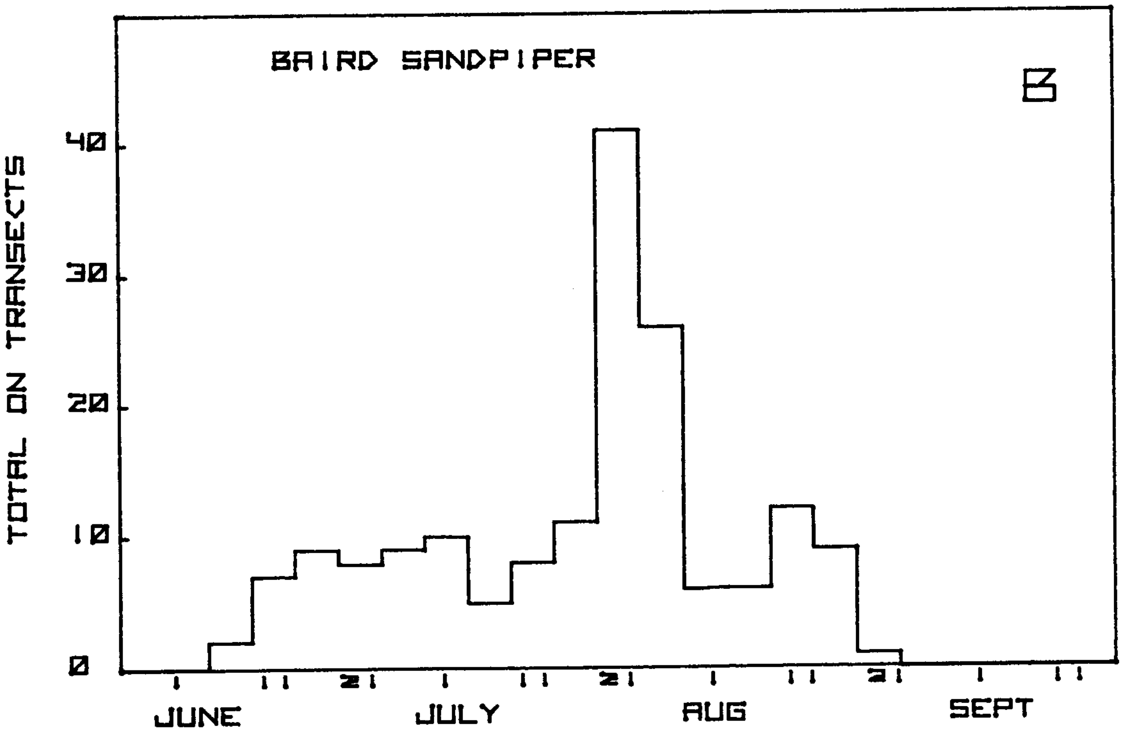


Figure 10. Seasonal population change. A. Tundra, total.

B. Littoral, total.

other sandpipers, and all Baird Sandpipers have left the area by middle to late August.

11. Sanderling (Calidris alba). Figure 11B. In 1975, in early to mid June, small numbers of Sanderlings were fairly common around early melting pools near lagoons and beaches and in open areas on gravel beaches. These pre-breeding adults were also seen in similar littoral areas in 1976 but in smaller numbers. No nests were found in 1976, and the species was not seen again until early August when juveniles began migrating through the Barrow area. All Sanderlings seen in late summer of both years were juveniles. This species is common in August and early September and is almost entirely restricted to outer coast gravel shorelines where it forages principally on zooplankton washed up on the shore.

12. Pectoral Sandpiper (Calidris melanotos). Figures 11A, 12, 13. Of the several common sandpipers at Barrow, this species occurs least often along open shores. Littoral habitats most commonly utilized by Pectoral Sandpipers consist of grass-bordered innner lagoon and brackish pool shores. Movements through the Barrow area differed considerably between the two summers. In 1975, a relatively heavy movement of non-breeding adults or post-breeding males occurred in both the littoral and wet tundra areas, with a peak population on all transects combined occurring during the first week in July. In 1976, this movement was less pronounced and almost restricted to tundra areas. Flocks of males remained later during 1976, however. Both male and female populations reached peak densities on about July 21, with most males disappearing abruptly afterward. At Cape Krusenstern, north of Kotzebue, on June 3, 1976, we encountered several flocks of Pectoral Sandpipers moving northward along the beach ridge.

13. Dunlin (Calidris alpina). Figure 14, 15, 16. Movements of this very common north slope breeder were similar during both years with high densities in tundra habitats throughout summer but high densities in littoral areas only during August and early September. Patterns of comparative habitat use between adults and juveniles remain confusing. The accompanying figures show a somewhat higher proportion of juveniles in littoral areas, especially during late August, but this distinction is not as clear as earlier observations had indicated (Holmes, 1966a, b). Dunlins foraging in littoral areas utilize mudflats, brackish pool margins, lagoon shores, and outer coast gravel beaches. Non-transect observations suggest to us that even in littoral areas such as Barrow Spit, adults are more likely to forage in mudflat and brackish pool margin habitats, and juveniles are more likely on gravel shores where they forage on plankton.

Densities and total numbers of Dunlin observed in muddy brackish pool areas near Lonely were again very high in 1976. This species also occurred in flocks with Pectoral Sandpipers moving northward along the beach ridge at Cape Krusenstern on June 3, 1976.

14. Stilt Sandpiper (Micropalama himantopus). Migrant, seen rarely in both seasons.

15. Long-billed Dowitcher (Limnodromus scolopaceus). Figure 17.

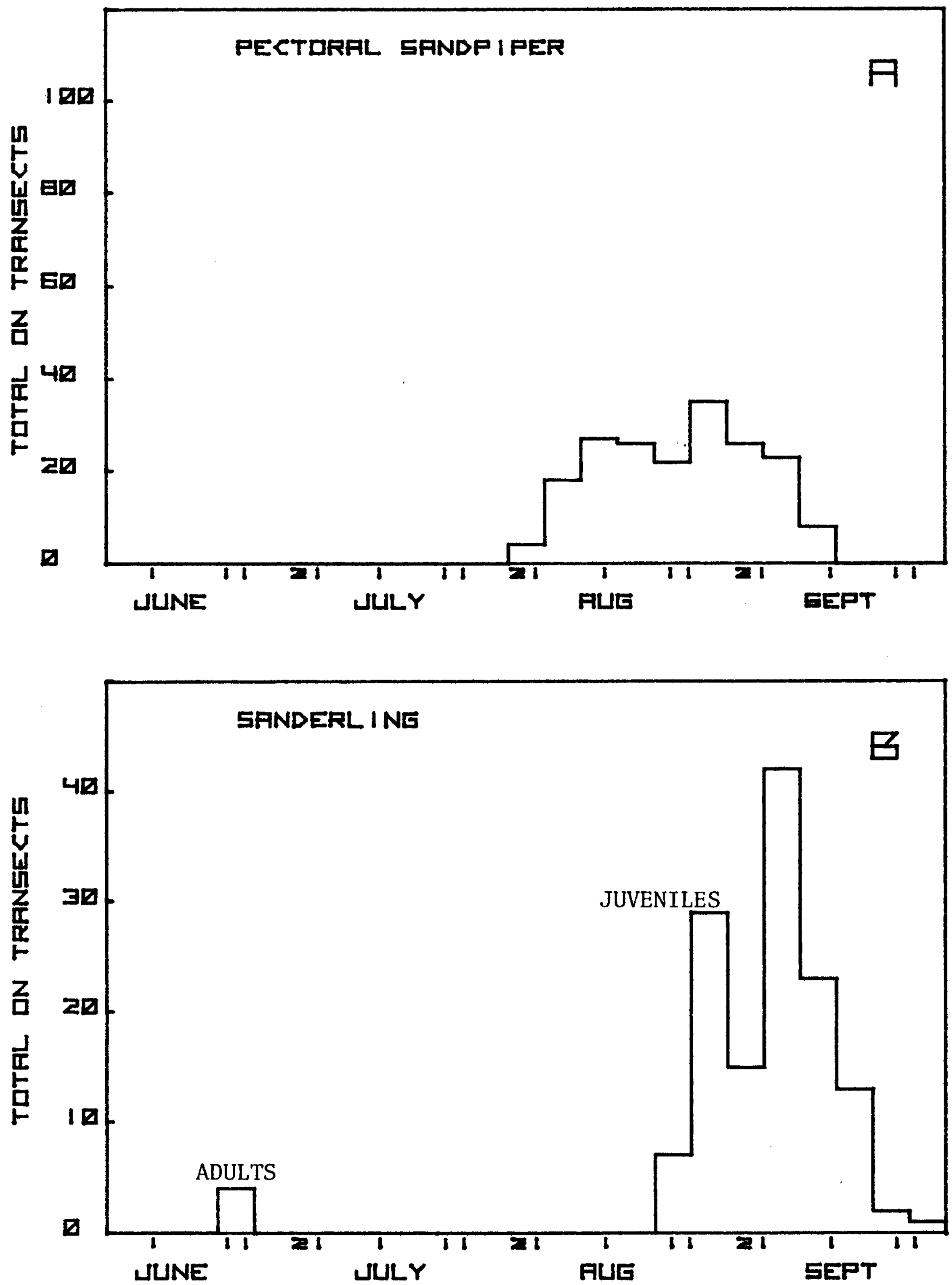
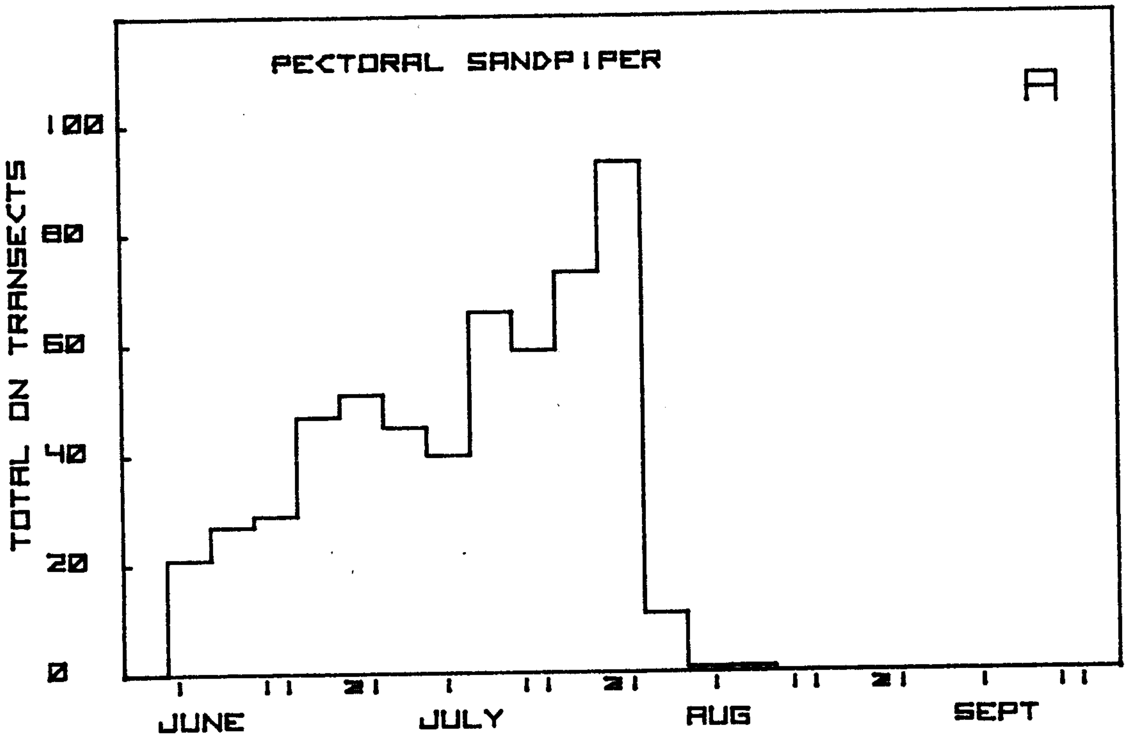


Figure 11. Seasonal population change. A. Pectoral Sandpiper, tundra, juvenile. B. Sanderling, littoral, adults and juveniles. No Sanderlings on tundra transects.



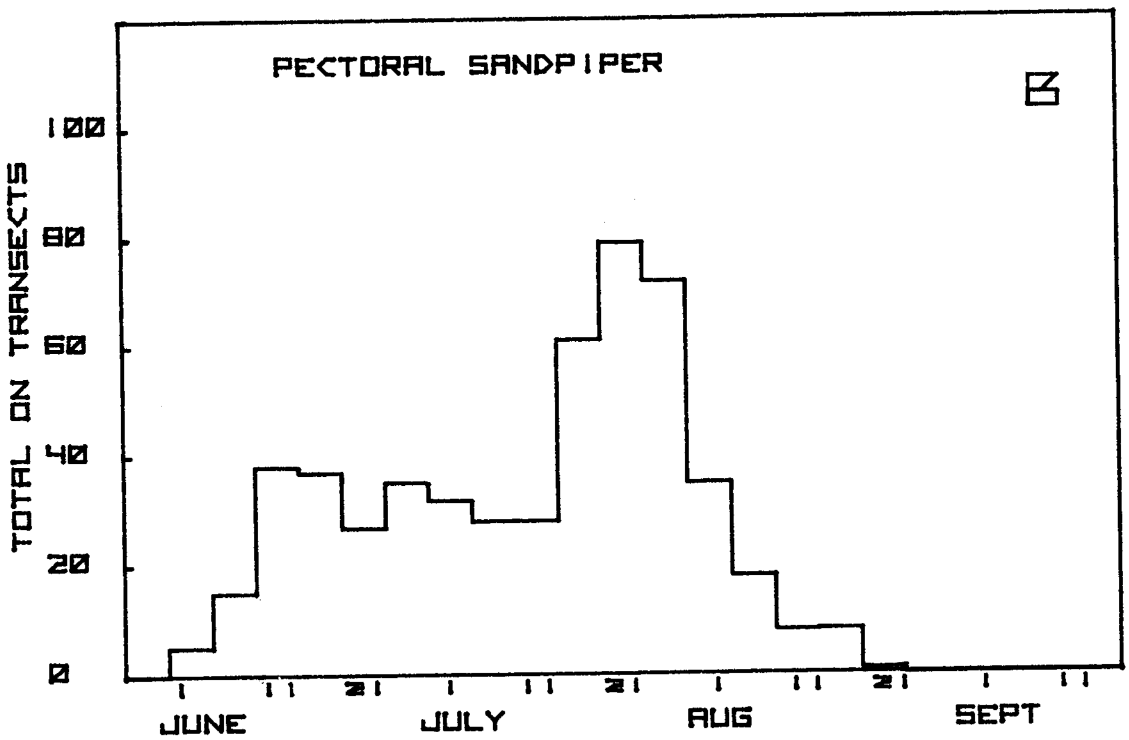


Figure 12. Seasonal population change. A. Tundra, adult males.

B. Tundra, adult females.

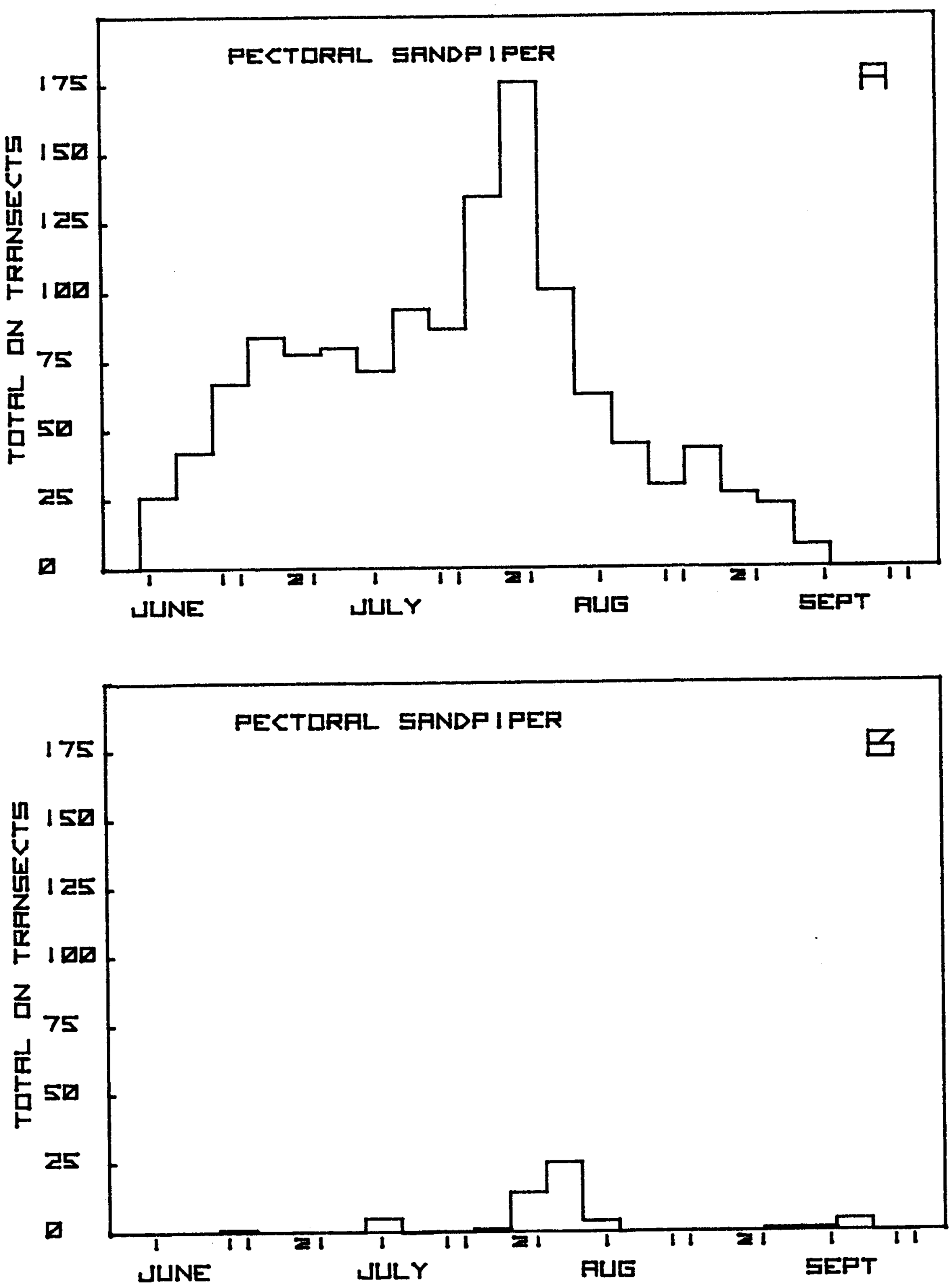


Figure 13. Seasonal population change. A. Tundra, total.

B. Littoral, total.

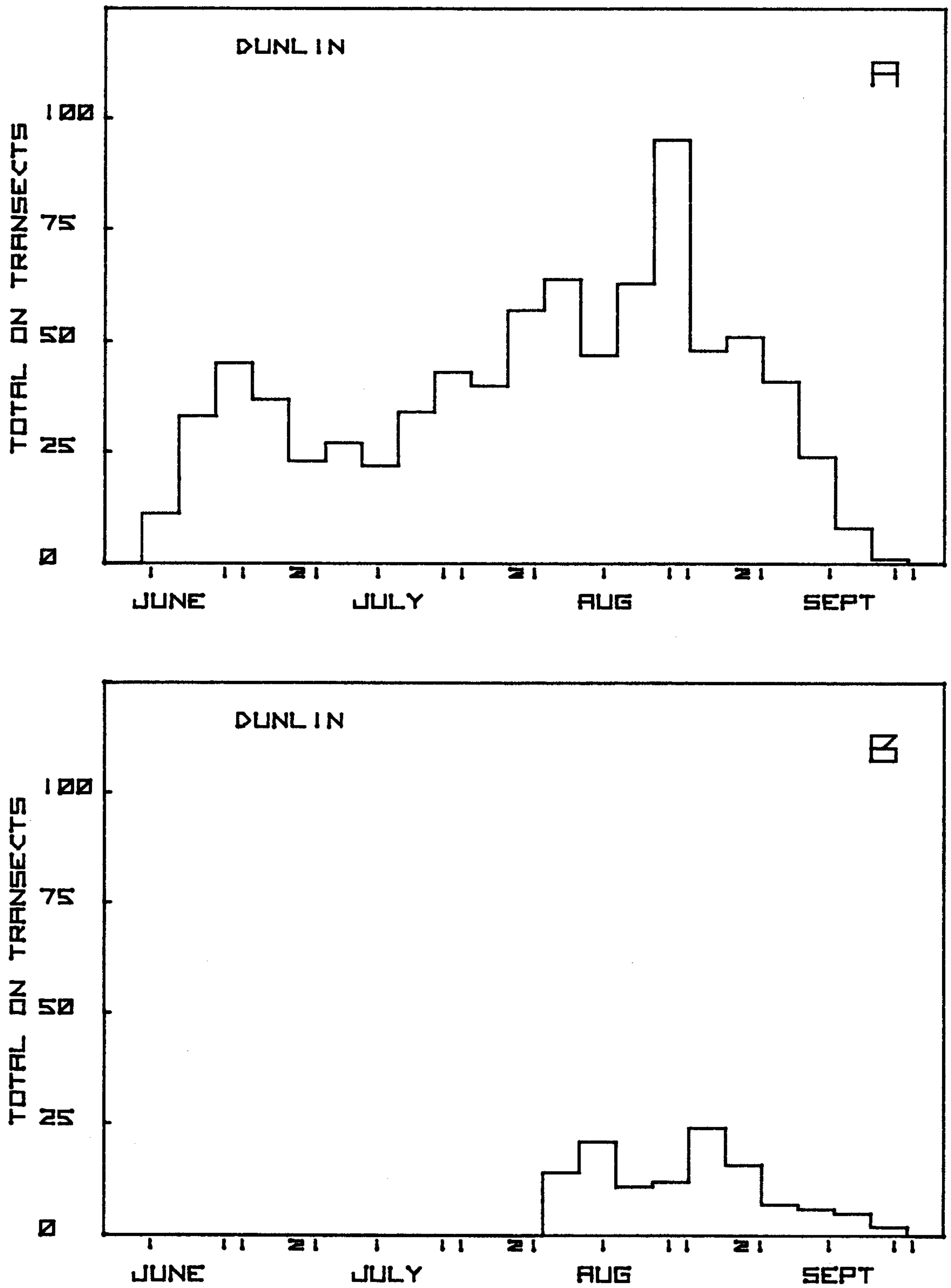


Figure 14. Seasonal population change. A. Tundra, adults.
B. Tundra, juveniles.

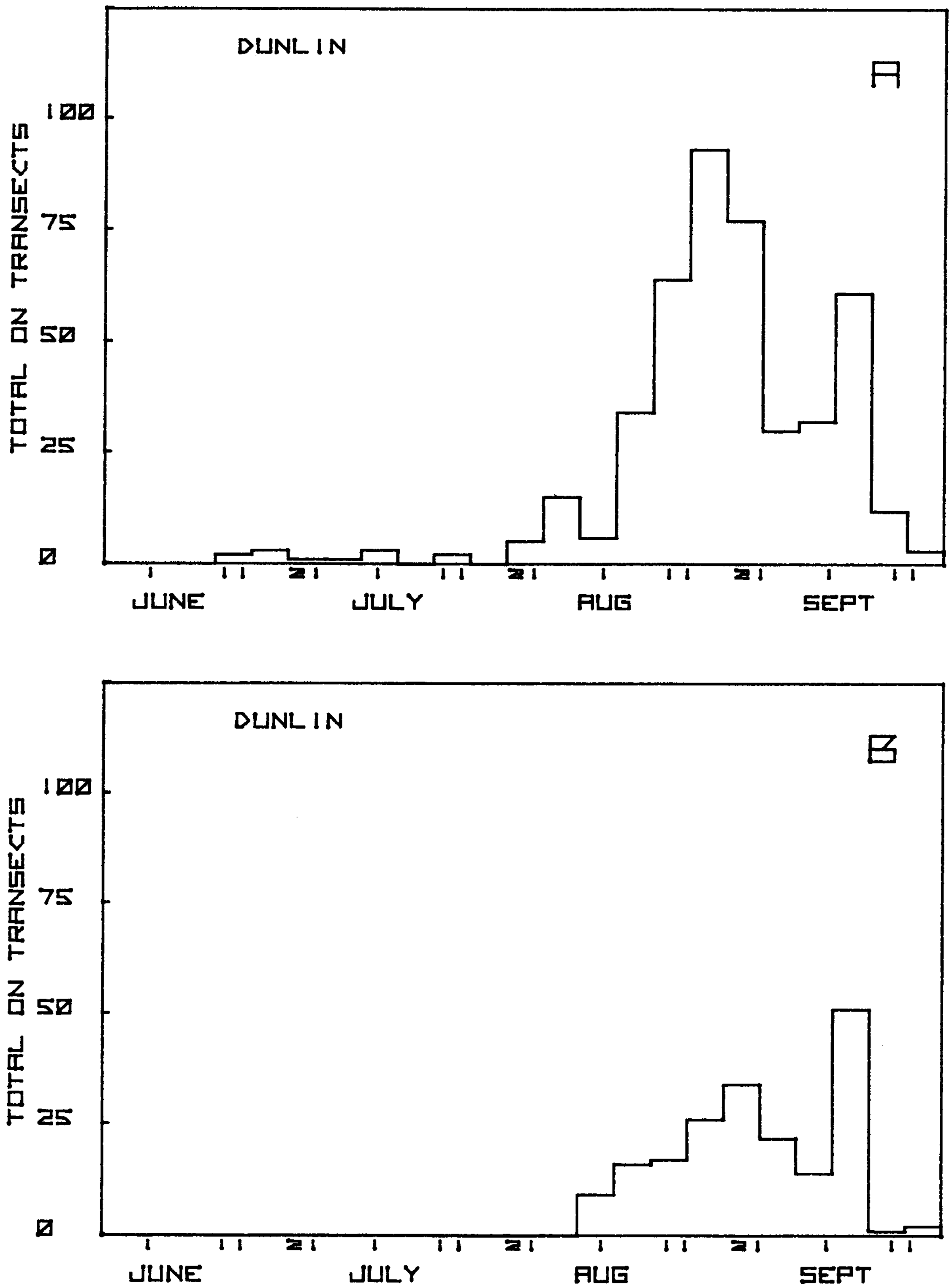


Figure 15. Seasonal population change. A. Littoral, adults.

B. Littoral, juveniles.

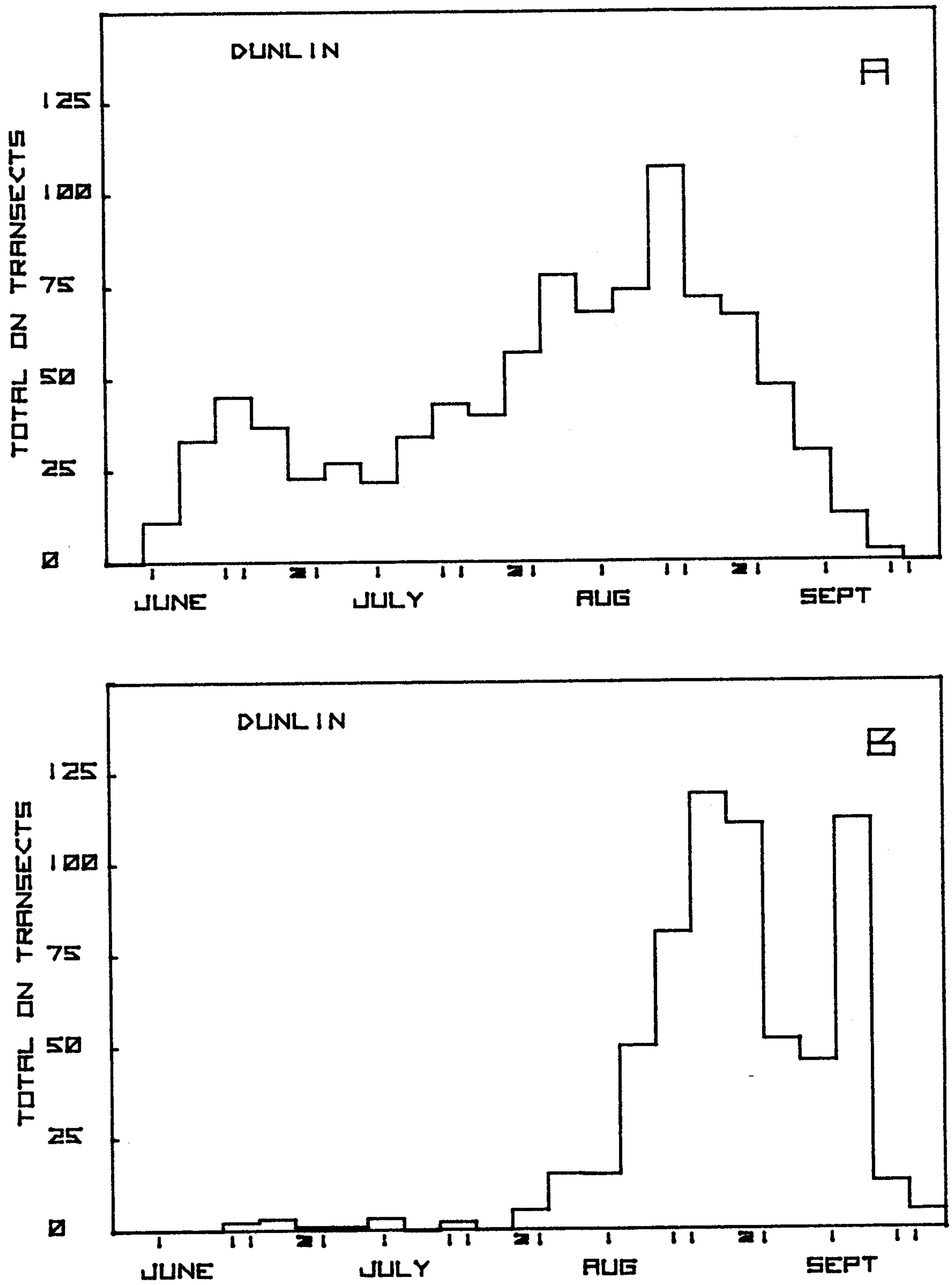
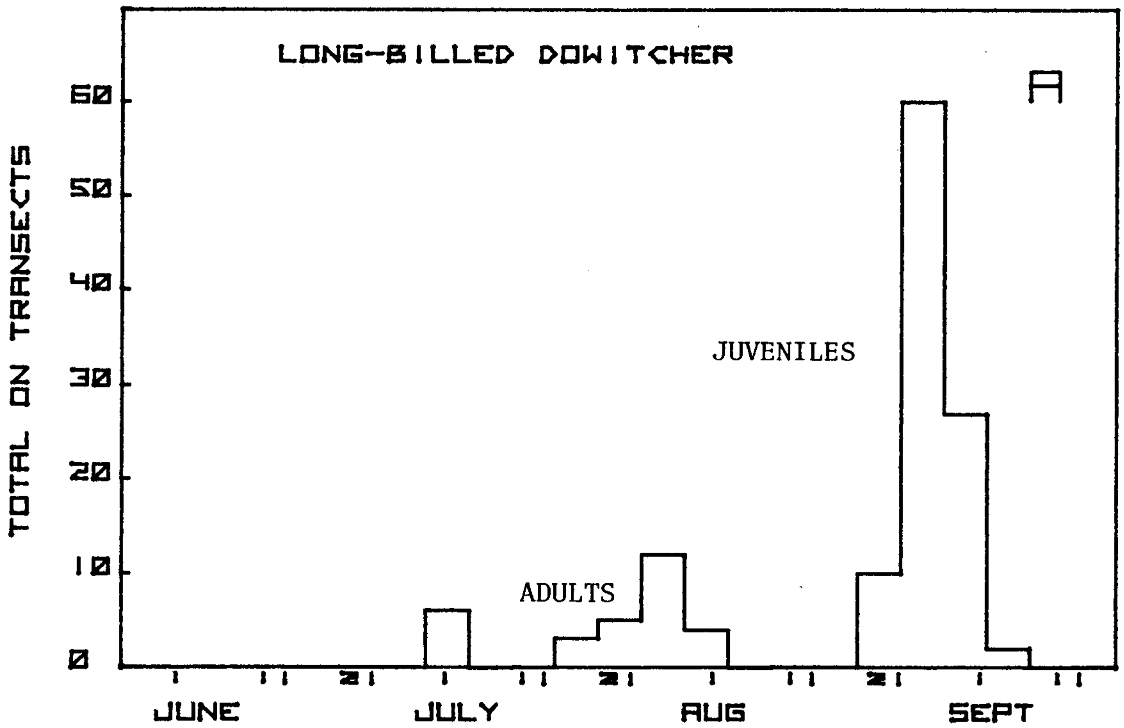


Figure 16. Seasonal population change. A. Tundra, total.
B. Littoral, total.



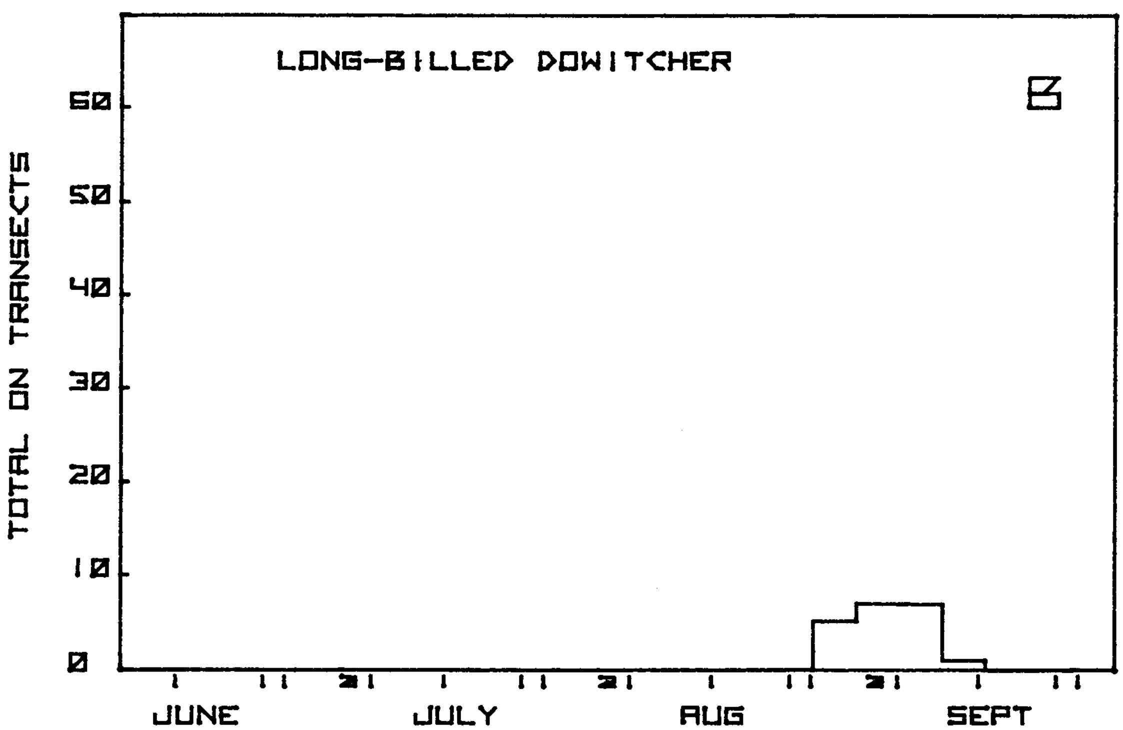


Figure 17. Seasonal population change. A. Tundra, adults and juveniles. B. Littoral, total (all juveniles).

Dowitcher movements differed considerably in 1976 from the 1975 pattern. Adults were seen occasionally on tundra transects and may have nested locally. The juvenile movement occurring in middle to late August was somewhat more extended in time in 1976 and did not reach the high density in littoral areas which had been recorded in 1975. Data from 1976 alone would have suggested that Long-billed Dowitchers in migration are almost restricted to tundra habitats. However, transect observations in 1975 and observations at Icy Cape in 1976 suggested that littoral zone use by these migrating juveniles can also be very important.

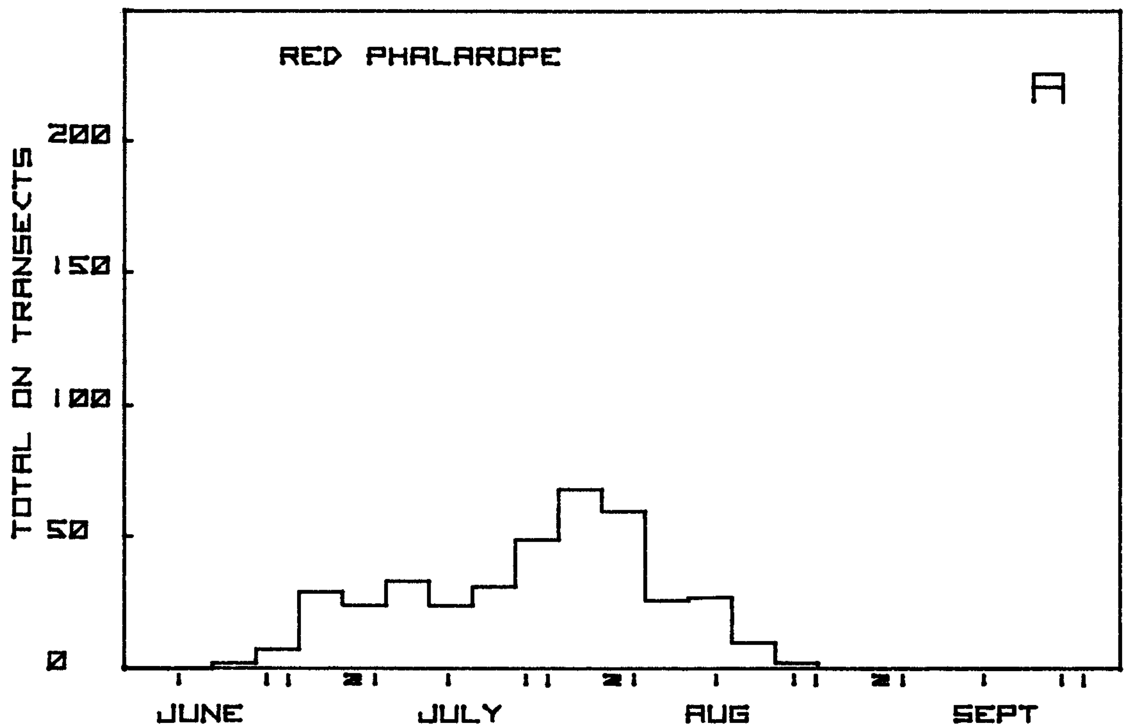
16. Hudsonian Godwit (Limosa haemastica). One individual seen in late August each year.

