Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1979

Volume I. Receptors — Mammals
— Birds

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

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

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

Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1979

Volume I. Receptors — Mammals
— Birds

Outer Continental Shelf Environmental Assessment Program
Boulder, Colorado

October 1979

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

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

DISCLAIMER

ACKNOWLEDGMENT

These annual reports were submitted as part of contracts with the Outer Continental Shelf Environmental Assessment Program under major funding from the Bureau of Land Management.

CONTENTS

Page

RECEPTORS -- MAMMALS

CONTENTS

ANNUAL REPORT

Contract: #03-5-022-56
Research Unit: #194
Task Order: #8
Reporting Period: 4/1/78-3/31/79
Number of Pages: 37

MORBIDITY AND MORTALITY OF MARINE MAMMALS

Principal Investigator

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

Assisted by: Associate Investigators

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

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

and

Nancy K. Murray
Anne Hoover
Brendan P. Kelly
Research Assistants
Division of Life Sciences
University of Alaska
Fairbanks, Alaska 99701

March 1979

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF FIGURES

I. SUMMARY

This is an investigation of the kinds, rates of occurrence, and causes of pathological conditions in the living populations of marine mammals on the Alaskan continental shelf, through necropsy of specimens collected principally for use in other OCSEAP projects. Coupled with this is an investigation of the kinds, numbers, distribution, and causes of death of marine mammal carcasses that wash ashore along the Alaskan coast. Work in FY78 was distributed among the Beaufort, Norton, St. George, Bristol Bay, Kodiak, Cook Inlet, and northeastern Gulf lease areas. A total of 171 collected specimens was necropsied, and the digestive tracts of these and 109 others were examined for parasitic helminths. Findings indicated that pathological conditions were more common in pinnipeds from the Bering Sea lease areas than elsewhere. Ectoparasite and nasal mite infestations were most common in specimens from the Kodiak, Cook Inlet, and Gulf areas. In a total of 4,281 km of shorelines that were surveyed in FY78, 152 carcasses of marine mammals were found. These occurred most frequently per kilometer of shoreline in the Bering Sea (1/30 km), less often in the Kodiak-Gulf areas (1/107 km), and least often in Cook Inlet (1/663 km). In areas where three or more replicate surveys have been done in recent years, the variation in rate of occurrence has been less than ± 200% of the mean. Long term (30-yr) comparative data from one locality in the Bering Sea suggest that the rate of occurrence of gray whale carcasses has increased dramatically in the present decade, while that of walruses had not changed, up to the spring of 1978.

II. INTRODUCTION

General Nature and Scope of Study

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

Specific Objectives

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

Relevance to Problems of Petroleum Development

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

III. CURRENT STATE OF KNOWLEDGE

A resumé of information available on pathology of marine mammals that occur in Alaskan waters was presented in the 1978 Annual Report of this project. A more detailed, up-dated account will be presented in the final report of this project in FY80.

IV. STUDY AREA

The study areas in FY78 and 79 for this project have included the Beaufort, Norton, St. George, Bristol Bay, Kodiak, Cook Inlet, and northeast Gulf lease areas and adjacent waters. The results from these will be considered separately by region.

V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

Rationale

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

1. Necropsy of specimens collected non-selectively from the living populations. This provides information on the kinds, causes and relative severity of pathological conditions currently occurring in those populations and probably contributing to natural mortality. Given that the samples are sufficiently large (i.e. at least 100 specimens of each regional population), the approximate rate of occurrence and relative importance of each condition can be estimated.

2. Necropsy of beach-dead carcasses. This provides information on the actual causes of mortality in the populations, as well as data on the usual frequency of occurrence and distribution of dead animals along the coasts. While it does not provide direct data on rates of mortality, rates may be inferred from the composition by age and sex, provided that the samples are sufficiently large for each species in each region.

Sources

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

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

Methods

Necropsy procedures for both the collected specimens and beach-dead carcasses are as described in the project's Manual for Postmortem Examination (Fay, 1976). Basically, these consist of:

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

In the past year, pathology in the living populations was investigated during one research cruise in the Beaufort Sea (CGC *Northwind* 15-26 August), two cruises in the Bering Sea (*Surveyor* 1-19 May, 20 May-16 June), three in the Kodiak, Cook Inlet, and northeast Gulf areas (*Surveyor* 6-20 April, 19 June-5 July, and 28 August-12 September), and one trip via helicopter to Cape St. Elias (3-7 April). Data on beach-dead carcasses of marine mammals were obtained in the Bering Sea on several occasions (western Seward Peninsula, 9 June; St. Lawrence Island, 1-2 June and 3 December; St. Matthew Island, 27 May; Alaska Peninsula, 28-29 May and 7-19 July). In the Kodiak area, the Trinity and Chirikof Islands were surveyed in April, June, and August; Lower Cook Inlet was surveyed in April and August, and parts of the northeastern Gulf were surveyed in March and April.

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

VI. RESULTS

Beaufort Sea

Only three ringed seals, *Phoca hispida*, were available for complete necropsy from this area in FY78. The first of these had no grossly evident pathological conditions; the second had only a large, healed wound on its right hip, presumably from an encounter with a polar bear; the third had a few parasite-induced focal abcesses in its liver and lungs.

The digestive tract of these and of 70 others, made available by personnel of R.U. #230, were examined for endoparasite burdens. Eight species of helminths, parasitic in the stomach and intestines, were identified; their frequency of occurrence was as shown in Table I. In addition, the small intestine of one of these seals was found to be nearly occluded by two elongate, cystic tumors of the intestinal wall, about 3 cm in diameter. The same type of tumor (leiomyoma) was found in one of 55 ringed seals from this area in 1976-77. The causative agent is unknown.

Surveys of beached carcasses were not conducted in the Beaufort Sea.

Bering Sea

Pathological conditions in the living populations of pinnipeds in the Bering Sea lease areas were investigated in 59 specimens collected in the winter and spring pack ice zone. The findings in these are summarized in Table II and annotated below.

Wounds

Two adult bearded seals, *Erignathus barbatus*, a male and a female, had large contused wounds to the hindquarters with extensive hemosiderosis, yellowing of the blubber layer, and only minor external scarring. Presumably these damages were caused by a predator, i.e. either killer whale or polar bear. One ribbon seal, *Phoca fasciata*, had an old bullet wound in the shoulder that had penetrated only the skin and blubber and was healing. Two others had superficial wounds of unknown origin that were in a more advanced state of healing; the fourth ribbon seal had lost part of a toe from the left hind flipper to a shark, the tooth marks of which were unmistakable. One spotted seal, *Phoca largha*, and one ringed seal had minor lacerations of the flippers, probably made by the teeth of other seals.

Dermatitis

The mycotic lesions found so frequently in seals from this area in previous years were conspicuously absent in 1978. However, one animal, a spotted seal, showed the small (1-2 mm) nodular lesions on the hind flippers that had been seen, especially in ribbon seals, in the past. Although these were referred to previously as "pox-like" lesions, they apparently were not caused by a viral agent.

Lungs

Nodular lesions in the lungs were present with about the same frequency of occurrence as in the past. In all cases histologically examined, these have been caused by parasitic nematodes, the precise identity of which has not yet been determined.

TABLE I

FREQUENCY OF OCCURRENCE OF HELMINTH PARASITES IN THE DIGESTIVE TRACT OF 73 RINGED SEALS FROM THE BEAUFORT SEA, 1978

Helminth	Seals infected	
	Number	Percent
Diphyllobothrium sp.	3	4
Anophryocephalus ochotensis	3	4
Diplogonopours tetrapterus	3	4
Contraceacum osculatum	31	42
Phocanema decipiens	1	1
Corynosoma strumosum	70	96
Corynosoma semerme	49	67
Corynosoma hadweni	69	94

TABLE II

GROSS PATHOLOGICAL LESIONS OBSERVED IN 59 PINNIPEDS TAKEN IN THE BERING SEA, WINTER-SPRING 1978

	Kind of seal (no. examined)				
Lesions	Sea lion (1)	Bearded seal (10)	Ribbon seal (27)	Spotted seal (15)	Ringed seal (5)
Wounds	0	2	4	1	1
Dermatitis	0	0	0	1	0
Pneumonia, focal	0	1	0	2	0
Hepatitis, focal	0	6	11	12	3
Bile ducts, fibrous	0	1	0	0	0
Kidney stones	0	0	1	0	0
Stomach ulcers	0	1	0	1	0
Pancreas, granular	0	2	1	0	0
Lymphadenitis	0	0	1	5	0
Hemoglobinuria	0	0	1	0	0

Liver

As in previous years, a high proportion of the seals examined had numerous focal abscesses in the liver, evidently caused by invasion by parasitic helminths, the identity of which remains unknown. One case of renal calculi (gall stones) in a ribbon seal and one of fibrous thickening of the bile ducts in a bearded seal also were found. As in previous cases, the latter was associated with the presence of abundant trematodes (*Orthosplanchnus* sp.) in the ducts.

Stomach

One bearded seal had a small perforating ulcer of the stomach wall, associated with an abundance of anasakid nematodes. Several others of each species had non-perforating ulcers where these parasites were attached in clumps to the stomach wall. One spotted seal had a prominant serosal scar, probably resulting from a healed ulcer of this type.

Pancreas

Two bearded seals and one ribbon seal showed enlargement and fibrous granulation of portions of the pancreas. In one of the bearded seals, this was associated with fibrosis of the pancreatic ducts, which contained an abundance of trematodes of the genus *Orthosplanchnus*. It is not yet clear whether these parasites also had caused the granulation.

Lymphadenitis

Enlargement of the lymph nodes to about twice their normal size was evident in 5 spotted seals and one ribbon seal. This was suggestive of general systemic infection by a microbiological agent; however, we were unable to demonstrate the presence of such an agent.

Hemoglobinuria

One ribbon seal that appeared to be normal in all other respects had a considerable amount of hemoglobin in its urine, suggestive of damage to one or both kidneys by infection or trauma. Further study of this specimen is underway.

Parasitic helminths

The digestive tract of one Steller sea lion (*Eumetopias jubatus*), 13 bearded seals, 30 ribbon seals, 19 spotted seals, and 24 ringed seals were examined for the presence of parasitic helminths. Of these, only two bearded seals, one spotted seal, and two ringed seals had none. The frequency of occurrence of each species of helminth in these pinnipeds was as shown in Table III. Also examined were 195 fishes known to be eaten by these pinnipeds and potentially the intermediate hosts of some of their parasites. In representatives of 15 of the 16 species examined, at least one larval helminth of the kinds infesting the seals was found (Table IV). Most heavily infected was one specimen of shorthorn sculpin (*Myoxocephalus jaok*), which contained larvae of at least three kinds of nematodes and two kinds of acanthocephalans that occur as adults in the seals.

One of the more interesting aspects of the helminthological investigation was the finding that bearded seal pups taken approximately one month after weaning were already heavily infested with parasitic helminths, some of which were as much as 1 meter long. This has presented some useful information on the rate of development of these helminths. Because the feeding habits of these weanling seals covers a rather narrow spectrum of prey, it has provided also some clues as to possible intermediate hosts of the helminths.

Ectoparasites

Phocid seals of the Northern Hemisphere presumably are all infested with anopluran lice of the species *Echinophthirius horridus*. While we have not examined each seal in detail for these lice, we have examined them all cursorily and can state with confidence that, in none was there any remarkable abundance. Indeed, they were scarce to absent on the 8 to 10 individuals of each species that we did examine in detail and were rarely noticed on any of the others. None have been found on any bearded seals; they occur rarely on ringed and ribbon seals, and then only in small numbers (1-5/seal); and they are uncommon on spotted seals, where they occur also in numbers usually less than 10/seal. The spotted seal is the most social of these species, which may explain the more frequent occurrence on them of these parasites.

Nasal mites

A number of different species of nasal mites (Acarina:Halarachnidae) have been reported from pinnipeds of the world. However, our findings indicate that they are very scarce in seals of the Bering and Beaufort seas. Thus far, we have examined 202 ringed, ribbon, bearded and spotted seals and have found nasal mites in only four individuals, all of which were spotted seals.

The numbers, distribution, and (insofar as possible) cause of death of beached carcasses of marine mammals were investigated in four areas along the shores of the Bering Sea in 1978. Work in the first three (Seward Peninsula, St. Lawrence and St. Matthew islands) was on an opportunistic basis, during the second ice-front cruise (78A, Leg VI) of the NOAA Ship *Surveyor*, utilizing the ship's Bell 206 helicopter. The findings were as follows:

TABLE III

PERCENTAGE FREQUENCY OF OCCURRENCE OF PARASITIC HELMINTHS IN PINNIPEDS COLLECTED IN THE BERING SEA, 1978

Helminth	Host and number (n) examined				
	Sea lion (1)	Bearded seal (13)	Ribbon seal (30)	Spotted seal (19)	Ringed seal (24)
Anophryocephalus ochotensis	(100)	-	10	95	-
Diplogonoporus tetrapterus	(100)	-	13	37	8
Diphyllobothrium cordatum	-	85	-	-	-
Diphyllobothrium lanceolatum	-	77	-	-	-
Diphyllobothrium sp.	-	23	6	37	4
Pyramicocephalus phocarum	-	69	-	-	-
Orthosplanchnus fraterculus	-	7	3	-	-
Phocitrema fusiforme	-	-	-	16	-
Contracaecum osculatum	(100)	-	96	89	25
Phocanema decipiens	(100)	77	6	-	13
Corynosoma strumosum	-	-	83	100	96
Corynosoma semerme	(100)	-	90	95	50
Corynosoma villosum	(100)	-	6	11	-
Corynosoma validum	(100)	15	30	16	17
Corynosoma hadweni	-	-	-	-	58
Bulbosoma sp.	-	-	6	5	-

TABLE IV

OCCURRENCE IN BERING SEA FISHES OF LARVAL HELMINTHS POTENTIALLY CAPABLE OF INFECTING PINNIPEDS

		Kind of helminth and presence (X) or absence (-)							
Fishes	No. exam.	*Diphyllobothrium*	*Contracaecum*	*Phocanema*	*Anasakis*	*Corynosoma strumosum*	*C. Semerme*	*C. villosum*	*C. validum*
Herring *Clupea harengus*	9	-	-	-	X	-	-	-	-
Capelin *Mallotus villosus*	33	-	-	X	X	-	-	-	-
Pacific cod *Gadus macrocephalus*	17	X	-	-	X	X	-	-	-
Saffron cod *Eleginus gracilis*	1	X	-	-	-	-	-	-	-
Arctic cod *Boreogadus saida*	1	-	-	X	-	-	-	-	-
Pollock *Theragra chalcogramma*	101	X	X	X	X	-	-	-	-
Searcher *Bathymaster signatus*	3	-	X	-	-	-	-	X	-
Spotted prickleback *Lumpenus maculatus*	1	X	-	-	-	-	-	-	-
Eelpout *Lycodes raridens*	1	-	-	X	-	-	-	-	-
Eelpout *Lycodes palearis*	3	-	-	-	-	X	-	-	-
Thorny sculpin *Icelus spiniger*	8	-	-	X	-	-	-	-	-
Irish lord *Hemilepidotus jordani*	8	-	-	-	-	X	X	-	-
Bering Sea sculpin *Gymnocanthus galeatus*	2	-	-	-	X	X	-	-	-
European sculpin *Myoxocephalus scorpius*	5	-	-	-	-	-	-	-	-
Shorthorn sculpin *Myoxocephalus jaok*	1	-	X	X	X	X	-	-	X
Spinyhead sculpin *Dasycottus setiger*	1	-	X	X	-	-	-	X	-

Part of the western coast of the Seward Peninsula, from Cape Spencer to Cape Rodney (65.4 km), was surveyed on 9 June, at which time 8 dead walruses and 2 moribund spotted seal pups were sighted. Since it was not feasible to stop for examination of any of these, we do not know their cause of death or illness.

The ice-free part of the southern coast of St. Lawrence Island, from Powooiliak Point to Siknik Cape (60.3 km), was surveyed on 1 June. Findings there included one walrus (*Odobenus rosmarus*) and 3 gray whales (*Eschrichtius robustus*), which had died at least 6 months earlier, plus one fresh (gunshot) walrus, and 4 moribund seal pups. At least three of the latter were ringed seals; the fourth could not be identified with certainty. Each of the pups still retained its birth coat (lanugo), which is typical of starveling pups at that time.

Fresh carcasses of two dead walruses also were found floating at sea, among the ice floes near St. Lawrence Island. The first of these, a newborn calf, had many external lacerations on its body and appendages, extensive subcutaneous hemorrhages, fractured ribs, punctured lungs, and ruptured liver. The proximate cause of death was internal hemorrhage from the punctured lungs and ruptured liver. The external lacerations, which occurred as groups of 2 to 4 in parallel, 2.5 to 3 cm apart, resembled the tooth-marks of killer whales (which were seen in the vicinity); hence, it was presumed that this animal had been captured by them, played with much as a cat plays with a mouse, then discarded. The second specimen, an adult female, evidently had died some weeks or months earlier, since it was partly frozen internally. This one showed no gross pathological conditions other than mycotic dermatitis on the flippers and sever hemoglobinuria, the latter suggestive of kidney damage or infection. It had not been shot.

On 2 June, we surveyed the Punuk Islands, just east of St. Lawrence Island. The northernmost of these small islands is a regularly used hauling ground for walruses in autumn, and the beaches are predictably littered with the carcasses of those that die there each year, mainly from natural causes. We found 48 carcasses there of walruses that had died at least 6 months earlier, 7 of which were still in condition suitable for necropsy. With the time available, we were able to examine only three of these in detail. While we could not identify with certainty the primary cause of death, each of these animals had suffered a series of premortem traumatic injuries (as indicated by localized hemorrhage) that could have contributed to their death. None had been gunshot.

The northeastern coast of St. Lawrence Island was surveyed briefly on 3 December via snow-machine from Savoonga, in response to a plea from the local villagers (via the Alaska Department of Fish and Game) to investigate some unusual cases of mass mortality and mass spontaneous abortion of walruses that were hauling out on the island. Unfortunately, by the time of the survey, about a month after the events took place, nearly all of the carcasses had been drifted over by snow; those few that were not covered were already solidly frozen. The reported numbers of animals aborting ranged from 25 to 300; the actual numbers will not be known until a follow-up survey can be made, probably in June 1979. Apparently, at least 100 other carcasses of animals that died on the beach or washed ashore from the open sea also were present on the northern coast of St. Lawrence Island and on the outlying Punuk Islands. The causes of this mortality remain largely unknown; conceivably, some light can be shed by a follow-up survey this spring. The walrus population at present appears to be at or above its pre-exploitation level (Estes and Gol'tsev, MS, in prep.), in which case increased mortality rate and reproductive failure are to be expected.

Some 57.8 km of the northeastern and northwestern coasts of St. Matthew Island were surveyed by helicopter on 27 May. Findings included two walruses that had lain in place for more than 6 months and one fresh spotted seal. Since the remains of the walruses were little more than skeletal, cause of death could not be determined with certainty. However, a contributing (and perhaps primary) factor in one case was severe inflammation of the right posterior portion of the mandible, with severe osteolysis and probable abscess. This probably was caused by bacterial invasion of a wound, perhaps from a bullet or, more likely, from the tusk of another walrus. The seal had died from a bullet wound in the head.

A dead belukha (*Delphinapterus leucas*) was found floating in open water about 160 km northwest of St. Matthew Island on 6 May. This animal, an immature female, showed internal damages comparable to those of the walrus calf described above, but it had none of the external lacerations of the latter. Death was diagnosed as having been caused by internal hemmorrhage from trauma of unknown origin.

The northern coast of the Alaska Peninsula was surveyed twice in 1978, from Naknek in the east to Bechevin Bay in the west (654.2 km). In the first survey, via NOAA UH1H helicopter on 28-29 May, fresh remains of one minke whale (*Balaenoptera acutorostrata*), 3 sea otters (*Enhydra lutris*), 6 walruses, 1 sea lion, and 2 spotted seals were found, mainly in the easternmost and westernmost thirds of the coast. Too little remained of the whale (which mainly had been consumed, probably by brown bears, *Ursus arctos*) for necropsy, but the absence of its lower jaw and tongue suggested that it may have died from predation by killer whales (*Orcinus orca*). The proximate cause of death in two of the sea otters was starvation; the third showed an enlarged spleen, fatty degeneration of the liver, and some hemorrhage around the neck, but it was not clear which of these conditions was of primary or secondary importance. One of the walruses had suffered from an old, abcessed bullet wound in the head; each of the others was too badly mutilated (presumably by bears) for necropsy. The sea lion, an adult female, showed signs of having died while giving birth. Each of the seals had been intensively scavenged by terrestrial vertebrates, but absence of the head in one and a hemorrhage in the neck in the other suggested that both had died from gunshot.

A replicate survey of the same coastal district on 7-14 July via chartered fixed-wing aircraft, yielded 3 gray whales, 1 belukha, 5 sea otters, 4 walruses, 3 sea lions, 4 spotted seals, and 5 harbor seals (*Phoca vitulina*), only one of which (1 walrus) was an animal that had been sighted in the May survey. The remains of all others sighted in the May survey had disappeared or been reduced to a few bones by this time, indicating that the rate of deposition of carcasses on this coast is considerably higher than the single annual surveys have indicated in the past, and that the rate of their removal from the beach, principally by terrestrial scavengers, also is high.

The gray whales, the walruses, 2 of the sea lions and one of the sea otters were greatly dismembered and badly autolized; hence, the cause of death could not be determined. The belukha had become entangled and, presumably, drowned in a salmon gillnet. One of the sea lions, one of the spotted seals, and all of the harbor seals had died from gunshot wounds. One of the spotted seal pups and one sea otter apparently had starved to death; another spotted seal pup showed acute verminous pneumonia; the fourth spotted seal, a sub-adult, had suffered a diaphragmatic hernia and presumably suffocation as a result of it. One of the sea otters was diagnosed as having had bronchiopneumonia; a second showed hepatitis, probably acute, from a microbiological agent; a third sea otter showed severe fibrous peritonitis, evidently resulting from perforation of its small intestine and massive invasion of the abdominal cavity by the gut flora, especially *Eschrichia coli* (which was isolated in pure culture).

Also surveyed were 158.6 km of shoreline in inner Bristol Bay, from Naknek to Ekuk Point, on 19 July. Only two carcasses were found there: a belukha that apparently had been shot, and a walrus for which the cause of death could not be determined.

Western Gulf - Kodiak Area

A total of 24 sea lions and 59 harbor seals taken in the western Gulf of Alaska - Kodiak Island region were examined by necropsy in 1978. These showed a remarkable scarcity of pathological conditions. One sea lion had a sterile, draining puncture wound on its face; one harbor seal had a small (1 cm) papillomatous tumor on its right shoulder; another harbor seal showed severe focal necrosis of the liver, and a third had a serosal scar on its stomach suggestive of a healed penetrating ulcer. All others appeared to be in good health.

Thirteen species of parasitic helminths were identified from the digestive tract of these animals. Most of these occurred in both the harbor seals and the sea lions, though usually with strikingly different frequencies (Table V). One other endoparasite, a filariid nematode (*Dipetalonema spirocauda*) which lives as an adult in the right ventricle of the heart and in the pulmonary artery, was found in two of the 58 harbor seals and in none of the sea lions. The frequency of occurrence of each of these parasites in harbor seals and sea lions of the western Gulf - Kodiak area corresponded closely to those found in seals and sea lions of the northeastern Gulf in 1977.

We have not seen any remarkable abundance of ectoparasites (anopluran lice) in pinnipeds from this region. However, nasal mites have been found in abundance in about 80% of both the seals and the sea lions.

TABLE V

PERCENTAGE FREQUENCY OF OCCURRENCE OF PARASITIC HELMINTHS IN PINNIPEDS COLLECTED IN THE WESTERN GULF-KODIAK REGION, 1978

	Host and number (n) examined	
Helminth	Steller sea lion (25)	Harbor seal (58)
Anophryocephalus ochotensis	96	12
Diplogonoporus tetrapterus	92	28
Diphyllobothrium sp.	24	-
Pricetrema phocae	-	7
Pricetrema eumetopii	52	-
Phocitrema fusiforme	12	62
Dipetalonema spirocauda	-	3
Contracaecum osculatum	60	93
Phocanema decipiens	32	24
Anasakis sp.	16	7
Corynosoma strumosum	12	93
C. semerme	-	3
C. villosum	92	86
Bulbosoma sp.	-	5

Surveys of beached carcasses of marine mammals in this area were conducted sporadically, on an opportunistic basis. The shore of Sanak Island (63.5 km) was surveyed on 22 June via helicopter from the NS *Surveyor*; no carcasses were present. The shore of Chirikof Island (40.6 km) was surveyed on 17 April, 30 June, and 29 August, also by helicopter from the NS *Surveyor*. One Steller sea lion carcass was found on the first survey; the same carcass was the only one found on the second survey; none was found on the third. The Trinity Islands, Sitkinak (78.8 km) and Tugidak (104.2 km), just south of Kodiak Island, were surveyed on 15 April, also via helicopter from the *Surveyor*; no carcasses were found. Tugidak was surveyed again on 26 June via all-terrain vehicle and on foot, at which time 40 dead and moribund harbor seal pups, one dead fur seal (*Callorhinus ursinus*), and one very old set of remains from a large cetacean were found. The harbor seal pups were all starvelings (abandoned by the mother) associated with the large breeding colony there; the fur seal apparently had died at sea from becoming entangled in a fishnet. Carcasses of one sea otter and one minke whale also were found later in the summer in the same area.

Most of the Barren Islands (48.3 km), between Kodiak and the Kenai Peninsula, were surveyed via small boat on 12 April by K. Pitcher and K. Schneider (ADF&G), who reported that their only finding was of one prematurely aborted fetus of Steller sea lion.

Lower Cook Inlet

Twenty-five harbor seals collected in Lower Cook Inlet in 1978 were examined for pathological conditions. Seventeen of these had no gross signs of disease or injury, other than helminth infestations. Of the remainder, 7 showed focal abscesses in the liver, 5 had nodular lesions in the lungs typical of low-intensity lungworm infection, and one had a puncture wound of unknown origin on its chest. Ten species of helminths were isolated from these 25 and from the digestive tract of 11 others (Table VI). In general, their frequency of occurrence did not differ significantly from those in seals from the western Gulf - Kodiak region. As in the latter also, ectoparasites were scarce, and nasal mites occurred in about 80% of the seals.

Samples of urine, blood, and kidney from 23 of the harbor seals collected in Lower Cook Inlet were cultured by appropriate methods for isolation of *Leptospira* sp. Leptospires were isolated from 2 of these animals and have been forwarded to specialists for further study and identification.

The shores of Lower Cook Inlet were surveyed during 4-12 April via helicopter from the NS *Surveyor* and via small boat. In the 686.2 km covered at that time, mainly on the western side of the Inlet, the only findings were two prematurely aborted fetuses of harbor seals. The entire shores of the Inlet, from Cape Douglas and Katchemak Bay northward (1302.4 km), were surveyed again via helicopter on 14-18 August, at which time only one carcass was found. The latter, a large male sea lion, near Homer, was not in suitable condition for necropsy, hence its cause of death was not determined.

TABLE VI

FREQUENCY OF OCCURRENCE OF PARASITIC HELMINTHS IN 36 HARBOR SEALS TAKEN IN LOWER COOK INLET, 1978

Helminth	Seals	
	No. infected	Percent infected
Anophryocephalus ochotensis	1	2
Diplogonoporus tetrapterus	4	11
Phocitrema fusiforme	27	75
Dipetalonema spirocauda	4	11
Contracaecum osculatum	34	94
Phocanema decipiens	17	47
Corynosoma strumosum	36	100
Corynosoma semerme	1	2
Corynosoma villosum	35	97
Bulbosoma sp.	3	8

Through long-term personal acquaintance with the area and by correspondance and interview with local residents over the past twenty years, we have accumulated records of some 60 occurrences of beached carcasses of marine mammals on the shores of cook Inlet (Table VII). Most of these (47) have been of cetaceans, presumably because they attract more attention and because they persist longer on the beach. The distribution of these along the shore (Fig. 1) does not suggest any significant pattern, only that they are most often noticed and reported from areas accessible by highway along the eastern side of the Inlet, between Anchorage and Homer. The greatest proportion of them (about 50%) was of carcasses seen during the 1970's; about one-third was reported from the 1960's, and the remainder from earlier times. This does not imply that the rate of their occurrence has increased; rather, the apparent increase probably is more a function of human memory, increased population of observers, and more intensive recent effort to secure such reports. Their frequency of occurrence by month, irrespective of year, suggests that the greatest accumulation of dead marine mammals in this area takes place in spring, that it continues at a low level through the summer, and then increases again in autumn. The scarcity of strandings in winter probably reflects the low numbers of marine mammals in the inlet at that time, as well as the reduced number of observers scanning the beaches.

These records indicate that at least twelve species of marine mammals inhabit the inlet, and that most of them occur there with some regularity, mainly in spring and summer. While there are few published records of their occurrence there, the presence of most of them is common knowledge to the local residents. Apparently, only a few (harbor seal, minke whale, harbor porpoise, and belukha) utilize the entire inlet; the other eight species occur rarely north of Kachemak Bay. Most frequently reported as beached remains were the belukha (n = 20) and minke whale (n = 9), which seem to be the most abundant cetaceans in the inlet. Both occur as far north as Anchorage and to the eastern extremity of Turnagain Arm, as well as throughout the lower Inlet. It is probable that all or most of the unidentified large whales (n = 5) in Table VII were minke whales. Also common in the inlet are the harbor seal and harbor porpoise, though they were poorly represented in the records of beached carcasses. Presumably, the reason for this poor representation is their small size, which makes them most subject to swift removal by scavengers (especially bears, foxes, and eagles).

As our shoreline surveys have indicated, and the beached carcass reports have confirmed, the normal rate of accumulation of marine mammal remains in Cook Inlet is very low, relative to the other areas studied. In 1978, only eight occurrences were reported for the entire year; in 1977, there were only six. While the actual numbers certainly were higher than these (e.g. the three sighted by us during our 1978 surveys were not reported by the local residents), carcasses certainly are scarce there, and any significant increase probably would be apparent at once to the local residents.

TABLE VII

REPORTED OCCURRENCES OF BEACHED CARCASSES OF MARINE MAMMALS IN COOK INLET, 1940 to MARCH 1979

Species	Number	Location	Date	Source
Sea otter	"several"	Homer area	"since early 1960's"	Jim Reardon
Enhydra lutris	1	Homer area	"recently"	Will Anderson
Harbor seal	1	Turnagain Arm	"some years ago"	Chuck Evans
Phoca vitulina	"several"	Kasilof-Clam Gulch	"recent years"	George Jackinsky, Carl Cuseo
	1	Redoubt Bay	24 June 1976	Paul Arneson
	1 (fetus)	McNeil Head	8 April 1978	Ken Pitcher
	1 (fetus)	Duck Island	10 April 1978	F. H. Fay
Steller sea lion	1	Salamatof Beach	"early 1960's"	Regine Lewis
Eumetopias jubatus	1	Homer	September 1977	Will Anderson
	1	NW of Homer	14 August 1978	R. A. Dieterich, N. K. Murray
Gray whale *Eschrichtius robustus*	1	Deep Creek	"fall 1970 or 1971"	R. Schenier
Minke whale	2	vicinity Rabbit Cr.	spring 1960	Jerry Titus
Balaenoptera acutorostrata	1 (bones)	Seattle Creek	1962	A. A. Stuart
	1	Bird Point	14 June 1965	F. H. Fay
	1	Peterson Creek	20 June 1965	F. H. Fay
	1	Twenty-Mile Creek	early June 1971	Raymond Naddy
	1	Hope	1972 or 1973	Ross Miller
	1	Kenai River	early May 1978	Jim Lowendow
	1	Whiskey Gulch	6 October 1978	Kent Wohl
Fin whale	1	Redoubt Bay	1967	E. L. Ciechanski
Balaenoptera physalus	1	Anchor Point	21 June 1975	Al Thompson

TABLE VII

CONTINUED

Species	Number	Location	Date	Source
Humpback whale *Megaptera novaeangliae*	1	Point Bede	fall 1964	Clem Tillion
Unidentified large whales	1	Halibut Cove	1950's	Bob Moss
	1	Cape Starichkof	August 1963	Ave Thayer
	1	Chisik Island	1967 or 1968	Jim Reardon
	1	off Homer Spit	4 November 1977	Dave Hardy
	1	Johnson River	23 February 1979	Ken Pitcher
Killer whale	1	Hope	1950's	Carl Clark
Orcinus orca	1	Anchor Point	23 October 1946	Ivar Skarland
Harbor porpoise	1	Mackenzie Point	October 1959	Dick Drew
Phocoena phocoena	1	Homer Spit	summer 1977	Will Anderson
	1 (bones)	Homer Spit	spring 1978	Dave Erickson
	1	Bootlegger Cove	3 October 1978	Ted Schmidt
Dall porpoise *Phocoenoides dallii*	1 (bones)	Chickaloon Bay	4 September 1961	Ave Thayer
Belukha	1	Kalifonski Beach	"some years ago"	Charles Platt
Delphinapterus leucas	1	Mud Bay	"some years ago"	Bob Moss
	1	Salamatof Beach	1940's	Regine Lewis
	1	Hope	1950's	Carl Clark
	1 (bones)	Moose Point	July 1959	Ave Thayer
	1 (bones)	Nikishka Beach	July 1963	Dave Spencer
	1	North Kenai	July 1960's	Peggy Arness
	1 (bones)	Point Woronzof	July 1964	Doug Hilliard
	1	Kenai	about 1968	Phil Ames
	"more than 2"	Salamatof Beach	1974-1978	Louisa Miller
	1	SW Kalgin Island	1974	Mr. Herman
	1	North Kenai	May 1975	Carl Girten

TABLE VII

CONTINUED

Species	Number	Location	Date	Source
Belukha (cont.)	1	Swanson River	August 1977	Carl Girten
	1	Ninilchik	Sept. or Oct. 1977	Loren Flagg
	2 (1-bones)	Chinitna Bay	June 1978	Sam Stoker
	1	Kalifonski Beach	27 June 1978	N. K. Murray
	1 (bones)	SW Kalgin Island	August 1978	Bob Hartley
Bering Sea beaked whale	1	Cape Kasilof	11 May 1960	Ave Thayer
Mesoplodon stejnegeri	1	Homer Spit	13 November 1977	Dave Hardy

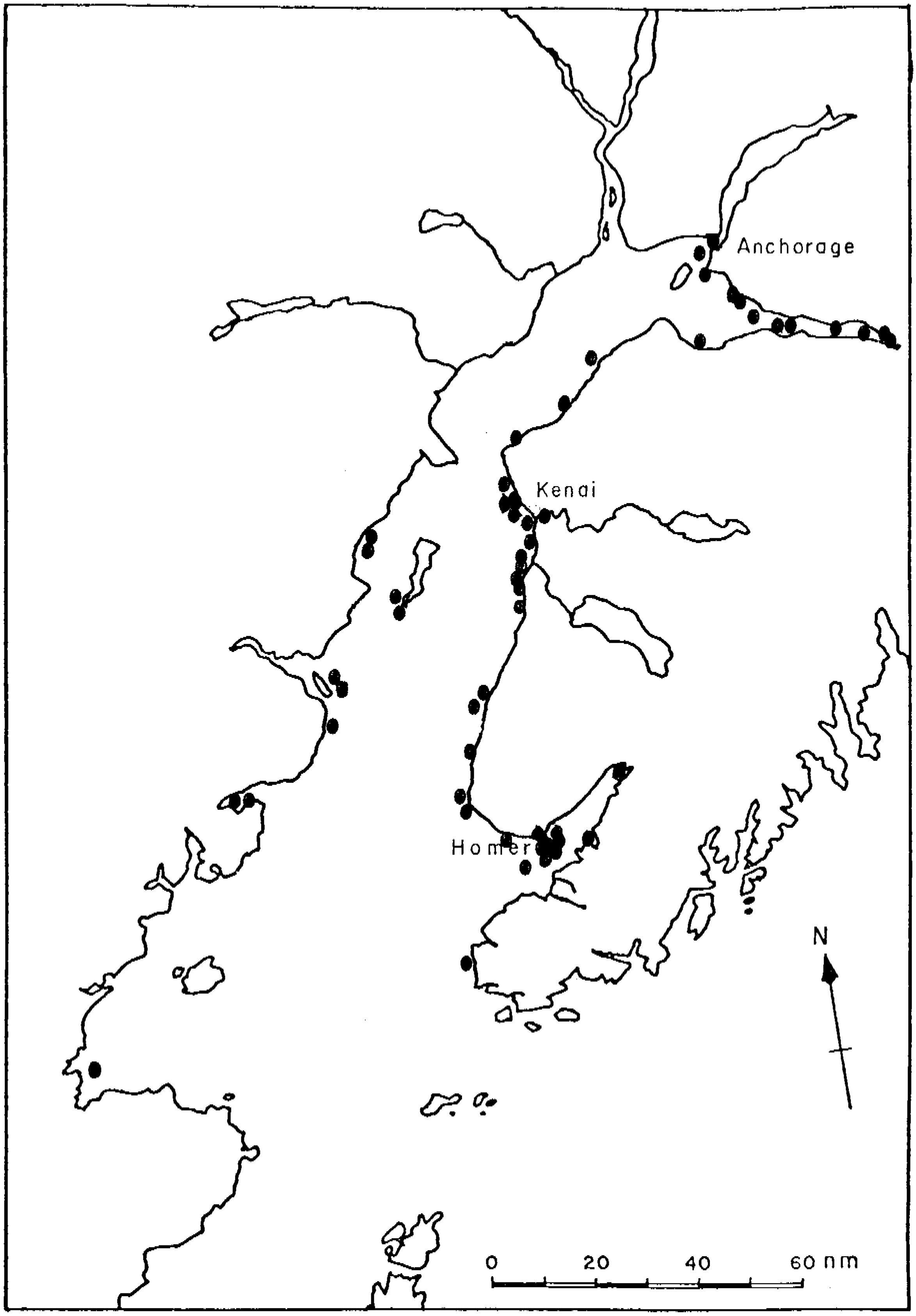


Fig. 1. Distribution of beached remains of marine mammals on the shores of Cook Inlet, from reports of local observers, 1940-1979.

Northeastern Gulf

Only one collected specimen was examined in this region in 1978. This was an adult female Steller sea lion that suffered a premature birth of its fetus on 4 April, at Cape St. Elias. Attempts to isolate viral or bacterial pathogens that might have caused or contributed to the abortion were unsuccessful. Of the 44 known births in this locality in 1978, 50% were premature abortions (Cunningham and Stanford, 1978). These took place between 25 March and 27 May; all of the normal, live births took place in June. However, even in the latter, the survival rate was extremely low (about 10%). Similar findings were recorded by the same investigators in this area in 1977, indicating that the sea lions using Cape St. Elias are markedly unsuccessful in reproduction, the reasons for which are not entirely clear.

Approximately 8% of the 700 animals that were hauled out on Cape St. Elias on 4 April 1978 showed circular dermatitis lesions in various locations on the body. Thus far, we have not succeeded in isolating the causative agent of these target lesions (apparently a bacterium), the effect of which is depilation, some swelling, and occasional cracking of the skin. We have seen them in sea lion populations of the Bering Sea and western Gulf - Kodiak region, as well, and have received a report of their presence in this species also in Japan (A. Niizuma, *in litt.*, 1976).

Beach surveys for dead marine mammals were conducted opportunistically during transit to and from Cape St. Elias on 3 and 6 April. These included most of the northwestern coast of Kayak Island, all of Wingham and Kanak islands, and the mainland shore from there to the western edge of the Copper River delta (86.4 km). No carcasses were sighted from the air (helicopter), but ground observers at Cape St. Elias reported findings of one additional sea lion abortus and of skeletal remains from a female sperm whale, *Physeter catodon*, that had stranded there some years previously.

The coast of Middleton Island (17.8 km), in the north-central Gulf, was surveyed at least twice in 1977 and 1978 by other OCSEAP investigators (J. D. Hall, R.U. #481; K. Wohl, R.U. #341), who reported the finding there of a Risso's dolphin (*Grampus griseus*) on 1 December 1977 and of a harbor porpoise on 11 March 1978.

Meetings

Project personnel participated in three relevant meetings in the past year:

1. US-USSR Marine Mammal Project, Ulan-Ude, USSR, 3-8 July

2. 29th Alaska Science Conference, Fairbanks, 15-17 August

3. OCSEAP Vertebrate Consumer Workshop, Fairbanks, 17-19 October

Publications

Fay, F. H., L. M. Shults and R. A. Dieterich. 1979. Natural mortality of marine mammals in Alaskan waters. *Trans. Alaska Sci. Conf.*, 29 (in press).

Shults, L. M. 1979. *Ogmogaster antarcticus* Johnston, 1931 (Trematoda: Notocotylidae) from the bowhead whale, *Balaena mysticetus* L. *Can. J. Zool.*, 57 (in press).

VII. DISCUSSION

The pathological conditions and agents observed in the collected specimens from each of the study areas in 1978 were not remarkably different from those seen in earlier samples, with the exception that, in the Bering Sea, the frequency of occurrence of mycotic infections seems to have declined over the past three years. Most remarkable is the apparently higher frequency of occurrence of pathological conditions in pinnipeds of the Bering Sea than in those from the Gulf of Alaska. Although the latter were more often affected by ectoparasites and nasal mites, presumably because of their more gregarious nature, they showed less evidence of exposure to the kinds of diseases and injuries that seem to be characteristic of the Bering Sea animals. This suggests either that life in the Gulf is less precarious than in the pack ice, or that the populations in the Gulf are in better equilibrium with their environment than are those in the Bering Sea.

This difference between areas has been indicated also by the lesser abundance of beached carcasses in the Gulf than on the shores of the Bering Sea. In 1978, the rate of occurrence of carcasses on the 643 km of shoreline surveyed in the Gulf (excluding the 40 starveling pups on the Tugidak harbor seal rookery) was 1/107 km, whereas on the 1,650 km surveyed in the Bering Sea (excluding the Punuk Islands), it was 1/30 km - more than three times as great. The lowest rate (1/663 km) was found in Cook Inlet, where 1,988 km of shoreline were surveyed in 1978.

In the few areas that we have been able to survey repeatedly over the past four years, the rate of occurrence of beached carcasses per survey has varied much less than we had anticipated. In Bristol Bay (5 surveys), the rate has ranged from about one carcass per 20 km to one per 80 km ($\bar{x}$ = 1/30), and on the southern coast of St. Lawrence Island (3 surveys), from 1/7 to 1/24 km ($\bar{x}$ = 1/12). This suggests that the normal range of variation may be on the order of ± 200% of the mean rate, and that any deviation of greater magnitude is likely to be indicative of some major change in the ability of the local environment to support the existing populations (or that the populations themselves have changed).

Some continued monitoring of these rates would be appropriate in the Bering Sea, where all of the pinnipeds and several of the cetaceans appear to be at or near their maximum levels of population. At least two of these populations, the California whale and the Pacific walrus, appear to have recently re-attained or exceeded their former, pre-exploitation levels, after prolonged suppression (Rice and Wolman, 1971; Estes and Gol'tsev, MS, in prep.); hence they can be expected to show increased mortality over the next few years, which should be reflected in the rate of occurrence of beached carcasses. Any significant perturbation of the environment of these animals, especially of their benthic food supplies, probably would tend to precipitate their decline.

The only long-term longitudinal data available on the rate of occurrence of gray whale and walrus carcasses in this area is from St. Lawrence Island

(Fay, unpublished). There, the number of gray whale carcasses that beached in 1955 to 1959 ranged from 0 to 5 per year ($\bar{x} = 2.4$); from 1960 to 1966 the range was from 3 to 7 ($\bar{x} = 4.8$); and in 1975 and 1976 their numbers were at least 10 and 17, respectively. Since the gray whale population is believed to have reached its upper level in the late 1960's (Rice and Wolman, 1971), the increased rate of occurrence of carcasses in the 1970's may indicate that the population is not yet in balance with the carrying capacity of its summer environment, i.e. that its mortality rate is substantially higher than it was during its growth phase.

The rate of occurrence of walrus carcasses along the southern coast of St. Lawrence Island, which is away from most of the influence of hunting mortality, has not changed significantly since 1953. In the 1950's and 60's (9 surveys), it amounted to about 1 carcass per 28 km, and in the 1970's (3 surveys), it averaged 1/26 km. Since there have been signs in recent years of the population's having reached or exceeded the carrying capacity of its environment (Fay *et al.*, 1977, 1978), an increase in mortality may be imminent. If so, it should be reflected by an increase in number of carcasses coming ashore in this area (and others), over the next few years.

IX. NEEDS FOR FURTHER STUDY

Beached Carcasses

Monitoring of the rate of occurrence of beached carcasses of marine mammals should be continued in a few key areas, in order to keep abreast of any changes as they occur, and to acquire statistically adequate data for their evaluation. Of highest priority would be areas in the Bering and Chukchi seas, where the majority of mammal populations appear to be at or near the carrying capacity of their environment and most likely to be affected by any natural or man-made changes in the ability of that environment to support them. Since carcasses already occur there at the highest rates in Alaska, subtle changes indicative of subsequent major events are not likely to be noticed by the sparsely distributed local populace but probably could be detected by a monitoring system. The areas in which monitoring should be continued would be those in which several annual replicates already have been obtained, i.e. Bristol Bay, St. Lawrence Island, and Bering Strait. Perhaps, one additional area farther north in the Chukchi Sea (e.g. Cape Lisbourne - Icy Cape) should be added.

Since the rates of occurrence of beached carcasses already are very low in the Kodiak, Gulf, and Cook Inlet areas, and since these areas already are closely minitored by the local populace, any significant changes there are likely to be noticed immediately and reported. Hence, there appears to be no immediate need there for an OCSEAP monitoring system, other than through phone and correspondence with key contacts.

Trophic relations/Helminthology

The helminth parasites in the digestive tract of marine mammals are acquired from the prey that they have eaten over some period of time. Hence, the kinds and numbers present are potentially translatable into kinds and numbers of prey consumed, provided that:

a) the intermediate host (i.e. the prey species) in which each parasite occurs is known,

b) the number of infective larvae per intermediate host has been determined,

c) the rate of development of the helminths in the final host (marine mammal) is described, and

d) the longevity of the parasites in the final host has been measured.

Whereas, examination of stomach contents provides information mainly of an instantaneous nature, i.e. of the seal's last meal, the helminthological data, given the above information, may provide a profile of the seal's feeding habits over several weeks or months previous to that last meal. Information points (a) and (b) are readily determined from necropsy and/or *in vitro* digestion of known or potential prey. Points (c) and (d) must be determined experimentally in animals held in captivity.

On an opportunistic basis to date, we have made some headway toward identifying some of the intermediate hosts from which Bering Sea seals acquire their parasites, but much more needs to be done. The remainder of the hosts need to be identified; the samples of each species of prey need to be greatly enlarged for determining with confidence the number of infective larvae per host. The experimental aspect for determining the developmental and longevity characteristics of the parasites also needs to be done. The helminthological data from the seals already have been obtained by this project, and much of the data from the intermediate hosts also will have been obtained in FY79. The remainder of the data from the intermediate hosts and much of the experimental work probably could be completed in two or three cruises in the Bering Sea in FY80-81, plus some additional work in the laboratories of the University of Alaska. This could be done in conjunction with personnel of R.U. #230-232 and, conceivably, could add substantially to the trophic information presently available from their work.

X. SUMMARY OF 3RD QUARTER OPERATIONS

Ship or Field Trip Schedule

10 April - 3 May	NS *Surveyor*, Bering Sea ice edge (Shults, Hoover). Necropsy of collected specimens (by R.U. #230-232 of marine mammals and their prey.

o/a 10 - 30 June	Charter aircraft and small boat, St. Lawrence Island (Fay, Shults). Assessment and necropsy of beached walrus carcasses which accumulated in fall 1978.

Laboratory Activities

Complete processing of FY78 histopathological materials; begin processing of FY79 materials. Prepare final report on feeding habits and feeding strategies of Alaskan arctic foxes, relative to their use of the marine environment.

XI. MILESTONE CHART

The milestone chart for this project has been revised extensively, as a result of analysis of the FY78 data and some change in emphasis.

1. Vertebrate Consumer Workshop, October 1978: This activity was not foreseen at the time of preparation of the original milestone chart, hence was not entered.

2. The proposed NEGOA/Cordova-C. St. Elias field trip with personnel of R.U. #243 (Pitcher-Calkins) was re-scheduled by Calkins as a short cruise via chartered ADF&G vessel to Puale Bay and Latax Rocks, Kodiak area, and actually took place from 28 March to 4 April. Though this cruise was completed, foul weather and unforeseen logistical difficulties resulted in unsuccessful completion of the scheduled field work.

3. In order to make best use of the logistic support available, the proposed Kodiak beach survey was deleted, and the funds for it were re-scheduled to allow project personnel to participate in the April-May ice edge cruise in the Bering Sea via the NS *Surveyor* (79A-Leg IV). Deletion of the Kodiak survey was based on the low probability of logistic support for it.

4. Addition of the arctic fox report was the result of amendment to the basic work plan, which was approved late in the 2nd quarter of FY79.

5. The St. Lawrence Island survey and necropsy field trip has been added, following approval of requested supplementary funding.

6. Bering Sea Synthesis Workshop: Not foreseen at time of preparation of the original milestone chart. First meeting (March 1979) could not be attended, due to conflict with other (non-OCSEAP) obligations. Possibility for attendance at second meeting (July 1979) questionable with present funds.

MILESTONE CHART

0 - Planned Completion Date

X - Actual Completion Date
(to be used on quarterly updates)

RU # 194 PI: F. H. Fay

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

		1978					1979								
MAJOR MILESTONES	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Quarterly Reports			XO						O			O			
Annual Report						O	X								
Vertebrate Consumer workshop	XO														
Kodiak-Puale Bay-Latax Rocks						XO									
NS Surveyor 79A-Leg IV								O							
Final Report, Arctic fox trophics										O					
St. Lawrence I. carcass survey (tentative)										O					
Bering Sea synthesis workshop (tentative)						O				O					
Cook Inlet survey											O				

XII. PROBLEMS ENCOUNTERED/RECOMMENDED CHANGES

Our only serious problems have been weather, which caused unsuccessful completion of one field operation, and shortage of funds, especially for workshop involvement (e.g. Vertebrate Consumer, and Bering Sea) which could not be foreseen at the time of submission of the basic proposal.

For those of us in this and other OCSEAP projects who are entirely dependent on grant and contract support for our programs, either advance warning or supplementary funding must be provided, rather than expenditure of research funds, if we are expected to invest our work time in unpredictable OCSEAP workshops and other regional meetings and conduct our research, as well.

LITERATURE CITED

Cunningham, W. and S. Stanford. 1978. Steller sea lion investigations at Cape St. Elias, March 22 through July 5, 1978. Processed Rept., Alaska Dept. Fish Game, Anchorage.

Estes, J. A. and V. N. Gol'tsev. Abundance and distribution of the Pacific walrus: results of the first Soviet-American joint aerial survey, autumn 1975. Manuscript in preparation.

Fay, J. H. 1976. Morbidity and mortality of marine mammals - Bering Sea. OCSEAP Quarterly Rept. R.U. #194, 31 March 1976.

Fay, F. H., H. M. Feder and S. W. Stoker. 1977. An estimation of the impact of the Pacific walrus population on its food resources in the Bering Sea. Rept. to Marine Mammal Commission. NTIS PB-273-505.

Fay, F. H., R. A. Dieterich and L. M. Shults. 1978. Morbidity and mortality of marine mammals. OCSEAP Quarterly Rept. R.U. #194, 31 December 1978.

Koeman, J. H., W. H. M. Peeters, C. H. M. Koudstaal-Holl, P. S. Tjioe and J. J. M. deGoeij. 1973. Mercury-Selenium correlations in marine mammals. *Nature* (London) 245:385-386.

Rice, D. W. and A. A. Wolman. 1971. *The Life History and Ecology of the Gray Whale (Eschrichtius robustus)*. Spec. Publ. No. 3, Amer. Soc. Mammalogists.

Stirling, I., W. R. Archibald and D. DeMaster. 1977. Distribution and abundance of seals in the eastern Beaufort Sea. *J. Fish. Res. Bd. Canada* 34:976-988.

Annual Report

Contract #03-5-022-53
Research Unit #232
Reporting Period - 1 October 1978 -
1 April 1979
Number of Pages: 71

Trophic Relationships Among Ice Inhabiting Phocid Seals[1]

Principal Investigators

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

Assisted by: Glenn Seaman, Richard Tremaine, Robin Lynn,
Dan Strickland, Pam Fields and Lawrence Miller

1 April 1979

---

[1] Results of our Beaufort Sea work are presented in a separate Beaufort Sea Final Report.

Table of Contents

I. Summary

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

In this report we will also present preliminary information on the foods of belukha whales in the Bering and Chukchi Seas. This information will be included in our assessment of possible effects of OCS development on trophic relationships of ice-associated marine mammals.

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

A total of 1,585[1] specimens are included in this report, more than twice the number reported on in 1978. Stomachs containing food from 979 ringed seals, 397 bearded seals, 104 spotted seals, 26 ribbon seals and 79 belukha whales have been collected and examined. The majority of the samples were collected at coastal hunting sites in the Bering and Chukchi Seas during summer. These collections were supplemented by shipboard and helicopter collections made by Alaska Department of Fish and Game personnel in the Bering, Chukchi and Beaufort Seas. Of particular note is the increase in Beaufort Sea samples, as well as the increase in specimens collected during fall and winter months.

Results are presented by locality and time of year for three major geographical areas: southeastern Bering Sea, northern Bering Sea and Chukchi Sea. Results of analysis of specimens from the Beaufort Sea are presented in a separate Beaufort Sea Final Report.

---

[1] Includes specimens reported in our Beaufort Sea Final Report.

General feeding patterns are discussed for each species in each area. A brief evaluation of geographical, temporal and age- and sex-related dietary differences is made. Results of our investigations of feeding habits are compared to those of previous investigators and to what is known of food availability. Key prey items for each species in each area are identified.

The determination of prey items is only an initial step in this project. In order to attain the goal of predicting effects of OCS development, much information is needed on the functioning of other components of the ecosystem. Other OCSEAP projects have provided much of this information.

II. Introduction

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

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

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

Specific objectives of this project are as follows:

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

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

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

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

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

Given the fact that leasing of tracts may soon occur in the Beaufort Sea, we have concentrated our synthetic efforts on this area. Results of our Beaufort Sea studies are presented in a separate Beaufort Sea Final Report. Discussion and synthesis for other areas included in this report are considerably less extensive. However, we have included all new data we have gathered from other areas and updated our assessment of key prey species and data needs in those areas. Detailed synthesis of information collected in the Bering and Chukchi Seas will be undertaken in FY 80.

In the discussions that follow it will be necessary to give the names of many species of marine animals. The authors realize that there are advantages to the use of either common or scientific names. In this report we will use common names whenever such are available and appropriate. For purposes of clarity and ease of reference, the accepted scientific names of most species for which we will use common names are given in Table 1. For species mentioned seldom in this report, both common and scientific names are given at the first mention of that species.

Table 1. Common and scientific names of species commonly mentioned in this report.

Common Name	Scientific Name
Pollock	*Theragra chalcogramma*
Arctic cod	*Boreogadus saida*
Saffron cod	*Eleginus gracilus*
Herring	*Clupea harengus*
Boreal smelt	*Osmerus esperlanus*
Sand lance	*Ammodytes hexapterus*
Capelin	*Mallotus villosus*
Greenling	*Hexagrammos* sp.
Stickleback	*Pungitius pungitius*
Prickleback	*Lumpenus* sp.
Sculpin	Family Cottidae
Flatfish	Family Pleuronectidae
Poacher	Family Agonidae
Tanner crab	*Chionocetes opilio*
Spider crab	*Hyas* spp.

III. Current state of knowledge

The search for information on distribution, abundance and natural history of potential prey items is essentially complete. Our efforts have been to a large degree aided by the efforts of other projects (e.g. Carey 1977). However, although literature searches have turned up a great many references, it is evident that such information as is presently available (e.g. Stoker 1973, Crane 1974) is in most cases not sufficient to satisfy the needs of this study. This is in part due to the fact that many of the prey species utilized by ice-associated marine mammals are not of commercial importance and therefore have received little detailed study.

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

A. Ringed seal

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

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

McLaren (1958) examined stomachs of ringed seals taken at several localities in the eastern Canadian Arctic. The feeding pattern observed in this area appeared to be largely determined by water depth. In shallow inshore areas the major food items were fishes (mostly arctic cod and sculpins), mysids and shrimps. In deeper offshore waters the primary food was Parathemisto libellula. No seasonal or age-related differences in food items were noted. A decreased percent of stomachs containing food was noted from late April to the end of June.

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

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

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

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

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

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

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

B. Bearded seal

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

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

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

Kosygin (1966, 1971) reported on the foods of the bearded seal in the Bering Sea in spring and early summer (March to June) 1963 to 1965. Stomachs from 565 animals were examined, 152 of which contained food. The tanner crab was the species most commonly eaten, making up from 53 to 76 percent of the food. Shrimp (particularly Argis (=Nectocrangon) lar) were the second most important food. Snails were also important. Octopus, priapulids and fishes (particularly pricklebacks and flatfishes) were eaten quite regularly.

Kosygin noted considerable constancy in the diet from year to year which he explained by the fact that the animals tend to be found in the same areas each year. Some annular changes were noted (e.g. polychaetes were commonly eaten in 1963 but not in 1964 or 1965) which Kosygin thought were mostly due to heavy ice fields excluding animals from certain feeding areas. No age- or sex-related feeding differences were noted with the exception that it appeared that young bearded seals foraged mostly in the morning while mature animals ate more in the afternoon. The average amount of food in the stomachs decreased from April to June.

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

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

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

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

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

C. Spotted seal

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

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

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

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

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

Gol'tsev (1971) examined 319 stomachs from seals collected primarily in the northwest Bering Sea during the 1966-68 hunting seasons (April-June). From his collections he concluded that spotted seals feed in the morning and in the evening and digest their food quite rapidly. The food of newly weaned young (5 weeks old) was entirely amphipods (*Nototropis* sp. and *Anonyx nugax*) and some algae. At 7 to 8 weeks old they begin to feed on shrimps (*Spirontocaris macarovi*, *Eualus fabricii* and *E. gaimardii*) and sand lance. When 12 weeks old, larger fish (flatfish and saffron cod) begin to be eaten. Juveniles (age 1 to 4 years) fed mostly on fish (arctic cod, sand lance, saffron cod) and shrimps (*Pandalus* sp.). Adults appear to feed more on benthic forms with octopus, crabs, flounders, sculpins and other bottom fishes prevalent.

Recent data on foods of spotted seals collected in the Bering Sea by Soviet and American investigators are presently being summarized (Bukhtiyarov, Frost and Lowry, in prep.).

D. Ribbon seal

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

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

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

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

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

E. Belukha whale

Kleinenberg et al. (1964) summarized the information available on foods of belukha whales in Soviet waters. In the Sea of Okhotsk the main foods were herring, pink and chum salmon (*Oncorhynchus gorbuscha* and *O. keta*), saffron cod and shrimps. In the Barents Sea, Kara Sea and the vicinity of Novaya Zemlya arctic cod were the major food. In the White Sea the diet of belukhas was more varied, including herring, capelin, saffron and arctic cod, flatfishes, haddock (*Melanogrammus aeglefinus*) and crustaceans.

Vladykov (1946) conducted an intensive study of the foods of belukhas in the Gulf of St. Lawrence. He found that belukhas fed almost exclusively on capelin in June and July. In August and September the diet included sand lance (Ammodytes americanus), flatfishes, cod (Gadus spp.), polychaete worms and cephalopods. He noted that animals in their second year ate mostly capelin, sand lance and shrimps. Larger fishes were eaten by older animals. In addition, he found that males tended to eat more large fishes.

Sergeant (1973) reported the summer foods of belukhas at two locations in western Hudson Bay. At Churchill he found that the whales had eaten mostly capelin and smaller amounts of whitefish (Coregonus sp.), pike (Esox lucius), crustaceans and squid. At Whale Cove, about 350 km north of Churchill, belukhas ate mostly crustaceans, including crabs (Hyas coarctatus) and several species of shrimps (Pandalus montagui, Eualus gaimardii, E. fabricii and family Crangonidae). He also reported that two belukhas taken in summer at Cape Dorset, Baffin Island had eaten arctic cod.

The only published information on foods of belukhas in Alaska comes from the work of Brooks in Bristol Bay, reported in Klinkhart (1966). Five species of salmon (Oncorhynchus spp.), smelt, flatfishes, sculpins, blennies, lamprey, shrimps and mussels were found in the stomachs examined. Smelt were the main food in early May. In late May downstream migrating fingerling salmon were the most important food. From the first of July through the end of August upstream migrating adult salmon were the main prey.

IV. Study area

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

V. Sources, methods and rationale of data collection

A. Literature

Compilation of existing literature and unpublished data on the food habits and trophic interactions of ice inhabiting seals is essentially complete. Available information on the distribution, abundance and natural history of potentially important prey species has also been compiled. Pertinent literature has been obtained through an OASIS literature search for information about food habits of seals, discussion and consultation with personnel from the University of Alaska Marine Museum/Sorting Center, use of

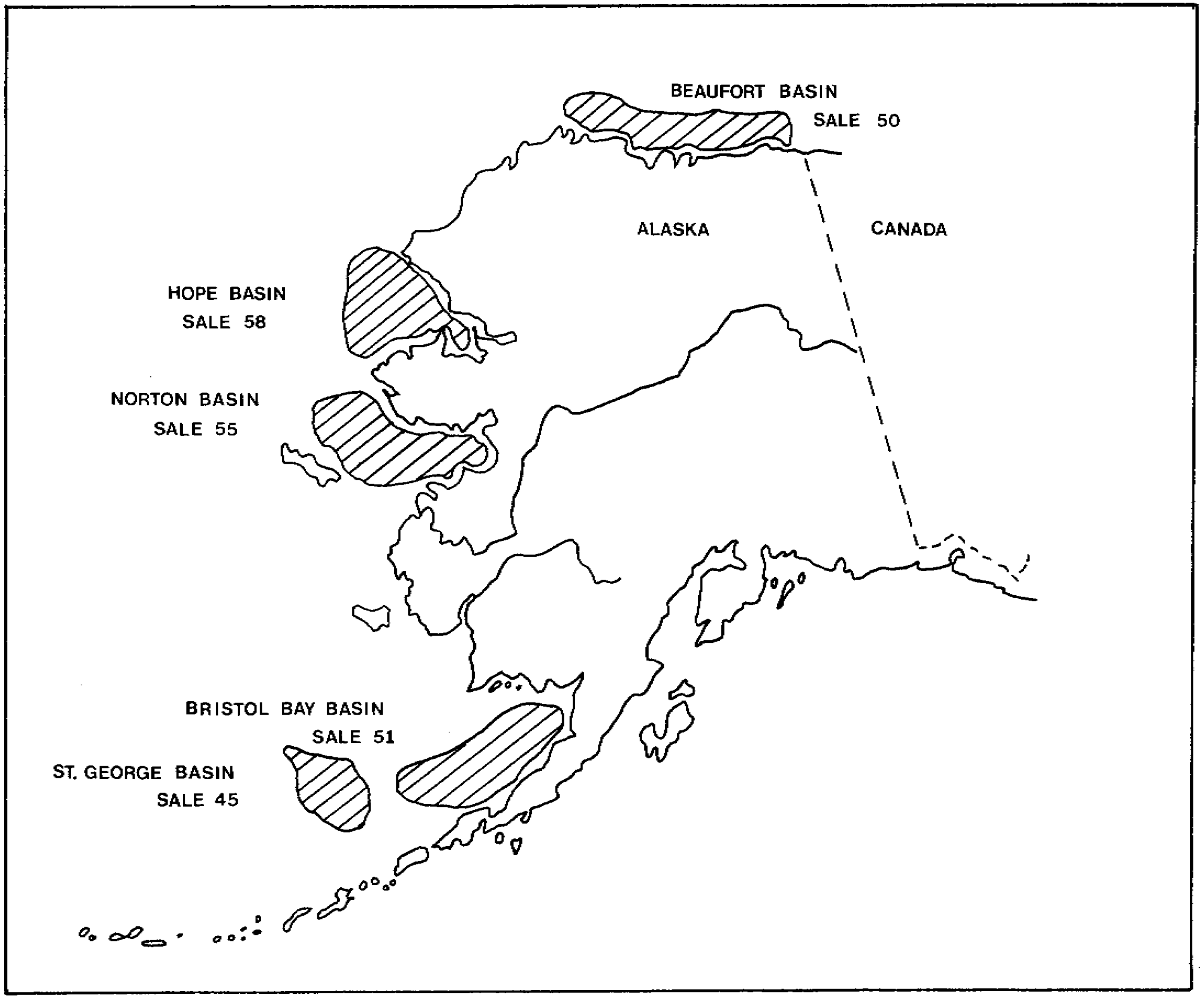


Figure 1. Map of Alaska showing proposed OCS lease areas which are included in the study area of this project.

various translation services (Israel Program for Scientific Translations and Fisheries Research Board of Canada) for access to Russian literature, search of Alaska Department of Fish and Game reprint files, library and other literature collections, use of University of Alaska library facilities and inter-library loan services.

B. Field collection of specimen material

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

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

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

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

When possible, in addition to collection of stomach specimen material, bottom sampling for fishes and invertebrates was conducted with a 19-foot Marinovich otter trawl (1-3/8-inch stretch mesh body, 1/4-inch mesh cod end liner). Trawls were of 10-20 minutes duration at a ship speed of 2-4 knots. Contents of each trawl were identified, enumerated and representative specimens of organisms retained. Fishes were measured and weighed, and the otoliths removed and measured to determine the correlation of otolith size to fish size. Stomach contents of some fishes were examined. Examples of selected invertebrate species were measured and weighed to provide an index of length/weight ratios that could be applied to partially digested food items found in seal stomachs.

C. Laboratory procedures and identification

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

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

The washed contents were either transferred to finger bowls and petri dishes for immediate rough sorting, or placed in jars and stored in 10 percent formalin until sorting could be done. If the latter took place, otoliths were first sorted out and stored separately in 70 percent ethyl alcohol to avoid degradation by the formalin. Rough sorting entailed separation of parasites from food items and separation of food items into major taxonomic groups. Some parasites were examined by other ADF&G personnel as part of natural history studies on ringed and bearded seals (RU #230). Recently parasites have been provided to RU #194.

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

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

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

D. Data management

With minor modifications, design of formats to handle data and design of compatible data sheets to facilitate keypunching were completed prior to last year's annual report. Since then data have been keypunched, recorded on magnetic tape and submitted to NODC to meet data archiving requirements. Extensive time has been devoted to quality control of data. We have recently obtained a PDP-8 computer system which is being used for data entry and checking as well as for data analysis.

VI and VII. Results and Discussion

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

As mentioned in section IV, our presentation and discussion of results will be broken down into several sub-areas. Detailed presentation of results has been presented in quarterly reports and the annual reports for 1976 and 1977. In the following presentation and discussion, as in our 1978 annual report, we will deal with results in more general terms in order to elucidate patterns and to increase the potential use of our findings. For example, in areas where samples have been collected each year for several years, the results may be presented for all years combined if year-to-year differences do not appear important.

In the following presentation and discussion of results, feeding patterns will usually be described in terms of groups of similar organisms, for example shrimps, crabs or clams. This is done for simplification and to make the results more understandable to those not familiar with the numerous species of animals involved in this study. The specific identity of prey items is in some instances of great importance and these species will be pointed out where appropriate such as in identification of key prey species.

In this report, data from all specimens collected and analyzed since spring 1975 will be reported. In addition, information from specimens collected prior to the beginning of OCSEAP is included where it will significantly add to the understanding of the trophic relationships of the species being studied. Table 2 summarizes the number of specimens included in this report as compared to the 1977 and 1978 annual reports of RU #232. Numbers in Table 2 refer only to processed specimens which contained food.