17. Bar-tailed Godwit (Limosa lapponica). A few individuals seen in 1975; none observed in 1976.

18. Red Phalarope (Phalaropus fulicarius). Figure 18, 19, 20, 21. This species was an extremely common nester at Barrow and the most abundant late season migrant in littoral habitats in both 1975 and 1976. Because of the extended late summer period of high density littoral zone use, we regarded the Red Phalarope as a key species in our understanding of the littoral zone ecosystem and in our evaluation of potential impact of oil-related development. Accordingly, we have given special emphasis to trophic studies, habitat use, behavior, and energetics of juvenile Red Phalaropes. These topics will be discussed in Section D and E of the Results.

Figure 18 shows the densities of Red Phalaropes in three age and sex classes on all tundra transects in 1976, clearly indicating the unusual social system of the phalaropes. Males and females increase in similar proportions in early June when nests are being set up and clutches completed. Soon after, females abandon the nesting effort and flock together on tundra near the coast before migrating southward. Densities of males incubating clutches remain fairly constant throughout June and early July. As nests fail or hatch, males are released from nesting duties and begin to flock before migration. Finally in late July and early August, fully fledged juveniles are encountered on transects and these gradually leave the tundra, moving to littoral areas before they migrate southward. The pattern of the same age and sex classes in littoral habitats (Figure 19) shows a striking contrast. Post-breeding female flocks do occur in littoral areas (brackish pools, principally), but this use is small compared to tundra populations at the same time. Adult males are rare in littoral habitats until fledging is complete when a sudden and fairly sharp peak of adult males occurs along the coast in littoral areas. In early August, fledged young move suddenly to the shoreline, building up to extremely high densities. Note that the juvenile peak densities are several-fold offscale. Figure 20 combines all three age and sex classes, comparing total use on littoral transects versus tundra transects. Activity is heaviest on tundra habitats from early June to July, shifting abruptly about August 1 to littoral areas and remaining in these habitats until phalaropes depart in about the middle of September.

These habitat use patterns were fairly consistent between the two



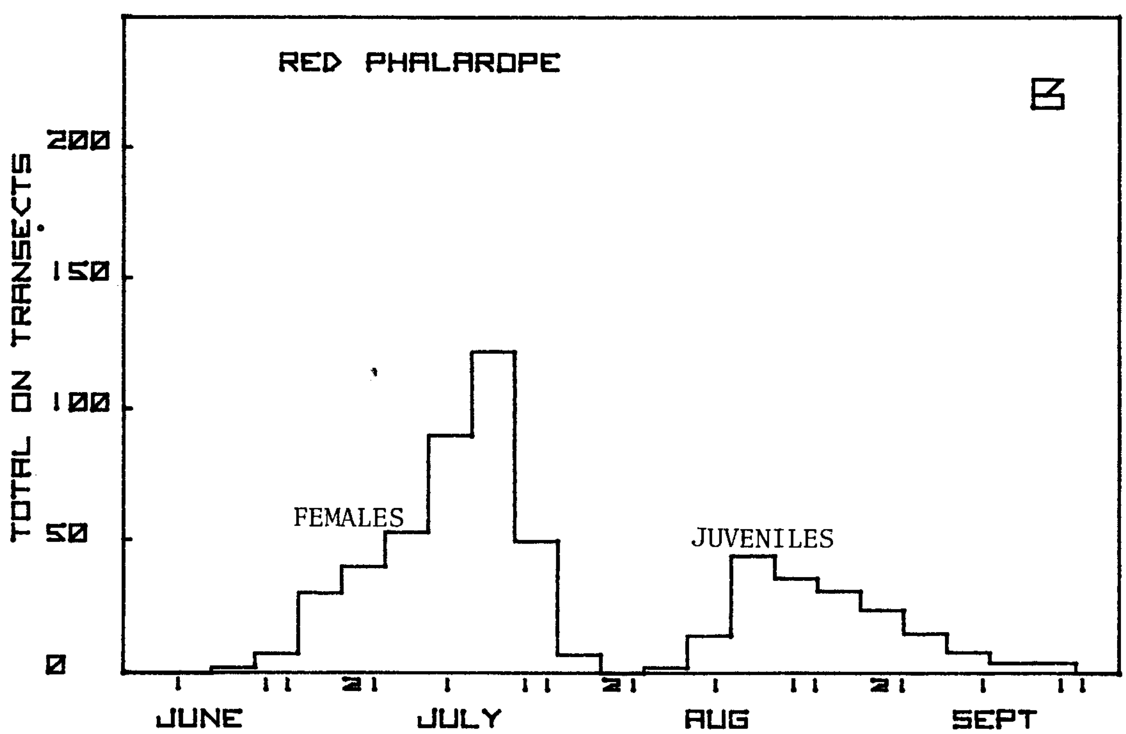
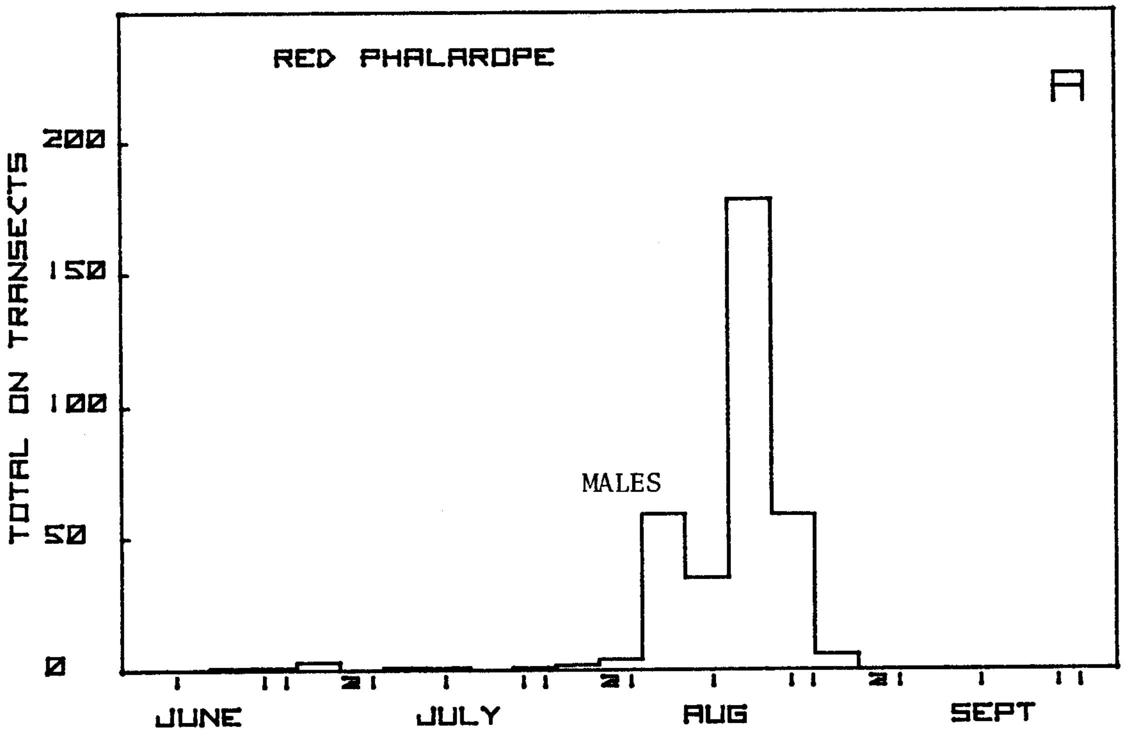


Figure 18. Seasonal population change. A. Tundra, adult males.

B. Tundra, adult females and juveniles.



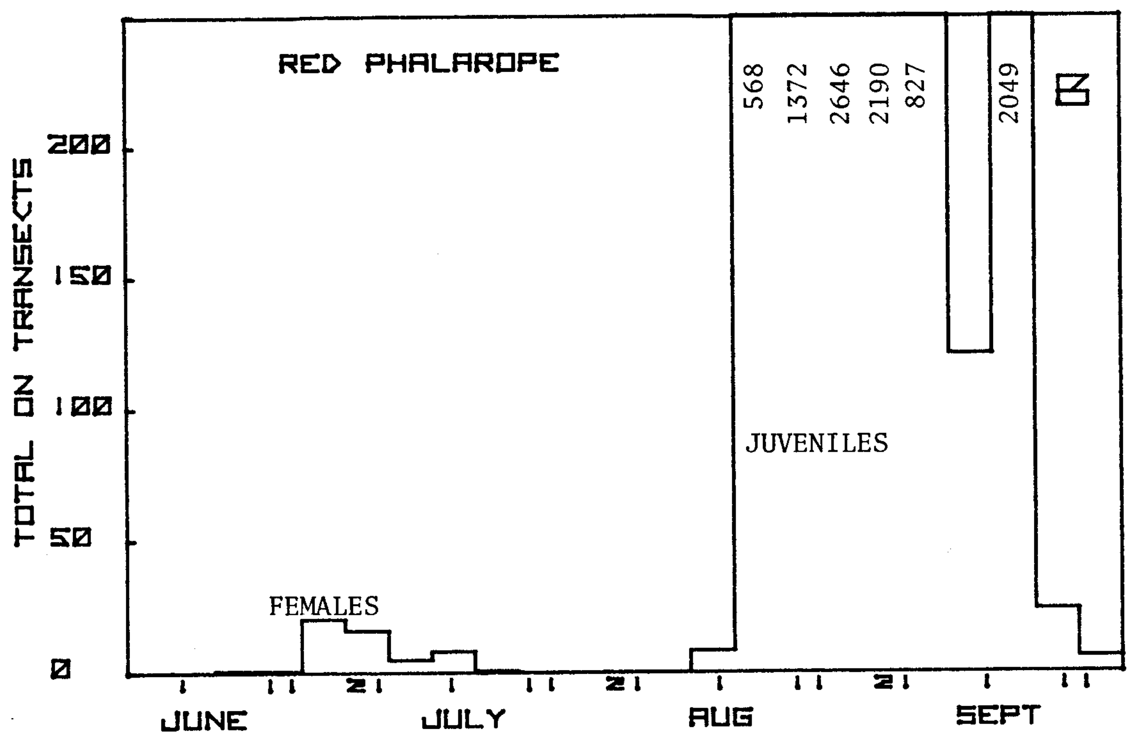


Figure 19. Seasonal population change. A. Littoral, adult males. B. Littoral, adult females and juveniles. Off-scale values are given.

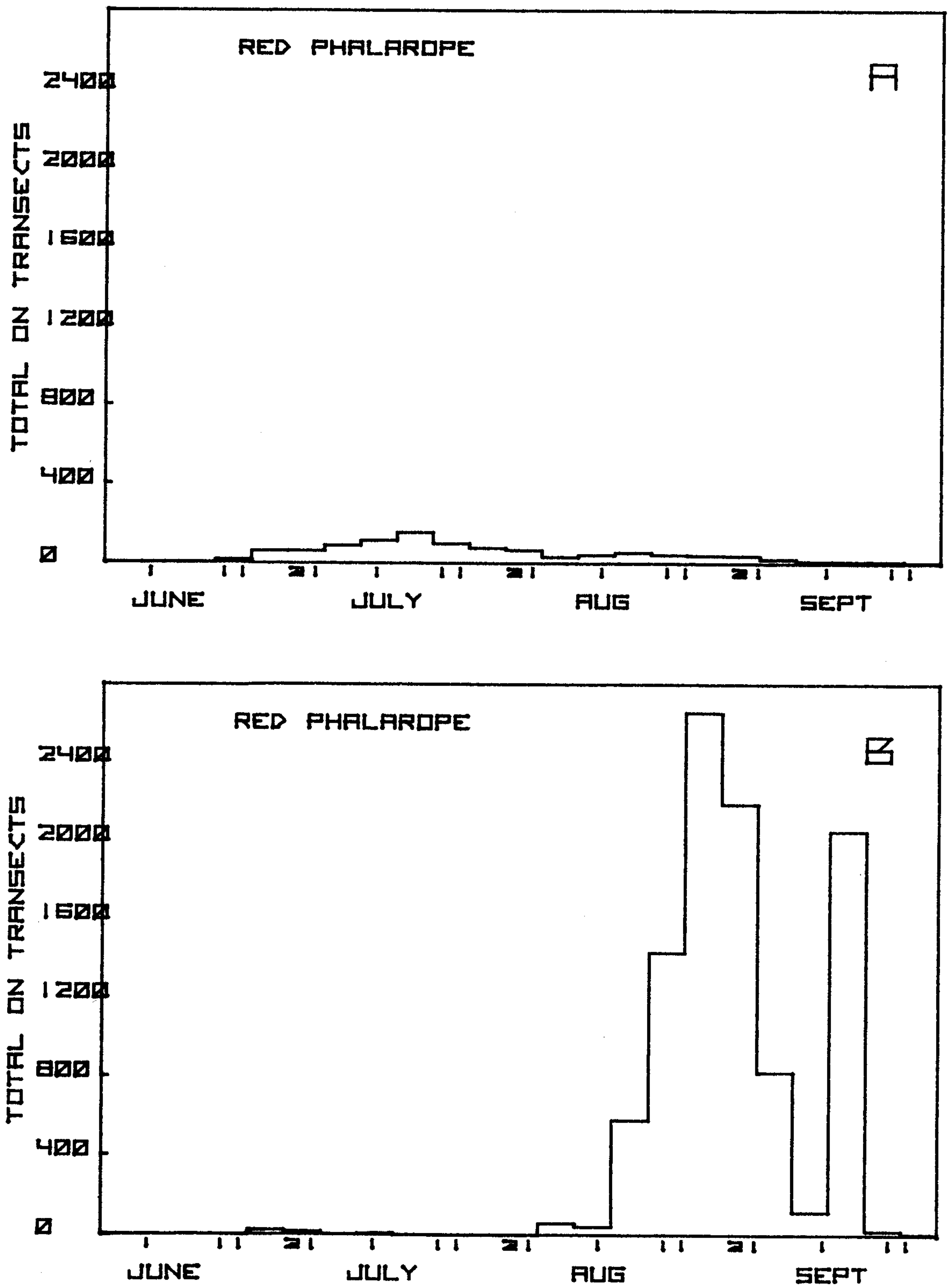


Figure 20. Seasonal population change. A. Tundra, total.
B. Littoral, total.

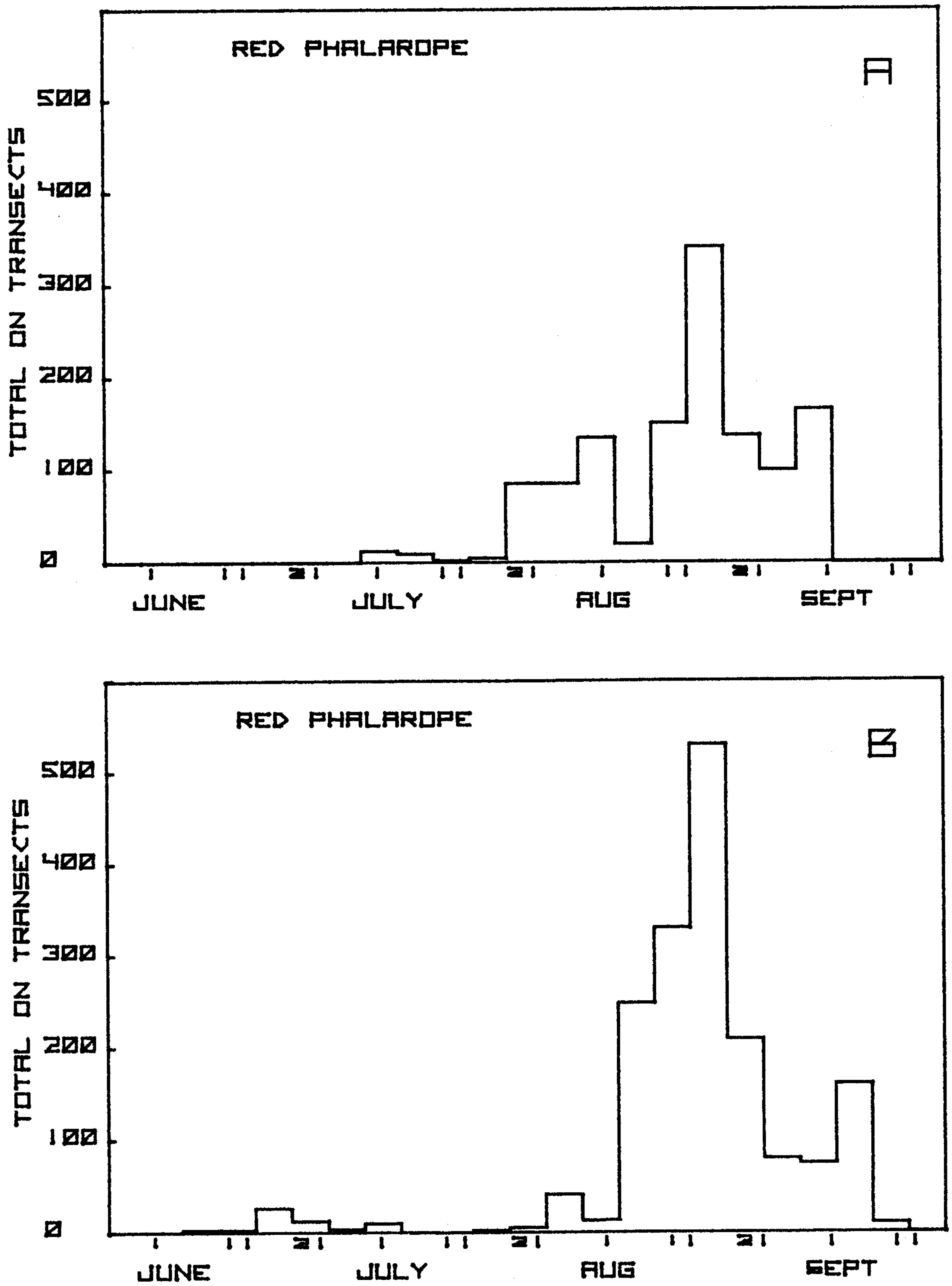


Figure 21. Seasonal population change. A. Littoral, 1975 transects. B. Littoral, same transects, 1976.

summers. Figure 21 shows a comparison of total phalarope densities on those littoral transects which were censused in both seasons (BS, WS, NSL-1,2, BP, VC, NB, CSN, CM, EL; several new transects were added in 1976 to increase our coverage of habitats within the study area). Patterns are similar, with higher cumulative populations in 1976. In late July, 1975, a much heavier movement of adult male Red Phalaropes occurred in littoral areas than in 1976; following this, the movement of juveniles into these areas occurred several days later in 1975 than in 1976.

Aerial censuses made during August by observers in this study and by observers of the ADF&G RU 3/4 indicate that this high density of juvenile Red Phalaropes foraging along the Barrow Spit area is repeated through much of the Plover Islands but occurs at reduced densities in most of the Barrier Island areas farther east in the Beaufort Sea. Mainland beaches, backed by eroding tundra banks, in general seem to have lower use than barrier islands and spits. In particular, densities on the Chukchi coast from Barrow to Peard Bay were very low throughout August. In the Seahorse Islands - Peard Bay Spit system, however, high densities comparable to Barrow Spit densities were observed by researchers in both projects. Red Phalaropes were not present on September 1 and 2, 1976 on Cape Krusenstern and at Wales.

19. Northern Phalarope (*Lobipes lobatus*). As in 1975, Northern Phalaropes were seen rarely at Barrow. However, Vermeer and Amweiler (1975) reported a very heavy migration of this species in August along the Yukon coast of the Beaufort Sea in western Canada, and ADF&G personnel (RU 3/4) reported high densities of juvenile Northern Phalaropes along the Chukchi coast near Cape Lisburne in August.

Other Species

On all shoreline transects non-shorebird species were also recorded, both within the 50 m plots and in a 200 m zone extending out from the shore. Population results for loons and waterfowl were consistent with the results presented in the first annual report (Connors and Risebrough, 1976) and will not be duplicated here. Populations of most of these species recorded on these nearshore transects do not truly represent seasonal movements of these species through the area, since open water conditions so overwhelmingly control whether these birds occur on or off the transect. Thus, peaks of Oldsquaw in early July do not represent the peak of the Oldsquaw movement through Barrow but merely a period during which any Oldsquaw present must be close to shore because of ice conditions. Census results for several species of larids which are more properly considered shoreline species are presented here, along with census results for two passerine species occurring commonly in some portions of the littoral zone.

20. Glaucous Gull (*Larus hyperboreus*). Figure 22A. The most common gull during most of the season at Barrow. J. P. Myers and R. Greenberg report this species probably breeding near Lake Ikaravik 8 km inland from Barrow. Almost all Glaucous Gulls in the area, however, are non-breeding or migrant

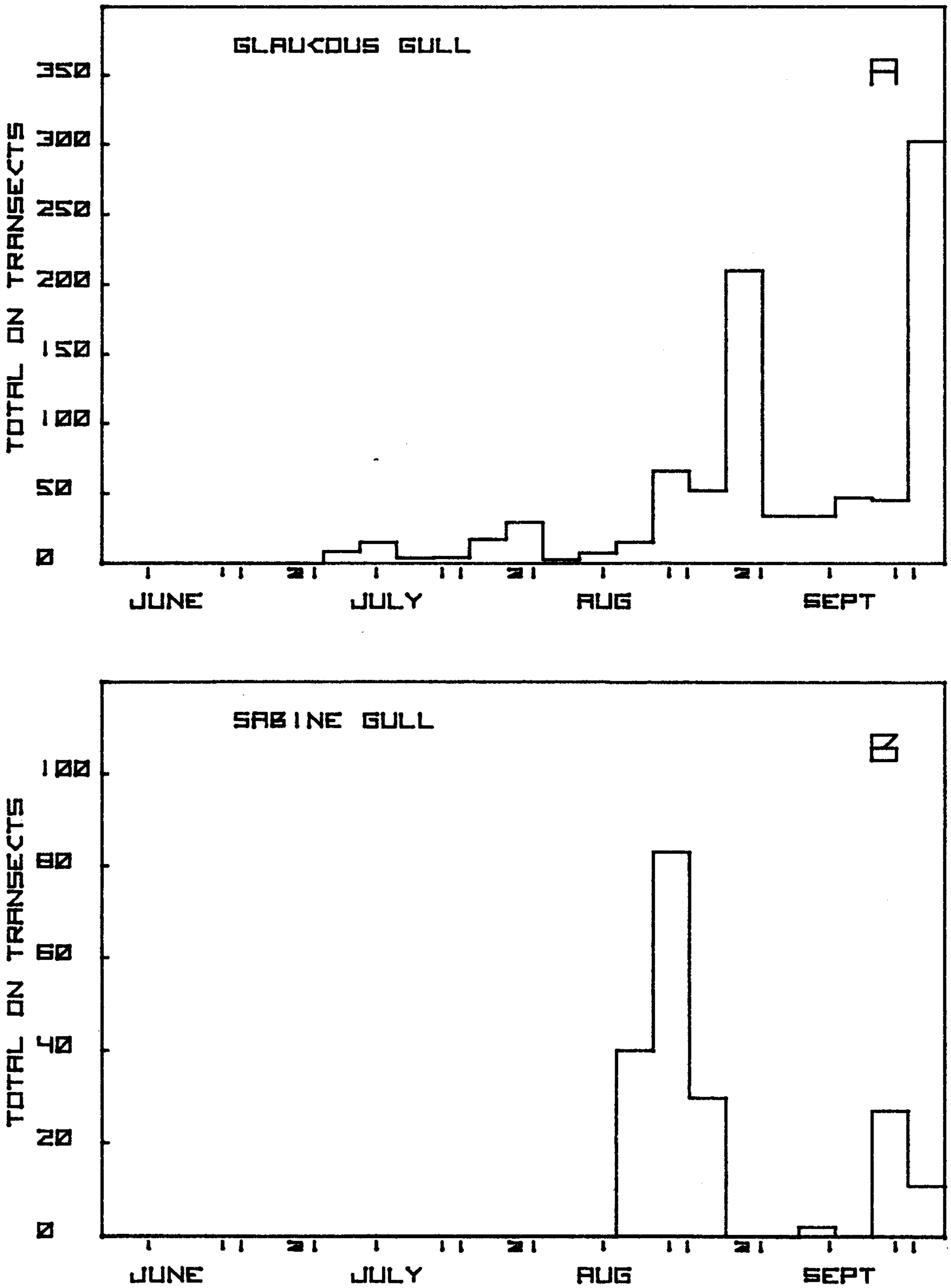


Figure 22. Seasonal population change. A. Glaucous Gull, littoral, total. B. Sabine Gull, littoral, total.

birds, mainly associated with the Barrow dump.

21. Sabine Gull (Xema sabini). Figure 22B. This species was very common in both years, with juveniles and adults foraging along gravel shores during August and early September.

22. Black-legged Kittiwake (Rissa tridactyla). Figure 23A. Less common during July 1976 than during the preceding July but irregularly present throughout August and September. This species does not nest east of Cape Lisburne in Alaska.

23. Ross' Gull (Rhodostethia rosea). A movement of juveniles and adults in mid-August of 1975 was not repeated in 1976. Large numbers of this species were reported in late September by ADF&G personnel (G. Divoky, pers. comm.).

Other gull species seen in littoral areas in small numbers included Herring Gull (Larus argentatus), Thayer's Gull (Larus thayeri), Mew Gull (Larus canus) and Ivory Gull (Pagophila eburnea).

24. Arctic Tern (Sterna paradisaea). Figure 23B. As in 1975, this species was sporadically present in very high numbers in the Barrow Spit area throughout the month of August. Peak concentrations were higher in 1976 than in 1975, however. Large numbers of Arctic Terns roosted on Barrow Spit in dense flocks on several days during August. This same condition was seen on the Seahorse Islands on 27-August 1976. Arctic Terns are an exception to most of the species studied in that the direction of August migration can often be readily observed. On several days in August almost all terns seen individually and in flocks were traveling west past Barrow Spit. Heavy movements in other directions were never observed.

25. Lapland Longspur (Calcarius lapponicus). Figure 24. This common tundra nesting passerine occurred in high densities on tundra transects throughout the breeding period, when it was rare in the littoral zone. In August, however, flocks of migrating birds, mostly juveniles, appear in areas of saline pools, lagoon edges, and saltmarsh flats. Two juveniles collected in these habitats had been feeding principally on seeds.

26. Snow Bunting (Plectrophenax nivalis). Figure 25. Throughout the breeding season, Snow Buntings nesting near brackish pool and saltmarsh flats and near gravel beaches forage in these littoral habitats, as well as on the tundra. During August migration, flocking activity is much heavier in littoral areas than on the tundra. Two birds collected near brackish pools had been eating seeds.

B. Trophic studies

Detailed results of all bird stomach analyses are presented in Appendix D. Total esophageal and stomach contents, by locality, date, species, number, size, and per cent of total prey mass, are shown next to either plankton or benthic samples, usually taken synchronously with the bird samples.

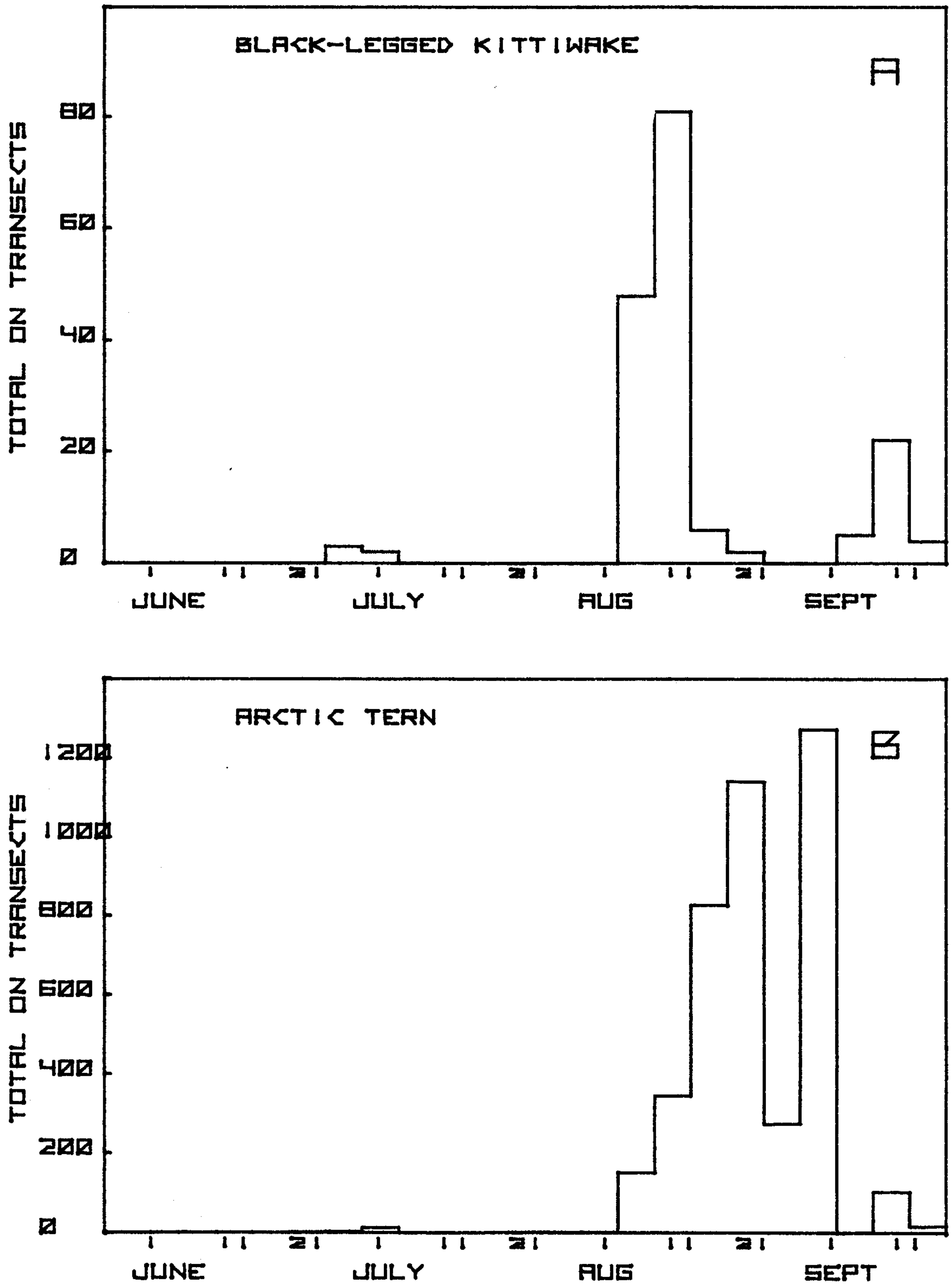


Figure 23. Seasonal population change. A. Black-legged Kittiwake, littoral, total. B. Arctic tern, littoral, total.

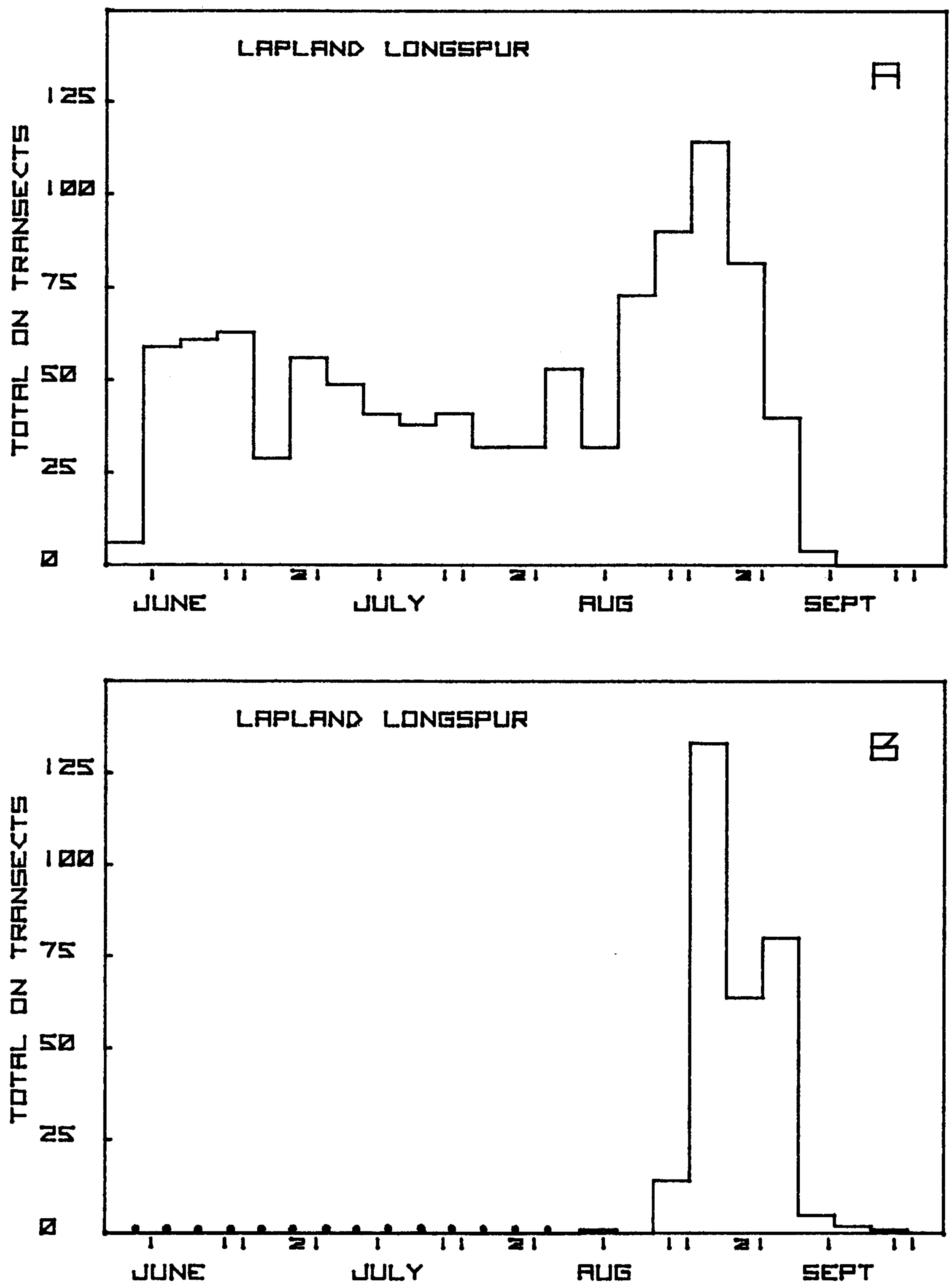


Figure 24. Seasonal population change. A. Tundra total. B. Littoral total. Dotted line prior to 28 July is approximate average.