A. Southeastern Bering Sea

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

Due to the prioritization of work in the various lease areas, we conducted no field work in the southeastern Bering Sea during FY 79. The results we presented in our 1978 annual report are therefore complete for the southeastern Bering Sea area and will not be repeated here. We plan to conduct field work from the SURVEYOR in this region in spring 1979, and the results from those and previous collections will be synthesized and presented in a final report prepared in FY 80. Some aspects of feeding of seals in the southeastern Bering Sea have been treated in a recent publication (Lowry et al, in press; see Section XI-B).

B. Northern Bering Sea

A map of the northern Bering Sea is shown in Figure 2. The Norton Basin lease sale area covers much of this region. Seasonal sea ice is present in this area from late fall until late spring.

Table 2. Breakdown by species and geographical area of stomach contents data included in this report and in the 1977 and 1978 annual reports of this research unit. Numbers include only stomachs which contained food.

Location	Report Year	Species Ringed	Bearded	Spotted	Ribbon	Belukha
SE Bering	1977	6	12	15	5	--
	1978	6	16	23	9	--
	1979	6	16	23	9	--
N Bering	1977	29	29	6	--	--
	1978	143	61	19	--	--
	1979	211	139	41	17	3
Chukchi	1977	161	40	5	--	--
	1978	223	67	30	--	--
	1979	559	222	40	--	76
Beaufort	1977	21	3	--	--	--
	1978	75	17	--	--	--
	1979	203	20	--	--	--
Total	1977	217	84	26	5	--
	1978	447	161	72	9	--
	1979	979	397	104	26	79

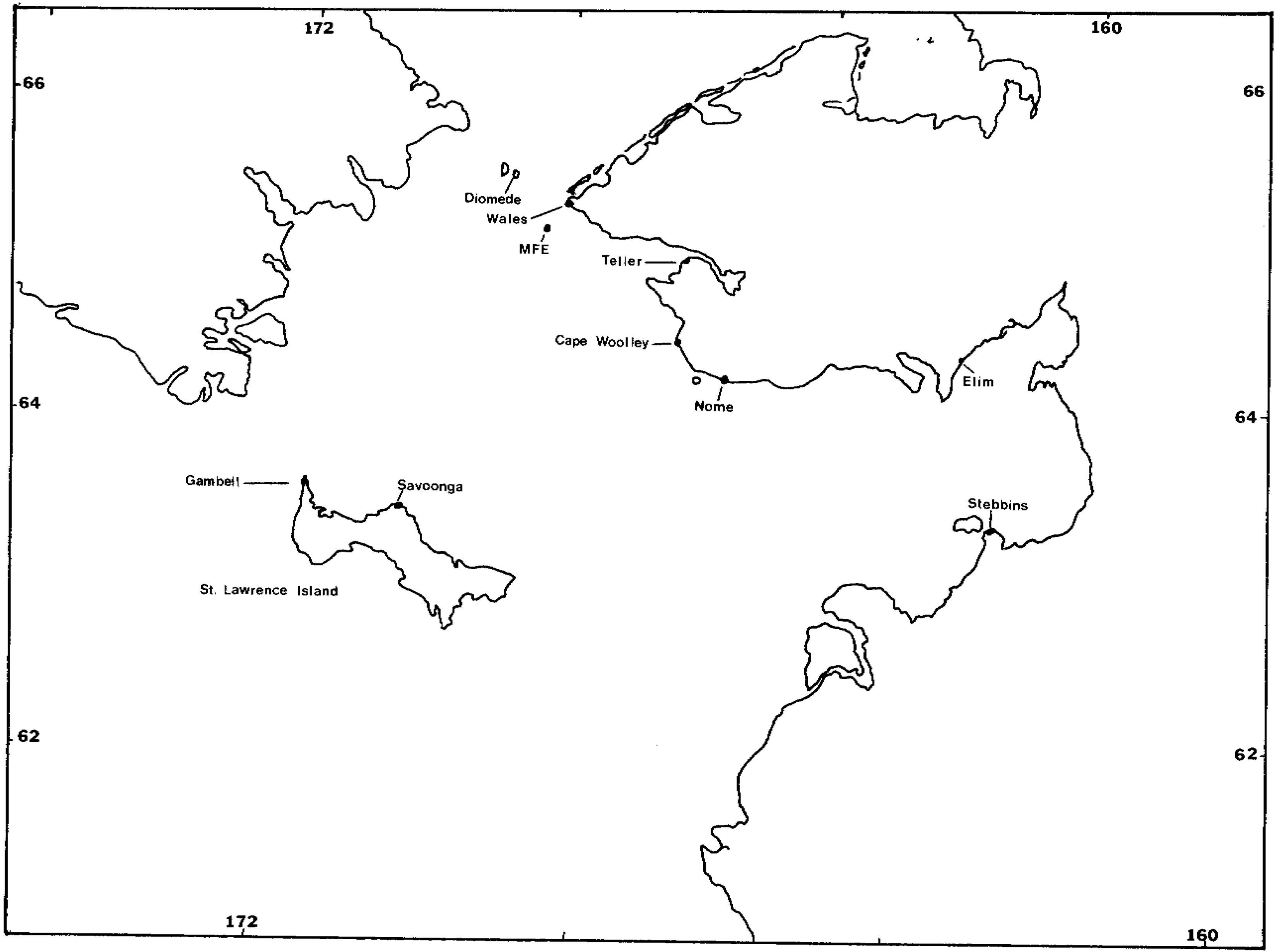


Figure 2. Map of the northern Bering Sea showing locations of specimen collections.

Large numbers of ringed and bearded seals winter in this area. Ringed, bearded and spotted seals pass through the area during spring and fall migrations. Spotted seals and occasionally ringed and bearded seals summer in some parts of Norton Sound and around St. Lawrence Island. Residents of Gambell, Savoonga, Diomede, Wales, Nome and Stebbins actively engage in seal hunting. The peak of hunting activity occurs in the spring, with fall and winter hunting occurring sporadically at some localities.

Table 3 gives a schedule of field activities conducted in the northern Bering Sea during the past year. Locations are shown in Figure 2. Results of stomach content analysis are given in Tables 4-15.

Table 3. Schedule of field activities in FY 1979, northern Bering Sea.

Location/Platform	Dates	Personnel
SURVEYOR	1 May-15 June 1978	L. Lowry, K. Frost, J. Burns
Gambell	1-24 March 1978 28 April-29 May 1978	G. Seaman ADF&G personnel
Savoonga	27 May-11 June 1978	ADF&G personnel
Wales	31 May-17 June 1978	D. Strickland
Diomede	19 May-15 June 1978	ADF&G personnel

Relatively few spotted seal specimens have been obtained from the northern Bering Sea. The stomach contents of 31 animals taken in May and June are shown in Table 4. Although the foods eaten seem to differ among the collection locations, sample sizes are too small to treat these variations with confidence. The overall most important food items in the northern Bering Sea in spring were several species of fishes, shrimps (mostly *Pandalus goniurus*) and octopus. Available information on foods of spotted seals in this area in fall is given in Table 5. Most of these data were collected prior to OCSEAP at two locations on the Seward Peninsula. Fishes made up almost all of the stomach contents. Saffon cod, smelt, herring and sand lance were the species most frequently eaten.

Although spotted seals are numerous in some areas of the northern Bering Sea and Norton Sound in summer, we have made no effort to collect animals at that time of year. It is likely that during summer they eat mostly abundant forage fishes such as saffron cod, herring, smelt and sand lance.

Table 4. Spotted seal stomach contents data from the northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area: Dates: Sample Size:		Gambell May-June 1977-78 5	Savoonga May 1975-78 7	Wales June 1977-78 8	SURVEYOR May-June 1978 11	All Areas May-June 1975-78 31
Mean Volume (ml)		304.9	75.7	76.9	270.5	182.1
Food Items	1	Fish 95 Sand lance 52 Sculpins 48	Shrimp 90	Fish 70 Saffron cod 62 Boreal smelt 12 Herring 10 Sand lance 6	Fish 96 Arctic cod 43 Capelin 26 Saffron cod 20 Herring 4	Fish 84 Saffron cod 29 Arctic cod 26 Capelin 14 Sand lance 10
	2	Shrimp 4	Hyperiid Amphipods 5	Shrimp 29	Octopus 3	Shrimp 13
	3		Euphausiids 5			Octopus 2
	4					
	5					

Table 5. Spotted seal stomach contents data from the northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Cape Woolley	Teller	Teller	Nome	
Dates:		14 Aug.-20 Sept. 1971 & 1972	12 Sept.-15 Oct. 1970 & 1972	8-21 November 1972	21 November 1976	
Sample Size:		2	5	2	1	
Mean Volume (ml)		50.1	1480.0	965.0	867.0	
Food Items	1	Fish 97 Saffron cod 97 Sand lance 2	Fish 100 Herring 70 Smelt 20 Capelin 10	Fish 100 Smelt 76 Saffron cod 24	Fish 100 Sand lance 99 Saffron cod 1	
	2	Gammarid amphipods 2				
	3					
	4					
	5					

Some aspects of the feeding of spotted seals in the Bering Sea will be dealt with in a manuscript currently in preparation (Bukhtiyarov, Frost and Lowry, in prep.).

Data on the foods of ribbon seals in the northern Bering Sea in May and June are presented in Table 6. These results are based on identification and enumeration of material found in stomachs and intestines and may therefore underestimate the importance of soft-bodied prey. Most of the otoliths found in ribbon seals taken southwest of St. Lawrence Island were from pollock. Northeast of St. Lawrence Island most of the otoliths were from arctic cod. These results, combined with those for the southeastern Bering Sea presented in our 1978 annual report, indicate a decreasing importance of pollock in the ribbon seal diet in more northerly areas. These results correspond well with the known distribution and abundance of pollock (Pereyra et al. 1976, Wolotira et al. 1977) which become less abundant north of St. Matthew Island. Eelpout and flatfishes were eaten most commonly in the area southeast of St. Lawrence Island, while sculpins and saffron cod were eaten most commonly north of St. Lawrence Island. Results of our work on ribbon seals will be treated in detail in a manuscript currently in preparation (Shults and Frost, in prep.).

Ringed seal specimens from the northern Bering Sea have been collected from a number of locations, years and times of year. Geographical variation in the late spring and early summer diet is shown in Table 7. All samples obtained since the beginning of OCSEAP in this area in the May-July period are included in order to represent the overall foods of ringed seals in the area. Arctic cod, saffron cod and shrimps were the major foods at most locations. However, mysids were the primary food of seals taken at Savoonga and gammarid amphipods were a major food at Diomede. The results shown for Diomede include seals taken during the years 1975-1978. Table 8 shows these results by year and includes 4 years of pre-OCSEAP data. Although shrimps, arctic cod and gammarid amphipods are major prey in all years, the relative importance of these three prey types varies from year to year. The highest volumes of stomach contents were generally found in years when arctic cod were the primary food. This suggests that abundance and availability of arctic cod may be the factor which controls the total quantity of food consumed and the relative importance of the various prey in the diet. Sea ice characteristics and hydrographic conditions may be the factors influencing the abundance of arctic cod in the vicinity of Diomede in the various years.

Age-related differences in feeding of ringed seals in the northern Bering Sea are shown in Tables 9 and 10. Table 9 includes all specimens collected in the area in the spring-summer months since 1975. The importance of fish in the diet increases from only trace amounts in pups to 91 percent of the food found in seals older than 5 years. The importance of shrimps and small crustaceans (mysids and amphipods) in the diet decreases with age. In addition,

Table 6. Ribbon seal stomach and intestinal data, northern Bering Sea.

Location:	Southwest of St. Lawrence I.		Northeast of St. Lawrence I.	
Dates:	4-12 May 1978		28 May-10 June 1978	
Sample Size:	10		7	
Food Item	No. Occurrences	Percent of Total Fishes	No. Occurrences	Percent of Total Fishes
Invertebrates				
Mysid	1	--	--	--
Shrimp	--	--	1	--
Tanner crab	--	--	1	--
Octopus	--	--	2	--
Fishes				
Pollock	10	52.9	1	1.1
Arctic cod	1	4.0	7	86.0
Saffron cod	--	--	1	9.7
Capelin	5	9.0	--	--
Eelpout	5	8.6	--	--
Prickleback	4	11.9	--	--
Sculpin	--	--	2	3.2
Flatfish	9	13.7	--	--

Table 7. Ringed seal stomach contents data from the northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		SURVEYOR	Savoonga	Gambell	Nome	Wales
Dates:		June 1978	May-June 1975-78	May-June 1977	May-June 1975-77	May-July 1977-78
Sample Size:		5	5	30	17	30
Mean Volume (ml)		125.9	53.8	95.7	345.8	122.5
Food Items	1	Shrimp 78	Mysids 62	Shrimp 41	Fish 96 Saffron cod 96 Sticklebacks 3	Fish 67 Saffron cod 100
	2	Fish 20 Arctic cod 72 Saffron cod 17 Herring 6 Sculpins 6	Shrimp 17	Fish 36 Saffron cod 47 Arctic cod 23 Sculpins 23 Sand lance 3	Shrimp 3	Shrimp 27
	3	Gammarid amphipods 2	Euphausiids 6	Mysids 13		Mysids 5
	4			Hyperiid amphipods 6		
	5			Gammarid amphipods 3		

Table 7. cont. Ringed seal stomach contents data from the northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Diomede				
Dates:		May-June 1975-78				
Sample Size:		23				
Mean Volume (ml)		63.5				
Food Items	1	Shrimp 38				
	2	Gammarid amphipod 34				
	3	Fish 18 Arctic cod 81 Saffron cod 11 Sculpin 5				
	4					
	5					

Table 8. Ringed seal stomach contents data from the northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area: Dates: Sample Size:		Diomede 17 May-14 June 1958 14 Kenyon (1962)	Diomede 20 May-3 June 1970 12	Diomede 23 May-11 June 1971 14	Diomede 15 May-1 June 1974 15	Diomede 28 May-1 June 1975 12
Mean Volume (ml)		86.0	118.3	255.7	138.1	54.9
Food Items	1	Shrimp	Fish 99 Arctic cod 81	Fish 99 Arctic cod 100	Fish 88 Arctic cod 69 Saffron cod 23 Sculpins 8	Gammarid amphipods 58
	2	Gammarid amphipods		Shrimp 1	Gammarid amphipods 10	Shrimp 18
	3	Fish			Shrimp 2	Fish 14 Sculpin 54 Arctic cod 43
	4	Mysids				
	5					

Table 8. cont. Ringed seal stomach contents data from the northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Diomede	Diomede			
Dates:		27 May-3 June 1977	21-28 May 1978			
Sample Size:		7	3			
Mean Volume (ml)		50.8	136.1			
Food Items	1	Shrimp 44	Shrimp 83			
	2	Fish 40 Arctic cod 86 Saffron cod 12	Gammarid amphipods 17			
	3	Gammarid amphipods 15				
	4					
	5					

Table 9. Ringed seal stomach contents data from the northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		N. Bering	N. Bering	N. Bering	N. Bering	
Dates:		May-July 1975-78	May-July 1975-78	May-July 1975-78	May-July 1975-78	
Sample Size:		31 Pups	30 Yearlings	21 2-5-Year-Olds	23 More than 5 Years	
Mean Volume (ml)		44.8	57.2	147.4	351.2	
Food Items	1	Shrimp 62	Shrimp 50	Fish 53 Saffron cod 98 Arctic cod 1	Fish 91 Saffron cod 98 Arctic cod 2	
	2	Mysid 25	Fish 22 Saffron cod 86 Arctic cod 7 Sand lance 2	Shrimp 37	Shrimp 6	
	3	Gammarid amphipods 6	Mysids 15	Gammarid amphipods 5	Gammarid amphipods 2	
	4	Hyperiid amphipods 4	Hyperiid amphipods 7	Mysids 4		
	5		Gammarid amphipods 4			

Table 10. Ringed seal stomach contents data from the northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Gambell	Gambell		Wales	Wales
Dates:		May-June 1977	May-June 1977		June 1977-78	June 1977-78
Sample Size:		23 Pups & Yearlings	7 ≥ 2 Years Old		21 Pups & Yearlings	7 ≥ 2 Years Old
Mean Volume (ml)		43.5	267.3		50.1	369.3
Food Items	1	Shrimp 49	Fish 55 Saffron cod 54 Sculpins 29 Arctic cod 17		Shrimp 76	Fish 94 Saffron cod 100
	2	Mysids 25	Shrimp 37		Mysids 17	Shrimp 6
	3	Hyperiid amphipods 16	Mysids 6		Fish 3 Saffron cod 73 Arctic cod 13 Sand lance 13	
	4	Gammarid amphipods 8			Gammarid amphipods 2	
	5	Fish 1 Arctic cod 50 Saffron cod 17 Sand lance 17			Hyperiid amphipods 2	

the species composition of the shrimp eaten changes with age. *Eualus gaimardii* was the shrimp eaten most by pups and yearlings. *Pandalus goniurus* assumed a greater importance in the diet of older seals. The mean volume of contents in stomachs of seals over 5 years old was about eight times that found in pups. Similar age-related differences are seen when only specific collection areas are considered (Table 10). Shrimps and small crustaceans make up over 95 percent of the food found in pups and yearlings taken at Gambell and Wales. Fishes were the major food of seals 2 or more years old at both localities. Shrimps were important in the diet of both age categories of seals taken at Gambell. The shrimps eaten by pups and yearlings were 89 percent *Eualus* spp. and 1 percent *Pandalus goniurus* (by volume), while those eaten by older animals were 70 percent *P. goniurus* and 18 percent *Eualus*. These differences are quite surprising since *Eualus* spp. and *P. goniurus* are similar in size and usually occurred together in our trawls taken in the northern Bering Sea. We know of no mechanism to explain such selection.

Seasonality of ringed seal feeding at three locations in the northern Bering Sea is shown in Tables 11 and 12. Table 11 gives results from seals collected in Norton Sound, primarily from Nome, but also including two seals taken in November at Stebbins. Saffron cod were the main food in November and May-June. Arctic cod were the main food in January-February and March, with saffron cod of secondary importance. Shrimps (mostly *Pandalus* spp.) were eaten in considerable quantities in March and were the main food found in seals collected in April. Small volumes of food were found in seals collected in January-February. At Savoonga, the foods of ringed seals collected in February-March and May-June were similar (Table 12). Crustaceans, mostly mysids, were the main food in both samples. At Gambell sufficiently large samples were available to allow consideration of only seals 2 or more years old, thereby eliminating variation that might be caused by younger age classes in the sample. Seals taken in March had eaten small quantities of food, mostly gammarid amphipods and sculpins. Seals taken in May-June had eaten large amounts of saffron cod, shrimps and sculpins (Table 12). These differences may be caused by an increased abundance of saffron cod in the Gambell area in May-June. Our samples reflect a similar possible change in saffron cod abundance at Nome, but not at Savoonga.

Bearded seal specimens have been obtained from several locations in the northern Bering Sea over a period of several years. Geographical patterns in foods eaten during the late spring-early summer period are shown in Table 13. Shrimps, brachyuran crabs (*Hyas coarctatus* and *Chionocetes opilio*) and clams (mostly *Serripes groenlandicus*) made up from 59 to 93 percent of the stomach contents at the various locations. Clams were of particular importance in the diet of bearded seals taken at Nome where they accounted for 69 percent of the total stomach contents. Fishes were usually of minor importance

Table 11. Ringed seal stomach contents data from the northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Nome and Stebbins	Nome	Nome	Nome	Nome
Dates:		November 1976	January-February 1976-78	March 1977-78	April 1978	May-June 1975-77
Sample Size:		7	8	26	3	17
Mean Volume (ml)		246.3	64.1	228.2	182.1	345.8
Food Items	1	Fish 96 Saffron cod 78 Boreal smelt 13 Arctic cod 4 Sand lance 3	Fish 100 Arctic cod 85 Saffron cod 15	Fish 63 Arctic cod 83 Saffron cod 12 Sculpins 3 Sticklebacks 1	Shrimp 99	Fish 96 Saffron cod 96 Sticklebacks 3
	2	Shrimp 3		Shrimp 36	Fish 1 Sculpins 50 Sticklebacks 38 Saffron cod 12	Shrimp 3
	3					
	4					
	5					

Table 12. Ringed seal stomach contents data from the northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Savoonga	Savoonga		Gambell	Gambell
Dates:		February-March 1976	May-June 1975-78		March 1978	May-June 1977
Sample Size:		4	5		9 ≥ 2 Years Old	7 ≥ 2 Years Old
Mean Volume (ml)		71.8	53.8		58.0	267.3
Food Items	1	Mysids 79	Mysids 62		Gammarid amphipods 54	Fish 55 Saffron cod 54 Sculpins 29 Arctic cod 17
	2	Hyperiid amphipods 11	Shrimp 17		Fish 32 Sculpins 81 Saffron cod 12 Sand lance 6	Shrimp 37
	3	Shrimp 8	Euphausiid 12		Shrimp 12	Mysids 6
	4	Gammarid amphipods 2			Mysids 1	
	5					

Table 13. Bearded seal stomach contents data from the northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		SURVEYOR	Savoonga	Gambell	Nome	Wales
Dates:		May-June 1978	May-June 1975-78	April-June 1975-78	May-June 1975-77	June-July 1977-78
Sample Size:		10	21	39	14	18
Mean Volume (ml)		595.3	444.0	449.5	535.3	307.0
Food Items	1	Shrimp 41	Shrimp 36	Brachyuran crab 39	Clam 69	Shrimp 46
	2	Clam 22	Brachyuran crab 35	Shrimp 17	Shrimp 22	Brachyuran crab 45
	3	Brachyuran crab 13	Fish 15 Sculpin 93 Pollock 1	Clam 16	Anemone 3	Fish 4 Saffron cod 79 Sculpins 17 Arctic cod 2 Flatfishes 1
	4	Snails 5	Clam 6	Fish 15 Sculpins 94 Arctic cod 3 Pricklebacks 1 Poacher 1	Brachyuran 2	Clam 2
	5	Fish 3 Sculpins 56 Arctic cod 27 Saffron cod 17		Sponge 3	Fish 1 Sculpins 66 Saffron cod 25 Flatfishes 4	

Table 13. Bearded seal stomach contents data from the northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Diomede				
Dates:		May-June 1975-78				
Sample Size:		16				
Mean Volume (ml)		501.5				
Food Items	1	Brachyuran crab 44				
	2	Fish 22 Sculpins 90 Sand lance 3 Arctic cod 2 Pricklebacks 1				
	3	Shrimp 11				
	4	Clam 4				
	5	Octopus 4				

in the diet. Sculpins, saffron cod and arctic cod were the fishes most commonly eaten.

Table 14 shows the available data on foods of bearded seals at Diomede for the years 1958-1978. In samples collected in 1958 and 1967, clams and brachyuran crabs were the two major foods. In samples taken in 1974-1978, brachyuran crabs were the main food and clams were a minor component in the diet. This change in diet may be the result of a decrease in abundance of clams in the area caused by foraging activities of walruses. The size of the walrus population has increased markedly in recent years, resulting in an increased pressure on their food resources. This important trend may be indicative of the types of changes in food and carrying capacity which can occur in one species when populations of a competitor change.

Information on seasonality of bearded seal foods at Gambell and Nome is shown in Table 15. At Gambell sculpins were of major importance in the diet in March and were much less common in stomachs of seals taken later in the year. At Nome, shrimps (mostly <u>Pandalus hypsinotus</u>) were the main food in January-April. In May-June shrimps were of lesser importance in the diet and were mostly <u>Argis lar</u>. A major seasonal difference is the importance of clams in the diet. In the 11 seals taken at Gambell in March and Nome in January to April, clams occurred in only two and the amounts eaten were very small. At Gambell in April-June clams occurred in 10 of 39 stomachs examined and amounted to 16 percent of the contents. At Nome in June clams occurred in 10 of 14 stomachs and accounted for 69 percent of the volume of contents. A similar lack of clams in the winter diet of bearded seals was noted by Burns (1967). Some aspect of the behavior of the clams being consumed (mostly <u>Serripes groenlandicus</u>) is probably responsible for the observed seasonal preference.

C. Chukchi Sea

A map of the Chukchi Sea is shown in Figure 3. The Hope Basin lease sale area occupies a large portion of the southern Chukchi Sea. Many ringed, bearded and spotted seals pass through the Chukchi Sea as they follow the seasonal advance and retreat of sea ice. Spotted seals summer along the coast in certain areas. Bearded and ringed seals summer in the northern Chukchi Sea pack ice. In winter and spring, bearded and ringed seals are common in the region, with breeding ringed seals mostly on shorefast ice and bearded seals most common in the flaw zone. Seal hunting occurs regularly at the villages of Shishmaref, Point Hope and Wainwright. Hunting activity occurs primarily in the spring and early summer.

Table 16 presents the schedule of field activities conducted in the Chukchi Sea during the past year. Locations are shown in Figure 3. Results of stomach contents analyses are presented in Tables 17-26.

Table 14. Bearded seal stomach contents data from northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Diomede	Diomede	Diomede	Diomede	
Dates:		11 May-6 June 1958	24 Apr-30 May 1967	25 May-1 June 1974	May-June, 1975-78	
Sample Size:		17 (Kenyon 1962)	6 (Burns unpublished)	4	16	
Mean Volume (ml)		850.0	2523.3	788.3	501.5	
Food Items	1	Brachyuran Crabs	Clams	Brachyuran Crabs 48	Brachyuran Crabs 44	
	2	Clams	Brachyuran Crabs	Anomuran Crabs 18	Fish 22 Sculpin 90 Sand lance 3 Arctic cod 2 Prickleback 1	
	3	Shrimp	Snails	Fish 9 Sculpins 60 Arctic cod 30 Saffron cod 10	Shrimp 11	
	4	Fish Saffron cod Sculpins	Shrimp	Shrimp 3	Clam 4	
	5	Sponge		Clams 1	Octopus 4	

Table 15. Bearded seal stomach contents data from northern Bering Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Gambell	Gambell		Nome	Nome
Dates:		18-24 March 1978	Apr-June 1975-78		Jan-Apr 1977-78	May-June 1975-77
Sample Size:		4	39		7	14
Mean Volume (ml)		778.1	449.5		753.8	535.3
Food Items	1	Fish 71 Sculpin 98 Flatfish 1 Eelpout 1	Brachyuran Crab 39		Shrimp 87	Clam 69
	2	Brachyuran Crab 20	Shrimp 17		Fish 7 Sculpin 76 Arctic cod 11 Saffron cod 9 Flatfish 2	Shrimp 22
	3	Shrimp 6	Clam 16		Brachyuran Crab 2	Anemone 3
	4	Gammarid amphipod 1	Fish 15 Sculpin 94 Arctic cod 3 Prickleback 1 Poacher 1		Anomuran Crabs 1	Brachyuran Crab 2
	5		Sponge 3			Fish 1 Sculpin 66 Saffron cod 25 Flatfish 4

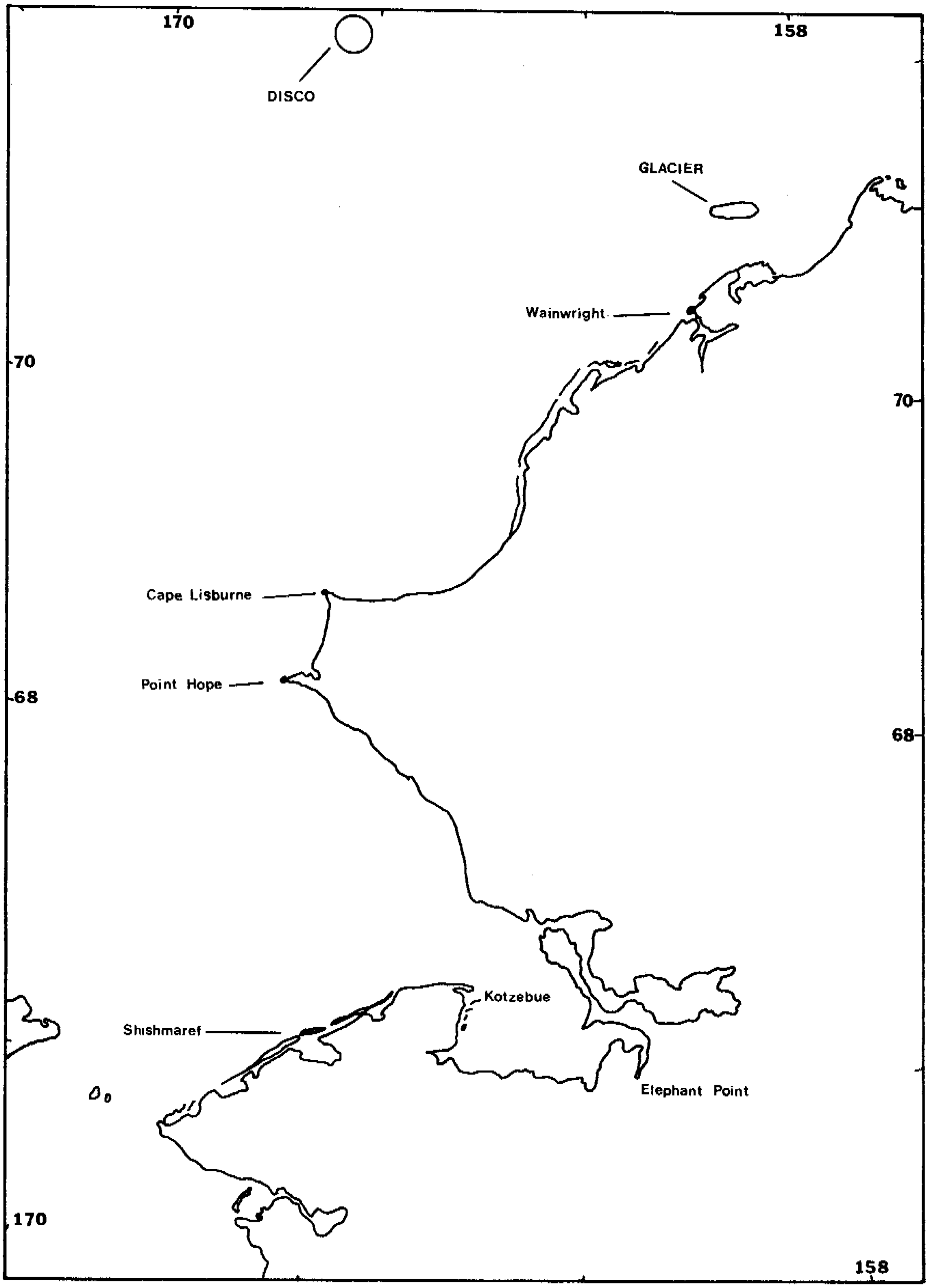


Figure 3. Map of the Chukchi Sea showing locations of specimen collections.

Table 16. Schedule of field activities in FY 79, Chukchi Sea.

Location/Platform	Dates	Personnel
Shishmaref	20 May-21 June 1978	R. Tremaine
Wainwright	25 April-22 May 1978 7-12 July 1978	R. Tremaine D. Strickland
Point Hope	10-28 April 1978	G. Seaman

Most spotted seal specimens we have examined from the Chukchi Sea have been taken at Shishmaref. Results of our analysis of these specimens are shown in Table 17. Foods found in the spring-summer samples of 1976-1978 varied widely. Largest volumes of food were found in seals taken 8-19 July 1977 which had eaten mostly herring. Our results are obviously influenced by the timing of herring spawning concentrations at Shishmaref. Barton et al. (1977) reported schools of herring off Shishmaref on 25 July 1976. Herring were obviously abundant in the vicinity of Shishmaref from 8-19 July 1977 when our spotted seal samples were taken. Herring were apparently not abundant when seals were taken in early July 1976 and June 1978. Spotted seals taken at Shishmaref in October 1977 had also eaten mostly herring. A seal taken in early November had eaten almost entirely arctic cod. Two spotted seals taken at Wainwright in summer 1975 had eaten small amounts of sculpins (Table 18).

Our largest samples of ringed seal stomachs have been collected from Shishmaref during 1976-1978. Results obtained from the various collections are shown in Table 19. Foods eaten in the June-July period were quite similar over the 3 years sampled. Fishes (mostly saffron cod) and shrimps (mostly *Crangon septemspinosa*) make up over 70 percent of the food each year. Hyperiid amphipods were more important in the diet in 1978 than in previous years. Seals collected in October had eaten mostly hyperiid amphipods, while those taken in November and January-February had eaten mostly arctic cod. The seasonality observed at Shishmaref was similar to that found at Nome (Table 11), with the exception that saffron cod were more common in the diet at Nome and arctic cod and hyperiid amphipods were eaten more commonly at Shishmaref.

The results of our spring-summer collections at Shishmaref are shown by age and sex classes in Table 20. Little difference was seen in the foods of male and female ringed seals. Females ate slightly more fish of which a higher proportion was saffron cod. Males ate more flatfishes than did females. Although the sample sizes involved are large, we cannot say at this time whether these differences are significant. Major differences were seen in the

Table 17. Spotted seal stomach contents data from Chukchi Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Shishmaref	Shishmaref	Shishmaref	Shishmaref	Shishmaref
Dates:		4-6 July 1976	8-19 July 1977	6-21 June 1978	10-24 Oct 1977	4 Nov 1977
Sample Size:		3	10	10	14	1
Mean Volume (ml)		402.9	632.0	49.7	432.9	751.0
Food Items	1	Shrimp 87	Fish 99 Herring 96 Saffron cod 4	Fish 80 Sand lance 94 Saffron cod 3 Sculpins 2	Fish 99 Herring 83 Saffron cod 17	Fish 100 Arctic cod 100
	2	Fish 13 Flatfish 62 Saffron cod 38	Shrimp 1	Shrimp 8		
	3			Hyperiid amphipod 7		
	4			Mysid 3		
	5			Gammarid amphipod 1		

Table 18. Spotted seal stomach contents data from Chukchi Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Wainwright				
Dates:		29 July-4 Aug 1975				
Sample Size:		2				
Mean Volume (ml)		91.2				
Food Items	1	Fish 97 Sculpins 100				
	2	Isopods 1				
	3	Shrimp 1				
	4					
	5					

Table 19. Ringed Seal stomach contents data from Chukchi Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Shishmaref	Shishmaref	Shishmaref	Shishmaref	Shishmaref
Dates:		4 June-11 July 1976	13 June-19 July 1977	9-21 June 1978	23-28 Oct 1977	4-5 Nov 1977
Sample Size:		105	228	56	6	7
Mean Volume (ml)		97.5	98.9	104.2	122.0	272.7
Food Items	1	Shrimp 47	Fish 57 Saffron cod 84 Arctic cod 8 Sand lance 4 Flatfish 3	Fish 44 Saffron cod 89 Sand lance 8 Arctic cod 1	Hyperiid amphipod 88	Fish 100 Arctic cod 86 Saffron cod 14
	2	Fish 42 Saffron cod 92 Flatfish 5	Shrimp 31	Shrimp 27	Fish 7 Saffron cod 100	
	3	Mysid 4	Euphausiids 3	Hyperiid amphipod 16	Shrimp 5	
	4	Isopod 4	Mysid 3	Mysid 6		
	5	Gammarid amphipod 2	Gammarid amphipod 2	Gammarid amphipod 3		

Table 19. cont. Ringed Seal stomach contents data from Chukchi Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area: Dates: Sample Size:		Shishmaref 6 Jan-2 Feb 1978 24				
Mean Volume (ml)		314.9				
Food Items	1	Fish 99 Arctic cod 83 Saffron cod 10 Sculpins 3				
	2					
	3					
	4					
	5					

Table 20. Major food items of ringed seals collected at Shishmaref in June-July 1976-1978. Results are presented by age and sex categories. Numbers indicate percent of total volume for invertebrates and total fish, and percent of total number for species of fishes.

	Sexes Combined			Seals ≥ 2 Years Old	
Food Item	Pups N=80	Yearlings N=39	≥ 2 Years Old N=253	Males N=119	Females N=133
Shrimp	20	36	30	32	28
Hyperiid amphipod	9	2	2	1	3
Gammarid amphipod	9	*	2	2	2
Mysid	7	6	3	4	2
Euphausiid	5	*	2	3	1
Isopod	*	*	1	*	1
Total Fish	38	47	53	49	56
Saffron cod	98	64	89	83	91
Arctic cod	2	33	4	5	3
Sand lance	--	2	2	*	3
Sculpin	--	*	*	*	*
Flatfish	--	*	3	9	1
Mean Volume of Contents (ml)	39.0	69.6	120.2	118.4	122.3

* Indicates values less than 1 percent.

foods of pups, yearlings and older seals. The importance of fish in the diet increased with age. All the fishes eaten by pups were saffron and arctic cod, while other fishes such as sand lance and flatfish were eaten by older seals. The proportion of small crustaceans (mysids, euphausiids and amphipods) in the diet decreased from 30 percent in pups to 8 percent in yearlings and 9 percent in seals over 1 year old. These age-related changes in foods are generally similar to those we found in the northern Bering Sea (Tables 9 and 10).

Results of our analysis of foods of ringed seals taken at Point Hope (Table 21) are similar to those reported by Johnson et al. (1966). Gammarid amphipods, primarily Ampelisca spp., are quite important in the diet of seals at this locality in winter and spring. Arctic cod and shrimps are also major foods of seals at Point Hope.

Foods found in ringed seals collected at Wainwright are shown in Table 22. Gammarid amphipods (mostly Anonyx sp.) were the main food found in seals taken in winter and spring. Seals taken in summer 1975 had eaten mostly shrimps, while those taken in summer 1978 had eaten arctic cod and gammarid amphipods (mostly Gammarus sp.). The volumes of food eaten were much larger in 1978 when arctic cod were the main food.

Food items identified from ringed seals at other locations are shown in Table 23. Of particular interest is the presence of herring in seals taken in Kotzebue Sound in February, indicating the presence of herring in that area during winter months.

Aspects of seasonal and geographical variability in ringed seal foods have been dealt with in more detail in Lowry et al. (in prep., see Section XI-B).

Most of our specimens from bearded seals have been taken at the village of Shishmaref. Foods of bearded seals at that locality in June-July were very constant in 1976, 1977 and 1978 (Table 24). Shrimps (mostly Crangon septemspinosa), crabs (mostly Telmessus chieragonus) and clams made up 65-76 percent of the total contents in all years. Bearded seals taken at Shishmaref in October had eaten only shrimps and fishes. The lack of clams in the seals taken in fall is consistent with our observations in the northern Bering Sea. The lack of crabs in the October sample is surprising and unexplainable at this time.

Foods of bearded seals collected at Shishmaref are shown by sex and age classes in Table 25. Foods of males and females were generally similar with the exception that males ate proportionately more echiuroid worms and females ate more isopods. Major differences were seen in the proportion of the major food items in pups, yearlings and older animals. The proportion of shrimps in the diet decreased with age, while the proportion of crabs and clams increased.

Table 21. Ringed seal stomach contents data from Chukchi Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Point Hope	Point Hope	Point Hope	Point Hope	Point Hope
Dates:		January 1977	February 1978	March 1976	April 1976-78	May 1976-77
Sample Size:		2	1	1	45	27
Mean Volume (ml)		149.5	140.0	15.6	65.7	35.1
Food Items	1	Fish 84 Arctic cod 96 Sand lance 4	Gammarid amphipod 100	Gammarid amphipod 59	Fish 46 Arctic cod 49 Sand lance 29 Sculpins 16 Saffron cod 3	Shrimp 38
	2	Hyperiid amphipod 16		Fish 32 Sand lance 100	Gammarid amphipod 29	Gammarid amphipod 27
	3			Shrimp 5	Shrimp 19	Mysid 11
	4				Hyperiid amphipod 2	Fish 10 Saffron cod 42 Sand lance 37 Arctic cod 16 Sculpin 4
	5				Echiuroid worm 1	Euphausiid 7

Table 22. Ringed Seal stomach contents data from Chukchi Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area: Dates: Sample Size:		Wainwright winter 1978 2	Wainwright 4-5 May 1978 2	Wainwright 1-2 July 1978 22	Wainwright 28 July-11 Aug 1975 20	
Mean Volume (ml)		27.0	82.1	126.0	23.6	
Food Items	1	Gammarid amphipod 65	Gammarid amphipod 97	Fish 73 Arctic cod 99 Sand lance 1	Shrimp 45	
	2	Shrimp 26	Shrimp 3	Gammarid amphipod 26	Fish 25 Sculpins 43 Cod 28 Capelin 14	
	3	Fish 9 Arctic cod 100			Gammarid amphipod 8	
	4				Isopod 5	
	5				Hyperiid amphipod 2	

Table 23. Ringed Seal stomach contents data from Chukchi Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Kotzebue	Elephant Point	Cape Lisburne	DISCOVERER	
Dates:		February 1978	June 1978	March-April 1976	27-28 August 1976	
Sample Size:		3	3	3	2	
Mean Volume (ml)		212.3	21.9	36.6	75.9	
Food Items	1	Fish 100 Herring 51 Saffron cod 37 Smelt 6 Arctic cod 3	Fish 62 Saffron cod 71 Sculpins 29	Fish 31 Arctic cod 96 Sculpins 4	Shrimp 84	
	2		Mysid 17	Shrimp 29	Fish 13 Arctic cod 100	
	3		Shrimp 15	Gammarid amphipod 20	Gammarid amphipod 2	
	4		Isopod 2	Mysid 1		
	5		Gammarid amphipod 1			

Table 24. Bearded Seal stomach contents data from Chukchi Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Shishmaref	Shishmaref	Shishmaref	Shishmaref	
Dates:		4 June-11 July 1976	24 June-20 July 1977	9-21 June 1978	16-30 Oct 1977	
Sample Size:		40	112	16	13	
Mean Volume (ml)		415.2	460.4	423.0	631.8	
Food Items	1	Shrimp 51	Shrimp 35	Shrimp 40	Shrimp 87	
	2	Brachyuran Crab 19	Brachyuran Crab 21	Clam 18	Fish 13 Flatfish 72 Sculpins 25 Saffron cod 2	
	3	Clam 16	Clam 14	Echiuroid 17		
	4	Isopod 4	Isopod 13	Brachyuran Crab 13		
	5	Fish 3 Flatfish 54 Saffron cod 15 Sculpins 14 Sand lance 7	Echiuroid worm 6	Fish 4 Sculpins 43 Flatfish 35 Sand lance 15 Saffron cod 7		

Table 25. Major food items of bearded seals collected at Shishmaref in June-July 1976-1978. Results are presented by age and sex categories. Numbers indicate percent of total volume for invertebrates and total fish, and percent of total number for species of fishes.

	Sexes Combined			Seals ≥2 Years Old	
Food Item	Pups N=38	Yearlings N=14	≥2 Years Old N=87	Males N=30	Females N=68
Shrimp	58	36	31	25	36
Isopod	18	17	8	2	10
Clam	4	16	18	18	17
Brachyuran crab	6	12	23	27	23
Echiuroid worm	*	*	11	17	4
Total Fish	7	17	6	6	5
Saffron cod	51	15	36	29	31
Sculpin	28	60	27	24	22
Flatfish	22	21	35	37	39
Mean Volume of Contents (ml)	324.8	345.5	526.3	553.4	486.5

* Indicates values less than 1 percent.

Data on foods of bearded seals collected at other locations in the Chukchi Sea are shown in Table 26. Little can be concluded from the small samples collected at Point Hope and the GLACIER and DISCOVERER. Seals collected at Wainwright had eaten large quantities of clams (*Serripes* sp. and *Clinocardium* sp.) similar to those collected in June at Nome. Interestingly, clams were not a major component of the food of bearded seals collected from the GLACIER north of Wainwright. This indicates that the clams eaten by seals in the vicinity of Wainwright may be concentrated in a small geographical area.

D. Belukha whales

We have obtained and examined stomach contents of belukha whales from Elim (Norton Sound), Elephant Point (Kotzebue Sound) and Point Hope. Most of our samples have come from Elephant Point where the largest Native harvest takes place. Very little food was found in the stomachs of the belukha whales. However, otoliths and cephalopod beaks were numerous and we have based most of the results shown in Table 27 on identification of those hard parts. Foods eaten by belukhas taken at Elim and Elephant Point were quite similar. At both localities saffron cod were the most frequently eaten species, followed by sculpins. Herring were eaten in small numbers at both locations. Octopus, smelt and eelpout were found in animals taken at Elephant Point. Most of the food remains found in belukhas taken at Point Hope were beaks of octopus. These beaks were particularly numerous in in the stomachs of whales taken in 1977. Some arctic cod otoliths were found in belukhas taken at Point Hope in April 1978.

With the exception of octopus, foods eaten by belukha whales were quite similar to those eaten by ringed seals in the same areas. Saffron cod were the main food of ringed seals taken at Nome, Shishmaref and Kotzebue in June. This species of fish is apparently abundant in both Kotzebue and Norton Sounds and provides an abundant food source for several species of marine mammals. Arctic cod were eaten by both ringed seals and belukha whales taken at Point Hope during spring. In northerly areas and in winter months arctic cod are very important in the diet of seals and belukhas.

VIII. Conclusions

A. Foods and feeding of seals

To date we have examined the stomach contents of more than 1,500 seals and 79 belukha whales. The majority of this material has come from coastal hunting villages in the Bering and Chukchi Seas. Most of these seals were taken in the spring and early summer. During the past 2 contract years we have made a particular effort to balance the geographical and temporal distribution of our samples and to increase our data base for the Beaufort Sea. Specimens

Table 26. Bearded Seal stomach contents data from Chukchi Sea. Numbers in parentheses indicate percent of the total stomach contents volume made up by that taxon, except for fish taxa which are percent of the total number of fishes identified which belonged to that taxon.

Area:		Point Hope	DISCOVERER	GLACIER	Wainwright	
Dates:		16 April 1978	27 August 1976	1-5 August 1977	May-Aug 1975-78	
Sample Size:		1	1	2	37	
Mean Volume (ml)		1172.4	655.5	454.5	619.8	
Food Items	1	Shrimp 88	Fish 29 Eelpout 91 Sculpins 9	Snails 48	Clam 49	
	2	Fish 6 Sculpins 100	Brachyuran Crabs 26	Shrimp 9	Shrimp 26	
	3	Brachyuran Crab 5	Shrimp 6	Priapulids 6	Fish 7 Sculpin 77 Sand lance 14 Arctic cod 8	
	4		Priapulids 3	Amphipods 4	Brachyuran Crab 4	
	5			Brachyuran Crabs 3	Isopod 3	

Table 27. Food items identified from stomachs of belukha whales taken at three locations in the Bering and Chukchi Seas.

	Elim (N=3) June 1977		Point Hope (N=5) May 1977		Point Hope (N=9) April 1978		Elephant Point (N=62) 13-18 June 1978	
Food Item	% Frequency of Occurrence	Mean No.	% Frequency of Occurrence	Mean No.	% Frequency of Occurrence	Mean No.	% Frequency of Occurrence	Mean No.
Shrimp	--	--	20	--	67	--	79	--
Octopus	--	--	100	165	78	4	52	1.2
Total Inverts	--	--	100	--	100	--	85	--
Total Fish	100	1323	--	--	22	5	94	64
Arctic cod	--	--	--	--	11	5	--	--
Saffron cod	100	1303	--	--	--	--	92	55
Sculpin	67	18	--	--	--	--	44	8
Smelt	--	--	--	--	--	--	34	*
Herring	67	2	--	--	--	--	3	*
Eelpout	--	--	--	--	--	--	3	*

* Indicates values less than 1.0.

from fall and winter have been collected from the Prudhoe Bay area, Barrow, Shishmaref and Nome. Geographical coverage has been increased in the ice front of the Bering Sea, the Bering Strait region and the Beaufort Sea. These samples have considerably refined our evaluation of feeding patterns of ice-inhabiting seals, particularly ringed seals. Our samples from belukhas represent essentially the only available data on foods of that species in Alaskan waters.

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

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

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

Crabs and crangonid shrimps are important food items of bearded seals at all areas. At Nome and Wainwright in summer clams are major foods. It appears that clams are eaten in quantity only during summer. At Diomede in 1958 and 1967 clams were major food items. In recent years the importance of clams in the diet of bearded seals at Diomede has decreased considerably. This may be due to a long-term decrease in abundance of clams in the vicinity of Diomede, perhaps due to foraging activities of walruses. Many other food items occur in bearded seal stomachs, occasionally in substantial quantities. This is a reflection of the patchy and diverse nature of benthic communities. Age-related changes in diet were found in bearded seals taken at Shishmaref. The importance of shrimps in the diet decreases with age, while the importance of crabs and clams increases.

Belukha whales taken in Norton and Kotzebue Sounds in June had eaten mostly saffron cod and smaller numbers of sculpins and other fishes. Belukhas taken at Point Hope in spring had eaten octopus and arctic cod.

Key prey species of the four species of seals and belukha whales in each area are shown in Table 28. These are general patterns and it should be remembered that the exact foods will vary with time and location.

B. Potential effects of petroleum development

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

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

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

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

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

Table 28. Key prey species of ice seals and belukha whales in the Bering, Chukchi and Beaufort Seas.

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

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

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

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

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

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

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

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

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

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

4. Fecundity and spawning behavior are changed.

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

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

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

Eldridge et al. (1978) found herring larvae to accumulate benzene. Yolk-sac larvae, non-feeding post yolk-sac larvae and feeding larvae all rapidly accumulated benzene from contaminated water. In addition, and more significantly, larvae showed secondary accumulation through ingestion of benzene-contaminated rotifers. Rotifers apparently have no mechanism for short-term depuration of benzene, and accumulated 10^3-10^4 times the original concentrations for up to 8 days. Herring larvae, after the first rapid uptake from water, acquired 62 percent of the accumulated benzene from ingested rotifers. After 72 hours no depuration of this secondarily acquired benzene had occurred. Hydrocarbons accumulated through the diet appear quantitatively more important than those from solution. Herring larvae feeding on contaminated prey do accumulate hydrocarbons in excess of exposure concentrations.

Cods are an important part of the trophic structure of all study areas. Pollock are eaten by all species of seals in the southern Bering Sea. They are also consumed by sea lions, numerous species of birds and other fishes. They are the target of the second largest commercial fishery in the world. Saffron cod and polar cod are seasonally important to spotted, ringed and bearded seals throughout the northern Bering, Chukchi and Beaufort Seas. The effects of hydrocarbon pollution on these three species are largely unknown. However, acute toxicity tests using water-soluble fractions of Cook Inlet oil have been done on saffron cod from

Norton Sound (DeVries 1976). Concentrations of 1.83 ppm paraffins at 3°C and 2.48 ppm at 8°C produced 50 percent mortality within 24 hours.

Almost nothing is known about the sensitivity of Alaska pollock. DeVries (1977) in reporting results of preliminary tests stated that Alaska pollock and Pacific cod died with 2 hours of exposure to 4 ppm napthalene at +1°C. At 3 ppm they lost equilibrium after 3 hours and ceased to ventilate at 13 hours, with no recovery upon return to clean sea water. In contrast, sculpins and flatfishes tested at 4 ppm lived 20 hours, and at 3 ppm suffered only 10 percent mortality after 48 hours.

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

Kuhnhold (1970), working with another cod species, Gadus morhua, found water extracts of crude oils to be highly toxic to eggs tested 5-30 hours after fertilization. Mortality was lower in older eggs, but many of the hatched larvae were abnormal and died within a few days. Mironov (1967) also working on cod found that crude oil killed all eggs within 2 days at 100 ppm and within 3 days at 10 ppm.

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

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

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

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

Brodersen et al. (1977) reported on acute toxicities of four species of shrimps (Eualus fabricii, E. suckleyi, Pandalus goniurus, P. hypsinotus) and king and tanner crabs. Each of those species is a prey species of seals. In all cases larvae were more sensitive than adults. Concentrations as low as 1-2 ppm caused 50 percent moribundity in larvae. At WSF concentrations of less than 1 ppm all king crab larvae ceased swimming (NAFC 1978). Shrimp larvae were somewhat less sensitive but, after 3 hours at 3.5 ppm, 50 percent did not swim. After 24 hours no recovery to normal occurred. This fast-acting narcotic effect may be of greater consequence than the ultimate lethal toxicity because of the increased susceptibility of these non-swimming larvae to predation.

Percy and Mullin (1975) found the arctic amphipod Onisimus affinus was the most sensitive to oil of all invertebrates tested. They were killed by high concentrations (30-140 ppm) in water and also by oil in the sediment. Oil-tainted food and sediment were avoided. Anonyx nugax and Ampelisca sp., also arctic forms, are important food items in the northern Bering and Chukchi Seas. They too may be affected in the same manner. Atlas et al. (1978) found in recolonization studies that arctic amphipods were less frequent in oiled sediments than in unoiled (control) sediments. Contaminated sediments were recolonized but the species composition was quite different.

Bivalve molluscs are major food items of bearded seals at a number of locations. In addition, they are the major food of the Pacific walrus and an important food of Alaska king crabs and some fish. Scarratt and Zitko (1972) reported that scallops and clams (Mya sp.) assimilate hydrocarbons. Renzoni (1975) found that water-soluble fractions of crude oil cause reduction in gamete fertilization at concentrations of 1 ml/1. Decreased survival of eggs, sperm and larvae, and abnormal embryos were caused in Mulinea and Crossostrea. Dow (1975) reported 20 percent reduction in clam populations and reduced growth on oil-contaminated mudflats. Mironov (1970) reported that molluscs in the Black Sea were sensitive to oil and oil products. Vandermeulen and Penrose (1978) found that bivalves at Chedabucto, Nova Scotia, retained 40 percent of initial hydrocarbon concentrations after 75 days. Retention was especially long in the gonads. They found no evidence for any aryl-hydrocarbon hydroxylase (AHH) activity in response to petroleum hydrocarbons. (The AHH system is an important part of an organism's biological response to oil contamination.) A very slow depuration rate increases the probability of unaltered aromatic hydrocarbons entering the food chain. Gilfillan and Vandermeulen (1978), also working at Chedabucto, found that 6 years after the "Arrow" spill clam stocks were 60 percent below normal and older clams still had reduced growth rates, presumably due to oil present deep in the sediment. Five years after a spill of light refined oil in Maine and 3 years after a No. 6 fuel oil spill, clams of the genus Mya showed reduced growth, survival and recruitment rates.

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

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

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

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

3. Arctic cod and saffron cod spawn in nearshore areas under the ice. Eggs, larvae, juveniles and adults may be localized in areas where environmental perturbation is apt to occur.

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

IX. Needs for further study

One of the basic goals of this project has been to describe the foods of ringed, bearded, spotted and ribbon seals throughout Alaskan waters and to examine geographical, seasonal, and age- and sex-related feeding patterns. This goal has been largely achieved for ringed and bearded seals. For ribbon and spotted seals only limited data are available for the spring months. Since ribbon and spotted seals are major consumers in the Bering Sea ecosystem, information on their feeding in summer, fall and winter months would be very valuable.

In order to interpret our data on foods of seals, data on distribution, abundance and natural history of prey species must be considered. Some of these data have been gathered and reported on by other OCSEAP projects. We will incorporate these data in our final reports for the Bering and Chukchi Seas. Unfortunately, natural history information on some key prey species, particularly arctic and saffron cods, is not available. Studies directed particularly toward these species would be very desirable.

In order to predict the possible effects of OCS development on the trophic systems of which seals are a part, information on hydrocarbon sensitivity of key species must be available. We need such data for at least the key prey species indicated in Table 28. To our knowledge, little or no information is available for most of those species. Unless such information is made available, our assessment of the possible effects of oil in the environment on seal foods will be purely speculative.

We have found considerable variability in seal foods both seasonally and geographically, and from year to year at a single location and season. Such variations are presently difficult to explain. Experiments designed to investigate selectivity by simultaneous collection of seals and seal foods (by otter trawl) would be very valuable.

Due to the schedule of proposed lease sales we have emphasized work in the Beaufort Sea at the expense of work in other areas. For this reason, our most adequate data are for the Beaufort Sea. As lease sale dates are approached in other areas it will be desirable to increase the resolution of our data in those areas. For example, the Norton Basin appears to be an important feeding area for ringed seals in fall, winter and spring, and for spotted seals in summer. Prior to tract selection and leasing in the Norton Basin, studies should be conducted to delineate and evaluate critical feeding areas for all species of marine mammals.

X. Summary of 4th quarter operations

A. Ship or laboratory activities

1. Field and laboratory schedule

A schedule of field and laboratory activities conducted during the second quarter of FY 79 is given in Table 29. Field work was restricted to the Beaufort Sea. Seal collections were made at Prudhoe Bay and Barrow to obtain information on winter food habits of ringed seals. Stomach samples from those collections were processed and analyzed immediately.

Table 29. Schedule of field and laboratory activities during the second quarter of FY 79. All personnel are employees of the Alaska Department of Fish and Game.

Activity	Dates	Personnel
Specimen collection - Prudhoe Bay	20-23 February	L. Lowry
Specimen collection - Barrow	24-27 February	L. Lowry, R. Nelson
Laboratory processing of stomach material	March	L. Lowry, K. Frost, R. Tremaine, G. Seaman
Data analysis	January-March	L. Lowry, L. Miller
Preparation of annual report	March	L. Lowry, K. Frost
Preparation of Beaufort Sea Final Report	March	K. Frost, L. Lowry

Most of the time and effort of the principal investigators was devoted to data analysis. All data collected since 1975 are now data managed and available for computer analysis. A Final Report of Beaufort Sea Activities was prepared in addition to the annual report.

2. Scientific party

See Table 29.

3. Methods

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

4. Sample localities

Sample localities are shown in Figures 2 and 3 of the preceding annual report, and in Figure 1 of our Beaufort Sea Final Report.

5. Data collected or analyzed

Forty-four ringed seals were collected in February, 25 from the area off Prudhoe Bay and 19 from the area north and east of Barrow. Two bearded seals were collected at Barrow. All data have been analyzed and the results are included in our Final Report of Beaufort Sea Activities, April 1979. Ringed seals had eaten primarily arctic cod. The two bearded seals had eaten arctic cod, spider crabs, shrimps and priapulids.

6. Milestone charts and data submission schedules

Milestone charts are given on the following pages. Field and laboratory activities and data processing have proceeded on schedule and as anticipated.

All 1975-February 1979 stomach contents data have been data managed and are on computer diskette from which they can be accessed for data analysis. Data check programs are being run on all data prior to submission to NODC. Submission of 1978 data to NODC awaits completion of the analysis of ringed seal reproductive material by RU #230 personnel.

B. Problems encountered/recommended changes

None.

Project: RU #232

PI: Lowry, Frost, Burns

MILESTONE CHART

MAJOR MILESTONES - Other Project Activities	1978			1979								
	O	N	D	J	F	M	A	M	J	J	A	S
Acquisition and archival of reference specimens	●	—	●	—	—	●						
Processing of stomach contents	●	●	●			●				0–	- -	0
Analysis of data	●	—	—	—	—	●	- -	- -	- -	- -	- -	0
Data entry and submission	●	—	—	—	—	●	- -	- -	- -	- -	- -	0
Preparation of quarterly and annual reports			●			●			0			0
Submission of Beaufort Sea final report						●						
Preparation of FY 80 proposal								0				

Project: RU #232

PI: Lowry, Frost, Burns

MILESTONE CHART

MAJOR MILESTONES - Specimen Collections	1978			1979								
	O	N	D	J	F	M	A	M	J	J	A	S
Beaufort Sea												
Barrow - helicopter		●			●							
Prudhoe Bay - helicopter		●			●			0				
Chukchi Sea												
Shishmaref - village										0		
Belukha whale collections and/or data analysis	●	—	—	—	—	●		0	0			
Norton Sound/Northern Bering Sea												
Nome		●						0	0			
Gambell								0				
Diomede								0	0			
Southcentral Bering Sea							0	0				
St. George Basin - Bristol Bay												
Ice-reinforced vessel with helicopter							0					

XI. Auxiliary material

A. References and literature cited

Arseniev, V. A. 1941. Food of the ribbon seal (Histriophoca fasciata) (in Russian). Izv. TINRO 20:121-127.

Atlas, R. M., A. Horowitz and M. Busdosh. 1978. Prudhoe crude oil in arctic marine ice, water and sediment ecosystems: degradation and interactions with microbial and benthic communities. J. Fish. Res. Bd. Can. 35:585-590.

Barabash-Nikiforov, I. I. 1936. Pinnipeds of the Commander Islands. Pages 223-237 in S. V. Dorofeev and S. J. Frieman, eds. The marine mammalia of the USSR Far East (in Russian). TRUDY VINRO, Vol. III, Moscow.

Barton, L. H., I. M. Warner and P. Shafford. 1977. Alaska marine environmental assessment project: herring spawning surveys - southern Bering Sea. OCSEAP Annu. Rep., RU #19, April 1977. 112pp.

Briggs, K. T. and C. W. Davis. 1972. A study of predation by sea lions on salmon in Monterey Bay. Bull. California Fish and Game 58:37-43.

Brodersen, C. C., S. D. Rice, J. W. Short, T. A. Mecklenburg and J. F. Karinen. 1977. Sensitivity of larval and adult Alaskan shrimp and crabs to acute exposures of the water-soluble fractions of Cook Inlet crude oil. Proc. 1977 Oil Spill Conf., Am. Petroleum Inst., Washington, DC.

Burns, J. J. 1967. The Pacific bearded seal. Alaska Dept. Fish and Game, Juneau. 66pp.

__________. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi Sea. J. Mammal. 51:445-454.

__________. In press. The ribbon seal.

__________ and S. Harbo, Jr. 1972. An aerial census of ringed seals, northern coast of Alaska. Arctic 25:279-290.

Carey, A. G. 1977. Summarization of existing literature and unpublished data on the distribution, abundance, and life histories of benthic organisms (Beaufort Sea). Vol. IV, Part B. Annotated Bibliography NOAA/BLM OCSEAP Final Rep.

Clark, R. C., Jr. and J. S. Finley. 1977. Effects of oil spills in arctic and subarctic environments. Pages 411-476 in D. C. Malins, ed. Effects of Petroleum on Arctic and Subarctic Environments and Organisms. Academic Press, Inc., New York.

Craddock, D. R. 1977. Acute toxic effects of petroleum on arctic and subarctic marine organisms. Pages 1-94 in D. C. Malins, ed. Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms. Academic Press, Inc., New York.

Crane, J. J. 1974. Ecological studies of the benthic fauna in an arctic estuary. M.S. Thesis, Univ. of Alaska, Fairbanks. 104pp.

DeVries, A. L. 1976. The physiological effects of acute and chronic exposure to hydrocarbons and of petroleum on the nearshore fishes of the Bering Sea. NOAA/BLM OCSEAP Annu. Rep. 8:1-14.

__________. 1977. The physiological effects of acute and chronic exposure to hydrocarbons on nearshore fishes of the Bering Sea. OCSEAP Annu. Rep., RU #62, March 1977. 22pp.

Dow, R. L. 1975. Reduced growth and survival of clams transplanted to an oil spill site. Mar. Pollut. Bull. 6:124-125.

Dunbar, M. J. 1941. On the food of seals in the Canadian eastern Arctic. Can. J. Res. Dis. 19:150-155.

__________. 1954. The amphipod crustacea of Ungava Bay, Canadian eastern Arctic. J. Fish. Res. Bd. Can. 11:709-798.

Eldridge, M. B., T. Echeverria and S. Korn. 1978. Fate of ^{14}C-benzene in eggs and larvae of Pacific herring (*Clupea harengus pallasi*). J. Fish. Res. Bd. Can. 35:861-865.

Fay, F. H. 1974. The role of ice in the ecology of marine mammals of the Bering Sea. Pages 383-399 *in* D. W. Wood and E. J. Kelley, eds. Oceanography of the Bering Sea. Inst. Mar. Sci., Univ. Alaska, Fairbanks.

Fedoseev, G. A. 1965. Food of the ringed seal. Izv. TINRO 59:216-223.

__________ and Iv. A. Bukhtiyarov. 1972. The diet of seals of the Okhotsk Sea. *In* Theses of Works 5th All-Union Conf. Stud. of Marine Mammals. Part 1:110-112. Makhachkala, USSR. (abstract).

Gilfillan, E. S. and J. H. Vandermeulen. 1978. Alterations in growth and physiology of soft-shell clams, *Mya arenaria*, chronically oiled with Bunker C from Chedabucto Bay, Nova Scotia, 1970-76. J. Fish. Res. Bd. Can. 35:630-636.

Gol'tsev, V. N. 1971. Feeding of the common seal (in Russian). Ekologiya 2:62-70.

Inukai, T. 1942. Hair seals in the north Japanese waters. Shokubutsu Oyobi Dubutsu 10(10&11).

Johnson, F. G. 1977. Sublethal biological effects of petroleum hydrocarbon exposures: bacteria, algae, and invertebrates. Pages 271-318 *in* D. C. Malins, ed. Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms. Academic Press, Inc., New York.

Johnson, M. L., C. H. Fiscus, B. T. Ostenson and M. L. Barbour. 1966. Marine mammals. Pages 897-924 *in* N. J. Wilimovsky and J. N. Wolfe, eds. Environment of the Cape Thompson Region, Alaska. USAEC, Oak Ridge, TN.

Karinen, J. F. and S. D. Rice. 1974. Effects of Prudhoe Bay crude oil on molting Tanner crab, Chionocetes bairdi. Mar. Fish. Rev. 36(7).

Kenyon, K. W. 1962. Notes on the phocid seals at Little Diomede Island, Alaska. J. Wildl. Manage. 26:380-387.

Kleinenberg, S. E., A. V. Yablokov, B. M. Bel'kovich and M. N. Tarasevich. 1964. Beluga (Delphinapterus leucas): Investigation of the species. Transl. from Russian, Israel Program for Scientific Translations, 1969, 376 pp. (IPST Cat. No. 1923).

Klinkhart, E. G. 1966. The beluga whale in Alaska. Alaska Dept. Fish and Game. Rep. 11pp.

Kosygin, G. M. 1966. Some data on food and food habits of lakhtak (bearded seal) during spring and summer in the Bering Sea (in Russian). Izv. TINRO 58:153-157.

__________. 1971. Food of the bearded seal, Erignathus barbatus nauticus (Pallas), of the Bering Sea in the spring-summer period. Izv. TINRO 75:144-151. (Transl. from Russian by Fish. Mar. Serv. Transl. Ser. No. 3747).

Kuhnhold, W. W. 1970. The influence of crude oils on fish fry. FAO Tech. Conf. Mar. Pollut., Rome. Paper FIR:MP/70/E-64.

Lowry, L. F., K. J. Frost and J. J. Burns. In press. Potential resource competition in the southeastern Bering Sea: Fisheries and phocid seals. Proc. 29th Alaska Sci. Conf., Fairbanks, 15-17 August 1978.

Malins, D. C., E. H. Gruger, Jr., H. O. Hodgins and D. D. Weber. 1977. Sublethal effects of petroleum hydrocarbons and trace metals, including biotransformations, as reflected by morphological, chemical, physiological, pathological, and behavioral indices. OCSEAP Annu. Rep., RU #73/74, April 1977. 174pp.

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

Mironov, O. G. 1967. Effects of low concentrations of oil and petroleum products on the development of eggs of the Black Sea turbot. Vop. Ikhtiol. 7:577-580.

__________. 1970. The effect of oil pollution on the flora and fauna of the Black Sea. FAO Tech. Conf. Mar. Pollut., Rome. Paper FIR: MP/70/E-92.

NAFC. 1978. Northwest and Alaska Fisheries Center, Monthly Report, March 1978.

Nikolaev, A. M. and V. A. Skalkin. 1975. On the food of true seals of the eastern coast of Sakhalin. Izv. TINRO 95:120-125.

Parker, P. L. and D. Menzel. 1974. Effects of pollutants on marine organisms. Report of NSF/IGOE Workshop, Sidney, British Columbia, Canada, August 11-14, 1974.

Percy, J. A. and T. C. Mullin. 1975. Effects of crude oils on arctic marine invertebrates. Beaufort Sea Proj. Tech. Rep. No. 11. 167pp.

Pereyra, W. T., J. E. Reeves and R. G. Bakkala. 1976. Demersal fish and shellfish resources of the eastern Bering Sea in the baseline year 1975. NOAA, NMFS, NWFC Processed Rep.

Pikharev, G. A. 1946. The food of the seal Phoca hispida (in Russian). Izv. TINRO 22:259-261. (Transl. Fish. Res. Bd. Can. No. 150).

Pimlott, D., D. Brown and K. Sam. 1976. Oil under the ice. Can. Arctic Resour. Com., Ottawa. 178pp.

Rae, B. B. 1973. Further observations on the food of seals. J. Zool. 169:287-297.