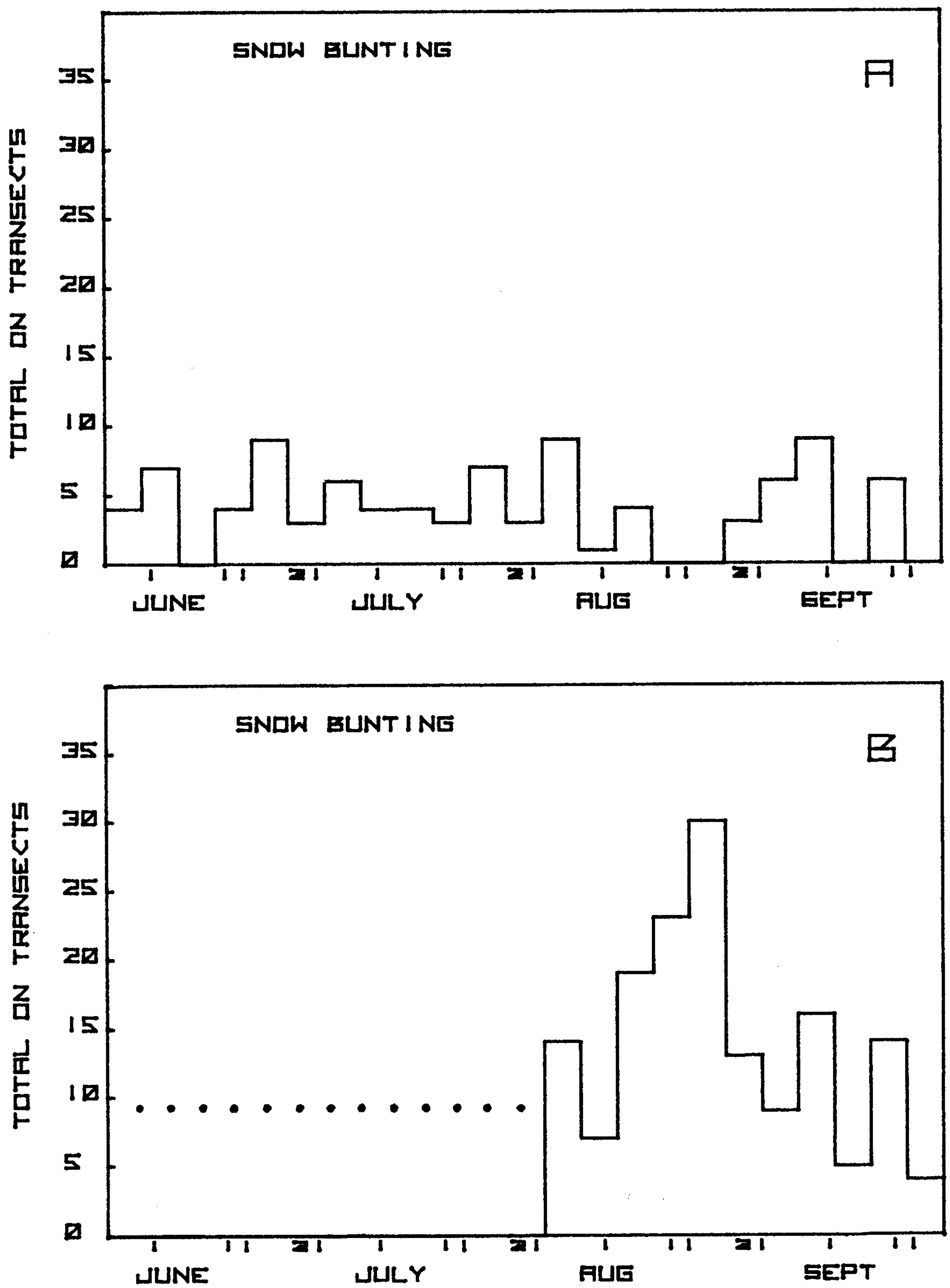


Figure 25. Seasonal population change. A. Tundra total. B. Littoral total. Dotted line prior to 28 July is approximate average.

A comparison of prey items taken by birds in two habitat types, ocean stations and closed lagoons/ brackish pools is shown in Table 3. At ocean stations, birds were generally taking common ocean plankters, including large crustaceans, chaetognaths, and pteropods. On inner shores in lagoons and pools of low salinity, birds depend on several insects (especially chironomid larvae), calanoid copopods, and oligochaetes. Similar categories of food sources were found in 1975. There is in general an excellent correspondence in lagoon and pool samples between prey items in stomach contents and the abundance of the same prey species in coincident benthic samples. Most birds feeding on chironomid larvae, oligochaetes, and copepods were taking these from areas where these prey items made up 90% or more of the fauna. A generally poor correspondence in ocean samples between prey species and organisms occurring in plankton samples are dealt with in individual species discussions below, but can often be attributed to individuals roosting or foraging in other habitats or localities just prior to collection.

Comparisons of prey taken between 1975 and 1976 are limited because of low sample sizes of most birds. For illustration, however, Table 4 compares the rates of occurrence of eight different zooplankton prey items as major components of the diet for samples of 8 Red Phalaropes foraging along ocean shores for each year. No large Calanus were taken by any bird in 1976, although it was an important component of 1975 diets. In 1976, Calanusoccurred at consistently low densities (Appendix D; Table 5). The under-ice amphipod Apherusa was taken in 1976, but by no birds in 1975; this is associated with variable grounded ice conditions. No pteropods were taken by birds in 1975, and were apparently rare in the nearshore plankton; three Red Phalaropes taken in 1976 had fed on Spiratella, making up trace amounts, 50%, and 90% of the contents, respectively.

As noted in 1975, several bird species within a habitat at the same time may be utilizing the same prey resource. Examples from shorebird stomach samples are shown in Table 6.

Plankton species taken at Barrow in 1976 are listed in Appendix E. Densities of plankton by station for the 8 species (five crustaceans, two molluscs, one chaetognath) of large size and of importance as bird prey items are shown in Table 7. Thirteen plankton samples are shown in detail in Appendix D in comparison to stomach contents.

Several difficulties encountered in sampling the very nearshore plankton populations may be mentioned. The extreme closeness of the net both to the shoreline and to the gravel bottom made it difficult, under certain wave and wind conditions, to keep the net off the bottom, or off the shore. Along-shore concentrations of large amounts of plant detrital material, feathers, and occasional blooms of the spinose diatom Chaetoceros, with associated mucus-gelatinous masses, at times severely hampered sample collection, aliquoting, and sorting. Finally, the slow towing of the net by hand may have led to a net-avoidance response by some plankters, such as Thysanoessa and Apherusa, but continual visual inspection of the area in front of the net suggests that net-avoidance responses in the low-density plankton of 1976 at Barrow were relatively unimportant.

Table 3. List of Prey Items in Two Habitat Types, Barrow, 1976.
(n) = number of birds

Ocean Stations	Closed Lagoons & Brackish Pools
Sanderling (8) *Thysanoessa raschii* *Apherusa glacialis* Decapod zoea Insecta: Chironomidae : Collembola Calanoid Copepods Seeds Total: 7 species	Sanderling (1) Insecta: Chironomidae : Collembola Seeds Western Sandpiper (1) Chironomidae
Baird Sandpiper (1) *Onisimus litoralis*	Red Phalarope (5) Calanoid copepods Chironomid larvae Seeds Blue-green algae
Red Phalarope (16) *Onisimus litoralis* *Apherusa glacialis* *Thysanoessa glacialis* Decapod zoea Insecta: Chironomidae Gammaridae, undet. sp. *Spiratella helicina* Seeds Polychaeta Total: 9 species	Dunlin (4) Chironomid larvae Oligochaeta Ruddy Turnstone (3) Insecta: Chironomidae : undet. sp. Oligochaeta
Dunlin (2) *Thysanoessa raschii*	Semipalmated Sandpiper (5) Insecta: Hymenoptera : Diptera, undet. sp. : Diptera: Chironomidae : Collembola Cyclopoid Copepoda Cladoceran ephippia
Ruddy Turnstone (3) *Thysanoessa raschii* Insecta, undet.sp. Pycnogonida Chironomidae Total: 4 species	Snow Bunting (2) Seeds Insecta, undet. sp. Lapland Longspur (2) Seeds Insecta: Chironomidae

Table 4. Food Items of Red Phalaropes at Ocean Stations, Barrow, 1976 vs. 1975.

(Number of birds with the indicated food item 25% or more by volume of the total stomach contents; based upon eight birds each year)

Plankton Species	1976	1975
Copepoda: *Calanus* sp. (>2 mm)	0	5*
Amphipoda: *Apherusa glacialis*	3	0
Onisimus litoralis	1	0
Decapoda: Zoea	2	3
Euphausiacea: *Thysanoessa raschii*	0	0**
Crustacea: fragments	1	0
Pteropoda: *Spiratella helicina*	2	0
Chaetognatha: *Sagitta elegans*	1	2

*Eight birds had *Calanus* as 10% or more of the total stomach contents.

**One bird each in 1975 and 1976 had *Thysanoessa* as 10% or more of the total stomach contents.

Table 5. Comparisons of Three Most Common Plankters: Barrow 1975 vs. 1976.

		Species (No./m^3)		
Date	Location*	*Sagitta elegans*	*Calanus* sp.	Decapod Zoea
1975				
15 August	EL	539	39 (all sizes)	77
19 August	CS	39	--	39
23 August	CS	1231	615 (all sizes)	1769
30 August	EL	469	169 (>2 mm)	--
31 August	EL	2192	162 (>2 mm)	--
Means:		894	197	377
1976 (15-30 August data only for comparison)**				
15 August		14	13 (3-29)	13 (6-19)
20 August		16	3 (2-3)	16 (3-37)
22 August		2	10 (6-14)	2
25 August		69 (8-130)	3 (2-5)	43 (3-130)
27 August		57	10	8
30 August		2	25 (6-46)	10 (6-18)
Means:		27	11	15

*on Barrow or Plover Spit: EL = Elson Lagoon side; CS = Chukchi Sea side.

**averages for all stations on Barrow and Plover Spits that date; numbers in parentheses are ranges if taken at more than one station. All *Calanus* shown in 1976 section are greater than 2 mm.

Table 6. Bird species utilizing the same prey resource at the same time and place.

Sample	Location	Date	Prey Item	Birds Feeding on Prey Item
30,31 33,34	BP	29 July 30 July	Chironomid larvae	Ruddy Turnstone Semipalmated Sandpiper
43,44	BD	1 August	*Onisimus litoralis*	Red Phalarope Baird Sandpiper
45-6, 47	NSL	3 August	Chironomid larvae	Dunlin Semipalmated Sandpiper
62,61	GF/CB pool	11 August	Oligochaeta	Ruddy Turnstone Dunlin
66,68	BSS	14 August	*Thysanoessa raschii*	Red Phalarope Ruddy Turnstone
79,80,81	WS	17 August	*Thysanoessa raschii*	Sanderling Dunlin Ruddy Turnstone

Table 7A. Plankton Densities (no./m^3) on Barrow and Plover Spits, by Station, 1976.

Sample No.	Date	Species: *Thysanoessa raschii*	Decapod Zoea	*Apherusa glacialis*	*Onisimus litoralis*	*Sagitta elegans*	*Clione limacinea*	*Spiratella helicina*	*Calanus* (>3 mm)
PLOVER SPIT									
10	21 July								
53	10 August		1.6	5		14			21
70	15 August					14			8
89	20 August		8						3
97	22 August					1.6			9.5
106	25 August		32			8		3	5
112	28 August					57			
115	30 August		8						24
130	4 September		54						
BEAUFORT SEA STATION									
56	10 August		5			35		3	9.5
71	15 August		6.3						3.2
90	20 August		37		1.6	16		3	1.6
98	22 August							1.6	
107	25 August		3						1.6
113	28 August				1.6				
116	30 August		17.5			1.6		3	6.4
131	4 September	2.7	292	6.3		6	154	5	5
BARROW SPIT									
7	20 July								
40	31 July								8.7
58	10 August		15			22		4	81.7
72	15 August								29
92	20 August		3						3
95	22 August			3					
108	25 August		130			130			

Table 7A, continued

Sample No.	Date	Species: *Thysanoessa raschii*	Decapod Zoea	*Apherusa glacialis*	*Onisimus litoralis*	*Sagitta elegans*	*Clione limacinea*	*Spiratella helicina*	*Calanus* (>3 mm)
111	27 August		8.7						
117	30 August		10		1.6				
132	4 September		5	8			3	1.6	
WHALEBONE SPIT									
12	21 July								
39	31 July	2.5			2.1				
51	10 August		73			48		1.6	
69	15 August	1.6	19				6		
87	20 August	3			1.6				
96	22 August		1.6						14
105	25 August	6	5						1.6
110	27 August								9.5
114	30 August		6						46
129	4 September	5				9.5			

Table 7B. Plankton Densities (no./m^3), Other Localities, 1976.

		Species							
Sample No.	Date	Thysanoessa raschii	Decapod Zoea	Apherusa glacialis	Onisimus litoralis	Sagitta elegans	Clione limacina	Spiratella helicina	Calanus (3 mm+)
Location:	NB								
16	23 July	17	.5			14			
Location:	CSS								
17	23 July	2.5	3.7		1.6	6			6
Location:	AT								
27	28 July	.5	1.5	1.6		5		1	
Location:	BD								
43	1 August		1.6		58	.8			.8
Location:	WB								
64	12 August	11	.5			4			
Location:	WB								
100	23 August	1.6	3			55			28

The most common large plankters at Barrow in August-September 1976 were the chaetognath Sagitta, the copepod Calanus sp. (large species over 2 mm), and decapod zoea. Small species, such as barnacle cyprids and copepods, were occasionally common to abundant on all transects. Barnacle cyprids, for example, sporadically reached densities as high as 2,867 and 1,965 per cubic meters, but none were found in bird stomachs in 1976.

Comparison of plankton collected in 1975 with that collected in 1976 indicates extreme variation. Some species present in 1976, such as Spiratella and Clione, were not collected in 1975. More striking are the differences in densities, shown for three species in Table 5. The average 1975 density of Sagitta, Calanus, and zoea is 25 x that of the 1976 density. Several contrasts in species of plankton taken by foraging Red Phalaropes in 1976 are evident also.

Redburn (1974) studied the zooplankton community one to four km offshore of the Barrow area from May to August, 1972. He found statistically significant temporal changes in plankton populations, associated with the summer intrusion of Bering Sea water into the area. Redburn found very low numbers of chaetognaths (Sagitta elegans) (less than $1/m^3$) and decapod zoea ("extremely low quantities") in open water from mid-July through August, although numbers of each under the ice were higher in May and June. One Calanus species, Calanus glacialis, occurred in densities of only $.23/m^3$ between August 11-17. The different location of Redburn's study, different sampling methods, and the different dates make the usefulness of detailed comparisons between his data and ours limited. It is interesting to note, however, that these offshore concentrations of major bird prey species were on the order of 1/10 to 1/1000 the densities we measured in 1975 and 1976 along the shores where most Red Phalaropes, Sabine Gulls and Arctic Terns foraged.

Variation in plankton densities at small distances from the shoreline was not examined extensively, although tows both at Nunavak Bay and Whalebone Bight indicate that such organisms as Thysanoessa and Sagitta may be denser closer to shore. At Nunavak Bay (sample 16, 23 July) Thysanoessa occurred at $32/m^3$ within .3 meter of shore, but dropped to $11/m^3$ and $10/m^3$ 2 and 4 meters from shore, respectively. Sagitta occurred at $10/m^3$ within .3 meter of shore, and $8/m^3$ and $16/m^3$, 2 and 4 meters from shore, respectively. At Whalebone Bight (sample 64, 12 August) Thysanoessa occurred at $30/m^3$ within 1 meter of shore and was absent in samples 2 and 3 meters from shore.

Only one large plankton "die-off" was noted during the sampling season. On August 7, windrows of Thysanoessa raschii were washed ashore in Whalebone Bight; Ruddy Turnstones, Western Sandpipers, Sanderlings, Dunlins, Red Phalaropes, and Glaucous Gulls were feeding on these. Much smaller euphausiid "die-offs" were noted at other times. Another heavy die-off was reported in this area in late September (G. Divoky, pers. comm.). Despite the numbers of euphausiids at Whalebone Bight on August 7, Thysanoessa occurred in densities of only $11/m^3$ here on August 12.

Plankton composition in the closed lagoons is distinct in diversity and composition from that of the ocean shores. Fewer species occur in

Middle Salt Lagoon (MSL); copepods of several species reach peak densities of more than 116,000/m^3 (Table 8). Other organisms in MSL included larval and adult insects and cladoceran ephippia. MSL (and other closed lagoons in the NARL area) remains brackish throughout the summer (Table 9). Copepod densities at MSW reached their peak in mid-August, declining thereafter, while at MSE a peak was reached in late August after rising steadily since July.

Size Selectivity

Birds collected at ocean stations and in closed lagoons and brackish pools show a tendency to prey on the larger species of organisms present. Our data do not indicate any selectivity for larger size individuals within a particular species of prey, however. At ocean stations, Red Phalaropes select species which are relatively large and conspicuous, such as purple pteropods (*Spiratella*), small yellow-brown amphipods (*Onisimus*, *Apherusa*), euphausiids (*Thysanoessa*), chaetognaths (*Sagitta*), and decapod zoea. These are apparently taken preferentially over the smaller barnacle cyprids, and calanoid, harpacticoid, and cyclopoid copepods, which often occur in the plankton at densities considerably greater than the larger species. Similarly, a Baird Sandpiper was selecting the larger *Onisimus* (5 mm) over the denser, one mm barnacle cyprids and cyclopoid copepods (sample no. 44). In closed lagoons and brackish pools, birds select the larger chironomids and oligochaetes over the much smaller cladoceran ephippia, ostracods, tardigrades, nematodes, and the like (see Appendix D: for example, diets of lagoon- or pool-feeding Ruddy Turnstones, Dunlins, and Semipalmated Sandpipers *versus* potential food items available in the infauna).

In summary: Red Phalaropes feed on emerging dipterans near lagoons and brackish pools in late July. In August and September, brackish and marine zooplankton comprise the major food source. Along gravel shores, Ruddy Turnstones, Sanderlings, and some Dunlins, Red Knots, Baird Sandpipers, and Western Sandpipers forage at the water's edge, apparently all utilizing the same supply of live and dead large zooplankton washed up on shore. Ruddy Turnstones, Dunlins, Western Sandpipers, Semipalmated Sandpipers, and Baird Sandpipers also forage on saltmarsh and mudflats, brackish pool margins and closed lagoon edges, taking brackish water copepods, oligochaetes, and chironomid larvae and adults.

Table 10 indicates the contents of regurgitation pellets of Glaucous Gulls (*Larus hyperboreus*) at Barrow and at Icy Cape. Most of the Barrow pellets consist of molluscs, including three species of bivalves and four or more species of gastropods.

C. Foraging microhabitat preferences

Table 11 lists the sample sizes of foraging microhabitats obtained for each of nine shorebird species. Data were obtained during the two month period (mid-July to mid-September) when shorebirds foraged commonly in the Barrow littoral zone. Most points for a given species were gathered during its period of peak abundance along our transects.

Table 8. Copepod densities (no./m^3) in MSL, Barrow, 1976.

Sample No.	Date	MSW	MSE
19/20	25 July	720	4394
49	6 August	no sample	7437
76/78	16 August	116,388	8695
103/104	25 August	87,111	10,476
133	5 September	4143	no sample

Table 9. Salinities ($^{o}/oo$) near Barrow, 1976.

Date	BSS	PS	Stations CB/GF	WS	BS
(A) Barrow and Plover Spits					
20 July					3
21 July	(TW: 5)	5	CB:2	4.5	
31 July	(DM: 4)	29		4.5	
10 August	(DM: 30)	27	GF:15/CB:28	29	32
15 August	28	25		25	34
20 August	34	25		24	34
22 August	32	32		32	32
25 August	31	30		31	34

Date	AP	NSL	EL	CMS	MSE	MSW	VC	BP	BD
(B) NARL									
22 July		8			5	5		2	
25 July						5			
28 July	33			5					
30 July							7		
1 August									30
3 August		9							
6 August			31	28					
10 August	30	10	28	30	10	10	9	4	
15 August									34
21 August		10			12	15	10	4	
22 August			29	25					
25 August					12	12			

Date	NB	CSS
(C) Nunavak Bay Area		
23 July	30	20(surface)/23(22 cm below surface)
15 August	35	34
22 August	34	33

(Tap Water, NARL: 9 August: .5; 22 August: 1.0)

Table 10. Contents of Glaucous Gull Regurgitation Pellets at Barrow and Icy Cape, 1976.

Sample	Loc.	Date	Composition
2 (one pellet)	PS	19 June	Bivalvia: numerous clam fragments, 6 mm each average, some with periostracum intact; also a few pebbles and dried mud
5 (three pellets, combined)	PS	6 July	As above
8 (one entire, one partial pellet)	BS	20 July	Bivalvia: larger fragments than preceding,possibly of Mya; also mud
13 (three pellets)	CB	21 July	Gastropoda: Tachyrynchus reticulatum (5 mm max) : Cylichna occulta (5-6 mm) : neogastropod, undet. sp. (4 mm) : undet. sp. (frag.) : opercula, not of any of above (4 mm) Bivalvia: Astarte sp. (frags.) Liocyma fluctuosa (All with same silt, pebbles and miscellaneous detritus)
59 (numerous fresh pellets)	WB	7 Aug	Euphausiacea: Thysanoessa raschii (Taken from windrows washed ashore)
-- (two pellets)	Icy Cape	29 Aug	Isopoda: Saduria (=Mesidotea) entomon (Whole and fragments)

Table 11: Species studied in microhabitat analysis

Species	Sample Size	Mean Factor Scores I	II	III
Baird Sandpiper	60	-.2673	-.4827	-.0150
Semipalmated Sandpiper	84	-.5089	-.2508	-.2313
Pectoral Sandpiper	120	.1228	-.7986	.0994
Dunlin	316	-.1093	-.1496	.0640
Red Phalarope	224	.7612	.3416	-.0763
Western Sandpiper	66	-.2047	-.4463	.0334
Sanderling	154	-.3049	.7076	.0910
Ruddy Turnstone	146	-.4376	.4878	-.1752
Long-billed Dowitcher	40	.8894	-1.0059	.4240

The factor analysis of these data revealed three major gradients, summarized in Table 12. The first factor defines a habitat gradient running from upland tundra (negative values) out past the water line into deeper water. This can be inferred from the loadings of two variables: DEPTH correlated strongly with Factor 1 in the positive direction; points recorded in deep water will therefore fall far to the right of the origin. WATERDS correlated strongly in the negative direction; points with high WATERDS values, i.e. those far above the water line, will therefore appear to the left of the origin, while those recorded in the water will weight toward the right.

Factor 2 defines an axis of variation due to changing particle size. Three variables are correlated with this factor: GRNSIZE, DISTALG, and BILLPEN. The positive correlation of GRNSIZE with Factor 2 indicates that particle sizes are increasing along Factor 2, while the negative correlations of DISTALG and BILLPEN suggest that in areas of decreased particle size, foraging sites are closer to algae (i.e. there is more algae in the area) and bill penetrations are deeper.

The third gradient, defined by Factor 3, concerns variation in vegetation: DISTVEG weights positively on FACTOR 3, indicating that distances from the foraging point to vascular plants increase along the defined gradient. DISTALG also is affected, weighting positively, suggesting that along this axis vascular and algal vegetation characteristics vary together. Species responses to these environmental gradients are summarized in Table 11, Table 13, and Figures 26-30: In Table 1 are listed mean factor scores of each species along each of the gradients: Red Phalaropes, for example, have an average score along Factor 1 of .76, indicating that they forage in relatively deep water. The most terrestrial of all the species ordinated here is the Semipalmated Sandpiper, with an average factor score of -.51. The relative position of each species along the gradient is shown in Table 13: here they are ranked on each factor from large positive scores on top to negative scores below. The trend just discussed with respect to Red Phalaropes and Semipalmated Sandpipers is clearly summarized. The lines to the left of each ranking show groups of species defined along each gradient using a Tukey B a posteriori multiple comparison test: each line brackets a set of species whose mean values are not significantly different at the .05 level. Thus, Semipalmated Sandpiper through Western Sandpiper species are not significantly different in their response to Factor 1, but this group of species does contrast with Red Phalaropes and Long-billed Dowitchers. Dunlins, while differing significantly from Semipalmated Sandpipers and Ruddy Turnstones, cannot be separated from other species similar to these latter two, i.e. Sanderlings, Baird Sandpipers, and Western Sandpipers.

Rankings along the second factor suggest three groups of species in terms of their response to grain size: Long-billed Dowitchers and Pectoral Sandpipers forage in areas where particle sizes are very small, in muddy substrates where they can probe deeply (i.e. large values of BILLPEN). In contrast, Red Phalaropes through Sanderlings use areas characterized by high values along this gradient. Baird, Western, and Semipalmated Sandpipers, as well as Dunlin, forage in intermediate microhabitats.

Table 12. Factor Loadings

Variable	Factor Loading		
	Factor I	Factor II	Factor III
WATERDS	-.66622	-.09974	-.11923
DEPTH	.78203	.12067	-.10426
GRNSIZE	.05388	.68313	-.05089
DISTALG	.10693	.45897	.29452
DISTVEG	.01696	.01371	.40823
BILLPEN	.36292	-.29126	.15853

Table 13: Species' Rankings along Habitat Gradients

Factor I.	Factor II.	Factor III.
Long-billed Dowitcher	Sanderling	Long-billed Dowitcher
Red Phalarope	Ruddy Turnstone	Pectoral Sandpiper
Pectoral Sandpiper	Red Phalarope	Sanderling
Dunlin	Dunlin	Dunlin
Western Sandpiper	Semipalmated Sandpiper	Western Sandpiper
Baird Sandpiper	Western Sandpiper	Baird Sandpiper
Sanderling	Baird Sandpiper	Red Phalarope
Ruddy Turnstone	Pectoral Sandpiper	Ruddy Turnstone
Semipalmated Sandpiper	Long-billed Dowitcher	Semipalmated Sandpiper

Figures 26-30 convey these patterns graphically in terms of the frequency of occurrence of each species in different areas of habitat space. Each drawing is a contour map, with the height of the surface implied by the contour line reflecting the intensity of use of a region of habitat space by the species. Contour lines are drawn at .075 intervals, beginning at 0. Thus, outside the outermost line of each figure, no observations were obtained for the species in question.

At first, one is struck by the overall similarity between the species' habitat use patterns. Most notable is the strong peak evident in many species around (0,0) - the water line along the X dimension. This peak is especially pronounced in Western, Semipalmated, and Baird Sandpipers. In contrast, several species obviously forage in deeper water. These include Red Phalaropes, Long-billed Dowitchers, and Pectoral Sandpipers. Dunlins also range into this microhabitat, though they also forage in microhabitats more similar to that of the first group.

Along Factor 2, Ruddy Turnstones, Sanderlings, and Red Phalaropes all show a pronounced bias toward higher values, as was indicated in Table 13. But it is also apparent that other species, particularly Dunlins and to a lesser extent, Semipalmated Sandpipers, and Baird Sandpipers range into similar microhabitats, i.e. large grain size, where they forage without deep bill penetration.

We have yet to explore seasonal variation in these patterns. Our qualitative impressions of the phenology of habitat use suggest that several species do change microhabitat foraging preferences along the littoral zone through the post-breeding period. This is to be expected: first, microhabitat conditions change markedly with the breakup of sea ice and onset of wave action. These induce other physical changes, such as altered salinities, and are accompanied by changes in the abundance and availability of prey items. Second, as shown in Results VII.A, as the season progresses, different sex and age classes of each species move through littoral habitats. Changes in microhabitat preference may result from either of these phenological patterns, or from an interaction between them. Our data will yield a description of such changes.

The significance of these results for assessing species' susceptibilities to oil-related damage lies in the probability that a species' preferred microhabitat will be affected by oil spillage, either directly through the presence of oil, or indirectly through detrimental effects on the food chain. Our quantification of microhabitat use provides one essential data set for this assessment; the problem of how likely different microhabitats are to be affected, and the magnitude and the duration of such effects, however, are questions of multidisciplinary scope which will require considerable integration of the results from several OCSEAP research programs. Nonetheless, we offer the following educated guesses as a first attempt at interpreting the importance of these microhabitat patterns:

First, we assume that preferred microhabitats below the water line are more susceptible than those above, at least to damage from oil spillage

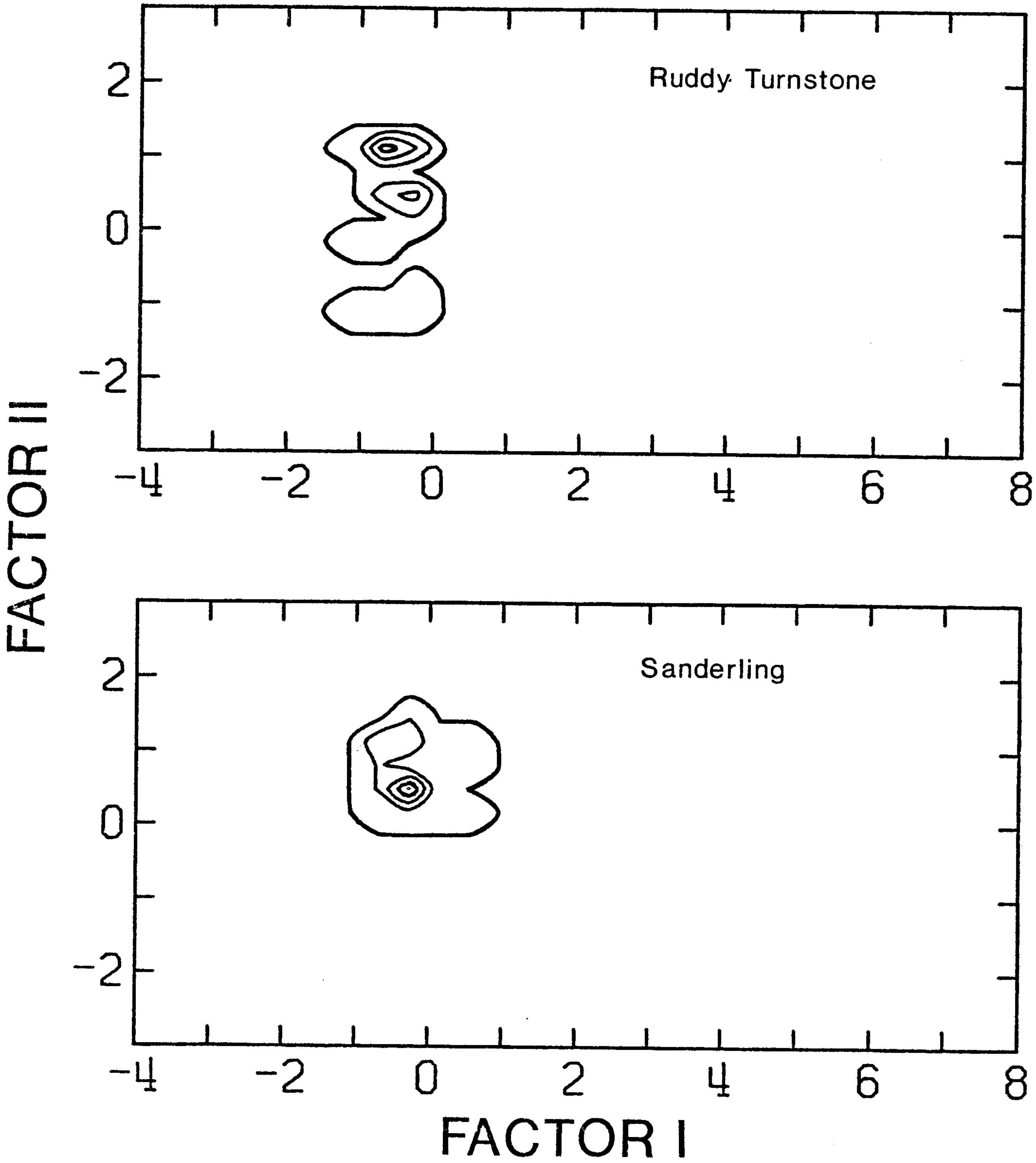


Figure 26. Distribution of foraging in microhabitat space.

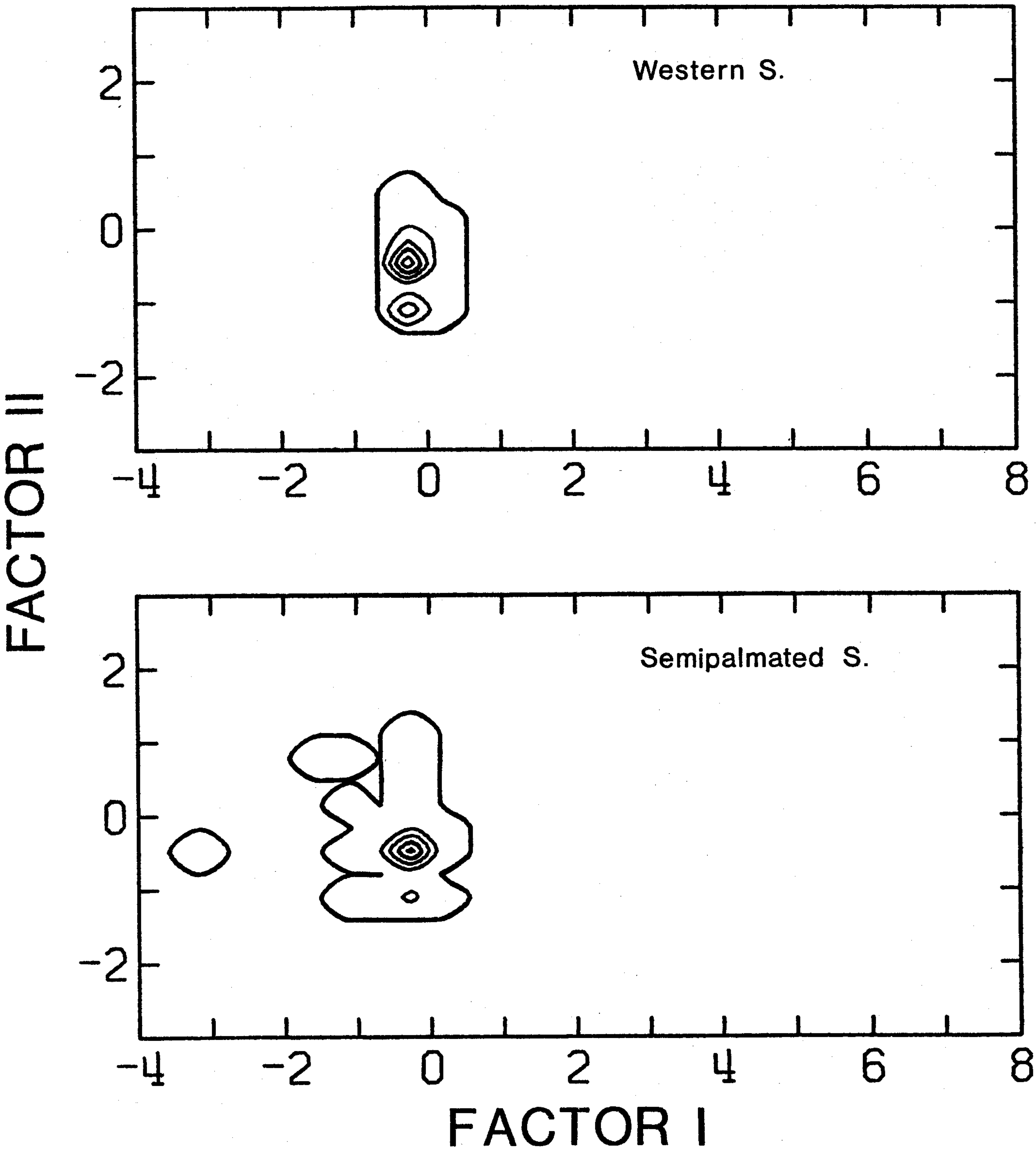


Figure 27. Distribution of foraging in microhabitat space.

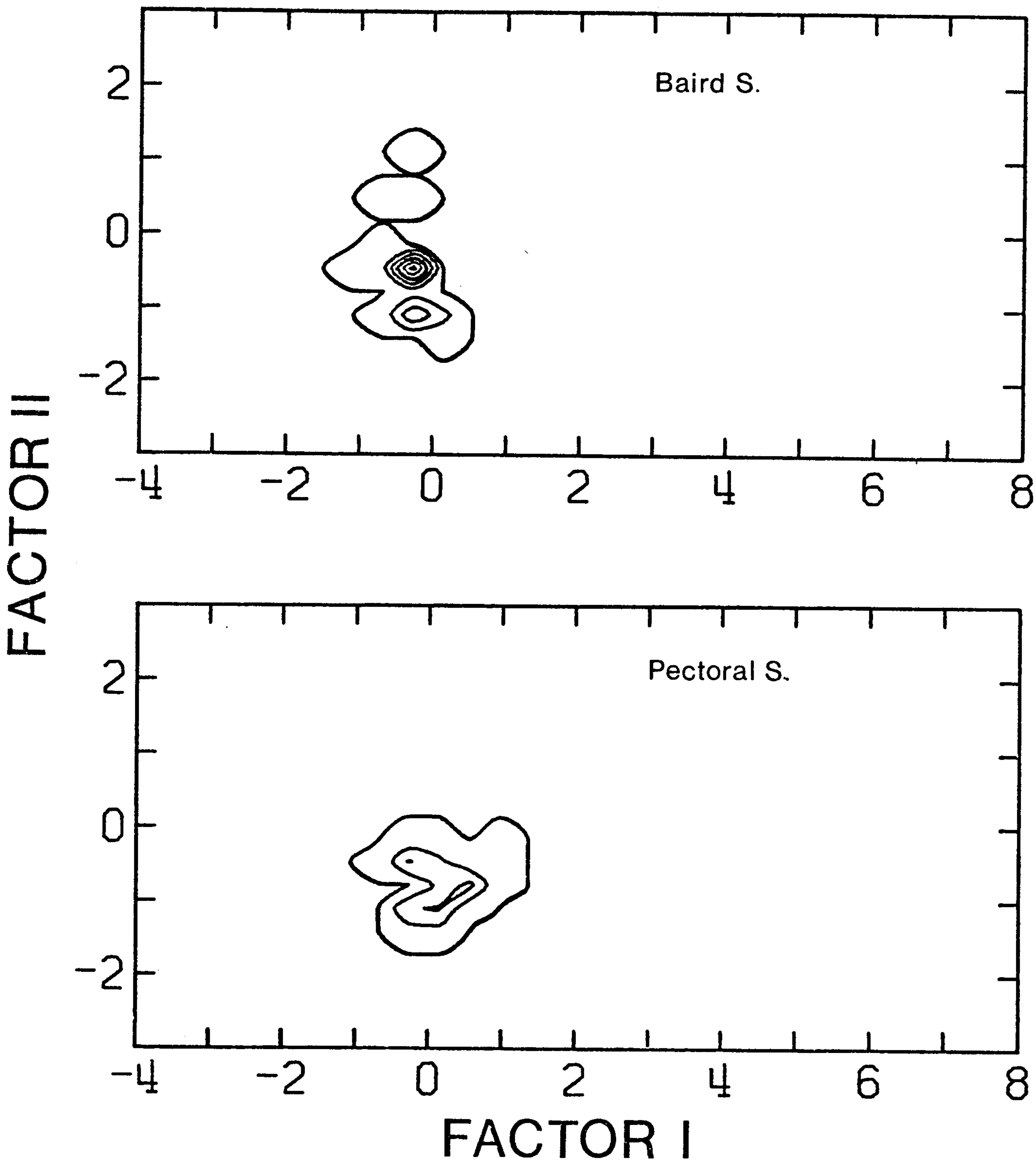


Figure 28. Distribution of foraging in microhabitat space.