Rathbun, M. J. 1919. Decapod crustaceans. Rep. Can. Arctic Exped. VII Crustacea: A-14A.

Reiger, G. 1975. Song of the seal. Audubon 77:6-27.

Renzoni, A. 1975. Toxicity of three oils to bivalve gametes and larvae. Mar. Pollut. Bull. 6:125-128.

Rice, S. D., J. W. Short, C. C. Brodersen, T. A. Mecklenburg, D. A. Moles, C. J. Misch, D. L. Cheatham and J. F. Karinen. 1976. Acute toxicity and uptake-depuration studies with Cook Inlet crude oil, Prudhoe Bay crude oil, No. 2 fuel oil and several subarctic marine organisms. N.W. Fish. Cent. Auke Bay Fish. Lab. Processed Rep. May 1976. 90pp.

Scammon, C. M. 1874. The marine mammals of the northwestern coast of North America. John H. Carmany and Company, San Francisco. 319pp.

Scarratt, D. J. and V. Zitko. 1972. Bunker C oil in sediments and benthic animals from shallow depth in Chedabucto Bay, Nova Scotia. J. Fish. Res. Bd. Can. 29:1347-1350.

Scheffer, T. H. and C. C. Sperry. 1931. Food habits of the Pacific harbor seal, Phoca richardii. J. Mammal. 12:214-226.

Sergeant, D. E. 1973. Biology of white whales (Delphinapterus leucas) in western Hudson Bay. J. Fish. Res. Bd. Can. 1065-1090.

Shustov, A. P. 1965. The food of ribbon seals in the Bering Sea (in Russian). Izv. TINRO 59:178-183.

Smith, M. A. 1976. Chronic effects of oil exposure on the ultrastructure of king crab gills and other tissues. Paper presented at the Alaska Sci. Conf. Univ. Alaska, August 6, 1976.

Smith, R. L. and J. A. Cameron. 1977. Acute effects - Pacific herring roe in the Gulf of Alaska. OCSEAP Final Rep., RU #123, March 1977. 39pp.

Spaulding, D. J. 1964. Comparative feeding habits of the fur seal, sea lion and harbour seal on the British Columbia coast. Fish. Res. Bd. Can. Bull. 146. 52pp.

Stoker, S. W. 1973. Under-ice studies of the winter benthos on the continental shelf of the northeastern Bering Sea. M.S. Thesis, Univ. Alaska, Fairbanks.

Van Winkle, M. E. and W. L. Schmitt. 1936. Notes on the Crustacea, chiefly Natantia, collected by Captain Robert A. Bartlett in Arctic Seas. J. Wash. Acad. Sci. 26:324-331.

Vandermeulen, J. H. and W. R. Penrose. 1978. Absence of arylhydrocarbon hydroxylase (AHH) activity in three marine bivalves. J. Fish. Res. Bd. Can. 35:643-647.

Vibe, C. 1950. The marine mammals and the marine fauna in the Thule district (northwest Greenland) with observations on ice conditions in 1939-1941. Medd. om Gron. 150:1-115.

Vladykov, V. D. 1946. Nourriture du Marsouin Blanc ou Beluga (Delphinapterus leucas) du fleuve Saint-Laurent. Contribution du Departement des Pecheries Quebec, No. 17:157pp.

Wilke, F. 1954. Seals of northern Hokkaido. J. Mammal. 35:218-224.

Wolotira, R. J., Jr., T. M. Sample and W. Morin, Jr. 1977. Baseline studies of fish and shellfish resources of Norton Sound and the southeastern Chukchi Sea. OCSEAP Final Rep., RU #175, 21 October 1977. 292pp.

XI. Auxiliary material

C. Translations of pertinent references

Polar cod (<u>Boreogadus saida</u> Lepech.) and its importance for certain life processes in the Arctic

S. K. Klumov

Introduced by Academician S. A. Zernov

From: Izvest. Akad. Nauk SSSR (biol.) No. 1. 1937

Translated by: Meg L. Poppino for the Alaska Department of Fish and Game

The complex of arctic vertebrates which feed on the polar cod is united by the author in a special group, called a "pleiad," which is not the same as our understanding of a "biocenosis."

In addition, material is presented on the feeding of the polar cod on phytoplankton, on the times and places of its spawning in the Barents Sea, and on its fall-winter migrations from the Barents Sea to the Kara Sea and back. The author also presents the possibility of the taxonomic variety of polar cod populations.

The author considers the polar cod the biological pivot of the lives of the majority of vertebrates of the far north, and stresses its importance in the transfer of organic matter in the Arctic Ocean.

In studying the feeding habits of marine mammals of the Arctic (belukha, ringed seal, bearded seal and others) I was able to establish that the polar cod (<u>Boreogadus saida</u>) is one of the main objects of feeding for a whole group of vertebrates of the far north.

I became interested in this cod, and discovered that its biology is almost entirely unknown, as this fish has not yet served as an object of commercial fishing, and its huge concentrations have gone unnoticed until now.

Since 1952 I have collected material on the biology of this fish, with the help of winter researchers from polar stations and the participants of Arctic expeditions. In addition, during my stays in the north (1932, 1933, 1934), I made observations and collected data with workers, under my direction, of an expedition to study the biology and industrial exploitation of marine mammals.

As a result of this work, certain material on the biology of the form now being described had been concentrated in my hands. Reworking it and making use of the scanty available literature, I found that I was in possession of very interesting, although incomplete, data characterizing the role of the polar cod in the Arctic. One may say boldly that the polar cod is the basis of life for a large group of vertebrates of the far north, if not all year, then at least during a significant part of it.

We found that the polar cod serves as a source of food for the following animals: the narwhal (Monodon monoceros L.) and the Minke whale (Balaenoptera acutorostrata Lad.)--specimens caught near the shores of Greenland had only polar cod in their stomachs, as Alvin Pedersen (4) writes; belukha [Delphinapterus leucas (Pall.)], which accompanies schools of polar cod--thus to a certain extent the migrations and distribution of this animal depend on the distribution and movements of the polar cod, which fact was also presented in my 1933 work (5)[1]; the ringed seal (Phoca hispida Schreb.), also following schools and feeding intensively on them (observations of G. A. Ushakov, N. A. Ostroumov and others) (1,5); the bearded seal (Erignathus barkatus Fabr.), which feeds in certain regions only on polar cod during its massive concentrations (observations made on my request by M. P. Rozanov, M. Voronchikhin and others) (1); the harp seal (Histriophoca groenlandica oceanica Lepech.), which eats polar cod in large quantities during its stay in the Belyy Sea in the winter and on the selveges of polar ice in the summer (1,5,6,7); the polar bear (Thalassarctos maritimus Philips), according to M. P. Rozanov's observations, which catches polar cod from the water, and also eats fish which have been thrown onto the shore by autumn storms. The latter occurrence is observed annually in Vaigach, Koluchev, Novaya Zemlya, and in the summer on the ice in the Kara Sea. Coming to shore to spawn, polar cod are thrown onto shore even by an insignificant storm.[2] The arctic fox (Alopex lagopus L.) also feeds on polar cod which have been thrown to shore. Even after a heavy snowfall during the polar night this animal will dig the cod from under the snow and ice, which costs it much effort.

Fish such as the Atlantic cod (Gadus morhua L.), the American plaice (Hypoglossoides platessoides) and others also feed on polar cod fairly intensively, which fact was presented in reports of the first session of GOIN (8).

The populations of bird rookeries found at high latitudes (Franz-Joseph Land, the northern part of Novaya Zemlya)--the thick-billed murre (Uria lomvia L.); the kittiwake (Rissa tridactyla L.), Mandt's (black) guillemot (Cepphus grylle mandti Licht.) and others--and the birds of the Kara Sea--the jaegers (Stercorarius pomarinus, St. epphus, St. parasiticus), the gull Larus taimyrensis But., and the arctic tern (Sterna paradisea Brunn) also feed on this fish fairly extensively.[3] It must be noted that the latter two Kara Sea forms comprise quite numerous colonies.

The animals mentioned above also show a certain interconnectedness among themselves. Thus, for example, the polar bear feeds on the ringed seal (its main feeding object), with which its migrations are therefore connected, on the bearded seal, and occasionally on belukha. The arctic fox, which accompanies the polar bear and feeds on the remains of its kill (primarily ringed seal), sometimes becomes the object of the bear's hunt itself.

Sea birds catch polar cod both directly and with the cooperation and "help" of marine mammals, particularly belukha, which, by frightening the polar cod from under the ice where the latter usually hide, makes them accessible for the birds.

The interrelationship between the animals united by the polar cod is depicted in Figure 1. I composed this schema for the European North and the Kara Sea, and it should be somewhat altered for the Far East (Chukchi Sea and the Bering Strait). Thus, for example, the harp seal should be excluded, and its biological analog, the ribbon seal (*Histriophoca fasciata* Limm.), should, in all probability, be added in its place. This seal's habits have still been much too little studied. The ringed seal (*Phoca hispida*) will probably be replaced by its far eastern subspecies the "akiva" (*Phoca hispida* Kraschenínnikovi Naum. Smirn.). The humpback whale (*Megaptera nodosa* Bon.) and the fin whale (*Balaenoptera physalus* L.), which feed on polar cod during their exit from the Chukchi Sea and the Bering Strait, should also come into this schema, as should other animals.

I call this group of animals the "pleiad" of the polar cod. In our understanding of the word "biocenosis" there is sensed a definite, narrowly defined place (a geographical point) and a specific, unvarying group of components, which comprises the biocenosis.

The pleiad unites migrating animals, which are not bound to any geographical point. Certain of these animals enter the pleiad only at certain times of the year (variably).

It follows that the pleiad is a group of animals united by one constant component (the determinant of the pleiad), and distinguished by complex interrelationships and by dynamism in duration and location of these connections.

Of course, the list and schema presented above do not exhaust the group of animals connected with the polar cod. We have shown only one side of the complex, the *use* of the polar cod by its predators--vertebrate animals. The other side of this complex consists of the animals on which the polar cod itself feeds. I will not touch on these animals for the present, although we will concern ourselves much with them a little later.

The polar cod is, to a certain extent, an accumulation of huge reserves of microscopic marine food sources, inaccessible for direct use by vertebrates. Therefore, the use of these resources takes place through the polar cod, which, along with zooplankton, is one of the main intermediary links in the food chain and plays an important role in the transfer of organic matter in the Arctic Ocean.

This is schematically represented in Figure 2, although this schema is without doubt incomplete and requires further specification and so forth; but for all that it is probably close to reality.

Figure 2 requires some explanation, but for that it will be necessary to digress slightly and touch first on several aspects of the polar cod's biology.

Up until the present time it has been accepted to think that the polar cod's distribution is circumpolar [(9,10,11) and others]. However, on close examination of the data from a great deal of broad-based material, it becomes evident that there are gaps in the polar cod's distribution. This compels us to consider the polar cod's distribution amphipolar, or amphiarctic [term introduced by Prof. L. S. Berg (12)]. The absence of polar cod has been confirmed for the southwestern part of the Barents Sea and the eastern part of the Laptev Sea. In the western part of the East Siberian Sea the polar cod is evidently entirely absent, or appears exceptionally rarely, and of course does not form large concentrations. It is entirely possible that in these places it is completely replaced by the recently described cod Arctogadus borisovi Drjag (13). Farther to the east the polar cod is encountered in the Chukchi Sea and the Bering Strait, where, as in the European North, it forms mass concentrations. In the Bering Sea it occurs rarely; it appears only by chance along with the ice from the Kolyar Sea (14).

In the Sea of Okhotsk, notwithstanding the data in the literature on this question (11, 15 and others), the polar cod does not occur; Lindberg and Soldatov state this definitely.(14). It is evidently replaced here by its biological analog, the Alaska pollock (Theragra chalcogramma Pall.). The latter fish, which is widespread in the Bering Sea, the Sea of Okhotsk and the northern part of the Japan Sea, displays great ecological similarity to the polar cod [pelagic mode of life, feeding on plankton, etc. (16)], and also serves as a basic food source for several of the marine mammals, for example the sea lion Eumetopias jubatus Schreb. Bearing in mind the herding behavior of this sea lion, it must be concluded that the pollock forms fairly significant concentrations.

In its distribution the polar cod is almost always connected with ice, displaying "glaciophilia," if one may so express it.

The polar cod's winter feeding is based on the following primary objects (for the Barents Sea): Rhoda (Thysanoessa) inermis, Themisto libellula (cold water form[4]), eggs of fish (species unknown) and of shrimp [apparently Crangon (17)]. Besides that, G. N. Sofronov informed me that in October 1933 he found juveniles of some sort of fish, up to 5 cm in length, in the stomachs of polar cod which he had caught. It must be noted that a careful microscopic analysis of the stomach contents of polar cod taken in the winter has not been made. In the summer the contents are of an entirely different nature.

As we know, during the melting of marine ice a wild growth of organic life is observed in the melt areas, which are rich in nutrients (carbonates, nitrates, phosphates). Along the edge of the melting ice, be it a small separate iceberg or a huge ice field, the huge and varied growth of ice forms of diatomic algaes and flagellates is observed (18,19,20,21). The latter attract a large number of invertebrates, and also the polar cod, which also feeds on phytoplankton in the spring and summer.

In support of this I would like to produce the report on the dissections of polar cod done by T. I. Usachev, a participant in the "Sedov" expedition of 1934, in the northeastern sector of the Kara Sea.

"Polar cod, taken 2 August 1934 near station #15 (22), at approximately 79°N latitude and 80°E longitude, had the following stomach contents:[5]

Polar Cod #1	In the stomach were greenish remains, consisting of diatomic algaes:
Main mass:	*Fragilaria oceanica* - fresh *Thalassiosira* - several species, remains *Nitzschia frigida* - fresh
Polar Cod #2	Stomach and intestine with food. Greyish-green viscous mass. In the stomach: remains of zooplankton, quite a lot (not classified). Phytoplankton: *Fragilaria oceanica* - much
Relatively large amount:	*Nitzschia frigida* *Thalassiosira* sp. *Melosira arctica* *Chaetoceros* - remains Phytoplankton predominate."

On 5 August of the same year P. L. Usachov dissected another polar cod taken near station #18 at about 79°N latitude and 85°E longitude. The dissection showed:

"Polar Cod #3	Stomach slightly filled
In the stomach:	*Nitzschia frigida* - very little *Fragilaria oceanica* - much *Melosira arctica*, *Thalassosira* and other diatoms - quite a lot

Zooplankton - little. Remains of the same diatoms in the intestine."

The diatoms found in large numbers in the stomachs of polar cod are typically representative of ice flora of the Kara Sea. Thus, phytoplankton are shown once again to be part of the polar cod's food, and again demonstrate its glaciophilia.[6]

To conclude from the data we possess, we can offer the following schema of the polar cod's feeding habits:

Phytoplankton:	included in food in the summer; absence from polar cod stomachs in winter can be explained either by the inadequate number of observations or by the weak development of phytoplankton in the fish's feeding areas in this period.
Zooplankton:	primary food source in the winter and probably secondary in the summer.
Juvenile fish, of fish and crustacea:	eggs secondary object of feeding in winter and fall, evidently; entirely absent in summer.

Now the schema presented above will be clearer (Fig. 2).

With the onset of the period of increased insolation, the sea's ice cover begins to break up and melt, and favorable conditions are created for the growth of phytoplankton, which attract a group of invertebrates, and the polar cod. Concentrations of the latter attract birds, predatory fish, and marine mammals, which in turn attract a higher order of predators (the polar bear, for example). Almost all of these vertebrates are used by man.

In our model we give the same series of transformations of solar energy into the final product, used by man, which was so beautifully described by K. A. Timiryazev (23): "Food serves as our organism's source of power only because it is nothing more than the conserved rays of the sun." (Underlined by Timiryazev [23], p. 354.) Further: " A plant forms organic material from the sun's rays--stored power." ([23], p. 348). This "organic material" and the "stored power"--i.e. energy--accumulated by phytoplankton, are used by the polar cod, and, through it, by a group of animals, and man. Thus we have here a transformation and transfer of energy, which is shown in Figure 2.

I would like to pause again on three points in the biology of the polar cod, until now little or practically not at all illuminated in the literature: its seasonal relocations (migrations); spawning; and the systematic variety of its population (the formation of biologically distinct groups).

I have many observations on the polar cod's migrations. Sleptsov, Rozanov, Ushakov and others observed colossal concentrations of polar cod in August-September in the Kara Sea. In October huge migrations of polar cod were noted: by Voronchikhnyy near the shore of Vaigal (Karekiye Vorota); by Kliyug and Sofronov near Cape Hope (Novaya Zemlya); in Matochkin Shar by the Nenets brothers, F. and I. Vylko; and so on. All of the polar cod's autumn migrations are explained by spawning, which, according to all observations, takes place near the shores of Novaya Zemlya, Vaigach, Kolguyev, Cheshkiy Bay, Kanin Peninsula, etc. From the movement of the marine mammals accompanying the schools of polar cod (belukha, ringed seal and others), the polar cod's direction can be ascertained. In autumn it passed through all of the straits and near Cape Hope from the Kara to the Barents Sea. Considering the large concentrations of polar cod in the Kara Sea in the summer, the absence of observations of such concentrations in the winter, and, on the other hand, the large concentrations in the Barents Sea in the autumn and winter, and the migrations, repeated from year to year, in the fall from the Kara to the Barents Sea, and also the absence of polar cod in its central and southern areas (only individual specimens have been noted)--it must be agreed that the polar cod's autumn migration from the Kara to the Barents Sea and its spring run in the opposite direction (sparser and therefore less noticeable) take place annually and naturally. This will be especially clear if we recall that the polar cod's distribution is always connected with the ice (especially in the summer), as it feeds on ice phytoplankton (5).

In the summer, as has been said, the polar cod forms huge concentrations in the Kara Sea, spreading in large numbers to the shore of Novaya Zemlya, and often entering the western part of the Laptev Sea. In its eastern section the polar cod, if it is encountered, which has not yet been finally demonstrated, is evidently present only by chance and in small numbers.

The polar cod's distribution in the Kara Sea is connected above all with the ice. Every small, even isolated iceberg, not to mention large ice fields and the selvege of the polar glacier, is literally surrounded by a tight ring of polar cod, feeding on phytoplankton--diatoms, richly represented in the water where the ice is melting, and in the breaks and cornices of the ice. The same may be said of the high latitudes of the Barents Sea, although here large concentrations of polar cod around the ice have not been ascertained.

In the autumn, in connection with the dying out of the glaciopelagic complex, brought on by decreased insolation and lowering temperatures, the polar cod moves from the Kara Sea to its feeding fields, still rich in organic matter, i.e. to the Barents Sea. In addition to the onset of unfavorable feeding conditions, the polar cod's migrations are caused by one other extremely powerful factor--the reproductive factor.

The polar cod's spawning within the western part of the Eurasian sector of the Arctic, as is clear from the material presented above, takes place only in the Barents and Belyy Seas, probably due to the excellent thermal and general hydrological conditions in these seas in comparison with the rest of the Arctic Ocean, to the east of the Barents Sea. There is almost no information in the literature besides Rass's statement (24) on the spawning habits of the polar cod. L. Zenkevich ("On certain moments in the zoology of the northern polar basin...," "Zoological Journal," vol. XII, #4, 1933) writes that the biology of the polar cod "has not been investigated at all," and, citing Richardson's data, states that, according to the latter, the polar cod spawns near the shores of Greenland in February.

The concentrations of polar cod in the Kara Sea have a clearly prespawning, migratory character, as at this time the fish is beginning its movement to the spawning places, grouping in extremely large schools.

Spawning takes place in the eastern part of the Barents Sea, in various regions at various times.

At the present we can observe two waves in the polar cod's spawning migrations. The first comes in October-November and includes the following regions: Cape Hope, Admiralteistvo Peninsula, Krestor Bay (it must be held that spawning takes place along the whole western shore of the northern end of Novaya Zemlya), Matochkin Shar, Karmakula, Vaigach Island, Kolguyev, etc.

The second wave falls in January-February, sometimes also in the beginning of March. At this time, spawning, according to the observations available, takes place in the following areas: Cheshkaya Bay, Kaninskiy Bank, the western shores of Kanin Peninsula, and on the western shores of the Belyy Sea (in places), extending to the mouth of the northern Dvina. We have not been able to ascertain how numerous the runs to the Dvina Bay are. According to N. Khaldinovaya, in some years large numbers of polar cod arrive at the shores of Sorokskiy Bay simultaneously with navaga (January, February).

Just before spawning (although, it is true, this is not observed everywhere) the polar cod, like the navaga, enters the rivers, although it does not swim far upstream, and then, slipping down again, spawns in the sea near the shore. The meaning of this phenonmenon is not clear, since no one has thus far studied this question.

It must be noted that the eggs thrown out by the polar cod in October-November (the first wave of spawning) do not have favorable conditions to encourage fast development, appearing as they do in the middle of the period of low temperatures and the darkness of the polar night; therefore, it is to be expected that they develop rather slowly.

The rate and conditions of growth of polar cod's eggs have not been fully studied, although they are of undoubted interest. Special research should be undertaken in this direction.

According to T. S. Rass (24), in May in the Barents Sea juvenile polar cod "from 4 to 9 mm long" were found. This, it seems to me, supports the data indicating that spawning does not take place all at one time, but at two periods, and indicates, moreover, that the eggs also develop during the polar night, although slowly, and their intensive growth probably begins with the onset of insolation and higher temperatures. It may be considered that the hatching of young from eggs occurs from April to the end of May.

Our data indicate that the polar cod always spawns in the shore zone, and, evidently, one cannot judge from the presence of young exactly where spawning takes place. It must be borne in mind that both eggs and the young (polar cod eggs are pelagic) may be carried for long distances from their spawning place by winds and currents.

In connection with the existence of two entirely separate spawning periods, a question arises: are we dealing with two distinct groups (races), or can this delay in spawning be explained as the different spawning times of different age groups, as we observe in certain marine mammals, specifically in the majority of marine mammals, of which different age groups whelp at clearly established times?

Certain clues supporting the existence of two systematic groups of polar cod have been presented earlier. Thus, Prof. V. K. Soldatov (15), referring to polar cod taken in the Belyy Sea (in March), observes that they are distinguished from those in the Barents Sea by a number of morphological characteristics. It should be noted that the polar cod which Prof. Soldatov had at his disposal were taken in autumn from the Barents Sea, but as we have said, those from the Belyy Sea were taken in the spring. Thus these fish served as representatives of the very two biological groups (the two waves of spawning) which I discussed earlier.

Unfortunately, the lack of the necessary amount of material deprives us of the opportunity to answer this question finally, and forces me to limit my statements to those already presented. However, I am certain that with careful study of the biology and morphology of the polar cod, the genus Boreogadus undoubtedly will be found to consist of several taxonomically separate entities (The Barents-Chukchi, Eurasian, Greenland and other forms). This must be expected, considering the gaps in distribution, the presence of several morphological peculiarities, and especially the major variations in the biology of this fish, among the separate groups which have been observed.

In speaking of spawning, it is impossible to silently pass by the colossal concentrations, undoubtedly of great commercial interest, which the polar cod forms at this time. It should be noted that everywhere in the spawning places polar cod are thrown onto shore by storms in such huge numbers that the local population and winter scientific workers can collect enough for the whole winter, both for their own use and as food for their dogs.

In addition to the huge spawning concentrations in the Barents Sea, there are large concentrations of polar cod in the Kara Sea in the summer, which I have called migratory or pre-spawning.

When in these concentrations (in summer in the Kara Sea and in fall and winter in the Barents Sea), the polar cod is the primary, and, it may be, the only object of feeding of the marine mammals mentioned above (Fig. 1), and of other vertebrates. The belukha, the ringed seal, the bearded seal and other animals feed exclusively on polar cod when it is found in these concentrations.

During the polar cod's migrations to the southern part of the Novaya Zemlya shallows and other parts of the Barents Sea, the number of empty stomachs found in Atlantic cod is minimal (6%), and the index of fullness is at its highest; "polar cod exclusively" is found in the stomachs ([8], p. 27). The same may be said of other animals (the arctic fox, sometimes the polar bear, sea birds, etc.). Thus the polar cod, which feeds on phytoplankton and zooplankton and accumulates in its body the food resources of the sea, largely inaccessible for use by higher animals, is an important intermediary link in the sea's food chain, swallowing, assimilating and transferring food resources to other animals as an already fully usable albuminous product.

The colossal numbers of polar cod which are eaten by various animals are transformed into a huge store of energy, much of which in one form or another is returned to the sea, and part of which is transferred by man, marine mammals, birds, etc., to various geographic regions.

The quantitative side of this phenomenon at present can only be noted, and for now cannot be adequately illuminated, as we do not know many of the necessary details about the lives of the polar cod itself or of most of the animals included in the schema for Figure 1. But the solution of this problem, which is of a scientific and practical value that we cannot presently appreciate, is not far away. The wide-ranging research lately being undertaken in the Arctic on assignment from the government testifies to that, as does the great interest expressed by the people in the study and exploitation of the Far North of the USSR.

Vsesoyuznyy nauchno-issledovatel' skiy institut morskogo rybnogo
khozyaistva i okeanografi (VNIRO)
(All-Union Scientific-Research Institute of Marine Fisheries and
Oceanography)

FOOTNOTES

1. Of course, hydrometeorological conditions are also very important in the migrations of this animal, and also influence the distribution of the polar cod.

2. The information of G. N. Sofronov (a winter researcher on Cape Hope), who collected about 600 kg of polar cod thrown onto the shore by a storm in 6 hours of work with a co-worker, serves as one of the many examples of this occurrence.

3. Data for the Kara Sea birds were collected on my request by M. Slentsov, for Novaya Zemlya by G. N. Sofronov, and for Franz-Joseph Land I used the data of N. T. Demme (18).

4. According to the data of the Laboratory of Marine Biology (VNIRO).

5. I consider it by pleasant duty to express my deep appreciation to P. I. Usachov for the extremely valuable and interesting material which he presented to me. The data on the dissection of stomachs are quoted from P. I. Usachov's journal.

6. The biological peculiarities of the polar cod which have arisen in the process of adaptation to an ice habitat and which permit it to remain active at low temperatures have not been explained to the present time. It is beyond doubt, however, that having adapted to the aforementioned conditions, the polar cod filled an existing gap, since it is still the only pelagic fish closely connected with the ice and making use of the rich food sources of the ice zone.

REFERENCES

1. Androsova, Kalyanov, Savvatimskiy. Papers of GOIN, t. IV, ed. 2, 1934. Gov't. Oceanographic Institute.

2. Berg, L. S. Fresh water fish of the USSR and adjacent countries. Part II, 3, VNIORKH, 1933. (All-Union Scientific Research Organization of Fisheries Industry).

3. _____, _____. Izv. Gosud. geogr. O-va., v. 66, vyp. 1, 1934.

4. Gratsianov, Trudy Otd. ikhtiologii o-va akklimatizatsii shivothykh i ratseniy, T. IV, 1907. (Papers of the Department of Island Ichthiology, Acclimatization of Animals and Plants).

5. Driagin, P. A. Zool. Anz., Bd. 98, 1932.

6. Zubov, N. N. Collection, "The Northern Waterway," II, 1935.

7. Klumov, S. K. Papers of the Polar Commission of the Academy of Sciences, ed. 27, in press.

8. _____, _____. "Fisheries of the USSR," #5, 1935.

9. _____, _____. "The Soviet Arctic," #2, 1935.

10. _____, _____. "Fisheries of the USSR," #11, 1935.

11. Knupovich, N. M. Papers of the Institute for Study of the North. 1926.

12. Krogh, A. Zeitschrift vergleich. Physiol., 12, 688, 1930.

13. Soldatov, V. K. and Lindberg, G. U. Survey of the fish of the far-eastern seas. PIRKh, 1930.

14. Materials of the feeding of fish of the Barents Sea. Ed. L. Zenkievich. Papers of the I. session of GOIN, 1931.

15. "Why the animal goes south." from "For a Fisheries Industry in the North," #12, 1934.

16. Rass, T. S. The Karelo-Murmansk Region. #3-4, 1934.

17. Samoilovich, R. Geografiska Annalu, 1935, SVEN HEDIN.

18. Soldatov, V. K. Trudy Plavmornina, vyp. 3, 1923.

19. Smirnov, N. A. On marine animal industry on Russian vessels. S.P. 6, 1903.

20. Suychiro Jasno, Bull. of Japan. Soc. of Science Fish., vol. III, #1.

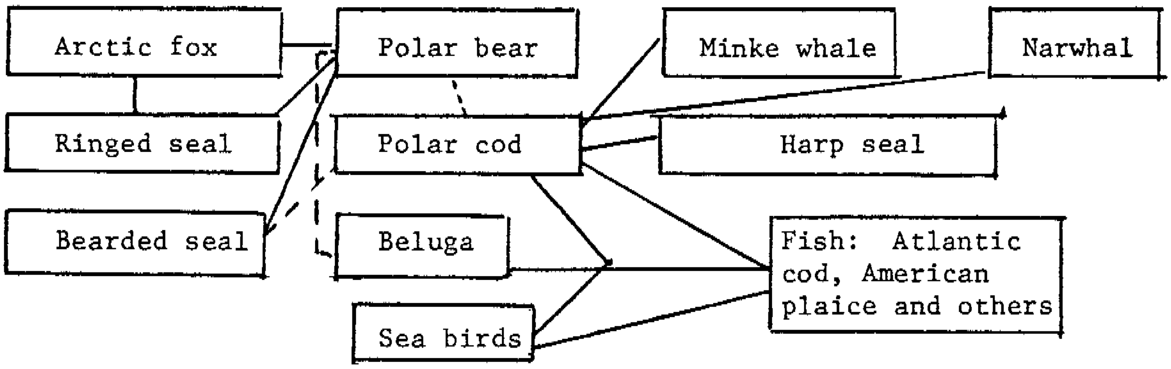
21. Timiryazev, K. A. The life of the plant. Br. Sabashnikovykh, 1914.

22. Usachov, P. I. Papers of the All-Union Arctic Institute, v. XXI, 1935.

23. Kharvey, Kh. V. Biochemistry and physics of the sea. Acad. of Sciences, 1933.

24. Pedersen, Alvin. Fortgesezte Beiträge zur Kenntnis der Säugetiere und Vogelfauna der Ost-Küste Grönlands. Meddelelser om Grönland, LXXVII, Köbenhavn, 1931.

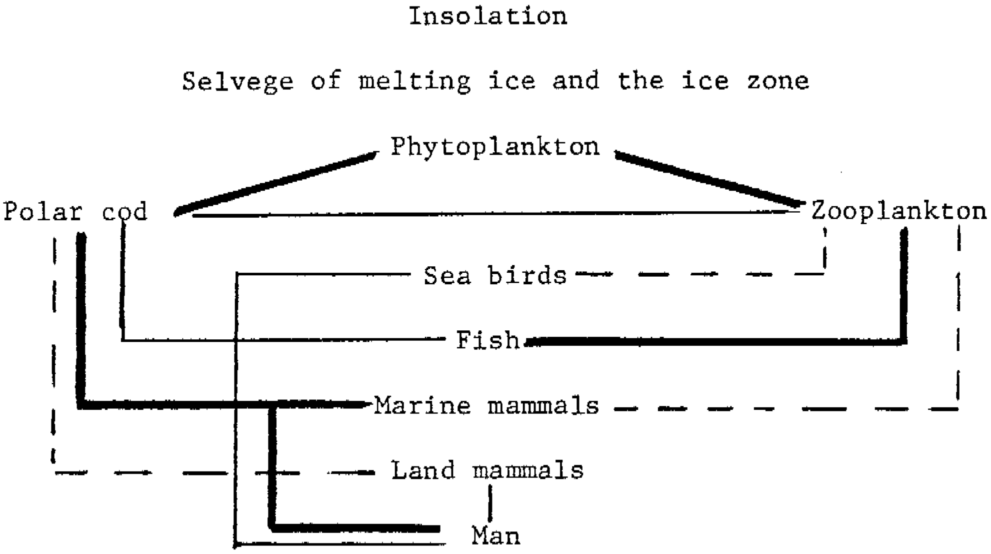
Figure 1. Schema "The Pleiad of the Polar Cod."



__________ A clearly shown connection

---------- A weak connection

Figure 2.



Varying thicknesses of lines indicate varying degrees of use of certain components by others.

On the biology of the polar cod Boreogadus saida

B. K. Moskalenko

From: Voprosy Ikhtiologii 4(3):32, 433-443. 1964.

Translated by: Meg L. Poppino for the Alaska Department of Fish and Game

A significant increase in fish catches is anticipated in the long-range plan for industrial development in the Ob'-Irtysh Basin, due to the opening of new regions to the fishing industry in the Kara Sea. The polar cod, Boreogadus saida (Lepechin), the most numerous fish of our arctic seas, may well become one of the objects of marine fishing in the Arctic.

The biology of the polar cod has been little studied. Information in the literature describes only its spawning migrations to the White Sea (Manteifel 1943, Tambovtsev 1952). Material on the biology of the polar cod of the Kara Sea is very sparse (Kiseleva 1940, Kravchuk 1958) and there are no data at all on the life of this fish in the Pechorsk and Laptev Seas. During our work in the Pechorsk Sea (1941-44), the Laptev Sea (1946-47) and the Kara Sea (1951-52) material was collected which somewhat increases our knowledge of the biology of this fish. In this article we have also used material from research carried out by the Ob'-Tazov division of GosNIORKh in 1961. These data permit us to indicate the basic direction for further study and industrial exploitation of this fish.

Polar cod in the Pechorsk Sea

The polar cod appears in the winter in the northern part of the Pechorsk Gulf and in the neighboring Kolokolkov Bay, and also near Sengeisk Island between November and December. In winter of 1940-41 the migration began in the first 10 days of December; in 1941-42 in the third 10 days of November; in 1942-43 in the first 10 days of January; and in 1943-44 in the third 10 days of December. In the inner parts of the Pechorsk Gulf migrations take place in the middle of January, and in open sea areas they take place in February.

With the tides driven by north and west winds, the polar cod enters the tundra rivers which flow into the Pechorsk Gulf (Dresvjanka, Chornaya), swimming upstream as far as the limit of the high tide.

The polar cod evidently approaches the Pechorsk Gulf area from the east. In winter 1943-44 the first school appeared in the eastern part of the Gulf, near Varand Island on 23 December. The cod entered Kolokolkov Bay, to the west of the Gulf, almost 2 weeks later, on 5 January.

The size of the migrations may be judged from catches on 1 day of fyke-netting (control catches) (Table 1).

The total catch in the Pechorsk Region in the winter of 1943-44 was 10,000 centners in 794 fyke-nettings, and an average catch in one netting was 12.7 centners. In the same nettings in the same period 8000 centners of navaga (Eleginus) were caught. The main bulk of polar cod (7.3 thousand centners) were caught near Kolokolkov Bay, where 35 fyke nets were cast. The average catch per fyke netting here was 208 centners.

Mass migrations of polar cod in the winter of 1941-42 and 1942-43 coincided with north and west winds of storm force which caused high tides. However, there were also cases of migrations of schools in the presence of winds, where no corresponding relationship can be established. The influence of wind-driven waves is more definitely observed in the entrance of polar cod into the tundra rivers, where they rush on the high tide when the school has stopped near the mouth of the river.

The polar cod also enters the Pechorsk Gulf in the summer, in small numbers. Thus in August and September of 1943 it appeared near the shore of Zakharin, where water temperatures were 6-10°. V. K. Soldatov's 1920 statement (1923) that the polar cod "constitutes the usual food of Atlantic salmon caught in brackish waters by fishermen on the way out of Pechorsk Bay" bears witness that this fish remains near the Pechorsk Gulf more or less constantly in the summer. The appearance of the polar cod in warm waters is not accidental, as evidenced by its summer migrations to other regions. Thus, in Cheshkiy Bay (August 1942) 40 centners of this fish were caught in several fyke nettings. According to the data of E. V. Kiseleva (1940) in Obsk Bay (first half of September 1937), 2-3 centners of polar cod were found each time the net was checked. The author cited stresses that "polar cod was caught without exception at favorable temperatures, which reached 10°." However, such summer runs can hardly have consistent significance for the fishing industry.

In Pechorsk Gulf polar cod from 2-6 years old are encountered; the mass of the fish are 3-4 years old. The number of yearlings is insignificant; they were represented by a few individuals in samples taken in the summer near the shore of Zakharin. We did not note any young of the year. The length of polar cod of the age groups mentioned fluctuates from 10 to 24 cm (Table 2).

The amplitude of the fluctuation in length of the fish in every age group is significant. Thus the size of polar cod of 3+ years varies from 15 to 24 cm.

Polar cod matures at an age of 3 years. In winter samples fish of 2+ years, even the smallest ones (13-14 cm in length), had mature sexual products. In all of the material collected there were only five sexually immature individuals in the summer samples. We do not have samples at our disposal which reflect the growth of polar cod throughout all months of a single year. Therefore, in order to describe the state of the sex glands in different months we must make use of samples from different years, where fluctuations in the development of the sex glands are possible, depending on the differences in the hydrological conditions. However, one can obtain an impression of the general scheme of development from this material.

The yearly cycle of sexual development in the polar cod coincides with the sexual cycle of the navaga. In the summer both the polar cod's and the navaga's sex glands are in a rest stage which generally ends by September. With the fall of water temperature in autumn, active pre-spawning development begins. A sample taken 17 August 1943 in Pechorsk Gulf contained 91% individuals in Stage II. In a sample of 8 September the number of fish in Stages II-III and III increased. In samples from 23 November 1941, 50% of individuals were in Stage III and the remainder were in Stages III-IV and IV. A sample from 5 and 6 December 1940 contained 98% fish in Stage IV.

From the end of December to the beginning of February the polar cod spawns. A mass migration by a school which was ready to spawn was noted in Pechorsk Gulf (in the area of Dresvyanka River) on 2 January 1943. A sample taken on that day contained 42% individuals in Stage V and 57% in Stage IV-V. Throughout January a significant number of fish had mature sexual products. By the end of the month, the number of spawned-out fish increased. In the beginning of February spawning ended; a sample taken 8 February contained over 50% fish in Stage VI. The change from Stage VI to Stage VI-VII took place during February (Table 3).

Thus, the cycle of sexual development of the polar cod can be represented by the following schema:

spawning	Stage V - Jan.
post-spawning period	Stage VI - Feb.
period of renewal of sexual products and rest stage	Stage VI-VII and VII - Mar. - Aug.
beginning of pre-spawning development of sexual products	Stage II-III - Sept.
pre-spawning development of sexual products	Stage III and III-IV - Oct. - Nov.
the same	Stage IV - Dec.

Winter samples contain mainly fish with empty stomachs. This bears witness to the fact that before and during spawning the polar cod stops feeding or feeds only lightly. In samples from 13 January 1942, 22 January 1943, and 10-15 January 1944, all polar cod had empty stomachs. There were no traces of food in the intestine. In samples from 31 December 1942, 10 January and 8 February 1943, the stomachs of one or two individuals contained a small amount of food, and the stomachs of the rest were empty. A sample from 2 January 1943 was an exception, including 95% individuals with some food in their stomachs. In a sample from 26 February 1943, offering spawned-out cod, 80% of individuals had traces or a small amount of food (fish eggs) in their stomachs.

After spawning the polar cod is completely emaciated. Its body is flaccid and without elasticity. Its food value sharply declines at this time. Cases of polar cod perishing in large numbers, noted in the coastal zone near Pesyakov Island, Cape Russkiy Zavorot and Kolokolkov Bay, belong to the post-spawning period.

Polar cod in Anabarsk Gulf

Nothing was known of the polar cod's migrations in the nearshore areas of the Laptev Sea, but we found a comparatively large number of them in Anabarsk Gulf. On 12 August 1947, in one set of a 100-meter drag seine near Cape Khorgo, over 1,000 polar cod were caught. In the days following there were several more such catches. In general, in August and September polar cod was a common incidental catch. From October to December 10 to 20 individuals were caught per fyke-net set under the ice. In January the polar cod vanished, and it appeared again in the summer of 1948 after the Gulf opened. South of Cape Khorgo the polar cod is evidently not widespread. Near the mouth of the Anabara River only solitary specimens were noted.

Samples taken from August to December 1947 in the Cape Khorgo area served as material for study (Table 4).

The (zoological) length of the polar cod in these catches fluctuated from 8 to 21 cm, and weight from 5 to 75 g. The larger part of the sample consisted of fish 11 to 15 cm in length and 10 to 25 g in weight. Ages ranged from 1+ to 4+. The 1+ age group was only found in the August sample. From September to December the age composition of the samples was limited to three groups: 2+, 3+, and 4+. Polar cod of the 3+ group predominated. In all age groups other than the first there were significantly more females than males. The age, length and weight data for these fish are presented in Table 4.

Polar cod belongs to the fast-maturing fishes. It achieves sexual maturity at 2 to 3 years. As our material shows, the polar cod of the Laptev Sea is not distinguished in this respect from that of the Barents and Kara Seas. Fish of 2+ years had developed sexual products in Stages II-III and III (Table 5).

The dynamics of the development of the gonads for August-September 1947 are given in Table 6.

In August and September, the gonads of a large percentage of the fish (97 and 91%, respectively) were in Stage II-III. According to our observations in the Pechorsk Gulf, the presence of this stage at the beginning of autumn indicates that the polar cod will spawn in January. In October a significant group, 29%, consisted of individuals in Stage III of maturation. In November and December the number of fish with gonads in Stage III increased; individuals in Stages III-IV and IV appeared. This permitted us to suggest that in January most of the population would spawn within the time period usual for polar cod.

The disappearance of polar cod from catches near Cape Khorgo from January on can be explained by its departure for the spawning sites. The polar cod usually spawns in the nearshore regions of the sea, which are covered with ice. The fish does not penetrate beneath the ice very far from the selvege. With full development, the polar cod moves from the shore out closer to the open water; evidently this happened in the Anabarsk Sea. The possibility exists that, particularly in warm winters when the Gulf region of the sea freezes late, spawning schools may appear in the Gulf and become the object of late fishing. While in the Gulf the polar cod feeds intensively (Table 7).

Judging by the degree of fullness of the stomachs (Table 7), there is no essential difference in the intensity of feeding in summer and winter months. Since the polar cod continues to grow in length and weight during the winter months, one can conclude that the low water temperature does not hinder feeding or assimilation of food by the organism. Basic food components are Mysis, Limnocalanus, Gammarus, and Pontoporeia. In several stomachs the remains of Mesidothea entomon and sea-sculpin young were noted. The polar cod itself serves as the main food object of ringed seals and nelma in the Anabarsk Sea.

The polar cod that enters Anabarsk Gulf is distinguished from the Barents Sea type by external characteristics. The body does not have the lilac tint characteristic of the typical polar cod. Its color is greyish yellow, similar to the color of the toothed cod. The edge of the caudal fin is more rounded and its indentations are smaller than those of the Barents Sea cod. Along with the large number of small polar cod, individuals were found with the coloration typical of large cod--a lilac tint--and whose caudal fins had a deep indentation, the upper part of each lobe being almost pointed. These polar cod were 19.7 to 31.8 cm in length and weighed 51 to 160 g. They ranged in age from 4+ to 6+.

Polar cod of the Kara Sea

Our material gives us an idea of the summer distribution of the polar cod in the southwest part of the Kara Sea, and of its size and age composition.

We noted polar cod in trawls in Obsk and Baidaratskiy Bays, in Gydansk Gulf and in the coastal zone of western Yamal. It does not accumulate in large numbers in these places in the summer. On the basis of trawls one may conclude that the polar cod stays in the shallow coastal zone in small scattered schools, or even as solitary individuals. At any significant distance from the shore or in deep water they were not found in trawls.

In the northern part of Gydansk Gulf each trawl yielded 10 to 20 polar cod. The largest catches did not exceed 100 to 200 individuals. In the northern part of Obsk Bay each trawl yielded 300 to 500 individuals. To the north of Shokal'skiy and Belyy Islands, near the northwest shore of Yamal, only isolated individuals were caught in a trawl. More polar cod were found in the coastal zone of central Yamal, where catches consisted of up to 500 polar cod in a single trawl. In Baidaratskiy Bay each trawl produced only a few polar cod.

In all of the regions mentioned the majority of polar cod individuals were small. Four-hundred sixty from the catch of 19 August 1951 in the northern part of Obsk Bay weighed 3.2 kg; the average weight of individual fish was 7 g. The length varied from 8.2 to 13 cm, and the weight from 3.2 to 10.7 g. Polar cod from trawls made on 18 August 1952, in the area of Marye-Salye Spit (western shore of Yamal), were 7.5 to 16 cm in length (average length 11.5 cm), and 2 to 21 g in weight (average 11.8 g). Occasionally, single large individuals would be found among the small ones, or separately from them. E. V. Kiseleva's (1940) material, collected in the beginning of October 1937, in the northern part of Obsk Bay, consists of small polar cod. The same small fish predominate in the samples taken in Yeniseiskiy Gulf in 1948 by V. A. Kravchuk (1958).

Small polar cod of the coastal regions of the Kara Sea are distinguished in size, age composition, rate of growth and certain external characteristics (body coloration, form of the caudal fin) from the large polar cod, known from spawning migrations to the coastal areas of the Barents Sea, and also encountered in the open waters of the Kara Sea.

For comparison we offer the data for the polar cod of various regions (Table 8).

In Baidaratskiy and Obsk Bays and Anabarsk Gulf, polar cod is largely represented by individuals from 7 to 16 cm in length, and in Pechorsk Bay from 17 to 24 cm.

The suggestion may arise that the material from Pechorsk Gulf consists of sexually mature fish of the older age groups, and that from Obsk, Baidaratsk and Anabarsk Bays of young specimens. However, age composition, growth rate and condition of gonads indicate that not only age affects distribution by length. But first we will show that the growth rate of the polar cod from the coastal areas of the Kara and Leptev Seas is very different from that of the polar cod of the Barents Sea (Table 9).

From the data in Table 9 it is evident that the polar cod is divided into two groups according to rate of growth. The first, the Barents Sea group, from Pechorsk Gulf, Yaemskaya Bay and Kanin, grows approximately one-and-a-half to two times faster than the second, which consists of small polar cod from the coastal regions of the Kara and Laptev Seas.

A sample taken in the Kara Sea during the winter spawning period is distinguished from our other Kara Sea samples. Polar cod from this sample are larger than the other samples, which were taken in August and September. As E. I. Ivanova (1959) states, the size of these fish ranges from 14 to 30 cm, and fish 20 to 25 cm in length predominate. All of the individuals are sexually mature. They range in age from 3 to 7 years; individuals of 5 to 7 years predominate.

In October 1961 in Baidaratsk Bay (Gulf of Nyaru-Yakh), V. I. Zakharov, a colleague from the Ob'-Tazovsk branch of GosNIORKh, caught a small sample of polar cod in a fyke-net along with navaga. As in E. I. Ivanova's material, the polar cod was represented by large individuals (Table 10). These data show that in the Kara Sea the typical large polar cod occurs in addition to small specimens. As was noted above, the latter are observed in the summer in Obsk Bay as well as in Baidaratsk Bay. Mass migrations of large polar cod are known to occur near Dixon Island. In a sample taken in the area of Dixon Island in August 1941, the average length of polar cod was 20.4 cm, and the average weight 53 g.

In his work, V. K. Soldatov (1923) pointed out several differences between the White Sea and the Kara Sea polar cod. The data which we have presented permit us to conclude that the polar cod population in our polar seas is not of a single type. There are at least two forms, which differ in body size, growth rate, form of the caudal fin, and coloration. Certain data permit us to suggest that neither form is geographically localized, and that both are encountered together in the Kara and Laptev Seas. The possibility is not excluded that the small polar cod is more closely associated with the coastal areas of these seas--bays and gulfs--and that the large one is an open-sea form, which appears in the coastal zone only in pre-spawning and spawning periods. The answering of these questions remains a task for further research.

The greatest age of large and small polar cod in our samples is the same (4 to 5 years), but the age composition is different. In the Pechorsk Gulf and near Kanin, older fish predominate, and in Baidaratsk Bay and Gydansk and Anabarsk Gulfs they are younger. This distribution of age groups is completely natural. In the former areas we were dealing with spawning fish, representing only the older groups, and the fish in the latter were both sexually mature individuals and juveniles in a foraging period (Table 11).

Polar cod of Baidaratsk and Obsk Bay, like those of Anabarsk Gulf, attain sexual maturity in the same amount of time as the polar cod of the Barents Sea. According to the data of E. V. Kiseleva (1940), the gonads of all polar cod from Obsk Bay in October were in Stage III of maturity. According to V. A. Kravchuk (1958) the majority of polar cod from Yeniseiskiy Gulf from July to September were in Stage III, also. In Gydansk Gulf an entire sample taken in August 1961 consisted of fish with gonads in Stage III. Half of the polar cod from Baidaratsk Bay in August were individuals with gonads in Stages II-III and III (Table 12).

In August the coefficient of sexual maturity of females varied from 0.46 to 4.60 (average 2.5), and of males from 1.2 to 8.4 (average 4.8). From these data it is evident the pre-spawning development of sexual products in polar cod from Baidaratsk Bay, i.e. the transition from the stage of rest (II) to Stage III, is completed in August-September. Fish with gonads in this stage are sexually mature, and they will spawn that winter. Thus, polar cod from Baidaratsk and Obsk Bays and Yeniseiskiy Gulf cannot be considered entirely as belonging to the group of sexually mature juveniles. It is represented, if not completely (data of Kiseleva), then in any case by a majority of individuals which are preparing to spawn.

We have no information on the sites and periods of the polar cod's spawning in the Kara Sea, unless we consider E. I. Ivanova's report (1959) of a run of spawning fish to the Kara Bay in 1945-46. As this author states, polar cod appeared in the Bay in small numbers at the end of November. Spawning began at the end of January. In the middle of February the polar cod swam out to the sea.

Migrations by polar cod are not mentioned in the observations of colleagues of the Ob'-Tazovsk branch of GosNIORKh, made in the southern part of Baidaratsk Bay in fall and winter of 1958-62. Nor have they been noted at the mouths of the Yuribei and Morda-Yakh Rivers (western shore of Yamal), where navaga were fished in 1960-62. In Baidaratsk Bay and in the Kara Bay area we observed, in August 1952, small schools of juvenile polar cod, which remained near the surface during calm weather.

It cannot be said with certainty that all Kara Sea polar cod move to the Barents Sea to spawn. Obviously, this fish has Kara Sea spawning sites. Possible locations are the northwest shore of Yamal, the eastern shores of Novaya Zemlya, and the western shores of Taimyr.

The polar cod's food was determined with samples taken in the northern part of Baidaratsk Bay in August 1952. We visually established the degree of fullness of the stomachs, according to a four-point scale. 7% of stomachs (n=200) had 0 degree of fullness; 1 degree - 29%; 2 degrees - 40%; 3 degrees - 24%. In addition, the contents of 20 stomachs were analyzed. According to the data from quantitative and qualitative analyses, the average index of fullness was 353. The composition of the food was not varied. Over 50% consisted of mysids, and the rest of young Ammodytes and sea sculpins. The main food component of polar cod from Gydansk Gulf was Limnocalanus. According to V. A. Kravchuk (1958), in Yeniseiskiy Gulf the polar cod feeds primarily on copepods (Calanus, Limnocalanus) and secondarily on mysids. The index of stomach fullness was 224.

At present the distribution and migrations of the polar cod in our seas seem to be as follows: as drifting stations indicate, polar cod is present up to 80°N latitude. It is encountered in large numbers in the Barents, Belyy, Pechorsk and Kara Seas and is found in the eastern section of the Arctic (Laptev, East Siberian, and Chukotskoye Seas).

It is thought that the polar cod is most numerous in the Kara Sea. Having reached sexual maturity, it forms large schools in the second half of the summer, in those regions where it lived during spring and summer foraging. The largest schools form in the southern half of the Kara Sea and the northern and southeastern parts of the Barents Sea. From September on, these masses of polar cod move to the spawning places, which are primarily located along the shores of the Barents Sea. The schools of polar cod from the Kara Sea pass through the straits of

Novaya Zemlya and around its northern end to the west (Klumov 1937, Manteifel 1943, Tambovtsev 1952).

The actual data inadequately bear out this idea of the polar cod's seasonal distribution. Direct observations and the fishing industry have reliably established the fact of massive winter migrations of polar cod to the shores of the Belyy and Pechorsk Seas. In all other respects this schema is founded on only a few observations and information.

Does the polar cod, migrating from the Kara Sea, indeed spawn near the shores of the Barents Sea, or are the cod which approach these shores permanent residents of the Barents Sea? In other words, are there local populations of polar cod in the Barents and Kara Sea, or is there a single population, connected to both seas by its biological cycle? This basic question should be answered in future research, taking into account the following data:

1. Massive migrations of schools of polar cod to the southern coastal area of the Kara Sea in the months of August and September were not found in any of the following: the observations of E. V. Kiseleva in Obsk Bay in 1937; our 1951-52 observations in Baidaratsk Bay, the area of western Yamal, near Belyy and Shakal'skiy Islands, in Obsk Bay and in Gydansk Gulf; and V. M. Sudakov's observations in 1961 in Gydansk Gulf and near Shakal'skiy Island.

2. Polar cod encountered in the coastal areas in small numbers differ from those which spawn in the Barents Sea. They are members of a coastal form, differing from the typical polar cod.

3. In addition to the small polar cod encountered in the bays and gulfs, there is a large form found in the Kara Sea which resembles in size and external characteristics that of the Barents Sea. The presence of such a type has been established in the Dixon Island area and in winter in Kara Bay. It is possible that its absence in summer in the coastal regions of the Kara Sea can be explained by the significant freshening and warming of these waters as a result of the great continental runoff.

Bearing in mind these facts, which have been established by research, further study should concentrate on the biology of the Kara Sea polar cod, in order to solve the following problems:

1. to determine the summer-fall zones of habitat of the large polar cod;

2. to establish the location of the polar cod's spawning site in the Kara Sea;

3. to learn whether regular mass migrations take place from the Kara Sea to the Barents Sea and back;

4. to establish the duration and route of these migrations.

In order to solve the first problem, summer-fall investigations should be carried out in the areas where warm fresh water from continental runoff is dispersed. The Kara Sea is more subject to the influence of continental runoff than the other seas of the Soviet sector of the Arctic. According to V. S. Antonov (1948) the average annual runoff into the Kara Sea is 50.2 thousand m^3/sec, and its annual volume is 1585 km^3. The hydrological conditions of the Kara Sea depend more than those of the other polar seas on continental runoff, which lowers the salinity and increases the temperature of the water in its area of influence. Heavy continental runoff affects not only the hydrological face of the Kara Sea, but also determines certain aspects of the life of its inhabitants, including that of the polar cod.

In seeking the areas of concentration of the polar cod in summer and fall, it should be borne in mind that it is a typical cold-loving Arctic fish, which avoids warm water and lives primarily in water of a low and even negative temperature, so that its distribution is connected with sea ice (Klumov 1937, Manteifel 1943). If the small polar cod lives in the summer in warm, freshened coastal waters, the typical large form, as collections from Arctic expeditions show, is found as a rule in the Arctic sections of the Kara Sea at negative temperatures, and in highly saline water. Therefore, when seeking the polar cod in the Kara Sea, one should orient the search toward areas where the warm layer of water from the continental runoff disperses and gives way to marine, arctic water. It is necessary to take into account the distribution of ice, along the selvages of which the polar cod gathers.

In order to seek the spawning places of the polar cod in the Kara Sea, fall and winter investigations should be organized in the following places: Sharalova Koshka; Belyy, Shokal'skiy, Oleniy and Sibiryakov Islands; the area of Dixon Island. To determine the polar cod's migratory habits between the Kara and Barents Seas, autumn observations should be made in the strait of Yugorskiy Shar, Karskiye Vorota and Matochkin Shar.

(Presented 18-5-62)

REFERENCES

Andriyashev, A. 1945. Fish of the northern seas of the USSR. Akad. Nauk SSSR.

Antonov, V. S. 1948. On the role of rivers in conditions in the Arctic seas. Tr. II. Geogr. Syedz., t. II.

Ivanova, E. I. 1959. Ichthyofauna and the fishing industry of the Kara Bay. Probl. severa., vyp. 3.

Kiseleva, E. V. 1940. Polar cod of Obsk Bay. Tr. Nauchno-issled. Inst. Polyar. Zepl. i Prom. Khoz., vyp. 10.

Klumov, S. K. 1937. Polar cod and its importance for certain life processes in the Arctic. Izv. Akad. Nauk SSSR, ser. biol. #1.

Kravchuk, V. A. 1958. Polar cod. Vses. Nauchno-issled. Inst. Ozern. i. Rechn. Ryb. Khoz. (VNIORKh), vol. 144.

Manteifel, B. P. 1943. Polar cod and its use in the fishing industry. Arkhangelsk.

Soldatov, V. K. 1923. Material on the ichthyiology of the Kara Sea. Tr. Plav. Nauchn. Inst., vyp. 3.

Tambovtsev, B. M. 1952. Polar cod. Sbor.: Prom. Ryb. Barents. i Bel. Moryei.

Table 1. Catch on one day of fyke-netting by 10-day periods for December 1943-February 1944, in centners.

Region	December	January			February		
	III	I	II	III	I	II	III
Kolokolkov Bay	--	3.8	5.8	2.6	5.4	7.3	1.0
Berand Islands	2.3	4.6	2.5	0.3	--	--	--

Table 2. Length of polar cod by age groups (Pechorsk Gulf, 1942-43).

Length, cm	Number of fish of the given length at different ages				
	1+	2+	3+	4+	5+
10	1	-	-	-	-
11	1	-	-	-	-
12	3	2	-	-	-
13	-	1	-	-	-
14	-	7	-	-	-
15	-	8	4	-	-
16	-	19	33	-	-
17	-	18	99	6	-
18	-	12	125	11	-
19	-	2	131	53	1
20	-	-	83	79	3
21	-	-	26	54	4
22	-	-	2	23	-
23	-	-	2	5	-
24	-	-	1	1	1
Average length, cm	12.4	17.1	19.4	21.1	21.8
n	5	69	506	252	9

Table 3. Stages of sexual maturity of polar cod (Pechorsk Gulf).

Date	Percentage of fish of given stage								
	II	II-III	III	III-IV	IV	IV-V	V	VI	VI-VII
5-6.12 1940 (n=150)	-	-	-	2.0	98.0	-	-	-	-
23.11. 1941 (n=101)	-	-	50.0	21.0	29.0	-	-	-	-
13.1.42. (n=95)	-	-	-	-	53.3	23.4	22.3	1.0	-
31.12.42. (n=43)	-	-	-	-	-	44.2	41.9	13.9	-
2.1.43.	-	-	-	-	-	57.0	42.0	1.0	-
10.1.43. (n=93)	-	-	-	-	-	61.3	6.4	32.3	-
22.1.44. (n=100)	-	-	-	-	3.0	59.0	7.0	31.0	-
8.2.44. (n=100)	-	-	-	-	-	2.0	39.0	59.0	-
26.2.44. (n=20)	-	-	-	-	-	-	-	10.0	90.0
17.8.44. (n=100)	91.0	9.0	-	-	-	-	-	-	-
8.9.44. (n=100)	57.0	31.0	12.0	-	-	-	-	-	-
10-15.1. 1944 (n=176)	0.5	-	-	-	-	-	96.2	3.3	-

Table 4. Age, length and weight of polar cod of Anabarsk Gulf, 1947.

Age groups	Length, mm			Weight, g			
	smallest	largest	average	smallest	largest	average	n
1+	82	101	92.7	3	7	5.3	6
2+	91	148	117.8	5	21	11.4	121
3+	107	206	142.7	8	49	20.0	277
4+	126	213	168.8	14	71	32.4	68

Table 5. Stages of sexual maturity of the polar cod of Anabarsk Gulf, 1947.

Age groups	Number of fish in the given stage					
	II	II-III	III	III-IV	IV	n
1+	3	3	-	-	-	6
2+	9	102	10	-	-	121
3+	1	172	82	4	18	277
4+	1	31	29	3	4	68

Table 6. Stages of sexual maturity of the polar cod by months, 1947.

Month	Number of fish in the given stage					n
	II	II-III	III	III-IV	IV	
Aug.	3	97	-	-	-	100
Sept.	5	91	4	-	-	100
Oct.	2	69	29	-	-	100
Nov.	-	34	54	1	7	96
Dec.	4	17	34	6	15	76

Table 7. Feeding of the polar cod of Anabarsk Gulf, 1947.

Month	Percentage of stomachs with degree of fullness				n
	Full	Average	Little	Empty	
Aug.	4.0	89.0	7.0	0.0	100
Sept.	8.0	31.0	47.0	14.0	100
Oct.	14.0	37.0	29.0	20.0	100
Nov.	34.4	22.9	27.1	15.6	100
Dec.	67.1	13.2	11.8	7.9	76

Table 8. Distribution of the polar cod by length.

Length, cm	Percentage of fish of the given length			
	Pechorsk Gulf	Baidaratsk Bay	Obsk Bay	Anabarsk Bay
7-8	-	8.3	6.3	0.4
9-10	0.1	57.2	25.4	7.6
11-12	0.8	20.9	24.0	25.0
13-14	0.9	11.0	23.9	38.7
15-16	8.2	2.6	11.2	18.2
17-18	33.1	-	4.0	8.0
19-20	42.9	-	0.5	1.4
21-22	13.0	-	3.0	0.7
23-24	1.0	-	1.7	-
n	822	217	196	472

Table 9. Average length of polar cod of various age groups from various regions, cm.

Age	Kanin shore[1]	Cheshkiy Bay[2]	Pechorsk Gulf[3]	Kara Bay[4]	Baidaratsk Bay[3]	Shokalskiy Is.[5]	Gydansk Gulf[5]	Yeniseiskiy Gulf[5]	Anabarsk Gulf[3]
1+	-	-	12.4	-	9.2	8.0	7.0	7.5	9.3
2+	17.0	5.7	17.1	-	10.5	11.9	12.5	8.5	11.8
3+	19.5	18.9	19.4	15.3	13.2	13.0	14.5	10.5	14.2
4+	21.0	20.0	21.1	17.4	15.0	-	16.8	13.1	16.9
5+	22.0	21.0	21.8	21.6	16.0	-	-	15.5	-
6+	-	-	-	23.0	-	-	-	18.0	-
7+	-	-	-	25.0	-	-	-	-	-

[1] From Manteifel (1943)
[2] From Klumov (1949), quoted from Andriyashev (1954)
[3] Our data
[4] From Ivanova (1959)
[5] From Sudakov (1961) and Kravchuk (1958)

Table 10. Polar cod of Baidaratsk Bay (October 1961).

Age	Average commercial length, cm	Average weight grams	Amount of fish, percentage
2+	12.0	17.0	4.3
3+	16.4	36.5	39.3
4+	18.4	46.8	30.4
5+	19.2	62.0	17.4

Table 11. Age composition of the polar cod of various regions, percentages.

Age	Pechorsk Gulf[1]	Kanin shore[2]	Baidaratsk Bay[1]	Gydansk Gulf[3]	Anabarsk Gulf[1]
1+	0.6	-	22.1	1.0	1.3
2+	8.4	10.0	56.7	28.0	25.6
3+	61.7	70.0	18.0	58.0	58.7
4+	28.2	20.0	2.7	13.0	11.4
5+	1.1	-	0.5	-	-

[1] Our data
[2] From Manteifel (1943)
[3] From Sudakov (1961)

Table 12. Stages of maturity of the polar cod of Baidaratsk Bay (August 1952).

Age	Percentage of fish in the given stage of sexual maturity			n
	II	II-III	III	
1+	84.0	14.0	2.0	50
2+	54.5	40.5	5.0	121
3+	15.4	74.5	10.1	39
4+	-	83.5	16.5	6
5+	-	100	-	1
Average	52.5	42.0	5.5	217

XI. Auxiliary material

B. Papers in press or print

Lowry, L.F., K.J. Frost and J.J. Burns (1979). Geographical and seasonal variability in the diet of ringed seals (*Phoca hispida* Schreber) in Alaska. *J. Fish. Res. Bd.* Canada. In press.

Lowry, L.F., K.J. Frost, and J.J. Burns (19__). Potential Resource Competition in the Southeastern Bering Sea: Fisheries and Phocid Seals. In Proceedings of the 29th Alaska Science Conference, Fairbanks, AK, August 15-17, 1978. In press.

ANNUAL REPORT

Contract #03-5-022-69
Research Unit #243
1 April 1978 - 31 March 1979
Pages:

Population Assessment, Ecology and Trophic Relationships of Steller Sea Lions in the Gulf of Alaska

Principal Investigators:
Donald Calkins, Marine Mammal Biologist
Kenneth Pitcher, Marine Mammal Biologist
Alaska Department of Fish and Game
333 Raspberry Road
Anchorage, Alaska 99502

Assisted by:
Karl Schneider
Dennis McAllister
Walt Cunningham
Susan Stanford
Dave Johnson
Louise Smith
Paul Smith
Nancy Murray

TABLE OF CONTENTS

Introduction

This project is a detailed study of the population dynamics, life history and some aspects of the ecology of the Steller sea lion (*Eumetopias jubatus*). In addition to the sea lion investigations, the work has been expanded to include an examination of the distribution and abundance of belukha whales (*Delphinapterus leucus*) in Cook Inlet and the distribution and abundance of sea otters (*Enhydra lutris*) near the south end of the Kodiak Archipelago. As in the past, the basic objectives of the sea lion work are to provide information on population status, seasonal distribution, movement patterns, population composition and segregation, use of critical habitats, food habits, reproductive biology and productivity. Other objectives include collection of information on growth, pathology and environmental contaminant loads. The basic objectives of the belukha work are to gather information on seasonal distribution, and abundance and use of critical habitats, and to test practicality of survey methods. Basic objectives of the sea otter work are to provide information on the distribution of sea otters in the area between Kodiak Island and Chirikof Island, to identify specific areas critical to these sea otters and to determine the extent of repopulation in this former sea otter habitat.

This study has been carefully designed to examine the potential impacts associated with exploration for, development of and transportation of crude oil and natural gas reserves in the Gulf of Alaska. All three species studied under this research project are vulnerable to Outer

Continental Shelf oil and gas development through direct contact and contamination, indirect contamination of food sources or habitat, and disturbance generated by activities associated with exploring for and recovering oil and gas.

For a detailed description of the study area, current state of knowledge and sources, methods and rationale of data collection, see Calkins and Pitcher (1977) and Schneider (1976a and 1976b).

Steller Sea Lions in the Gulf of Alaska

Donald Calkins

Breeding Rookeries and Hauling Areas

I. Surveys

Sea lion surveys were conducted at selected rookeries and hauling areas on two different occasions this year. The first survey was a photo survey of the breeding rookeries in conjunction with pup counts made in June and July. Photo counts were limited to adults wherever possible. Table 1 shows the photo survey made in June and July, while Figure 1 shows the locaiton of those areas surveyed.

Table 1. counts of sea lions at selected locations in the Gulf of Alaska, June, July 1978.

[a] one roll of film did not expose est. 1500 more sea lions here

[b] count from ground

Name	Lat.	Long.	Photo Count
Marmot I.	58°12'10"N	151°47'50"W	8506
Seal Rocks	60°09'58"N	146°50'30"W	2463
Outer Island	59°30'50"N	150°24'07"W	3142
Chiswell Island	59°35'57"N	149°33'59"W	1477
Puale Bay	57°40'55"N	155°24'05"W	5109
Castle Rock	55°16'45"N	159°29'45"W	541
Atkins I.	55°03'05"N	159°17'50"W	2943[a]
Chernabura I.	54°45'15"N	159°33'00"W	2758
Sanak I.	54°17'45"N	162°42'30"W	1320
Clubbing Rocks	54°42'50"N	162°26'45"W	2663
Pinnacle Rock	54°46'15"N	161°45'45"W	3692
Lighthouse Rock	55°46'30"N	157°24'10"W	928
Chowiet I.	56°00'40"N	156°41'00"W	4519
Chirikof I.	55°49'25"N	155°44'20"W	3699
Sugarloaf I.	58°53'29"N	152°02'21"W	4810[6]

The second photo survey (Table 2) was accomplished in August and September. This survey, again, was at selected locations in conjunction with sea otter and harbor seal surveys.