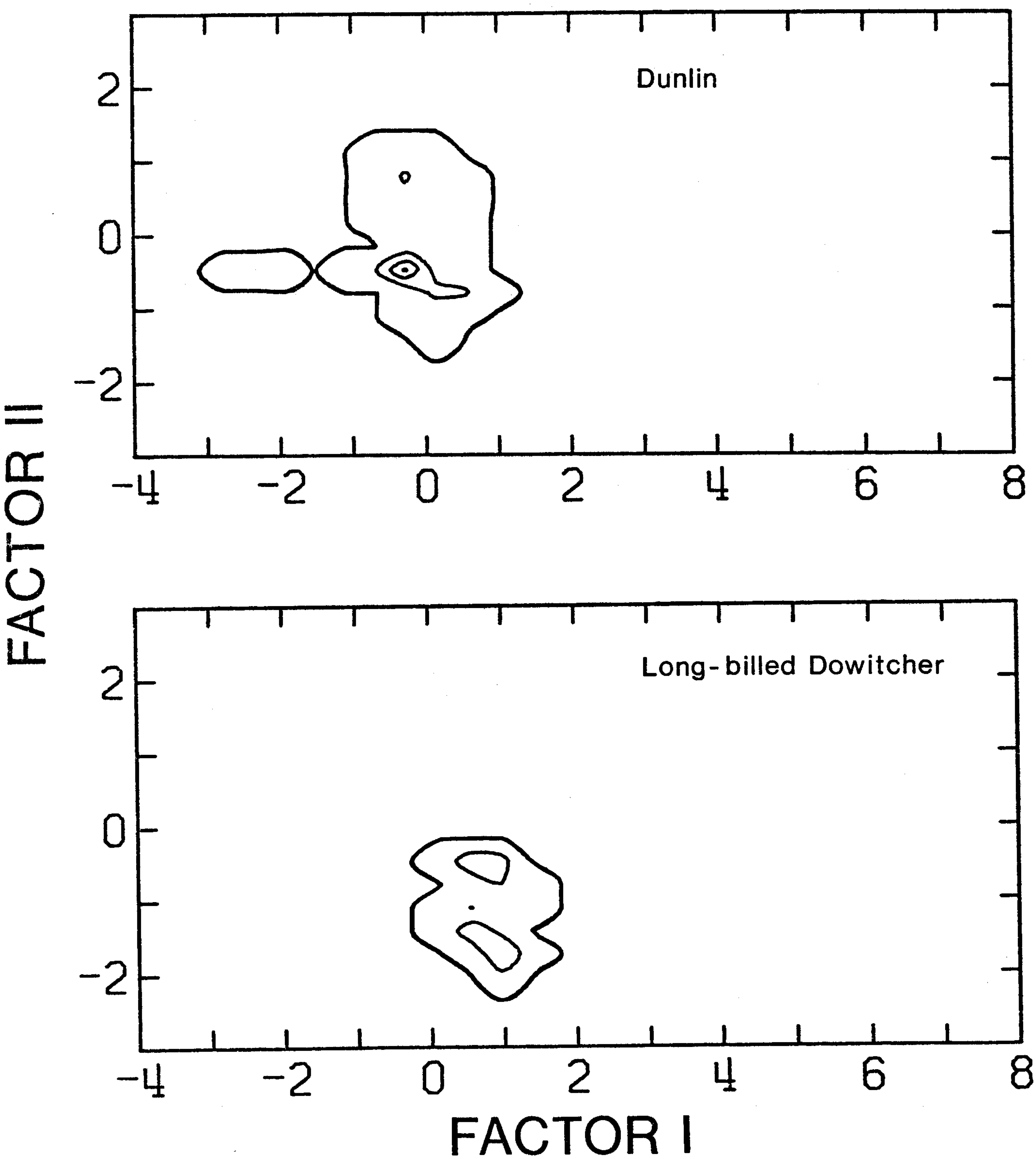


Figure 29. Distribution of foraging in microhabitat space.

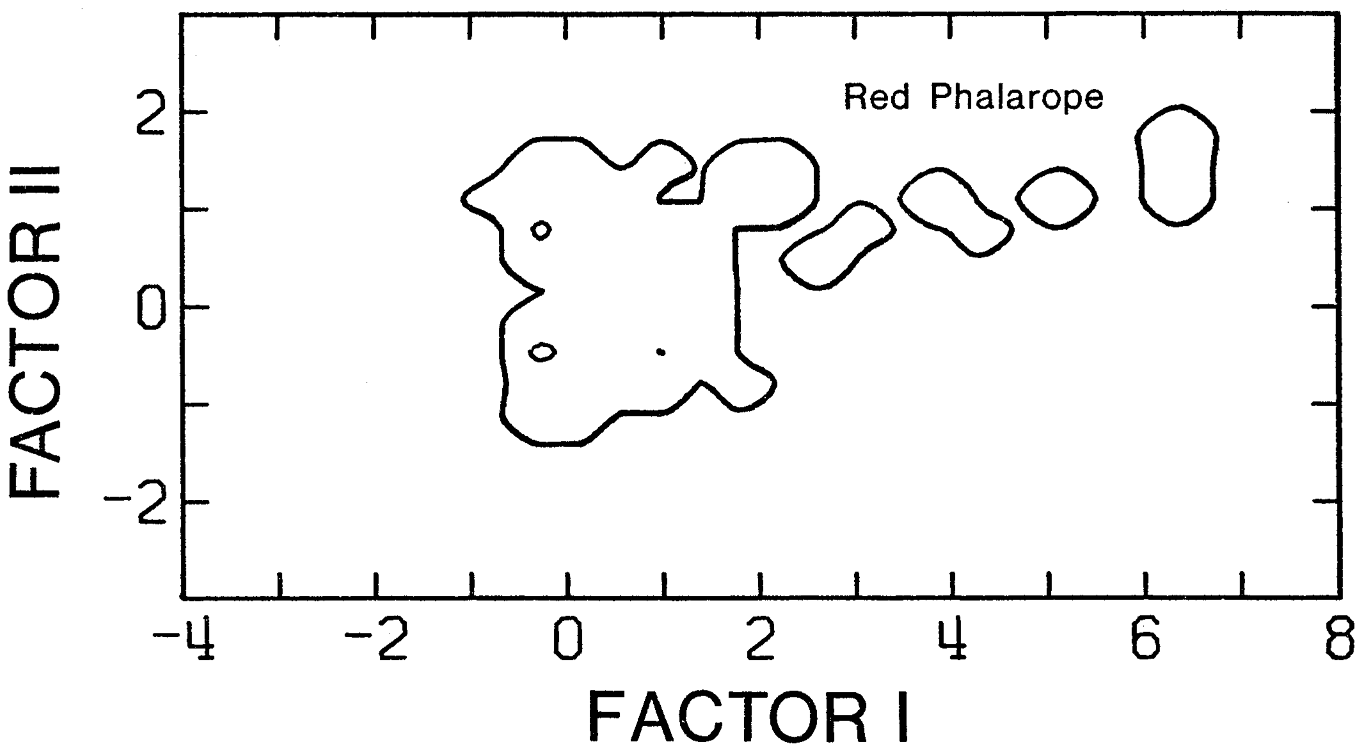


Figure 30. Distribution of foraging in microhabitat space.

transported by water. The reasoning is obvious: the oil's distribution will be controlled by water transport, and thus will spread only as far as water carries it. Second, we assume that increasing grain size indicates increased exposure to wave action. This means that sites characterized by increased grain size are more likely to be impacted because of the increased rate of water transport in these areas. However, the duration of impact may be less than in areas of smaller grain size, once the latter are hit, for the same reason: oil will be less likely to be carried away. Given these very qualitative assumptions we would argue that species using microhabitats falling high along Factor 1 and high along Factor 2 are those which will be most frequently exposed to oil damage: Red Phalaropes, Sanderlings, and Ruddy Turnstones stand out in this respect. Their foraging style exposes them to conditions where they are very likely to be contaminated with oil.

However, the decreased rate of transport which may be inversely correlated with Factor 2 must also be taken into account, particularly in light of our evidence on trophic dependencies: birds foraging in protected areas tend to rely on benthic infauna, especially insect larvae, which complete their life cycle in these habitats; birds foraging in areas characterized by large grain size, on the other hand, typically feed on wave-washed zooplankton, either in the water column or in windrows along the water line. Long-term effects of oil spills may therefore be much more pronounced in the protected areas, as the birds are using a resource originating in situ. The plankton feeders, in contrast, utilize a resource which may be replenished from outside the local area. Thus questions of susceptibility through secondary trophic and habitat effects tend to be complex, and will require further study.

D. Marking - resighting of Red Phalaropes

Table 14 is a summary of the color-marking schedule of Red Phalaropes trapped on Barrow Spit during August. Each of six separate date groups received distinctive color combinations. Table 15 presents the results of resighting efforts after these markings. Resighting efforts were made in the course of other studies rather than on a regular schedule. For each resighting effort, the fraction of the total Barrow Spit population actually observed well enough to see the color marking allows calculation of the number of marked birds expected, assuming a random mixing of marked individuals throughout the population. The last three columns in Table 15 apply this calculation assuming three different post-marking intervals during which all phalaropes remain in the area. Comparison of these expected resighting results with the actual number resighted allows us to estimate the interval during which most birds remain in the Barrow Spit area.

An inconsistent pattern results. From 11 August through at least 15 August, the relatively high resighting rate implies that most birds remain for at least four days. After 15 August, however, no resightings were achieved, implying a much quicker turnover rate in phalaropes in the Barrow Spit area. We do not consider the data extensive enough, however, to feel certain that there is a marked difference in movements between early and late August. However, as Figure 20B shows, densities of Red

Table 14. Summary of Red Phalarope Color-Marking Schedule

Date	Number marked	Number subsequently resighted
8 Aug 1977	7	2
11 Aug	4	0
12 Aug	17	6
14 Aug	3	0
17 Aug	3	0
23 Aug	13	0
Totals	47	8

Table 15. Resightings of Marked Painted Red Phalaropes

Date	Total population	Number observed	Number resighted	Number expected, if all remain for periods of		
				2 days	4 days	6 days
11 Aug	2000	300	1	0	1.1	1.1
12 Aug, AM	2000	250	1	.5	1.4	1.4
12 Aug, PM	2000	300	4	2.6	3.5	3.5
15 Aug	6300	700	2	.3	2.7	2.7
17 Aug	6000	1500	0	0	.8	6.0
19 Aug	4000	400	0	.3	.3	.6
20 Aug	3800	500	0	0	.4	.8
22 Aug	3600	300	0	0	0	.3
23 Aug	3200	500	0	0	0	.4
24 Aug	3200	1400	0	5.7	5.7	5.7
25 Aug	3800	500	0	1.7	1.7	1.7

Phalaropes on Barrow Spit were increasing steadily from August 5 through August 15, and this is consistent with an interpretation of a principally shoreward movement of juveniles leaving the tundra, with very little migratory movement along the coastline. After August 15, densities on the transects fluctuated over a large range indicating movement in and out of the Barrow area. The importance of this high turnover rate in most of August and early September to assessment of oil-related impacts is clear: A local habitat disturbance such as an oil spill, which may remain in a local area for one month or more, has the potential of affecting several times as many phalaropes as are present at any one time on the area. Wave after wave of migrating Red Phalaropes from undisturbed areas might be affected as they pass through the disturbed area.

E. Other results

(1) Roosting versus foraging activity in Red Phalaropes

Corresponding to the changes in zooplankton density between 1975 and 1976, discussed above, we observed differences in the foraging activity patterns of Red Phalaropes between the two summers. Although overall densities of Red Phalaropes on Barrow Spit during August of both years was similar, in 1975 almost no phalaropes were observed roosting during normal census hours (approximately 0900 to 1800). Roosting populations on all censuses remained below 10% of total census populations. On several occasions in 1976, however, roosting proportions of transect populations frequently exceeded 50%. Table 16 presents the roosting percentages of Red Phalaropes on three transects on Barrow Spit during four census days in August and September 1976. The data are limited in this way primarily because activity data were not gathered on all transects and all census days. However, these three transects do represent the areas in which phalaropes were most often seen roosting. The overall proportion of phalarope roosting time is therefore less than the figures given here. Nevertheless, this represents a striking difference between the two seasons in the behavior of Red Phalaropes. We suggest that the increased roosting time may be related to the lower plankton densities in 1976, possibly indicating that phalaropes do not continue foraging at low foraging efficiencies.

(2) Red Phalarope distribution in relation to wind direction

In 1975 juvenile Red Phalaropes foraging along the shores of Barrow Spit were most abundant in the shallow water zone, 0 to 2 m out from the shore. Day to day distribution along the shores of Barrow Spit and Plover Spit varied considerably, however. To test the hypothesis that phalarope distribution was affected by wind direction, seven sets of census data for all four shores of the Barrow Spit-Plover Spit system, taken on days with wind speeds above 8 knots, were treated as follows: First, the absolute value of the angle in degrees between the actual wind direction and the direction of a full onshore wind was determined for each census day for each shore. Second, the per cent of birds occurring on each shore was plotted against this parameter. The result is shown in Figure 31 taken from the first annual report (Connors and Risebrough, 1976). The very restricted scatter of these data indicate simply that

Table 16 . Per Cent of Red Phalaropes Roosting During Censuses, Barrow Spit

Date	Hours	Total on Transects GF, PS, WS	Per cent roosting
20 Aug 1977	1100-1330	574	74%
22 Aug 1977	1130-1300	157	67%
25 Aug 1977	1330-1500	784	66%
4 Sept 1977	1400-1530	1584	50%

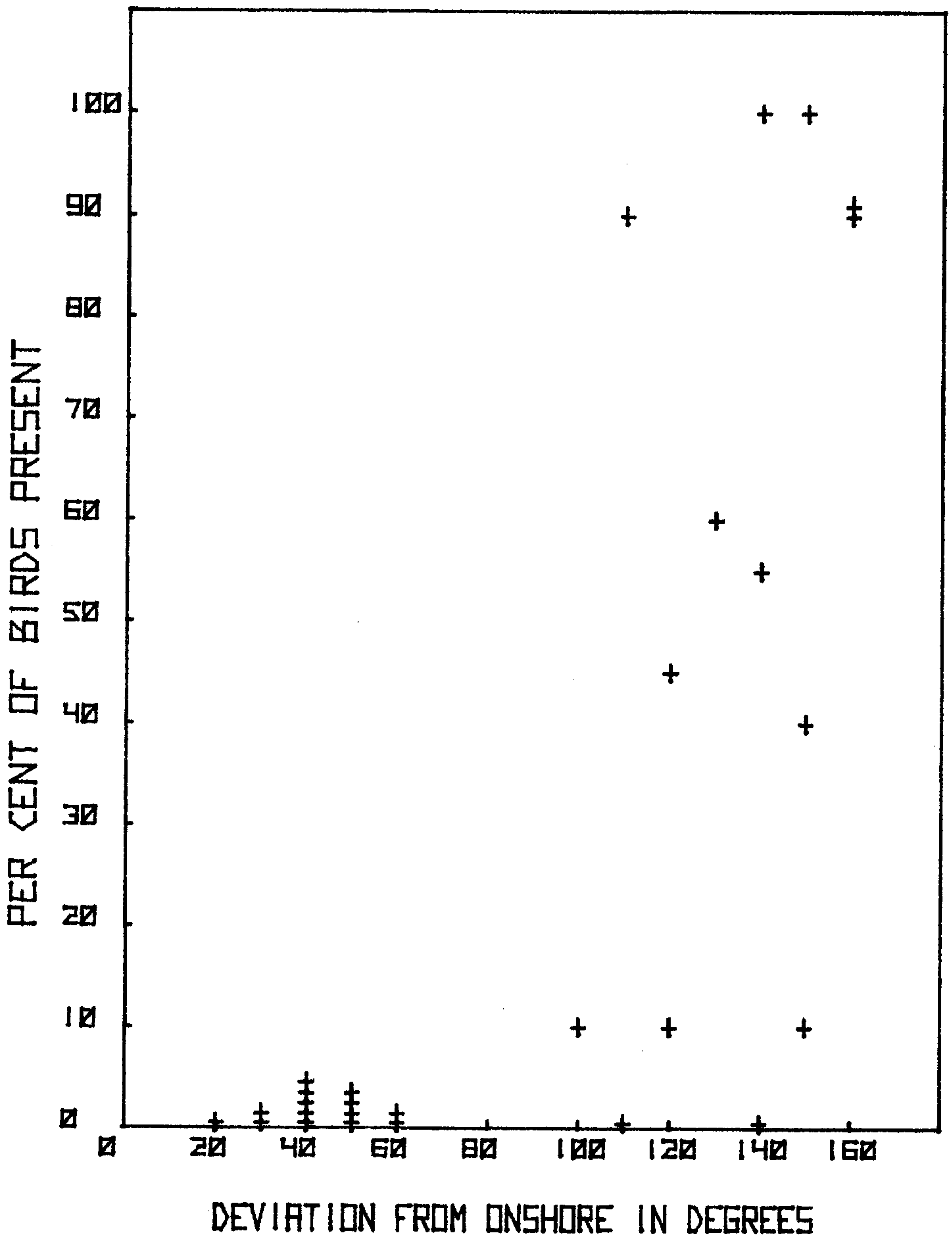


Figure 31. Distribution of foraging Red Phalaropes in relation to wind direction, 1975.

phalaropes seldom foraged on beaches with onshore winds (angles less than 90°) if alternative shores were available. Since in 1975 the phalaropes were feeding on dense zooplankton concentrations in shallow water within 2 m of shore almost exclusively, we suggested that wind conditions might affect foraging efficiency by altering surf and ice conditions and possibly through differences in plankton availability on different shores. We further suggested that the complex arrangement of shores around Point Barrow, which always provides a protected shore, may be much more attractive to migrating phalaropes than single shores along the mainland. For the same reason barrier islands would provide protection in most wind conditions and should also be heavily used.

In 1976 two transects on each of the four shores were established and censused throughout the season (Figure 1: BS, RW; TW, DM; PP, PS; CB, WS). Table 17 presents the results of population censuses on these eight transects on each of seven days in which wind speed was above eight knots. These data are then treated exactly as the 1975 data were, and the result is plotted in Figure 32. It is obvious that the same relationship does not hold in 1976. Clearly, the phalaropes were responding differently in the two years. We suggest the following interpretation, related directly to the change in zooplankton conditions between the two seasons. In 1975 phalaropes foraged on dense zooplankton in shallow water within 2 m of shore almost exclusively. In this situation, the protected shore probably provides increased foraging efficiency, possibly by improved surf and ice conditions and decreased turbidity and possibly through enhanced zooplankton density. In 1976, however, with drastically lower densities of the same zooplankton, Red Phalaropes also foraged on under-ice amphipods which become available on windy days when pieces of ice pile up on the windward shore. The absence of any wind-related pattern in Figure 32 results from Red Phalaropes utilizing multiple food resources with different responses to wind conditions.

(3) Premigratory fat deposition by shorebirds

Fat conditions of all collected bird specimens are included in Table 18. The OCS Fat Code can be compared to a scale similar to that of McCabe (1943) with the following definitions: Code 2, little fat; Code 3, moderate fat; Code 4, very fat; Code 5, excessive fat.

A trend is quite obvious in the fat levels of juvenile Red Phalaropes taken between 10 August 1976 and 2 September 1976, with fat levels increasing with later date. This suggests strongly that the long period in which Red Phalaropes forage along arctic shores is important for the deposition of fat prior to southward migration. This pattern was not evident from the weights of 40 juvenile Red Phalaropes trapped, weighed, and measured on Barrow Spit between 11 August and 23 August 1976. There was no significant increase from these data in weight, in weight divided by tarsus length, or in weight divided by cube of tarsus length. The much more precise estimate of fat condition possible on collected birds does show this pattern, however.

Of the five shorebird species for which at least five specimens were collected in 1976, considerable variation in fat accumulation schedule

Table 17. Red Phalarope Distribution on Four Shores of Barrow Spit-Plover Spit, 1976.

Date	Wind Speed (knots)	Wind Direction (degrees)	Numbers of Red Phalaropes				
			BS&RW	TW&DM	PP&PS	CB&WS	Total
8 Aug	12	70	27	73	84	268	452
10 Aug	10	310	239	226	13	429	907
15 Aug	12	70	184	358	161	195	898
20 Aug	10	240	69	660	301	46	1076
25 Aug	9	80	122	141	57	2	322
27 Aug	11	70	8	123	4	16	151
4 Sept	11	240	157	141	0	49	347

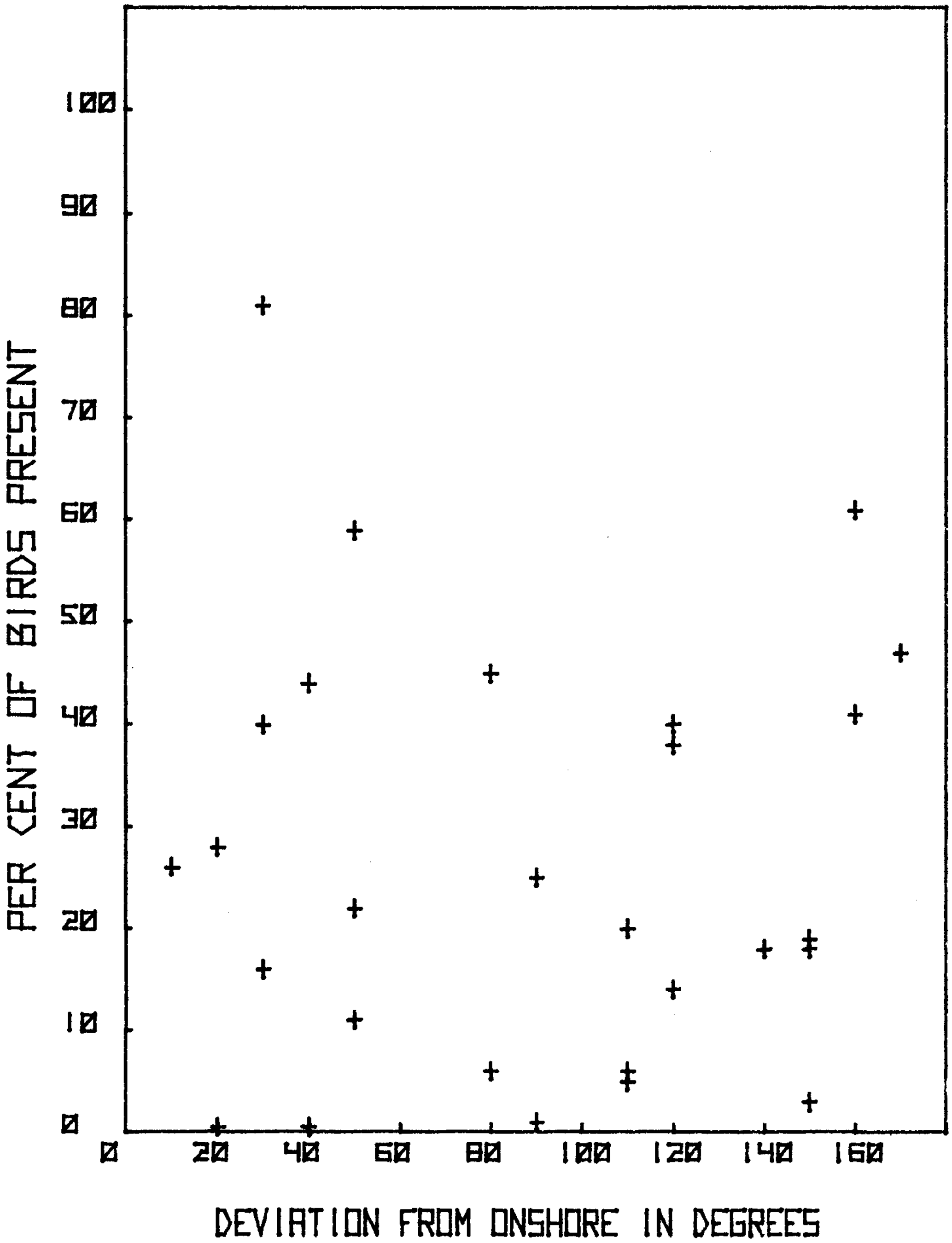


Figure 32. Distribution of foraging Red Phalaropes in relation to wind direction, 1976.

Table 18. Birds Collected for Trophic Studies, Barrow, 1976

Specimen No.	Weight (gm)	Sex	Age a-adults j-juveniles	OCS Fat Code	Loc/Date (1976)
Sanderling (*Calidris alba*)					
1	69.0	F	a	4	BP, 10 June
56	54.3	M	j	3	BSS, 10 Aug
63	68.4	M	j	5	WB, 12 Aug
67	66.9	F	j	4	BSS, 14 Aug
79	69.0	F	j	4	WS, 17 Aug
82	74.2	F	j	4	PS, 17 Aug
120	60.9	M	j	4	WB, 30 Aug
122	60.7	M	j	4	WB, 30 Aug
125	63.7	-	j	5	WB, 30 Aug
Total: 9	$\bar{x}$M=61.1 $\bar{x}$F=69.8			$\bar{x}$=4.1	
Semi-palmated Sandpiper (*Calidris pusilla*)					
29	23.1	M	j	2	VC, 29 July
30	23.8	M	j	2	BP, 29 July
33	28.4	-	j	3	BP, 30 July
47	22.4	M	j	2	NSL, 8 Aug
88	20.1	M	j	2	GF, 20 Aug
Total: 5	$\bar{x}$M=22.4			$\bar{x}$=2.2	
Baird Sandpiper (*Calidris bairdii*)					
44	36.2	M	j	2	BD, 1 Aug
Dunlin (*Calidris alpina*)					
45	58.6	M	a	2	NSL, 3 Aug
46	51.5	-	a	2	NSL, 3 Aug
57	54.5	M	a	2	WB, 10 Aug
60	61.6	M	a	2	GF/CB, 11 Aug
61	62.3	M	a	2	GF/CB, 11 Aug
80	47.9	M	j	2	WS, 17 Aug

Table 18, continued 2

					Peard Bay
83	58.9	F	j	2	19 Aug
84	47.2	M	j	2	19 Aug
85	51.4	M	j	2	19 Aug
86	56.7	M	j	2	19 Aug
Total:11	$\bar{x}$M=55.0 $\bar{x}$F=58.9			$\bar{x}$=2.0	
Western Sandpiper (Calidris mauri)					
3	30.7	M	a	4	VC, 1 July
Red Phalarope (Phalaropus fulicarius)					
43	48.9	M	a	2	BD, 1 Aug
51	50.0	-	j	2	WS, 10 Aug
52	48.8	M	j	2	WS, 10 Aug
54	44.7	M	j	2	BSS, 10 Aug
55	53.1	F	j	2	BSS, 10 Aug
65	44.5	M	j	2	BSS, 14 Aug
66	47.5	F	j	2	BSS, 14 Aug
76	47.2	M	j	2	MSW, 16 Aug
77	50.1	F	j	2	MSW, 16 Aug
90	53.8	F	j	2	BSS, 20 Aug
91	49.0	F	j	2	BSS, 20 Aug
101	45.6	F	j	2	TW, 24 Aug
102	58.8	F	j	3	TW, 24 Aug
109	51.9	F	j	3	GF, 25 Aug
118	63.1	F	j	3	WB, 30 Aug
119	48.5	M	j	3	WB, 30 Aug
121	44.8	M	j	4	WB, 30 Aug
123	58.6	F	j	3	WB, 30 Aug
124	43.9	M	j	3	WB, 30 Aug
127	52.5	F	j	3	GF, 2 Sept
128	50.7	M	j	3	GF, 2 Sept
Total:21	$\bar{x}$M=46.9 $\bar{x}$F=53.1			$\bar{x}$=2.5	

Table 18, continued

Ruddy Turnstone (*Arenaria interpres*)					
31	100.6	M	a	2	BP, 29 July
34	142.4	M	a	4	BP, 30 July
53	97.8	-	j	3	PS, 10 Aug
62	121.7	M	j	4	GF/CB, 11 Aug
68	123.5	F	j	4	BSS, 14 Aug
81	118.6	M	j	4	WS, 17 Aug
Total: 6	$\bar{x}$M=120.8 $\bar{x}$F=123.5			$\bar{x}$=3.5	
Snow Bunting					
35	39.8	-	j	3	BP, 30 July
36	40.2	-	j	2	BP, 30 July
Lapland Longspur					
74	29.7	-	j	4	BP, 16 Aug
75	32.2	M	j	4	BP, 16 Aug
Mew Gull					
126	256	F	j	1	PS, 30 Aug

is suggested. Red Phalaropes, Dunlins, and Semipalmated Sandpipers show considerably lower mean fat levels than Sanderlings and Ruddy Turnstones during August. Red Phalaropes and Dunlins remain in Alaska much later than Sanderlings and Ruddy Turnstones, reaching the latitude of California in middle October or later in most years. Sanderlings and turnstones apparently accumulate higher fat reserves during August and migrate southward more rapidly. The Semipalmated Sandpiper juveniles were taken relatively soon after fledging and may be able to maintain or replenish fat supplies at foraging sites during migration.

VIII. Conclusions

Many of the conclusions from this study have been presented in sections I and VII. These will be briefly summarized in this section.

In general the pattern of seasonality in habitat use by shorebirds, gulls, and terns was similar in both years, with heavy use of littoral areas developing in August and September. Variation between years in timing and magnitude of movements of particular species was evident, however. Detailed seasonal plots for habitat use and population movements for most of the common Barrow species have been presented in this and in the 1975 annual report. An appendix is added to this report presenting the general phenology of bird events in the Barrow area on a 10-day basis, both in the littoral zone and on the nearshore tundra.

Information on critical areas has been expanded. Information gathered in this project and the ADFG RU 3/4 has identified the Barrow Spit-Plover Islands area and the Peard Bay Spit-Seahorse Islands area as regions of very heavy use by migrating phalaropes, gulls, and terns in August and September. Mudflat areas near Lonely and Icy Cape are heavily used by shorebirds of several species. Coverage of the coast remains somewhat uneven, however, and visits to some areas have occurred in only one season. Therefore, identification of some of these areas remains tentative.

Work on trophic relationships of shorebirds in the Barrow area was expanded in this season and our appreciation of the range of food items taken by migrating shorebirds is increased. Considerable variation in diets with habitat, season, or plankton availability evidently exists for most species. Along gravel shores of spits and barrier islands in late summer, several species of zooplankton comprise the major food source of several species of shorebirds, gulls, and terns. In these two years of study, we have identified drastic fluctuations in the density of nearshore zooplankton. Our two summers of limited data do not, however, begin to define the range of variation in this volatile system or to answer the important questions concerning causes of this variation.

Our data indicate behavioral and possibly physiological responses of migrating juvenile Red Phalaropes to the change in zooplankton density between 1975 and 1976. In 1975, Red Phalaropes foraged predominantly on shores with offshore winds blowing. This relationship did not hold in 1976, probably because the low plankton densities required phalaropes to forage for under-ice amphipods on windward shores. Additional seasons of research will be necessary to fully understand this complex situation.

Our data also suggest that juvenile Red Phalaropes in migration spent more time roosting in 1976 than in 1975 in the Point Barrow area. Fat deposition by juvenile Red Phalaropes in 1976 was slow compared to other species of shorebirds, but comparison with conditions in future seasons will be necessary to determine whether this was caused by low food availability.

The results of our marking and resighting efforts with juvenile Red Phalaropes allow us to tentatively propose that a high turnover rate in the phalarope population on Barrow Spit occurs during most of late August and early September. As a result a very large population of birds moving through the area would be exposed to a single local disturbance such as an oil spill.

Finally, we have tentatively ranked the common Barrow shorebird species with respect to species susceptibility to oil development impacts. These rankings require several kinds of information: 1) distributional information gives us migration and residence patterns and allows us to consider what fraction of some larger population might be affected; 2) habitat use information should be treated on both a large scale and a microscale and we should know the relative abundance of different habitats and the flexibility of these species to disturbances within a habitat; 3) trophic information is obviously essential since the potential environmental disturbance may affect the shorebird species through their food resources. We need to know the vulnerability of the food resources and flexibility of the shorebirds with respect to the food resources; 4) patterns of social organization reflect differences in the seasonal occurrence and activities of different age and sex classes and, considered with distributional information, determine the schedule of potential use of available habitats. The dispersion of individuals within a habitat may also affect their vulnerability to an oil spill, for example; 5) a final category of information deals with many other behavioral questions: the reaction of individuals to an oil spill, the foraging method (swimming versus wading, for example), the tolerance of species to disturbance or noise during breeding or non-breeding activities and the general flexibility of the species when faced with a particular environmental disturbance. At present we do not know the answers to many of these questions.

The data gathered in the several aspects of this study contribute to most of these information classes. The seasonal habitat use patterns presented already in this section indicate the considerable range of variation between species within the Barrow shorebird community. Some species, such as Pectoral Sandpiper and Golden Plover, are almost restricted to tundra habitats throughout the season; Red Phalaropes, Sanderlings, and Ruddy Turnstones depend very heavily on conditions in littoral habitats. Several species exhibit intermediate habitat use patterns. Similar differences exist in other ecological and behavioral comparisons between species. Drawing from all these types of biological information, we are now able to construct a tentative classification of common Barrow shorebird species with respect to potential effects of oil development near Barrow (Table 19). This includes only common species near Barrow and attempts to relate species susceptibility to different kinds of development, basically onshore versus offshore. Note that some other shorebird species, for example Black-bellied Plover and Northern Phalarope, which are common farther east in the Beaufort Sea, are omitted from the table because our data for these species is very limited at present. At this point the biologist needs another class of information dealing with the type and magnitude of potential development and associated disturbances. The question marks in this table indicate our uncertainty in this respect, as well as our need for more information on the biology of several of the less common species.

Table 20 is a finer look at the relative susceptibilities of the common Barrow shorebirds to potential disturbances in the littoral zone arising from OCS oil development. Again, there is some uncertainty in the assignments, principally because they are based on only two years' data and because inevitably several of the species seemed to be borderline cases, but we are confident enough of these ratings to feel they provide a useful tool in management and planning decisions in the development of Alaskan oil.

IX. Needs for Further Study

Our initial first two seasons of study at Barrow have provided a solid first look at the fairly complex and relatively variable littoral zone biological system. We now have two points in the range of variation in timing and magnitude of many shorebird events in the Arctic. Since natural variation must be known in order to predict or to assess the impact of any development, we consider this an investment in a research situation which can profit from continuation in future seasons. In particular the unexpected and extreme variation in zooplankton densities along the shores of Barrow Spit between 1975 and 1976 presented one of the most striking examples of biological variation in the Arctic ever uncovered. Since the zooplankton community along these and similar shores represents the trophic basis for most of the shorebird and larid migration along the arctic coast, the entire biological system requires continued study.

One or more additional study areas might be developed. The ease of logistics and the two-year investment in marked transects and sampling sites at Barrow is a distinct advantage calling for continuation of studies at this site also. We feel continued transect census information is worthwhile both in littoral and adjacent tundra areas for comparative purposes. Increased emphasis, however, must be focused on the question of plankton variability and on relationships between birds and plankton. Questions about trophic relationships on several levels have repeatedly emerged as requiring continued work. In section I of this report, we have discussed the biological questions identified as most critical at the Barrow synthesis meetings in February 1977, where trophic studies were considered central to the OCSEAP effort in the Arctic.

In addition to these intensive studies, it is clear that continued area extensive information is required to assess the generality of results obtained at site specific studies and to understand the coastal movements of birds over large areas of the arctic coast. Our brief visits to two study sites in the Chukchi Sea (Cape Krusenstern and Cape Prince of Wales) suggest that seasonal bird use of littoral habitats at these locations may contrast markedly with conditions at Barrow. Since all the shorebirds and

Table 19. Shorebirds Potentially Affected by Oil Development near Barrow. *

COASTAL PLAIN TUNDRA		LITTORAL AND OFFSHORE
Lowland	Upland	
Red phalarope	Golden plover	Red phalarope
Pectoral sandpiper	Ruddy turnstone	Sanderling
Long-billed dowitcher	Semipalmated sandpiper	Ruddy turnstone
?	Baird sandpiper	Semipalmated sandpiper
?	Dunlin	Western sandpiper
	?	Baird sandpiper
	?	Dunlin
		Long-billed dowitcher
		?
		?

Table 20. Relative Susceptibility to Littoral Zone Disturbances.*

High	Moderate	Low
Red phalarope	Dunlin	Golden plover
Sanderling	Baird sandpiper?	Pectoral sandpiper
Ruddy turnstone	Long-billed dowitcher	
Semipalmated sandpiper?		
Western sandpiper?		

*From: Connors, Myers, and Pitelka, in prep.

larids studied in the Arctic are long distance migrants moving between the Beaufort and Chukchi Seas, and usually well beyond, it is reasonable to consider conditions in the Chukchi Sea to evaluate effects in the Beaufort Sea. Survival rates or nesting success in one of these regions may depend upon conditions and fat accumulation rates while birds are migrating in the other region.

During the past year information exchange between bird researchers and other biologists has profitably increased in OCSEAP projects. With respect to plankton measurements we recognize the great advantage of standardization of some sampling methods and coordination of sampling in time and space. On another level, attempting to explain the extreme variation in zooplankton density and distribution, we will almost certainly benefit by input from chemical and physical oceanographers operating in the Beaufort and Chukchi Seas concurrently with plankton sampling studies.