Table 2. Sea lion surveys at selected locations August/September 1978.

Location	Lat.	Long.	Photo Count
Twoheaded Island	56°53'55"N	153°33'30"W	1955
Chirikof Island	55°49'25"N	155°44'20"W	2094
Sugarloaf Island	58°53'29"N	152°02'21"W	5504
Marmot Island	58°12'10"N	151°47'50"W	8383

II. Pup Counts

Steller sea lion pupping takes place at pupping and breeding rookeries throughout the Gulf of Alaska. A pupping and breeding rookery can be defined as any area where a large percentage of the sea lions present from the period of late May to early July are taking part in breeding and pupping. Many of the areas that are used by sea lions as rookeries are used as hauling areas throughout the rest of the year while other areas are used only as rookeries and have few sea lions the rest of the year.

The composition of haulout areas prior to May can vary from a single age group and sex to both sexes and all age classes. Beginning near the first of May the composition of those areas which change to rookery areas shifts towards pregnant females and mature males. At about the same time pregnant females and mature males begin arriving at those rookeries which are not used the rest of the year. Males which arrive

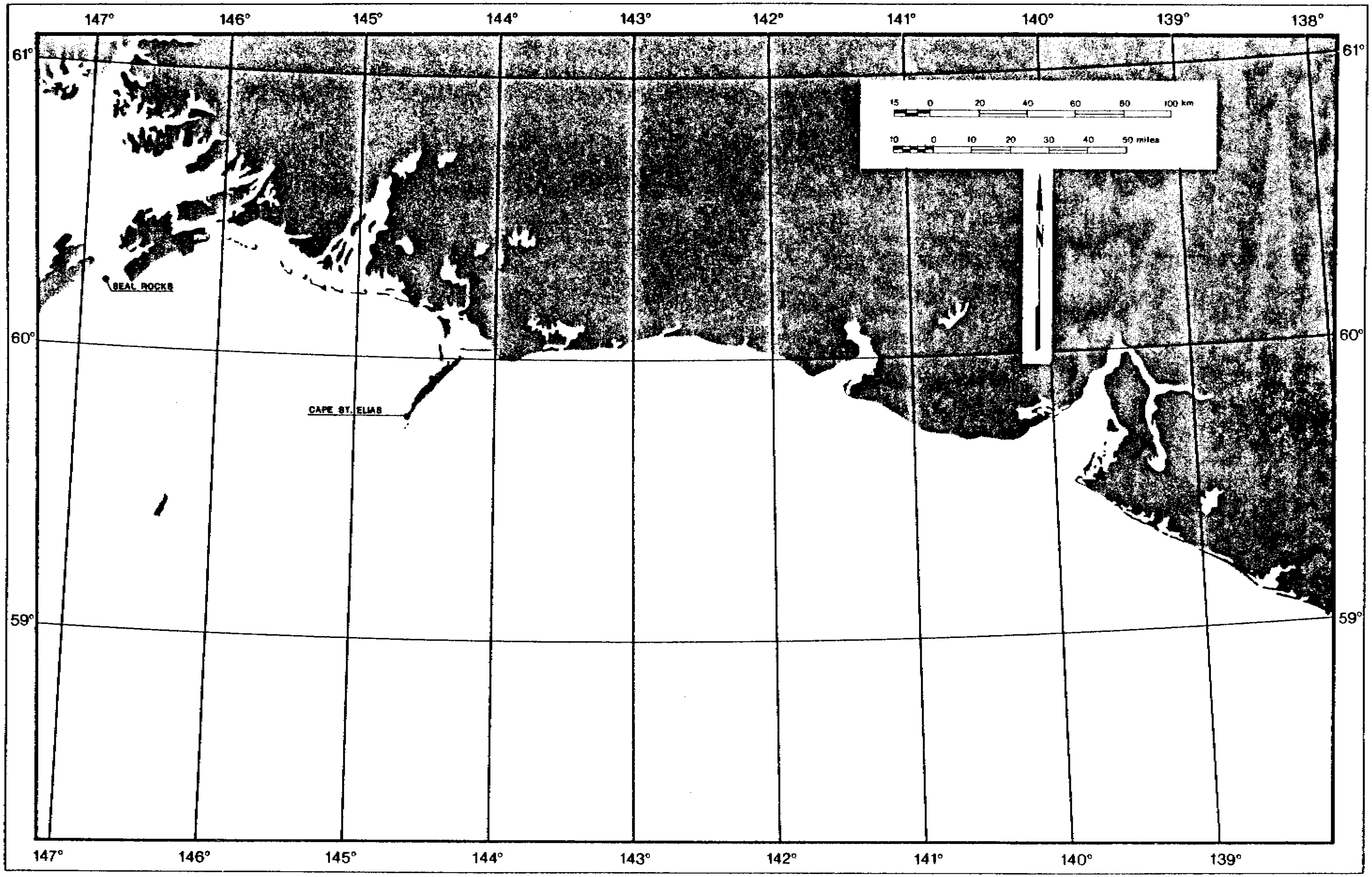


FIGURE 1A. LOCATIONS OF STELLER SEA LION HAULOUTS AND ROOKERIES SURVEYED IN 1978.

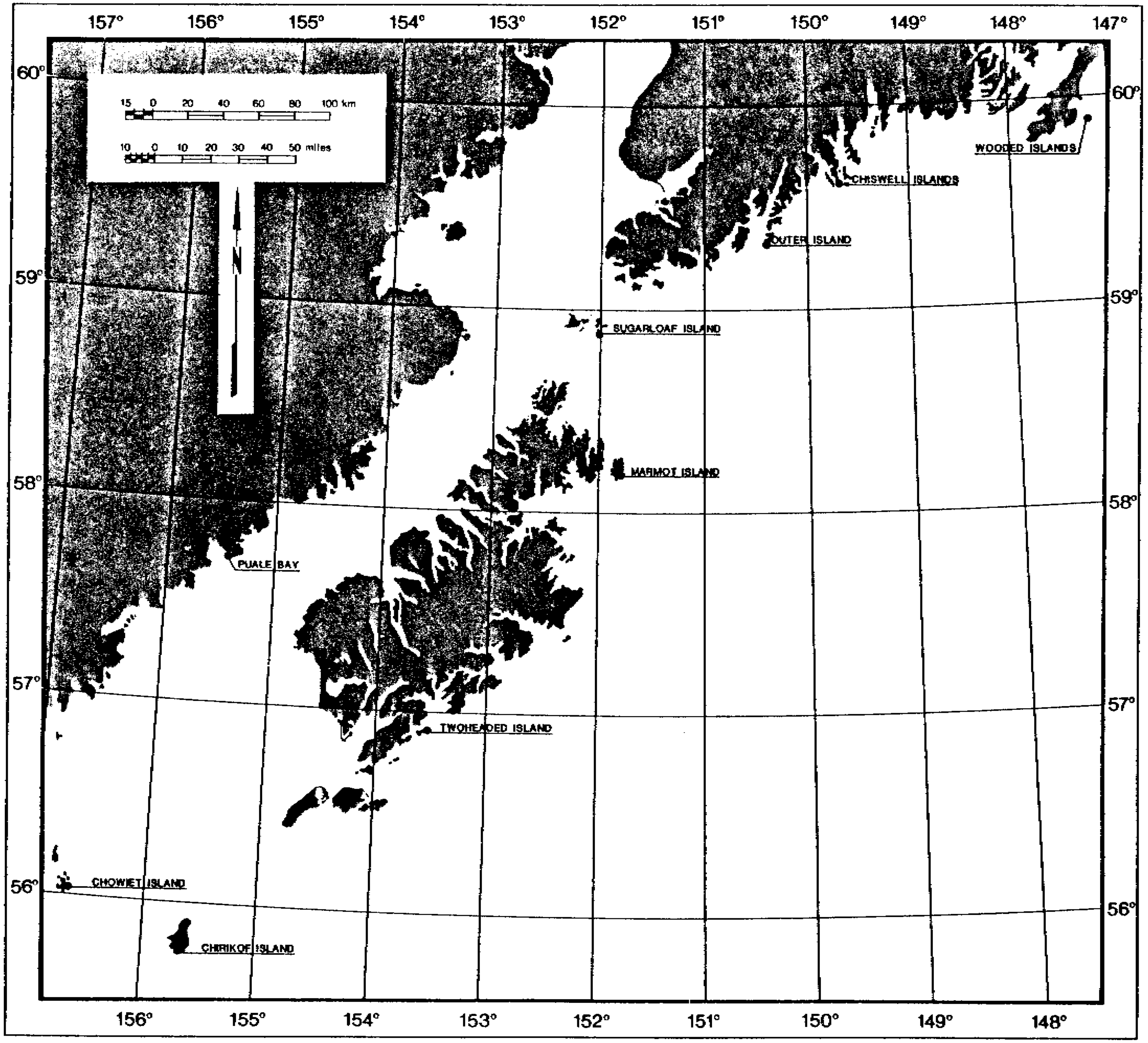

157°
156°
155°
154°
153°
152°
151°
150°
149°
148°
147°
60°
59°
58°
57°
56°
15 0 20 40 60 80 100 km
10 0 10 20 30 40 50 miles
N
WOODED ISLANDS
CHISWELL ISLANDS
OUTER ISLAND
SUGARLOAF ISLAND
MARMOT ISLAND
PUALE BAY
TWOHEADED ISLAND
CHOWIET ISLAND
CHIRIKOF ISLAND

FIGURE 1B.

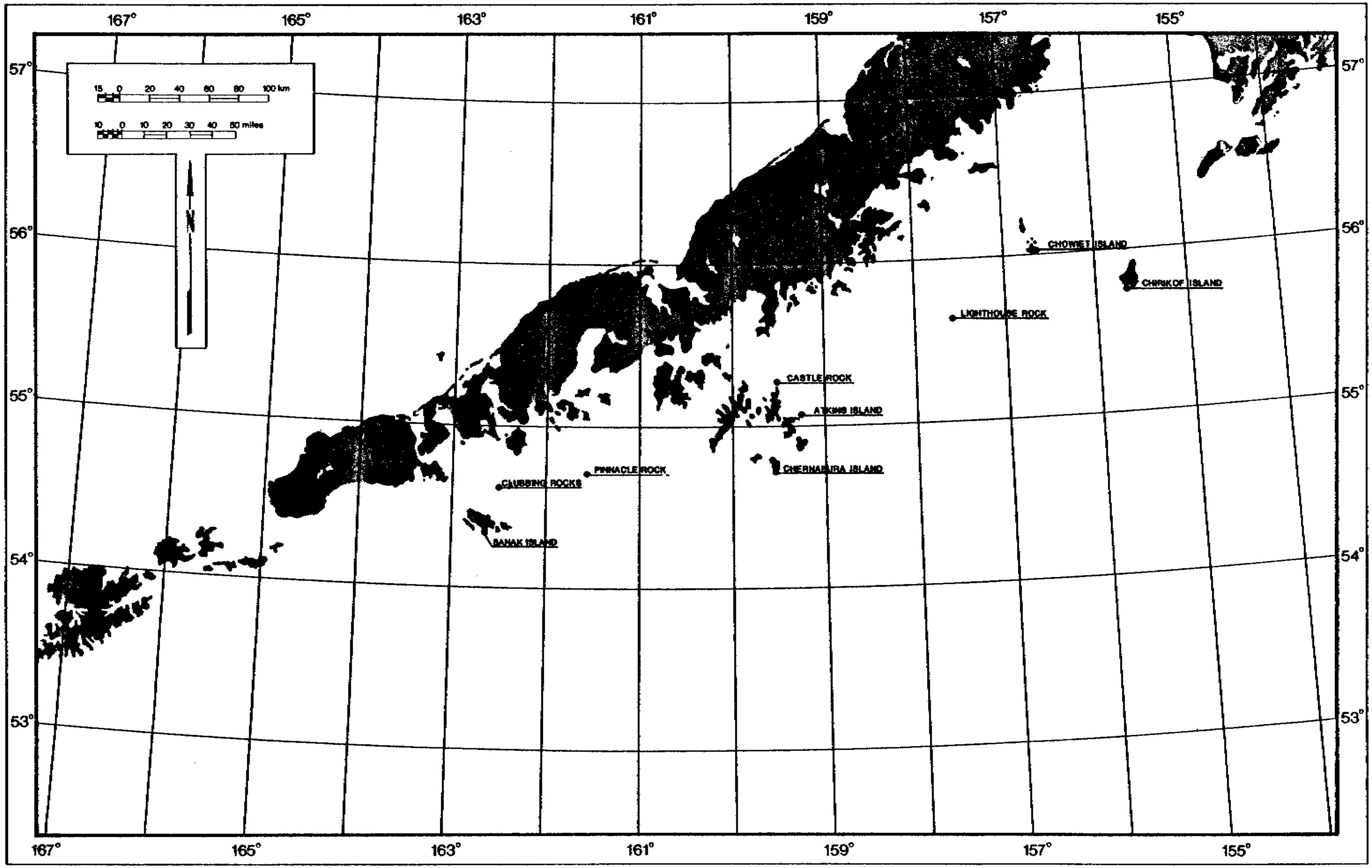

167°
165°
163°
161°
159°
157°
155°
57°
56°
55°
54°
53°
15 0 20 40 60 80 100 km
10 0 10 20 30 40 50 miles
N
CHOWIET ISLAND
CHIRIKOF ISLAND
LIGHTHOUSE ROCK
CASTLE ROCK
ATKINS ISLAND
CHERNABURA ISLAND
PINNACLE ROCK
CLUBBING ROCKS
SANAK ISLAND

FIGURE 1C.

in early May often begin establishing territories even though there may be no females present on the areas where they establish themselves. It is not uncommon at areas like Sugarloaf Island, where the majority of animals are present only during pupping and breeding, to see several large males positioned along the shore at regular intervals with no other animals near them. These animals usually positioned themselves in areas which eventually became parts of the breeding and pupping rookery, but some apparently inexperienced males occasionally established and defended territories which never became a functioning part of the rookery. Gentry (1970) observed similar occurrences of males establishing territories without females by Steller sea lions in California, although he felt that these territories were not maintained as long as a normal territory with females.

Pupping begins in approximately mid-May. Gentry (1970) states that the first live young appear about mid-May in California, while Pike and Maxwell (1967) observed pupping to commence about the last week in May. The first surviving pup recorded in our study was born at Sugarloaf Island in the Barren Islands on May 15, 1978. Sandegren (1967) first observed the birth of a pup on May 29. Henceforth, we are using May 15 as the arbitrary birth date for all Steller sea lions born in the Gulf of Alaska. The occurrence of premature births in Steller sea lions in the Gulf of Alaska appears to be common as it is in California (Gentry 1970).

In late June and early July of 1978 we surveyed a total of 17 different sea lion haulouts for possible pupping activity. Of the 104 recorded locations where sea lions haulout in the Gulf, these 17 sites were selected as possible pupping rookeries on the basis of size, location and observed pupping activities in the past. It is highly unlikely that significant pupping takes place at any other location in the Gulf. Table 3 shows the sites selected and the pup counts made during the summer survey. Eleven of the sites selected proved to be areas where pups are produced in significant numbers (sites number 1 through 11, Table 3). At these 11 sites a minimum of 250 pups were counted at Lighthouse Rocks and a maximum of 6,140 were counted at Marmot Island. The total number of pups counted on these surveys was 23,288. Rookeries number 1 through 5 (Table 3) produced a total 20,154 pups. This accounts for 87 percent of all pups counted in the Gulf of Alaska.

Although we have counted the majority of pups born in 1978 in the Gulf of Alaska, we have by no means counted all of them. These pup counts consisted of driving the adults off the rookery and counting, viewing and counting from above with adults present, counting from a boat, and estimating numbers of pups from an airborne helicopter. These methods are given in ascending order of accuracy. Even with the most accurate method of counting pups after driving adults off, some pups are missed, while counting from the helicopter can only be considered an estimate. Beyond these problems associated with counting sea lions in the Gulf of Alaska, a problem also exists with timing of the counts. Timing of the counts had to be balanced between the time the majority of pups are born and the time when pups readily enter the water and swim. Scheffer 1946 observed the pupping season to last until June 20 for sea lions on the Pribilof Islands, with no marked peaks although the highest frequency was from June 10-12. Observations on Sugarloaf Island indicate pupping occurs there as late as July 14 with the highest rate from June 10 to June 20. Sandegren (1967) indicates that pups begin to enter the water on their own at approximately 14 days old. This means that in order to count the majority of pups, the counts should be initiated no earlier than June 20 and should be completed no later than July 15.

Breeding takes place shortly after pupping at the same locations where the pups are born, as well as any other locations a cow might be when estrus begins. Generally only those cows which are pregnant go to the rookeries while mature cows which are not pregnant may come into estrus at any other location. Pike and Maxwell (1958) thought that approximately 25 percent of the mature cows failed to breed each year in British Columbia while approximately 81 percent of all females we have collected are pregnant (Calkins and Pitcher 1978).

Distribution and Movements

The investigation of distribution and movements of sea lions in the Gulf of Alaska was carried out through both intensive, long term, on site studies at one major rookery and one hauling area, and by short term visits at numerous other rookeries and hauling areas.

Sugarloaf Island was the site selected this year for the long term rookery study. Daily observations were made for branded sea lions. A total of 251 different branded animals were seen at Sugarloaf Island in 1978. Sea lions branded with X on both left and right shoulders were

Table 3. Sea lion pup counting sites and pup counts in the Gulf of Alaska, June 20 through July 4, 1978.

Site Number	Location	Date Counted	Number Live Pups	Number Dead Pups	Comments
1	Marmot Island	July 4	6140	63+	
2	Sugarloaf Island	July 4-5	5021	213	
3	Chowiet Island	June 29	4670	80	
4	Atkins Island	June 26	2750	107	
5	Chirikof Island	June 30	1573	14	
6	Clubbing Rocks	June 28	725	No Count	estimated from helicopter
7	Pinnacle Rock	June 29	615	No Count	estimated from helicopter
8	Seal Rocks (PWS)	June 20	545	46	
9	Chernabura Island	June 26	486	No Count	
10	Outer Island	June 21	431	4	estimated from boat
11	Lighthouse Rock	June 29	250	No Count	estimated from helicopter
12	Sanak Island	June 27	30	1	
13	Wooded Islands	June 20	29	1	
14	Chiswell Islands	June 21	11	No Count	estimated from helicopter
15	Puale Bay Rocks	June 24	9	0	part count from boat
16	Cape St. Elias	July 4	3	27	
17	Castle Rock	July 25	0	0	counted from helicopter

Total Pups Counted in the Gulf of Alaska - 23,288

Table 4. Daily totals of branded animals seen in April - Sugarloaf Island (1978).

	Left Shoulder			Right Shoulder			
Date	X	O	UN	X	T	UN	Daily Total
16		2					2
17				1	1		2
19	1	1	1		2	1	9
20					2	3	5
21	1		1	2	2	1	7
22				1		1	2
23				2	1		3
24	1		4	2	1	2	10
25		1	2	1			4
26						1	1
27		4	4		4	1	13
28	2	3	3	3	5		16
29		2	4	1	2		9
30		3				2	5
							88

Table 5. Daily totals of branded animals seen in May - Sugarloaf Island (1978).

	Left Shoulder			Right Shoulder			
Date	X	O	UN	X	T	UN	Daily Total
1			2	2	3	3	10
2		1	4	1	2		8
3	1	1	2	8	9	10	31
5			1				1
7		1				1	2
8		2			1	3	6
9					1	1	2
10			1				1
11		1			1		2
12		1	1	1		3	6
13	1	1	2	5	1	2	12
14	1		1	3		1	6
15		2					2
16	2	1	3	2	1	4	13
18	3		2	2	1	4	12
20	2				1	1	4
21			2	4			6
22					1		1
24				2	1		3
25							1
26			1	6	1	1	9
27				3		1	4
28				2	1	1	4
29						1	1
							147

Table 6. Daily totals of branded animals seen in June - Sugarloaf Island (1978).

	Left Shoulder			Right Shoulder			
Date	X	O	UN	X	T	UN	Daily Total
1	1						1
2	1						1
4			1				1
5				1			1
10				1	1		2
12	1						1
13	1						1
15				1	2		3
19			1	1			2
21			1			1	2
23				1			1
24							1
27	1					1	2
28				1		2	3
29				1	1	1	3
							25

Table 7. Daily totals of branded animals seen in July - Sugarloaf Island (1978).

	Left Shoulder			Right Shoulder			
Date	X	O	UN	X	T	UN	Daily Total
1				1			1
2			1				1
3	1		4				5
4			4				4
5	1		3	1			5
6	1		3	1	1	2	8
7	2		2	1		1	6
8			2				2
12	1			1		2	4
14			1				1
15				1			1
							38

Table 8. Monthly totals of branded animals seen, April - July - Sugarloaf Island (1978).

	Left Shoulder			Right Shoulder			
Month	X	O	UN	X	T	UN	Total
April	5	16	19	16	20	12	88
May	10	11	22	42	25	37	147
June	5		3	8	4	5	25
July	6		20	6	1	5	38
	26	27	64	72	50	59	298

seen as well as with O's on the left shoulder and T's on the right shoulder. This indicates that sea lions were present at Sugarloaf Island in 1978 which were born at both Sugarloaf and Marmot Island in 1975 and 1976.

Tables 4 through 7 show the daily sightings of sea lions at Sugarloaf Island in 1978. Table 8 shows the monthly totals of brands sighted at Sugarloaf Island. Figure 2 depicts the distribution of sightings at Sugarloaf over the observation period.

A total of 6,429 sea lion pups were branded at Marmot Island and Sugarloaf Island in 1975 and 1976. Sixty-six percent of those were branded at Marmot Island while 34 percent were branded at Sugarloaf Island. Of the 2 and 3 year old branded sea lions re-sighted at Sugarloaf in 1978, 53 percent had been branded at Sugarloaf and 47 percent had been branded at Marmot. Three percent of all sea lions branded at Sugarloaf in 1975 were re-sighted in 1978, 4 percent of those branded at Sugarloaf in 1976 were re-sighted in 1978. Four percent of these sea lions branded at Marmot in 1975 were sighted at Sugarloaf in 1978, while only 1 percent of those branded at Marmot in 1976 were re-sighted at Sugarloaf in 1978.

Cape St. Elias was again used as the sea lion hauling area for intensive observations. The pattern of use by branded sea lions was substantially different here than at Sugarloaf Island. Table 9 shows the daily counts of branded sea lions at Cape St. Elias, while figure 3 illustrates the distribution over time of the total number of branded sea lions observed each day at Cape St. Elias.

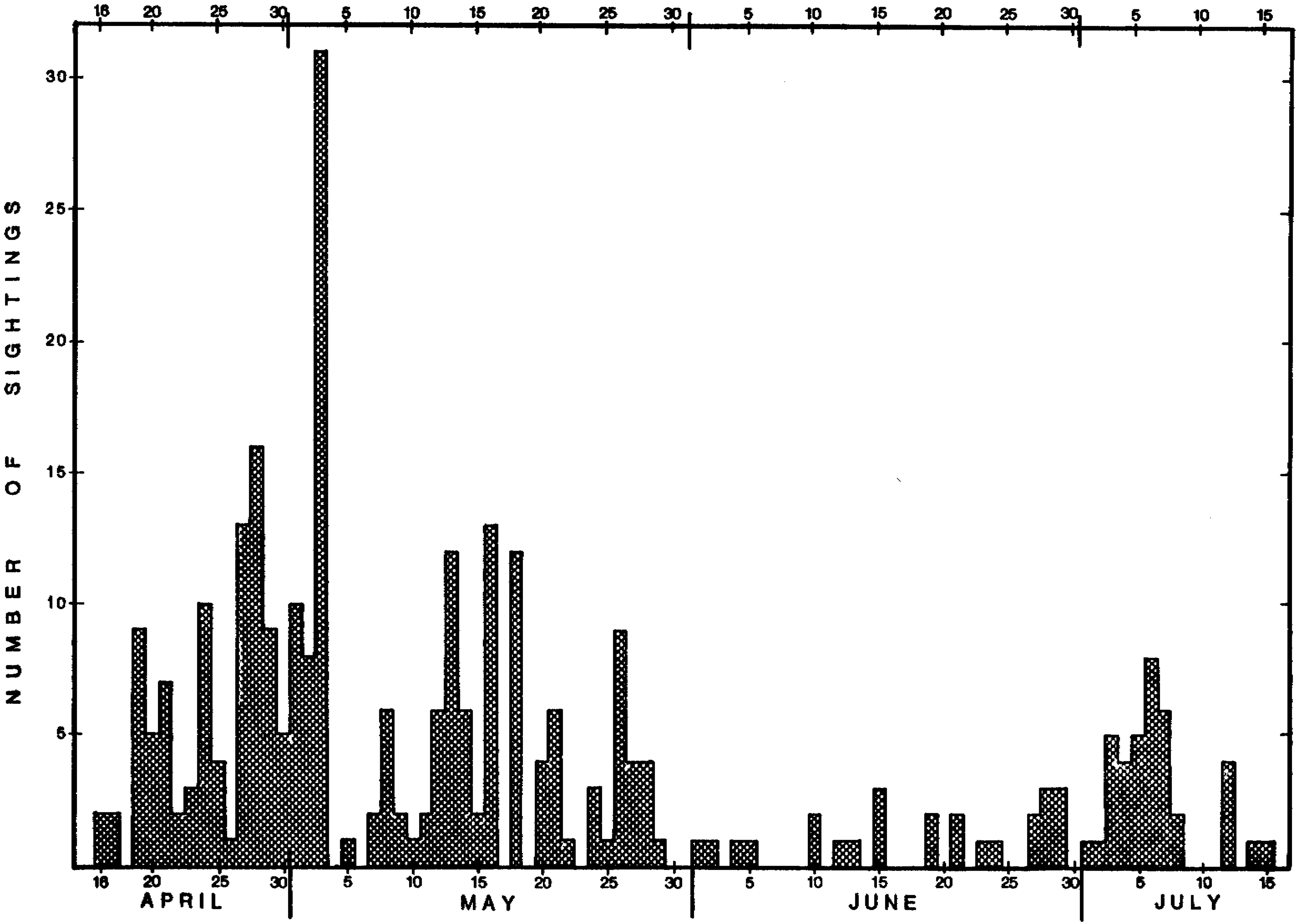


FIGURE 2. DISTRIBUTION OF DAILY TOTALS OF BRANDED SEA LION SIGHTINGS - SUGARLOAF ISLAND (1978).
(DATES BETWEEN 16 APRIL AND 15 JULY WITH NO SIGHTINGS SHOWN INDICATE DAYS NO ONSITE CHECKS WERE TAKEN.)

Table 9. Complete counts of branded sea lions observed on Cape St. Elias, March through June, 1978.

	Right Shoulder							Left Shoulder			Day
Date	X	T	J	E	L	V	Unknown	X	0	Unknown	Totals
22 March	1	3						2			6
23 March	5	5	5			1		1			17
24 March	1	1	1								3
25 March	6	2	1			1	2			4	16
26 March	3	7	4	1			1	3		2	21
27 March	2	5	1				1	2		1	12
28 March	2	2	1					1		1	7
29 March	17	10	7		1		6	3		4	48
30 March	15	10	7	1			3	2		3	41
31 March	4	8	2				2	1		2	19
1 April	3	7	1			1	3			4	19
2 April	7	8	3				7	4		4	33
3 April	14	8	4				2	3		6	37
4 April	6	10	3	1			6	2		1	29
5 April	3	2	1					1		2	9
10 April	10	8	6	1		1	3	1		2	32
11 April	8	4	2				5	1		3	23
12 April										2	2
13 April	1									1	2
14 April		2	1					1		1	5
Totals	108	102	50	4	1	4	41	28		43	381

Table 9 (cont.).

	Right Shoulder							Left Shoulder			
Date	X	T	J	E	L	V	Unknown	X	O	Unknown	Daily Totals
14 April	3	1	1				2	1		2	10
16 April	6	1	2	1			3	1		1	15
17 April		3	2				2				7
18 April	3	2	1								6
19 April	2	1	2								5
20 April	3	2				1					6
21 April	2	1	2				3			2	10
22 April	3	1	1				4			1	10
23 April	4	3					5	2		1	15
25 April	6	6	2				5	1		1	21
28 April	4	1	2				2			2	11
29 April	1	1	1				1		1		5
2 May	3	2	1					1	1	1	9
3 May	4		5								9
4 May	5	8	2				3	1			19
5 May	4	4	2			1	1			1	13
8 May	3	5	2				5			4	19
10 May	6	4	1					2			13
12 May	2	2									4
13 May	9	7	5	1	1		8	1		6	38
15 May	10	4	5		1		2	2	2	2	28
16 May	1										1
19 May	6	9	3					3	1	5	27
20 May	7	4	3				4				18

continued

Table 9. (Cont.)

	Right Shoulder							Left Shoulder			
Date	X	T	J	E	L	V	Unknown	X	O	Unknown	Daily Totals
21 May	5	6	2				3	1	1	2	20
22 May	7	6	4				5	2	1	2	27
26 May	2	4		1		1	5	1	1		15
29 May	5	5	1				5			1	17
31 May	15	14	3			1	6	2	1	5	47
1 June	7	8	5			1	6	2	1	4	34
2 June	9	9	1				3	1		2	25
3 June	12	8	1		1		4	2	1	5	34
5 June	5	7	2		1		10	1	1	2	29
6 June	8	9	1				6	1			25
7 June	11	8	5				5	2		2	33
8 June	5	8	2				5		1	1	22
9 June	20	12	2		1	1	5	3	1	1	46
10 June	11	3	1				2		1		18
12 June	9	3	3				7	1		1	24
17 June	6	3	2	2	1		1			4	19
18 June							1				1
19 June	13	4	3	2			4	3		1	30
20 June	12	7	1	1	1		3	1			26
21 June	8	1					1		1		11
23 June	9	9	1	1	1		2			2	25
24 June	5	2	1			1	3			1	13
26 June		4					1			1	6
27 June	5	5	4				6			1	21
Totals	286	217	90	9	8	7	149	38	16	67	887

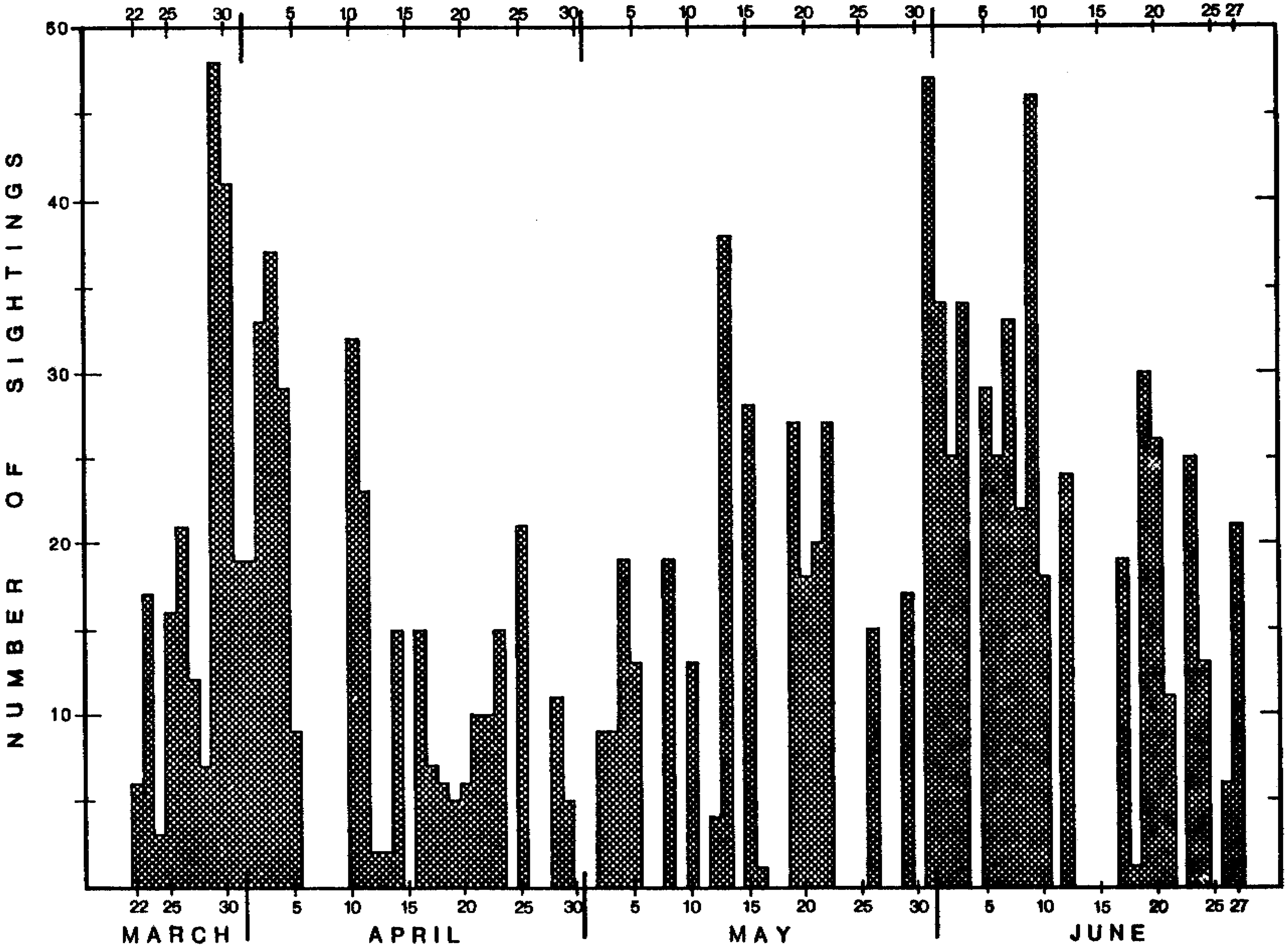


FIGURE 3. DISTRIBUTION OF DAILY TOTALS OF BRANDED SEA LION SIGHTINGS - CAPE ST. ELIAS (1978).
(DATES BETWEEN 22 MARCH AND 27 JUNE WITH NO SIGHTINGS SHOWN INDICATE DAYS NO ONSITE CHECKS WERE TAKEN.)

In general sea lions have moved away from their rookeries of birth in large numbers and have been sighted at haulouts from Chirikof and the Semidi Islands in the southwest to Cape St. Elias in the northeast. Nearly all animals leave Sugarloaf Island in the winter while many sea lions remain at Marmot Island in winter. Figure 4 illustrates the hypothetical movement patterns away from Marmot Island with the destinations shown as those locations where sea lions branded at Marmot have been sighted. Figure 5 illustrates movements of sea lions away from Sugarloaf Island.

Sea lions branded at Sugarloaf Island as pups in 1975 and 1976 were 2 and 3 years old during the summer of 1978. Few of these 2 and 3 year old animals returned to Sugarloaf Island in 1978. Large numbers were sighted at several other locations throughout the Gulf of Alaska, particularly Cape St. Elias.

Information on sea lion reproductive parameters, food habits, and growth and body condition will be presented in the final report.

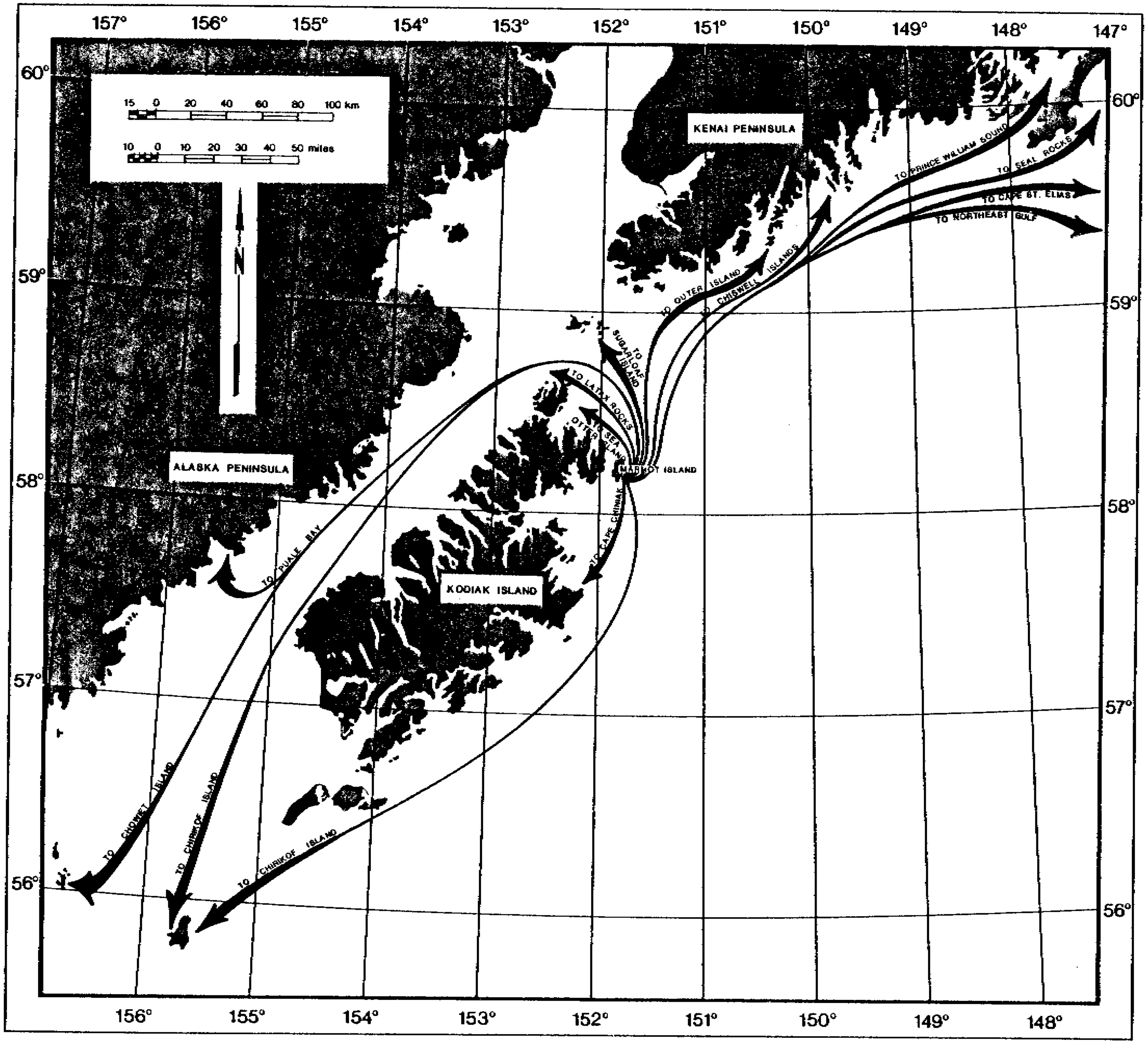


FIGURE 4. MOVEMENTS OF STELLER SEA LIONS AWAY FROM MARMOT ISLAND.

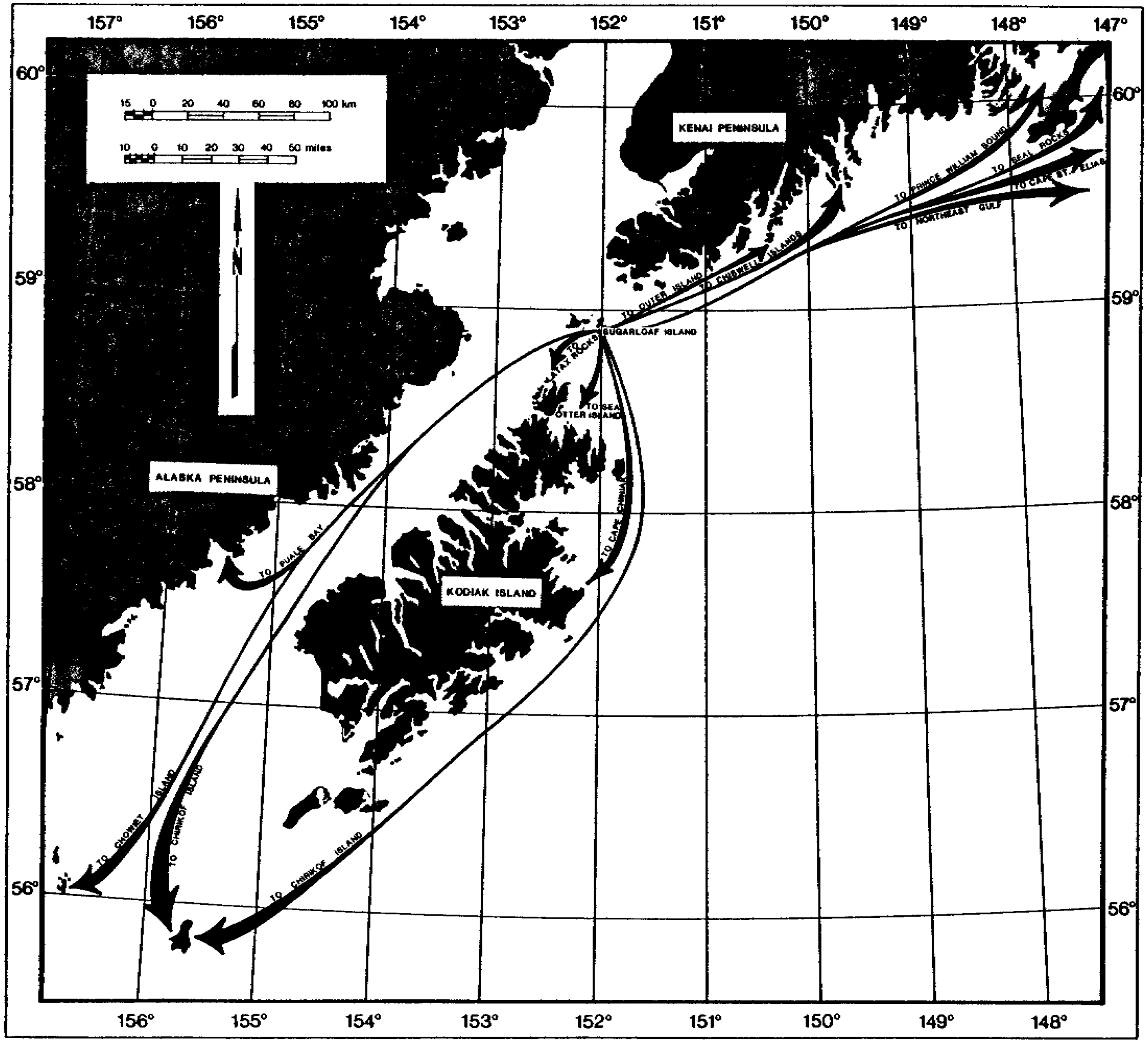


FIGURE 5. MOVEMENTS OF STELLER SEA LIONS AWAY FROM SUGARLOAF ISLAND.

SEA OTTER DISTRIBUTION AND ABUNDANCE
SOUTHERN KODIAK ARCHIPELAGO AND THE SEMIDI ISLANDS

Karl Schneider

April, 1979

SUMMARY

The distribution and abundance of sea otters in the waters between Kodiak Island and Chirikof Island and around the Semidi Islands were assessed through aerial surveys, incidental sightings and location of beach dead animals.

Sea otters have been sighted throughout the shallow waters southeast of Kodiak Island but established breeding groups occupy only two areas. The largest colony inhabits the waters south of the Trinity Islands and is roughly estimated to number between 400 and 700 sea otters. A second concentration of less than 100 sea otters exists around Chirikof Island. Sea otter densities in these areas are believed to be well below the capacity of the habitat but numbers are increasing. Both colonies are vulnerable to oil spills because of their small size, limited distribution and proximity to proposed OCS lease tracts.

Sea otters have been present in the Semidi Islands at least since 1957. The present population is small (30 to 50 animals) and not occupying all available habitat.

INTRODUCTION

Changes in sea otter distribution and abundance have been monitored since the 1930's when it first became apparent that the species was repopulating portions of its former range. Studies intensified during the 1950's (Lensink 1960, Kenyon 1969) but were concentrated in the Aleutian Islands. During the 1970's the threat of oil and gas development created a need for information on the status of sea otters in other parts of Alaska. While the distribution of sea otters in these areas was generally known there was a lack of detailed, current information.

Pitcher (1975) conducted two surveys of Prince William Sound filling major data gaps in an area likely to be impacted by the Trans-Alaska Pipeline and associated tanker traffic. The proposed Outer Continental Shelf leasing program created a need for similar information from several other areas. Schneider (1976a and b) upgraded information from the Kenai Peninsula, lower Cook Inlet, the northern portion of the Kodiak Archipelago and southwestern Bristol Bay.

Major gaps remained in the northeast Gulf of Alaska, southern Kodiak Archipelago, south side of the Alaska Peninsula, eastern Aleutian Islands and Pribilof Islands. However direct funding from OCSEAP for sea otter studies was terminated before these gaps could be filled. This has made it necessary to gather information opportunistically in conjunction with activities directed at other species. This report summarizes information which helps fill some of these data gaps and is intended as a supplement to Pitcher (1975) and Schneider (1976a and b).

KODIAK ARCHIPELAGO

Background

Schneider (1976a) summarized available information on sea otter distribution and abundance around the Kodiak Archipelago. At that time the status of sea otters around the northern half of the archipelago was well known. A remnant population had apparently survived north of Shuyak Island and by 1976 had grown and expanded its range southward to Marmot Strait on the east and Raspberry Island on the west side of the archipelago. The rate of range expansion in recent years had been rapid and it appeared likely that substantial numbers would move into Marmot Bay in the near future.

Another group of sea otters was known to inhabit portions of the 10,00 km^2 shallow area between Kodiak Island and Chirikof Island. That area had never been adequately surveyed and knowledge of the distribution and abundance of sea otters there was based on isolated sightings, a few fragmented surveys and speculation. Small numbers were present in the Trinity Island area in the 1950's although no significant population could be found (Lensink 1962). This group probably represented a remnant population but could have formed from animals straying from Shuyak Island. During the 1960's sightings around the Trinity Islands and Chirikof Island increased. Beach dead animals were found on Tugidak Island each year by seal biologists but live otters were rarely seen from shore. In 1971 a survey of the area between Tugidak Island and Chirikof Island was attempted but poor conditions and fog interfered. Six sea otters were seen midway between Tugidak and Chirikof Islands.

This suggested that the range of the population was extensive and that the population was larger than suspected.

Schneider (1976a) surveyed portions of the area in 1976 and located two concentrations. One was distributed around Chirikof Island and the other appeared centered south of the Trinity Islands. Scattered sea otters were seen along the southern shore of Kodiak Island but these appeared to be stray animals.

Potential sea otter habitat extends over 20 km from shore in this area and includes proposed oil and gas lease tracts. As sea otters are the most vulnerable of all marine mammals to the effects of oil more detailed information on their distribution and abundance in this area was needed. Consequently systematic aerial surveys of suspected sea otter concentration areas were conducted.

Methods

Aerial systematic strip transect surveys were made over suspected sea otter concentration areas. A Bell 206 helicopter based on the NOAA ship Surveyor was flown along predetermined tracklines at an altitude of 200 feet and an airspeed of approximately 80 mph. An electronic navigation system was used to maintain tracklines and determine positions. Two observers counted sea otters within 0.1 nm wide strips to either side of the aircraft. Width of the strips was determined by maintaining a constant altitude and using an inclinometer. Sea otters sighted outside of the strips were recorded separately.

Substantial portions of the Kodiak Island coastline were visited by small boat during seal and sea lion studies. Significant sightings of sea otters were recorded. These observations served primarily to confirm the absence of sea otters in areas not surveyed and to monitor the rate of range expansion of the northern Kodiak population.

In past years the incidence of beach dead sea otters found by biologists studying seals along the northwest side of Tugidak Island has been used as a crude indicator of the status of sea otters in the Trinity Islands. This information collected between 1965 and 1978 was summarized. A transect for locating beach dead sea otters was established on the southeast side of Tugidak Island and surveyed from foot twice during 1978.

Results and Discussion

Sea otter sightings available prior to the surveys (Fig. 6) indicated that at least scattered individuals occurred throughout the area and established groups inhabited the waters surrounding Chirikof Island and south of Tugidak Island. The primary questions were 1) What was the distribution of these groups? Specifically how far offshore did they range and did the Tugidak Island group's range extend south of Sitkinak Island and north of Tugidak Island. 2) What was the approximate size of each colony? Consequently the survey transects were positioned over the two known concentrations and extended beyond the maximum suspected limits of their distribution (Fig. 7).

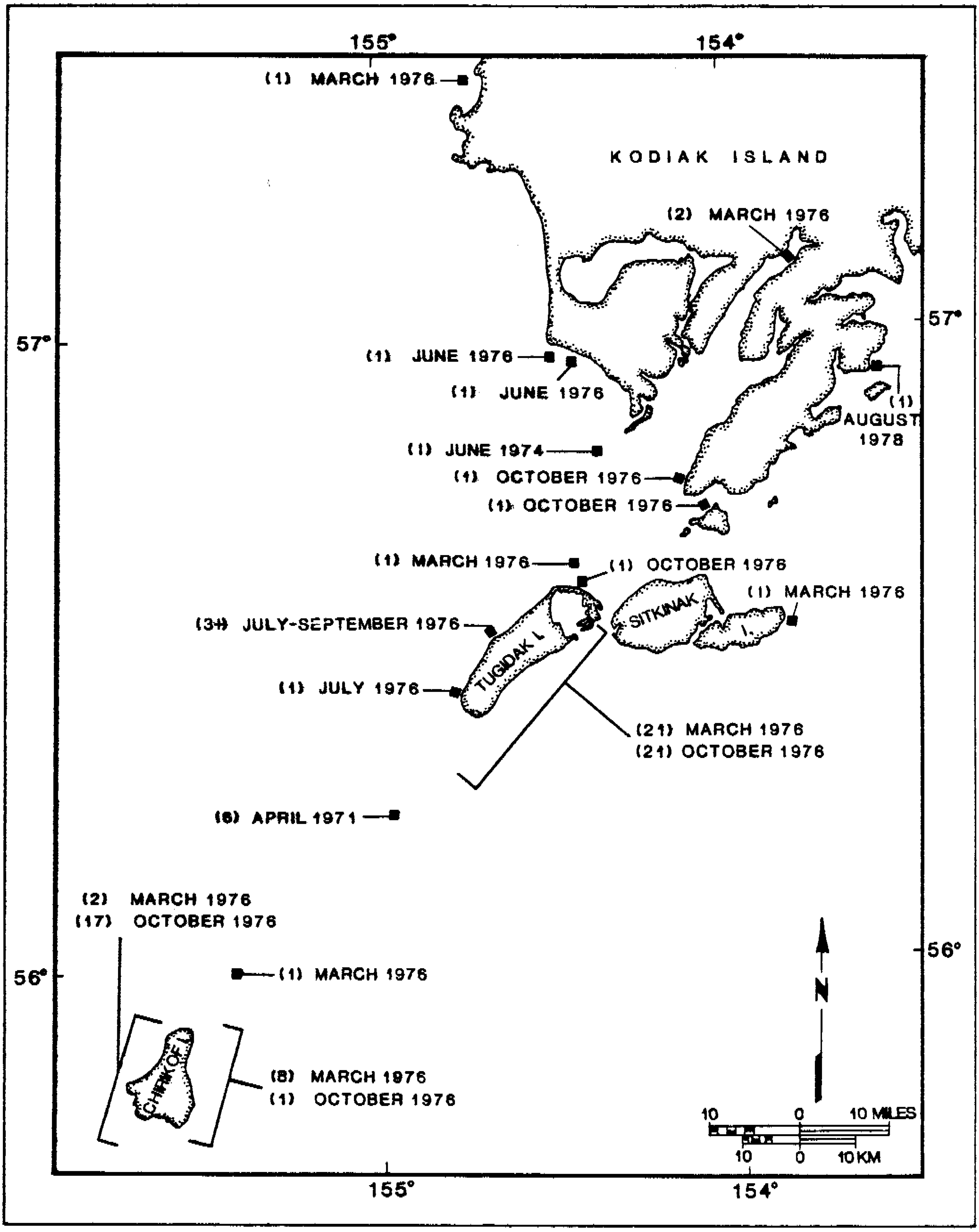


FIGURE 6. SIGHTINGS OF SEA OTTERS, SOUTHERN KODIAK/CHIRIKOF REGION, 1971-1978.

Results of the two surveys are presented in Tables 10 and 11. Several factors combined to make these surveys relatively inefficient. Visibility conditions were generally fair to poor because of wind and lighting conditions. This was a particular problem on the Trinity Island survey where the only sea otter seen outside of the strips was directly in the path of the helicopter during transit between transects and none of the sea otters within the strips were near the outer edges of the strips. A substantial portion of the sea otters especially those farther from the path of the helicopter may have been missed. The right observer had poor forward visibility making him less efficient than the left observer. Even under ideal conditions some sea otters are missed during such surveys either because they were under water or were simply not recognized by the observer.

Therefore the quality of the surveys was marginal but when viewed with other data they provided enough information to satisfy the gross objectives of delineating the distribution of sea otters in the area and at least establishing an order of magnitude of abundance.

1. Distribution - Specific locations of sea otters sighted on the surveys are presented in Table 13 and Figs. 8 and 9.

   Sea otters regularly occur on all sides of Chirikof Island but densities appear greatest north of Nagai Rocks along the west side of the island and along the rocky shores north of South Cape on the east side. While the number of otters seen on the systematic survey was low the distribution was similar to that observed on previous occasions (Fig. 10). It is unlikely that any major concentrations were missed.

Table 10. Results of sea otter aerial strip transect survey. Chirikof Island, 30 June 1978.

Transect Number	Latitude	Longitude Start	Longitude End	Length (nm)	Sea otters sighted: Left strip	Sea otters sighted: Right strip	Sea otters sighted: Outside strips
C-1	55° 44'	155° 45'	155° 15'	14	0	0	0
C-2	55° 46'	155° 15'	155° 33'	11	0	0	1
C-4	55° 48'	155° 33'	155° 15'	10	0	0	2
C-6	55° 50'	155° 15'	155° 32'	10	0	0	3
C-8	55° 52'	155° 32'	155° 15'	10	0	0	0
C-10	55° 54'	155° 15'	155° 32'	10	0	0	1
C-12	55° 56'	155° 15'	155° 50'	20	0	0	0
C-13	55° 58'	155° 14'	155° 50'	20	0	0	0
C-11	55° 54'	155° 50'	155° 37'	6	0	0	0
C-9	55° 52'	155° 39'	155° 50'	6	1	0	3
C-7	55° 50'	155° 50'	155° 43'	4	1	0	0
C-5	55° 48'	155° 43'	155° 50'	4	0	0	0
C-3	55° 46'	155° 50'	155° 43'	4	0	0	0
			Total	129	2	0	10

Table 11. Results of sea otter aerial strip transect survey. Trinity Islands, 28 August 1978.

Transect Number	Longitude	Latitude		Length (nm)	Sea otters sighted		
		South end	North end		Left strip	Right strip	Outside strips
South of Trinity Islands							
T-2S	153° 55'	56° 25'	Sitkinak I.	5.5	0	0	1
T-3S	154° 00'	56° 25'	Sitkinak I.	5.9	1	0	0
T-4S	154° 05'	56° 25'	Sitkinak I.	5.3	0	0	0
T-5S	154° 10'	56° 25'	Sitkinak I.	6.1	0	1	0
T-6S	154° 15'	56° 25'	Sitkinak I.	5.7	0	0	0
T-7S	154° 20'	56° 23'	Sitkinak I.	8.4	0	0	0
T-8S	154° 25'	56° 23'	Tugidak I.	10.2	0	0	0
T-9S	154° 30'	56° 23'	Tugidak I.	8.0	1	2	0
T-10S	154° 35'	56° 20'	Tugidak I.	9.6	1	0	0
T-11S	154° 40'	56° 15'	Tugidak I.	11.8	3	0	0
T-12S	154° 45'	56° 15'	Tugidak I.	9.9	0	0	0
T-13S	154° 50'	56° 15'	56° 26'	11.0	2	0	0
T-14S	154° 55'	56° 15'	56° 26'	11.0	1	1	0
T-15S	155° 00'	56° 15'	56° 26'	11.0	0	0	0
Total				119.4	9	4	1
North of Trinity Islands							
T-15N	155° 00'	56° 26'	56° 45'	19.0	0	0	0
T-14N	154° 55'	56° 26'	56° 45'	19.0	0	0	0
T-13N	154° 40'	56° 26'	56° 45'	19.1	0	0	0
T-12N	154° 45'	Tugidak I.	56° 45'	14.8	0	0	0
T-11N	154° 40'	Tugidak I.	56° 45'	12.1	0	0	0
T-10N	154° 35'	Tugidak I.	56° 45'	11.2	0	0	0
T-9N	154° 30'	Tugidak I.	56° 45'	9.1	0	0	0
T-8N	154° 25'	Tugidak I.	56° 45'	9.1	0	0	0
T-7N	154° 20'	Sitkinak I.	56° 45'	12.8	0	0	0
T-6N	154° 15'	Sitkinak I.	56° 45'	9.3	0	0	0
T-5N	154° 10'	Sitkinak I.	56° 45'	9.2	0	0	0
Total				144.7	0	0	0

Table 12. Locations of sea otters sighted on aerial systematic strip transect surveys.

Chirikof Island - 30 June 1978

Group Size	Latitude	Longitude	Distance offshore	Water depth (fathoms)
1	55° 46'	155° 33'	<1 nm	<10 fm
2	55° 47.5'	155° 33'	<1 nm	<10 fm
1	55° 50.1'	155° 30'	2 nm	10 fm
2	55° 51'	155° 33'	<1 nm	<10 fm
1	55° 54'	155° 28'	5 nm	20 fm
3	55° 51.8'	155° 39.8'	near shore	<10 fm
1	55° 52'	155° 42'	<2 nm	10 fm
1 (w/pup?)	55° 50'	155° 43'	near shore	<10 fm

Trinity Island - 26 August 1978

Group Size	Latitude	Longitude	Distance offshore	Water depth (fathoms)
1	56° 30.3'	154° 01.3'	50 yd	< 5 fm
1	56° 27.0'	154° 02'	2.8 nm	20 fm
1	56° 26.1'	154° 12'	3.5 nm	20 fm
2	56° 24.4'	154° 31.7'	5.3 nm	15 fm
1	56° 25.4'	154° 31.6'	4.2 nm	12 fm
1	56° 27.9'	154° 37'	0.5 nm	< 5 fm
2 (♀ w/pup)	56° 23.4'	154° 42.1'	1.0 nm	<10 fm
1	56° 22.5'	154° 42'	1.6 nm	<10 fm
1	56° 23.3'	154° 51.2'	2.7 nm	10 fm
1	56° 23.3'	154° 51.2'	2.7 nm	10 fm
2 (♀ w/pup)	56° 23.3'	154° 52.3'	3.2 nm	10 fm
1	56° 19.4'	154° 56.8'	7.5 nm	12 fm
1	56° 20.5'	154° 56.8'	6.9 nm	12 fm

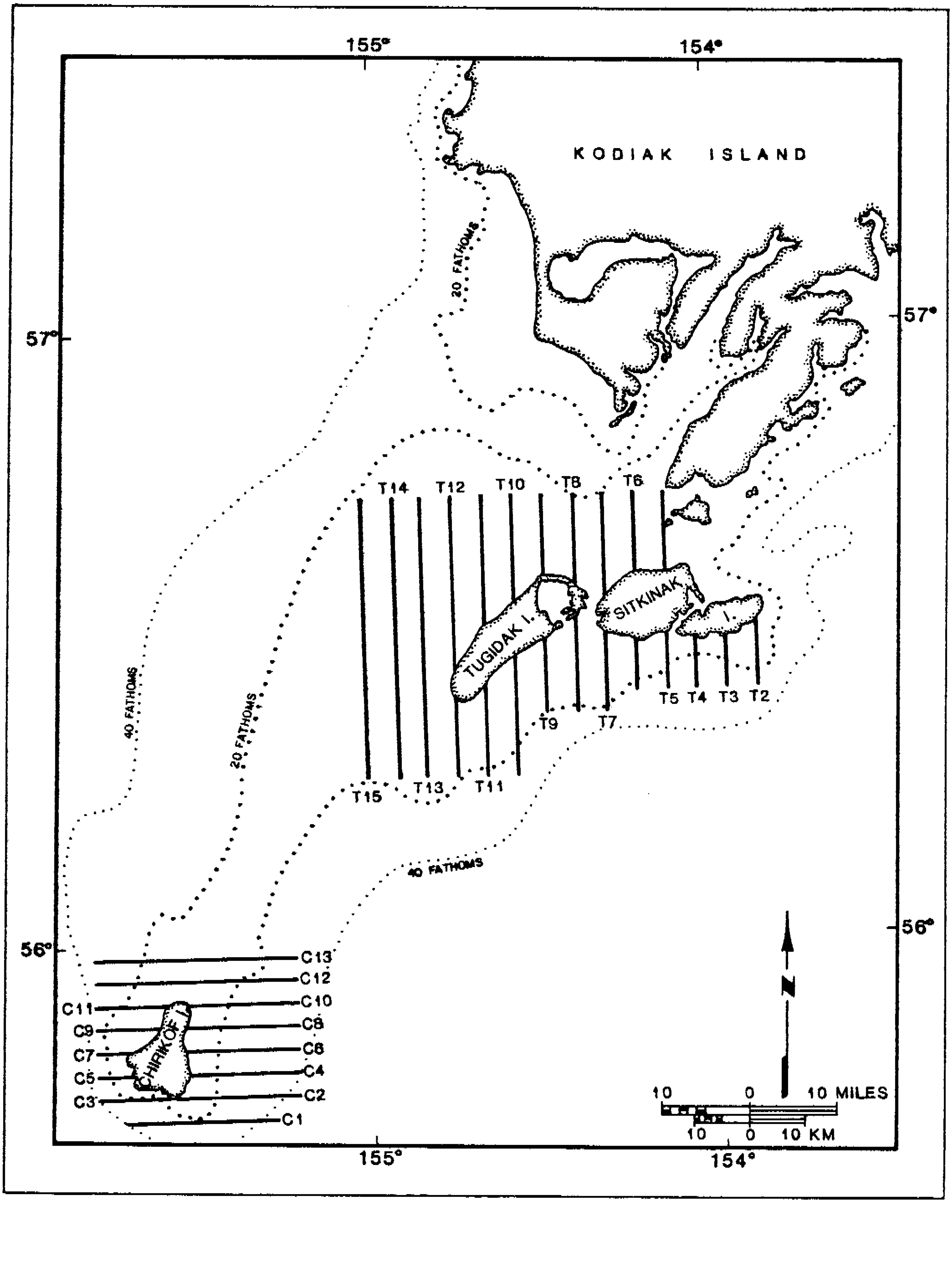


FIGURE 7. SEA OTTER SURVEY TRANSECTS.

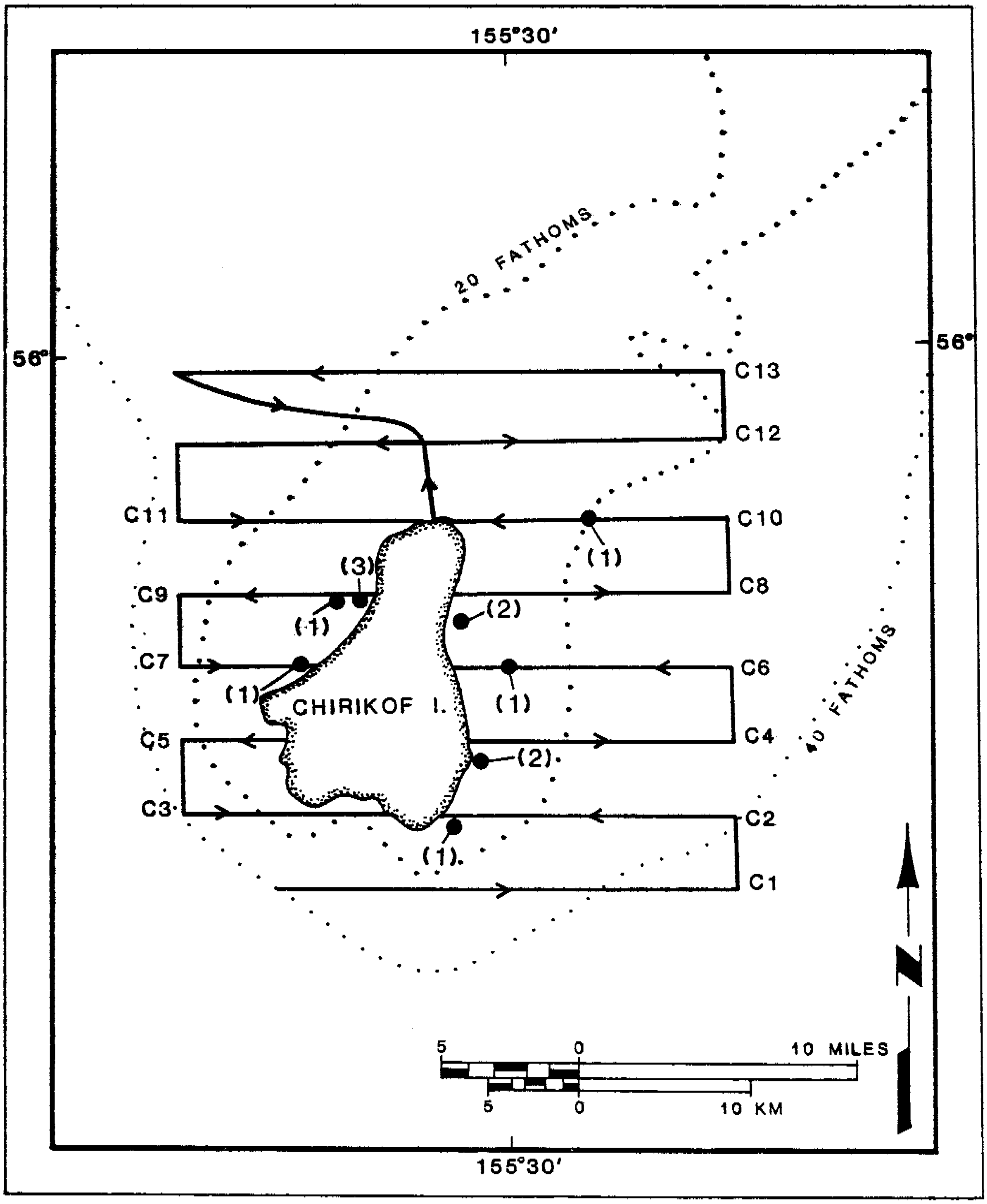


FIGURE 8. LOCATIONS OF SEA OTTERS SIGHTED ON SYSTEMATIC STRIP TRANSECT SURVEY, 30 JUNE 1978.

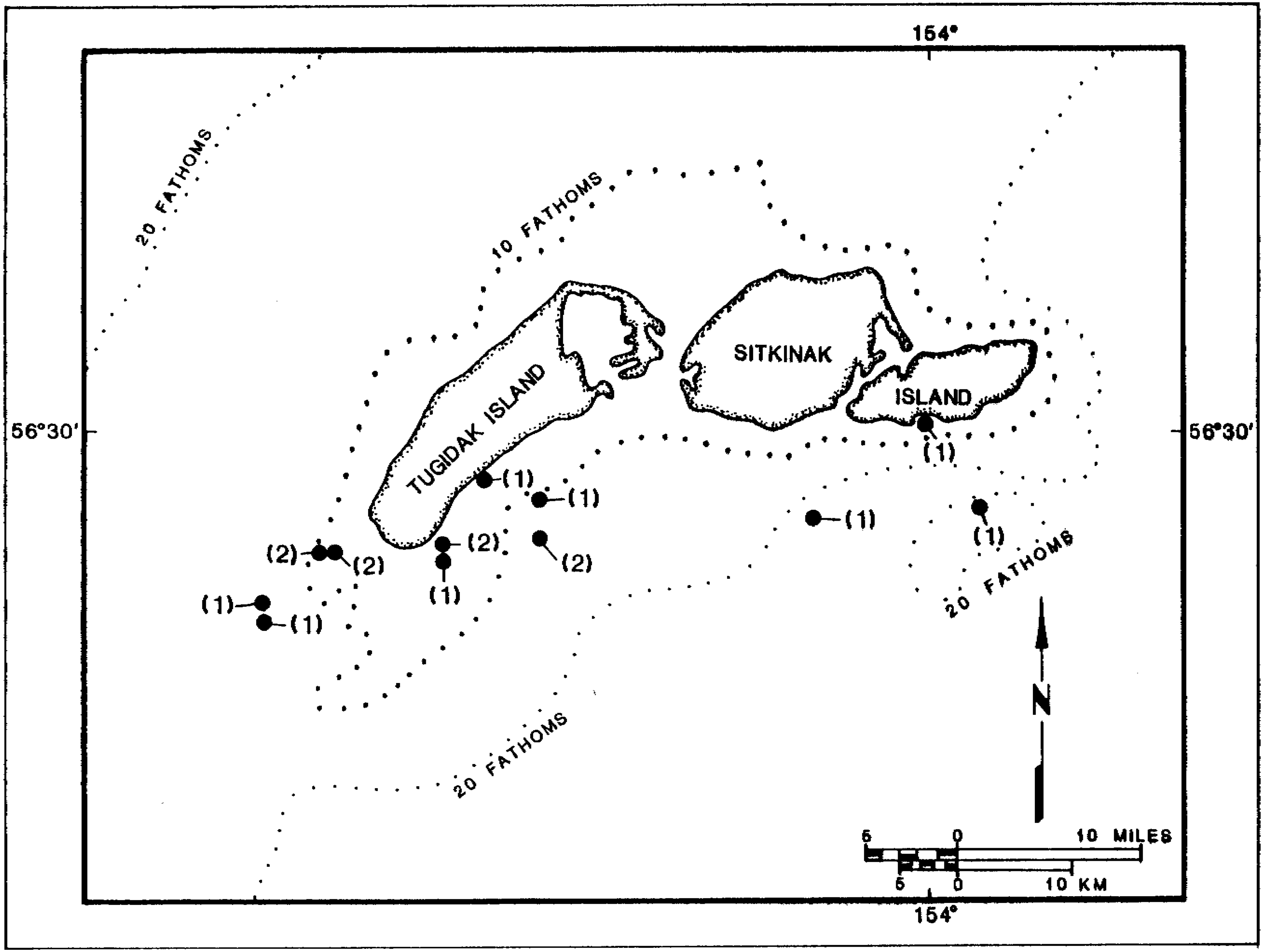


FIGURE 9. LOCATIONS OF SEA OTTERS SIGHTED ON SYSTEMATIC STRIP TRANSECT SURVEY, 26 AUGUST 1978.

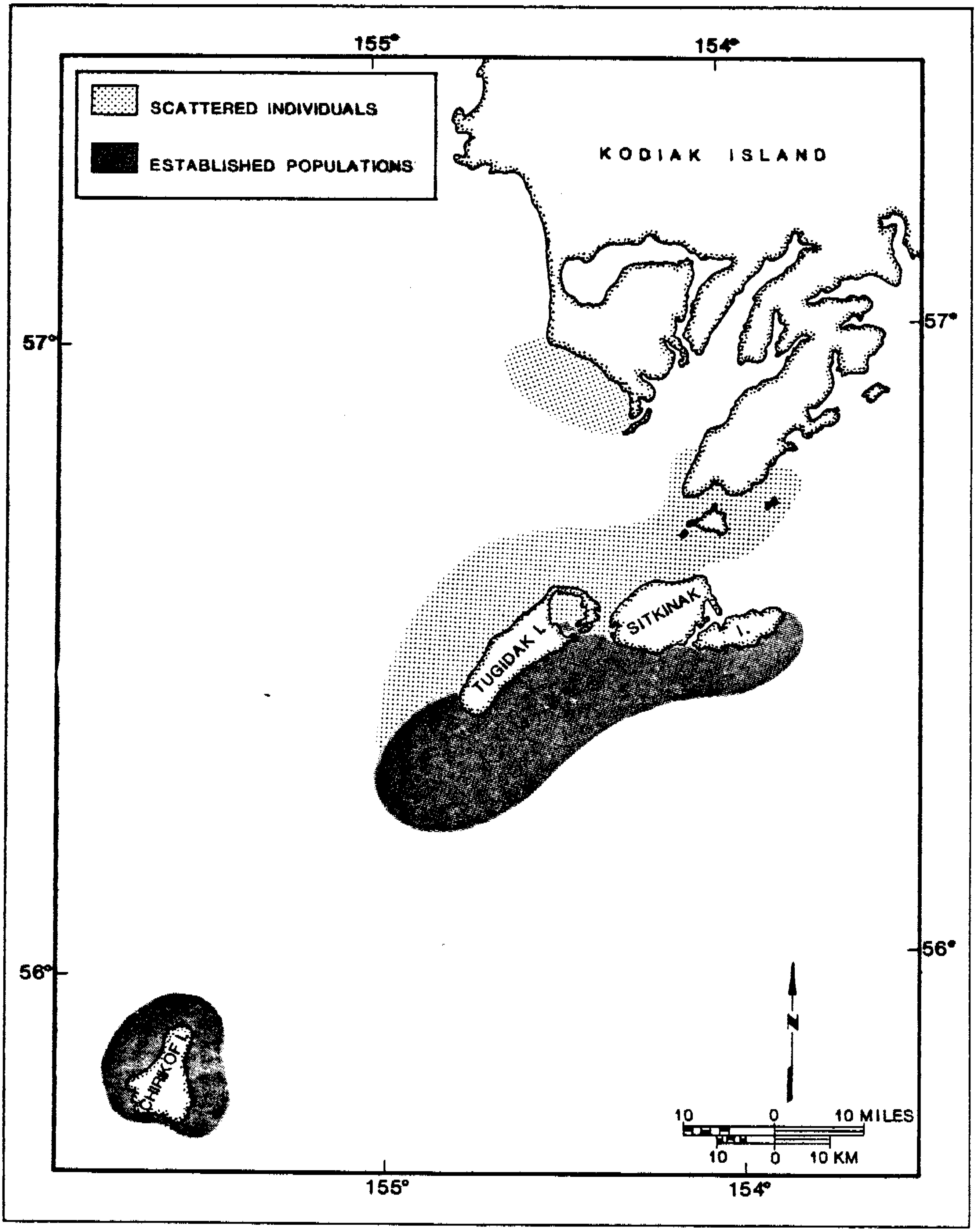


FIGURE 10. DISTRIBUTION OF SEA OTTER COLONIES. SOUTHERN KODIAK ARCHIPELAGO.

Sea otters have been sighted far from shore between Chirikof and Tugidak Islands but the lack of observations made on numerous trips by boat and aircraft between these islands indicates that no established concentration exists there at present. Therefore the Chirikof and Trinity Island colonies appear relatively distinct even though some interchange of individuals may occasionally occur.

As indicated by earlier observations, the Trinity Island concentration is centered south of Tugidak Island. The established range of this concentration appears to extend from the shallow area southwest of Tugidak Island to the vicinity of Cape Sitkinak. Most of the sea otters sighted in this area have been in waters less than 15 fathoms deep and the 15 fathom depth contour can probably be used to delineate the areas of highest sea otter use. Several sea otters were near the 20 fathom contour and it is possible that individuals may occasionally range offshore to waters up to 40 fathoms deep.

No sea otters were sighted north of the Trinity Islands. Biologists conducting seal studies along the northwest side of Tugidak Island have regularly found beach dead sea otters but few sightings of live sea otters have been reported except in 1976. At present it appears that the regular range of the population does not include the area north of the islands but that small numbers of otters move into the area periodically. This suggests that the population will extend its range in that direction in the near future.

The southern shore of Kodiak Island including Alitak and associated bays was surveyed by small boat and aircraft repeatedly between 1976 and 1978. Only stray individual sea otters were sighted and it is clear that no established concentrations presently exist east of Cape Alitak. The shallow area northwest of Cape Alitak has not been adequately covered. There is no evidence that more than stray individuals presently use this area but groups offshore may have been missed on the few flights made through the area.

2. Population Size - Available data are inadequate for development of a reliable population estimate. They do allow some guesses of the approximate magnitude of each colony however.

Approximately 10 percent of the potential sea otter habitat around Chirikof Island lay within the survey strips. Only two sea otters were seen inside these strips. A minimum of 18 different sea otters was seen during the survey and a seal survey conducted later the same day. Similarly a minimum of 18 were seen in October 1976. Experience with sea otter surveys in other areas indicates that such counts are usually biased low. The number of sea otters around Chirikof may be several times higher than these counts. However it is unlikely that any major concentrations have been missed and the total number of otters in the area probably does not exceed 100.

The Trinity Island colony is clearly larger than the Chirikof colony. Approximately 7 percent of the survey area fell within the survey strips. A simple expansion of the counts produced an estimate of 182 sea otters. If the left strip is excluded because of the poor viewing angle for the observer the estimate is increased to 252. Survey conditions were poor, the mean group size was small and a substantial portion of the population is likely to be underwater at any moment. Therefore these estimates are consistantly quite low. A subjective assessment based on comparative counts of other sea otter populations suggests that there may be two or three times the number estimated. A range of 400 to 700 would appear reasonable. The actual population may fall outside of this range but the incidence of beach dead animals is higher than would be expected in a smaller population. If the actual number exceeds that range one or more major concentrations must have been missed.

3. Status - Available information indicates that the southern Kodiak sea otter colonies are growing steadily but are far below carrying capacity. It is not possible to estimate the rate of population growth but sea otters probably numbered in the tens in the late 1950's and in the hundreds now.

There is no reliable basis for estimating carrying capacity directly so we must rely on comparisons with other areas. Southwestern Bristol Bay is the only area previously studied which appears outwardly similar to southern Kodiak. An estimate of 400 to 700 sea otters south of the Trinity Islands represents densities of 0.35 to 0.61 sea otters/km^2 in the area surveyed. Densities in southwestern Bristol Bay were estimated at over 3.0 sea otters/km^2

and up to 20 sea otters/km^2 may occur in other types of habitat. Therefore densities in the primary range of the present colonies are relatively low.

Extensive areas of evidently excellent sea otter habitat adjacent to the present colonies are essentially vacant. This indicates little population stress within the primary range.

The status of sea otter populations tends to be reflected in the age structure of beach dead animals. Natural mortality of young animals tends to be low in colonies well below carrying capacity and the majority of beach dead animals are old adults. As the population approaches carrying capacity, competition for food increases and juvenile mortality increases sharply resulting in a shift in the age structure of beach dead sea otters. Numbers of beach dead sea otters found on Tugidak Island have increased in recent years. As a result two areas have been selected as beach-dead sea otter transects (Fig. 11). Specific ages of dead otters found have not been analyzed, but all except two newborn pups (possibly stillborn twins) were adults fitting the typical pattern of a population well below carrying capacity.

4. Future - Both the Chirikof and Trinity Island colonies are well established and of sufficient size to survive any likely natural calamities. An unnatural event such as an oil spill could endanger either colony however.

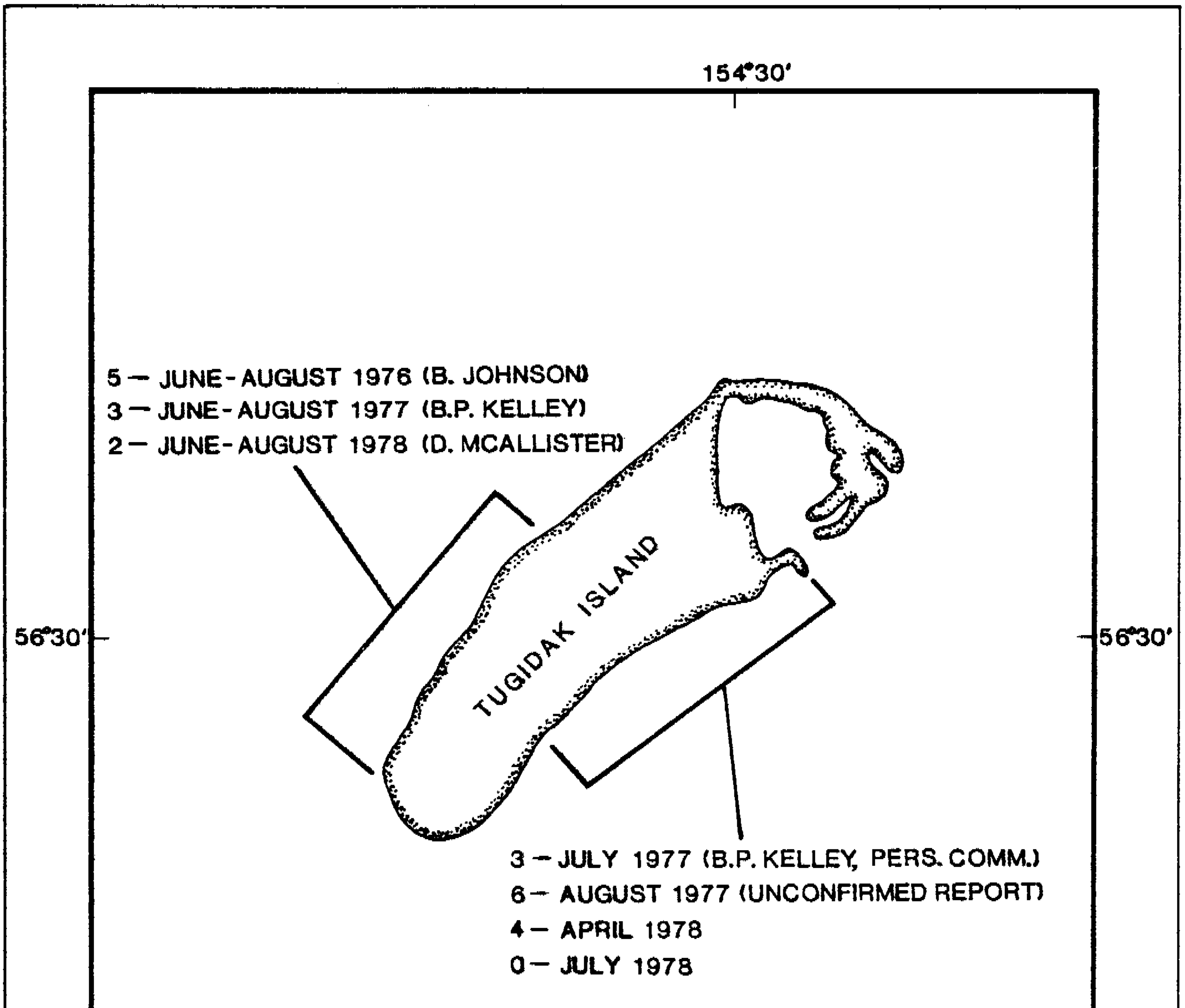


FIGURE 11. BEACH-DEAD SEA OTTER TRANSECTS. TUGIDAK ISLAND.

Most sea otter populations that have reached the size of the Trinity Island colony have continued to increase rapidly and expanded their range into adjacent vacant habitat when available. There is no reason to believe that this pattern will not be repeated here. As the population gets larger and less concentrated its vulnerability to oil spills will decrease.

SEMIDI ISLANDS

Background

The Semidi Islands have been virtually ignored by authors decribing the distribution of sea otters. Lensink (1962: 36) indicated that sea otters were present in a figure but made no mention of the islands in his text. Kenyon (1969) referred to a survey made by Lensink in 1957 when five sea otters were sighted. Apparently no other surveys have been made in this island group although W. Troyer (pers. comm.) confirmed that sea otters were present in small numbers in the late 1960's.

Methods

No special effort to survey the Semidi Islands has been made but sufficient information to provide a general picture of distribution and abundance has been collected incidental to other activities. The islands have been visited several times in the course of sea lion surveys. The waters around Anowik, Kiliktagik, Suklik, Aliksemit and the southeast portion of Chowiet Islands have been searched repeatedly from boat, helicopter and shore. On October 7, 1976 the shoreline of the entire island group was covered by helicopter although visibility conditions were considered unacceptable for sea otter surveying. S. Hatch (pers. comm.) conducted studies of Fulmars in the southern half of the island group for several years. He recorded sea otter observations in the vicinity of Chowiet Island.

Results and Discussion

All recent recorded sightings of sea otters in the Semidi Islands are presented in Fig. 12.

Coverage of the southern half of the island group has been sufficiently thorough that we can be confident of the distribution of sea otters there. A small concentration is centered around Kateekuk Island and the adjacent northern tip of Chowiet Island. The occasional individuals sighted away from this group are probably transient strays. At least 20 sea otters inhabited this area in 1977. Since Kateekuk Island wasn't covered when S. Hatch sighted the largest number this colony could be somewhat larger. Most likely this colony does not exceed 25 to 30 sea otters.

Information from Aghiyuk Island in the northern half of the group is less reliable. Sea otters sighted there on October 7, 1976 probably were not at Chowiet on May 11, 1977 but this possibility can not be ruled out. Regardless, a second concentration area and probably a relatively distinct group of individuals occurs along the northeast side

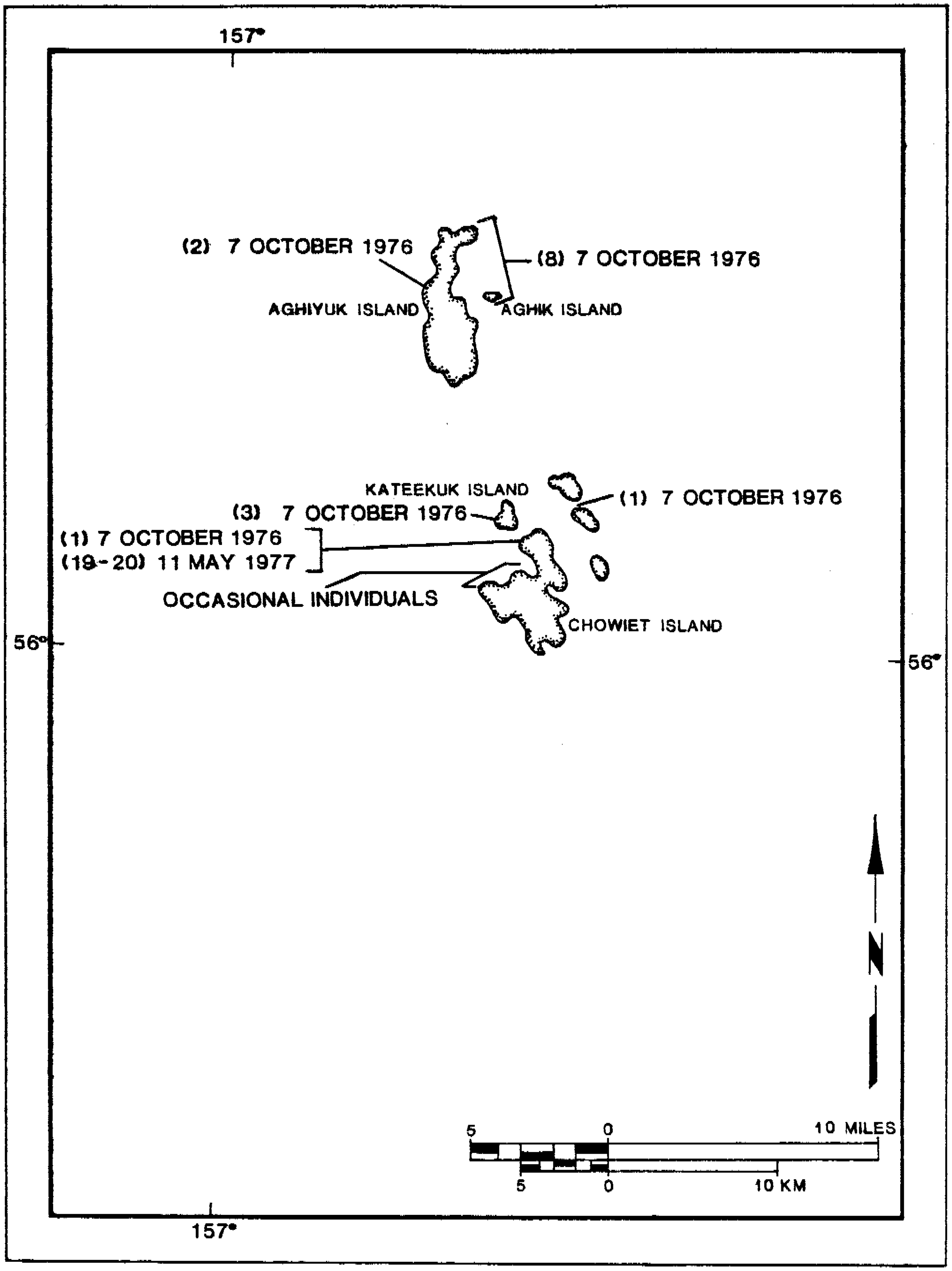


FIGURE 12. RECENT SIGHTINGS OF SEA OTTERS IN THE SEMIDI ISLANDS.

of Aghiyuk Island. Since survey conditions on October 7, 1976 were extremely poor a number of sea otters probably were missed.

Therefore the total sea otter population of the Semidi Islands is probably between 30 and 50. Portions of the available sea otter habitat are not currently inhabited. The population probably is growing through reproduction, immigration from Sutwick Island or both. It is impossible to predict the final population size but potential habitat is limited. A rough comparison with other areas indicates that the long term carrying capacity of the Semidi Islands is less than 200.

The population is obviously in a tenuous position because of its small size, limited distribution and relative remoteness from more securely established colonies.

BELUKHA WHALES IN LOWER COOK INLET

Nancy Murray

Distribution and Abundance

The Cook Inlet belukha population has been estimated by Klinkhart (1966) at 300 to 400. Recent survey conducted in the Inlet to determine distribution and abundance have not changed this estimate. Most surveys have involved shoreline observations and have not been intensive surveys of the open water areas of the Inlet. Accurate counting methods need to be developed so that a better population estimate will become available.

Fay (pers. comm.) feels the Cook Inlet belukha population could be a separate stock. A preliminary investigation of comparative crainial morphology indicates that the Cook Inlet belukhas may be taxonomically distinct from all other populations, perhaps as a consequence of long-term isolation in this area.

The Cook Inlet belukha population is thought to be resident in the Inlet year-round (Fay 1971; Klinkhart 1966; Scheffer 1973). Sighting data from 1976-1979 confirm that belukhas are present in all seasons in the Inlet.

Belukhas are seasonally distributed in the different regions of the Inlet. They have been sighted in the Upper Inlet primarily in late spring and summer. Belukhas are seen throughout the year in the central and lower areas, with heaviest use occurring in the central Inlet area (Fig. 13).

Within the Inlet, numbers appear to fluctuate seasonally, with the greatest number seen in mid to late summer and the fewest in winter. Ice conditions may have a strong correlation with winter abundance. In a winter of warm temperatures (1978) with little ice cover, belukhas were found in the central and lower Inlet. Whereas, in a winter of normally colder temperatures (1979) and extensive ice conditions, few belukhas were observed. The location to which the belukhas go when and if they leave the Inlet in winter has not been determined. No belukhas were sighted on an aerial survey in March, 1979 in the neritic waters from Chignik Bay on the Alaska Peninsula to the mouth of Cook Inlet to the eastern extremity of Prince William Sound. Belukhas have been sighted in Yakutat Bay which are presumably from Cook Inlet.

There is a paucity of information on breeding, calving and feeding concentrations of belukhas in Cook Inlet. Breeding whales have not been observed in the Inlet. Calving areas are not known; however, on aerial surveys in 1978 calves were observed at the Beluga River and in Trading and Redoubt Bays in mid-July. No calves were seen on the mid-June survey. Consequently, it appears that calving begins between mid-June and mid-July and may occur at the large river estuaries in the western upper Inlet. Calves were also observed in mid-August in the central Inlet between Kalgin Island and the Kasilof River and in mid-October in Tuxedni Bay.

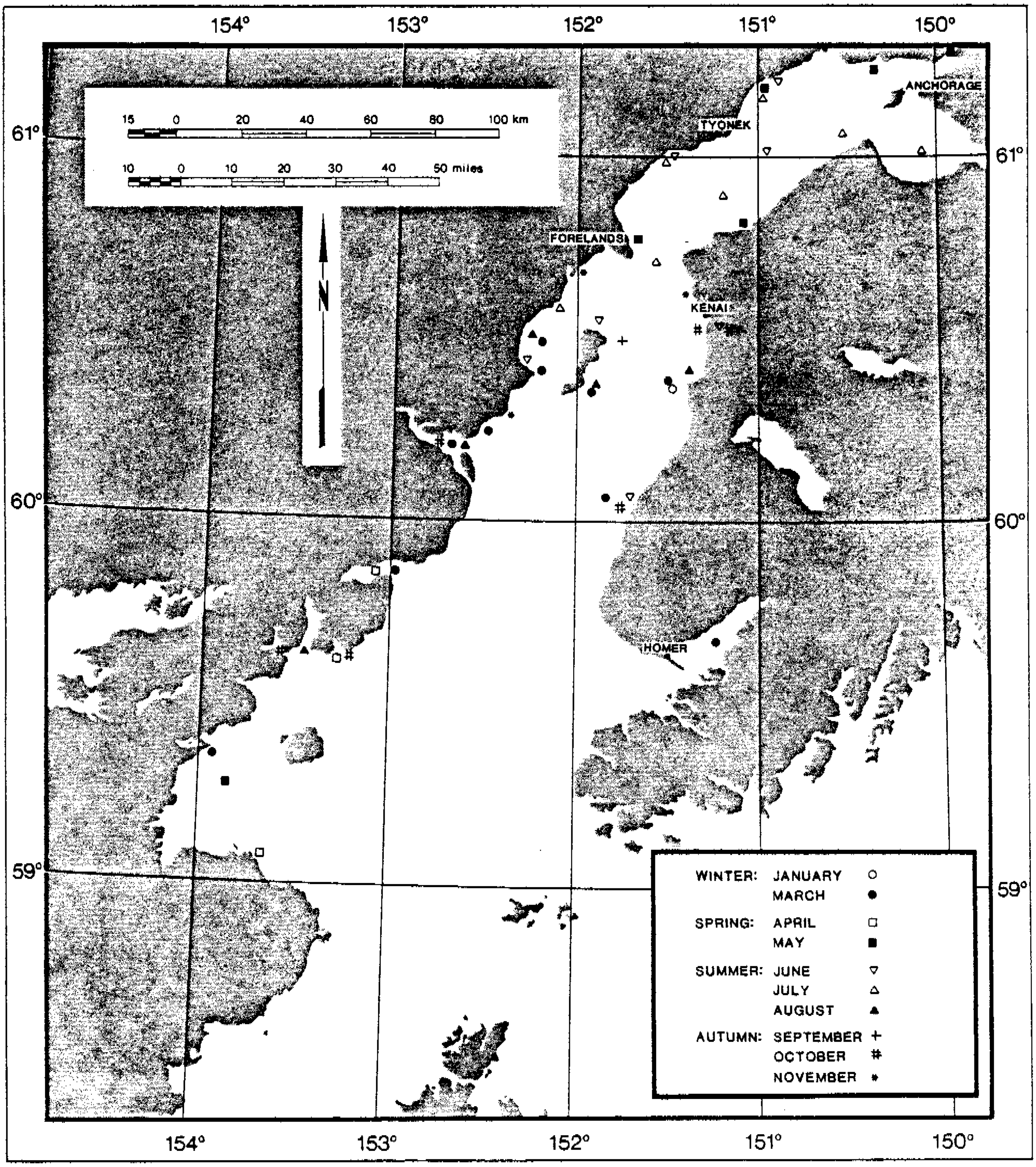


FIGURE 13. SEASONAL SIGHTINGS OF BELUKHA WHALES IN COOK INLET, 1976, 1977 AND 1978.

Concentrations were observed in mid-July at the mouth of the Beluga River and along the shoreline in Trading Bay, apparently feeding. The belukhas appeared to be eating fish caught close in to shore. These belukhas were in groups ranging from two to 25 animals. In mid-August a group of at least 150 whales was observed on three different days in the waters between Kalgin Island and the Kasilof River. The whales remained in this general area over at least a 4 day period. The whales were all aligned on the same directional heading with lead animals observed to break off from the front of the group. This behavior did not result in the remainder of the group changing its heading. Consequently, this type of large group formation most likely represents a feeding aggregation, although no feeding behavior (such as darting after a fish, etc.) or food source was directly observed.

Habitat

Studies have been conducted on various aspects of the biology of belukha whales in several major arctic and subarctic concentration areas, but no study directly addressing the problem of habitat requirements has been undertaken. The habitat types used by belukhas appear to fall into four categories: 1) migration routes, 2) feeding grounds, 3) breeding grounds, and 4) calving/ nursery grounds. Food resources may be the critical element determining the interrelationship of habitat requirements. The habitat requirements vary seasonally and with the age and sex of the whale. The seasonal variations are dynamic and introduce difficulties in determining simple habitat requirements.

Migrations, whether extensive or localized, can be influenced by abiotic and biotic factors. Some authors consider ice dynamics to be of primary importance, while others contend that availability of food resources dominates. Kleinenberg et al. (1964) held that these factors act in combination. Ice conditions have a definite impact on the direction and timing of movements. Both the pattern of distribution and the abundance of whales are dominated by ice (Fay 1974; Fraker 1977). Although migratory patterns along the Alaska coast are poorly known, the movements of belukhas appear to be related to the movements of smelt, salmon smolts, and Arctic cod (Fiscus et al. 1976). Major surface current patterns in Cook Inlet would suggest that the most energetically efficient route to the upper Inlet would be along the eastern coast, while the route from the upper Inlet to the lower would be on the western coast. Seasonal distribution in the Inlet suggest that localized movements, most likely related to food resources and possibly calving ground areas, are critical to sustaining this population.

Feeding grounds are determined and influenced by both biotic and abiotic factors. Concentration of food organisms is probably of major importance in determining where belukhas will feed. The biology and behavior of the food organisms play a key role in their accessibility to the belukha. Ice dynamics affect the presence of food organisms in certain areas as well as limit the movements of belukhas. Other abiotic factors, including temperature, salinity, depth, sediment characteristics, and tides and currents not only affect the distribution of the belukha but the distribution of the belukhas' food resources as well.

The belukhas' characteristic summer movement inshore to river estuaries appears to be associated with concentrations of fish in these areas (Klinkhart 1966; Sergeant 1962; Tarasevich 1960). These whales also leave the estuarine areas to feed on pelagic fishes and invertebrates in the open sea and among the broken ice (Hay and McClung 1976). Belukhas also feed along the migration routes on patchy plankton and fish concentrations (Kleinenberg et al. 1964), indicating an overlap between migration route and feeding ground categories. Large herd formation is associated with heavy concentrations of food organisms in small feeding areas (Bel'kovich 1960). Fluctuations in food organism numbers, periodicity of occurrence, and seasonal inaccessibility cause irregularity of food resources for the belukha. This variability has likely resulted in selection for the broad feeding spectrum exhibited by these whales.

There is a lack of information on the belukha's breeding biology. Breeding grounds are unknown in Cook Inlet. Due to the apparent timing of reproductive events, it is assumed here that breeding may occur along the migration route (overlap between categories) as the whales are approaching their summer feeding and calving grounds. It is also not known whether these whales feed while engaged in breeding activities.

While river estuaries are thought to be calving grounds, no births have been witnessed in these or any other areas. Recent evidence indicates that calves may be born outside the estuaries (Fraker 1977) and then move into these areas with their mothers (Hay and McClung 1976). Therefore, these areas might be considered more appropriately as nursery grounds.

Estuarine areas are important to newborn calves due to the higher temperatures which "may lessen the shock of birth and reduce heat loss in the first few days until the young animal has acquired some subcutaneous fat" (Sergeant 1973). Fraker (1977) also emphasized water temperature as the key factor in selection of these areas. He found that at the time of their use by large numbers of whales, these river estuaries had high temperatures, high turbidities, low salinities and shallow depths. All age classes congregate in the estuaries during the calving period. Fraker (1977) hypothesized that all age classes benefit from the thermal advantages, but that newborn calves would benefit the most from this advantage due to their small surface-to-volume ratio and limited fat deposits. Food resources have not been investigated in these areas, so it is possible that juvenile and adult whales may be feeding while in the calving/nursery grounds.

There is little information available at present on the seasonal use of specific habitat categories for the Cook Inlet population. Localized migrations occur throughout the Inlet during the year and may extend outside the Inlet into Shelikof Strait or possibly as far away as Yakutat Bay in the winter. Since food resources are likely the primary influence on localized migrations, the Cook Inlet belukhas are probably feeding in most areas where they are found. There are likely to be shifts in food items correlated with season and location. If Cook Inlet belukhas are breeding in May and or June, this activity is most likely occurring in the Upper Inlet. Calving/nursery grounds would be occupied in early to mid summer. Based on information from the literature as well as aerial survey data, the large river estuaries in the northwest Inlet (from

Susitna River to Trading Bay) are probably the primary location for these activities. In summary, the Cook Inlet belukhas range widely throughout the Inlet making seasonal use of specific habitat areas and food resources.

Population Dynamics

Mating behavior has not been observed in belukhas. Sexual maturity is reached in the female at an age of five years and in the male at about eight years (Brodie 1971). Strong pair bonding between any one male and female is unlikely, since trios of two adults and a calf are not observed (Fraker 1977). This also appears to be the case for the Cook Inlet belukhas. Although Vladykov (1946) states that breeding occurs from April to June and Doan and Douglas (1953) state that breeding can occur later in the summer, the general concensus is that a breeding peak occurs in May (Brodie 1971; Doan and Douglas 1953; Vladykov 1946). Klinkhart (1966) states that all adult males taken from the Bristol Bay population from May to September were in reproductive condition. However, a short peak of calving for this population suggested that breeding was confined to a relatively short period in May or June. This timing may also be found for the Cook Inlet population.

Belukhas have a three year reproductive cycle (Brodie 1971). The gestation period is about 14 months (Sergeant 1962 and 1973). The breeding period occurs approximately 2 months prior to the calving period. Assuming that breeding occurs in May, Brodie (1971) found that females gave birth approximately 14 months later, in late July and early August. Lactation lasted for the next 21 months, indicating an almost 2 year period of nursing. Reproductive rates have not been calculated for any population. However, assuming an average life span of 32 years (Kleinenberg et al. 1964) with the onset of maturity in the female at 5 years and a 3 year period between calving, a female would have an average of nine calves over her life span.

The sex and age structure has not been determined for the Cook Inlet population. Males cannot be easily differentiated from females. However, color differentiation can be made between juveniles and adults, since attainment of white coloration corresponds to sexual maturity. In the large concentration observed in August 1978, approximately one of seven whales was a juvenile.

Mortality factors include predation, parasites, diseases, and hunting. The only natural predator of the belukha known to occur in Cook Inlet is the killer whale, *Orcinus orca*. Killer whales are seen only in the lower Inlet in summer. Since the belukhas are generally in the central and upper Inlet areas during this time, there is probably little loss of belukhas to killer whale predation.

Endoparasites found in the belukha include acanthocephalans, trematodes, cestodes and nematodes (Kleinenberg et al. 1964; Klinkhart 1966). Their effects on the belukha are unknown. The occurrence of these parasites in Cook Inlet belukhas has not been studied. Other diseases are unknown in belukha populations.

Only limited hunting of the Cook Inlet belukhas has taken place since the 1950's. Belukhas found near fishing nets and vessels are occasionally shot and killed. There are no concrete data on the frequency of occurrence of whales killed in this manner, but it is unlikely more than two per year.

Food Habits

The belukha has a broad feeding spectrum. Their food resources include a variety of fishes and various kinds of octopus, squid, crab, shrimp, clams, snails, and sand worms (Fay 1971). The maximum size of food organisms is limited by the capacity of the esophagus, since food items are swallowed whole (Fay 1971; Fraker 1977). Kleinenberg et al. (1964) state that belukhas do not feed on deep water organisms.

Important food organisms of the belukha in Cook Inlet in the summer appear to be the osmerids and salmonids. Belukhas caught in Bristol Bay and Cook Inlet during the summer were found to contain salmon, smelt, flounder, sole, sculpin, shrimp and mussels. Data for the upper Inlet are not available. Possible foods for the belukha in the Kachemak Bay area are shrimp, crab, halibut, sole, herring and octopus.

The food of the belukha can be expected to vary seasonally and with location. During the spring and summer, the Cook Inlet belukhas probably feed on salmon smolts migrating from river estuaries as well as heavy concentrations of adult salmon schooling off the river mouths. Throughout the summer, belukhas may switch from one salmon species to the next.

King salmon run earliest in the Inlet with reds, pinks, chum and silvers following in that order. In the fall-winter season belukhas may eat smelt, bottom fishes and invertebrates. In the spring belukhas are found near concentrations of smelt.

Sergeant and Brodie (1969) suggest that productivity of the winter environment is critical in determining the adult size of belukhas in different regions. They suggest that "Selection has reduced the biomass of an individual white whale to that enabling it to maintain its metabolic activity on the available food." Further, "there appears to be no gross difference in numbers of white whales between trophically suboptimal and more suitable environments; the difference is expressed in individual biomass."

The food of the belukha also varies with age and sex. Lactation lasts about 2 years in belukha (Brodie 1971; Sergeant 1973). Young of the year feed only on milk, while yearlings supplement the milk by feeding on capelin, sandlance, shrimp, and small bottom dwelling crustacea (Brodie 1971; Kleinenberg et al. 1964; Sergeant 1962). The food of subadults is similar to the diet of adult animals. Adult males feed primarily on large fish while females prefer food items such as sandlance, octopus and particularly *Nereis* (Kleinberg et al 1964). Fluctuations in food organism numbers, periodicity of occurrence, and seasonal inaccessibility cause irregularity of food resources for the belukha. This may have caused the belukha not only to widen its feeding spectrum but to differentiate food habits by age and sex. This differentiation enables the belukha to successfully utilize the available food (Kleinenberg et al. 1964).

Behavior

Possible feeding behavior of belukhas has only been observed on two occassions during aerial surveys in Cook Inlet. Near shore feeding groups appear to consists of small aggregations of belukhas randomly aligned with respect to one another. Whales were seen lying at the surface facing the shore; individuals pitched forward in the water such that only the flukes were visible at the surface and then pitched back to the original position. The whales appeared to be operating individually in their efforts to catch food.

Groups of migrating belukhas vary in number and composition. Most groups contain a predominance of adults with a few juveniles. Generally the animals are closely spaced, although a widely scattered group in which all individuals had the same directional heading was observed in March 1979. In groups of 10 to 30 animals, all whales do not surface simultaneously. Instead, there is usually a wave of three groups: the first group surfaces; as it is beginning to submerge, the second group surfaces; as this group is beginning to submerge, the third group surfaces; this is closely followed by the first group surfacing while the third is still at the surface. Calves closely follow their mother's movements and on all occassions were seen to the left rear side of the adult.

LITERATURE CITED

Bel'kovich, V. M. 1960. Some biological observations on the white whale from the aircraft. Zool. Zur. 30:1414-1422.

Brodie, P. F. 1971. A reconsideration of aspects of growth, reproduction and behavior of the white whale (*Delphinapterus leucas*), with reference to the Cumberland Sound, Baffin Island, population. J. Fish. Res. Bd. Can. 28:1309-1318.

Calkins, D. G. and K. W. Pitcher. 1977. Population Assessment, Ecology and Trophic Relationships of Steller Sea Lions in the Gulf of Alaska. In Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators for the year ending March 1977, Vol. I. Receptors - Mammals.

__________. 1978. Population Assessment, Ecology and Trophic Relationships of Steller Sea Lions in the Gulf of Alaska. In Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators for the year ending March 1978, Vol. I. Receptors - Mammals.

Doan, K. H., and C. W. Douglas. 1953. Beluga of the Churchill region of Hudson Bay. Fish. Res. Bd. Can. Bull. 98:27 pp.

Fay, F. H. 1971. Belukha, arctic white whales. In A. Seed (ed.), Toothed Whales in the Eastern North Pacific and Arctic Waters, Pacific Search, Seattle, Wash., pp. 23-27.

__________. 1974. The role of ice in the ecology of marine mammals in the Bering Sea. In D. W. Hood and E. J. Kelley (eds.), Oceanography of the Bering Sea, Univ. of Alaska, Inst. of Mar. Sci., Occas. Publ. No. 2, pp. 383-399.

Fiscus, C. H., H. W. Braham, R. W. Mercer, R. D. Everitt, B. D. Krogman, P. D. McGuire, C. E. Peterson, R. M. Sonntag, and D. E. Withrow. 1976. Seasonal distribution and relative abundance of marine mammals in the Gulf of Alaska. Seattle: NOAA, NWAFC, Marine Mammal Division.

Fraker, M. A. 1977. The 1977 whale monitoring program, Mackenzie estuary, N.W.T. IOL: F. F. Slaney and Co. Lts., Vancouver, Can. :53 pp.

Gentry, R. 1970. Social Behavior of the Steller Sea Lion. PhD Thesis. U.C. Santa Cruz. Santa Cruz, Calif. 113 pp.

Hay, K., and R. McClung. 1976. Observations on beluga and narwal in the Canadian high arctic, summer 1974. Fish. Res. Bd. Can., MRS No. 1358:44 pp.

Kenyon, K. 1969. The sea otter in the eastern Pacific Ocean. U.S. Fish Wildl. Serv. N. A. Fauna No. 68. 352 pp.

Kleinenberg, S. E., A. V. Yablokov, V. M. Bel'kovich, and M. N. Tarasevich. 1964. Belukha (*Delphinapterus leucas*): Monographic investigation of the species. Moscow: Science Publisher (Isreal Prog. Sci. Transl. 1969).

Klinkhart, E. G. 1966. The beluga whale in Alaska. Alaska Dept. Fish and Game, Juneau. 11 pp.

Lensink, C. 1960. Status and distribution of sea otters in Alaska. J. Mammal. 41(2):172-182.

__________. 1962. The history and status of sea otters in Alaska. Unpubl. PhD. Thesis Purdue Univ. 188 pp.

Pike, G. C., and B. E. Maxwell. 1958. The abundance and distribution of the northern sea lion (*Eumetopias jubata*) on the coast of British Columbia. J. Fish. Res. Bd. Canada. 15:5-17.

Pitcher, K. W. 1975. Distribution and abundance of sea otters, Steller sea lions, and harbor seals in Prince William Sound, Alaska. Alaska Dept. Fish & Game. 56 pp. Proc. Rep.

Sandegren, F. E. 1970. Breeding and maternal behavior of the Steller sea lion (*Eumetopias jubata*) in Alaska. MSc. Thesis. Univ. Alaska, College, Alaska. 138 pp.

Scheffer, V. B. 1946. Growth and behavior of young sea lions. J. Mamm. 26:390-392.

__________. 1973. Marine mammals in the Gulf of Alaska. In D. H. Rosenburg (ed.), A Review of the Northern Gulf of Alaska, Univ. of Alaska. pp. 1975-207.

Schneider, K. B. 1976a. Distribution and abundance of Sea otters in Southwestern Bristol Bay, Final Report. In Environmental Assessment of the Alaskan Continental Shelf, Principal Investigators Reports October - December 1976. Vol. I. Receptors (Biota): Marine Mammals; Marine Birds; Microbiology, Pa 469-526. U.S. Dept. of Commerce, NOAA.

Schneider, K. B. 1976b. Assessment of the Distribution and Abundance of Sea Otters Along the Kenai Peninsula, Kamishak Bay and the Kodiak Archipelago. In Environmental Assessment of the Alaskan Continental Shelf, Principal Investigators Reports October - December 1976. Vol. I. Receptors (Biota): Marine Mammals; Marine Birds; Microbiology. pp. 376-468. U.S. Dept. of Commerce, NOAA.

Sergeant, D. E. 1962. The biology and hunting of beluga or white whales in the Canadian arctic. Fish. Res. Bd. Can., Arctic Unit, Circ. No. 8, 13 pp.

__________, and P. F. Brodie. 1969. Body size in white whales (*Delphinapterus leucas*). J. Fish. Res. Bd. Can. 26:2561-2580.

__________, and P. F. Brodie. 1975. Identity, abundance, and present status of populations of white whales, *Delphinapterus leucas*, in North America. J. Fish. Res. Bd. Can. 32:1047-1054.

Tarasevich, M. N. 1960. Characteristics of white whale migration toward the coast. NTIS, 1974. pp. 145-153.

Vladykov, V. D. 1946. Etudes sur les Mammiferes aquatiques IV. Nourriture du Marsouin Blanc ou Beluga...du Flueve St.-Laurent. Dept. Pecheries Prov. Quebec, Contrib. No. 17, 123 pp.

RECEPTORS -- BIRDS

RECEPTORS -- BIRDS

CONTENTS

16th Quarterly Report

Contract No. 03-5-022-72
Research Unit 083
Reporting Period 1 January 1979 -
31 March 1979

Reproductive Ecology of Pribilof Island Seabirds

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

1 April 1979

I. ABSTRACT

During the 16th Quarter all personnel were engaged in data reduction and work-up from the 1978 field season. Organization of the 1979 final report was completed and writing of some sections begun.

II. TASK OBJECTIVES

1) Analysis of data gathered during the 1978 Field Season.
2) Entry of 1978 data into the NODC files.
3) Organize and commence writing on the 1979 final report covering the period 1975-1979.
4) Develop, in conjunction with Dr. Hal Peterson, data products for the analyses and presentation of pelagic seabird surveys.

III. RESEARCH ACTIVITIES

A. Field Studies: none

Laboratory activity:

1) Burgeson completed rechecking identifications of food samples from 1975 and has begun analysis of 1978 samples. Analysis of 1978 Red-legged Kittiwake food samples is complete and the analysis of Black-legged Kittiwake samples is approximately one-half finished.

   Wallace has been measuring food items in food samples from all years for size class analysis.

2) Wallace has continued analysis of pelagic data and literature begun by Naughton. ADP products produced by Dr. Hal Peterson's Lab have greatly facilitated this effort.

3) Squibb has continued, with the help of Epply to analyze 1978 colony data and begin the process of integrating the results and graphics for colony work from 1975 - 1978.

4) Bush and now Mershman have essentially completed all 033 format pelagic bird data entry which are now being cleaned up and run by Dr. Hal Peterson. Additionally Mershman and Epply are working on the Texas Instruments 770 which arrived in the last week of March. They have been training in the use of the data entry terminal at Irvine with the help of Hal Peterson and Steffanie Windus of the University of Rhode Island.

B. Scientific Personnel

George L. Hunt, Jr.	Associate Professor, UCI, PI
Barbara Burgeson	Staff Research Associate I, UCI, foods studies; administration
Grace Bush	Coder, UCI; data management
Zoe Epply	Laboratory Assistant II, UCI, colony studies, replacing Ron Squibb
James Mershman	Coder, UCI, data management, replacing Grace Bush
Maura Naughton	Laboratory Assistant II, UCI, pelagic survey studies
Ron Squibb	Laboratory Assistant II, UCI colony studies
Carolyn Wallace	Laboratory Assistant I, UCI pelagic survey studies, replacing Maura Naughton

C. Methods

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

D. Sample Locations, Trackline

No field sampling was done.

E. Data Collected

No new data were collected in this report period.

F. Data Analyses

Data analysis is in progress. Food samples for Red-legged kittiwakes have been worked up and Black-legged kittiwake foods samples are about one half finished. Colony data for 1978 have been largely worked up, and integration of the results from 1975-1978 in progress. All previous data analyses are being rechecked in view of the updates in products design agreed to in Victoria at the 1977 Annual Pacific Seabird Group meeting workshop on kittiwakes. Pelagic survery data have all been coded and sent to Dr. Hal Peterson at the University of Rhode Island where his group is now entering corrections and updates subsequent to range and code checking. Pelagic data for 1975-1977 have been range and code checked and have been used to generate five products 1) transect summaries, 2) digital density maps, 3) star diagrams of flight direction vectors, 4) step-wise multiple regressions of density against location and oceanographic data and 5) bird density contour maps. All products are satisfactory and functional except for the contour plots in which what we hope is the final bug has just been identified.

IV, V. RESULTS AND PRELIMINARY DISCUSSION

I prefer not to speculate until analysis has progressed further. It is clear that for both Black-legged and Red-legged kittiwakes, 1978 was a bad year although it was not remarkably different for the other species studied. It is also interesting to note that our preliminary examination of weather data from St. Paul shows 1975 and 1976 to be somewhat milder summers than normal, 1977 much milder than normal and 1978 about average for wind and rain.

VI. AUXILIARY MATERIAL

None.

VII. PROBLEMS ENCOUNTERED

No problems were encountered in the work contracted for. The turnover in personnel represents loss of people to alternate jobs as the end of the contract approaches. Replacement personnel in Epply and Mershman involve rehiring a previous colony worker (Epply) who has moved back to the Irvine area and picking up additional computer expertise (Mershman) at a time when we are doing more ADP using the newly acquired T.I.

A potential problem exists in our taking on the Bering Sea synthesis tasks. The deadlines for this work as presently envisaged are very tight and additional time and funding will be required if personnel are shifted from production of the final report to write the synthesis material. This matter is under discussion with the Juneau Project Office.

Annual Report
October 1978 - March 1978
Research Unit # 108

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

John A. Wiens
Glenn Ford
Dennis Heinemann
Carol Fieber

University of New Mexico
Albuquerque, New Mexico 87131

Submitted 15 April 1979

I. SUMMARY

The objectives of this research unit are to develop computer simulation models that estimate the energetic demands that seabirds place upon marine ecosystems, the temporal changes in these demands, and the spatial patterning of use of oceanic areas in the vicinity of breeding colonies by the birds. These models may then be used to explore through simulation the potential effects of petroleum development, especially oil spills, on the energetics, spatial patternings, and population dynamics of marine birds. This report describes the third phase of model development, which deals with space-use patterns of colonial seabirds, their sensitivity to perturbations, and the effects of the perturbations upon seabird population dynamics.

The initial phases of model development, reported previously, indicated that in the Pribilof Islands total breeding bird community energy demand was concentrated in the area about St. George, and that murres accounted for most of the energy flow through marine birds in this system. Peak total community energy demands during the breeding season were approximately 7×10^8 kcal day^{-1}; energy demands over the entire breeding season totaled 6.49×10^{10} kcal, which represents approximately 53,600 metric tons of prey consumed during the 4-month breeding period. Most of the energy flow and consumption of prey was within 40 km of the home island, largely because murres largely restricted their activities to such areas.

These initial model analyses ignored spatial dynamics of the birds and the consequences of changes in these dynamics on population characteristics. The model described in this report deals with such effects. Perturbations, as from oil spills in feeding areas used by colonially-nesting birds, may have both short-term and long-term effects, and we considered both in our model development. The initial analyses using these models that are reported here deal with breeding populations of murres and kittiwakes on the Pribilof Islands; future applications will consider dynamics of colonies in the Kodiak Lease Area.

Short-term perturbation effects may influence adults directly, through their encounters with oil spills, and/or may effect chicks, through reductions in food delivery rates and consequent starvation or reduction in growth rates of the young. The model we describe here derives impacts of perturbations through a coupling of submodels dealing with demography and with aspects of foraging behavior of adults. Our model results indicate that the St. George murre population is very sensitive to development within 40-50 km of the island. Moderate size spills (about 1,000 barrels) in this region could result in a 30-50% mortality of breeding murres. Kittiwakes utilize a much larger foraging area than do murres, and also have less tendency to concentrate their activities in a single region at a time. The maximum mortality sustained by kittiwakes from a given size spill will therefore almost always be less than that for murres. Kittiwakes, however, are susceptible to pollution occurring at much greater distances from their breeding colony than murres. A corridor extending SSE of St. George along the shelf break is a region of particular sensitivity to kittiwakes. Spills in excess of 1,000 barrels in this area could result in a 10-20% adult mortality even at distances of 150 km from the island.

Analysis of long-term effects of spill mortality and reproductive failure reveal that populations of all species are highly vulnerable to mortality of breeding-age birds. Because these are long-lived species, recovery of the

populations from mortality of sub-adult age classes will take much less time than recovery from mortality of adults. Common Murres, for example, can recover from a total breeding failure in only 5 yr, whereas the same population would require in excess of 100 yr to recover from destruction of the breeding adult population. Small long-term changes in annual survival or fecundity schedules resulting from chronic low levels of disturbance could also lower population growth rates sufficiently that a species could not persist on the Pribilofs. Thus, in terms of the persistence and size of Pribilof Island seabird populations, critical efforts should be made to avoid both massive annual adult mortality and long-term, low level effects on survivorship and fecundity.

II. INTRODUCTION

Marine ecosystems are structured according to their patterns of energy fluxes and their nutrient flows and cycles, and are regulated through biotic feedback controls and by abiotic driving variables. While the dynamics of any ecosystem component may be considered in all of these dimensions, evaluation of energy flows is perhaps the most appropriate starting point. Energetics provides a framework in which we may consider the overall impact, role, importance, or potential sensitivity to disruption of a consumer component such as marine birds (e.g. Wiens and Dyer 1977). Moreover, as energetic demands directly link marine bird populations to the oceanic areas they use for feeding, consideration of energy flows may provide a means of quantitatively assessing the importance of feeding areas to the birds. Finally, because the energy demands of individual organisms directly reflect metabolic processes, they may be among the more sensitive aspects of marine bird biology in responding to local environmental perturbations, such as may result from petroleum development activities.

During the breeding season, seabird populations occupy large breeding colonies along coastal Alaska and on nearshore and offshore islands. To obtain the energy required to sustain their own metabolic demands and that necessary to feed growing chicks, adults forage radially from the breeding colony, in a typical "refuging" or "central place" manner (Hamilton and Watt 1970, Orians and Pearson 1979). The oceanic distribution of foraging birds at various distances from the colony presumably reflects some compromise between the availability and abundance of food in different areas and the energetic (and time) costs associated with foraging at different distances from the breeding colony. There is thus a significant spatial component to the pattern of energy demands of breeding seabirds: not only are the energetic requirements of the birds and their offspring important, but the distribution of these energy flows in space is of major consequence. For example, a population of murres and their chicks may require a specified amount of energy at a given time in order for the adults to maintain themselves and for the chicks to accomplish normal growth. Obviously one would predict that a reduction in the availability of energy sources to the birds, as might result from an oil spillage near the breeding colony, could easily produce reductions in the survival probabilities of either adults or young, or both. But the severity of this effect, and the potential for the birds to adjust their foraging behavior to compensate for the reduction in energy availability, should also be expected to depend on precisely where such an environmental perturbation is located in relation to the normal foraging distribution of the birds. If we are to use energetics as a means of evaluating the role of birds in marine ecosystems and their sensitivity to system perturbations, then, both the magnitude and the spatial patterning of energy flows must be determined.

Obtaining information on the energy demands of natural populations of free-living birds at sea, however, is virtually impossible, and our knowledge of the spatial distribution of foraging colony-associated birds, and how these distributions might respond to environmental changes, is woefully inadequate. Faced with such difficulties, we have chosen to employ computer simulation models to estimate the dynamics of energy flows and of breeding colonies, and how these may be influenced by changes in the distribution or availability of energy sources. This approach is consistent with the long-range goals of this research unit: to define ways of exploring the energetic linkages of marine birds to their ecosystems in both space and time; to provide a means of using this approach to synthesize data gathered in diverse OCSEAP marine bird investigations with a common framework; and to offer some initial estimations of the potential impacts of marine birds on marine systems, and of various petroleum-related perturbations upon the bird populations and communities.

III. CURRENT STATE OF KNOWLEDGE

Our development of this research approach has occurred in three distinct phases. In the first phase, we used an existing simulation model (BIRD II, Wiens and Innis 1974, Innis and Wiens 1977) to derive estimates of the magnitudes of energy demand by pelagic bird populations in the Gulf of Alaska and by colonially-breeding birds on the Pribilof Islands. These analyses, reported in detail elsewhere (Wiens et al. 1978a), indicated that in the Gulf of Alaska, energy flow was greatest in the Kodiak area during August-September (24,300 kcal km^{-2} day^{-1}), but varied both between areas and with season, primarily as a consequence of movements of species populations associated with changing reproductive status. Shearwaters were usually the energetically dominant species in these systems, accounting for up to 92% of the total community energy demand. In the analysis of the Pribilof Islands bird communities we estimated the overall distribution of energy demands about the islands. Total community energy demand was concentrated in the area about St. George, largely as a result of the major contribution of murres to community energetics. There also, energy demands varied both with season and year, and different species populations exhibited different spatial patterns of energy demands in relation to distances from islands and depth of water, especially in relation to the continental shelf break.

In the second phase of model analysis (Wiens et al. 1978b), we concentrated on the temporal distribution of energy demands by the breeding bird populations associated with the Pribilof Islands. This exercise, which involved a detailed assessment of various model functions in relation to their specific applicability to seabirds, indicated a rapid increase in energy demands in early May with the arrival of the murre population. Energy demands remained relatively high and fairly stable at about 7×10^8 kcal day^{-1} until early August, when demands declined coincident with the departure of murres and auklets from the breeding colonies. The total breeding season energy demand of the marine bird assemblage on the Pribilofs was 6.49×10^{10} kcal; converted into prey, this represents an estimated 53,600 metric tons of food consumed during the 4-month breeding season by all bird species. Most of this consumption was localized within 40 km of the home island.

Both of these phases of analysis were based upon <u>static</u> simulation modeling, in that energy flow was calculated and varied through time and space strictly in accordance with specified input values or spatial iterations of the model. The third and most difficult phase of model development is reported here. In this phase, we have generated a new family of simulation and analytic models that enable us to deal with the <u>dynamics</u> of such breeding seabird systems in space and time. Briefly, these models consider the patterns of foraging movements of individuals from breeding colony locations in terms of the spatial array of food availability, the overall distribution of the population of birds, and the costs associated with different foraging patterns, in the context of optimal foraging theory. The distribution of foraging movements in a population is altered in response to changes in these features--this produces the dynamics of the modeling. These foraging distributions in space, and their changes in time, are related to energy demands of both adults and offspring, which in turn are used to derive projections of the behavior and survival of adults and young under various environmental regimes. Finally, the long-term consequences of these variations in survivorship on population persistence are evaluated. Because the construction and testing of these interrelated models has involved substantial time and effort as well as consideration of previously unexplored questions and relationships, we have chosen to continue this phase of the model development using the Pribilof Islands' colonies as our operational example. This is because we know that system and the data base available for it, and because our earlier analyses conducted in phases one and two provide some important background perspective. With the completion of this third phase of model development, we are now in a position to apply the approach to seabird colonies in other OCSEAP areas, notably those in the Kodiak area. Our procedures for implementing such analyses will be described later in this report.

IV-VII. MODEL STRUCTURES, ANALYSES, RESULTS, AND DISCUSSION

In our development of models to explore the effects of oil perturbations on breeding seabird colonies, as depicted by the Pribilof Islands' colonies, major attention was given to short-term (within-year) and to long-term (multi-year) effects. The following sections describe the model structures, analyses, and results for each level of modeling, and discuss the relevance of these exercises for oil-related impacts on colonially-breeding marine birds. All analyses in this section are based on data collected by George Hunt and by our staff.

SHORT-TERM EFFECTS

The model of short-term effects of oil perturbations on marine bird colonies is divided into two interacting parts. The demographic submodel simulates changes in population size and age structure throughout the course of a breeding season. Adults arrive at the breeding colony, attempt (with or without success) to rear young, and leave at the end of the season. The foraging submodel simulates the daily foraging activities of colony members and estimates their daily energetic intake and their mortality due to spill contact.

Daily energetic intake is used by the demographic submodel to estimate the growth and survivorship of the young; adult mortality affects production and survivorship of young and the size and structure of the adult population. The demographic model feeds back to the foraging model by determining the number and energetic requirements of foraging birds; these, along with the state of the enrivonment, determine the at-sea distribution of colony members. These basic interactions are shown in flow diagram form in Fig. 1. We will describe the mechanics and structure of the two submodels separately.

Demographic Submodel Structure

Adult birds are assumed to exist in eight mutually exclusive states:

(1) alive, but not at breeding colony;
(2) present at colony, but non-breeding;
(3) clutch initiated, but not laid;
(4) eggs laid, but not hatched;
(5) chick hatched, stage I;
(6) chick in stage II;
(7) chick in stage III;
(8) dead.

Adults with chicks were divided into three discrete stages to facilitate the implementation of age-specific chick mortality, age-specific chick energy demands, and chick-age-specific adult foraging behavior. The classes are determined by fitting three straight lines to the chick growth curve, corresponding to early, middle, and late stages of chick development.

Young of the year were, in turn, divided into five states:

(1) eggs;
(2) chick stage I;
(3) chick stage II;
(4) chick stage III;
(5) fledglings.

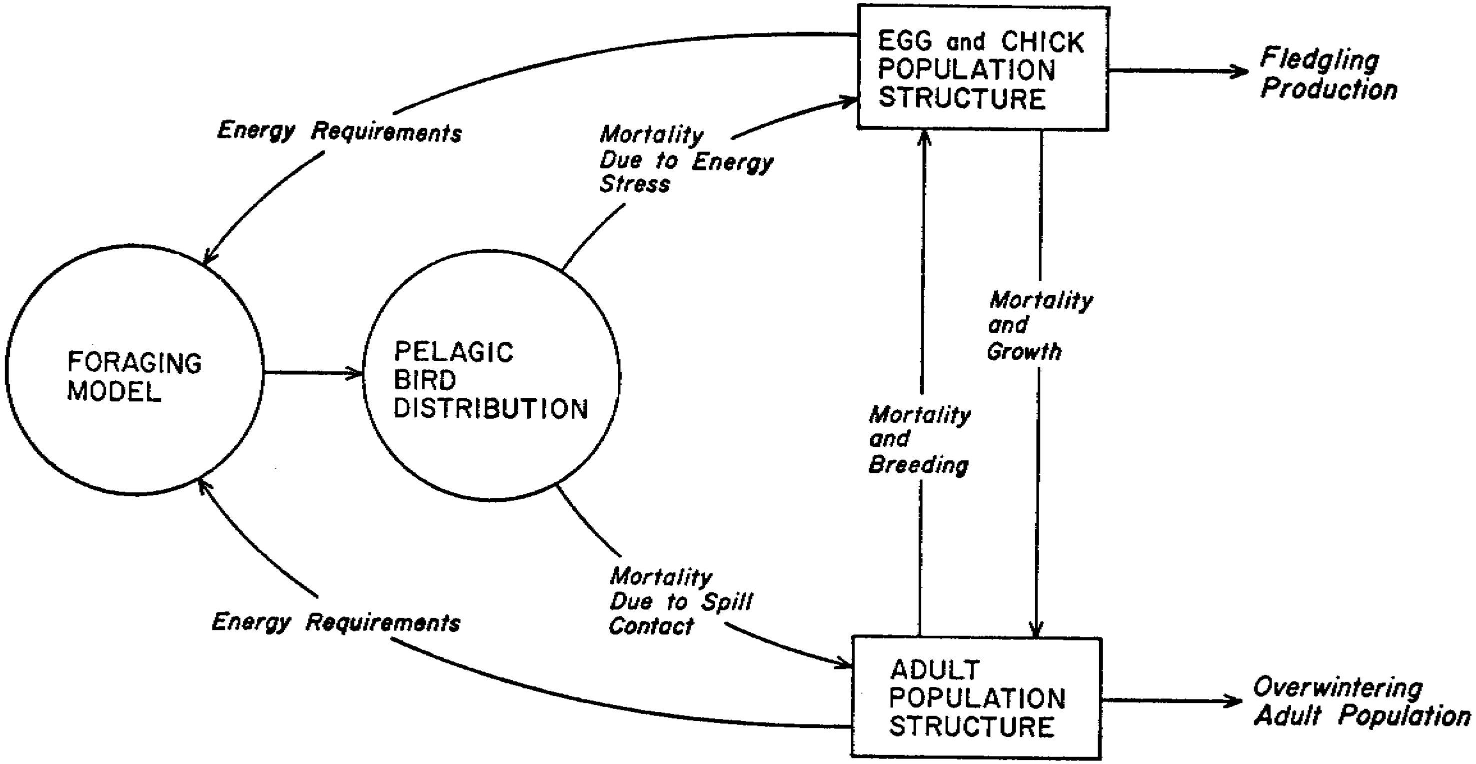


Fig. 1. Generalized flow diagram of the major elements of the model of seabird space-use and population dynamics.

Transfer from one state to another occurs on a daily basis. State changes of adults (see Fig. 2) may take place due to:

(1) immigration to colony;
(2) emigration from colony;
(3) initiation of clutch;
(4) growth or aging of chick;
(5) loss of egg or chick;
(6) death of adult.

Data from cliff counts suggest that for most species on the Pribilof Islands, adults arrive at a constant rate until a maximum population size is achieved, remain at that population size until the onset of emigration, and depart at a relatively constant rate. Immigration and emigration are therefore defined only by their beginning and ending points. The probability of an individual arriving on the island from the at-sea population or leaving the island and rejoining the at-sea population is adjusted so that (in the absence of mortality) the number of birds leaving or arriving per unit time is constant during the respective periods. It is assumed that during the period of immigration all birds in the at-sea population arrive at the island and enter the colony population as non-breeders, and that at the end of the season all birds leave the island and rejoin the at-sea population.

The data also indicate that the rate at which adults initiate breeding is relatively constant over a discrete period of time. However, not all adults initiate clutches. The rate of transfer of birds from the non-breeding to the breeding state is modeled as a constant increase between the onset and the end of breeding, with a specified maximum proportion of the population breeding. Adults may return to the non-breeding population if their breeding attempt fails due to loss of egg, death of chick, or death of mate, or because of fledging of the chick. A summary of adult state transfers is shown in Fig. 2.

Adult death occurs only as a result of spill contact and acts on all classes of adults except those not present at the colony. Adult death rate is calculated by the foraging submodel and will be described later. Loss of one or both members of a breeding pair leads to nest failure and chick death. In the case where only one member of a pair is lost, the remaining adult returns to the non-breeding population.

Although chick mortality can occur for a variety of reasons such as exposure, disease, predation, or starvation, our principal focus is the effect of food delivery rate on survivorship. We consider the primary effect of oil spills on chick survivorship, aside from the loss of one or both parents, to be an increase in mortality resulting from lowered food availability to the foraging adults and therefore lowered food delivery rates to the chicks. The foraging submodel can estimate the changes in food delivery rates resulting from habitat degredation or spill avoidance. However, no data are available for sea birds (or for any other species of birds) that quantitatively link food delivery rates to survivorship. Our strategy in modeling this relationship has been to assume that the death rate increases linearly as the ratio of energy delivered to metabolic demands approaches zero. Under "normal" conditions, when intake is approximately equal to demand, chick mortality will be at the average levels described in standard colony surveys, which we use as an approximation of the minimum death rate. The maximum death rate is achieved as the delivery rate tends to zero and the ratio of intake to demand

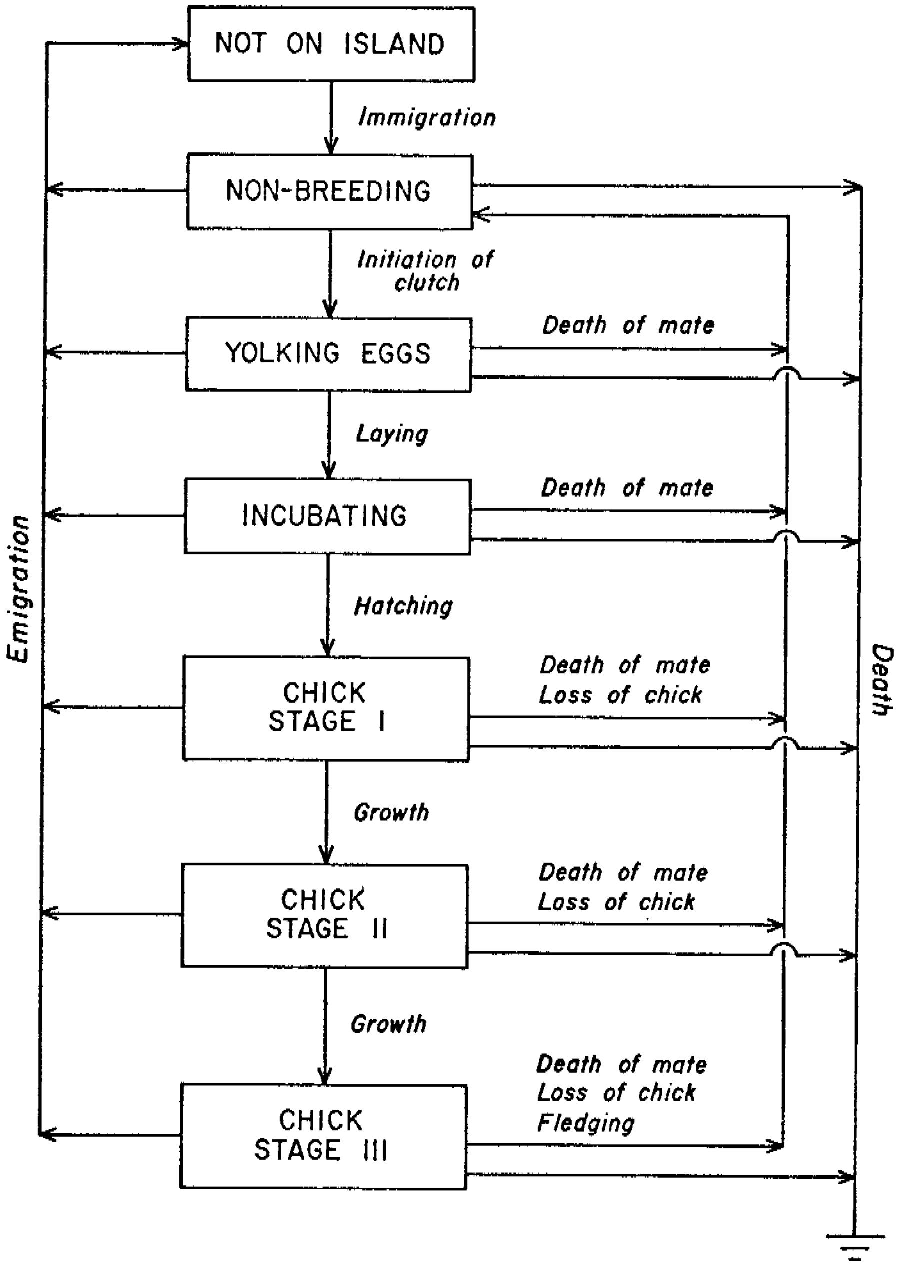


Fig. 2. States and processes causing state changes of adults in the demographic submodel.

falls to zero. The value of maximum mortality is estimated from the number of days of starvation that a chick of a given age class can withstand (Fig. 3). Thus, within the region where demand exceeds intake, i.e. the intake to demand ratio is less than 1.0, mortality rate is estimated by linear interpolation between the maximum and minimum values. At intake to demand ratios exceeding 1.0, mortality is held at the minimum level, which we presume is unrelated to adequacy of food supply.