X. Fourth Quarter Operations

1. Field Schedule.

   No field activities during this quarter.

2. Scientific party.

   Dr. Peter G. Connors, University of California Bodega Marine Laboratory, research coordinator.
   Mr. James T. Carlton, University of California, Davis, research assistant.
   Mr. Frank Gress, Bodega Bay Institute, research assistant.
   Mr. J. P. Myers, University of California, Berkeley, research assistant.

3. Methods.

   Laboratory analysis:

   (1) Summary and computer plotting of shorebird seasonal distributions.

   (2) Computer statistical analysis of foraging microhabitat data.

   (3) Final analysis and identification of invertebrates in stomach samples.

   (4) Interpretation of results and preparation of annual report.

4. Sample localities.

   None.

5. Data analyzed.

   (1) Analysis of 1000 microhabitat data sets.

   (2) Analysis and identification of 160 bird stomach and invertebrate samples.

   (3) Analysis of 700 transect censuses.

6. No serious problems encountered.

7. Total funds expended, 1 April 1975 - 1 March 1977: $60,367.

Appendix A. Published studies of shorebird ecology near Barrow, Alaska.

Holmes, R. T. 1966 Breeding ecology and annual cycle adaptations of the red-backed sandpiper (Calidris alpina) in northern Alaska. Condor, 63: 3-46.

Holmes, R. T. 1966 Feeding ecology of the red-backed sandpiper (Calidris alpina) in arctic Alaska. Ecology, 47: 32-45.

Holmes, R. T. 1966 Molt cycle of the red-backed sandpiper (Calidris alpina) in western North America. Auk, 83: 517-533.

Holmes, R. T. 1970 Differences in population density, territoriality, and food supply of dunlin on arctic and subarctic tundra. Symp. British Ecol. Soc., 10: 303-319.

Holmes, R. T. 1971 Latitudinal differences in breeding and molt schedules of Alaskan red-backed sandpipers (Calidris alpina). Condor, 73: 93-99.

Holmes, R. T., and F. A. Pitelka 1964 Breeding behavior and taxonomic relationships of the curlew sandpiper. Auk, 81: 362-379.

Holmes, R. T., and F. A. Pitelka 1968 Food overlap among co-existing sandpipers on northern Alaskan tundra. Syst. Zool., 17: 305-318.

MacLean, S. F., Jr. 1969 Ecological determinants of species diversity of arctic sandpipers near Barrow, Alaska. Ph.D. thesis, Univ. of California, Berkeley.

MacLean, S. F., Jr. 1974 Lemming bones as a source of calcium for arctic sandpipers (Calidris spp.). Ibis, 116: 552-557.

MacLean, S. F., Jr., and R. T. Holmes 1971 Seasonal patterns of abundance of tundra arthropods near Barrow. Arctic, 24: 19-40.

Myers, J. P., and F. A. Pitelka 1976 West Coastal Plain Tundra #'s 1 and 2. In Van Velzen, W. T. (ed.), Thirty-ninth Breeding Bird Census. American Birds, 29: in press.

Norton, D. W. 1972 Incubation schedules of four species of calidridine sandpipers at Barrow, Alaska. Condor 74: 164-176.

Norton, D. W. and U. N. Safriel 1971 Homing by nesting semipalmated sandpipers displaced from Barrow, Alaska. Bird Banding, 42: 295-297.

Norton, D. W. 1973 Ecological energetics of calidridine sandpipers breeding in northern Alaska. Ph.D. Dissertation, University of Alaska, Fairbanks. 163 pp.

Pitelka, F. A. 1959 Numbers, breeding schedule and territoriality in pectoral sandpipers of northern Alaska. Condor, 61: 233-264.

Pitelka, F. A. 1974 An Avifaunal review for the Barrow region and north slope of arctic Alaska. Arctic and Alpine Res., 6: 161-184.

Pitelka, F. A., R. T. Holmes, and S. F. MacLean, Jr. 1974 Ecology and evolution of social organiaation in arctic sandpipers. Amer. Zool., 14: 185-204.

Appendix B. Phenology, Barrow 1975, 1976

I. Littoral Zone

May 20 All habitat frozen; no birds present.

May 30 First birds arriving; staging on few open areas, often near beaches and lagoons.

June 10 Migration and staging continues; most birds have moved to tundra. Peak of sanderling migration, mainly using littoral pools, beaches. Also ruddy turnstones, Baird sandpipers, occasional other species near littoral pools, inner lagoon shores.

June 20 Tundra mostly ice-free; outer shores frozen; inner lagoons beginning to melt. Spring migration over; early post-breeding female red phalaropes flocking on tundra and on littoral pools. (small numbers). Some Baird sandpipers, semipalmated plovers, snow buntings nesting near littoral pools, lagoon shores, gravel spit. Semipalmated sandpipers foraging on mudflats, nesting on tundra.

June 30 Same as preceding period, except small flocks of non-breeding western sandpipers join semipalmated sandpipers on mudflats. Non-nesting glaucous gulls, black-legged kittiwakes along shores.

July 10 Most of female red phalaropes and western sandpipers departed. Nesting pattern continues. Oldsquaws, eiders flocking in open water of lagoons.

July 20 All mudflats, inner lagoons ice-free; outer shores with moats of varying width. Habitat use pattern similar to preceding period, with increase in density of Baird sandpipers in littoral areas.

July 30 Major movement of shorebirds into littoral areas begins; striking influx of migrating juvenile semipalmated sandpipers onto mudflats, littoral pools, lagoon edges; ruddy turnstones (mostly adults), adult male red phalaropes, and Baird sandpipers common. Juvenile lapland longspurs and snow buntings foraging around pools. Old-squaws, eiders continue common in lagoons and along shores.

August 10 Most of shoreline open, but changing with wind direction. Density of shorebirds continues to increase in littoral zone, with a shift to outer gravel shoreline habitats. Ruddy turnstones, dunlins, western sandpipers common; juvenile red phalaropes abundant; male red phalaropes almost gone. Loons and ducks in open water along shores. Peak of Sabine gull and black-legged kittiwake movements. Arctic terns abundant, glaucous gulls common. Flocks of juvenile lapland longspurs near littoral pools.

August 20 Red phalaropes, Arctic terns continue abundant along most shores. Ruddy turnstones, dunlins, sanderlings common on gravel beaches; Long-billed dowitchers, western sandpipers, dunlins, lapland longspurs common on mudflats. Baird sandpipers mostly gone.

August 30 Heavy use of littoral areas continues, mainly red phalaropes, ruddy turnstones, dunlines, sanderlings, arctic terns, gulls. Western sandpipers, long-billed dowitchers have mostly departed. Oldsquaws common offshore.

Sept. 10 Bulk of migration has passed. Shores still mostly open, but tundra freezing, some ice reforming on shores. Dunlins, ruddy turnstones, sanderlings, red phalaropes, arctic terns, gulls still present, but in lower densities.

Sept. 20 Tundra frozen, shoreline conditions variable. Some individuals of any of the above species may remain. Influx of Ross' gull.

Sept. 30 End of shorebird season.

II. Coastal Tundra

May 10	100% snow cover, no birds on tundra.
May 20	100% snow cover, onset of passerine arrival, snowy owls beginning to breed if lemmings abundant.
May 30	patches of tundra exposed; onset of passerine breeding; shorebird arrival, lemming predators arrive.
June 10	50% uncovered by snow, surface water present, ponds melting but still frozen at bottom; shorebird breeding underway; waterfowl arrival; lemming predator breeding commenced.
June 20	snow cover gone, most ponds largely melted, drainage underway; passerine hatching commenced; shorebirds, waterfowl, lemming predators breeding.
June 30	passerine hatching and brooding; shorebirds incubating, brooding; coastal influx of pectoral males and red phalarope females begun; waterfowl, lemming predators incubating.
July 10	tundra surface drying, marked plant growth, high levels of surface invertebrates; passerines fledging, shorebirds incubating, hatching, peak densities of male pectoral, female red phalaropes movement continues; ruddy turnstones and semipalmated sandpipers moving broods toward littoral zone, female pectorals taking broods into low sedge marshes; waterfowl and lemming predators incubating.
July 20	high levels of surface invertebrates; passerines fledged, shorebirds hatching, fledging, shorebird territorial dispersion largely broken down, pectoral males migrating in flocks coastally, movement of adult Golden plovers along coast; waterfowl, lemming predators hatching.
July 30	surface invertebrates dropping in abundance; passerines flocking, shorebirds fledging, dunlin flocks appearing in littoral and adjacent tundra; semipalmated sandpiper migration underway, movement of adult Golden plovers continuing, female pectorals moving in small flocks along coast; waterfowl brooding and moving to littoral zone; lemming predators brooding.
August 10	passerines flocking; strong shorebird migration to and along coast, particularly dunlins, red phalaropes, and female and juvenile pectorals (latter two restricted to coastal tundra); lemming predators fledging.
August 20	increasing chance of frosting and frozen pond surfaces; passerine migration; invasion of longbilled dowitcher juveniles with large flocks appearing in coastal tundra strip; dunlins using tundra along coast; red phalaropes diminishing on tundra.

August 30 snow cover likely; tundra activity falling drastically.

Sept. 10 no birds on tundra; freezing likely.

Appendix C. Patterns of Variability in Barrow Weather

Arctic environmental conditions are notoriously variable, as comparison between two successive years of prey species used by shorebirds at Barrow clearly demonstrates (see Results, VII). In light of this contrast, the similarities in overall bird abundance and timing of movements between years are striking. This suggests that exploitation patterns by littoral birds may be remarkably labile, adapted to respond to a wide range of habitat conditions, and has important implications for predicting the effects of environmental disturbance: for us to properly gauge susceptibility to perturbations we must understand the natural patterns of variation to which species normally respond.

One major component of environmental variation in the Arctic is weather; it is also a parameter for which records exist over sufficient time to allow some exploration into the magnitude and patterns of variability. We have begun to examine variation in weather patterns with the phenomena mentioned above in mind. Our first efforts have gone toward describing the variability between years, examining the ranges of conditions which exist, and in particular, their seasonal patterns.

This appendix summarizes results obtained to date: they concern wind and temperature patterns over the 25 year span 1951-1975 at Barrow for the period May-August when birds are present in abundance.

Figure 1 shows the seasonal pattern of temperature at Barrow: daily mean temperature (^{o}F) is plotted as a function of date. Average temperatures normally encountered during this period span a range between 12^{o} and 42^{o} F. The breeding season, from early June to early July, thus covers a period during which mean temperatures shift from below freezing to approximately 40^{o} F. Through mid-summer, temperatures remain in this vicinity, but drop in August, reaching the freezing point by early September. While these changes are not great in terms of the absolute differences involved between minimum and maximum, their biological significance is amplified by the fact that the temperature remains near the freezing level.

Figure 2 represents a graphical comparison of the temperature regimes of different years: A statistic, d_n, was calculated to reflect the cumulative deviation from the 25 year average daily mean temperature:

$$d_n = \sum_{i=1}^{n} (t_i - \bar{t}_i)$$

where t_i is the daily mean temperature and $\bar{t}_i$ is the 25 year average for day i.

This statistic has been plotted in Figure 2 for four years representative of different patterns of variation evident in the 25 years we have examined. A year in which temperatures never deviates from average would plot as a line parallel to the x-axis with a y-intercept of 0; periods when temperatures are warmer than the average daily mean have a

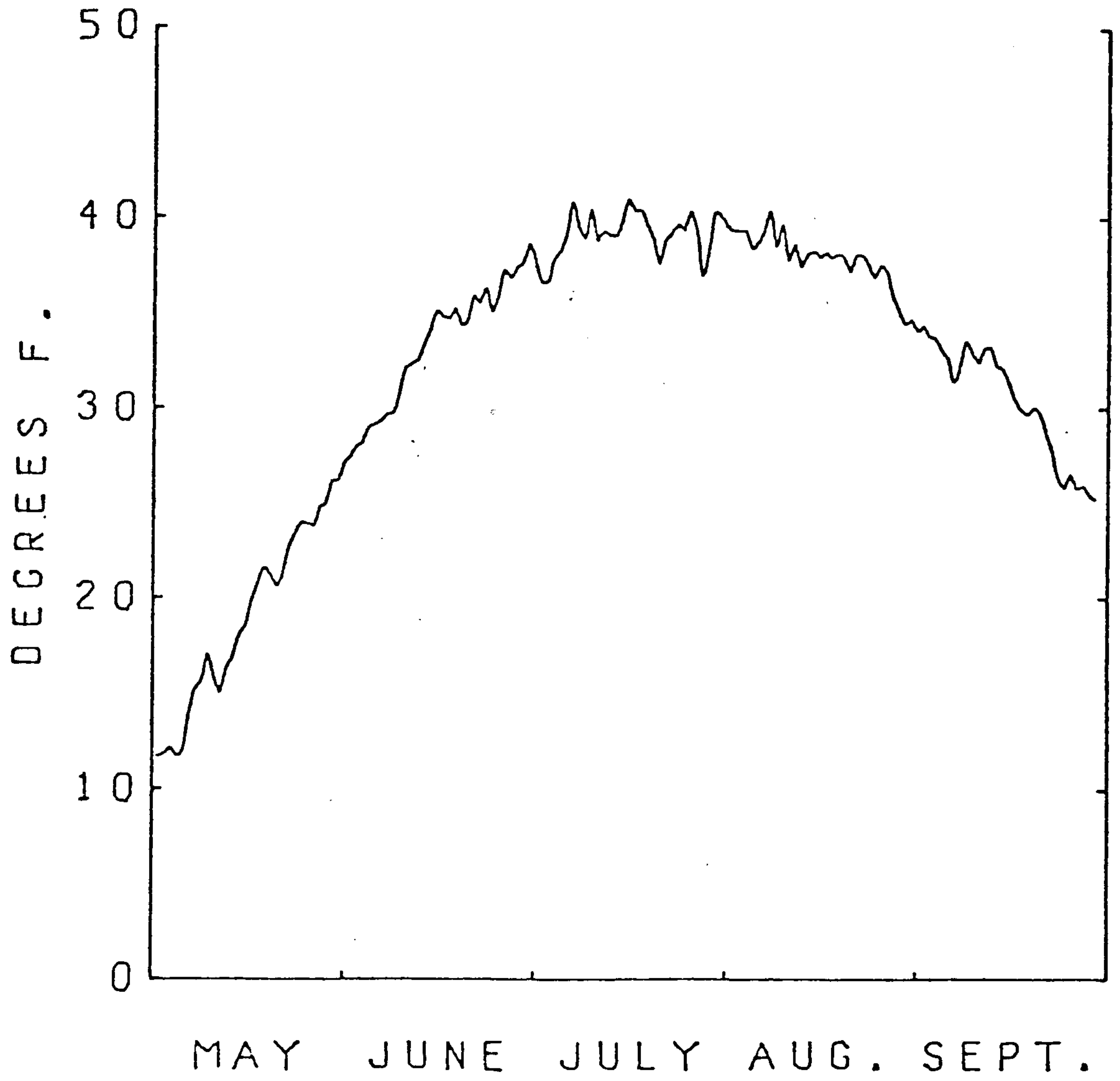


Figure 1. The progression of daily mean temperature at Barrow, Alaska, based on the period 1951-75.

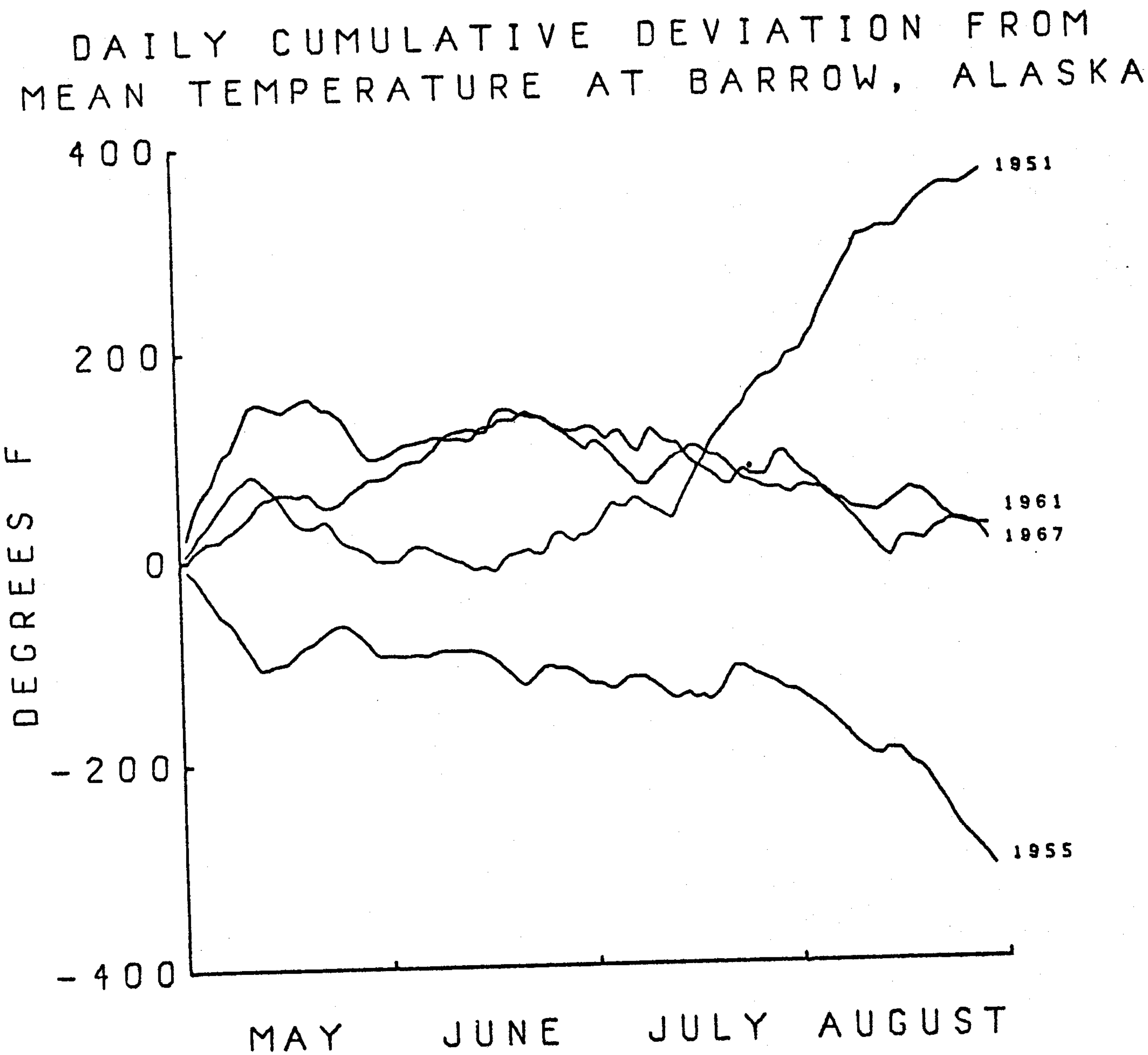


Figure 2. Changes in d_n through the summer at Barrow, Alaska.

positive slope, while those characterized by cooler temperatures plot negatively. Thus, the latter part of the summer in 1951 was consistently warmer than the average daily mean, while 1955 was cooler than normal throughout the entire season.

Years similar to the "average year" do in fact exist: 1961 and 1967 end with cumulative deviation values close to 0. During one of these years, 1967, temperatures never deviated markedly from the average daily mean. On the other hand, the final value of 1961 was reached only after a sharp period of deviation in May followed by a long period with only slightly cooler than normal temperatures.

An intriguing feature of these patterns involves the way variability is distributed through the summer: we found two months, May and August, which characteristically deviated from normal throughout the 25 year span. This pattern is apparent in 1951, 1955, and at least partially in 1961 (Figure 2): slopes are consistently either much greater or much less than 0 during these two periods. From June through mid-July, however, deviations are typically small, as reflected in Figure 2 by the flat slope of the d_n function.

To examine this more thoroughly we devised an index reflecting the variability in temperature regime during different periods of the summer: after determining the average temperature for each of eight 15 day periods for each year, we then calculated the variance in mean temperatures for each period over the 25 year data span. Seasonal change in the value of this index is presented in Figure 3.

The suggestion of a seasonal pattern in temperature variability is clearly borne out by this analysis: May and August show high levels of variability, while June and the first part of July are relatively uniform. In other words, temperature regimes at Barrow fluctuate markedly between years during some parts of the season but not during others, inducing a seasonal variation in weather predictability. During the height of breeding in mid June, environmental conditions are relatively predictable, insofar as they are determined by prevailing temperatures. In contrast, it appears that much of the Arctic's striking variability is concentrated in a period when birds are dependent upon littoral resources from late July through August. This may be a major consideration in assessing their ability to respond to altered environmental circumstances.

Some appreciation for the factors contributing to this pattern of variability emerged from our exploration of other weather parameters: in essence, they appear to derive from features of Barrow geography: situated at the apex of a point jutting between two major bodies of water, the Beaufort and Chukchi Seas, Barrow is exposed to the vagaries of two important weather producing systems, with rapid shifts in the dominance of local weather from one system to the other. This certainly contributes to the high level of variability. But the seasonal change in variability can be interpreted in more restricted terms as a result of Barrow's coastal position between two areas of markedly different temperature regimes: the Arctic Ocean and the interior coastal plain. As the contrast in temperature between interior and marine environments increases during the summer,

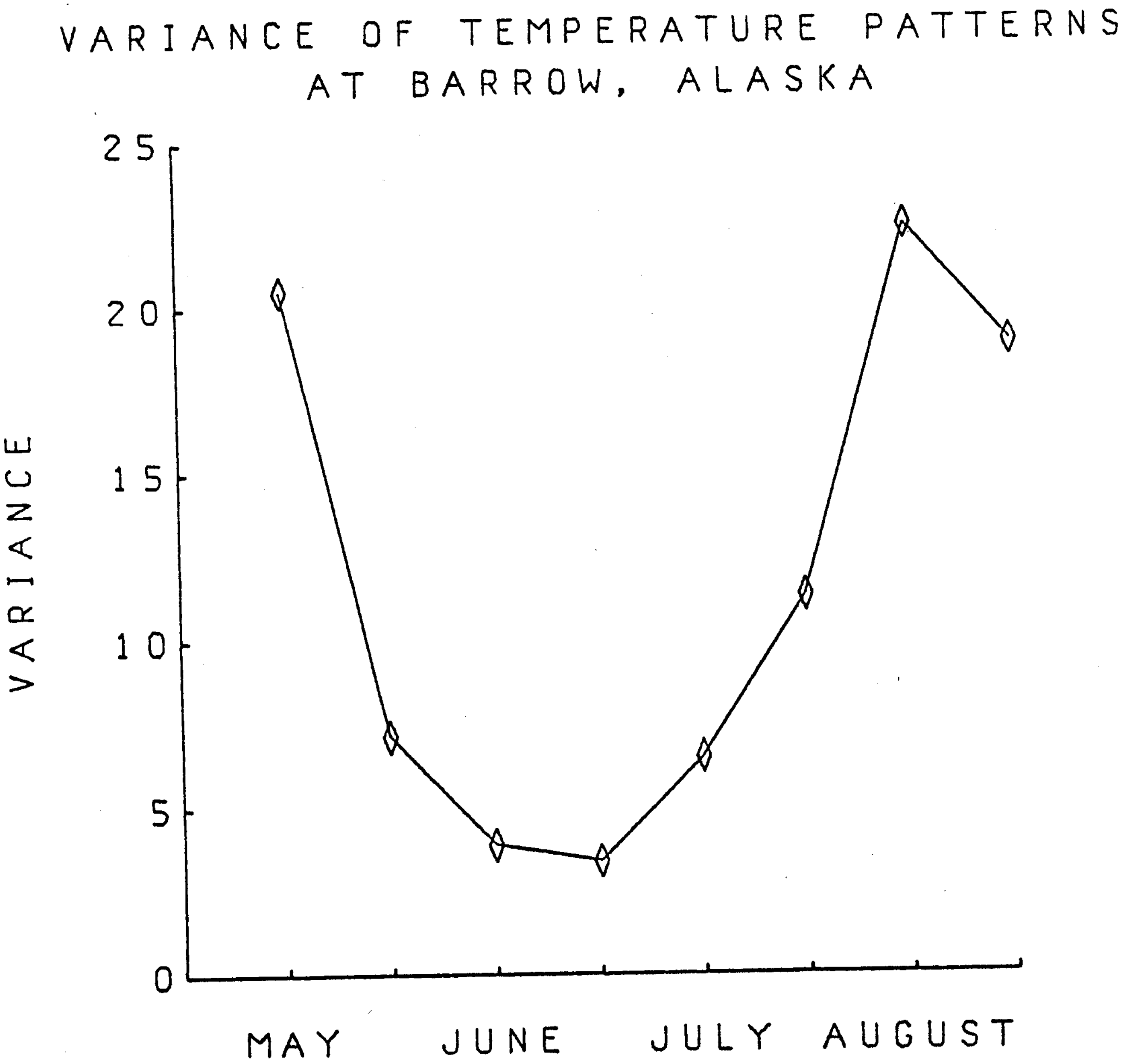


Figure 3. Seasonal pattern in temperature variability at Barrow, Alaska.

the sensitivity of temperature at Barrow to wind direction increases accordingly. This interpretation is supported by the following analyses:

Figure 4 presents four histograms of wind directions recorded at Barrow during different periods of the summer. These are four of the eight fifteen-day periods represented in Figure 3 for temperature variance. Each histogram indicates the number of days during a period over the 25 year data span that the wind was from a given direction. The figure shows that during early May, most winds blow from the east,. while by August a distinct bimodality develops in the distribution. The shift from unimodality in early summer implies that wind directions are less predictable as the season progresses.

Not only does the distribution of wind direction change seasonally, but so does the dependence of temperature on wind direction: Presented with the histograms in Figure 4 is an indication of the average temperature of winds blowing out of each direction during a given period. For example, during early August, winds from the southeast are accompanied by temperatures on the order of 50^{o}, while those from the west are much colder, averaging 37^{o}. Within this period, the strong peak in temperature across wind direction reflects the degree to which temperatures are sensitive to changes in wind direction: a shift in direction from SE to W would be accompanied, on the average, by a change of 13^{o} in daily mean temperature. In contrast, early June temperatures are relatively insensitive to wind direction.

Thus, as for overall patterns in temperature variability (Figure 3), we again have a seasonal pattern of changing levles of variability. Figure 5 summarizes this trend by considering the variance in temperature across wind direction during the eight 15 day periods used in Figure 3. This variance reflects the variation in temperature between wind directions within each period. This seasonal change in variance documents the qualitative picture obtained from the histograms in Figure 4: early in the season, particularly in June, temperature does not change with wind direction but by mid-August it shows extreme sensitivity. The similarity between Figures 3 and 5 suggests that this late summer sensitivity of temperature to wind direction may be a major factor contributing to the overall pattern of temperature variability.

Figure 6 emphasizes the geographic basis for this interpretation, showing a polar histogram of wind directions during the first fifteen days in August. We have plotted two classes of days: those exceeding and those less than the average daily temperature by more than one standard deviation. It is obvious that these two temperature-defined classes are characterized by very different wind directions. Warm days typically occur when winds blow from the S or SE, that is, when they are from the well-insolated interior. Winds off either the Chukchi or Beaufort Seas (W to NE) are colder. The contrast in temperature between these two areas should be strongest in August, and certainly greater then than in June before the interior has been warmed by prolonged summer insolation. This changing degree of temperature contrast contributes substantially to the increased variability in August temperatures.

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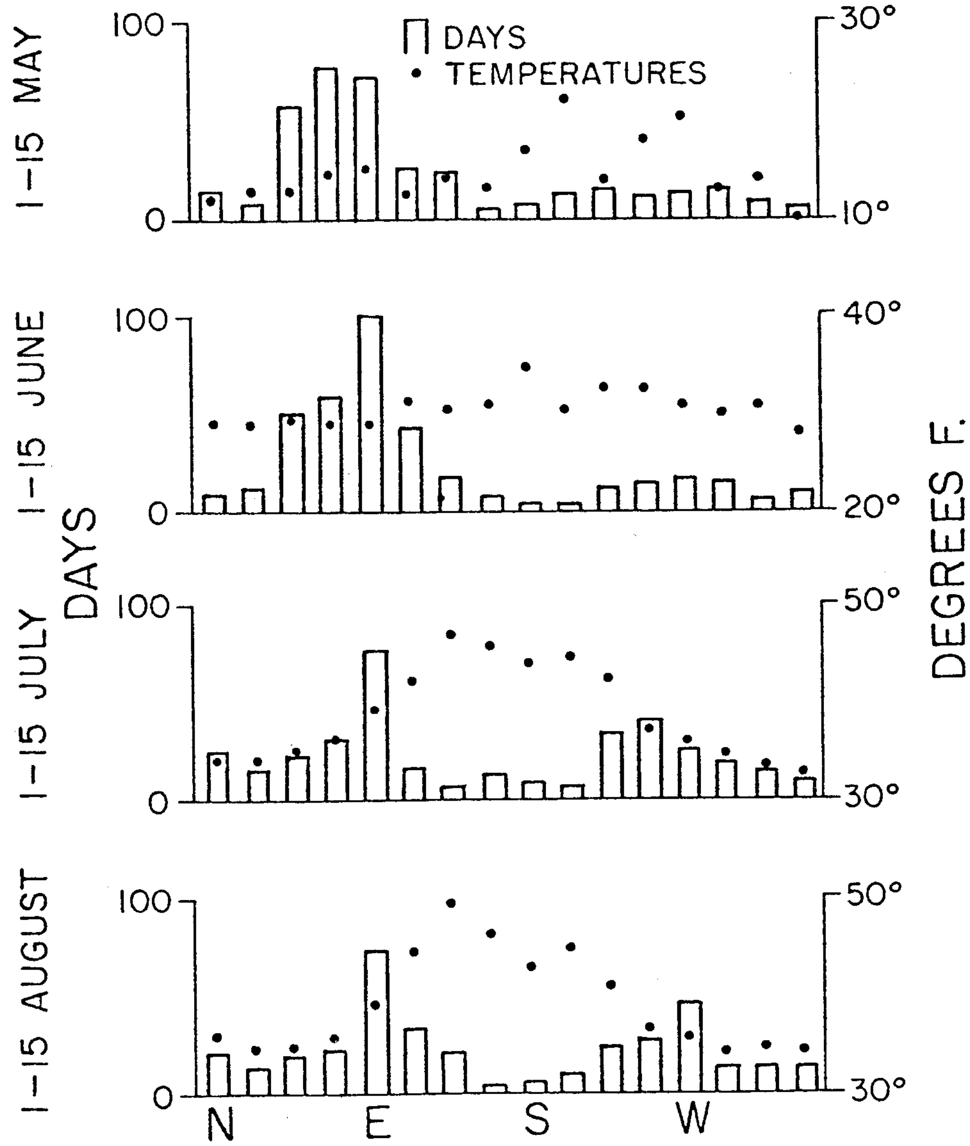

Figure 4. Distribution of wind directions and their associated temperatures during different periods of the summer at Barrow, Alaska.

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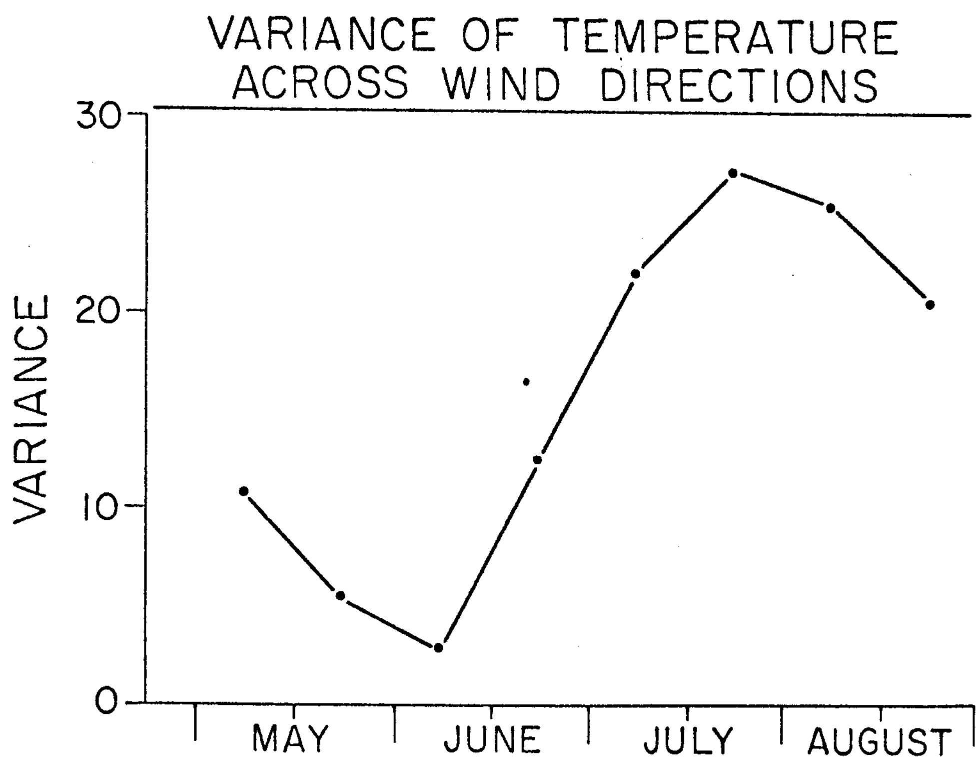

Figure 5. Seasonal changes in the sensitivity of temperature to wind direction at Barrow, Alaska.

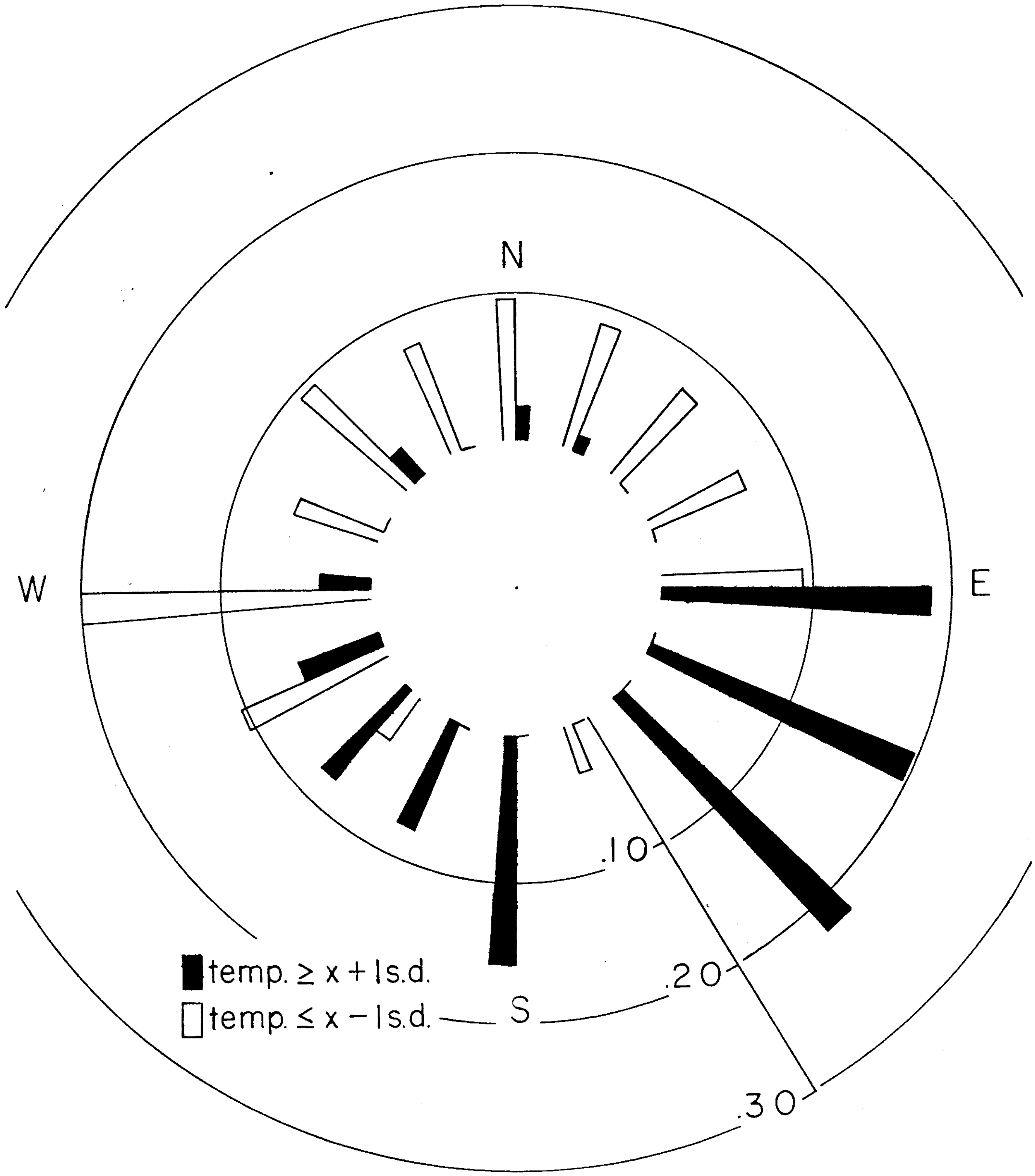

Figure 6. Polar histogram of wind directions for warm vs. cold days, August 1-15.