State changes of chicks, aside from mortality, occur either due to growth or aging (Fig. 4). Chicks hatch after a fixed number of days and enter the first chick stage. Transfer to older chick stages is determined by growth rates. Growth rate within a chick stage is a function of food delivery rates. The growth increment per day is determined by subtracting metabolic demands from the quantity of energy delivered to the chick and correcting this for digestive efficiency and efficiency of growth. Growth rates are not allowed to exceed those found under normal unstressed conditions. Chicks fledge when they achieve a threshold body weight. If this weight is not achieved by a maximum age, they die without fledging. This approach to chick mortality under stressed conditions thus takes into account both the effects of inadequate energy for maintenance and the cumulative effect of inadequate energy for growth.

Demographic Variables

All demographic variables, unless otherwise indicated, were taken from Hunt (1977). Names given are program mnemonics.

IARRI--Date (Julian) on which immigration begins.
IARR2--Date on which immigration ceases.
IEMI1--Date on which emigration begins.
IEMI2--Date on which emigration ceases.
IBR1--Date of onset of reproduction (clutch initiation).
IBR2--Date of end of reproduction.
BRMAX--Maximum proportion of the population breeding.
CDRMAX(J)--Maximum death rate per day for chicks of stage J.
CDRMIN--Minimum chick death rate per day for chicks of all stages.
ADREQ--Energetic requirement of an adult, excluding the added cost of foraging and corrected for digestive efficiency (kcal).
GREF--Efficiency of conversion of kilocalories of food to grams of body weight for chicks. Set to 0.75 after Ricklefs (1974).
CHKREO(J)--Metabolic maintenance requirements of a chick at the midpoint of stage J. Calculated from the equation of Aschoff and Pohl (1970). Units are kcal per day.
CMG(J)--Average weight gain per day of a chick of stage J (g per day).
HW--Weight at hatching (g).
AFMAX--Maximum age at fledging (days).
INC--Period of incubation (days).
WTLIM(J)--Upper limit on weight of chick of stage J.

Foraging Submodel Structure

Little is currently known about the precise nature of the daily movement patterns of individual seabirds during the breeding season. Nor are data available that can be used to describe the distribution and availability of food resources at sea. We do, however, have three basic pieces of information that can be used

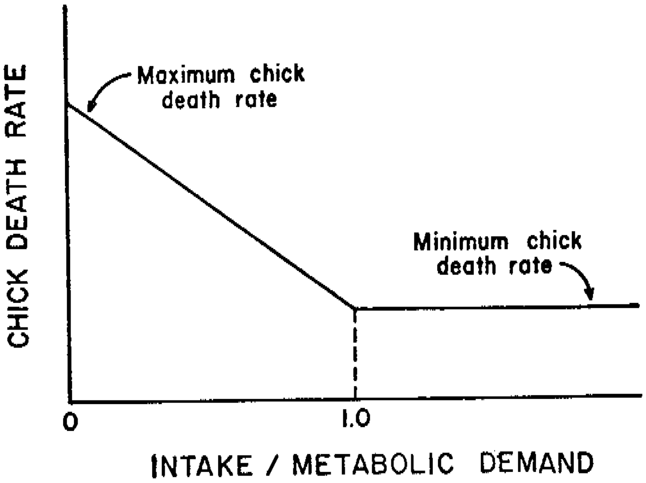


Fig. 3. The function employed in the demographic submodel to relate chick death rate to the ratio of food intake to metabolic demand.

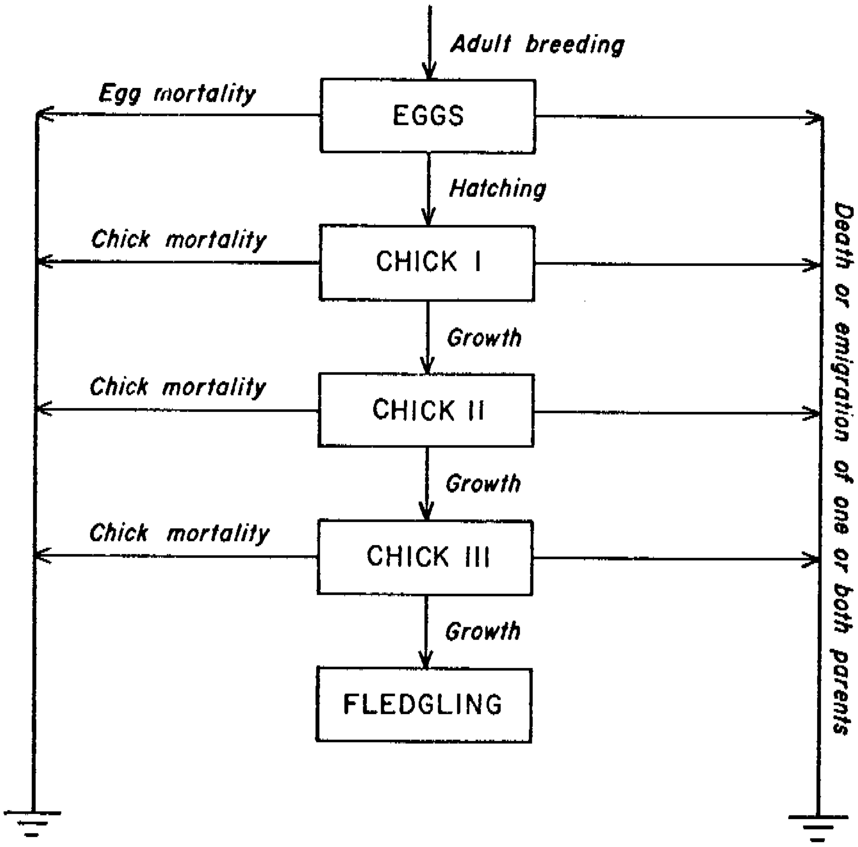


Fig. 4. States and processes causing state changes in eggs, chicks, and fledglings in the demographic submodel.

to approximate both daily movement patterns and food distribution: (1) the distribution of birds at sea, (2) the length of time individual birds spend foraging, and (3) the daily energy requirements of nesting seabirds. We can use this information to simulate the pattern of movement and rate of energetic uptake of these birds using a combination of central place and optimal foraging theory if we make two basic assumptions. First, we must assume that birds minimize the time spent in gaining the daily net energy requirements for themselves and their chicks. If it is impossible to meet their daily requirements, they maximize their net energy gain. Second, we assume that the rate at which birds assess the productivity of the environment is short relative to the rate of change of the productivity.

Given the state of knowledge of seabird foraging behavior, it is not currently possible to verify these assumptions. There are data available for other species of birds that indicate, in general, that birds are capable of and practice varying degrees of time minimization or energy maximization (Krebs and Davies 1977, Orians and Pearson 1979). There is little doubt that their behavior tends in the direction of optimality within the constraints of environmental variation. Evaluation of the degree to which optimization is possible and the effectiveness with which it is executed must await the collection of further data. We are confident, however, that the use of optimal foraging theory provides the basis for a model that in its general form responds realistically to perturbation, and that this is the best available modeling path given the data available.

Variable list.--The following variables are employed in the foraging submodel:

E--Daily energy requirement of an adult bird, including one-half the daily energy requirement of its chick (if appropriate) but excluding the energetic cost of foraging (kcal).

C--The energetic cost of foraging--i.e. the difference between the energetic demand of being at sea and the energetic demand of being at rest (kcal).

T--Expected (mean) trip time (min).

K--The maximum load size that can be brought back on one foraging trip (kcal).

S--Flight speed (km/min).

N_i--Bird density in the ith sector (Number $\cdot$ km^{-2}). For this analysis, a sector is defined as the region between two radii extending outward from St. George (or St. Paul) 45° apart and two concentric annuli at intervals of 12 km for murres and 16 km for kittiwakes.

W_i--Productivity of the ith sector available to foraging birds (kcal $\cdot$ km^{-2} $\cdot$ min^{-1}).

D_i--Flight distance to the ith sector (km).

A_i--Area of the ith sector (km^2).

u_i--Rate of total energetic uptake by birds foraging in sector i (kcal $\cdot$ km^{-2} $\cdot$ min^{-1}).

v_i--Productivity of sector i available but not utilized by foraging birds (kcal $\cdot$ km^{-2} $\cdot$ min^{-1}).

r_i--The rate of energy uptake in sector i (kcal $\cdot$ min^{-1}).

β--Constant of productivity between r_i and v_i.

N^*--Population size.

L--Day length (min).

Model structure.--The optimal strategy for a foraging bird is to maximize its rate of energy uptake--in other words, to minimize the time spent in capturing K kilocalories of food. For a bird foraging in sector i, the expected trip time, T, is:

$$T = K/r_i + D_i/S. \quad (1)$$

The term K/r_i is the time required to capture a full load of food while in sector i, and D_i/S is the time required to return from sector i to the island. Note that optimality requires a maximum load of food to be captured before returning on each trip, because returning with anything less would be a waste of the cost of transport to the foraging region. Optimality also requires that birds should tend to go where T is minimized. If $T_i > T_j$, where i and j are different sectors, birds should go to sector i in preference to sector j. This will continue until sector i is sufficiently depleted relative to sector j that $T_i = T_j$. Therefore, when equilibrium is achieved, T is equal for all sectors.

In order to make use of the fact that T is constant, it is necessary to know the relationship between N_i, the density of birds hunting in sector i, and r_i, Solving (1) for r_i,

$$r_i = K/(T - D_i/S). \quad (2)$$

The rate at which all birds are removing energy from i, W_i, is the product of N_i and r_i,

$$u_i = N_i r_i = N_i K/(T - D_i/S). \quad (3)$$

The rate at which energy is located and consumed will be a function of the rate at which energy is made available in the environment. Because energy already consumed by other birds, u_i, is not available to a foraging individual, the rate of uptake of an individual bird, r_i, must be a function of the unutilized production, v_i. If the rate at which prey items are located increases approximately linearly with the density of prey items, we can state that

$$r_i = \beta v_i, \quad (4)$$

where β is a constant of proportionality (units are km^2) that relates the rate of food uptake to the available productivity of a given region. Substituting for r_i from equation (2) into (4) and solving for v_i,

$$v_i = r_i/\beta = K/\beta(T - D_i/S). \quad (5)$$

The total productivity of a sector, W_i, is the sum of the utilized production, u_i, and the unutilized production, v_i,

$$W_i = u_i + v_i. \quad (6)$$

Substituting from (3) and (5),

$$W_i = (N_i + 1/\beta)r_i = [N_i + 1/\beta][K/(T - D_i/S)] \quad (7)$$

Solving for r_i,

$$r_i = W_i/(N_i + 1/\beta). \quad (8)$$

From (8) it can be seen that r_i decreases with increasing density of foraging birds, asymptotically approaching zero as N_i tends to infinity, and reaching a maximum value of W_i at N_i equals zero. At equilibrium, all r_i at a given distance are equal (Fig. 5), and there is an N_i corresponding to each sector.

To find the optimal trip time and the optimal bird density for each sector, we must be able to estimate the net daily gain in kilocalories, G, of an individual given a trip time, T. If we assume for the moment that T is known, then we can solve (7) for N_i,

$$N_i = W_i(T - D_i/S)/K - 1/\beta. \tag{9}$$

The sum of the products of all N_i and A_i, $\sum N_iA_i$, is the total number of birds foraging at any instant in time. The ratio of $\sum N_iA_i$ to N^*, $\sum N_iA_i/N^*$, is the maximum proportion of the colony that can be foraging at a given time and is also the proportion of time that an individual bird spends at sea, providing that $\sum N_iA_i/N^* \geq 1$ (or less than or equal to 0.5 for breeding birds with chicks or eggs, as those birds cannot spend more than one-half their time away from the nest). Knowing T and the proportion of time spent at sea, we can calculate G as a function of T. The total net energetic gain of a bird in the course of the day is the product of the rate of net energy gain while foraging and the time spent foraging. The net rate of gain per unit time on a foraging trip is the gross rate of uptake, K/T, less the cost of foraging, C, so

$$G = (K/T - C)(\sum N_iA_i/N^*)L \tag{10}$$

To find the optimal trip time, we search for the value of T such that

$$\begin{aligned} &G = E \text{ and } T \text{ is minimal,} \\ \text{or } &G < E \text{ and } G \text{ is maximized.} \end{aligned}$$

Once the optimal value of T is found, the distribution of birds is known and can be used for estimating the effects of environmental perturbations such as oil spills. Also, if the food supply has been altered such that $G < E$, G may be estimated and used as input to the demographic model for determining chick death rates.

Modeling the primary effects of an oil spill requires that we know two additional parameters: (1) the probability of death of a bird encountering a spill (P), and (2) the rate at which a population of foraging birds tracks environmental changes (τ). The first parameter, the probability of death, can be estimated from descriptions of oiled birds in the literature (Tuck 1961; Bourne 1967, 1968). For our purposes, it seems reasonable and conservative to assume that the probability of death is 1.0 for murres and 0.5 for kittiwakes. The second parameter, the rate of environmental tracking, is currently unknown, and until pertinent data can be collected, it must be approximated by guesswork.

At each time step, a foraging distribution is calculated. If a sector contains an oil slick, birds utilizing that sector suffer mortality proportional to the area of the sector covered by the slick. At the next time step, the population is reduced by that proportion of the population that had been utilizing the polluted sector. A new equilibrium distribution is generated. However, we do not assume that equilibrium is necessarily achieved in only one time step. The new distribution is the weighted average of the previous distribution and the new equilibrium distribution. The weighting factor, τ, determines the number of days, $1/\tau$, required for the population to move from one equilibrium to the next. As will be discussed later, adult mortality is very sensitive to the value of τ.

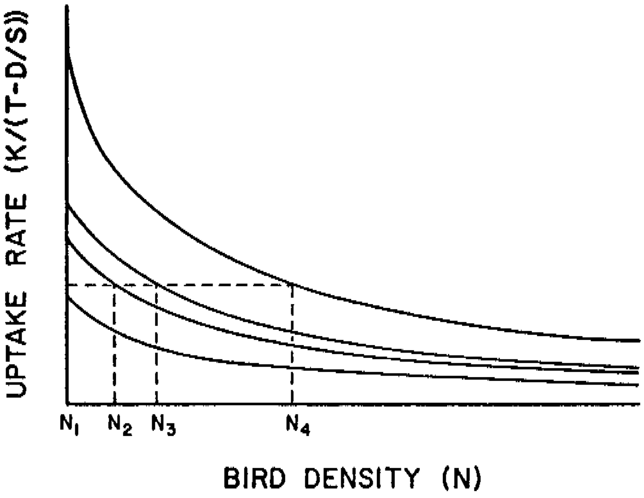


Fig. 5. The functions used to relate uptake rate (r_i, in kcal min^{-1}) to sector densities (N_i) in the foraging submodel.

Estimation of foraging parameters.--The following paragraphs indicate how each of the major foraging parameters used in this submodel are derived.

E--The daily energetic requirement of a non-active bird at thermoneutrality is calculated from the equation of Aschoff and Pohl (1970),

$$\text{Kcal/h} = (1.3)(3.60)(\text{Weight})^{0.734}.$$

This is incremented by the energetic requirement of a chick of the mean weight of stage III plus the growth requirement (assuming normal growth rate) for stage III and an efficiency of growth of 0.75 (Ricklefs 1974). Note that by using the same E for all birds, we slightly overestimate the requirements of part of the population, which has some effect on the final foraging distribution. The optimal foraging model can be solved for birds of any number of classes with different values of E (as well as of K, S, or β), but the solution requires a one to two order of magnitude increase in the run time of the foraging model. Because the effect on the foraging distribution is minor, we sacrificed a small degree of accuracy for faster run time.

C--The cost of foraging is a composite of the cost of flight, the cost of diving, and the cost of sitting on the water, depending on the relative proportions of time spent by a species in each of these three activities. It was necessary for us to estimate this parameter from our experience and the data of King (1974). The cost of foraging does not include the energetic expenditure that would have been required if not foraging; that is, it is the cost of foraging less the cost of resting metabolism that would have been spent in any event.

T--Mean trip time is calculated from the data of Hunt (1977) and R. Squibb (pers. comm.).

K--The maximum load of food (kcal) that can be brought back on one foraging trip is the total requirement of an adult bird, including both resting and foraging costs, plus one-half the maintenance and growth requirements of a chick of stage III. Both are corrected for a digestive efficiency of 0.75 (Wiens and Innis 1974).

S--Data on mean flight speed were collected by the authors on St. Paul in 1978.

N*--Estimates of total population size were taken from Hickey (1977).

N_i--The density of birds was calculated from the transect data of Hunt for the years 1975-1977. Density estimates were corrected for total population size and time spent foraging.

β--Given a subset of the total number of sectors within which it is reasonable to assume that productivity (W_i) is not a function of distance from the island, we can use equation (9) to estimate β. Rearranging equation (9), we find that bird density (N_i) is a linear function of distance, provided that W_i does not change systematically with distance:

$$N_i = [-W_i/SK]D_i + [TW_i/K - 1/\beta]. \qquad (11)$$

We regress bird density on distance for each sector to derive the equation

$$N = mD = b. \tag{12}$$

We then solve for β as a function of the constants of the linear regression line, m and b.

In calculating β for murres, we excluded sectors that contained densities of 200 or more birds per km^2. As can be seen in Figs. 6 and 7, exceptionally high densities of murres are present in some of the relatively shallow inshore waters around St. George. These high density regions may be associated with demersal feeding and as such their high densities are related in part to nearness to the island. These sectors were not used in the calculation of the regression equations.

Finding an appropriate subset of the kittiwake densities was a somewhat more difficult problem. Kittiwakes appear to localize much of their feeding activity along the shelf break south and west of St. George (Figs. 8 and 9). Thus W_i increases, at least to the southwest, as D_i increases. We therefore used only those sectors that lie along the region of the break for estimating β for kittiwakes.

W_i--One of the most difficult tasks in the development of the foraging model was to find a way of estimating the distribution of food available to foraging colony members. To estimate this parameter directly would require detailed knowledge of the abundance of both fish and invertebrates out to nearly 200 km from the islands. Data of this type are not available, and could only be obtained at enormous expenditure. An alternative method would be to use telemetry to determine the success rate of foraging individuals and use this indirect measure to estimate prey abundances. This approach has the advantages of being both less difficult and probably more accurate, as it would measure the density of available prey, which is potentially quite different from the absolute density of prey. Because neither of these approaches was open to us, we have resorted to a third, alternative method of estimating W_i that requires knowledge only of bird distributions and the assumption that the formulation of the foraging model that we have described is a substantially correct interpretation of their behavior. In other words, we use the distribution of N_i to tell us what the distribution of W_i must be in order to satisfy equation (9). Knowing K, T, and S, and having estimated β, we can solve (9) for each W_i given N_i and D_i. This has the advantage of guaranteeing consistency between observed and modeled foraging distributions under unperturbed conditions, but makes it impossible to double check the validity of the foraging model. The distribution of W_i for murres around St. George is shown in Fig. 10.

Sensitivity

Because little is known about the daily movement patterns of individual seabirds under either normal or perturbed circumstances, it was necessary for us to estimate two important parameters of the foraging model on the basis of very little data. The probability of death following a spill encounter (P) is not definitely known for any seabird species. We chose what we considered to be conservative values for these parameters, 1.0 for murres and 0.5 for kittiwakes. Murres were considered to be more susceptible than kittiwakes because they spend more time sitting on the surface and diving. Within what we consider to be a reasonable range of values for this parameter (the stippled region of Fig. 11), model results are relatively insensitive to the precise value of P, varying only by about 25%. This insensitivity, however, results in part from our basic assumption

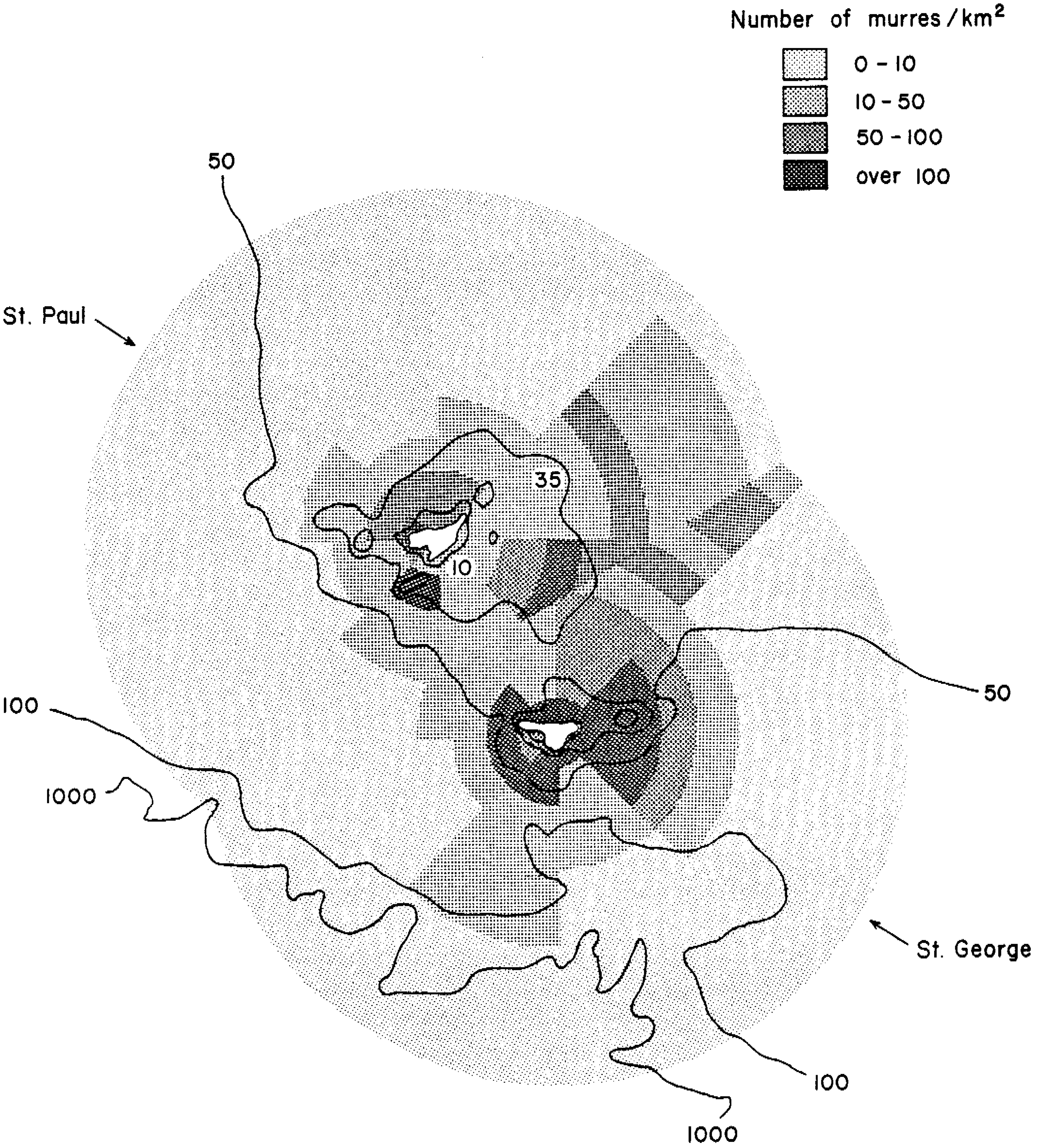


Fig. 6. The oceanic distribution of murre densities (birds km^{-2}) by sectors out to 120 km from St. Paul and St. George. Densities in sectors with no sampling effort were extrapolated from the densities in adjacent sectors.

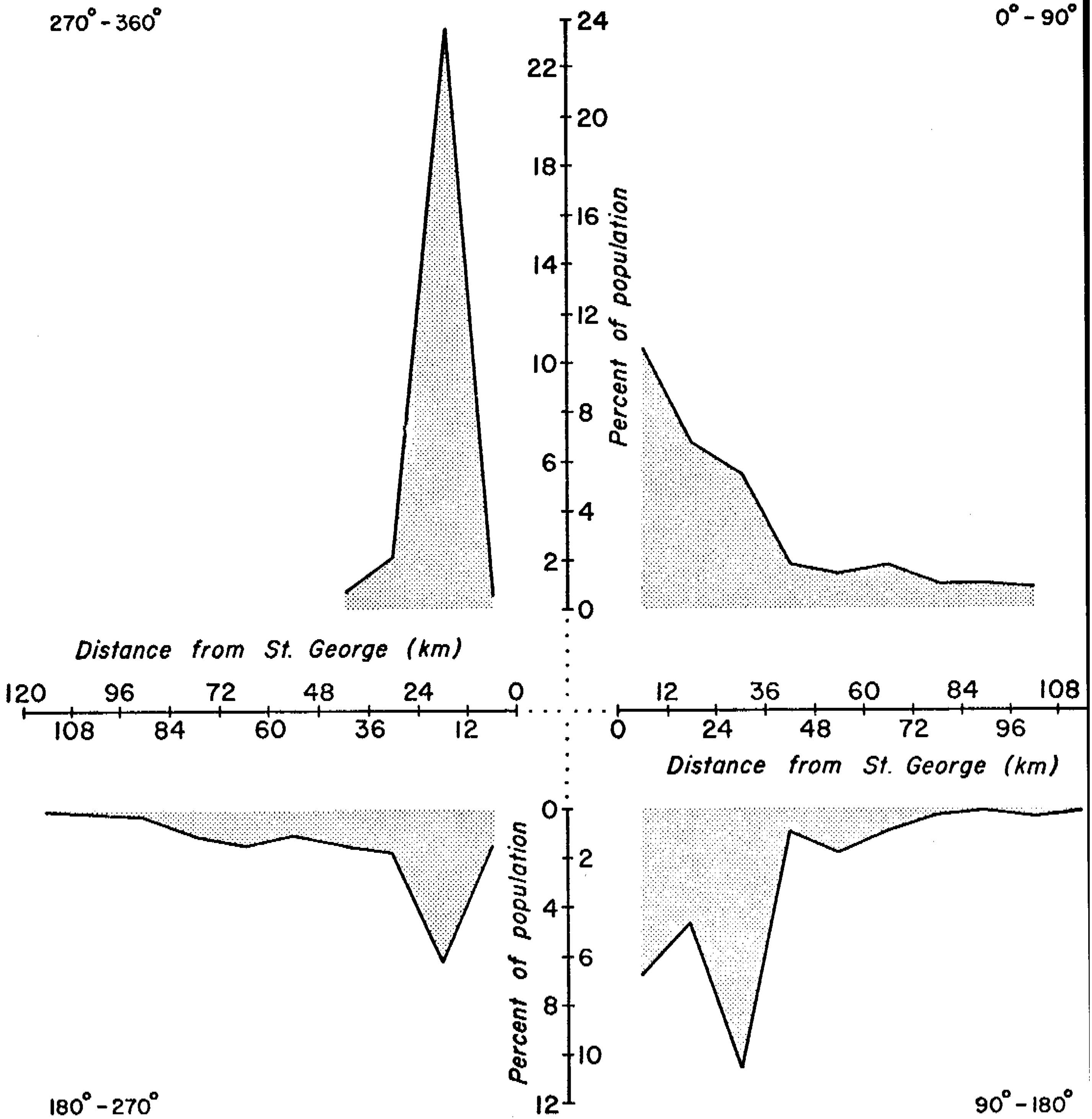


Fig. 7. The distributions of the proportions (%) of murres by distance from St. George in four quadrats (0^o is true north). The proportion in distance interval i equals the number in that interval divided by the total island population.

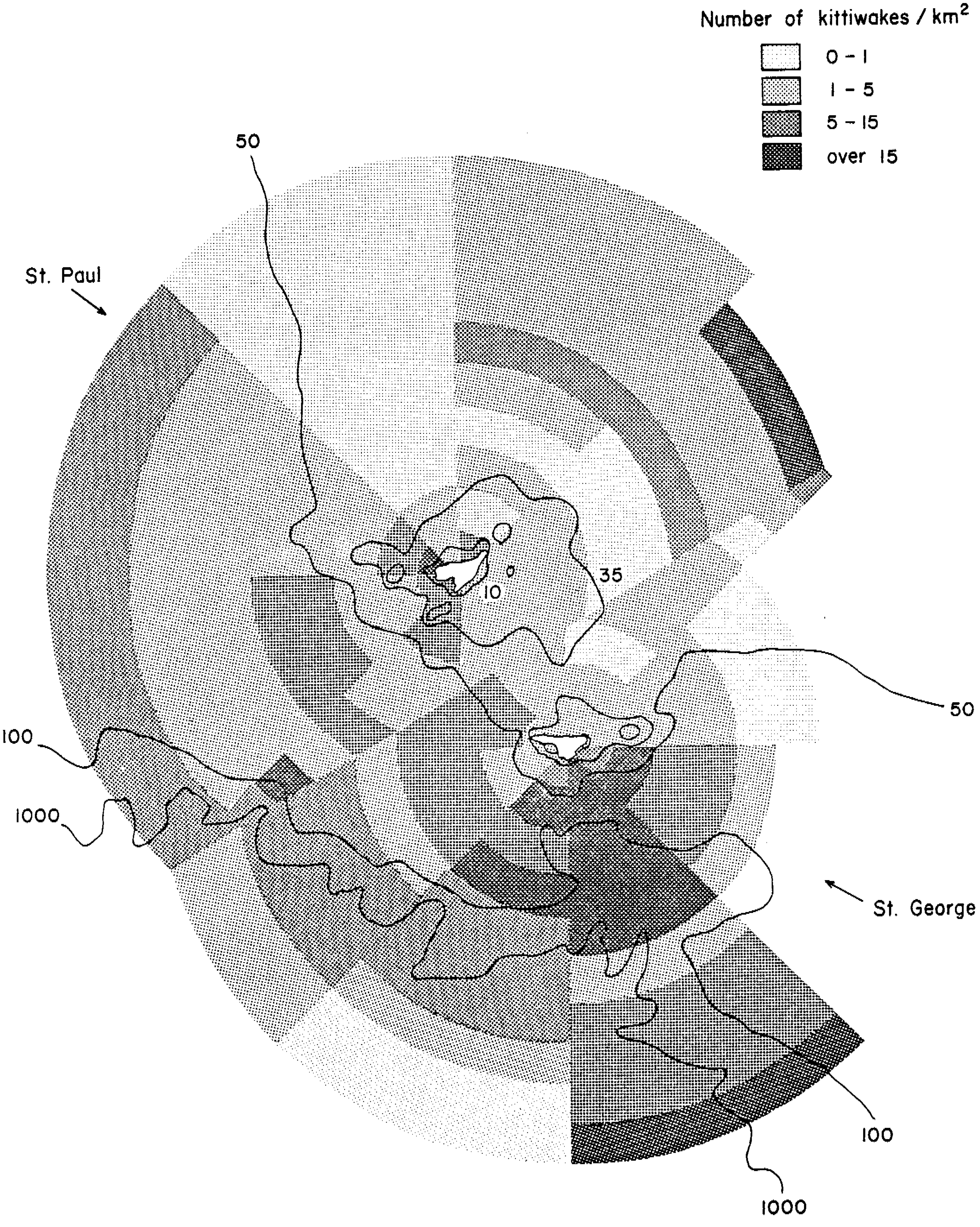


Fig. 8. The oceanic distribution of kittiwakes (densities in birds km^{-2}) by sectors out to 160 km from St. Paul and St. George. Blank sectors received no sampling effort, and the available data do not permit extrapolation from adjacent sectors.

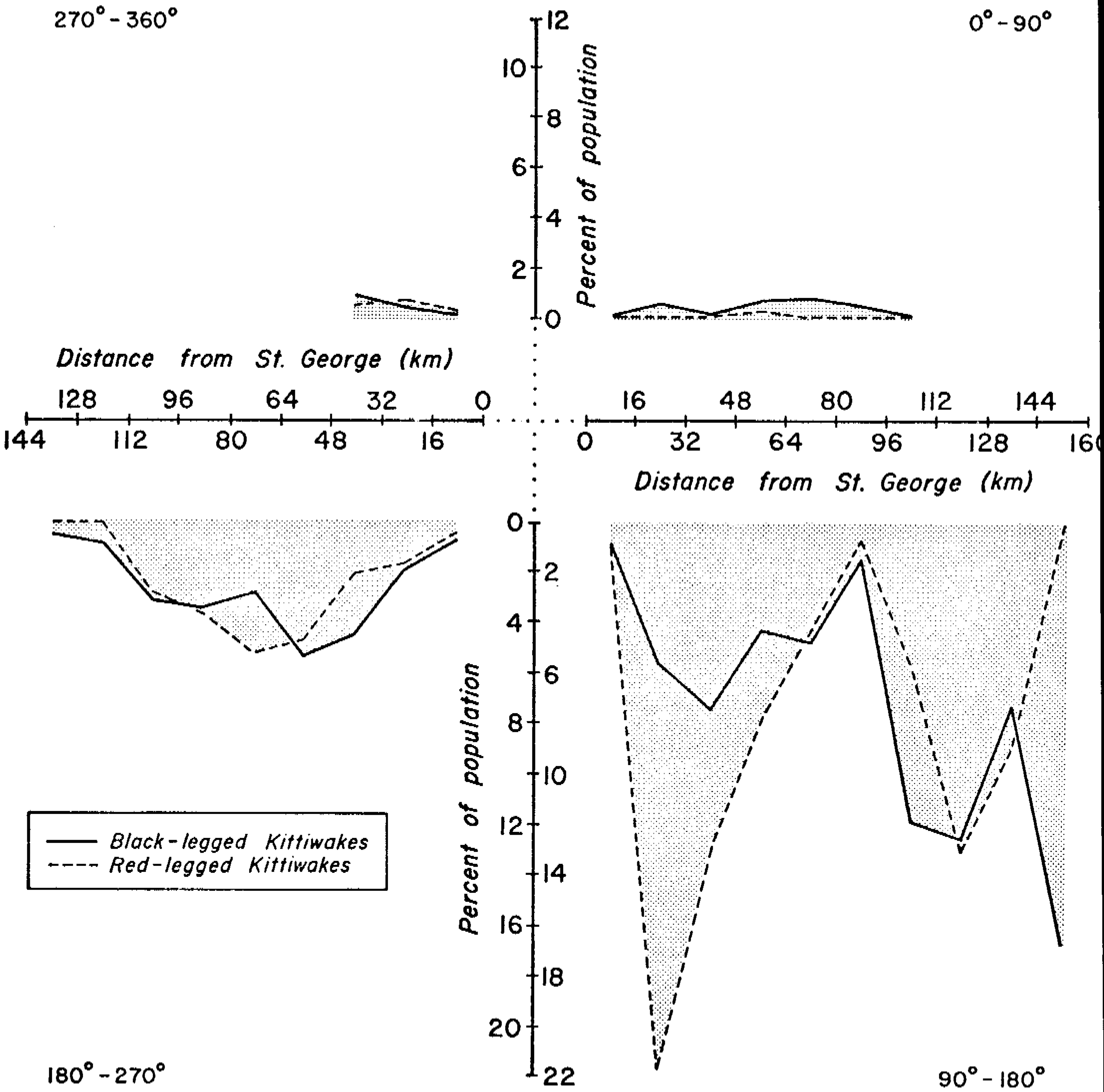


Fig. 9. The distributions of the proportions (%) of both kittiwake species by distance from St. George in four quadrats (0^{o} is true north). The proportion in distance interval i equals the number in that interval divided by the total island population.

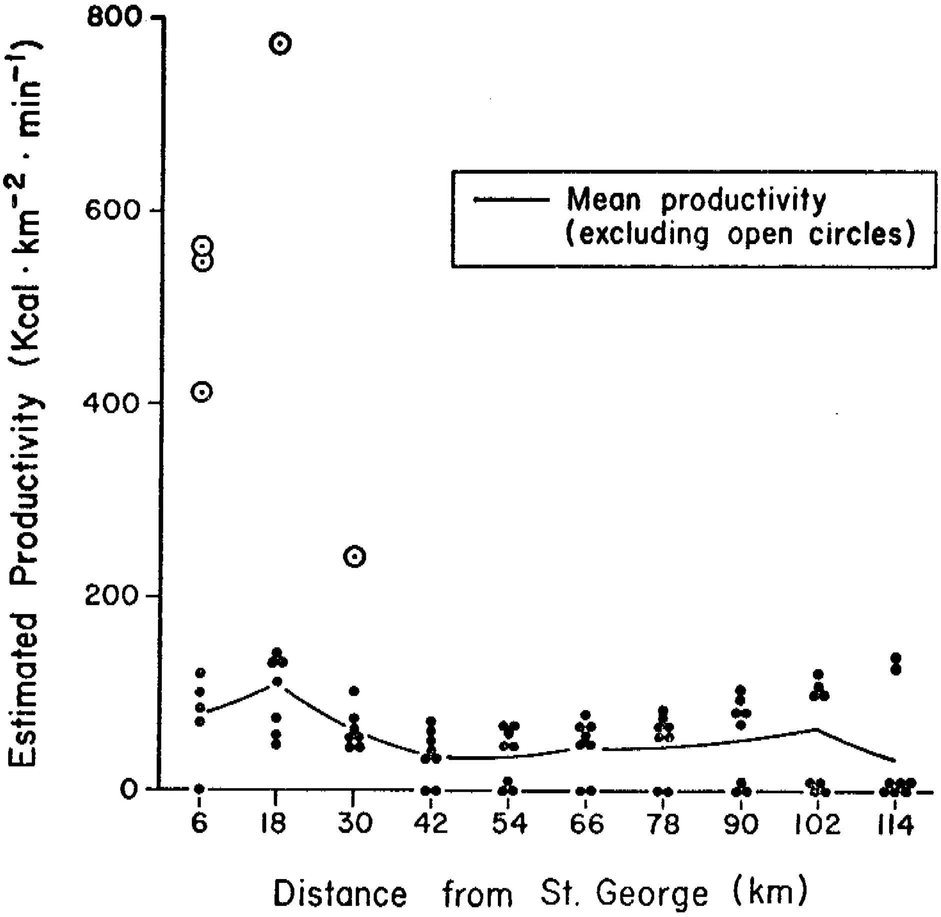


Fig. 10. The distribution of estimated productivity (W_i, in kcal·km^{-2}·min^{-1}) by distance from St. George for murres.

that no learning takes place on the part of the birds that have encountered a spill. This is a conservative assumption that cannot be verified until spill encounters can be described in more detail than is currently available.

The second important parameter for which the true value is only speculative at this time is the rate of environmental tracking, τ. Basically, it determines the rate at which new birds enter the polluted region and encounter the spill. The value of τ could only be measured by detailed monitoring of the movement patterns of individual birds, and again no data are available that bear on this measure. We chose what we consider to be a relatively rapid rate of environmental tracking, 5 days for both murres and kittiwakes. More rapid tracking rates lead to higher kills from oil spills because more individuals contact the spill (e.g. Fig 12). Within the range of reasonable values for this parameter, however, the model is more sensitive to τ than to P, varying by as much as 50% for various values of τ.

Model Runs: Results and Discussion

Our analysis of the potential impact of oil development has concentrated on the area around St. George because it is by far the largest of the Pribilof Islands' colonies and it is adjacent to the southeast corner of the potential lease area. We have carried out the analysis for both kittiwake and both murre species. We lacked adequate data to extend the analysis to additional species, but we feel that murres and kittiwakes are good indicators of potential impacts on other species, and collectively they comprise by far the major portion of the Pribilofs' breeding avifauna. Results for murres are probably applicable to auklets, and results for kittiwakes are probably also applicable to fulmars, as their respective distributions around the islands are similar (Wiens et al. 1978a). Horned and Tufted puffins, however, have much more extensive foraging ranges than murres, but, unlike kittiwakes, are diving birds. Thus, neither results for murres or kittiwakes are particularly appropriate for the puffin species.

We examined the effects of oil spills on murres and kittiwakes by simulating 80 small spills located 45° apart around St. George and spaced at intervals of increasing distance from the island, 12 km for murres and 16 km for kittiwakes. Each spill covered a 50-km^2 area and persisted for 10 days. The results of these analyses are shown if Figs. 13 and 14. The destruction of large numbers of adult murres, from 6% to 20% of the breeding population, is likely even from such a relatively small spill if the spill occurs within about 40 km of the island. If the location and timing of such a spill is such that a maximum number of individuals encounter it, it is possible that as much as 40% of the population could perish. A larger spill, of about 1,500 km^2, would probably result in at least a 50-75% loss of adults and a 75-95% loss of chicks if it occurred in inshore areas near St. George. The same size spill would typically result in only 15-25% adult mortality and 20-30% chick mortality if it took place 60-70 km offshore.

Because kittiwakes range over a much wider area than do murres, a given size of spill in a given location will have proportionately less effect on the kittiwake population than on the murre population. The maximum mortality indicated by our simulations for a 50-km^2, 10-day spill was about 9% of the adult population and 17% of the chick population, but more typical values would be 1-3% of the adults and 2-6% of the chicks. Because kittiwakes range so far, however, this level of sensitivity extends at least to 100 km and probably as far as 150 km from the island (Fig. 14). Areas located in a corridor extending southeast of St. George

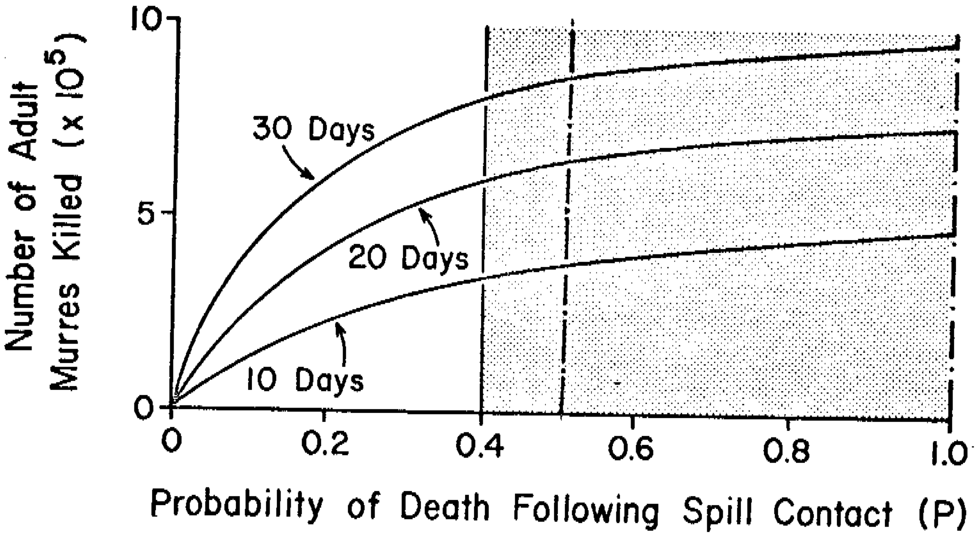


Fig. 11. The number of adult murres killed by a 1,000 km^2 offshore oil spill simulated with persistence times of 10, 20, and 30 days. The impact of the spill is plotted as a function of P, the probability of death following spill encounter. Dashed lines indicate values used in model runs; 0.5 for kittiwakes and 1.0 for murres. The stippled region corresponds to what we consider a reasonable range of values of P.

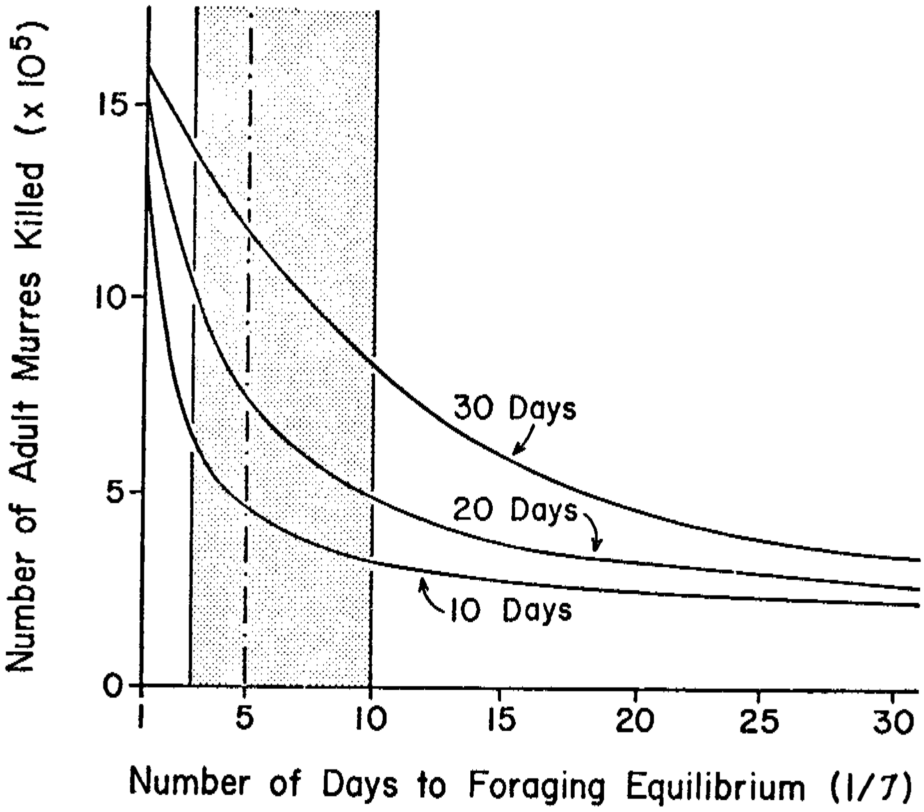


Fig. 12. The number of adult murres killed by a 1,000 km^2 offshore oil spill simulated with persistence times of 10, 20, and 30 days. The impact of the spill is plotted as a function of $1/\tau$, the number of days required for the population to reach a new equilibrium foraging distribution following perturbation. Stippled region and dashed lines as in Fig. 11.

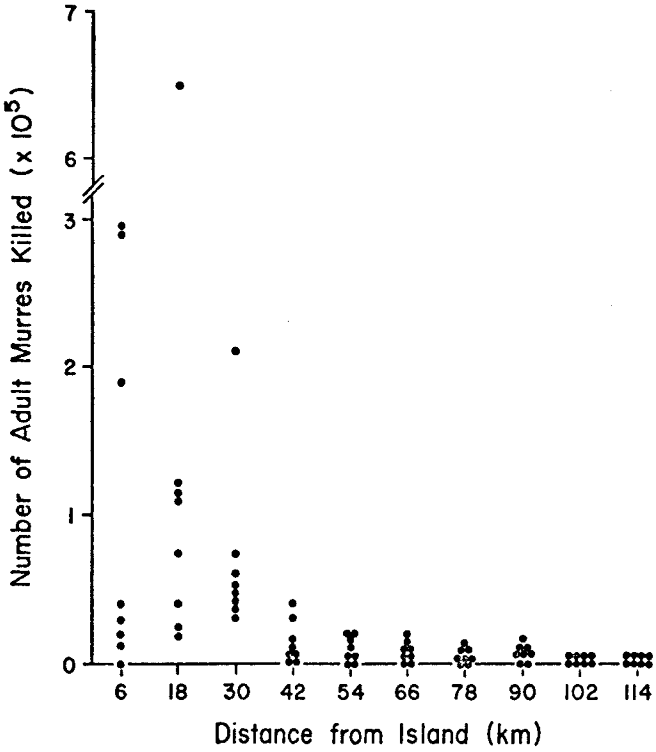


Fig. 13. The results of 80 simulations of a 50-km^2 spill persisting 10 days. Spill sites were located at 12-km intervals along radii extending outward from St. George at 45^o intervals. Total murre population of St. George is 1,690,000 (Hickey 1977).

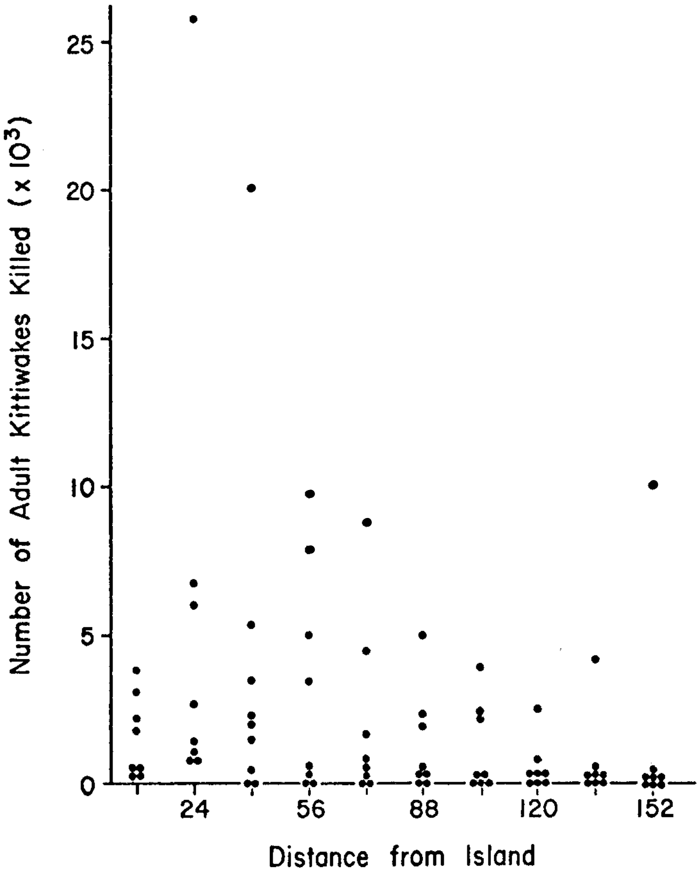


Fig. 14. As Fig. 13, for kittiwakes. Intervals along radii were 16 km. Total kittiwake population of St. George is 292,000.

down into the potential lease area along the shelf break would seem especially sensitive to perturbations (see Fig. 8).

Scenarios

The purpose of this modeling program is ultimately to provide a management tool for evaluating the potential effect of specific oil development policies on seabirds. As such, its optimal use is to provide scenarios that can ultimately be based on projections of those policies. As an example of the sorts of analyses that the model can provide, we present three oil spill scenarios and their projected impacts on the murres and kittiwakes of St. George. While we believe the bases of these scenarios, in terms of the oil spill magnitudes, trajectories, and persistence, are realistic, they are not based upon actual studies of oil dynamics in these oceanic areas.

Spill

Scenario A.--(Fig. 15)

Time: 22 June to 7 July

Origin: 24 km E. St. George

Direction: N.W., partly encircling the island

Maximum extent: 455 km^2 (approximately 1,000 barrels)

Effect on populations:
  Murres
    Reduction in adult population: 39% (627,500 killed)
    Reduction in fledgling production: 69%
    Years to population recovery: 19
  Kittiwakes
    Reduction in adult population: 15% (42,500 killed)
    Reduction in fledgling production: 27%
    Years to population recovery: 4

A moderate sized spill in mid-breeding season occurs near St. George and is carried inshore by currents. Murres are strongly affected because this region is one of their principal feeding grounds. Kittiwakes are less adversely affected, as their activities are not as concentrated in the vicinity of the island. The effect of the spill on the age structure and phenology of the breeding season for murres is shown in Fig. 17, which may be contrasted with an average year, Fig. 16.

Spill

Scenario B.--(Fig. 18)

Time: 5 August to 18 August

Origin: 60 km S.E. St. George

Direction: S.W., maintaining approximately the same distance from St. George

Maximum extent: 1,498 km^2 (approximately 3,500 barrels)

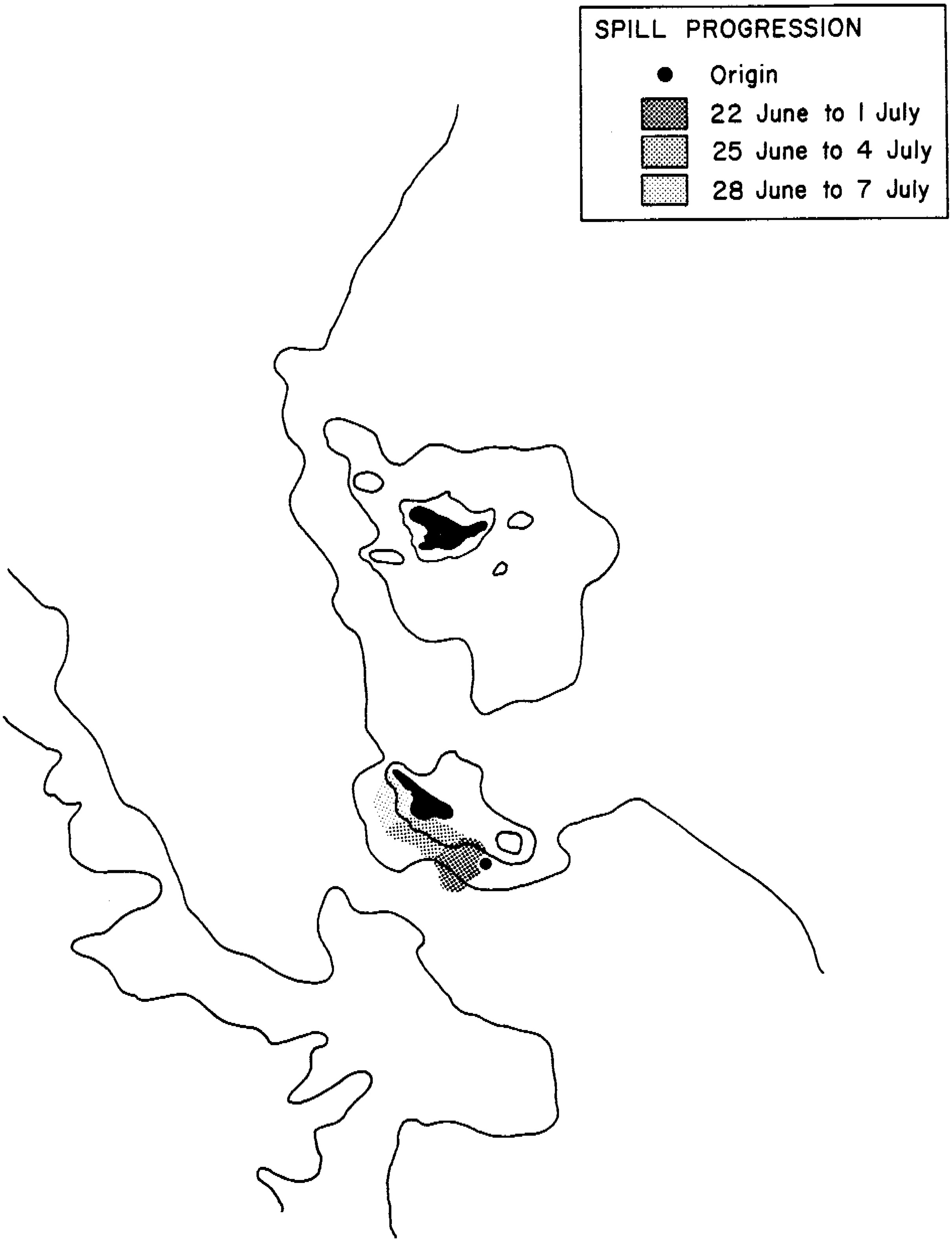


Fig. 15. Spill progression for scenario A.

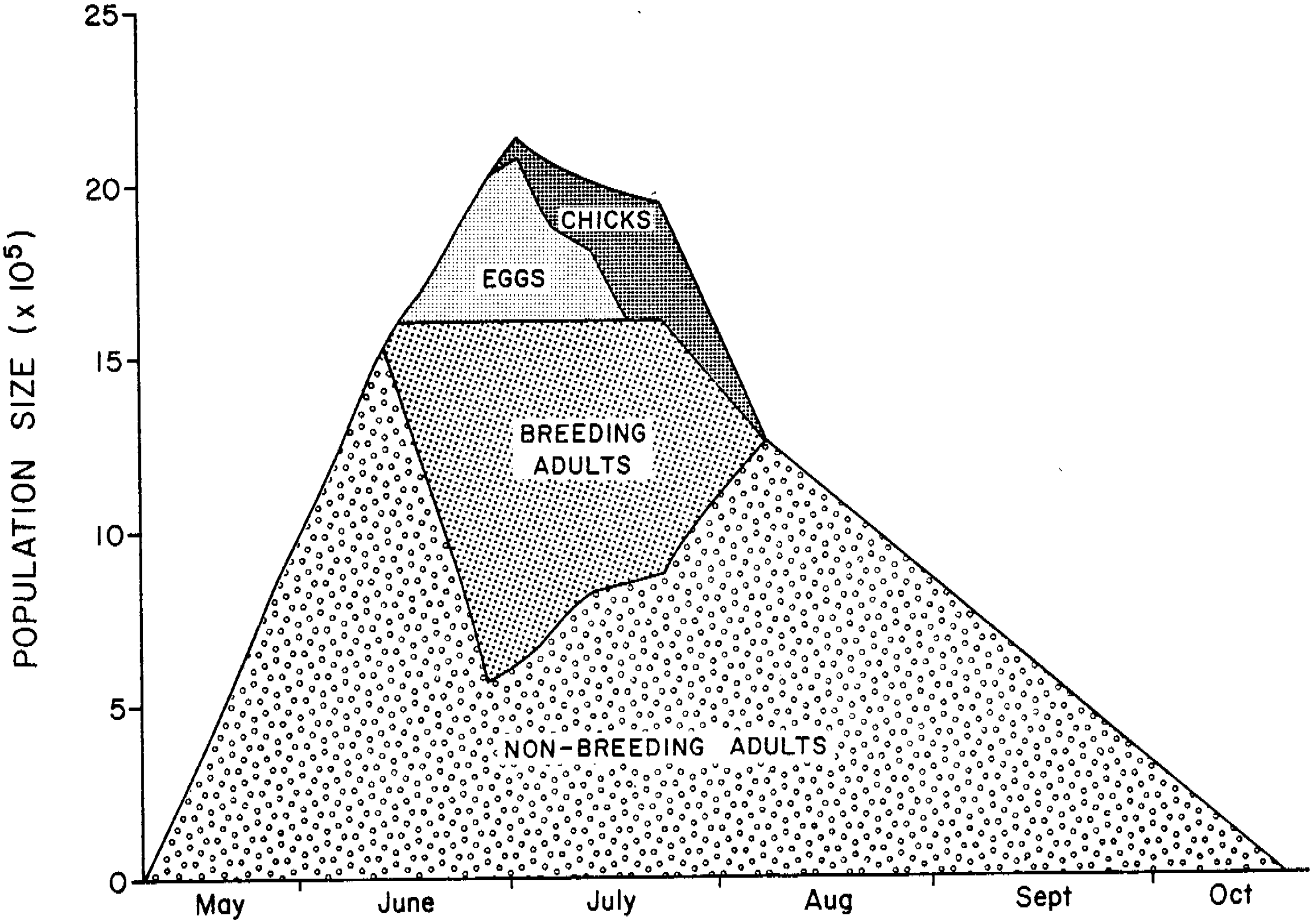


Fig. 16. Model age structure and phenology of the St. George murre population during a normal year. The width of each band is equal to the number of individuals in that category.

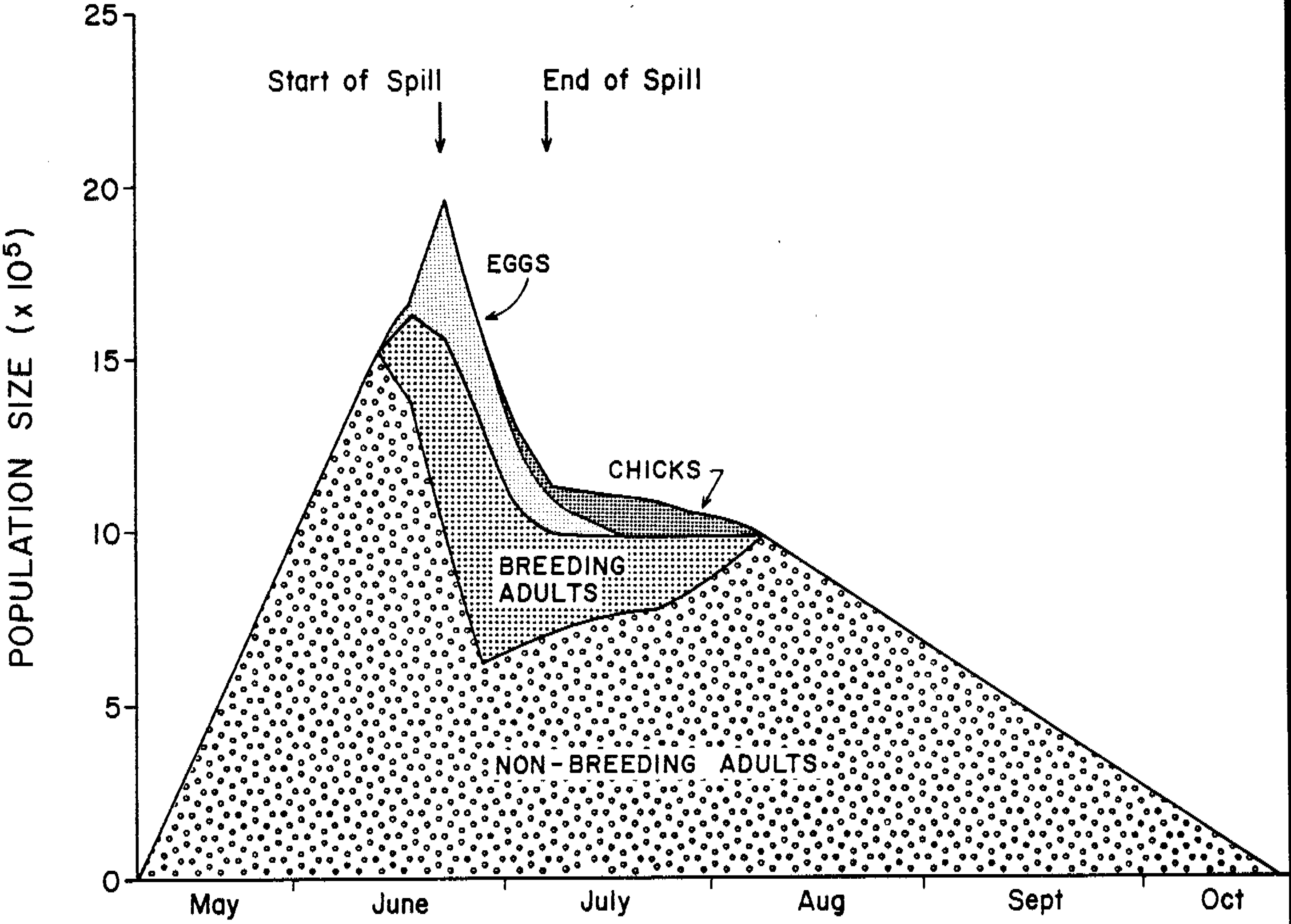


Fig. 17. Model age structure and phenology of the St. George murre population showing the effects of spill scenario A.

Fig. 18. Spill progression for scenario B.

Effect on populations:
  Murres
    Reduction in adult population: 6% (93,600 killed)
    Reduction in fledgling population: 14%
    Years to population recovery: 2
  Kittiwakes:
    Reduction in adult population: 14% (41,460 killed)
    Reduction in fledgling population: 8%
    Years to population recovery: 4

A relatively large spill occurs late in the breeding season 60 km off of St. George and drifts southwest with prevailing winds across the shelf break. Because this region is an important feeding area for kittiwakes but beyond the normal distance flown by murres, the kittiwakes are relatively more severely affected. Kittiwake chick mortality is also higher proportionately because many of their chicks are not yet fledged. The age structure and phenology resulting from such a scenario is compared with that of a normal year for kittiwakes in Figs. 19 and 20.

Spill

Scenario C.--(Fig. 21)

Time: 27 June to 27 July

Origin: 24 km W. St. George

Direction: south and west, partly encircling the island

Maximum extent: 1,680 km^2 (approximately 4,000 barrels)

Effect on populations:
  Murres
    Reduction in adult population: 68% (1,094,000 killed)
    Reduction in fledgling productivity: 96%
    Years to population recovery: 37
  Kittiwakes
    Reduction in adult population: 10% (28,200 killed)
    Reduction in fledgling productivity: 15%
    Years to population recovery: 3

A large spill occurs in mid-breeding season 24 km off of St. George and is carried around the island by inshore currents. The spill persists for 30 days over one of the principal murre foraging regions, resulting in 68% adult mortality. Kittiwakes are much less severely affected. The murre population requires nearly 40 years to recover.