Appendix D. Comparison of Prey (Stomach and Esophagus Contents) and Plankton/Benthic Infaunal Samples

In the tables, esophageal and stomach contents are shown separately. Neither number, size, nor percent of total mass are indicated if the stomach contents were too macerated, digested, or fragmentary, although in intermediate conditions estimates were made. Prey items are contrasted in the opposite column to plankton or benthic samples; if taken at different times or places, this is noted separately. Species in plankton and benthic samples are arranged in order of decreasing density. Plankton or benthic samples are not repeated if presented once in the table; cross-reference is made to these. Comparative analyses are presented in the text.

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
SANDERLING (*Calidris alba*)								
1	e+s: Chironomid larvae	435	6-9	95	1	Benthos:		
BP	Collembola	2	2	--	BP	Chironomid larvae	90%	5-9
10 Jun	seeds	20	1-4	5	10 Jun	Other dipteran larvae	10%	10
56	e: *Thysanoessa raschii*	4	15	50	56	Plankton:		
BSS	*Apherusa glacialis*	6	10-12	50	BSS	*Sagitta elegans*	35	4-18
10 Aug					10 Aug	Calanoids - large	10	3+
	s: crustacean frags.	--	--	55		Calanoids - small	18	1-1.5
	Thysanoessa	c.13	c.11	33		*Oikopleura* sp.	14	5-7
	Apherusa	c.14	8	12		Rare: decapod zoea, barnacle cyprids, barnacle nauplii, adult Diptera, medusae, *Spiratella*		
	Decapod zoea	1	4	--				
	Insect head	1	1	--				
63	e: chironomid head	1	1.5	--	64	Plankton:		
WB					WB	Calanoid copepods	15	1-2.2
12 Aug	s: crustacean tissue; no identifiable items	--	--	--	12 Aug	*Thysanoessa raschii*	11	16-18
						Rare: barnacle cyprids, *Sagitta*, medusae, decapod zoea		
67	e: empty				71	Plankton:		
BSS	s: digested crustacean tissue (incl. *Thysanoessa*)			100	BSS	Calanoids - large	3	3
14 Aug					15 Aug	Calanoids - small	30	1-1.2
						Rare: decapod zoea, cyclopoids		

(One day later)

Refer also to sample 56, above (4 days earlier)

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
SANDERLING (cont.)								
79	e: *Thysanoessa raschii*	2	9	100	69	Calanoids - small	32	1-1.2
WS			(post.)		WS	Decapod zoea	19	5-7.5
17 Aug	s: *Thysanoessa*	3	c.12	80	15 Aug	Rare: *Clione*, cyclopoids, *Thysanoessa* ($1.6/m^3$)		
	calanoid copepods	1	4					
	plant seeds	12	2)	20	(two days earlier)			
	?chironomid heads	3	1					
					87	Cyclopoid copepods	18	1.5
					WS	Rare: barnacle cyprids, *Thysanoessa* ($3/m^3$), *Onisimus litoralis*, decapod zoea, adult Diptera, spiders		
					20 Aug			
					(three days later)			
82	e: *Thysanoessa raschii*	27	18-22	100	70	*Sagitta elegans*	14	5-13
PS					PS	Rare: calanoids, barnacle cyprids, cyclopoids		
17 Aug	s: *Thysanoessa*	c.37	18-22	99	15 Aug			
	?chironomid head fragments	c.8	1-1.2	1	(two days earlier)			
					89	Barnacle cyprids	11	1
					PS	Rare: decapod zoea, calanoids, cyclopoids, harpacticoids		
					20 Aug			
					(three days later)			
120	e: empty				Refer to sample 114 (at Red Phalarope 118)			
WB								
30 Aug	s: crustacean tissue	--	--	--				
	seed	1	1.5	--				

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
SANDERLING (cont.)								
122 WB 30 Aug	e: empty				As above			
	s: small amount of amorphous debris, and one 6mm post. _Thysanoessa_ frag.	--	--	--				
125 WB 30 Aug	e: _Thysanoessa_ frag.	--	--	--	As above			
	s: _Thysanoessa_ frags.	c.4	10-14	100				
BAIRD SANDPIPER (_Calidris bairdii_)								
44 BD 1 Aug	e: _Onisimus litoralis_	5	6	100	Refer to sample 43 (at Red Phalarope 43)			
	s: _Onisimus litoralis_	c.60	6	100				
WESTERN SANDPIPER (_Calidris mauri_)								
3 VC 1 July	e+s: Chironomid larvae	80	6-10	100	6 VC 1 July	Benthos:		
						Chironomid larvae	--	5-6
						Oligochaeta	--	6

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
DUNLIN (*Calidris alpina*)								
45 NSL 3 Aug	e: Chironomid larvae	1	16	100	45 NSL 3 Aug	Benthos: (2 samples)		
	s: Chironomid larvae	36+	5-15	100		Chironomid larvae	40 - 50%	2 - 8
						Cladoceran ephippia	7.5- 11%	1.2-1.7
						Ostracoda	12 - 25%	.5-1.8
						Copepods	11 - 40%	1 - 2.5
						"*Daphnia*," adults	7.5- 15%	.5
						Oligochaeta	0 - .5%	2
						Notostraca	--	Body,20 Tail,10
46 NSL 3 Aug	e: Chironomid larvae	4	6-11	100	Refer to preceding sample			
	s: Chironomid larvae	16	7-15	100				
57 WB 10 Aug	e: empty				Refer to sample 51 (at Red Phalarope 51)			
	s: *Thysanoessa raschii*	2	13	100	(Note: Sample 51 at WS; no *Thysanoessa* taken in any plankton sample this day)			
60 GF/CB gravel pool 11 Aug	e: Oligochaeta (about 13 more, macerated)	2	c.13?	100	60 GF/CB gravel pool 11 Aug	Benthos: (gravel/mud)		
						Oligochaeta	98%	4-15+
	s: amorphous white debris	--	--	--		Harpacticoid copepods	2%	.5-1.

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
DUNLIN (cont.)								
61 GF/CB gravel pool 11 Aug	e: empty				61 GF/CB gravel pool 11 Aug	Benthos: (gravel/mud)		
	s: amorphous white debris	--	--	--		Oligochaeta	99%	4-15
						Collembola (surface)	--	--
80 WS 17 Aug	e: <u>Thysanoessa</u> <u>raschii</u>	1	frag.	--	No sample; <u>Thysanoessa</u> at WS 15 Aug: $1.6/m^3$ (No. 69), on 20 Aug: $3/m^3$ (No. 87).			
	s: <u>Thysanoessa</u>	16	15	100				
83 Peard Bay 19 Aug	e: empty				83 Peard Bay 19 Aug	Benthos: (sand/gravel)		
	s: medium amount of macerated <u>Thysanoessa</u>, incl. 2 frags.	--	--	100		Rare: Oligochaeta	--	.6
						Cyclopoid Copepods	--	.5
						Tardigrades	--	.5
						Nematodes	--	2.0
						Ostracods	--	.5
						Also present: <u>Onisimus</u> <u>litoralis</u>		

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
DUNLIN (cont.)								
84 Peard Bay 19 Aug	e: empty				84 Peard Bay 19 Aug	Benthos (intertidal mud-flat):		
	s: digested oligochaetes	10?	--	100		Oligochaeta	90%	5-10
	seed	1	2	--		Rare:		
						Tardigrades	--	.5
						Cyclopoid copepods	--	.5
						Nematodes	--	1.0
						Onisimus litoralis	frags.	
						Alderia (opisthobranch)	(one)	2.0
						seeds	--	2.0
						Sample consists of matted green algae, fine sand, and small gravel		
85 Peard Bay 19 Aug	e: *Onisimus litoralis*	2	6	100		Refer to preceding sample		
	s: *Onisimus litoralis*	7	6	90				
	amphipod and insect tissue, digested	--	--	10				
86 Peard Bay 19 Aug	e: *Thysanoessa raschii*	2	16	100		Refer to Sample 83, above		
	s: *Thysanoessa*	7	15	100				
	seed	1	1	--				

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
SEMIPALMATED SANDPIPER (<u>Calidris pusilla</u>)								
29	e: Hymenoptera, adult	1	3	20	29	Benthos: (plant frags.,		
VC	Diptera, adults				VC	detritus, chironomid		
29 July	(Chironomidae,				29 July	mud tubes)		
	other family)	2	1.2,2.5	20		Chironomid larvae	98%	4-7
	Diptera,					Calanoid copepods	1%	1-1.5
	Chironomid larva	1	c.3	20		Oligochaeta	1%	10
	Cyclopoids	1	2	20		Ostracoda	--	1
	Collembola	2	1.5	20		Ephippia	--	1.5
	s: Chironomid larva	29	3.5-15	80				
	Diptera, adults	6	1.5-3.2	19				
	Copepoda, frags.	2	1(frag.)	.5				
	Ephippia	3	2	.5				
30	e: Chironomid larvae	2	6	100	30	Benthos: (sand, gravel)		
BP	Chironomids, adult	2	2-3		BP	Chironomid larvae	c.90%	3-12
29 July	s: Chironomid larvae	96	5-11	99	29 July	Harpacticoid copepods	c. 8% (1000s)	1
	Insects, adult	2	2(frags)	1		Ostracods	c. 2% (100s)	1
						Nematodes	--(many)	1.1
						Ephippia	--	1.

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
SEMIPALMATED SANDPIPER (cont.)								
33 BP 30 July	e: empty				33 BP 30 July	Benthos: (black mud below filamentous green algae mats; plant seeds and plant fragments; sand and gravel; some chironomid larvae in mud tubes		
	s: Chironomid larvae	64	to 15	90		Chironomid larvae	94%	3.5-15
	Copepods	6	2	5		Calanoid copepods	1%	2
	Ephippia	5	1-1.2	5		Ostracoda	3%	1-2
						Cladocera ephippia	--	1
						Collembola	--	2
						Oligochaeta	--	3-4
						(Another sample from drier area from shore mud had 50% chironomid larvae, 45% collembola, 4% oligochaetes)		
47 NSL 3 Aug	e: Chironomid larvae	7	5-7	100	47 NSL 3 Aug	Benthos:		
	s: Chironomid larvae	c.14	6-16	100		Chironomid larvae	39%	7-9
	Copepods	c.4	.5-1	--		Oligochaeta	60%	5-12
						Rare: chironomid pupae, copepods, nematodes, tardigrades, egg cases		
88 GF 20 Aug	e: empty				88 GF 20 Aug	Benthos:		
	s: Calanoid copepods	200-300	2	100		Calanoid copepods	(abundant)	c.2

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
RUDDY TURNSTONE (*Arenaria interpres*)								
31 BP 29 July	e: Chironomid larvae	2	6	100	31 BP 29 July	Benthos: (thick algal mat, mud, sand)		
	Insecta: wings	2	2			Chironomid larvae	99%	3.5-12.5
	s: Chironomid larvae	63	3-6	99.5		Collembola	each c. .3%	2.0
	Insecta: wing frags.	3-4	2-3	.5		Ostracoda		1.2
						Ephippia		1.0
34 BP 30 July	e: Chironomid larvae	1	6	100	34 BP 30 July	Benthos: (mud, sand, gravel, filamentous algae)		
	s: Chironomid larvae	3	5	--		Chironomid larvae	97%	3-18
	(Stomach "packed" with sand and green algae fragments, and virtually nothing else)					Ephippia	2+%	1-2
						Ostracoda	--	1
						Collembola	--	1-2
53 PS 10 Aug	e: *Thysanoessa raschii*	10	c.10	100	53 PS 10 Aug	Plankton:		
	s: amorphous debris of (?) euphausiid and insect frags.	--	--	--		Harpacticoid Copepods	32	1.2
						Barnacle cyprids	18	1.0
						Calanoids -- small	18	1.0
						Rare: *Onisimus litoralis*; other copepods decapod zoea, collembola, medusae		

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
RUDDY TURNSTONE (cont.)								
62 GF/CB gravel pool 11 Aug	e: Oligochaeta s: amorphous material (digested oligochaetes?)	c.16 --	5-8 --	100 --	62 GF/CB gravel pool 11 Aug	Benthos: (coarse gravel, mud) Oligochaeta Rare: ostracods, copepods, collembola, ephippia	 99+%	 2-15
68 BSS 14 Aug	e: <u>Thysanoessa raschii</u> s: pycnogonid crustacean frags., euphausiid frags., ?amphipod frags.	c.23 1 --	15 4 --	100 -- 100	71 BSS 15 Aug (One day later)	(See at Sanderling 67)		
81 WS 17 Aug	e: <u>Thysanoessa raschii</u> s: <u>Thysanoessa</u> Chironomid head frags.	50 4 8	14-17 c.15 1.2	100 90 10	Refer to Sample 69, 15 Aug (2 days earlier) at Sanderling 79 Refer to Sample 87, 20 Aug (3 days later) at Sanderling 79			

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
RED PHALAROPE (*Phalaropus fulicarius*)								
43	e: *Onisimus litoralis*	56	6	98	43	Plankton:		
BD	other amphipods	c.5	4-12	2	BD	Barnacle cyprids	191	1.0
1 Aug					1 Aug	Cyclopoid copepods	182	1.0
	s: *Onisimus litoralis*	c.100	6	100		*Onisimus litoralis*	58	6-7
						Rare: other amphipods, other copepods, decapod zoea, barnacle nauplii, medusae, *Spiratella*, cumacea		
51	e: empty				51	Plankton:		
WS	s: amorphous organic material				WS	Decapod zoea	73	3-5
10 Aug					10 Aug	*Sagitta elegans*	48	15-22
						Cyclopoid copepods	23	2
						Calanoid copepods	11	1
						Rare: *Spiratella*		
52	e: Decapod zoea	2	--	--	Refer to preceding sample			
WS	Gammarid amphipod	1	frag.	--				
10 Aug	s: Decapod zoea	15	3-4	100				
	unrecognizable material							

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
RED PHALAROPE (cont.)								
54 BSS 10 Aug	e: eggs?	23	.5	33		Refer to sample 56, below		
	Cladoceran ephippia	9	1-1.2	33		(Note: While taken on the ocean, this bird had evidently been feeding on or near the Nuwuk tundra ponds)		
	Blue-green algae	4 (balls)	1-2	33				
	s: eggs?	8	.5	10				
	ephippia	9	1-1.2	30				
	Blue-green algae	5-6	1-2	30				
	insect frags.	--	--	10				
55 BSS 10 Aug	e: empty				56 BSS 10 Aug	Sagitta elegans	34.9	4-18
	s: Thysanoessa raschii	1	frag.	--		Calanoids -- large	9.5	3+
	Gammarid	1	frag.	--		Calanoids -- small	17.5	1-1.5
	Cladoceran ephippia	9	1	--		Oikopleura	14.3	5-7
	Spiratella helicina small shell frags.					Rare: Decapod zoea, adult Diptera, Spiratella ($3/m^3$), barnacle nauplii and cyprids, medusae		
	unrecognizable material							
65 BSS 14 Aug	e: Decapod zoea	5	4-8	--		Refer to sample 56 above (4 days earlier)		
	Gammarid	1	5(frag)	--		Refer to sample 71 below (1 day later)		
	s: Plant detritus	--	--	90		(Note: While taken on the ocean, this bird had evidently been feeding on tundra ponds, then moved to the shore only shortly before being taken (switch from plant material, cladoceran ephippia, and insects to decapod zoea and amphipods)		
	Ephippia	c.30	1.5	5				
	Crustacean frags.	--	--					
	Gammarid frag.	1	5	)				
	Decapod zoea	2	3	) 5				
	Chironomid head	1	1.5	)				
	Note: plant fibers are in tight matted packs							

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
RED PHALAROPE (cont.)								
66	e: Apherusa glacialis	2	6	100	71	Plankton:		
BSS	s: Apherusa glacialis	c.25	c.6	39	BSS	Calanoid copepods	30	1-1.2
14 Aug	Thysanoessa raschii	c.10	12-15	12	15 Aug	Rare: decapod zoea ($6.3/m^3$; 3-7mm), calanoids (3mm), cyclopoids		
	Decapod zoea	17	4-6	9				
	Crustacean frags.	--	--	40				
	Polychaete frag.	1?	4	--				
76	e: Calanoid copepods	c.50	c.2	100	76	Plankton:		
MSW	s: Calanoids	200-250	c.2	100	MSW	Calanoid copepods	116,388	.5-2
16 Aug					16 Aug			
77	e: Calanoids	75	2	100	Refer to preceding sample			
MSW	s: Calanoids	150-200	2	100				
16 Aug	Ephippium	1	1	--				
90	e: Spiratella helicina	1	frags.	--	90	Plankton:		
BSS	s: Spiratella	5-6?	frags.	90	BSS	Decapod zoea	37	3+
20 Aug	Seeds	13	1.5-4	10	20 Aug	Sagitta elegans	16	c.10
						Hyperiid amphipods (some on medusae)	11	1.5
						Rare: Onisimus litoralis, copepods, barnacle cyprids, Spiratella ($3/m^3$), medusae		

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
RED PHALAROPE (cont.)								
91	e: *Sagitta elegans*	8	13-17	45		Refer to preceding sample		
BSS	*Spiratella helicina*	4	4	45				
20 Aug	Decapod zoea	2	4,7	5				
	Gammarid	1	5	5				
	s: *Sagitta elegans*	3	7-8	10				
	Spiratella helicina	4	3-4	60				
	Decapod zoea	c.4	5-8	20				
	Polychaete frag.	1	10)					
	Gammarid	1	frag.)	10				
	Seed	1	1)					
101	e: *Apherusa glacialis*	4	6-10	100	107	Plankton:		
TW					BSS	Calanoid copepods	6	1.2
24 Aug	s: *Apherusa glacialis*	c.17	6-10	100	25 Aug	Rare: (all less than $3/m^3$) Calanoids (3mm), harpacticoids, barnacle cyprids, decapod zoea, gammarids		
102 TW	e: empty							
24 Aug	s: *Apherusa glacialis*	7-9	--	99+				
	seeds	1-2	1-2	--				

(Note: Birds 101 and 102 had been feeding in zone of grounded ice, in waves about 16 inches high)

(Note: One day later than bird; no ice at 107; sample 98, BSS (22 Aug) also had no ice and no *Apherusa*)

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
RED PHALAROPE (cont.)								
109 GF 25 Aug	e: Calanoid copepods	c.25	2	--		No sample; calanoid copepods observed swimming in water.		
	Chironomid larvae	1	3(frag)	--				
	Seeds	3	2-5					
	s: Calanoids	c.200	2	98				
	Chironomid larvae	c.5	5-6	--				
	Seeds	4	1-2	--				
	Blue-green algal ball	1	1.5	--				
(Note: bird was pecking very rapidly at pool surface)								
118 WB 30 Aug	e: empty				114 WS 30 Aug	Plankton:		
	s: Chironomid heads?	2	1	--		Barnacle cyprids	110	1.
	Seeds	4	2	--		Cyclopoid copepods	54	1.5
	Unrecognizable material					Calanoid copepods	46	3.0
					(Note: different loc.)	Rare: medusae; decapod zoea ($6/m^3$; 4-6mm), harpacticoids		
119 WB 30 Aug	e: empty					Refer to preceding sample		
	s: seeds	6	1-3	30				
	amorphous material, incl. some crustacean frags.	--	--	70				

Sample No. Loc. Date	Esophagus(e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
RED PHALAROPE (cont.)								
121	e: empty				Refer to sample 114 (at Red Phalarope 118)			
WB	s: seeds	2	2	--				
30 Aug	some crustacean debris, incl.:							
	Decapod zoea	2	2.5	--				
	Thysanoessa?	1	3, frag.	--				
123	e: empty				Refer to sample 114.			
WB	s: empty: amorphous organic material, and about 30 (3mm) sand grains							
30 Aug								
124	e: Decapod zoea	1	4	--	Refer to sample 114.			
WB	s: Decapod zoea	5	4-6	95				
30 Aug	Crustacean frags.	--	--	5				
127	e: empty				No sample; calanoid copepods observed swimming in water.			
GF	s: Calanoids	200-300	1	95				
2 Sept	Seeds	4-5	1.5-2	5				
128	e: Calanoids	2	1	--	As above			
GF	s: empty							
2 Sept								

Sample No. Loc. Date	Esophagus (e) Stomach (s)	No.	Size (mm)	%Total Mass	Sample No. Loc. Date	Plankton/Benthos (Rare = less than $10/m^3$)	$\#/m^3$ (or %)	Size (mm)
LAPLAND LONGSPUR (Calcarius lapponicus)								
74 BP 16 Aug	e: plant seeds	c.200	1.5	--	No sample			
	Chironomid larvae	1	6	--				
	s: plant seeds	c.350	1.5	--				
75 BP 16 Aug	e: plant seeds	c.100	1.5	--	No sample			
	s: plant seeds	c.250	1.5	--				
SNOW BUNTING (Plectrophenax nivalis)								
35 BP 30 July	e: empty				No sample			
	s: plant seeds	c.600	1.2-1.5	100				
	(also several 100 sand grains, to 3mm)							
36 BP 30 July	e: plant seeds	40	1-2	100	No sample			
	s: plant seeds (also about 200 sand grains)	c.300	c.1	100				
	crop: plant seeds	c.1500	1-2	--				
	adult insect frag.	1	3	--				

Appendix E . Systematic List of Zooplankton Collected at Barrow, 1976.

COELENTERATA
  Scyphomedusae (several species)
  Hydromedusae (several species)

CTENOPHORA
  Beroe cucumis Fabricius (observed, not collected)

ANNELIDA
  Polychaeta
    adults and larvae, undet.

MOLLUSCA
  Gastropoda: Prosobranchia?: unident. veligers
  Gastropoda: Opisthobranchia
    Thecosomata
      Spiratella helicina (Phipps)
    Gymnosomata
      Clione limacina Phipps

ARTHROPODA
  Crustacea
    Mysidacea, sp. undet.
    Cumacea, sp. undet.
    Copepoda: Cyclopoida (spp.)
      Calanoida (including Calanus spp. and C. glacialis Jaschnov)
      Harpacticoida
    Cirripedia: Balanus crenatus (cyprids and nauplii)
    Isopoda: Idoteidae: sp. undet.
      Bopyridae: sp. undet. (larva)
    Amphipoda: Gammaridea: Apherusa glacialis (Hansen)
      Onisimus litoralis Kroyer
      Acanthostepheia sp., cf. A. incarinata Gurjanova
      Gammarus sp.
      undetermined species
    Hyperiidea: Parathemisto sp.
    Euphausiacea: Thysanoessa raschii (Sars)
    Decapoda: (zoea)

CHAETOGNATHA
  Sagitta elegans Verrill

APPENDICULARIA
  Oikopleura sp.

PISCES
  Fish, larva and eggs

Non-planktonic organisms taken in net:
- Insecta: Diptera (Chironomidae, larvae, pupae, and adults, and other families), Collembola
- Arachnida, Hydracarina
- Crustacea: ostracod valves, cladoceran ephippia (blown in)
- Mollusca: Bivalvia, sp. undet. (nepionic); gastropod opercula
- Annelida: Oligochaeta
- Protozoa: Foraminifera (benthic)
- Plants: numerous seeds

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XIII. Research Personnel, 1976 Season

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THE DISTRIBUTION, ABUNDANCE AND FEEDING ECOLOGY OF BIRDS ASSOCIATED WITH PACK ICE

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Table of Contents

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

This study attempts to determine the distribution, abundance and feeding ecology of birds associated with the pack ice in the Bering, Chukchi and Beaufort seas. Information obtained on cruises next to the pack ice shows the winter Bering Sea ice edge to be of great importance to large numbers of birds. When the ice edge is in the Chukchi and Beaufort seas in summer far fewer birds are found in the ice. In these two seas bird densities are highest in nearshore waters.

Potential negative impacts of OCS development would be most severe in the Bering Sea ice front in winter. Oil spills in the Arctic Ocean would have much less immediate impact unless they occurred in nearshore waters. Slow degradation of oil in the Arctic could cause low mortality over a long period of time, however.

II. Introduction

A. General nature and scope of study

Sea ice represents a unique marine habitat. Acting as a barrier between the air and water, it has a wide range of effects on seabirds. Ways in which sea ice decreases seabird numbers include:

1. Decreasing the amount of open water available for feeding and roosting.

2. Lowering primary productivity in the water column by decreasing the depth of the euphotic zone and preventing wind mixing.

3. Reducing benthic prey by scouring the bottom in shallow water.

Ways in which sea ice can enhance bird numbers include:

1. Providing a roosting space for species that normally roost on solid substrates.

2. Providing a matrix for an in-ice phytoplankton bloom.

3. In areas of multi-year ice, providing a substrate for an under-ice community of zooplankton and fish.

4. Decreasing wind speeds and sea surface disturbance in the immediate vicinity of ice.

This research unit is designed to assess the effects that sea ice has on the distribution, abundance and feeding ecology of seabirds in the Bering, Chukchi and Beaufort seas. Field work is carried out primarily on icebreakers and vessels reinforced against ice. Information on distribution and abundance is obtained through systematic observations made while the ship is moving. All bird densities are correlated with ice and other oceanographic conditions. Feeding ecology is studies by analyzing stomach contents of birds collected during cruises and also by observing feeding behavior during the observation periods.

B. Specific Objectives

The specific objectives of this study are:

1. To determine the distribution and abundance of seabirds found in the open water south of the pack ice, at the ice edge and in the pack ice. Densities in the pack ice are analyzed with regard to ice type and amount of ice cover.

2. To determine the role that pack ice plays in the yearly cycles of seabirds and identify those species that are most dependent on the pack ice environment.

3. To determine the feeding habits of the seabird species associated with the pack ice.

C. Relevance to problems of petroleum development

The ice environment of the Bering, Chukchi and Beaufort seas will present problems unique to the exploitation of oil and gas reserves under these waters. Technical means have not been developed to keep moving pack ice from affecting oil platforms. Underwater pipelines transporting oil to the mainland will be in danger of rupture by keels on ice floes. For these and a number of other reasons, the occurrence of an oil spill or similar major disturbance is more likely in the pack ice than in ice-free waters.

When a spill occurs the impacts on marine organisms associated with the pack ice probably will be more severe and longer-lasting than the impacts on biological systems in warmer waters. Water temperatures adjacent to the ice are usually near 0° C and biodegradation of oil occurs very slowly at such low temperatures. Oil spreading out on the underside of ice can be incorporated into it and affect the in-ice algae bloom and associated fauna. Oil spilled directly into leads will foul the limited amount of open water available to birds deep in the pack ice.

The birds found in and next to the pack ice will be severely impacted by oil spills. Birds are typically one of the most obvious and immediate victims of oil spills. Direct mortality is caused by oil fouling feathers resulting in loss of insulation, stress and possible ingestion of oil. More subtle effects are caused by the impacts of oil on the lower levels of trophic webs. Seabirds are at the terminal end of the marine food chain and thus are sensitive to any changes that occur at lower levels.

Research on seabirds in coastal areas (R.U. 3/4) has centered on delineating critical habitat so that precautions can be taken to minimize the impacts in these areas. The pack ice is too dynamic, however, to allow the designation of specific geographic areas as critical habitat. Critical habitat in the ice environment has to be defined in terms of distance to ice edge, amount and type of ice cover, water temperature, etcetera. These factors are constantly changing during ice formation and deformation. This project will provide pre-development information on the distribution and abundance of birds in relation to these parameters and allow the development of a predictive model. Impacts of development on pack ice birds can then be measured using the information gathered by this project.

III. Current state of knowlege

Previous studies that attempted to correlate ice with bird distribution are few. Frame (1973) reported on bird observations in the Beaufort Sea in summer. He only counted followers however and his work is not directly comparable to this project's. Watson and Divoky (1972) present information on birds next to and south of the pack ice in the Chukchi Sea in September and October. Irving et al. (1970) presented general information on birds at the Bering Sea ice edge in March.

Published accounts of pelagic observations in and next to the ice that do not deal specifically with ice in relation to bird distribution include Watson and Divoky's (1974) observations in the Beaufort and Jacque's (1930), Nelson's (1883) and Swartz's (1967) observations in the Chukchi. Unpublished pelagic observations deep in the Bering Sea pack ice were made by Divoky in March 1973.

The feeding habits of birds in and next to the pack ice are poorly known. The only applicable studies are those of Watson and Divoky (1972) and Divoky (1976) who report on prey items and feeding behavior of birds at the Chukchi ice edge in September.

IV. Study area

The three seas covered by this project differ greatly in their amount and type of ice cover and their importance to seabirds. The following is a discussion of the marine and ice environment in each of these seas.

Bering Sea - Ice begins to cover the northern Bering Sea in late November. Ice coverage is at a maximum in February and March when the southern edge of the ice is usually found near the edge of the continental shelf. Decomposition of the pack ice begins in late April and continues until mid-June. This period (approximately six months) of ice cover is quite short compared to the Chukchi and Beaufort seas where some ice is present throughout the year. Because almost all of the ice in the Bering Sea is first year ice it lacks the extensive keels and pressure ridges found on ice in the Arctic. While the Bering Sea ice supports an in-ice photoplankton bloom (McRoy and Goering 1974) it is not known to have an under-ice fauna associated with its underside.

The Bering Sea ice "front" refers to the area of loose ice south of the more consolidated pack. It is composed primarily of bands of ice pans. Large floes are prevented from forming by swells on the open water to the south. When the wind is from the south the front is compacted against the main pack ice in a narrow band. When the wind is from the north the front becomes wider and more diffuse. In spring primary productivity is high in the water column under the ice front. At the same time productivity in the water column under the consolidated pack and south of the ice front is low (McRoy and Goering 1974). For this reason the ice front is an important biological area supporting large numbers of birds and mammals (Fay 1974).

Another feature of the Bering Sea pack ice of importance to birds is the open water associated with the islands found in the pack ice. These areas of open water (polynyi) are formed by the northerly winds which concentrate ice on the north side of islands and move ice away from the southern sides. These polynyi act as refugia deep in the pack ice.

The Bering Sea differs from the two Arctic seas studied by this project in that it has a high level of biological productivity. This is demonstrated by the large fishery the Bering Sea supports and by the large number of breeding and non-breeding birds present in summer.

Chukchi Sea - Ice covers the Chukchi Sea from November to May and coverage is almost complete during this period. Exceptions are the area of broken ice in the Bering Strait, a polynya associated with the shoreline in the Point Hope area (Shapiro and Bruns 1975) and a lead system northwest of Point Barrow. In late May the ice in the southern Chukchi Sea begins to decompose and most of the area south of Cape Lisburne is ice free by July. The edge of the Arctic pack ice is present in the northern Chukchi throughout the summer occurring anywhere between 70° and 72° N.

The ice in the Chukchi Sea apparently supports an in-ice algae bloom similar to those found in the Bering and Beaufort seas. The multi-year ice in the Chukchi is known to support an under-ice fauna of zooplankton and arctic cod. The underside of multi-year ice has numerous keels and pockets which create a large surface area. Amphipods are known to concentrate on the ice underside presumably obtaining food from the plankton blooms occurring in and on the underside of ice (Mohr and Geiger 1968; MacGinitie 1955). Arctic cod prey on the amphipods and other zooplankton found next to the ice. The underside of multi-year ice is thus similar to a reef in that it has fish and invertebrate populations associated with a substrate. Little is known about this community. It is present in the spring and summer but nothing is known about the winter situation.

The water flowing north through the Bering Strait is a major influence on the Chukchi Sea. This water is warmer than Arctic waters and is the main reason for the rapid decomposition of ice in the southern Chukchi Sea. This water also supports high levels of primary productivity in summer (McRoy et al. 1972) and makes the southern portion of the Chukchi Sea the most biologically productive waters in the Arctic Ocean off Alaska.

Beaufort Sea - Ice covers much of the Beaufort Sea for almost twelve months of the year. The amount of open water present in the summer is dependent on wind and weather conditions. Adjacent to the coast strips of open water is present from approximately June to October; its width is dependent on the wind with south winds moving the ice offshore and north winds pushing the ice inshore. The pack ice present in the northern Chuckchi and Beaufort Sea in summer contains much open water between ice floes. Thus even in areas deep in the permanent pack ice there is open water available to birds in summer.

The Beaufort Sea supports an in-ice plankton bloom followed by a bloom in the open water. The Beaufort Sea is characteristic of arctic waters with productivity being reduced due to the lack of upwelling or mixing. Because of this the Beaufort is the least productive of the three seas studied by this project.

V. Sources, methods and rationale of data collection.

Data reported on in this report were gathered on the following cruises:

Ship	Dates	Locations	# of 15 min.obs.	Figure #
USCGC GLACIER	30-31 July 1975	Northern Bering Sea	45	1
USCGC GLACIER	1-26 August 1975	Bering St., Chukchi Sea, Beaufort Sea	450	2,8
NOAA SURVEYOR	15 March-1 April 1976	Bering Sea, Gulf of Alaska	203	3
NOAA SURVEYOR	13-24 April 1976	Bering Sea, Gulf of Alaska	108	4
USCGC BURTON IS.	22-28 July 1976	Chukchi and Beaufort Sea	88	5
USCGC GLACIER	6 August-3 Sept. 1976	Chukchi and Beaufort Sea	282	6,7
R.V. ALUMIAK	19-30 August 1976	Beaufort Sea	135	5
USCGC GLACIER	5-17 Sept. 1976	Beaufort Sea	130	8
NOAA DISCOVERER	10-24 Sept. 1976	Northern Bering and Southern Chukchi Sea	256	9,10
ISCGC GLACIER	20 Sept.-2 Oct. 1976	Chukchi Sea	171	11
USCGC GLACIER	6-12 Oct. 1976	Chukchi and Bering Sea	102	12
		TOTAL:	1970	

A. Methods

Pelagic censusing is conducted from the flying bridge during 15 - minute observation periods. All birds seen in a 300-meter wide transect are recorded. Information is obtained on species, age, sex and activity. Ship followers are recorded once during each observation period but are not included in density computations. Information on oceanographic meteorologic and ice conditions are recorded for each observation period. All pelagic observations are entered on a standard OCSEAP format coding sheet for keypunching.

Specimens are collected with a shotgun from a small boat. Formalin is injected into the birds' esophagus with a plastic tube immediately after the bird is collected. On board ship information on weight, molt, gonad size, and fat deposition is obtained. Stomachs are removed, weighed and preserved in formalin.

Food items present in the mouth, esophagus and stomach are included in the analysis of prey items. All prey items are separated to the lowest possible taxon. Each prey item group is then weighed and volume is computed by displacement. Individuals within a group are measured and counted. Stomach contents information is recorded in a manner that will make it compatible with the results of the work being conducted by Gerald Sanger of the U.S. Fish and Wildlife Service (R.U. 77). Size of fish otoliths were correlated with body length for pollock (Theragra chalcogramma) and cod (Boreogadus saida). Information on otolith to body size relationships for Pollock are from Frost and Lowry (in prep.).

VI. Results

Keypunching of pelagic observations is currently being completed by the Arctic Environmental Information Data Center in Anchorage. No intensive analysis of the data will be possible until keypunching is complete. Steps are being taken to greatly reduce the lag time between the end of a cruise and data analysis. All results presented in this report were extracted from coded data sheets and should be considered preliminary results. No ship followers are included in the bird numbers in the following discussion.

A. Bering Sea - March and April

1. Pelagic observations

The two SURVEYOR cruises provided valuable information from the Bering Sea ice front and the open water south of the front. The SURVEYOR has no icebreaking capability and was not able to penetrate the consolidated ice pack. Most observations in March were made between St. George Island and Bristol Bay (Figure 3). The April cruise was conducted primarily west of the Pribilofs Islands with additional sampling in Bristol Bay (Figure 4). On both these cruises observations were made in the Gulf of Alaska and Unimak Pass while the ship was in transit to and from Kodiak.

Densities, displayed a similar distributional pattern on the two cruises and are presented in Table 2. Bird densities in the ice front were highest. With the average in March ten times that in April. Open water over the continental shelf supported the next highest average densities with March numbers almost three times those found in April. Most of these birds were just south of the ice or at the shelf break. Open water south of the continental shelf had the lowest densities encountered in the Bering Sea. With March densities averaging four times those of April. It is interesting that in both months densities in Unimak Pass were approximately four times the densities in the Bering Sea south of the continental shelf.

The lower April densities are probably due to birds moving inshore to areas near breeding sites. Possibly some of the difference in the densities found in the ice may be due to the geopgraphic location of the cruises. The ice east of the Pribilof Islands may support higher densities than the ice to the west.

In order to determine the importance of the ice front to bird numbers the March and April data were analyzed with respect to the distance to the edge of the consolidated pack ice (northern edge of the front) and distance to the southern ice edge. Satellite photos were used to determine these positions; the edge of the consolidated pack ice is distinguishable where ice cover becomes nearly complete and the southern ice edge is where the southernmost ice is visible. ERTS imagery is usually used for these determinations but is supplemented by NOAA weather satellite photos when no ERTS data are available.

Figures 13 and 14 show the distribution of transects in relation to the two ice edges. Figure 13 shows that few observations were made south of the southern ice edge and that most sampling occurred from the south edge to 50 km into the ice. Figure 13 and all figures showing distances to the southern ice edge show distances within the ice as negative numbers. Figure 14 shows that the area just south of the consolidated pack was intensely sampled.

Total birds

Figure 15 shows that high average densities show no relationship to the southern ice edge but that the high densities occur at scattered points within the ice front. Figure 16 shows that the densities are highest within 20 km of the consolidated pack.

Northern Fulmar (*Fulmarus glacialis*)

Northern Fulmars were seen primarily at the southern edge of the ice and in open water south of the front. Few were seen more than 15 km into the ice front (Figure 17). No relationship between distance to the consolidated pack ice and fulmar densities was found (Figure 18). Densities were highest during April at the shelfbreak west of the Pribilof Islands. Overall fulmars were seen on 22 percent of the transects and when present averaged 29.5 birds per km^2. Almost all fulmars seen in the Bering Sea were light phase while the dark phase predominated in the Gulf of Alaska.

Glaucous Gull (*Larus hyperboreus*)
Glaucous Gulls were found primarily within the ice front where densities averaged less than five per km^2 (Figure 19). An affinity to the edge of the consolidated ice edge was displayed with few birds being seen more than 30 km south of this edge (Figure 20). Glaucous Gulls were most commonly seen west of the Pribilof Islands on the April cruise. This species was seen on 29 percent of the transects and when present averaged 5.7 birds per km^2.

Glaucous-winged Gull (*Larus glaucescens*)
This species was more frequently encountered than the Glaucous Gull but displayed a similar pattern of distribution. Glaucous-winged Gulls were found primarily in the ice front with average densities being rather constant (Figure 21). Few birds were seen more than 90 km south of the consolidated pack ice (Figure 22). Glaucous-winged Gulls averaged 7.4 birds per km^2 when present and were seen on 61 percent of the transects.

Ivory Gull (*Pagophila eburnea*)
This species is one of the few specialized Arctic pack ice species and spends the entire year in proximity to ice. In the Bering Sea this species showed a strong affinity for the ice front with no birds seen south of the ice (Figure 23). Figure 24 shows that the species has little affinity for the consolidated pack ice edge but occurs in a broad band from the north edge of the front to 30 km south of the

consolidated edge. Ivory Gulls were seen on 29 percent of the transects and when present averaged 5.7 birds per km^2.

Kittiwakes (*Rissa spp.*)
~~Both Black~~ legged Kittiwakes (*R. tridactyla*) and Red-legged Kittiwakes (*R. brevirostris*) were seen in the Bering Sea. The former were the more abundant with Red-leggeds being seen only in April. For purposes of this discussion the two species are considered together. Kittiwakes were seen primarily in the ice front although scattered high average densities were encountered south of the ice (Figure 25). They occurred in numbers farther south of the consolidated pack ice than the Glaucous and Glaucous-winged Gulls. Kittiwakes occurred on 63 percent of the transects and averaged nine birds per km^2 when present.

Murres (*Uria* spp.)
Common Murres (*U. aalge*) and Thick-billed Murres (*U. lomvia*) together comprised the majortiy of the birds encountered on both cruises. Murres were present both in the ice front and in the open water south of the ice but had higher densities in the former (Figure 27). These high densities were usually within 15 km of the consolidated pack ice (Figure 28). Murres were present on 87 percent of the transects and averaged 432 birds per km^2 when present.

Most murres seen during the March cruise could not be identified to species. In April Thick-billed Murres were most common west of the Pribilof Islands and Common Murres were most common in Bristol Bay. In March approximately 66 percent were in breeding plumage. In April over 95 percent were in breeding plumage.

Additional species
Fork-tailed Storm-Petrels (*Oceanodroma furcata*) were seen on eight transects. Densities when present averaged 3 per km^2. No affinity to either the ice front or open water was noted.

Black Guillemots (*Cepphus grylle*) were seen only once on transects. The density was 23 per km^2 and was 46 km north of the southern ice edge.

Pigeon Guillemots (*C. columbus*) were seen on one occasion 24 km south of the ice. The density was less than .5 birds per km^2.

Parakeet Auklets (*Cyclorrhynchus psittacula*) were seen on nine transects and averaged 9.8 birds per km^2 on these transects. All sightings occurred in the ice front.

Least Auklets (*Aethia pusilla*) were seen on four transects all near or south of the southern ice edge. Densities averaged 2 birds per km^2.

2. Feeding habits

Pollock lengths given in the following accounts of feeding were obtained by measuring otoliths in the birds' stomachs and comparing them with otoliths from fish of known length. No otolith to body length relationship information is available for capelin (*Mallotus villosus*). Otolith lengths are given in Table 6. Stomach contents discussed below are presented on Tables 5 and 6.

Northern Fulmar

The two Northern Fulmars collected in April both contained squid remains.

Glaucous Gulls

The three Glaucous Gulls collected in April contained pollock averaging 20cm in length.

Ivory Gull

Six Ivory Gulls were collected in March. All contained only pollock. The gulls had been feeding on fish ranging from 8 to 13 cm and averaging 10 cm. Three Ivory Gulls collected in April had been feeding primarily on shrimp *Pandalus* sp. Pollock otoliths were in 75 percent of the stomachs. The otoliths had come from fish of 6 to 20 cm with an average size of 13 cm.

Black-legged Kittiwake

The two Black-legged Kittiwakes collected in March both contained pollock otoliths with one also having capelin otoliths. The birds had been feeding on pollock averaging 7.5 cm. The one Black-legged Kittiwake collected in April contained the remains of a 17 cm pollock and unidentifiable chyme.

Common Murre

Seventeen Common Murres were collected in March. The large volume of food in the stomachs provided a very good picture of the species' diet at the ice edge. Pollock and capelin occurred with equal frequency and volume. The pollock ranged in size from 7.5 to 18 cm averaging 11 cm. The capelin ranged in size from 10 to 14 cm.

The amphipod *Parathemisto* sp. had a high frequency of occurrence (29 percent) but made up less than one percent of the total volume. Stomachs contained 13 *Parathemisto* sp. which ranged in size from 18 to 26 mm and 3 euphausids, all 20 mm in length. The euphausids had probably come from the stomachs of fish since examination of a number of fish stomachs produced a number of euphausids.

In April pollock made up 60 percent of the volume but were present in only 21 percent of the stomachs. Pollock size ranged from 6 to 22 cm and averaged 15 cm. Capelin otoliths were present in one of the April samples.

Parathemisto sp. had a rather high frequency of occurrence (29 percent) but again constituted a rather small amount of total volume (8.2 percent). Euphausids were found in 57 percent of the stomachs and constituted 20.4 percent of the volume. A total of 153 were euphausids ranged in size from 15 to 29 mm.

Thick-billed Murre

In March only two Thick-billed Murres were collected. Both contained only *Parathemisto* sp. Nine individauls in the stomachs averaged 31 mm in length.

In April the nine Thick-billed Murres collected contained primarily pollock. The unidentified fish remains were probably also from pollock. The fish averaged 21 cm and ranged in size from 15 to 27.5 cm. Traces of squid and parathemisto were also present.

Black Guillemot

One of the two Black Guillemots collected in April contained *Parathemisto* sp. The other contained only trace of unidentifiable fish material.

B. Bering Strait

1. Pelagic observations

Although all of our cruises in the Bering Strait occurred at a time when the closest ice was approximately 500 km to the north, we censused birds in the Strait in order to provide a comparison with areas further north in the Chukchi (Figures 1, 2, 10 and 12). Table 1 shows that densities were high in the Bering Strait in early August 1975. Most of the birds seen were breeding birds associated with the colonies at Fairway Rock and Little Diomede. The species most commonly encountered were alcids, primarily murres, puffins and auklets. In mid-September 1976 densities in the Strait were slightly higher and the maximum densities much higher than in August 1975. The September 1976 cruise showed that Short-tailed Shearwaters (*Puffinus tenuirostris*) made up a greater proportion of birds than in August 1975. Whether this difference in species composition is due to a yearly or monthly variation is not known.

Limited observations in the Bering Strait in mid-October 1976 showed densities to be extremely low.

2. Feeding Habits

No analysis has been done on the small number of specimens collected in the Bering Strait in September 1976.

C. Chukchi Sea

1. Pelagic observations

In the Chukchi and Beaufort seas the ocean adjacent to the shoreline is an important migratory pathway for a large number of birds. While the presence or absence of ice near the shoreline has a definite effect on these shoreline migrants it is not the goal of this project to deal intensively with this nearshore phenomenon. Such work falls more logically in R.U. 3/4. Because these shoreline migrants create problems in interpreting densities we have left out of this discussion all sightings in the Barrow area from the Walakpa River to the east end of the Plover Islands. Nearshore migrants are frequently encountered at sea in this area.

July

Limited information was obtained on pelagic distributions in July. A cruise in late July between Peard Bay and Barrow was conducted primarily in heavy ice near shore (Figure 5). Average densities were low (Table 1 and 3) with eiders and murres being the most frequently encountered species. Sample size is too small to show the effect of varying ice cover on densities.

August

The 1975 GLACIER cruise provides the best information on bird densities in and south of the pack ice in the Chukchi Sea. The cruise track covered a large area and the sample size was high.

Densities in open water were found to be three times those in the ice (Table 1). Murres were the most commonly encountered and most abundant birds in open water, being found on 75 percent of the transects and comprising 50 percent of all birds seen. Eiders were the next most abundant group (35 percent of the total) but occurred only on a few transects close to shore. Black-legged Kittiwakes were seen on 36 percent of the open water transects but comprised only four percent of all birds seen. A large number of species was seen in small numbers. Bering Sea alcids and tundra nesting species made up the bulk of this group.

Transects in the ice show that densities remained rather constant in ice of one to six oktas cover (Table 3). Areas censused with this amount of ice cover were usually at the pack ice edge some distance from shore

In ice cover up to and including two oktas Black-legged Kittiwakes comprised 49 percent, murres 17 percent, jaegers 13 percent, Glaucous Gulls 11 percent, and Black Guillemots 9 percent of all birds seen. Loons, Red Phalaropes, Arctic Terns and Tufted Puffins were seen in very small numbers.

In ice of three and four oktas coverage murres comprised 61 percent and Black-legged Kittiwakes 26 percent of all birds seen. Jaegers, Glaucous and Ivory Gulls and Black Guillemots were present in small numbers.

In ice of five and six oktas cover Arctic Terns comprised 50 percent and Black-legged Kittiwakes 12 percent of all birds seen. Loons, Red Phalaropes, jaegers, Glaucous Gulls, murres and Black Guillemots were present in small numbers.

Ice of seven and eight oktas cover had higher densities of birds (Table 3) but this is due in part to the short distance traveled on transects in this coverage. This creates a bias when birds per km^2 are computed. These transects were also close to shore. The two most common species, Arctic Tern (81 percent of all birds seen) and Red Phalarope (13 percent) are both primarily shoreline migrants. Loons, jaegers, Black-legged Kittiwakes, Sabine's Gulls and Black Guillemots were also present.

In August 1976 the GLACIER cruise was in the area west of Peard Bay and northwest of Icy Cape (Figure 6). Censusing was conducted primarily in open water (Table 1) with only ten transects being conducted in the ice. This sample size is too small to allow comparisons between ice and open water.

The principal species seen in open water was the Thick-billed Murre. It constituted 37 percent of all birds seen. Murres comprised 54 percent, Red Phalaropes 17 percent, and Black-legged Kittiwakes 15 percent of birds seen. Jaegers and Black-Guillemots each made up five percent of the total. The limited transects in ice showed the Black-legged Kittiwakes and Thick-billed Murre to be the most common species.

September

The GLACIER cruise in the Chukchi Sea in September 1976 covered a large area from the ice north of Pt. Barrow to Kotzebue Sound (Figure 11). Densities in open water were found to be twice those in the ice. Red Phalaropes made up 74 percent of the birds seen in open water with no other species making up more than 10 percent.

In ice of one and two oktas coverage Ross' Gulls constituted 50 percent and Ivory Gulls 25 percent of all birds seen. Glaucous Gulls were seen on over 50 percent of the transects in this coverage but constituted only 13 percent of the total. Black-legged Kittiwakes and Black Guillemots were present in small numbers.

In ice of three and four oktas cover Ross' Gulls comprised 75 percent and Ivory Gulls 10 percent of the total. Glaucous Gulls were seen on 32 percent of the transects but made up only seven percent of the total.

In ice of five and six oktas cover Ross' Gulls made up 99 percent of all birds seen. The only birds seen in ice of seven and eight oktas cover were two Ivory Gulls.

Shoreline effects

In order to determine the importance of proximity to land, bird densities were analyzed with respect to distance from the mainland (Table 4). In the Chukchi the highest average densities were within 20 km of shore. Ice and shoreline effects will need to be sorted out in order to accurately determine the major factors affecting bird distribution and numbers.

October

The information gathered as the GLACIER left the Chukchi Sea (Figure 12) is too incomplete to provide a picture of ice and open water densities or species composition. The few observations made do show densities to be low in ice and open water (Tables 1 and 3).

Feeding habits

Stomach contents from the Chukchi Sea have not been analyzed. Observations in the ice showed that arctic cod are important to a number of surface feeding species.

D. Beaufort Sea

1. Pelagic observations

August

In August 1976 the GLACIER was offshore in the Beaufort Sea at the same time the ALUMIAK was sampling the nearshore waters (Figures 2 and 5). These two cruises thus provided much information on the relative importance of the two areas. The GLACIER operated primarily in ice while the ALUMIAK was in both ice and open water (Table 1).

Information obtained from the GLACIER in the ice showed densities to be low (Table 1). Densities were highest in ice of one to two oktas (Table 3). Red Phalaropes made up 75 percent of the birds seen in this coverage. Arctic Terns comprised 13 percent and Oldsquaw

7 percent of the total. Bird densities in heavier ice were low.

Open water transects conducted from the GLACIER were few. The 100 birds per km^2 average was 80 percent phalaropes.

Densities obtained from the ALUMIAK showed bird densities to be twice as high in ice as in open water (Table 1). Densities also increased with increasing ice cover. Shoreline migrants made up the bulk of the birds seen in ice. In ice of one and two oktas Oldsquaw comprised 37 percent, eiders 27 percent and Red Phalaropes 22 percent of the total. In ice of three and four oktas cover Oldsquaw and eiders each comprised 49 percent of the total. Oldsquaw comprised 82 percent of birds seen in open water. Eiders and phalaropes each comprised seven percent.

Limited information obtained in the Beaufort in August 1975 (Table 3) showed that no birds were present in ice of seven to eight oktas. 1975 was a very atypical year with heavy ice nearshore throughout the summer.

<u>September</u>

Most of the sampling conducted in the Beaufort Sea in September was in ice (Table 1). Sample size for areas with more than two oktas cover is small but densities appear to decrease with increasing ice cover (Table 3). In ice of one and two oktas Red Phalaropes constituted 46 percent of all birds seen. Oldsquaw and Glaucous Gulls were each 14 percent of the total. Glaucous Gulls were the most frequently seen birds, being present on 50 percent of the transects. Sabine's Bulls constituted ten percent of the total. Oldsquaw comprised 80 percent of all birds seen in ice of three and four oktas coverage. Loons comprised 81 percent of all birds seen in five and six oktas. No birds were seen in ice of seven and eight oktas.

Transects in open water showed Red Phalaropes comprised 50 percent and Oldsquaw 25 percent of all birds seen.

Shoreline effects
No clear relationship between bird densities and distance to land was observed in the Beaufort. There appears to be a drop in numbers past 50 km from shore however.

2. Feeding habits
Analysis of stomachs collected in the Beaufort is not yet complete. Observations at sea show arctic cod to be of importance to surface feeding birds. Oldsquaw stomachs being analyzed as part of R.U. 3/4 show mysids and amphipods to be important prey items.

VII. Discussion

Although there are major gaps in our knowledge of seabird distribution and abundance at the pack ice edge we now have a rough overview of the relative importance of the ice throughout the year.

Bering Sea - In terms of biomass and numbers the ice front is most important to birds in March with densities averaging over 500 birds per km^2. The ice supports large numbers of murres with gulls being much less abundant but occurring regularly in low numbers. South of the ice front over the shelf densities are lower (100 birds per km^2) with Northern Fulmars and Black-legged Kittiwakes occurring commonly. These same species are found in the open water south of the shelf where densities are lower still (10 birds per km^2). In April species composition remained roughly the same as March but densities decreased. Ice front densities averaged 50 birds per km^2. Sampling in open water south of the shelf was limited. Average densities there were 37 birds per km^2. Open water off the shelf had very low densities (2.4 birds per km^2).

The decrease in numbers from March to April could be due to a number of factors. As was mentioned, different areas were censused on these two cruises. More likely the start of the breeding season played a part in the difference observed. In April the main pack ice is not as consolidated as it is in March. This allows birds to occupy lead systems in the ice near breeding colonies. There is probably also a movement to inshore areas of the Bering Sea south of the ice.

Large feeding flocks of murres present in the ice front were apparently associated with large schools of pollock. Pollock appear to be important to all species found in the ice front. Pollock found in the birds' stomachs averaged 15 cm in length. April data suggests that Thick-billed Murres usually feed on larger pollock than Common Murres. Euphausids and the amphipod Parathemisto sp. were the only two commonly encountered invertebrates in ice front bird stomachs. They appear to be a regular but miminal part of the diet of murres.

Observations made deep in the Bering Sea in February and March 1973 confirm the evidence presented here on the importance of the ice front. In 1973 densities were low (less than one bird per km^2) in all areas except close to the front where large flocks of murres were encountered. The principal species seen deep in the ice in 1973 was the Black Guillemot.

The findings presented here correlate well with the primary productivity work of McRoy and Goering (1974) who found low productivity in the water in all areas of the Bering Sea except the ice front. The plankton bloom occurring in the ice is not available to grazers until the ice decomposes in May.

Chukchi Sea

Observations in the extreme southern Chukchi Sea in the Bering Strait show that this area supports over 100 birds per km^2 in the summer and early fall. The open water south of the pack ice rarely has average densities of more than 20 birds per km^2. Black-legged Kittiwakes and murres are the most common species south of the ice. Densities in the ice in the Chukchi are less than in the open water to the south with the average being approximately ten birds per km^2. Kittiwakes and murres again were the principal species. Most of these birds are assumed of be non-breeders. In September Ross' and Ivory Gulls begin to occur commonly in the ice and in October the Ross' Gull is one of the principal species at the ice edge (Watson and Divoky 1972). The Ross' Gull occupies the Chukchi only after it completes breeding in Siberia.

Beaufort

The manner in which the ice melts in the Beaufort Sea and the large number of nearshore migrants makes the Beaufort more complex than either the Bering or Chukchi. The average density for offshore ice is approximately ten birds per km^2. Open water supported higher densities but this is probably due to the open water being closer to land. Oldsquaw, eiders and phalaropes are the most abundant species seen offshore in the Beaufort Sea. They occur in the Beaufort after breeding on the tundra. While Oldsquaw and phalaropes feed extensively in the Alaska Beaufort, eiders use it primarily as a migratory pathway.

Observations from the ALUMIAK show that the nearshore Beaufort regularly supports densities of from 50 to 100 birds per km^2. The nearshore waters are thus far more important to birds than offshore areas.

Observations show that birds offshore are most dependent on arctic cod as a food source while nearshore areas support primarily plankton feeders.

VIII. Conclusions

The information presented here shows that the ice edge is most important to birds in March when ice cover is at a maximum. An oil spill or similar disaster occurring in the ice front during this time would directly affect large numbers of murres. Lesser impacts would occur in the open water south of the ice. The effects of spills furthur north in the Bering Sea ice would have little immediate effect. In areas where ice cover is extensive the oil would be contained in leads and only small numbers of murres and Black Guillemots would be affected. Spills contained in leads would be contained by the ice and could presumably be cleaned up by the time the ice decomposes. If a spill were to occur during the time of ice formation the oil would be incorporated into the ice. This would also presumably aid clean-up operations.

Since the period of ice cover in the Chukchi Sea is long the chances of a spill occurring in the ice and being contained in leads is good. If a spill were to occur in the Bering Strait in spring or summer there would be major mortality of the seabirds breeding in the Strait. Spills further north in the open water would have less of an effect unless they occurred near breeding colonies or in nearshore areas.

Spills occurring in the multi-year ice of the northern Chukchi and most of the Beaufort might present the most complex problems. Because the ice in these areas does not melt completely every year the oil could remain trapped in the ice for long periods of time. Although densities in the multi-year ice have been found to be less than in open water the long term effects of a spill in the ice may be worse than a spill in the water. This would be due to the limited water available for feeding and roosting and the fact that oil will spread out in the leads. The under-ice fauna associated with multi-year ice would also be affected by a spill and an important food source for certain species would be reduced.

In both the northern Chukchi and Beaufort it is obvious that nearshore waters support the highest bird densities and that spills occurring within 50 km of the coast will have the greatest effect on birds.

IX. Needs for further study

The most pressing need for future studies on pack ice birds is for trophic information. Integrated programs composed of plankton, fish, and bird studies could do much to explain what is occurring in and next to the ice. We need information on prey densities so comparisons can be made with stomach contents. In cases where a single prey species is of critical importance to a large number of birds as with pollock and arctic cod, we need to know the factors determining the distribution and abundance of prey. Efforts along these lines ha e begun in that a more integrated program is being attempted on Bering Sea ice edge cruises in 1977. In terms of bird studies this means we have to collect more specimens for stomach contents and conduct more observations of feeding flocks.

Additional studies would also greatly benefit from more ship time. Aerial surveys provide poor information on birds in ice and more cruises need to be conducted. It will obviously take the Coast Guard's cooperation but cruises in late June through October are needed for the Chukchi Sea and July through October cruises are needed for the Beaufort. Too much emphasis is being placed on August Beaufort cruises.

It should also be mentioned that repeated sampling of the ice edge is needed so we can determine year to year variation.

X. Summary of 4th quarter operations

A. Ship and Laboratory Activities

1. Ship or field trip schedule
   15 March to 2 May, NOAA ship, SURVEYOR

2. Scientific party
   Doug Woodby, Point Reyes Bird Observatory, Assistant Investigator
   Katie Hirsch, Point Reyes Bird Observatory, Assistant Investigator

3. Methods
   Pelagic censusing is conducted from the flying bridge. Observations periods last for 15 - minutes. All birds seen in a 300 - meter wide transect on one side of the ship are recorded. Information is obtained on species, age, sex, and activity. Only birds encountered in the 300 - meter swath are used to compute densities of birds. Ship followers are recorded at the end of each observation period but are not included in density computations.
   Specimen collection and processing - Specimens are collected with a shotgun from a small boat. As soon as a bird is collected a plastic tube is put down its esophagus and formalin is injected into the stomach. On the ship information on weight, molt, gonad size, and fat deposition are obtained. Stomachs are removed, weighed and preserved in formalin.
   Stomach contents analysis - Food items present in the mouth, esophagus and stomach are included in the analysis. All items are identified to lowest possible taxonomic group and counted and measured. Weight and volume of each prey item group is determined.

4. Sample localities
   Along the Bering Sea ice edge east of 174° W longitude.

5. Data collected and analyzed
   a. Data collected (projected for 15 March to 31 March):
      1) 120 15 - minute transect observations
      2) Stomachs from 40 birds of 5 species
   b. Data analyzed:
      1) 40 bird stomachs on board ship (projected for 15 to 31 March)

2) 110 bird stomachs in the laboratory
3) 1900 15 - minute shipboard transects from 7 cruises analyzed for
   a) densities of birds in relation to ice cover,
   b) densities of birds in relation to distance from the ice edge, and,
   c) densities of birds in relation to distance from land.

c. Miles of trackline: 600 nautical miles of trackline projected for 15 to 31 March.

6. Milestone chart and data submission schedule. All pelagic observations have been coded and sent to Michael Crane of the AEIDC in Anchorage. Keypunching of all data will be completed by 15 May. Standardization of formats and keypunching protocol have been arrived at and will allow all data gathered this year to be sent directly to Crane as soon as a cruise is completed. A format for reporting stomach contents is currently being developed by Gerald Sanger of the USFWS Anchorage office. All stomach contents will be coded as soon as OCSEAP approves the format. A milestone chart of 1977 tasks is presented on the following page.

B. Problems encountered and recommended changes.

The principal problem encountered in the course of this project has been the time lag between the end of a cruise and the time when data are available for analysis. Currently all data are being sent to Mike Crane of AEIDC for keypunching. In order to have data available for analysis immmediately after a cruise we are arranging for data to be put on magnetic tape on board ship. This will bypass the process of coding and keypunching and will result in substantial savings of both time and money. Data will be processed on board ship with the aid of a mini-computer. The hardware and software of such a system are currently being arranged through Mike Crane and computer specialists in northern California. If such a system proves to be worthwhile it can be used for pelagic observations and stomach contents. In addition other OCSEAP pelagic bird projects may find the system suitable for their work.

Proj: R.U. 330/196

PI: George J. Divoky

MILESTONE CHART

MAJOR MILESTONES	1977 A	M	J	J	A	S	O	N	D	1978 J	F	M	A	M	J	J	A	S
SURVEYOR Cruise-Bering Sea	—	Δ																
1976 Data keypunched	—	Δ																
1976 stomachs analyzed	—	Δ																
DISCOVERER Cruise-Bering Sea		—	Δ															
Barrow trophic studies				—	—	Δ												
Cooper Is. breeding birds				Δ														
GLACIER Cruise-Beaufort Sea					—	Δ												
ALUMIAK Cruise-Nearshore Beaufort Sea					Δ													
Computer analysis of R.U. 3/4 and 196						Δ												
1977 stomachs analyzed						Δ												

Δ Planned Completion Date ▲ Actual Completion Date

C. Estimate of funds expended

1.	Salaries and benefits:	$8,021
2.	Travel and shipment:	1,212
3.	Equipment and supplies:	0
		$9,233

Table 1. Densities of birds in the Beaufort and Chukchi Seas and Bering Strait in ice and open water. Densities in birds per km^2.

Beaufort

Date	Ship		mean	range	n
8/76	GLACIER	ice	7.4	0-177	95
		open water	100	0-145	7
8/76	ALUMIAK	ice	61	0-637	91
		open water	29	0-236	31
9/76	GLACIER	ice	12	0-277	113
		open water	16	0-39	5

Chukchi

Date	Ship		mean	range	n
7/76	BURTON IS.	ice	5.8	0-79.2	18
8/75	GLACIER	ice	6.4	0-68	188
		open water	18	0-302	139
8/76	GLACIER	ice	26	0-105	10
		open water	8.3	0-143	130
9/76	GLACIER	ice	11	0-148	59
		open water	22	0-227	99
10/76	GLACIER	ice	7.1	0-53	10
		open water	2.5	0-4.8	17

Bering Strait

Date	Ship		mean	range	n
8/75	GLACIER	open water	111	1.8-669	29
	DISCOVERER	open water	121	1-3420	30
	GLACIER	open water	1.1	0-3	6

Table 2. Densities of birds in the Bering Sea, Unimak Pass and Gulf of Alaska. Densities in birds per km^2.

March	mean	range	n
Bering Sea			
Ice	561	0-10,226	103
Open water over shelf	99	2-308	19
Open water south of shelf	11	0-23	28
Unimak Pass	44	1-212	12
Gulf of Alaska	5.5	0-19	21
April			
Bering Sea			
Ice	50	0-577	47
Open water over shelf	37	13-163	7
Open water south of shelf	2.4	0-7.2	11
Unimak Pass	13	1.1-54	16
Gulf of Alaska	4.4	1-13	22

Table 3. Densities of birds in relation to ice cover in the Beaufort and Chukchi seas. Densities in birds per km^2.

			Oktas of ice cover			
Beaufort			1 + 2	3 + 4	5 + 6	7 + 8
Date	Ship					
8/75	GLACIER	mean				0
		range				0
		n				12
8/76	GLACIER	mean	16.8	1.5	1.4	0.1
		range	0-177	0-7	0-50	0-1
		n	36	17	43	13
8/76	ALUMIAK	mean	56.5	129.5		
		range	0-322	17-673	-	-
		n	93	10		
9/76	GLACIER	mean	13.6	11.7	5.5	0
		range	0-57	0-54	0-44	0
		n	65	6	10	2
Chukchi						
7/76	BURTON IS.	mean	8.5		0	6.1
		range	8-9	-	0	0-79
		n	2		2	14
8/75	GLACIER	mean	5.3	6.7	4.6	18
		range	0-20	0-46	0-43	0-68
		n	67	16	14	21
8/76	GLACIER	mean	26.6			
		range	0-105	-	-	-
		n	10			
9/76	GLACIER	mean	8.5	10.6	18.6	5
		range	0-148	0-97	0-144	-
		n	30	19	8	1
10/76	GLACIER	mean	7.1	-	-	-
		range	0-53			
		n	10			

Table 4. Densities of birds in relation to distance from shore in the Beaufort and Chukchi Seas. Densities in birds per km^2.

Date	Ship		0 - 2	3 - 10	11-20	21-50	51-100	101-200	201-300
Beaufort									
8/76	GLACIER	mean		0.7	3.2	16.5	12.8		
		range		0-1	0-57	0-425	0-177		
		n		14	17	55	33		
8/76	ALUMIAK	mean	49.4	47.5	20.6	89.6			
		range	1.4-637	0-270	1-134	1-322			
		n	41	63	9	9			
9/76	GLACIER	mean				58	12.7	7.1	
		range				3-227	0-79	0-35	
		n				15	84	16	
Chukchi									
7/76	BURTON IS	mean	5.7						
		range	0-79						
		n	18						
8/76	GLACIER	mean		39.3	38.6	8.3	3.7		
		range		4-105	0-143	0-60	0-15		
		n		6	12	55	69		
8/75	GLACIER	mean		20	55	11	8	5	4
		range		0-68	0-302	0-167	0-47	0-46	0-20
		n		21	24	65	95	114	28
9/76	GLACIER	mean			2.3	5.6	33	14.4	8.0
		range			0-4.1	0-33	0-227	0-148	0-97
		n			4	27	48	31	32

Distance from shore in km

Table 5. Stomach contents of birds collected in the Bering Sea pack ice, March and April 1976

	n	Total Volume (ml)	Pollock	Capelin	Unid. fish	Unid. fish chyme	Parathemisto	Euphausid	Other (see text)
March									
Rissa tridactyla	2	0.8							
Percent of total volume			tr.	tr.		100			
Frequency of occurrence			100	50		100			
Uria aalge	17	789.7							
Percent of total volume			30.7	33.1	16.6	19	0.6	tr.	tr.
Frequency of occurrence			106	41	17	82	29	6	12
Uria lomvia	2	10.0							
Percent of total volume							100		
Frequency of occurrence							100		
April									
Fulmarus glacialis	2	17.2							
Percent of total volume									100
Frequency of occurrence									100
Larus hyperboreus	3	90.5							
Percent of total volume			12.2		71.8	16.0			
Frequency of occurrence			100		33	66			

Table 5. (cont.)

	n	Total Volume (ml)	Pollock	Capelin	Unid. fish	Unid. fish chyme	Parathemisto	Euphausid	Other (see text)
<u>Pagophila</u> <u>eburnea</u>	4	19.0							
Percent of total volume			tr.						100
Frequency of occurrence			75						100
<u>Rissa</u> <u>tridactyla</u>	1	41.0							
Percent of total volume			95						5
Frequency of occurrence			100						100
<u>Uria</u> <u>aalge</u>	14	196.1							
Percent of total volume			60.2	tr.	2.5		8.2	20.4	
Frequency of occurrence			21	7	7		29	57	21
<u>Uria</u> <u>lomvia</u>	9	486.0							
Percent of total volume			52.5		43.2	4.1	0.2		
Frequency of occurrence			89		11	33	11		
<u>Cepphus</u> <u>grylle</u>	2	2.2							
Percent of total volume						tr.	100		
Frequency of occurrence						50	50		

Table 6. Size of fish otoliths found in stomachs of birds collected in the Bering Sea pack ice. March - April 1976.

	Pollock			Capelin		
	# of otoliths	mean (mm)	range (mm)	# of otoliths	mean (mm)	range (mm)
March						
Pagophila eburnea	16	4.6	4-6			
Rissa tridactyla	5	4.6	4-5.5	2	2	0
Uria aalge	211	5.2	4-6	5	1.8	1-2
April						
Larus hyperboreus	12	8.3	7-9			
Pagophila eburnea	14	5.8	4-8			
Uria aalge	21	6.4	3.5-10	2	3	0
Uria lomvia	18	11.2	7-15			

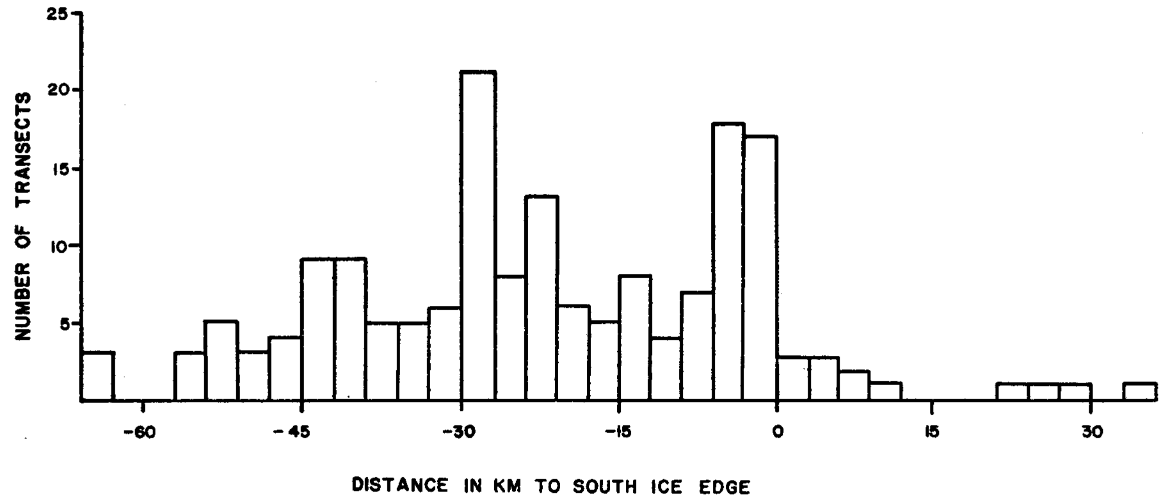

Figure 13. Number of transects with bird observations in relation to distance from southern ice edge. Negative distances represent distances within the ice.

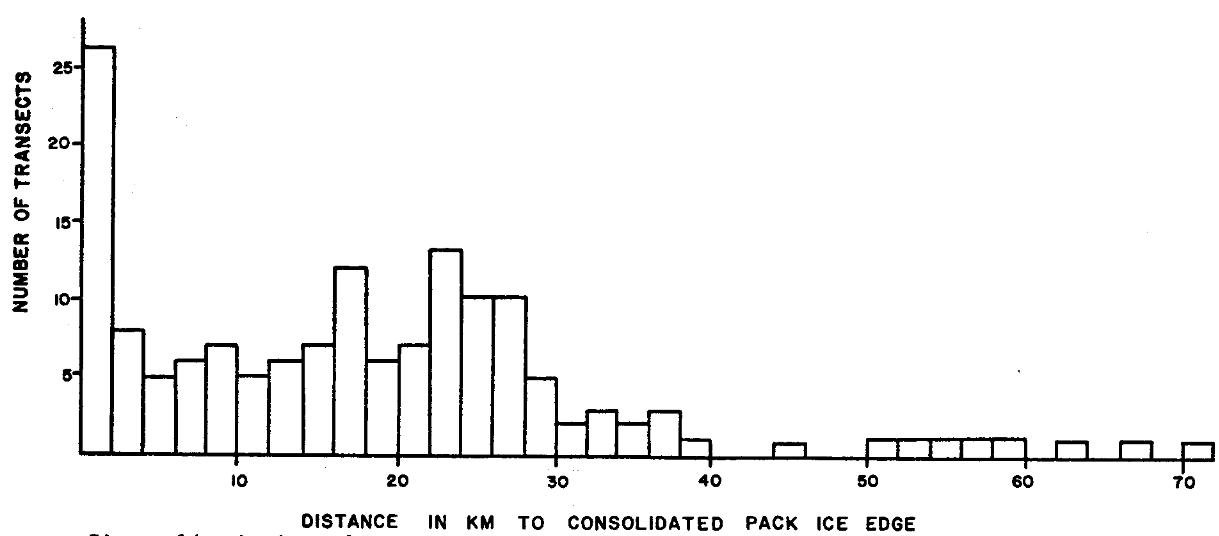

Figure 14. Number of transects with bird observations in relation to distance from consolidated pack ice edge.

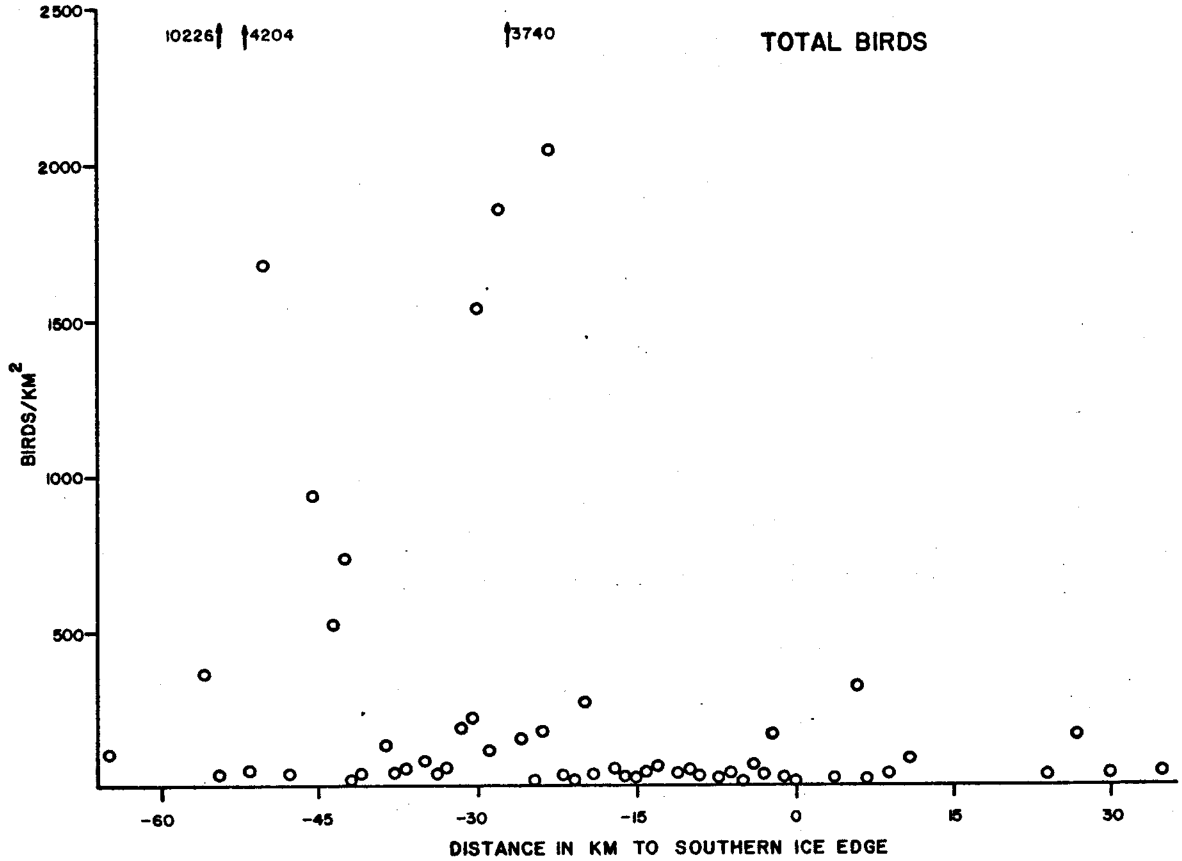

Figure 15. Average densities of total birds in relation to distance from southern ice edge. Negative distances represent distances within the ice.