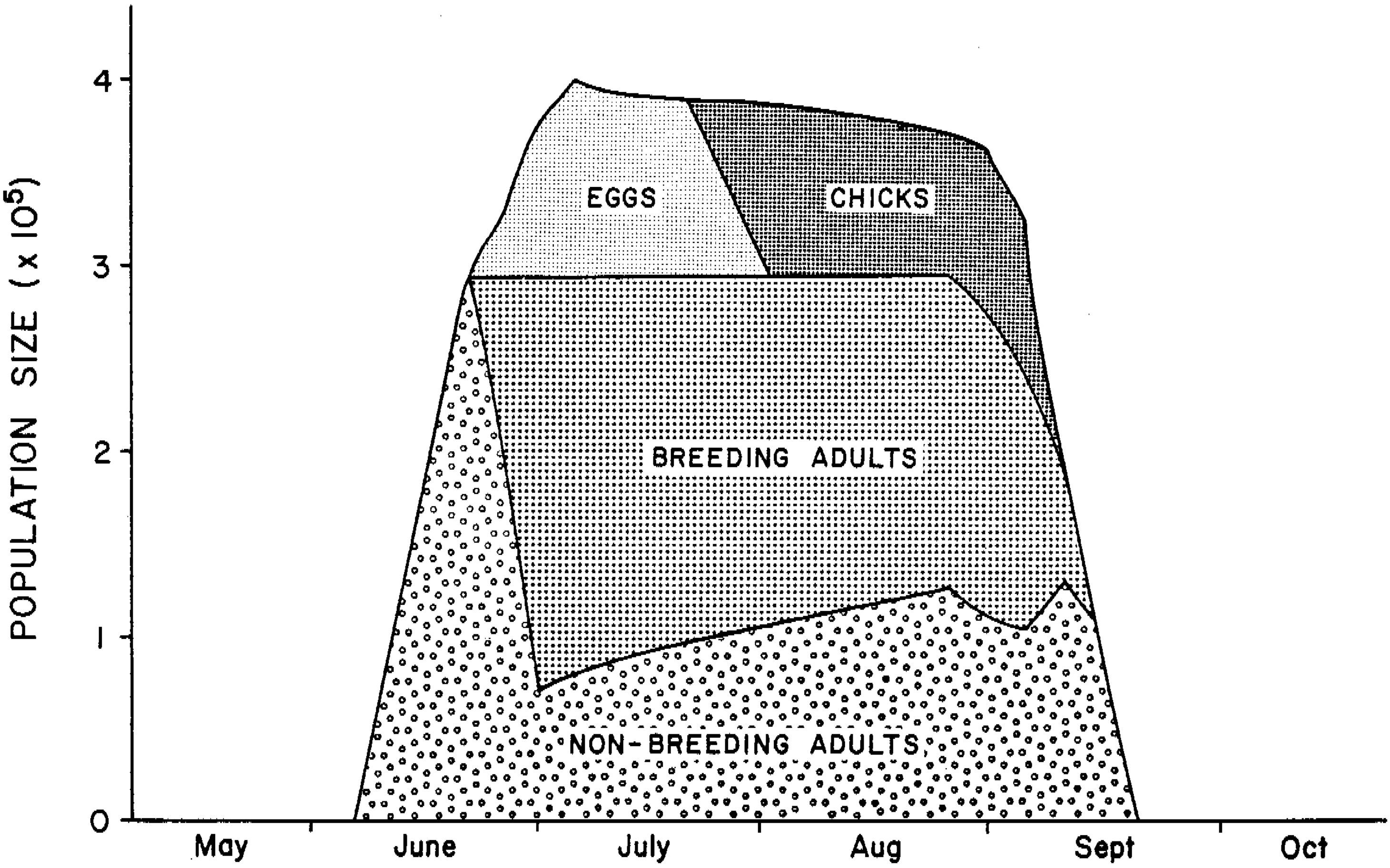


Fig. 19. Model age structure and phenology of the St. George kittiwake population during a normal year. The width of each band is equal to the number of individuals in that category.

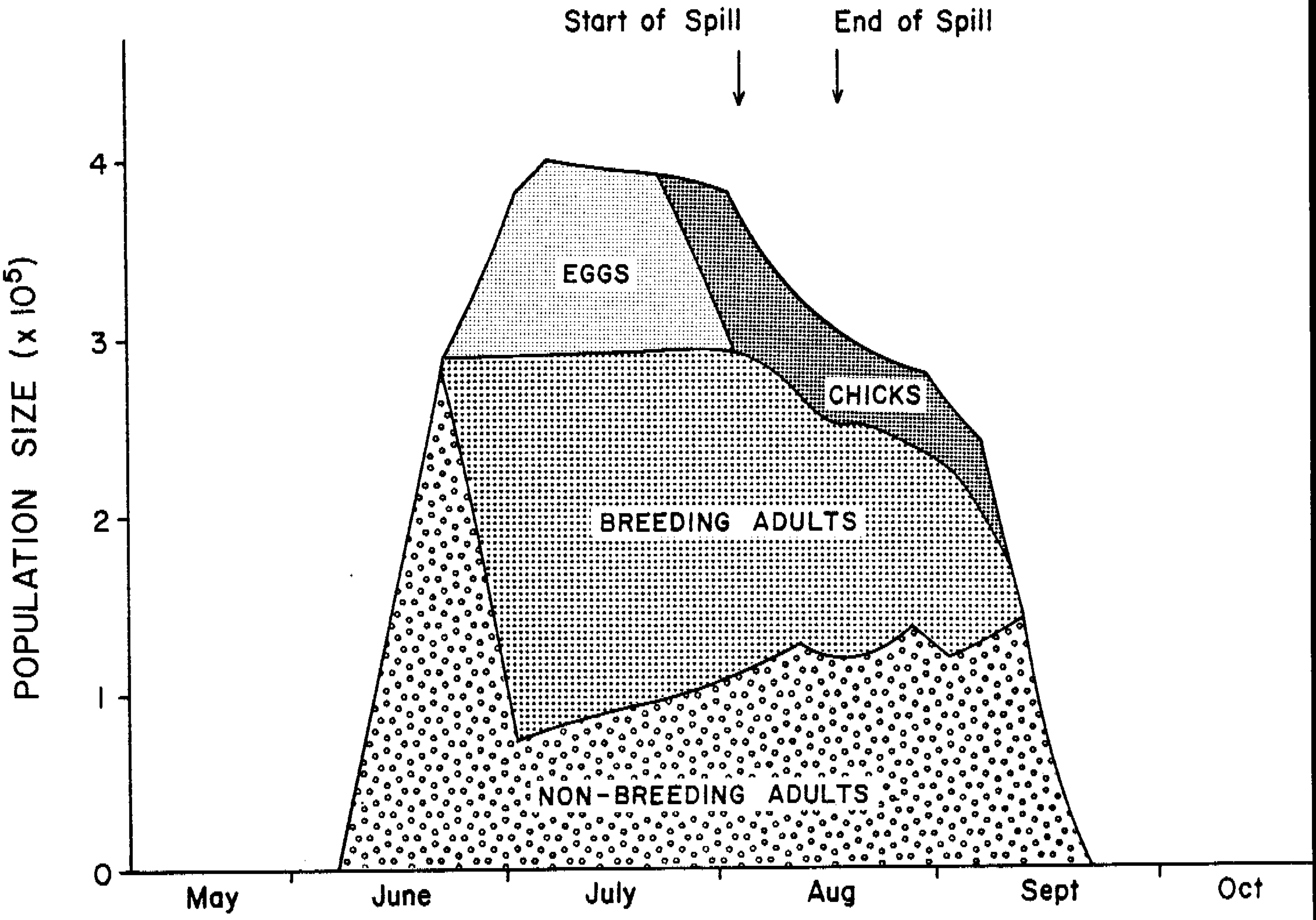


Fig. 20. Model age structure and phenology of the St. George kittiwake population showing the effects of spill scenario B.

Fig. 21. Spill progression for spill scenario C.

LONG-TERM EFFECTS

In the above section we considered the short-term effects of oil spills on the behavior and survival of murres and kittiwakes on the Pribilof Islands. Now we use computer simulation to examine the long-term effects of spills and/or oil development on these populations. To do this, we used a model that simulates the natural birth and death processes of these populations and then introduced two types of perturbations. The first type was a one-time episode of mortality such as might occur after an oil spill; the second type slightly altered the annual survival rate or fecundity of the populations to simulate the potential effects of low level pollution and human disturbance associated with oil development. In some simulations we looked only at the first type of perturbation and in others we explored both types simultaneously. In all cases we used the time required by the population to recover to its pre-perturbation population size as our measure of the magnitude of the impact.

The Model

The model consists of an age-apecific survival schedule, derived from the literature, for 1-yr-olds, 2-yr-olds, 3-yr-olds, and adults (>4 yr old), and a constant fecundity rate for breeding adults (>5 yr old). Given the number of 1- (N1), 2- (N2), 3- (N3), 4-yr-olds (N4), and adults (N5) in year t, their survival rates (S1, S2, S3, S4), and the fecundity rate (F), the numbers in each age class in year t + 1 can be calculated with the following equations:

$$
\begin{aligned}
N1(t+1) &= N5(t) \cdot F \\
N2(t+1) &= N1(t) \cdot S1 \\
N3(t+1) &= N2(t) \cdot S2 \\
N4(t+1) &= N3(t) \cdot S3 \\
N5(t+1) &= [N4(t) + N5(t)] \cdot S4
\end{aligned}
$$

The model is run until a stable age distribution (SAD) is reached. SAD is defined as less than a 0.1% change per yr in all age classes.

To conduct simulations, we introduced a one-time mortality factor in 5% increments from 5 to 100% on single or various combinations of age classes. Each case represented a possible one-time oil-spill-related mortality scenario. The following scenarios will be presented: (1) mortality of the first-year age class (the results were essentially the same for any single sub-adult age class), (2) equal mortality effects on all sub-adult age classes, (3) mortality of adults only, (4) equal mortality effects on adults and chicks (the first age class), (5) unequal mortality effects on adults and chicks, and (6) equal mortality of all age classes. The first and second scenarios were included primarily to contrast the scenarios involving adults, although they might represent the effects of spills in the fall or winter in areas where only these age classes are found (unfortunately we do not know how realistic these scenarios are, as we have no data on the migration routes or wintering areas of different age classes of murres or kittiwkaes). The third scenario represents the probable impact of a spill before egg-laying, when most of the birds at the islands are breeding adults. The fourth scenario represents the effect of a spill during the period when chicks are accompanying a parent at sea. The fifth scenario simulates the effect of a spill when there are eggs and/or chicks on the cliffs (if proportion q of the adults survive and a chick survives only if both its parents survive, then proportion q^2 of the chicks will survive). A spill affecting the entire population uniformly is simulated by the sixth scenario; this might occur during the winter if all age classes winter in the same area. The major emphasis will be placed on the third, fourth, and fifth scenarios, as these concern the period during which the populations are the most sensitive to the negative effects of oil spills in the St. George lease area, and because it is possible that a substantial proportion of these populations winter outside the St. George lease area.

On the one-time mortality episodes we superimposed a decreased fecundity or annual survival rate of selected age classes in some of the simulations. In addition, we increased survival and fecundity in order to examine the sensitivity of the model to slight changes in these parameters in both directions, and to illustrate the form and magnitude of possible positive effects of oil development on some species, perhaps through the removal of a competing species. In every case, we used the number of years required for the population size to recover to its pre-perturbation level as the response measure.

Model Inputs

We used one survival schedule for both murre species that was obtained from data on several populations of Common Murre and a few of Thick-billed Murre in the north Atlantic (Birkhead 1977). There are no survival data for murres from the Pacific and Birkhead's data did not allow us to construct separate species-specific survival schedules. Most birds begin breeding in their fifth year, so we used a life table with four nonbreeding age classes and one breeding age class. Birkhead gave adult annual survival rates of 0.870, 0.871, 0.879, 0.915, and 0.937 for five Common Muree populations, all in the British Isles, and 0.910 for one population of Thick-billed Murres in Canada. From these data we chose 0.90 as a representative annual survival rate and applied it to breeding adults and to 4-yr-olds, on Birkhead's assumption that the rate is constant after the third year. Birkhead gave banding data from several populations of both species, which he used to derive the survival rate to age five. Given his assumption of an adult survival rate from age four on, we adjusted the data to give survival to age three. These rates ranged from 0.190 to 0.529 ($\bar{x} = 0.334$). We chose the following survival schedule for 1-, 2-, and 3-yr-olds that produces an overall survival rate to age three of 0.340: $S1 = 0.60$; $S2 = 0.80$; $S3 = 0.875$; and, from above, $S4 = 0.90$. We felt that an increasing survival rate from age one to three was more realistic, and we were able to use the banding data to give us some idea of the form of that increase. In fact, the results differ very little from those obtained using the same annual survival rate (the cube root of 0.334) for all three age classes.

For the fecundity rate we used the mean number of fledglings per breeding adult for all undisturbed study sites on both islands in all years (for murres this is best estimated by 0.5 times the number of fledgings per egg laid; clutch size is always one in murres, so there are two breeding adults per egg laid). This gave a fecundity of approximately 0.30 for the Common Murre and 0.35 for the Thick-billed Murre.

There are no survival data for Red-legged Kittiwakes, and the only data for Black-legged Kittiwakes are from one population in the British Isles, although those data are extensive (Coulson and White 1959, Coulson and Wooller 1976, Wooller and Coulson, 1977). We made the assumption that the data are equally applicable to both species. Kittiwakes begin breeding anywhere from their third to their seventh year, with a mean of roughly the fifth year (there were significant sexual differences in this and other parameters, but in this analysis we used the overall means). The annual breeding adult survival rate is 0.92 in the first breeding year and gradually declines to 0.789 in the eighth-seventeenth years of breeding, while the fecundity gradually increases with breeding experience. As our fecundity data are population averages, we considered all breeding adults to have a constant annual survival rate equal to the mean rate for the British population (0.83). Assuming that all birds begin breeding at age five and that the fourth-year survival rate is the same as that for birds in their first year of breeding, and using data on sub-adult survival rates, we constructed the following survival schedule: S1 = 0.79, S2 = 0.85, S3 = 0.90, S4 = 0.92, S5 = 0.83. Using the British fecundity data (F = 0.65) we found that that population has an annual intrinsic rate of increase (r) at SAD of approximately 7%. The fecundity data for the Pribilof populations show no significant differences between the two species, so we used the mean (F = 0.265) for both species (the best estimate of fecundity for the kittiwakes is 0.5 times the number of fledglings per nest). However, when we used this fecundity rate, less than half the British rate, we obtained a net annual rate of decrease of approximately 2% at SAD. This is primarily due to a much larger clutch size in the British birds (≈2) than in the Pribilof birds (1.42 for Black-legged, and 1.0 for Red-legged kittiwakes). As we have reason to believe that the Pribilofs are producing an excess of offspring, we assumed that the low fecundity rate is offset by a higher survival rate. We arbitrarily raised the mean annual adult survival rate to survival rate of the first year of breeding, which changed the survival schedule to the following: S1 = 0.79, S2 = 0.85, S3 = 0.90, and S4 = 0.92, giving an r of approximately +4%.

Results and Discussion

The effects of the different scenarios (excluding #5) on Common Murres is shown in Fig. 22. Two important conclusions can be obtained from this figure, and as we shall see, they are common to all the results. First, time to recovery is not linear, but an exponential function of the one-time mortality rate. In other words, the recovery time from a 50% mortality episode is more than twice that from a 25% episode. Second, the population is most sensitive, in terms of time to recovery, to adult mortality. Mortality on even all of the sub-adults has only one-third the effect of mortality on the adults. Note that there is very little difference between scenarios 3 (adults) and 4 (adults and chicks equally). As we will show, oil-spill-related mortality rates of greater than 50% are not unreasonable; such would give a recovery time in excess of 50 yr.

Chronic changes in annual survival of adults have even more drastic effects. Very small decreases in annual adult survival result in very large increases in recovery time (Fig. 23). A 1% decrease results in a four-fold increase in recovery time, whereas a 1% increase results in only a 1.7-fold decrease. Indeed, a decrease of greater than 1.3% gives the population a negative r and makes recovery impossible (Fig. 24); this is not strictly correct, as it is likely that fecundity and survival rates are density-dependent and as density decreases, they will increase, giving the population a positive r. We were unable to include a density-dependent component in our model because of the lack of data, and at this point we are uncertain of the magnitude and direction of bias in recovery time introduced by its absence from the model; we suspect that it would decrease recovery times slightly from those that we have predicted. Increases in the adult annual survival rate will have relatively small effects on recovery time (Fig. 23). Therefore, if our choice of an adult annual survival rate from Birkhead's data (1977) is below the true value for the Pribilofs, our results should be accurate. However, if it is high, then recovery times may be longer than we have shown. Figure 25 again

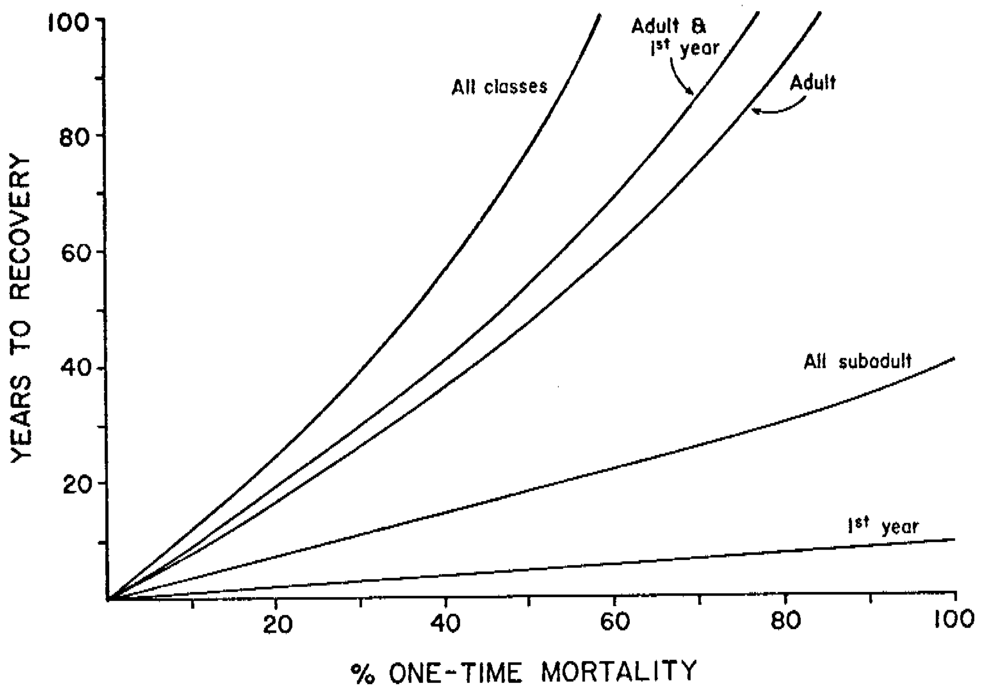


Fig. 22. Time to recovery as a function of one-time mortality of various age-class combinations of Common Murres.

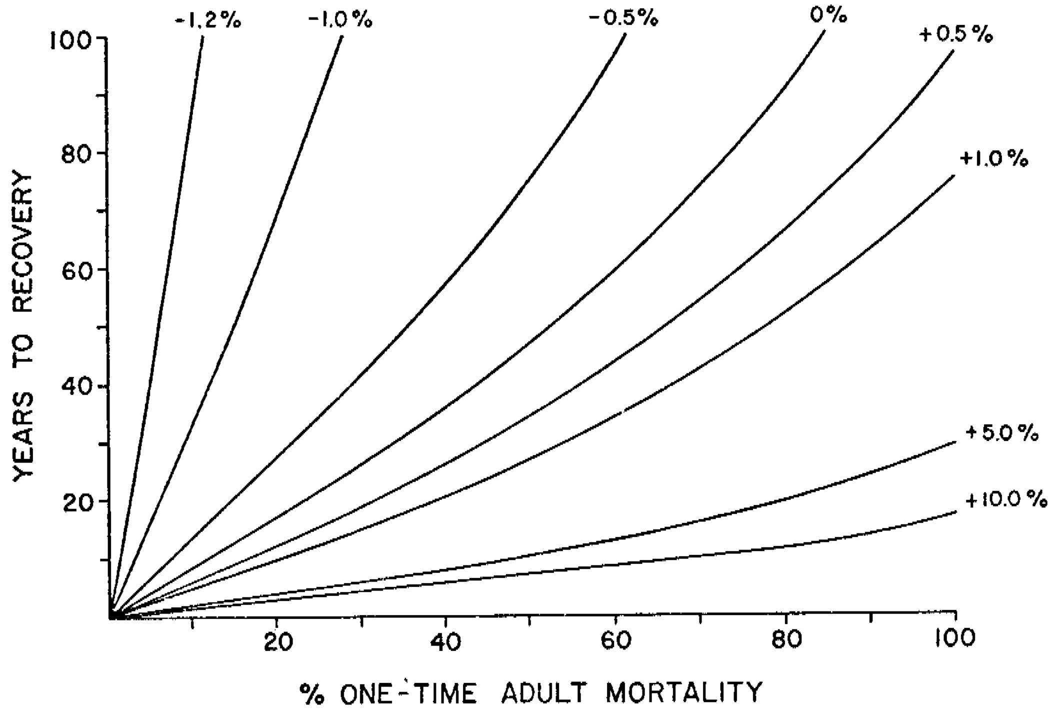


Fig. 23. Time to recovery as a function of one-time adult mortality at different levels of change in the mean adult annual survival rate of Common Murres.

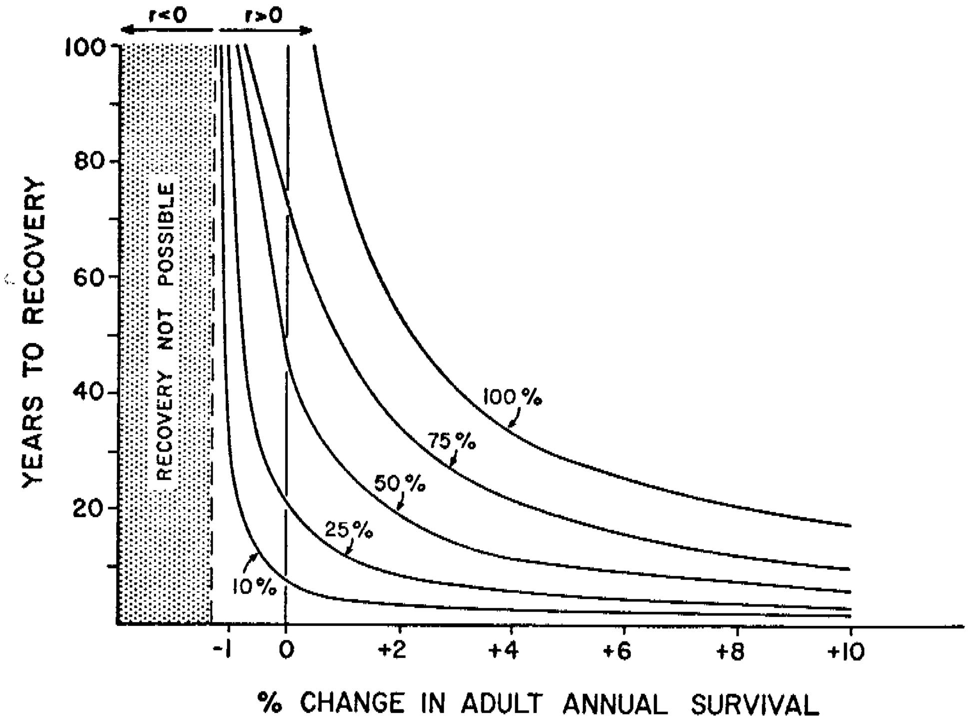


Fig. 24. Time to recovery as a function of change in mean annual adult survival rate at different levels of one-time adult mortality of Common Murres

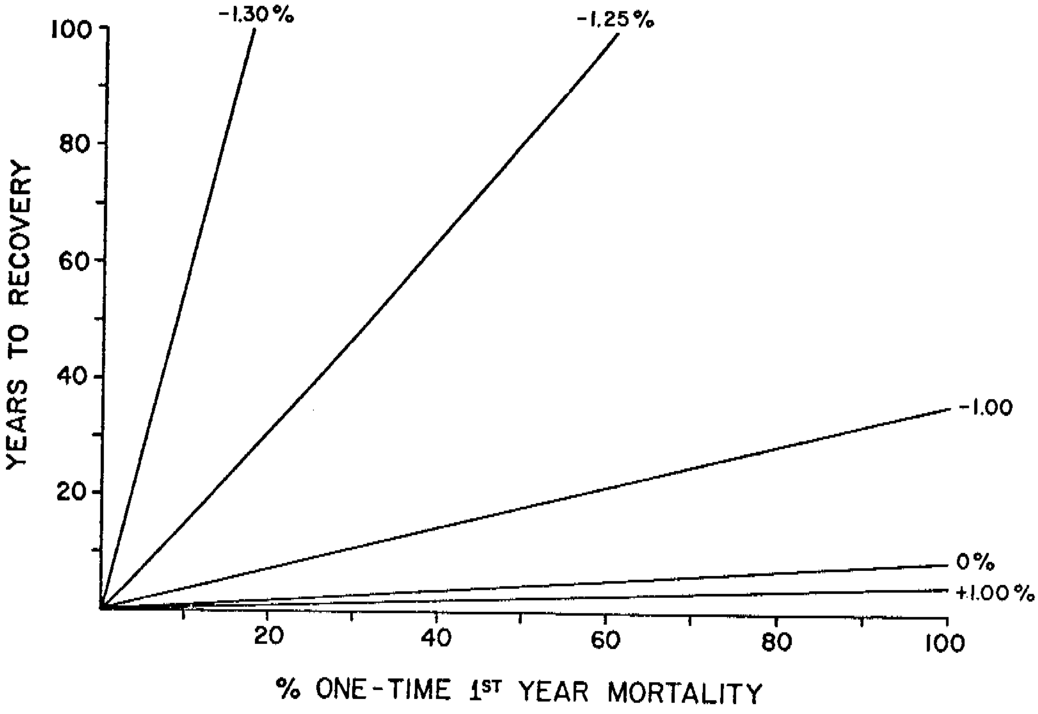


Fig. 25. Time to recovery as a function of one-time adult mortality at different levels of change in mean first year-class annual survival rate of Common Murres.

shows how relatively insensitive the population is to changes in sub-adult annual survival (compare with Fig. 23). The results for Thick-billed Murre differ only in the position of the curves (Figs. 26 and 27). For any given scenario and perturbation level, it takes Thick-billed Murres fewer years to recover than it takes Common Murres (compare Figs. 22 and 26). This is due to the higher mean fecundity rate of the Thick-billed Murre, which gives them an r of approximately 2% versus 1% for the Common Murre. Note that the dominance of the adult age class in determining the population's recovery time from one-time mortality is somewhat less when changes in annual survival are considered (Fig. 27).

The introduction of a permanent change in fecundity was examined using the data for Thick-billed Murres and scenario number 5 (this was the only place where we used scenario 5). The population turned out to be moderately sensitive to a fecundity change (Fig. 28).

Time to recovery for a given simulation was shorter for the kittiwakes than the murres because of their larger r value (Fig. 29), which results in the curves being shifted downward (compare to Figs. 22 and 26). Likewise, it takes a proportionately larger decrease in annual adult survival to reach the inflection point in the recovery curves near r = 0 (Fig. 30). A comparison of the sensitivity of kittiwakes and murres to fecundity changes shows how it is correlated with their differences in r (Fig. 31).

As we saw in the *Model Inputs* section, there is a large amount of variability in the survival and fecundity rates. The effect of this variability will be to introduce variance in the time to recovery, and, not unexpectedly, variability in annual adult survival and fecundity will have the greatest effect, although there is generally greater variability in sub-adult survival. An example of the effect of this variability is shown for kittiwakes in Fig. 32. We randomly selected adult annual survival and fecundity (sub-adult survival rates remained constant) from normal distributions with means and standard deviations given by the same data used in the other simulations; this was done separately for each year of the recovery period of the simulations. The ranges and standard deviations of recovery times were surprisingly large; the means were unchanged, as should be expected. The standard deviation is the best variance measure here, as we made 250 iterations of each simulation, and by that token the ranges are not as helpful, as they are extremely sensitive to sample size. This variability in recovery time suggests to us that the mean recovery times provided by the model may not be as useful as the results of the deterministic model suggest. This analysis tells us that the system is highly unpredictable, and will remain so as long as we are ignorant of the environmental causes of the variation in annual survival and fecundity.

CONCLUSIONS

Although our analyses of short-term and long-term effects of oil perturbations on breeding populations of murres and kittiwakes on the Pribilof Islands are not as complete and detailed as we might wish, several consequences of petroleum development in this area are quite obvious. The model analysis of the spatial distribution of birds and their foraging efforts indicates that beyond 50 km from the breeding colonies murres are likely to be relatively insensitive to petroleum events. This, of course, is because the main body of the population restricts activities to areas closer to the islands; we suspect that the generally uniform, low-density distribution of murres beyond 40-50 km shown in Fig. 6

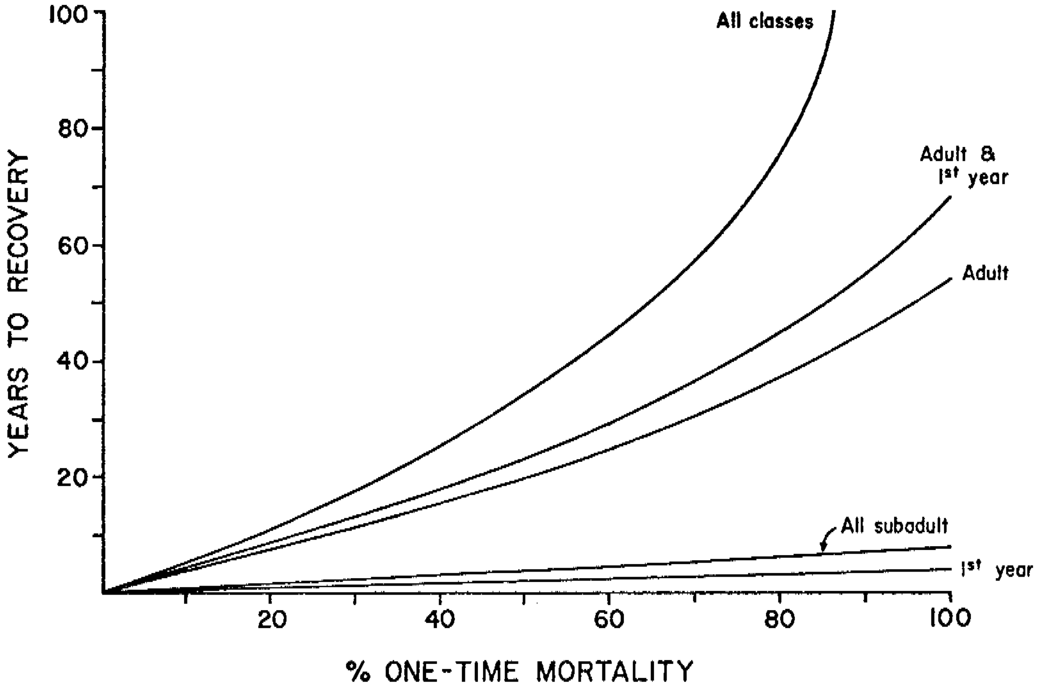


Fig. 26. Time to recovery as a function of one-time mortality of various age-class combinations of Thick-billed Murres.

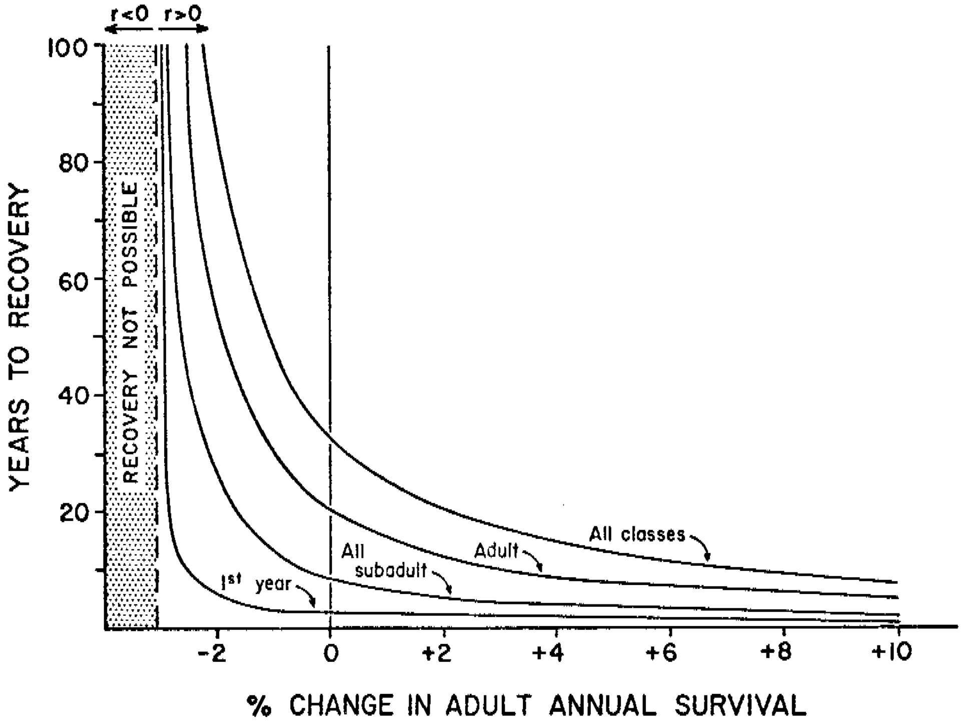


Fig. 27. Time to recovery as a function of change in mean adult annual survival rate of various age-class combinations, at 50% one-time mortality, of Thick-billed Murres.

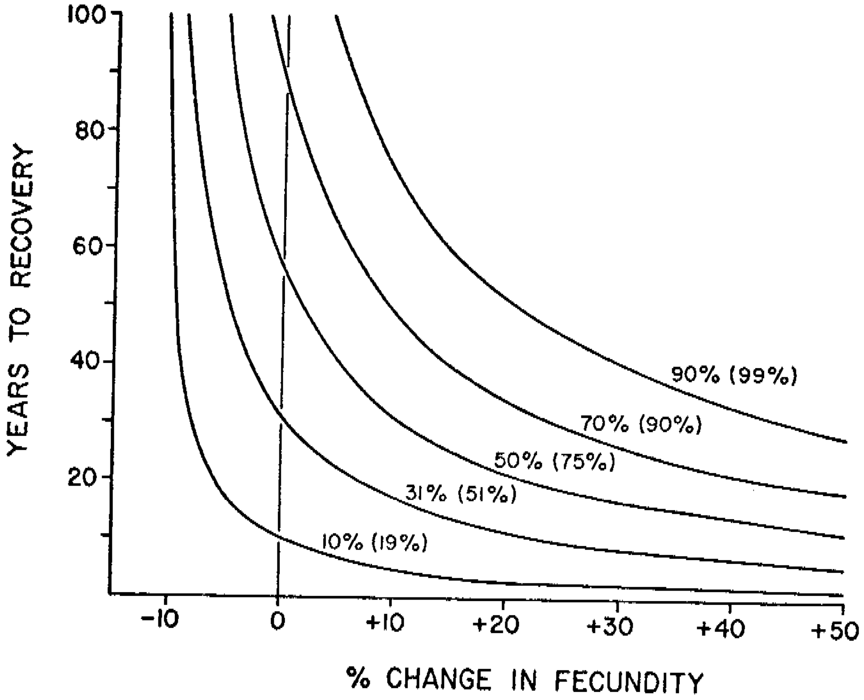


Fig. 28. Time to recovery as a function of change in mean fecundity rate at different levels of one-time adult and (in parentheses) chick mortality of Thick-billed Murres.

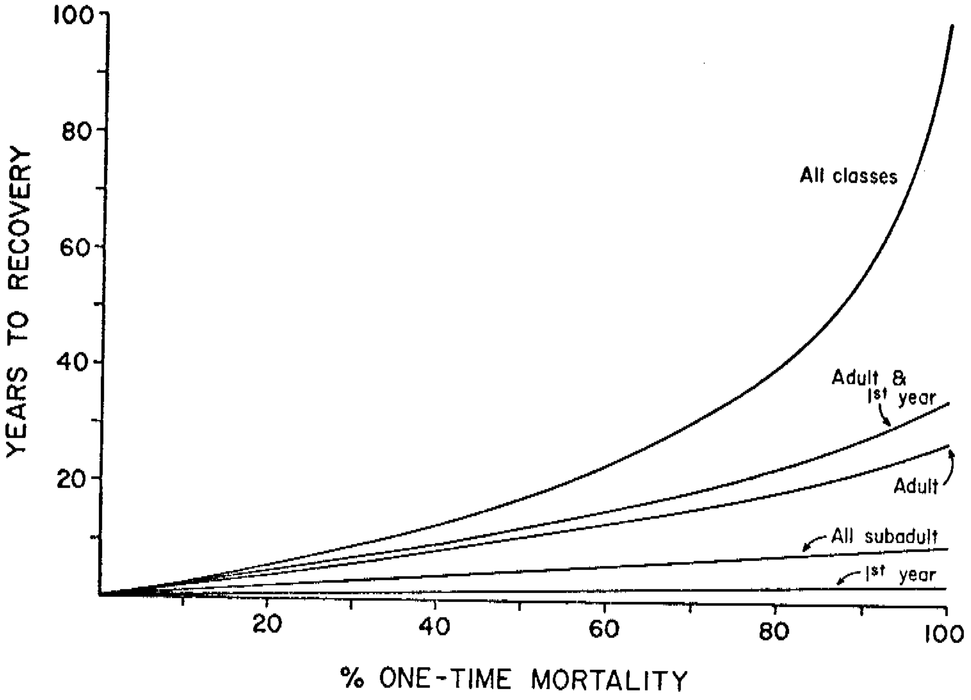


Fig. 29. Time to recovery as a function of various age-class combinations of kittiwakes.

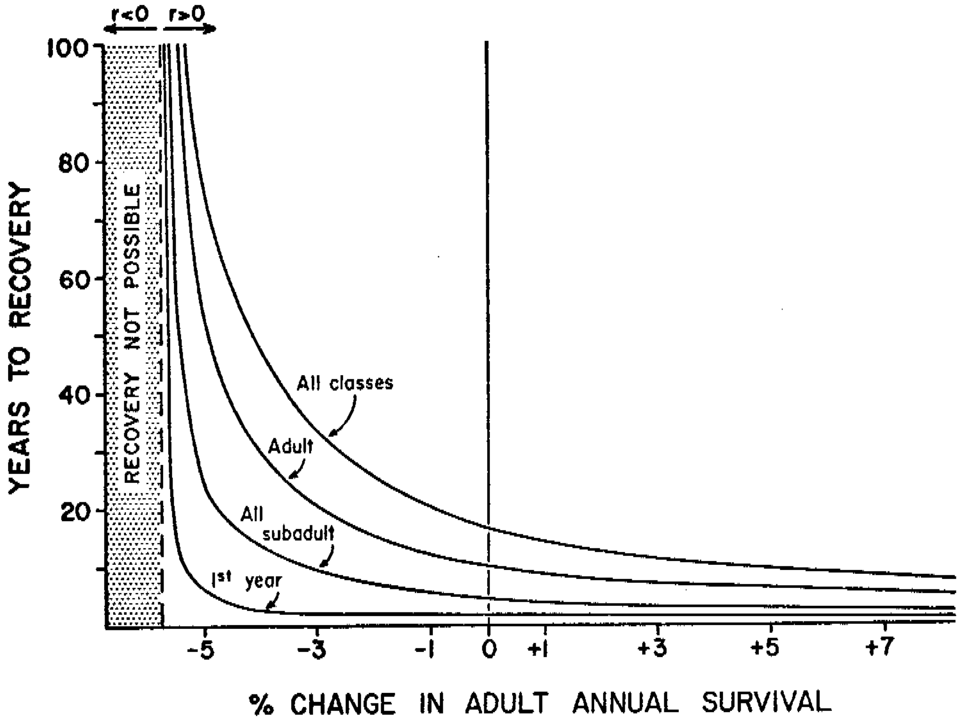


Fig. 30. Time to recovery as a function of change in mean adult annual survival rate at different levels of one-time adult mortality of kittiwakes.

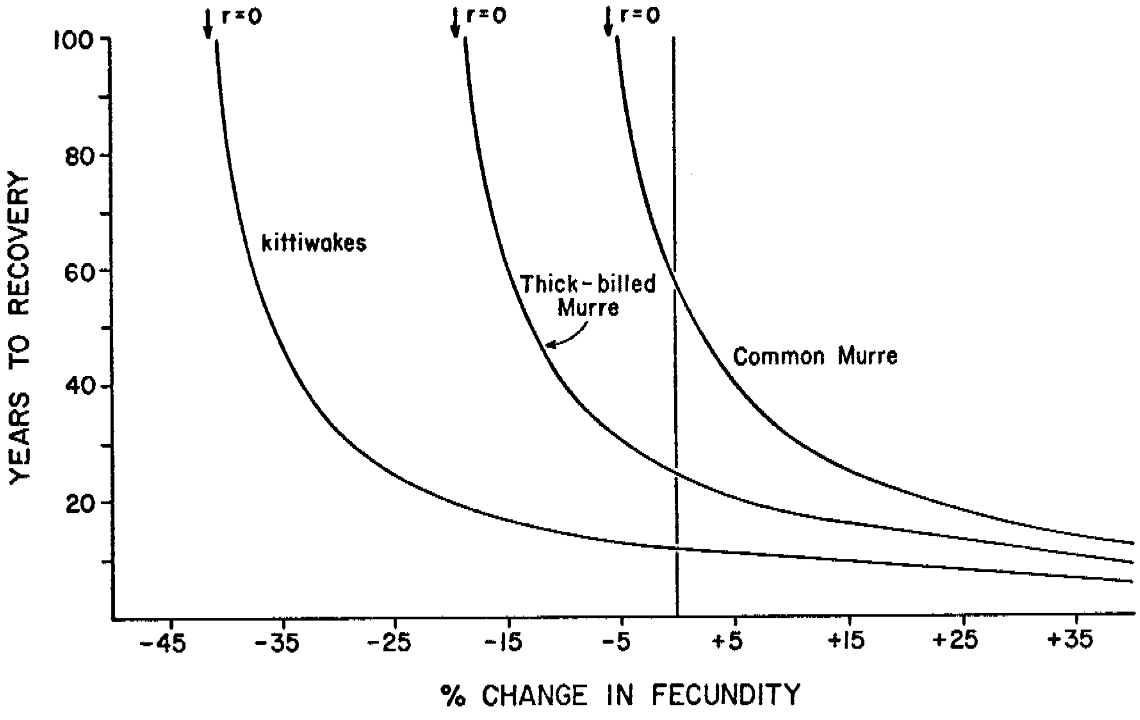


Fig. 31. Time to recovery as a function of change in mean fecundity rate, at 50% one-time adult and chick mortality, of Common Murres, Thick-billed Murres, and kittiwakes.

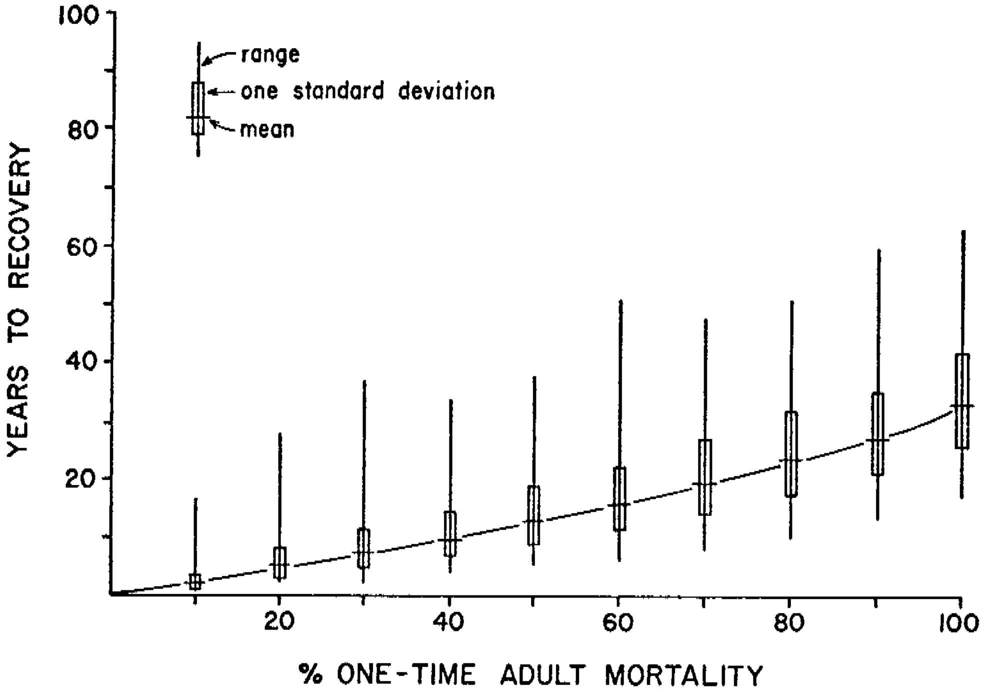


Fig. 32. The mean, standard deviation, and range in time to recovery as a function of one-time adult mortality of kittiwakes.

represents nonbreeding birds, possibly sub-adults that would further reduce the impact of an oil spill. Within 50 km of the breeding colonies, on the other hand, sensitivity of murre populations to oil events is substantially greater. Our simulations indicate that even a moderate-sized spill in this area could easily lead to 30-50% mortality. A very small spill occurring at a critical location at a critical time could easily kill 40% of the population.

The sensitivities of kittiwake populations differ from those of murres in both their spatial distribution and their magnitude. Kittiwake populations may be sensitive to oil spills in two areas within 30 km of St. George (Fig. 8), but the main area of their off-island distribution, and thus of their sensitivity, is in a corridor extending toward the continental shelf break SSE of St. George. This area corresponds with portions of the Lease Area adjacent to St. George, and therefore must receive close attention in any development plans. The region in which oil spills could adversely affect kittiwake populations extends at least 160 km from St. George in this direction; as census values for areas at greater distances were not analyzed, the outer boundaries of this zone of potential impact are unknown. Because kittiwake populations are generally more dispersed in their foraging than are murres, they are generally somewhat less sensitive to perturbations. A small, localized spill that might maximally lead to 40% mortality among murres, for example, might produce only a 9% mortality in the total kittiwake population. Nonetheless, because most of the world population of Red-legged Kittiwakes breeds on St. George, small percentage impact on the kittiwake populations are potentially much more devastating to the species population than are somewhat larger impacts on murres.

The most important finding of our long-term modeling exercise is that, in terms of vulnerability to oil development, the most sensitive age-class component of the Pribilof murre and kittiwake populations is breeding adults. The greatest recovery times occur after perturbations of annual adult survival or of fecundity. Because these species have long life spans (means of 10-20 yr, maxima of 25-35 yr), perturbations influencing sub-adults are relatively unimportant to the long-term dynamics of the populations. It takes Common Murres less than 5 yr, on the average, to recover from a single complete breeding failure; kittiwakes would recover in an average of 3 yr. However, a loss of all the adults during a single year would result in a recovery time of well over 100 yr for Common Murres, and an average of 28 yr for kittiwakes. We must emphasize that these species differences should be thought of as differences between populations with different intrinsic rates of increase, and until we have survival data on the Pribilof Islands' populations, we will not be able to assess the relative sensitivity of murres and kittiwakes at all reasonably.

Our analyses have shown that the chronic effects of oil development may be much more damaging than the short-term effects of an oil spill, because of the extreme sensitivity of these populations to slight changes in annual survival (especially of adults) and in fecundity. In general, the populations should be able to recover from oil spills, although in some cases it may take decades, but a permanent decrease in annual survival or fecundity may push a species over the edge, making it unable to persist on the Pribilofs. This argument is especially germane to Red-legged Kittiwakes, for as we noted above, over 95% of the world population of this species breeds on St. George. In addition, several other seabirds that breed on the Pribilofs are near the edges of their species ranges, increasing the probability that small environmental changes may push them to local extinction on the Pribilofs. This points to the urgent need for more data on the

Pribilof Islands' seabirds. We conclude that, given the meager knowledge at hand, the most logical course is a conservative one, with respect to oil development. Every effort should be made to eliminate the possibility of causing permanent changes in survival or fecundity rates. We believe that this can be achieved with careful attention to three areas: (1) the placement of drilling rigs or transport channels in areas that are not important feeding areas or movement corridors of the birds; the short-term model analyses suggest where some of these might be located; (2) the levels of pollutants in the birds' prey; and (3) the amount of direct disturbance of the nesting colonies by construction, recreation, ship, airplane, and helicopter activities.

IX. NEEDS FOR FURTHER STUDY

Despite the fact that FY 79 funding for RU #108 was to cover analyses of seabird colony data gathered in the Kodiak Lease Area, this report has considered exclusively the seabird colonies associated with the Pribilof Islands. This departure from our initial plans requires some explanation. There are several reasons that prompted us to direct the research in this way:

(1) With the transfer of RU 108 and its staff to the University of New Mexico, delays of several sorts were encountered. Some of these were anticipated and included in our initial planning, but we did not anticipate the deterioration of cooperation in the Zoology Department at Oregon State after the departure of the Principal Investigator, while 2 months remained on the FY 78 contract with that institution. Neither did we anticipate the rather inefficient and awkward computing system at the University of New Mexico. Because this computing system was really quite different from that at Oregon State, it took much longer than we initially planned to activate existing programs at UNM and then to construct new programs.

(2) The model that has been described and applied in this report is quite detailed in its structure, and involves many new routines. For most of these no hard data existed to guide our modeling efforts, and this forced us to explore the literature rather widely in order to develop sufficient intuitions to approximate model functions in the absence of real data.

(3) Because our FY 78 activities concentrated on the dynamics of the Pribilof Islands' colonies, we knew that system well, and had prepared a data base that was thoroughly analyzed and compatible with our model approaches. To switch to Kodiak area data sets at this stage of model development would have delayed the progress on model structuring substantially, as we would have needed to obtain the data and subject them to a variety of initial analyses before finding those values required for model operations. We chose to continue model development until we had completed those modeling exercises that we set out to do; with a complete family of models in hand, analysis of additional data sets would, in the long run, be facilitated.

(4) An unanticipated benefit of our delays in implementing analyses of Kodiak area data was that it permitted a substantial reduction in the amount and variety of data required of other investigators. In the initial operations of the BIRD II model, some 40 input variables were required; many of these were obtained from analyses of data sets, rather than being directly contained in the data sets. This development of our current models to the stage of operational effectiveness has allowed us to specify exactly what is required of other OCSEAP investigators in order to conduct spatial analyses of colony dynamics, thereby saving both them and us a fair amount of effort in working over data that, it now seems, are not required in our model analyses. We could not have anticipated which input variables would be needed before completing this latest modeling phase.

The Next Stage: Analysis of Kodiak Colony Dynamics

Now that the final stage of model development has been nearly completed (see below), we can turn to the analysis of the spatial energetic dynamics of selected seabird colonies in the Kodiak Lease Area. This will involve gathering appropriate information from the reports of several OCSEAP RUs, and/or from the investigators actually involved in gathering the field data. Following some initial analyses of these data in our laboratory to prepare them for the simulation programs, we will conduct an array of model analyses of these data sets. As the models are now virtually complete and operational, this final stage of model analysis will be swift once the data are in hand and prepared for computer access.

At this time, the following RUs seem likely to be able to contribute information for our model analyses; each will be contacted within April 1979 to establish procedures for data exchange.

RU #341--Population dynamics and trophic relationships of marine birds in the Gulf of Alaska and southern Bering Sea. U.S. Fish and Wildlife Service, Anchorage (note: we intend to emphasize colony studies conducted on the Barren Islands, Kodiak Island, the Semidi Islands, and Ugaiushak Island).

RU #338--Seabird colony catalog. U.S. Fish and Wildlife Service, Anchorage.

RU #337--Seasonal distribution and abundance of marine birds. U.S. Fish and Wildlife Service, Anchorage.

RU #5--Distribution, abundance, community structure, and trophic relationships of the nearshore benthos of the Kodiak Shelf, Cook Inlet, Northeast Gulf of Alaska, and the Bering Sea. Institute of Marine Science, University of Alaska, Fairbanks.

RU #551--Seasonal composition and food web relationships of marine organisms in the nearshore zone. NMFS, Seattle.

RU #552--Seasonal composition and food web relationships of marine organisms in the nearshore zone, including icthyoplankton, meroplankton, forage fishes, marine birds, and marine mammals. Alaska Department of Fish and Game.

RU #553--Seasonal composition and food web relationships of marine organisms in the nearshore zone of Kodiak Island, including icthyoplankton, meroplankton, forage fishes, marine birds, and marine mammals. Fisheries Research Institute, University of Washington, Seattle.

RU #239--Ecology and behavior of southern hemisphere shearwaters (Genus *Puffinus*) and other seabirds, when over the Outer Continental Shelf of Bering Sea and Gulf of Alaska during the summer. University of Calgary, Alberta.

Not all of these RUs have involved studies of marine birds, but some may provide some appropriate background information to enable us to construct realistic simulation scenarios of oil perturbations.

From those studies that have considered seabird colonies and/or oceanic distributional patterns during the breeding season in the vicinity of colonies, we will require the following information to conduct model analyses of the sorts presented in this report (other data may be necessary to conduct other model analyes, but these requirements should be minor):

A. *Demographic Variables*

1. Average growth rates of chicks of each major seabird species at three phases of the nestling stage. This requires data on

age-specific growth curves for the populations of each species at each of the breeding colonies analyzed.

2. Incubation period for each species (days)
3. Weight of chick at hatching (g) } preferably $\bar{x}$, SD, and range
4. Weight of chick at fledging (g) } preferably $\bar{x}$, SD, and range
5. Fledging success (% young that successfully fledge)
6. Hatching success (% eggs that hatch)
7. Beginning and ending of the population immigration period (dates)
8. Beginning and ending of the population emigration period (dates)
9. Beginning and ending of the population breeding period (dates on which egg-laying commences and terminates)
10. Maximum percentage of the total population that is breeding (% of total N that initiate nests with clutches)
11. Clutch size ($\bar{x}$, SD, and range for eggs per completed clutch)

B. *Foraging Variables*

1. Flight speed (km per min); for each species
2. Day length (average duration of daylight over the breeding season, to nearest 0.1 h)
3. Population size of each species (total N, at the peak of breeding activity)
4. Distribution of individuals of each species at sea (number observed per ocean area, area sampled, methods used, dates of sampling, weather conditions)

Further Modeling Activities

While this third phase of model development is virtually complete, we have not yet conducted some exercises designed to evaluate its performance and to provide greater resolution of the Pribilof Islands' colony dynamics and responses to perturbations. We anticipate conducting more extensive sensitivity analyses of the model described in this report, in order to evaluate how important various input variables and internal model parameters are to the derived estimates.

Identified Information Gaps

During the development of this third phase of our modeling, several rather conspicuous gaps in our knowledge of seabird systems (or of birds in general) have become apparent. While judgement of the importance of some of these will await the outcome of our sensitivity tests, two that are quite obvious deficiencies and that are of fundamental importance in model operations can be mentioned here.

(1) Our knowledge of how individuals move between the breeding colony and feeding areas at sea is gained entirely from inference. By observation at specific colony nest sites we can establish the departure and arrival schedules of known birds, and thus derive a measure of the time spent at sea for each foraging adult. From shipboard observations on transect counts at sea, we can establish point estimates of the frequency distribution of individuals of the various species occurring at a colony. Such estimates are by their very nature spotty, depending on the availability of ship cruises through appropriate areas (because cruises are usually scheduled for other purposes, key areas may be missed), and on the adequacy of census procedures. In fact, because the trajectories of ships-of-opportunity generally avoid shallow-water shoal areas, which we know to be favored feeding areas

of marine birds, there may be a systematic bias in data gathered in this manner. Moreover, while in the area of the Pribilofs we may be reasonably certain that birds seen at sea are either from the Pribilof colonies or are nonbreeding stragglers, in other areas where different colonies may have overlapping foraging zones, interpretation of such at-sea distributional data is quite equivocal. What we do not know is how much of the time a bird spends at sea (i.e. away from the colony) is spent in searching for foraging areas, how much is spent in active foraging, and how much is spent loafing or moving about in nonforaging movements. In order to tie attendance patterns at nest sites with at-sea distributional survey results, such information is critical. Moreover, the basic structure of the model that we have developed relates foraging success and the consequent survivorship of offspring to the distribution of food resources and the movements that the birds employ in exploiting these. We suggest that a well-designed, modest research program involving telemetric monitoring of the movements of small samples of individuals of several species would contribute substantially to resolving these difficulties; further, it would be cost-effective, in that it would provide detailed information on at-sea distributions at a tiny fraction of the cost of even a few days of ship-time. In addition, by tracing the details of individual foraging movements in association with known events at sea (e.g. oceanic fronts, tidal anomalies, planned oil perturbations), we would obtain a rather precise indication of how marine birds respond to variations in their environment, at relatively little expense. Because of its isolation from other colonies, such telemetry studies would be best conducted in the Pribilof colonies; alternatively, such studies could be scheduled concordantly with other OCSEAP investigations that would provide detailed information on oceanic conditions in the areas used by the birds.

(2) In order to derive a function relating reductions in food delivery rate to chicks (through increases in average trip time) to increased chick mortality, we have had to make several assumptions about the fasting endurance of chicks, the effect of reduced growth rate on fledging probabilities, and the relations of these to the developmental stage of the chick. Virtually no information is available on such functions for seabirds. We believe that the functions we have used are realistic, but they do represent a best approximation derived from careful intuition, and some empirical foundation would be nice to have. This might be obtained through rearing chicks of several species under laboratory conditions, where their growth rates and the influences of alterations in food delivery rates could be closely controlled. Alternatively, field monitoring of nests with different numbers of adults in attendance, or with the adults removed, might yield information on fasting endurance and survivorship relatively quickly and easily. Such studies could perhaps be conducted concurrently with telemetric investigations of foraging adults.

Research Plan, April-October 1979

A revised milestone chart is attached. This depicts critical phases of our analysis of the Kodiak area information, now that complete models are operational.

MILESTONE CHART

0 - Planned completion date

X - Actual completion date
(to be used on quarterly updates)

RU # 108 PI: J. A. Wiens

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

	1978			1979											
MAJOR MILESTONES	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Survey Kodiak area colony data; select colonies for modeling					—	—	—	△							
Confer with field investigators; acquire necessary data							—	—	—	△					
Process data								—	—	—	△				
Conduct initial model analyses								—	—	—	△				
Discuss initial results with field investigators									—	—	△				
Conduct final model simulations									—	—	—	△			
Prepare reports			△				△			△			△		

X. LITERATURE CITED

Aschoff, J., and H. Pohl. 1970. Der Ruheumsatz von Vögeln als Funktion der Tageszeit und der Körpergrösse. J. Ornithol. 111: 38-47.

Birkhead, T. R. 1977. Population parameters for the Common Guillemot *Uria aalge.* Ornis Scand. 8: 145-154.

Bourne, W. R. P. 1968. Oil pollution and bird populations. Pp. 99-121 *in* The biological effects of oil pollution on littoral communities (J. D. Carthy and D. R. Arthur, Eds.). Suppl. to Field Studies, Vol. 2. Hampton, England, E. W. Classey, Ltd.

———, J. D. Parrack, and G. R. Potts. 1967. Birds killed in *Torrey Canyon* disaster. Nature 215: 1123-1125.

Coulson, J. C., and E. White. 1959. The post fledging mortality of the kittiwake. Bird Study 6: 97-102.

———, and R. D. Wooller. 1976. Differential survival rates among breeding kittiwake gulls *Rissa tridactyla* (L.). J. Anim. Ecol. 45: 203-213.

Hamilton, W. J., and K. E. F. Watt. 1970. Refuging. Ann. Rev. Ecol. Syst. 1: 263-286.

Hickey, J. J., and F. L. Craighead. 1977. A census of seabirds on the Pribilof Islands. Final Report, R. U. No. 38, OCSEAP.

Hunt, G. L., Jr. 1977. Reproductive ecology, foods, and foraging areas of seabirds nesting on the Pribilof Islands. Annual Report, R. U. No. 83, OCSEAP.

Innis, G. S., and J. A. Wiens. 1977. BIRD model--version II: description and documentation. Utah State Univ. Wildl. Sci. Dept. Rept. Ser. No. 3.

King, J. R. 1974. Seasonal allocation of time and energy resources in birds. Pp. 4-85 *in* Avian energetics (R. A. Paynter, Jr., Ed.). Publ. Nuttall Ornithol. Club No. 15.

Krebs, J. R., and N. B. Davies (Eds.). 1978. Behavioral ecology. An evolutionary approach. Sunderland, Massachusetts, Sinauer.

Orians, G. H., and N. E. Pearson. 1979. Pp. 155-177 *in* Analysis of ecological systems (D. J. Horn, G. R. Stairs, and R. D. Mitchell, Eds.). Columbus, Ohio, Ohio State Univ.

Ricklefs, R. E. 1974. Energetics of reproduction in birds. Pp. 152-297 *in* Avian energetics (R. A. Paynter, Jr., Ed.). Publ. Nuttall Ornithol. Club No. 15.

Wiens, J. A., and M. I. Dyer. 1977. Assessing the potential impact of granivorous birds in ecosystems. Pp. 205-266 *in* Granivorous birds in ecosystems (J. Pinowski and S. C. Kendeigh, Eds.). Cambridge, Cambridge Univ.

———, G. Ford, D. Heinemann, and C. Fieber. 1978a. Simulation modeling of marine bird population energetics, food consumption, and sensitivity to perturbation. Annual Report, R. U. No. 108. OCSEAP.

———, ———, ———, and ———. 1978b. Simulation modeling of marine bird population energetics, food consumption, and sensitivity to perturbation. Quarterly Report, R. U. No. 108, OCSEAP. Submitted 15 October.

———, and G. S. Innis. 1974. Estimation of energy flow in bird communities: a population bioenergetics model. Ecol. 55: 730-746.

Wooller, R. D., and J. C. Coulson. 1977. Factors affecting the age of first breeding of the kittiwake *Rissa tridactyla*. Ibis 119: 339-349.

Shorebird Dependence on Arctic Littoral Habitats

Annual Report, R. U. 172

April 1, 1979

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

Principal Investigator: Robert W. Risebrough

Contract #03-5-022-84
Reporting Period: 1 April 1978 - 31 March 1979
Number of Pages: 60

Table of Contents

List of Tables and Appendices

Appendix No.

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 1975, shorebird work in the Arctic had concentrated on events on the tundra, where these birds nest, and had largely been confined to the brief breeding period. In this study we have documented seasonal, and occasionally very heavy, use of littoral (shoreline) habitats by shorebirds and other birds in the Arctic.

The ultimate objective of Research Unit #172 is the assessment of the degree and nature of dependence of shorebird species on arctic habitats which are potentially susceptible to perturbation from offshore oil development activities. Within this objective, we are identifying critical habitats, critical trophic processes, and critical areas of the Beaufort and Chukchi coasts, estimating the relative susceptibilities of each shorebird species to potential disturbances, and evaluating the effects on shorebird populations of habitat disturbances already in place along the arctic coast. Efforts in 1978 focused primarily on this last objective and on questions of trophic dependencies of shorebirds in mudflat and saltmarsh habitats.

Our studies of bird use of disturbed habitats indicate that coastal oil development will affect arctic shorebird populations. We anticipate a loss in local bird populations due to destruction of habitat associated with any construction on land, and an additional loss due to changes in the quality of habitat associated with any construction: from dust effects, activity disturbance, scarring of tundra, local onland pollution, and from deposited oil spills. We expect decreases or increases in bird densities in areas subject to drainage changes. We expect attraction of zooplankton-foraging birds to artificial gravel spits and islands, and an accompanying increase in their susceptibilities to potential oil spills. Whether these construction effects, or the direct effects of potential oil spills, will have a meaningful impact on species populations will depend on the areal extent of the development or oil spill, in combination with the particular biological and geographical features of the site.

In the Beaufort and northern Chukchi, and in saltmarsh regions of the southern Chukchi, the general pattern of seasonality in habitat use by shorebirds, gulls, and terns in 1978 was similar to that of previous years, with heavy use of littoral areas developing in August and September.

The trophic system of principal activity in the Beaufort littoral zone involves foraging by many species on marine zooplankton along shorelines. In the southern Chukchi, the greatest activity centers on mudflats and saltmarsh areas, where high concentrations of several shorebird species forage on benthic invertebrates, especially the larvae of chironomid flies. This difference between areas implies corresponding differences in the sensitivity of bird populations to environmental disturbances. The bulk of the shorebird population in Kotzebue Sound and along the north shore of Seward Peninsula from mid-July through mid-September is probably concentrated in littoral habitats. These birds might easily be affected by the direct effects of oil spills or by indirect effects on habitat and prey resources. Even spring migrants may be exposed to effects of oil spilled during the previous summer, since shorebirds foraged in high densities in areas of uplifted benthic sediments locked into surface ice on shallow lagoons in the Noatak Delta.

Juvenile Red Phalaropes move to the shorelines after fledging with significantly lower fat reserves than adult male Red Phalaropes just prior to southward migration. Fat levels increase during the 4 weeks of juvenile phalarope presence along the shorelines at Barrow. This pattern suggests that the shoreline foraging period may be very important to the survival of juvenile Red Phalaropes during their subsequent migration. Any indirect effects of oil spills on prey densities, or the loss of foraging opportunities due to oil spills or other perturbations during this period might decrease phalarope survival during migration.

II. Introduction

Shorebirds (Charadriiformes: Charadrii; Sandpipers, plovers and their close relatives) constitute a major and prominent segment of the avifauna of the Beaufort and Chukchi coasts of arctic Alaska (Bailey 1948; Gabrielson and Lincoln 1959; Pitelka 1974; Table 1). All of these 27 species, which occur regularly in the Arctic during summer months, spend their winters in temperate and tropical regions of both northern and southern hemispheres. As a group, they are an international resource, with individual species dependent in varying degrees on summer conditions along the Alaskan arctic coast.

Prior to 1975, considerable effort had been expended on studies of the ecology of tundra nesting shorebirds near Barrow, Alaska (see Connors and Risebrough 1977 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 sensitive species, habitats, areas, and periods to aid in OCSEAP 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 foraging habitat preferences; and behavioral patterns and other aspects of littoral zone use by shorebirds, gulls, and terns. Further, we are using habitats already subjected to development alterations, chiefly at Prudhoe Bay, to assess the probable effects of disturbances associated with the development of offshore oilfields.

The relevance of this investigation to problems of coastal 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.

Table 1. Shorebird species occurring regularly along the Beaufort and Chukchi coasts of Alaska (from Connors *et al*. 1979).

Regular Breeders

Semipalmated Plover, *Charadrius semipalmatus*
American Golden Plover, *Pluvialis dominica*
Black-bellied Plover, *Pluvialis squatarola*
Ruddy Turnstone, *Arenaria interpres*
Black Turnstone, *Arenaria melanocephala*
Common Snipe, *Capella gallinago*
Whimbrel, *Numenius phaeopus*
Red Knot, *Calidris canutus*
Pectoral Sandpiper, *Calidris melanotos*
White-rumped Sandpiper, *Calidris fuscicollis*
Baird's Sandpiper, *Calidris bairdii*
Dunlin, *Calidris alpina*
Semipalmated Sandpiper, *Calidris pusilla*
Western Sandpiper, *Calidris mauri*
Stilt Sandpiper, *Micropalama himantopus*
Buff-breasted Sandpiper, *Tryngites subruficollis*
Long-billed Dowitcher, *Limnodromus scolopaceus*
Bar-tailed Godwit, *Limosa lapponica*
Red Phalarope, *Phalaropus fulicarius*
Northern Phalarope, *Lobipes lobatus*

Additional Migrants

Killdeer, *Charadrius vociferus*
Sharp-tailed Sandpiper, *Calidris acuminata*
Least Sandpiper, *Calidris minutilla*
Rufous-necked Sandpiper, *Calidris ruficollis*
Curlew Sandpiper, *Calidris ferruginea*
Sanderling, *Calidris alba*
Hudsonian Godwit, *Limosa haemastica*

III. Current State of Knowledge

Available background information prior to RU #172 is referred to in the introductory paragraphs. The principal conclusions derived from our first two seasons of field work are discussed in sections I (Summary), VII (Discussion), and VIII (Conclusions). Briefly: we now have a good understanding of many shorebird habitat use patterns, seasonal movements, distributions, and relative susceptibilities near Prudhoe Bay, Barrow, the northern Chukchi and parts of Hope Basin. Our appreciation of trophic relationships in these areas has improved, but significant questions remain. And we now have estimates of the magnitude of effects of some habitat disturbances associated with development, but lack the information necessary to estimate the effects of spilled oil disturbances.

IV. Study Area

Field activities were conducted at three primary sites during 1978: (1) Prudhoe Bay (70°15'N, 148°20'W), 1 June-10 September; (2) Barrow (71°17'N, 156°46'W), 6 July-30 August; (3) Cape Krusenstern (67°08'N, 163°43'W), 26 May-6 September. At each site a variety of littoral and nearshore tundra habitats were studied intensively. Supplementary study areas at Sisualik in the Noatak Delta (66°59'N, 162°48'W), Kotzebue (66°54'N, 162°35'W) and several sites along the north shore of Seward Peninsula, east and west of Shishmaref (66°14'N, 166°08'N) were visited on an irregular basis throughout the summer.

V. Methods

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 and 1977), primary effort was focused on a permanent transect method. At the three primary sites, transects were marked at 50 m intervals in littoral and in tundra areas. A listing of names and locations of transects is given in Tables 2, 3, and 4 and Figures 2, 3, and 4.