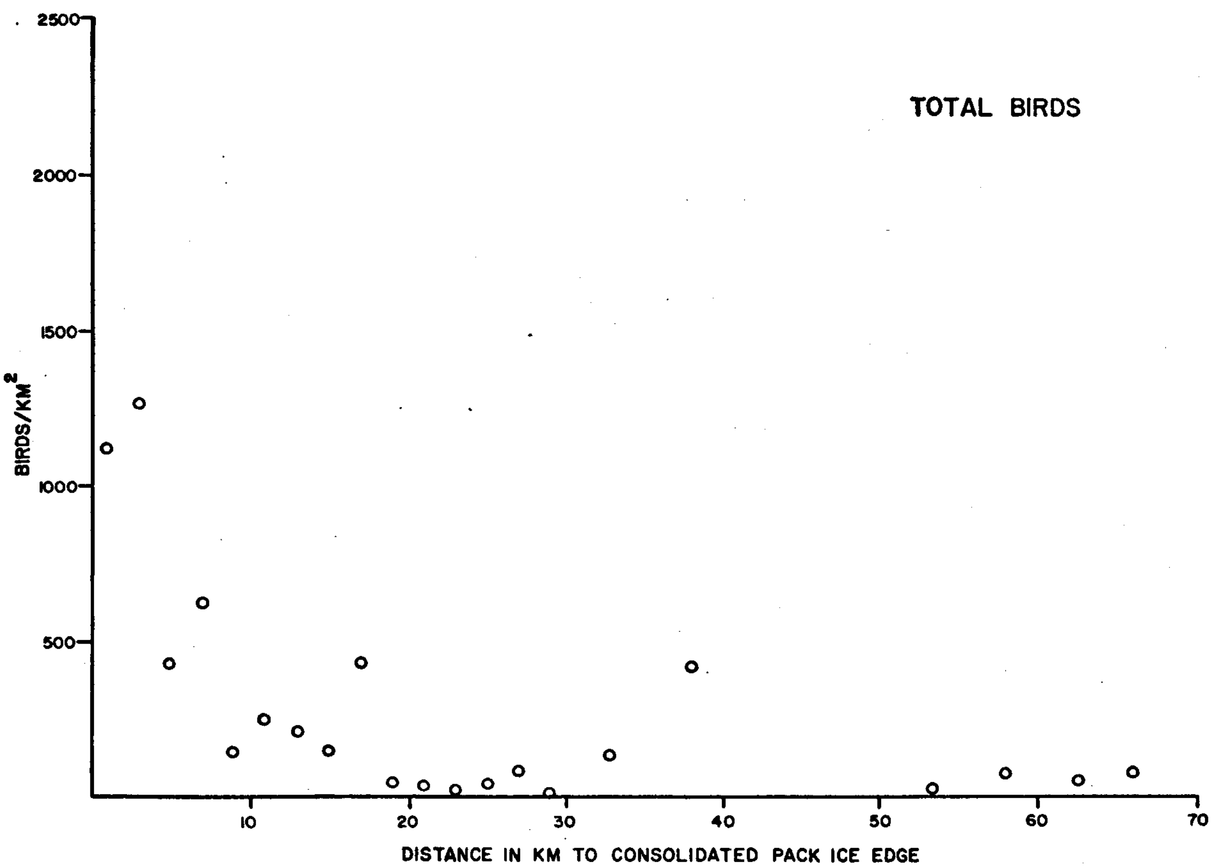

Figure 16. Average densities of total birds in relation to distance from consolidated pack ice edge.

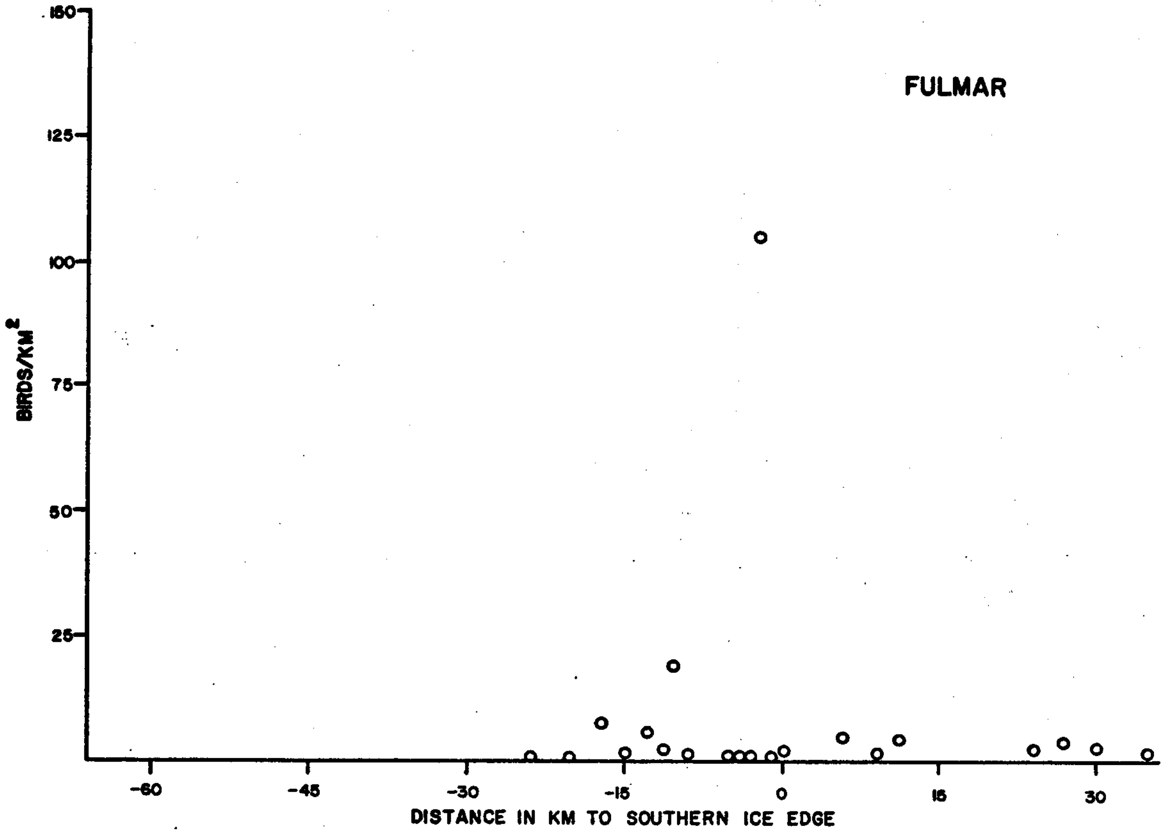

Figure 17. Average densities of Northern Fulmars in relation to distance from southern ice edge. Negative distances represent distances within the ice.

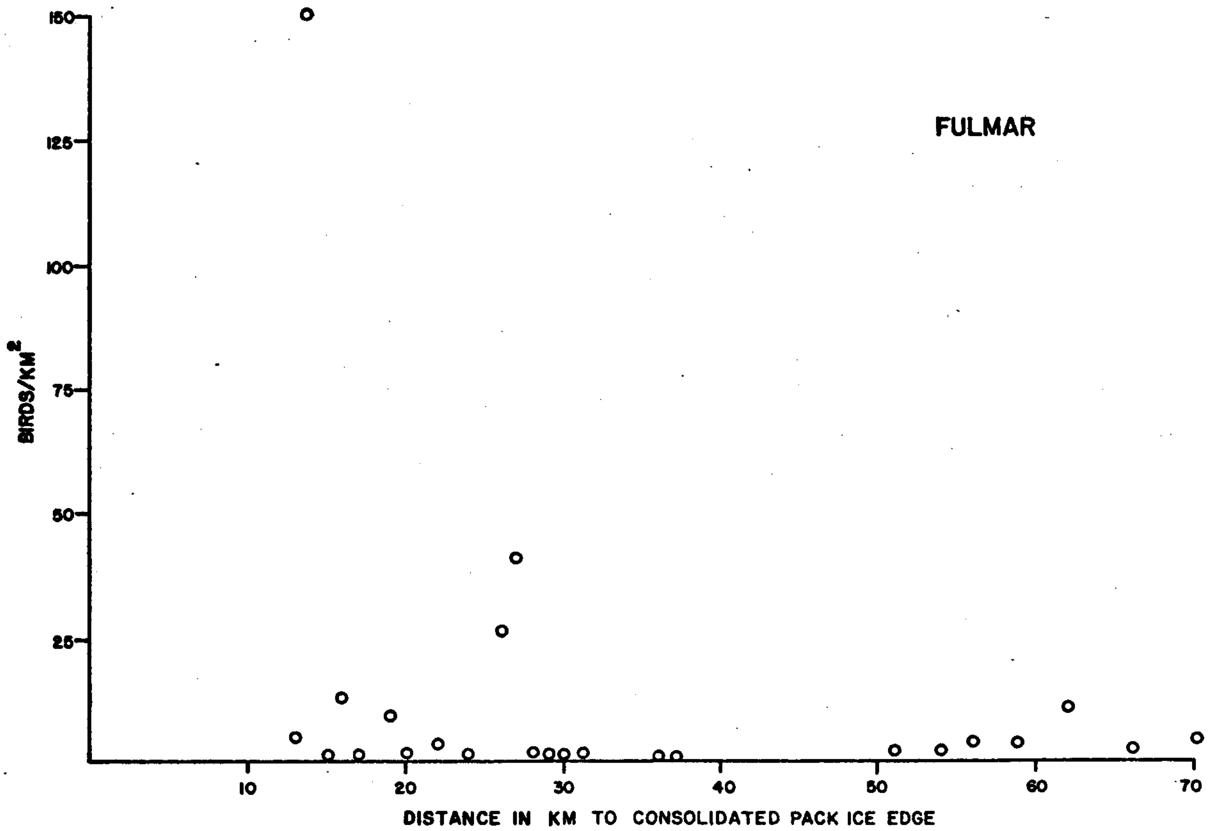

Figure 18. Average densities of Northern Fulmars in relation to distance from consolidated pack ice edge.

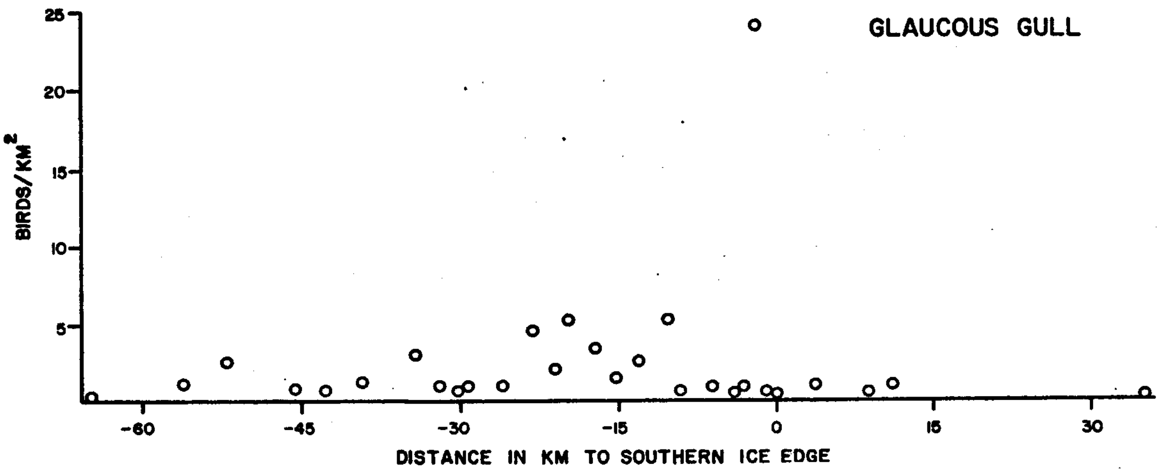

Figure 19. Average densities of Glaucous Gulls in relation to distance from southern ice edge. Negative distances represent distances within the ice.

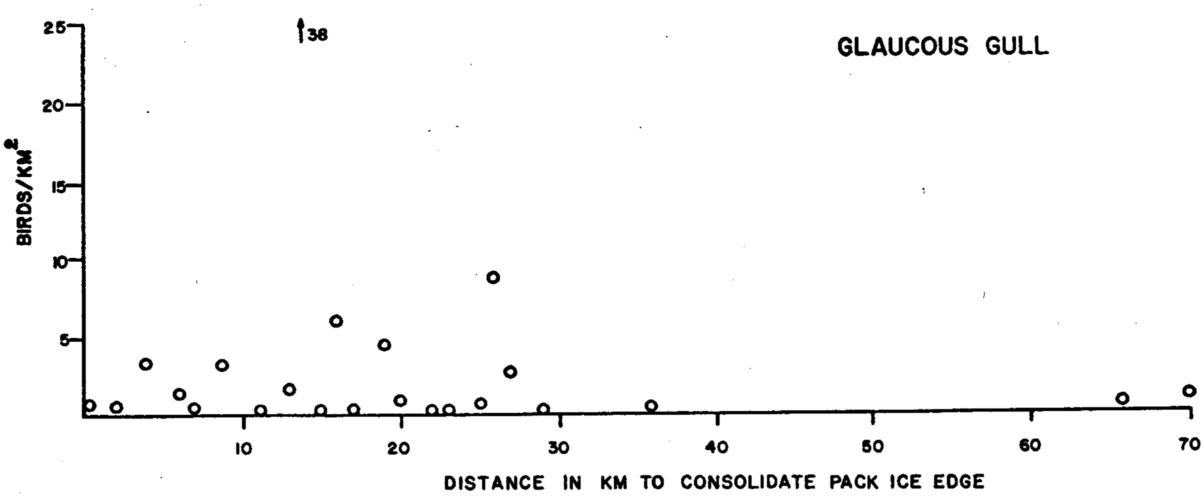

Figure 20. Average densities of Glaucous Gulls in relation to distance from consolidated pack ice edge.

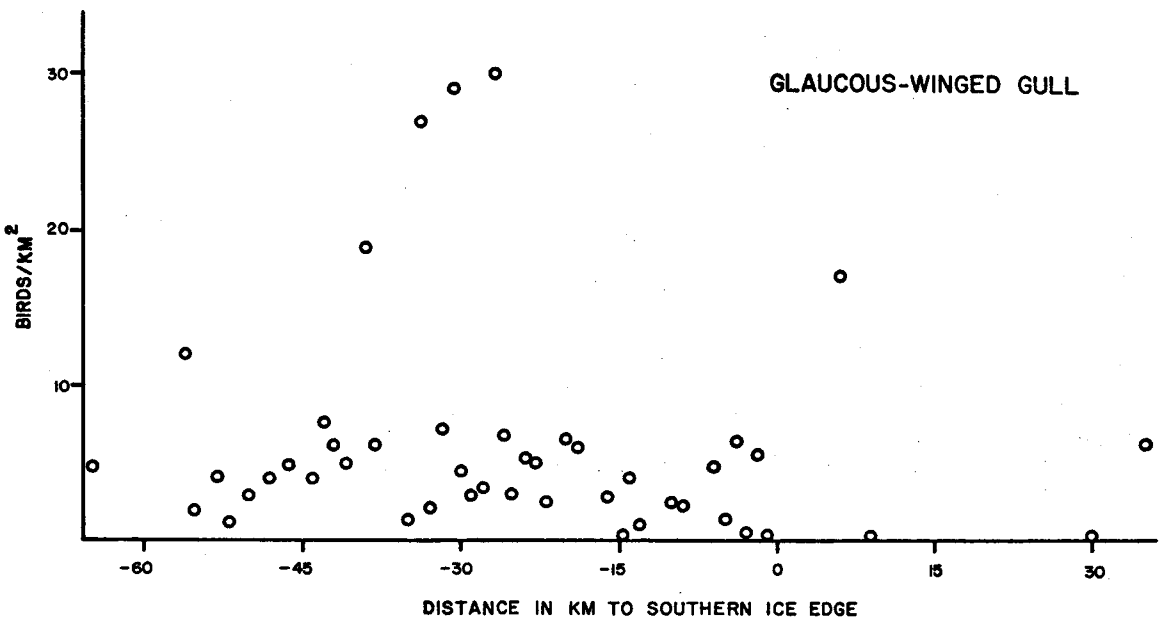

Figure 21. Average densities of Glaucous-winged Gulls in relation to distance from southern ice edge. Negative distances represent distances within the ice.

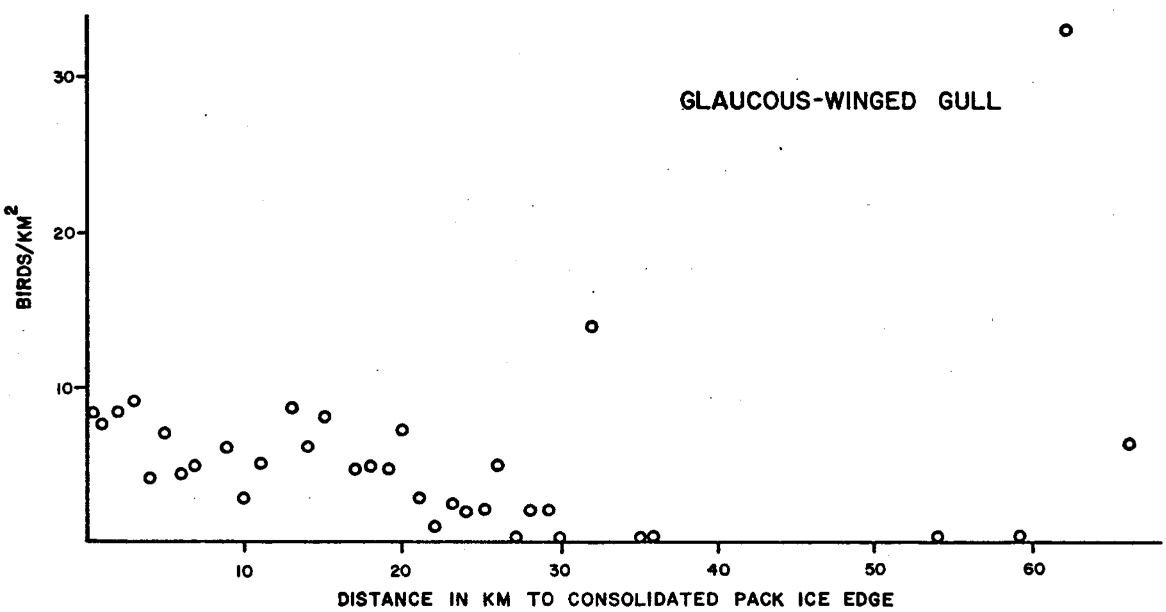

Figure 22. Average densities of Glaucous-winged Gulls in relation to distance from consolidated pack ice edge.

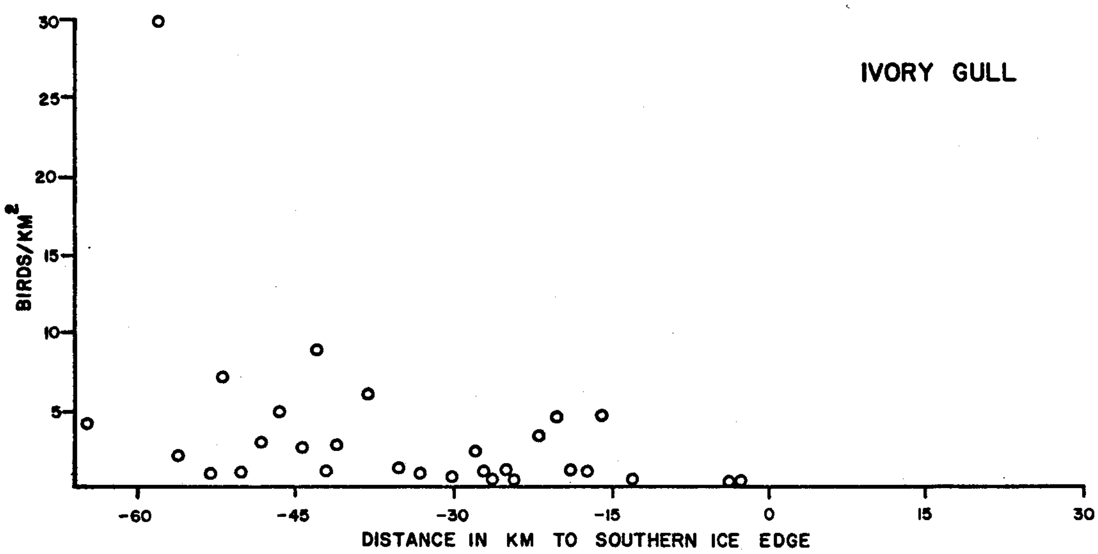

Figure 23. Average densities of Ivory Gulls in relation to distance from southern ice edge. Negative distances represent distances within the ice.

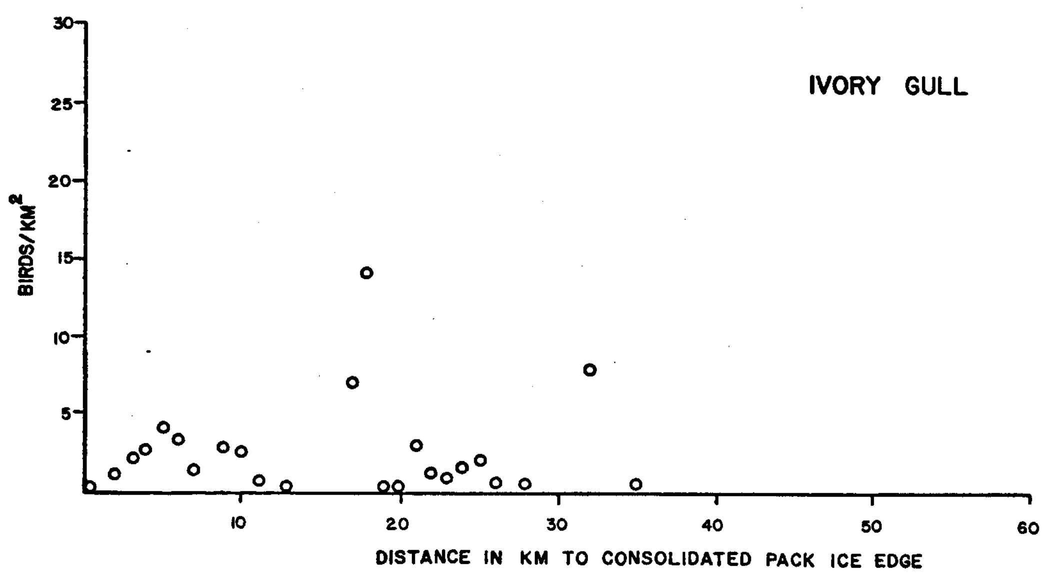

Figure 24. Average densities of Ivory Gulls in relation to distance from consolidated pack ice edge.

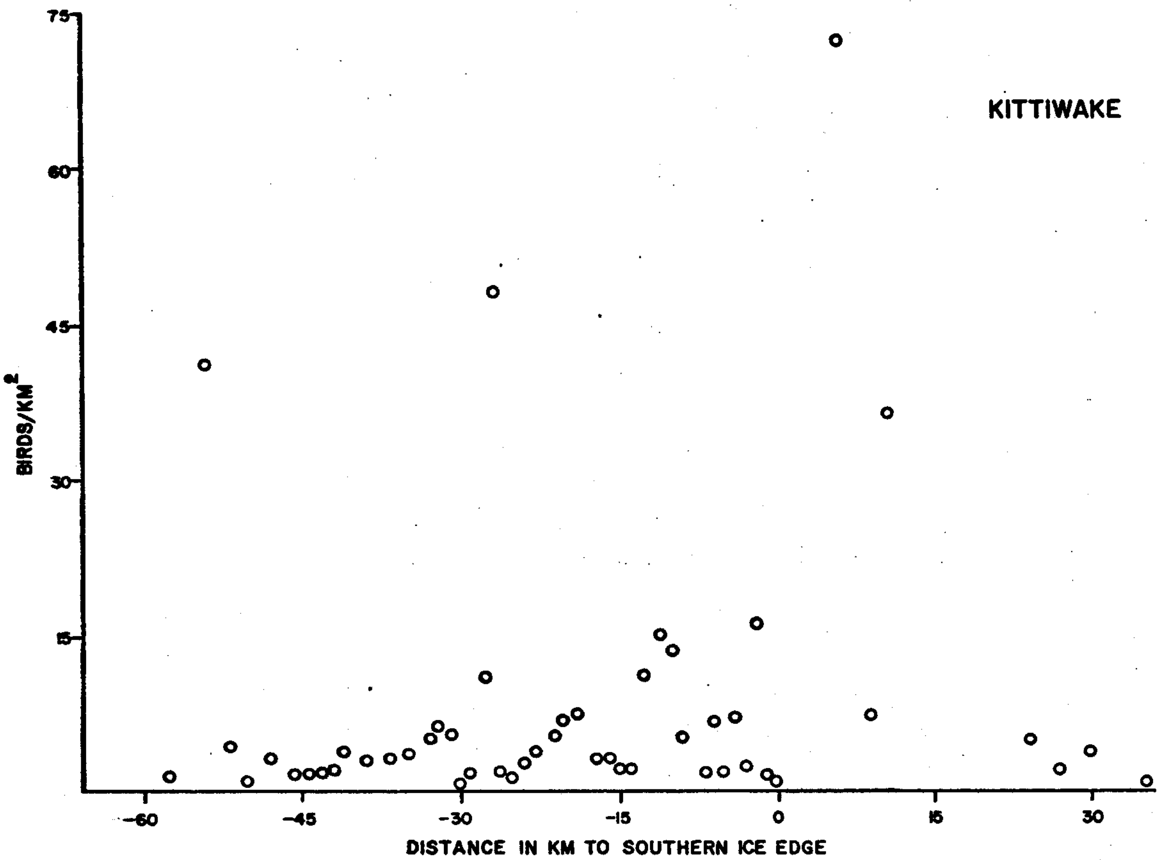

Figure 25. Average densities of kittiwakes in relation to distance from southern ice edge. Negative distances represent distances within the ice.

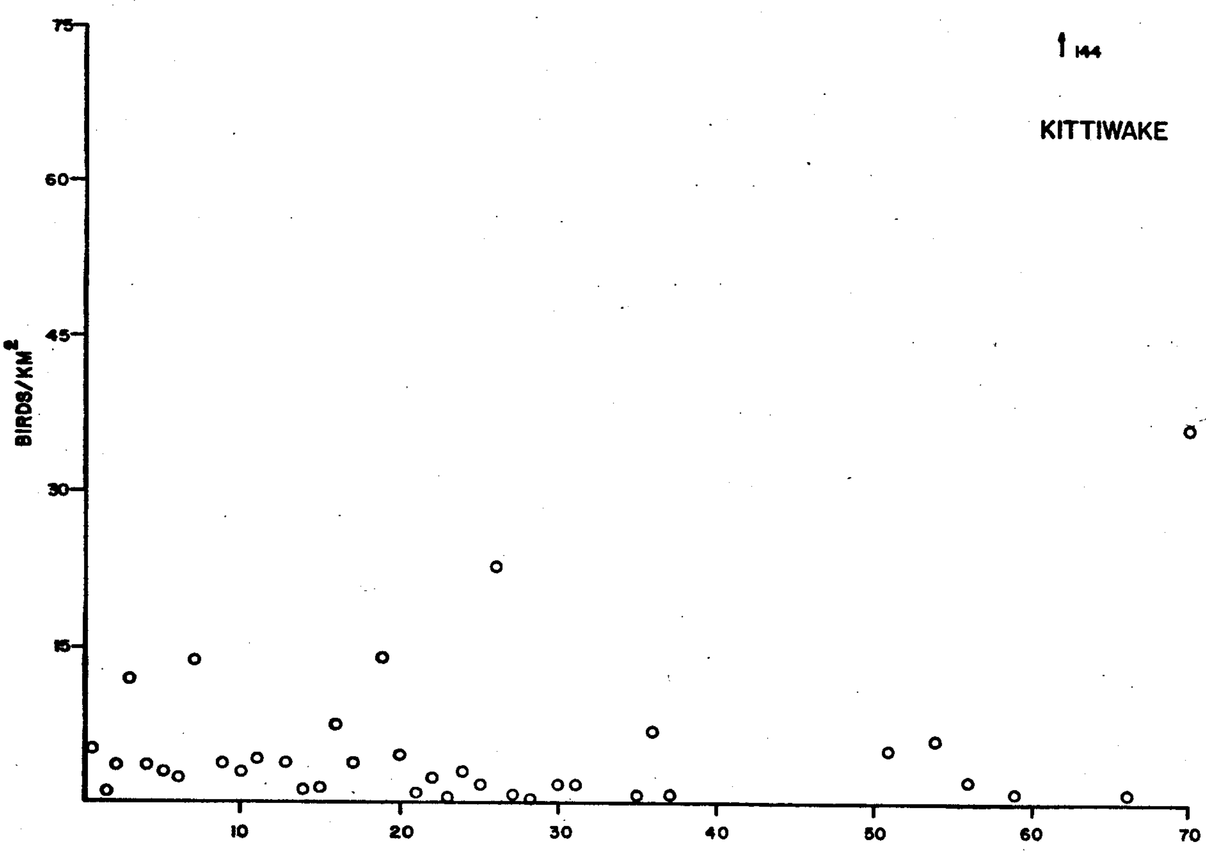

Figure 26. Average densities of kittiwakes in relat n to distance from consolidated pack ice edge.

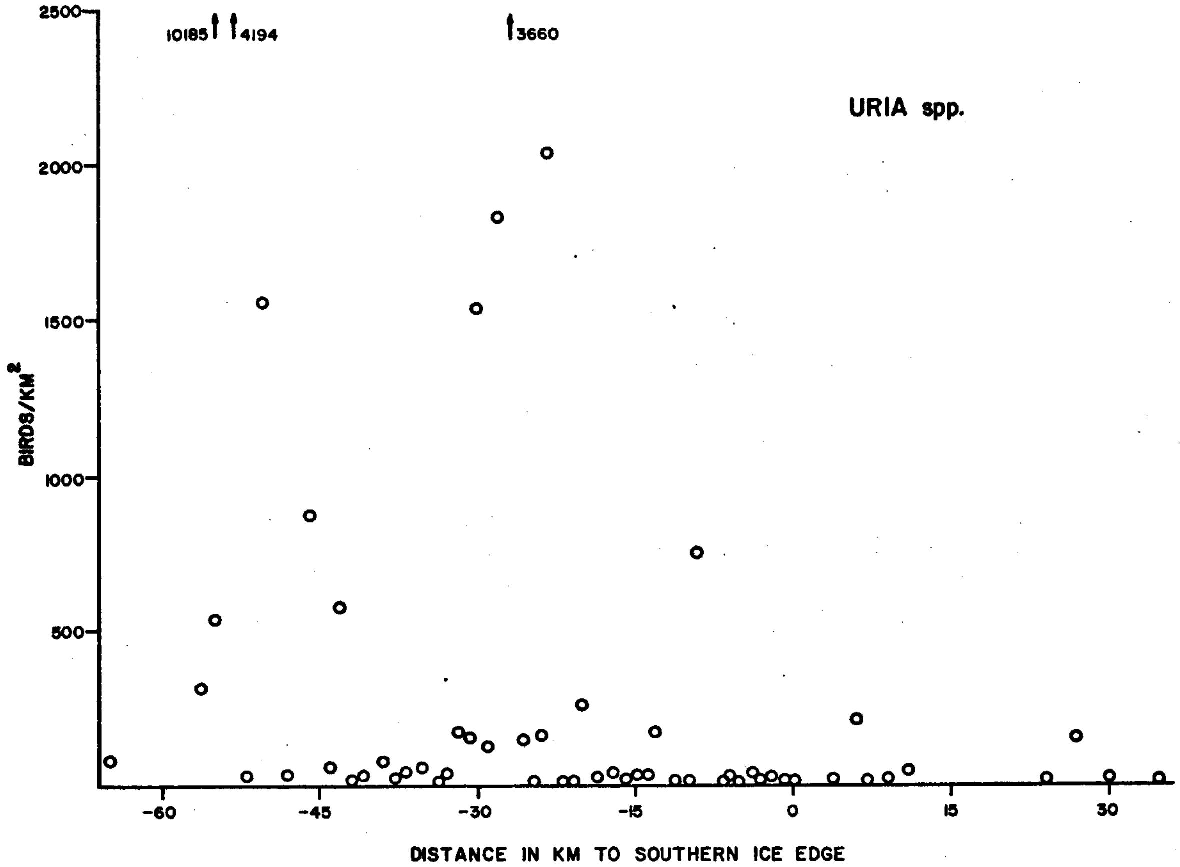

Figure 27. Average densities of Uria spp. in relation to distance from southern ice edge. Negative distances represent distances within the ice.

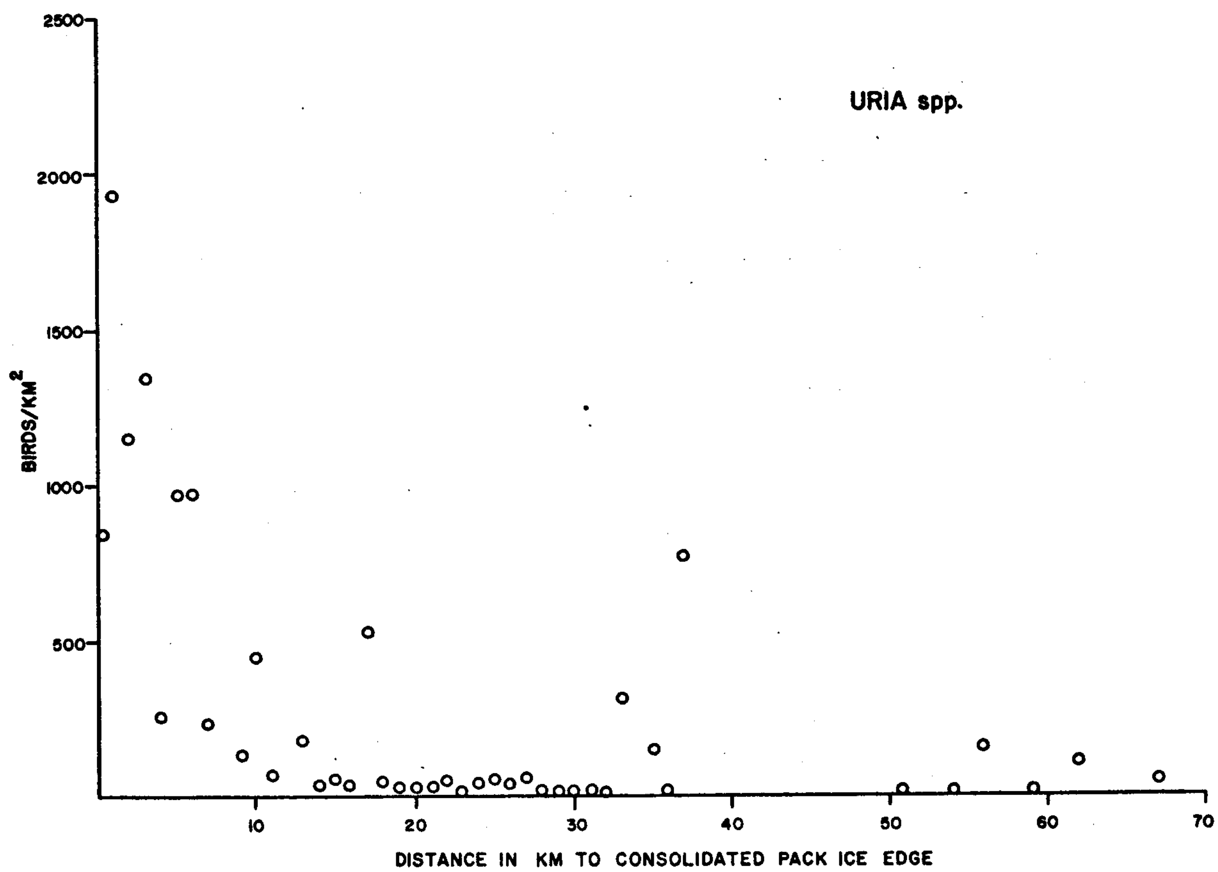

Figure 28. Average densities of Uria spp. in relation to distance from consolidated pack ice edge.

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GEORGE MUELLER

DOUGLAS SCHAMEL

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