In narrow shoreline habitat areas, as along outer beach shores, stakes defined a single row of square census plots 50 m 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.

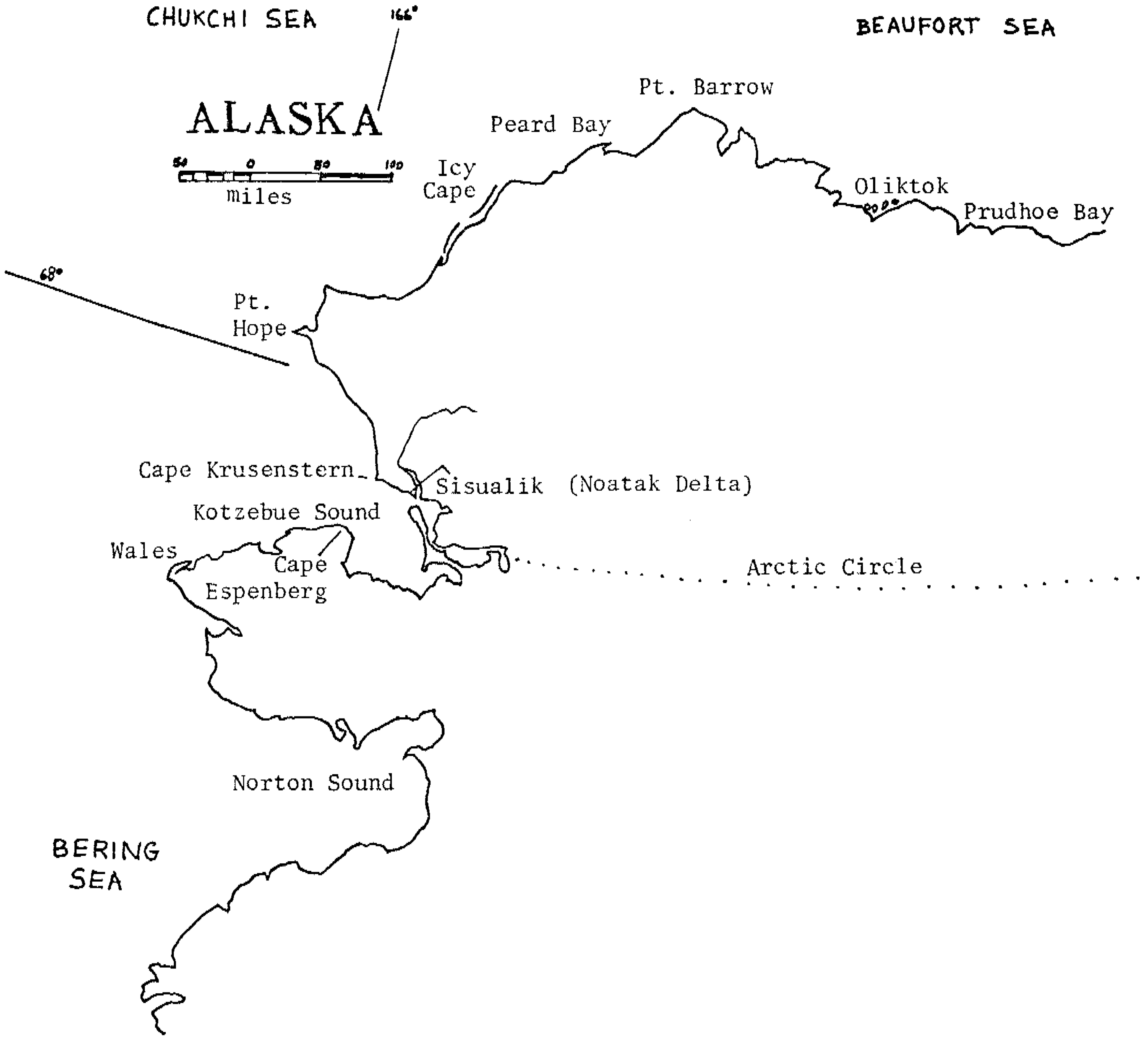


Figure 1. Map of Northern Alaska.

Table 2. Locality codes for transects and sampling, Prudhoe Bay, Alaska. (See Figure 2.)

Code	Transect Name	(M) Length	(M) Width	Habitat	Disturbed or Undisturbed
PAB	Aurora Borealis	1000	50	Shoreline	U
PBB	Black Brant	500	100	Saltmarsh	U
PBS	Baird's Sandpiper	500	100	Floodplain	U
PDW	Driftwood	1000	50	Shoreline	U
PEB	Eider Beach	1000	100	Shoreline	U
PED	East Dock	400	50	Shoreline	D
PF1	Flood Pond-1	700	100	Floodplain	U
PF2	Flood Pond-2	800	100	Floodplain	D
PG1	Guard Station-1	500	100	Tundra	U
PG2	Guard Station-2	500	100	Tundra	U
PG3	Guard Station-3	500	100	Tundra	D
PG4	Guard Station-4	500	100	Tundra	D
PGI	Gull Island	1000	50	Shoreline	U
PIS	Island	500	100	Saltmarsh	U
PMF	Mudflat	300	100	Saltmarsh	U
PNO	No Oil	150	100	Tundra	U
POS	Oil Spill	150	100	Tundra	D
PP1	Put River-1	250	50	River	D
PP2	Put River-2	250	50	River	D
PP3	Put River-3	250	50	River	D
PP4	Put River-4	250	50	River	D
PPB	Polar Bear	500	100	Dried Slough	U
PPM	Point McIntyre	1000	50	Shoreline	U
PPU	Puccinellia	350	50	Saltmarsh	U
PS1	Prudhoe Slough-1	500	50	Slough	U
PS2	Prudhoe Slough-2	500	50	Slough	U
PRB	River Bottom	400	100	River	D
PSB	Snow Bunting	1000	100	Shoreline	U
PSR	Sag River	500	100	River	D
PSS	Snail Shell	1000	100	Shoreline	U-north D-south
PW1	West Dock-1	1000	50	Shoreline	D
PW2	West Dock-2	1000	50	Shoreline	D
PW3	West Dock-3	1000	50	Shoreline	D
PW4	West Dock-4	1000	50	Shoreline	D

Total area: Disturbed transects 65.5 hectares

Undisturbed transects 88.25 hectares

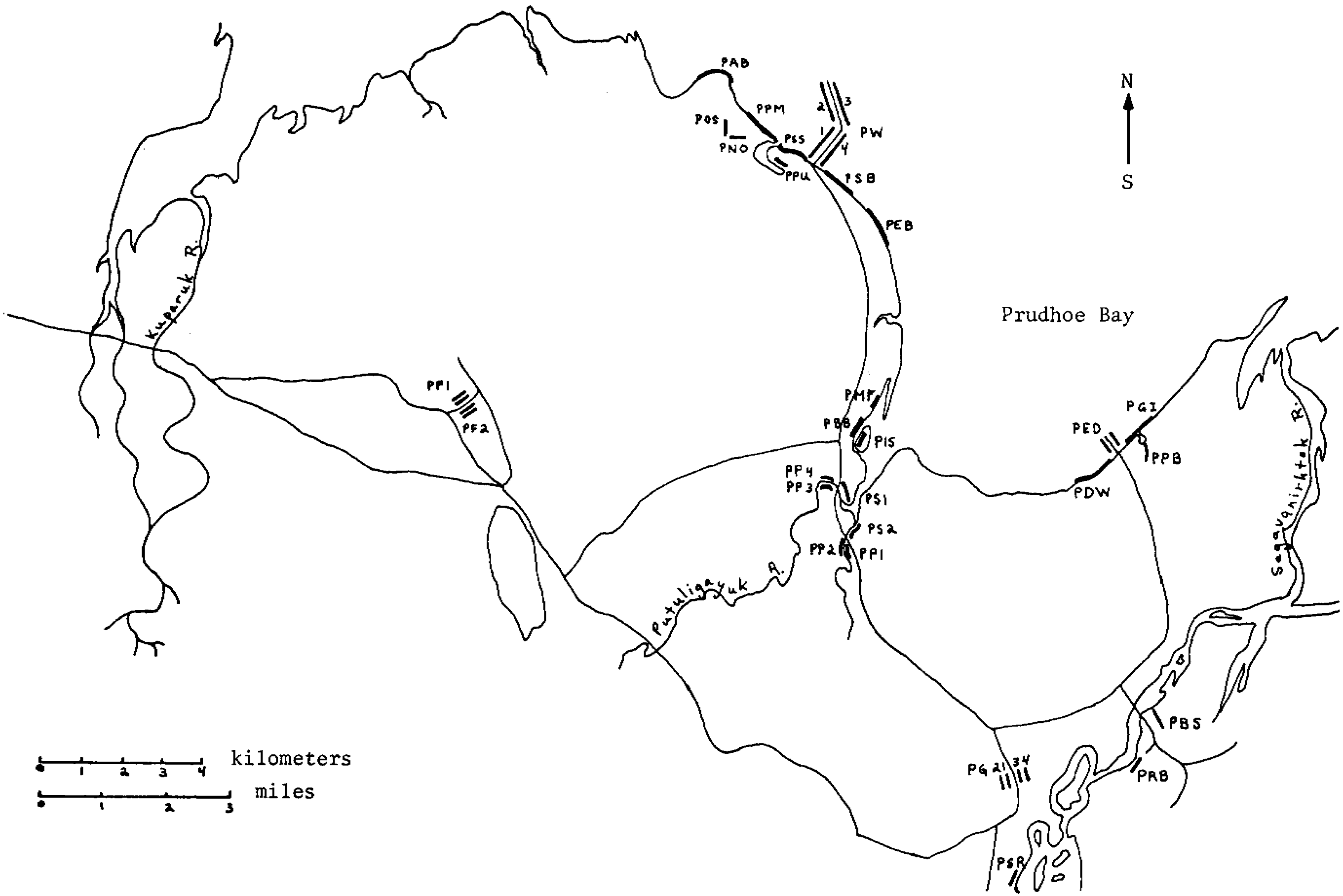


Figure 2. Locations of transects and sampling stations, Prudhoe Bay, Alaska.

Table 3. Locality codes for transects and sampling stations. Barrow, Alaska. (See Figure 3.)

Code	Transect or station name	Transect length (m)	Transect width (m)
BAP	Airport	1000	50
BBD	Barrow Dump	2900	50
BBP	Britton Ponds	300	100
BBS	Barrow Spit	1000	50
BSS	Beaufort Sea Station		
BBV*	Barrow Village	1000	50
BCB	Cemetery Beach	1000	50
BCN	Chukchi Sea North	1000	50
BCS	Chukchi Sea South	1000	50
BDM	Deadman	1000	50
BDP*	Dirt Pile	500	100
BDC*	Duck Camp	1000	50
BGF	Graveyard Flat	500	100
BME	Middle Salt East	500	50
BMW	Middle Salt West	500	50
BNB	Nunavak Bay	1000	50
BNS-1	North Salt Lagoon-1	500	100
BNS-2	North Salt Lagoon-2	500	50
BNT	Nuwuk Tundra	500	100
BPP	Plover Point	1000	50
BPS	Plover Spit	1000	50
BRW	Rotten Walrus	1000	50
BT-1 through BT-10	Tundra Transects 1-10	1000 each	100
BTW	Top-of-the-World	1000	50
BVC	Voth Creek	500	100
BWB	Whalebone Bight		
BWS	Whalebone Spit	1000	50

Total areas: Littoral transects: 105 hectares

*New littoral transects, 1978: 15 hectares

Tundra transects of Myers and Pitelka: 100 hectares

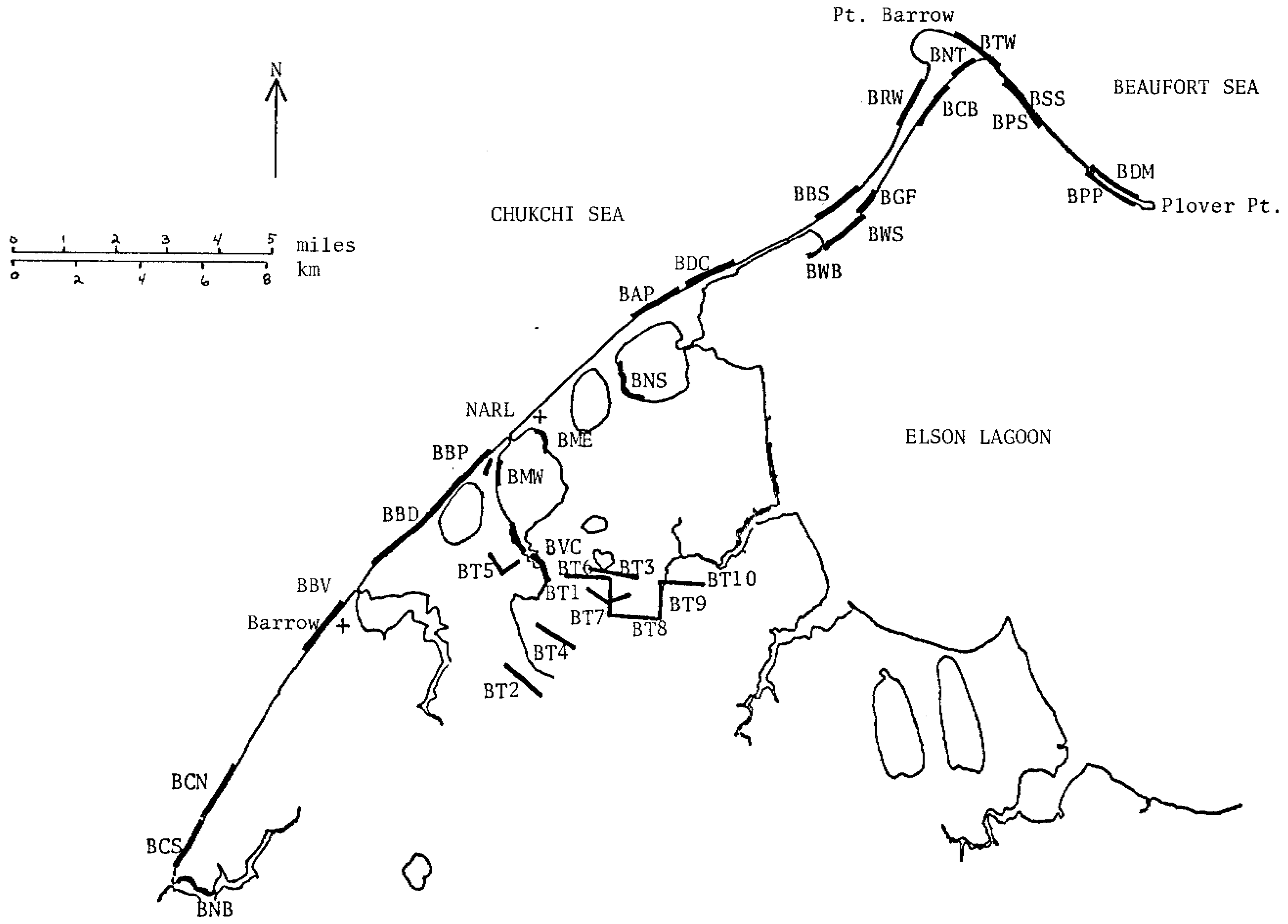


Figure 3, Locations of transects and sampling stations.

Table 4. Locality codes for transects and sampling stations, Cape Krusenstern, Alaska. (See Figure 4.)

Code	Transect or station name	(Tundra or littoral)	Transect length (m)	Transect width (m)
KBW	Baby Walrus	L	1000	50
KCB	Cliff Beach	L	1000	50
KED	Evelukpalik Delta	L	500	100
KG1	Grid one	T	850	100
KG2	Grid two	T	850	100
KG3	Grid three	T	850	100
KGC	Gull Colony	L	500	100
KLF	Lagoon Flood	L	1000	50
KLL	Lagoon Lake	L	1000	50
KLR	Lake Ridge	T	1000	100
KMS	Moon Snail	L	500	50
KNB	North Beach	L	1000	50
KNF	North Flats	L	500	100
KNL	North Lagoon	L	1000	50
KSB	Shell Beach	L	1000	50
KSL	South Lagoon	L	1000	50
KWB	Whimbrel Beach	L	1000	50
KWS	Whistling Swan	T	1000	100
	Not included in map: Transects located 4 km north of CB transect.			
KB1	Shelter Cabin Beach (SCB)	L	1000	50
KS1	Shelter Cabin Slough (SCS)	L	500	50

Total areas: Tundra: 45.4 hectares

Littoral: 70.0 hectares

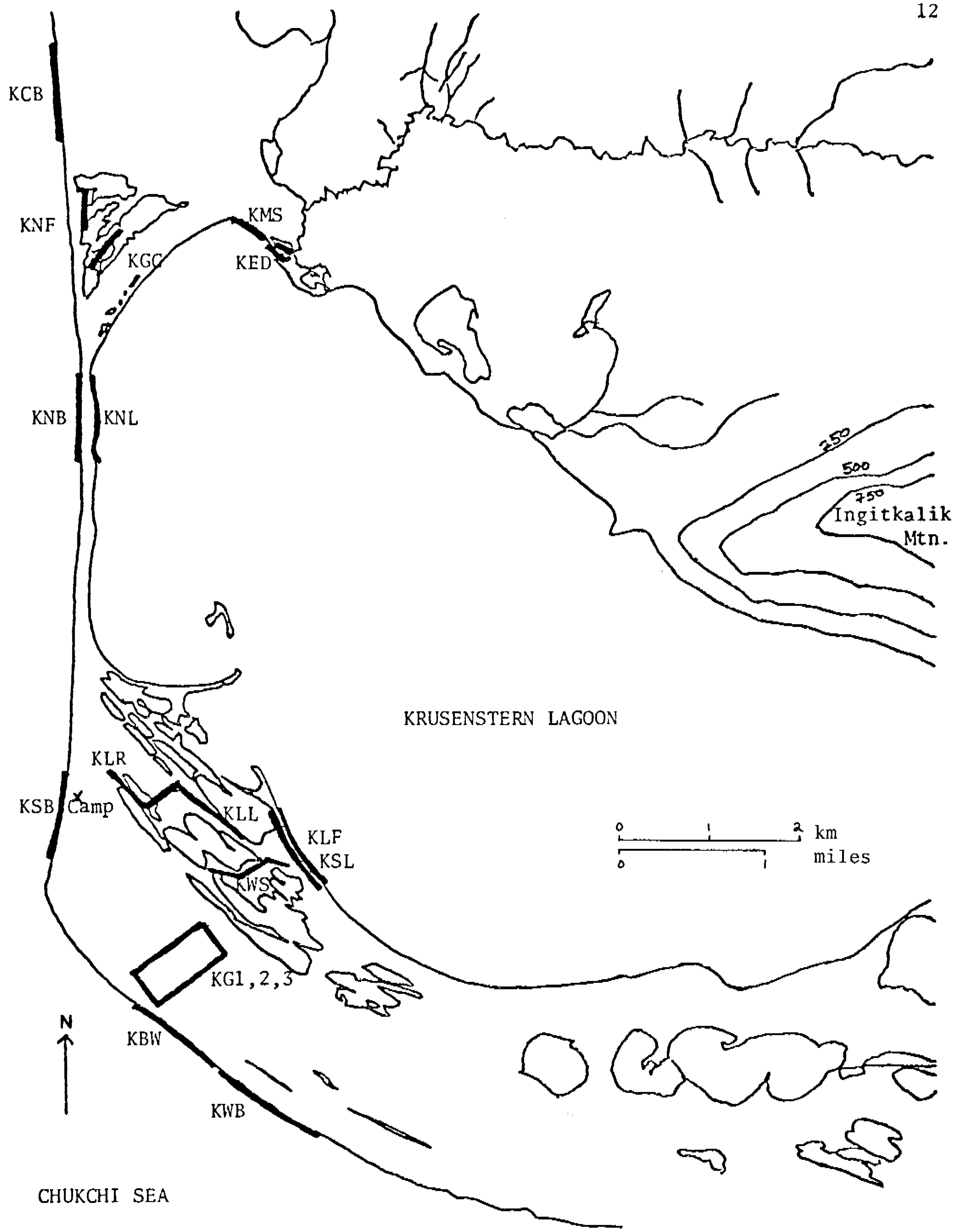


Figure 4. Locations of transects and sampling stations, Cape Krusenstern, Alaska.

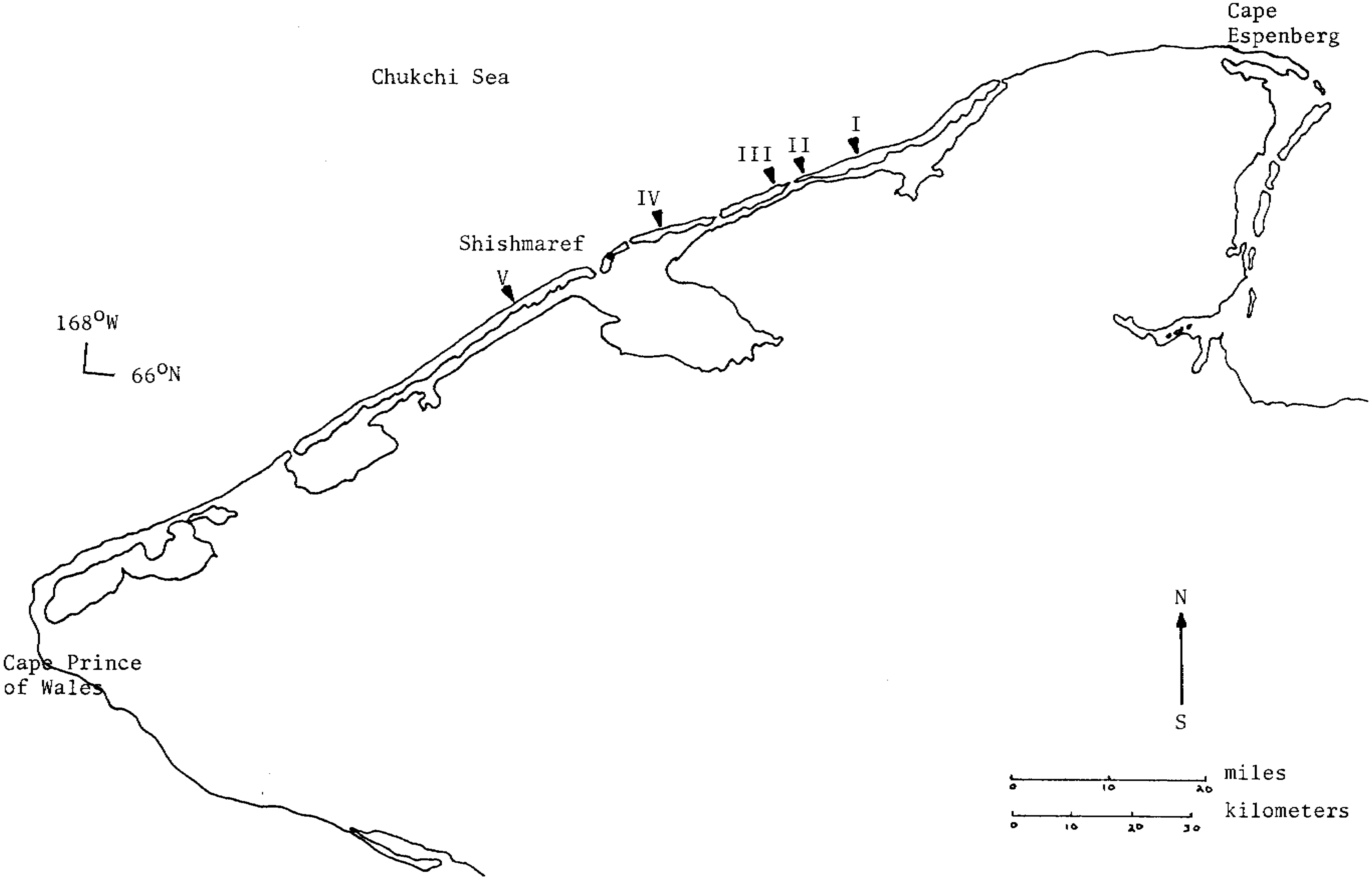


Figure 5. Locations of census sites, Shishmaref coast, Alaska.

At all sites, transect locations were selected to include the full range of available littoral habitats. Lengths of transects within single habitats ranged from .3 km to 2.9 km; almost all transects, however, were either .5 km or 1.0 km. All transect parameters for each site are listed in Tables 2, 3, and 4.

Transects were censused at least once every five days throughout the entire field season at each main study site. All birds within each census plot were recorded, as well as any birds within 200 m on the water side of shoreline transects. 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). We censused sites away from the main study areas less frequently. These transects were marked only at the transect ends rather than in 50 m intervals, and we estimated distances from a combination of pacing and use of topographical maps. These transects were censused as 100 m wide strips.

B. Bird use of disturbed habitat. At Prudhoe Bay, and to a lesser extent at Barrow and Kotzebue, we established transects in areas already subject to disturbances associated with onshore oil development, barge traffic, and heavy use by people. Whenever possible, we matched these disturbed transects with transects in equivalent undisturbed habitats. The comparison of seasonal habitat use on these paired transects gives an estimate of the effects of the particular disturbance.

C. Habitat descriptions. On all Prudhoe Bay transects we characterized the habitat within each 50 m x 50 m unit during August according to a scheme described in Connors and Risebrough (1978). The major parameters recorded on tundra transects included % water cover, % vegetative cover, average plant height, major plant taxa, and a subjective estimate of the degree of disturbance on a scale of 0 to 100. We also estimated the mean % water cover on each transect during each of the first 6 census periods, 5 June-28 June.

D. Trophic studies. At Barrow, Cape Krusenstern, Sisualik, and Shishmaref, we collected shorebirds for stomach analysis and fat level information to complement our previous studies. Collection methods (by shotgun followed by immediate injection of formalin fixative solution in the field) were described in Connors and Risebrough (1976).

Plankton net samples were collected at Barrow and Prudhoe Bay in July and August, at 10-day intervals when shoreline conditions permitted. The surface net, towed parallel to shore in very shallow water to sample the phalarope foraging zone, was described in Connors and Risebrough (1977). Sampling procedures and subsequent sample analysis were also as described previously.

VI and VII. Results and Discussion

Bird Use of Disturbed Habitats

In Table 5 we list the kinds of habitat alterations potentially associated with OCS development which might affect shorebirds. These include several kinds of habitat changes as well as the effects of noise and activity disturbances; our transect systems at Prudhoe Bay, Barrow, and Kotzebue were designed to address these factors. Changes in prey resources, through pollution effects on the prey organisms, and the direct effects of coastal oil spills on bird plumage or on bird foraging efficiency are potentially very severe effects, but we are unable to deal with these given our current data.

Habitat can be affected in varying degrees. At the crudest level, it is simply removed. Total loss due to gravel roads or construction pads for onshore facilities can be quantified in the Prudhoe Bay area. Our rough estimates of this tundra habitat loss within a 14 km x 26 km rectangle encompassing almost all the present oilfield amount to about 10 sq km. This is only about 3% of the enclosed tundra, which sounds unimportant, but it implies a total loss of about 1000-2000 pairs of nesting shorebirds from this area, along with waterfowl and other species.

Construction has other effects which also diminish usable habitat. A considerable dust shadow accompanies gravel construction, with vegetation coated to varying degrees with dust at distances measuring tens or hundreds of meters from all roads. This affects bird density.

A summertime prevailing wind direction from the northeast produces a more extensive dust shadow on the southwest side of roads at Prudhoe Bay. In Figure 6A, we compare the seasonal changes in total shorebird density on the dust shadow transects, PG1 and PG2 (see Figure 7), with the control transects, PG3 and PG4. Densities on the dusted tundra were significantly lower by a sign test ($p<.01$), especially during the breeding season. Comparing the inner and outer pairs of transects separately, densities are lower on PG1 than PG3 ($p<.01$) and lower on PG2 than PG4 ($p<.05$). The cross comparison of PG2 and PG3, transects with similar dust effects (Table 6A) was not significant ($p>.05$). A similar effect is evident for passerines (Lapland Longspur and Snow Bunting) (Figure 6B).

Before we interpret these differences in shorebird densities as the results of dust deposition on the tundra, we must establish that other habitat differences are unlikely to have produced the differences.

The four transects were chosen in early June in a level area of superficially uniform tundra with respect to topography, vegetation, and surface water area and distribution. More detailed measurements of habitat parameters made during the summer indicate that this initial assessment was substantially accurate. Some distinguishable differences

Table 5. Effects of oil development on arctic shorebirds.

1. Habitat changes
    a. Loss of habitat
    b. Change in quality of habitat
    c. Construction of new habitat

2. Disturbance

3. Changes in prey resource

4. Direct oil spill effects

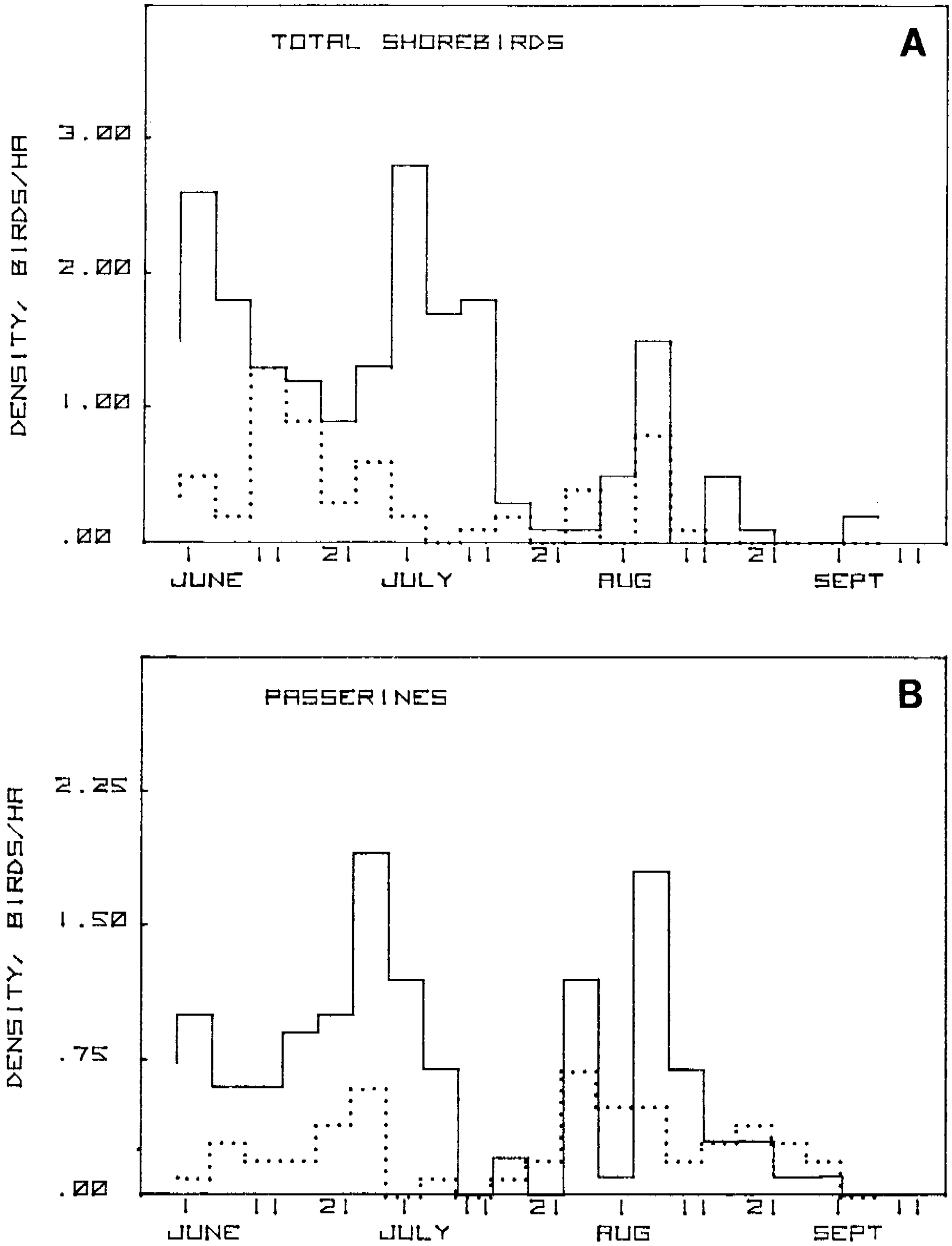


Figure 6. Comparison of bird densities on Prudhoe Bay dust shadow transects (dotted line) and on control transects (solid line).

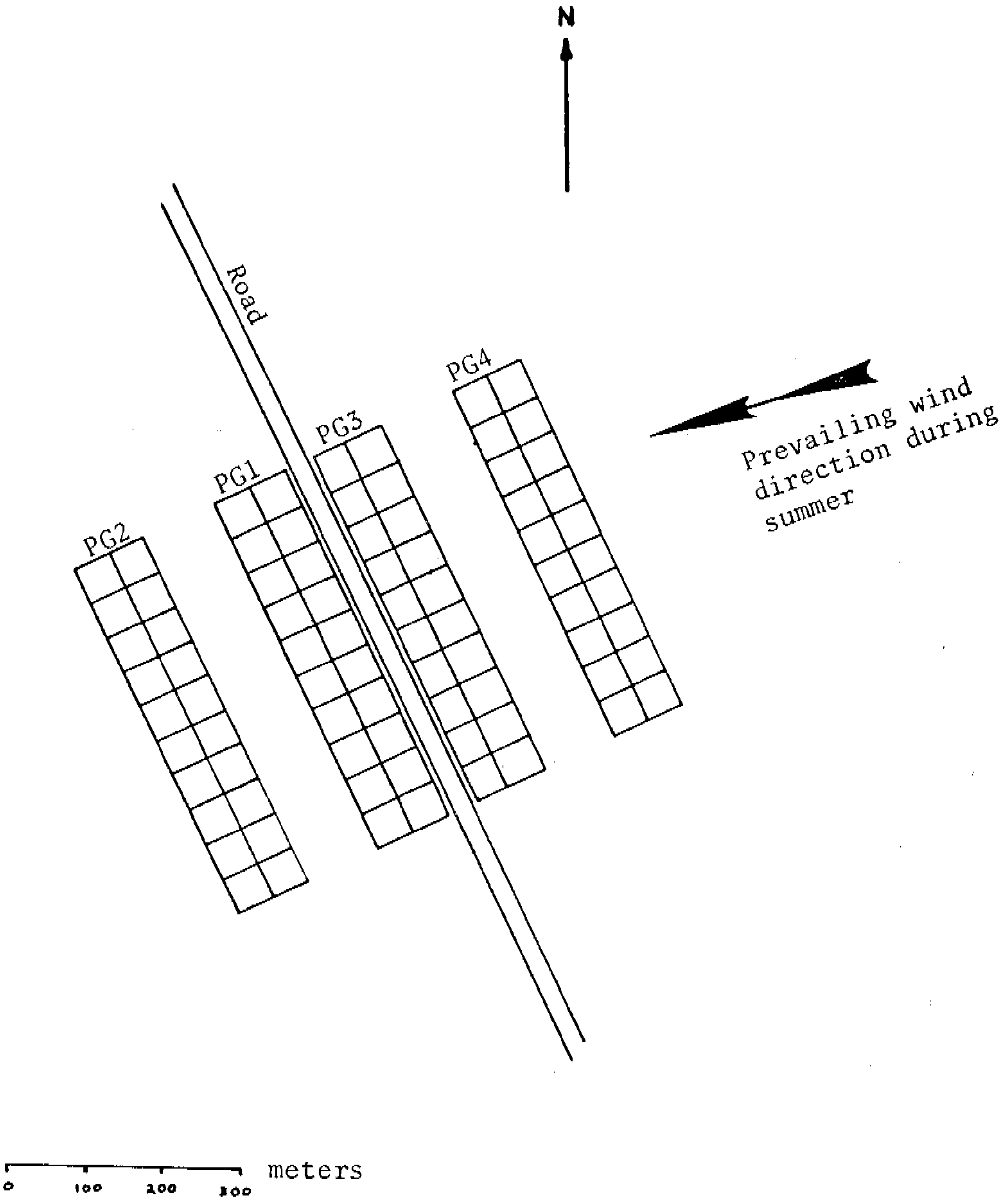


Figure 7. Diagram of Prudhoe Bay dust shadow transects (PG1 and PG2) and control transects (PG3 and PG4).

Table 6A. Per cent plant cover and relative disturbance on dust shadow and control transects.

	Dust		Control		
	PG1	PG2	PG3	PG4	n
Plant Cover[1]	74±11	77±4	82±6	86±4	20
Relative Disturbance[2]	60±10	15±5	25±5	0±0	20

[1] Per cent of non-water area. Mean of all plots in August, ± standard deviation

[2] Scale of 0 to 100, mean ± standard deviation

Table 6B. Per cent surface water on dust shadow and control transects.

	Dust		Control		
	PG1	PG2	PG3	PG4	n
June[1]	18	25	25	21	6
August[2]	4.4±11.4	13.0±12.0	7.0±7.1	5.9±4.1	20

[1] mean of 6 census period estimates

[2] mean of 20 transect plots ± standard deviation

do exist, however (Table 6B). Water cover decreased on all transects during June and between June and August, as expected. Average water cover in June on the four transects fell in a narrow range, with the disparity increasing toward the end of the month. By August several plots had become dry or nearly so, and the relative range of average transect values had increased further. A Mann-Whitney test comparing the disturbed transects (PG1 and PG2) with undisturbed transects (PG3 and PG4) distinguishes between August water conditions on PG1 vs PG3 ($p<.002$) but not between PG2 and PG4 or between the combined PG1 and PG2 compared to PG3 and PG4. Thus, some differences do exist in August, but these differences are smaller in June. Furthermore, elimination of the driest 10 plots from transect PG1, which leaves a half transect indistinguishable in water content from PG3, still provides a comparison of bird densities which is significantly lower on the disturbed transect. Finally, some of the habitat difference may, in fact, derive from the disturbance: the heavier deposition of dust on PG1 compared to PG3 may have reduced the surface water content of that transect, and may be responsible for the slightly lower per cent plant cover on the dust shadow transects (Table 6A).

The upwind transects are, of course, not completely dust free (Table 6A). The full effect of dust on shorebird densities may therefore be greater than that shown in Figures 6A and 6B.

A possible additional effect of noise and activity disturbance associated with the road is difficult to measure in the presence of the dust effect. We think there is such an effect, but that it is smaller than the dust effect.

The net result of these road effects is to increase the effective disturbance zone associated with the road. Instead of losing only the 30 m wide strip which is covered by gravel, the total loss of nesting habitat may be equivalent to a 60 m to 200 m wide strip. This change will multiply our total habitat loss by a factor of several times. In other words, the estimate of 1000-2000 pairs of shorebirds lost in the Prudhoe Bay oilfield increases to 3000 to 6000 pairs.

Tundra construction frequently affects drainage patterns, either by increasing or diminishing local drainage, and these changes, by altering water levels and areas, can greatly influence habitat use by shorebirds and waterfowl. We show one example of an altered drainage effect in Figure 8, comparing densities on pairs of transects differing principally in the effect of a road with an inadequate culvert system on drainage. The dotted line in each plot traces density of shorebirds (8A) and waterfowl (8B) on transects which remain flooded during early summer, but which drain considerably by late August. The area has been essentially eliminated as nesting habitat for shorebirds, but is very attractive to late summer migrants. Waterfowl were more common as spring migrants on the flooded transect.

Extensive gravel mining in river bottoms has accompanied all development at Prudhoe Bay, and has the potential for serious effects on fish populations (Weller _et al_. 1978). Effects on birds are less

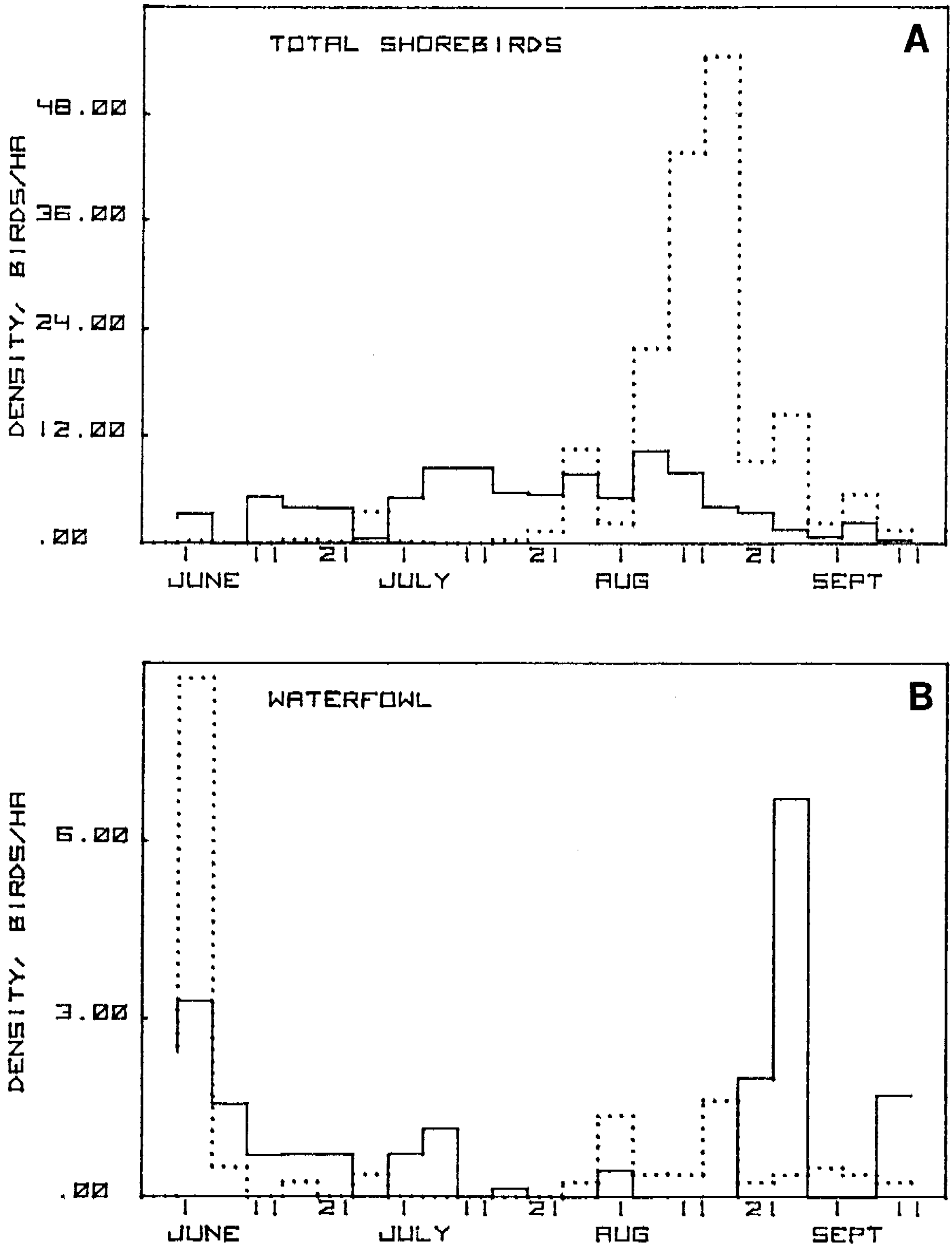


Figure 8. Comparison of bird densities on Prudhoe Bay altered drainage tundra transects (dotted line) and on control transects (solid line).

clear, however. Some riverbed islands and gravel bars are used by terns and gulls for nesting; removal of these might reduce nesting populations of these birds. No terns or gulls nested in the areas we studied at Prudhoe Bay. However, most of the local riverbed areas have already been drastically disturbed. Our attempts to compare bird use of disturbed and undisturbed river habitats were limited by the lack of suitable undisturbed areas. The results of one comparison are given in Figure 9. The undisturbed area was used by Baird's Sandpipers as nesting habitat, but none occupied the disturbed areas during the early summer. Densities in both areas were rather low throughout the season. Other river and slough transects showed little difference in bird use between disturbed and undisturbed transects.

One shoreline transect (PSS) included an all-terrain vehicle (Rolligon) track over most of its length. A comparison of this transect with others of similar habitat showed comparable densities of shorebirds, with heaviest use in late summer (Figure 10A). The Rolligon had little effect on densities of most species. On tundra, where Rolligon tracks may affect drainage (Walker _et al_. 1977) bird use effects may be appreciable.

We've also looked for effects of activity disturbance by people and machines along shorelines in late summer at Barrow, comparing densities on 7 shoreline transects, 3 with high disturbance (BBV, BBD, BDC) and four with low disturbance (BCS, BCN, BAP, BBS), scattered along 19 km of Chukchi coast. In general, most bird species occurred in higher densities along undisturbed shorelines, but the differences were not significant for any species. Two species were more common on the disturbed transects, however. Ruddy Turnstones (Figure 10B) and Glaucous Gulls are both preferential garbage foragers, occurring in higher densities on the transects where garbage was more frequent.

The extent of any deleterious effects of noise and activity disturbance will vary with the species involved and with their activities in the disturbed area. Colonies of nesting waterfowl will be very sensitive to disturbance during the breeding season. Our gravel shoreline transect comparisons indicate that the sensitivity of late summer migrant shorebirds and gulls is rather low, but that turnstone and gull populations might be locally enhanced if shoreline garbage becomes widespread.

Oil spills will certainly affect habitat quality. Oil deposited on tundra, in littoral areas, or incorporated in shallow water sediments may affect birds using resources in those habitats for several seasons. This impact has the potential to produce a more severe change in habitat quality than any of the effects discussed above. Impact of any oil spill will depend on many factors, including amount and type of oil, season, habitats affected, weathering rates, and recovery rates of prey populations and vegetation. Our studies have not provided any data for the necessary assessment.

Prudhoe Bay also offers a preview of what we might expect from the construction of artificial gravel shorelines -- drilling islands and causeways in shallow water -- in the form of the ARCO west dock, a

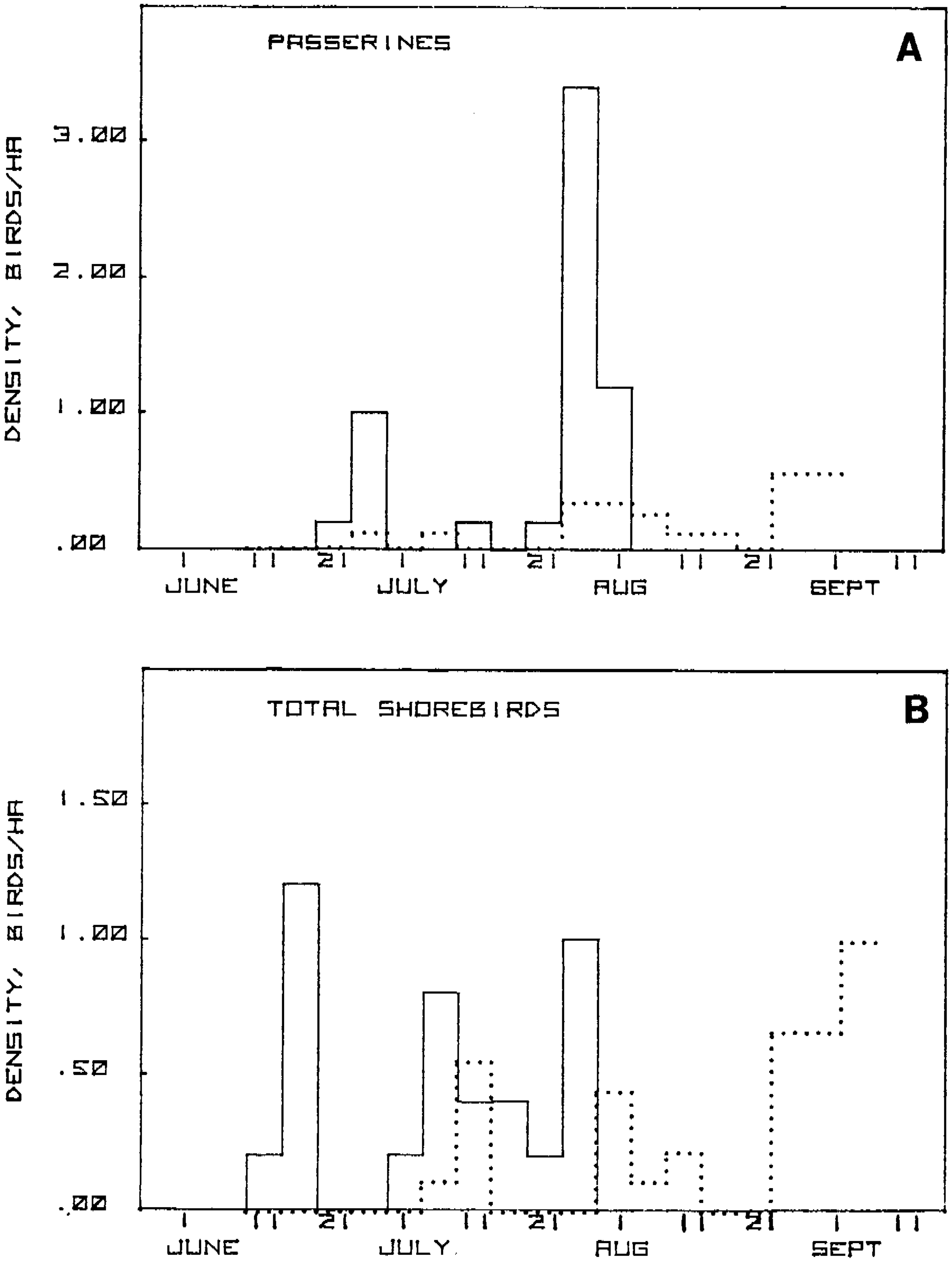


Figure 9. Comparison of bird densities on Sagavanirktok River transects. Dotted line, disturbed habitat. Solid line, undisturbed habitat.

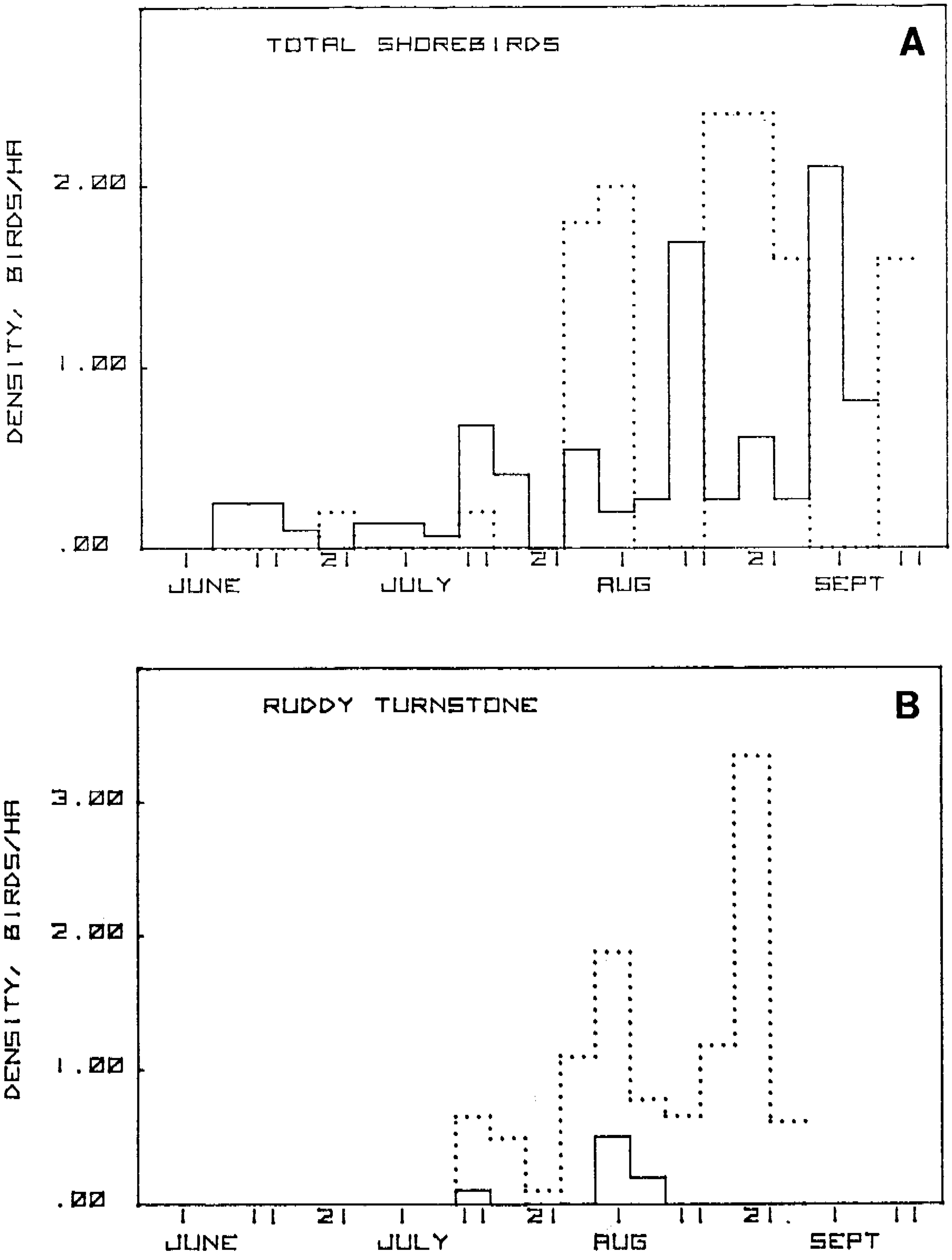


Figure 10. A. Shorebird densities on beach and saltmarsh transects. Solid line, undisturbed. Dotted line, disturbed by Rolligon tracks.
B. Ruddy Turnstone densities on disturbed shorelines (dotted line) and undisturbed shorelines (solid line).

gravel pier over 2 km long extending into the bay and used for unloading barges, and the shorter east dock. Our transects along these artificial spits indicate that zooplankton foraging birds -- phalaropes, gulls, terns and some other shorebirds -- will use these shorelines in preference to the natural mainland shores. In fact, densities of phalaropes (mainly Northern) were an order of magnitude higher along the artificial spits in August (Fig. 11B). Shorebirds which are less dependent upon zooplankton during this period (especially Dunlins) were more common on the muddier mainland shores (Fig. 11A). Lapland Longspurs and Snow Buntings, foraging on seeds and insects, were almost confined to the mainland shores (Fig. 12A).

This result for zooplankton-foraging birds is just what we predicted based on the high density use of natural spits and barrier islands in 1975-1977 along the Beaufort-Chukchi coasts (Connors and Risebrough 1978). Since the prey base is mainly marine zooplankton and under-ice amphipods, species more strongly associated with the water than with the particular shoreline substrate, the artificial spit apparently functions similarly to its natural counterpart. We don't know why spits and islands were more attractive than mainland shores during these 3 years, and a different result in 1978 calls this conclusion into question (see below). We suspect that local current effects may be involved in producing occasional blooms of zooplankton along these shorelines. Extremely high densities of euphausiids, copepods, and chaetognaths have occurred along Barrow Spit in the past 4 years, and a short but intense bloom of copepods along the ARCO dock in August 1978 attracted large numbers of phalaropes, gulls, and fish.

We have previously suggested an additional reason for the apparently heavier use of spits and islands by phalaropes (Connors and Risebrough 1977). The foraging behavior of phalaropes in relation to wind direction and zooplankton densities indicates that when prey conditions are good, phalaropes prefer to forage on protected shores. A spit or an island offers protected shorelines in more wind conditions than does a one-sided mainland shore, and therefore should be favored. During low zooplankton densities, however, phalarope options are reduced; they may be forced to forage on windward shores, searching for ice-associated amphipods, even if oil is present on these shores.

The distribution of juvenile Red Phalaropes along our Barrow shoreline transects showed a very different result in 1978 compared to the previous 3 seasons (Table 7). The densities given for each year are means of 4 August censuses on each transect. One mainland transect census in 1978 gave an extremely high density of 200 birds/ ha. Thus the unusually high mean for 1978 and for all 4 years is greatly influenced by one count on one transect. We lack sufficient prey density measurements to know whether a plankton bloom was involved in this high phalarope density.

Our Prudhoe Bay results suggest that artificial gravel piers and drilling platforms will be more heavily used than natural mainland shores by several species of shorebirds, gulls and terns, which on the surface sounds like an argument in their favor. However, the net effect will be one of attracting birds to precisely those habitats

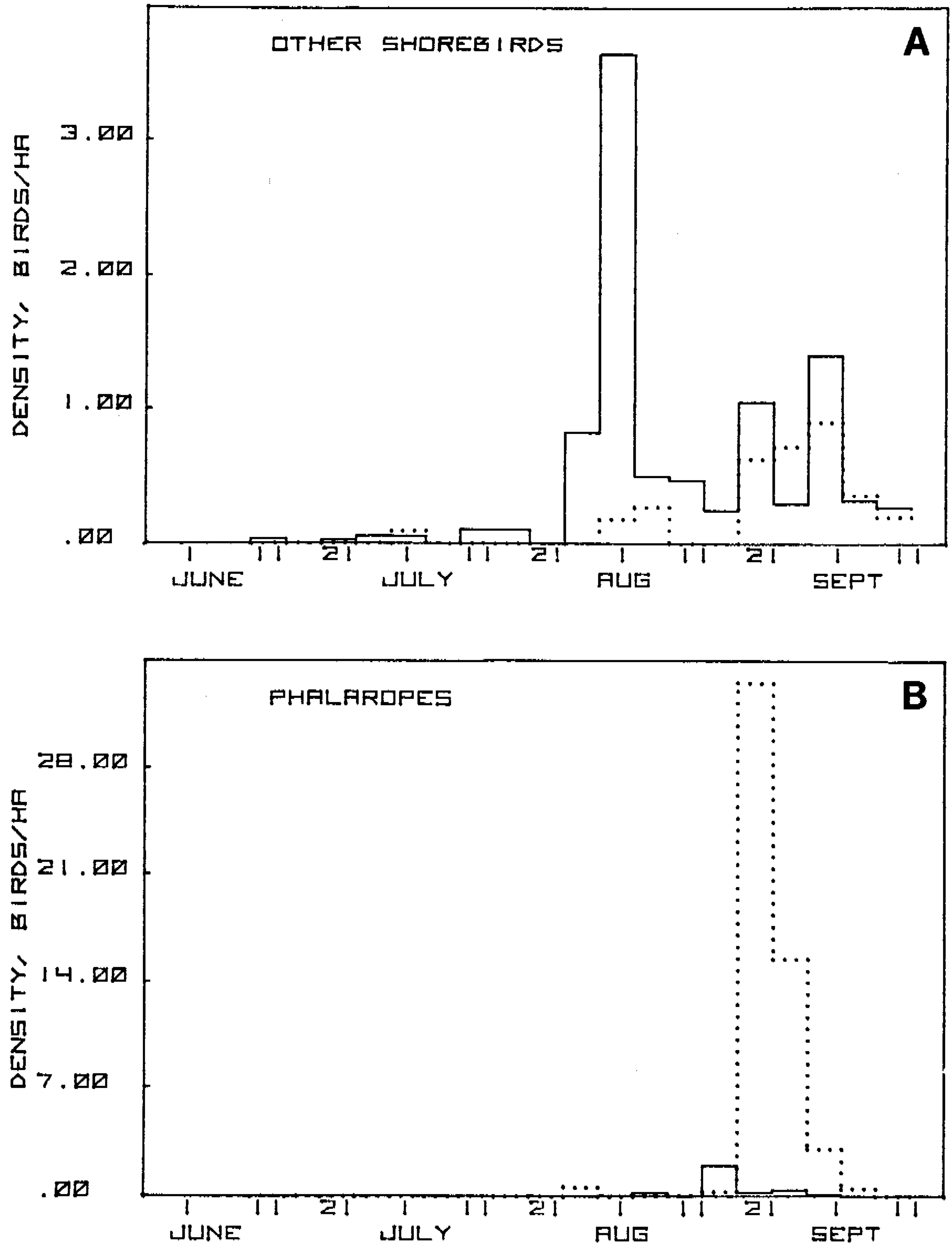


Figure 11. Comparison of bird densities on Prudhoe Bay artificial pier shorelines (dotted line) and on natural mainland shorelines (solid line).
A. Total shorebirds excluding phalaropes.
B. Red and Northern Phalaropes.

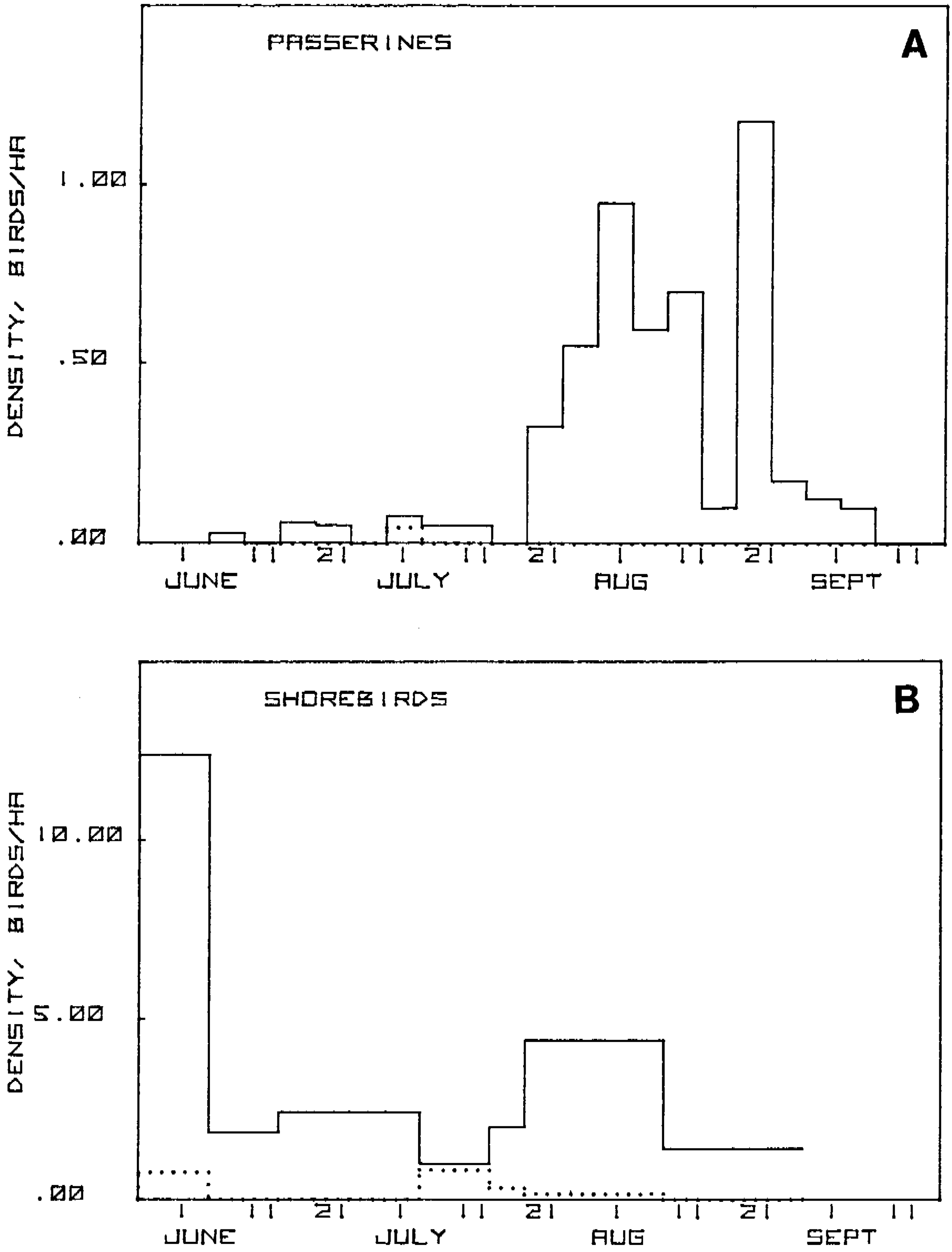


Figure 12. A. Densities of Lapland Longspurs and Snow Buntings on Prudhoe Bay artificial pier shorelines (dotted line) and on natural mainland shorelines.
B. Total shorebird densities on Kotzebue artificial lagoon shorelines (dotted line) and on natural lagoon shorelines (solid line).

Table 7. Comparison of mean densities (birds/ha) of Red Phalaropes on mainland shoreline transects and Barrow Spit shoreline transects during August.

Year	Mainland	Spit	Ratio (spit/mainland)
1975	0	5.8	-
1976	6.6	19.5	3.0
1977	5.5	6.3	1.2
1978	33.5	5.3	.2
means	11.4	9.2	-

where oil spills will be most likely to occur, that is, where construction, barge traffic, and drilling activities will be most intense.

Another arrangement of artificial gravel shorelines is much less heavily used than the natural shorelines it replaces. At Kotzebue, the airport runway system has been constructed across and adjacent to an almost closed brackish lagoon. The natural lagoon shores range from gravel to mud and were much more heavily used by shorebirds than were the artificial gravel shorelines (Fig. 12B). Airplane disturbance may be a factor in this difference, also, since the natural lagoon shores were farther from the runway.

Shorebird Dependence on Saltmarsh and Mudflats at Southern Chukchi Sites

A. Mud-on-ice during spring migration

Ice covering the shallow lagoons and sloughs of the western Noatak Delta and Sisualik area (Fig. 1) frequently supports a surface layer of mud during the meltoff in late May and early June (W. R. Uhl, pers. comm.). On 24 and 25 May 1978 we recorded very high densities of 10 species of shorebirds in two areas of mud-on-ice on a lagoon behind the Sisualik spit (Table 8). Densities were 10-15 times those on nearby saltmarsh transects, and 50 times the density on adjacent tundra transects. Mud patches did not occur on all lagoon ice, but were widespread in the Sisualik area. Thus, during spring migration, the bulk of the shorebirds present apparently used this substrate in preference to other tundra and littoral areas. Several questions are suggested: What process is responsible for the formation of the mud layer above the lagoon ice? What food resource is available in the mud to attract such high densities of birds? To what degree do migrating shorebirds depend on this resource? To what extent might this phenomenon expose shorebirds to the effects of oil pollution?

Observations by W. R. Uhl (pers. comm.) and a paper by F. C. Ugolini(1975) suggest the following mechanism for the formation of the mud layer: During autumn freeze-up, storms may produce an ebb tide sufficient to expose large areas of mudflat in the shallow lagoon areas. The exposed mud freezes to a depth of a few centimeters. With the subsequent change of wind direction, water floods back over these exposed flats, floating the frozen mud to the surface in sheets, where it is locked into the newly forming surface ice. During the spring, melt waters usually flood over the ice surface, melting the ice from above and exposing the thawed mud layer. The spring flood often floats the entire ice sheet.

We reject the alternative hypothesis (P. Craig, pers. comm.) that the observed mud layer results directly from the sediment load of the Noatak River spring meltwaters flooding over the winter lagoon ice, for these reasons:

Table 8. Shorebird densities in 3 habitats, Sisualik, 24-25 May 1978.

	Total transect area (ha)	Shorebird species	Total shorebirds	Total other birds	Density of shorebirds (#/ha)
Tundra	17.5	4	30	20	1.7
Saltmarsh	15.3	8	104	4	6.8
Mud-on-ice	5.6	10	501	0	90.3

Table 9. Densities of common species in 3 habitats, Sisualik, 24-25 May 1978.

	Semipalmated Sandpiper	Western Sandpiper	Red Knot	Bar-tailed Godwit
Tundra	1.1	0	0	0
Saltmarsh	2.1	.1	0	0
Mud-on-ice	15.0	31.5	12.4	13.2

(1) The occurrence of mud-on-ice is more common in the shallow areas at the west end of the lagoon system behind Sisualik spit than it is farther east in areas where the river flow is greater.

(2) The thickness of mud deposits is variable over distances of tens of centimeters; the surface looks lumpy. Sediment deposition by over-ice currents would probably be uniform on a fine scale, and show current patterns on a scale of meters.

(3) Sediment deposited on delta islands during spring floods is patchy and shows the irregular polygonal shape expected from ice-rafted sheets of mud rather than from current deposition (Ugolini 1975).

(4) Shorebirds foraging on mud-on-ice were taking almost exclusively chironomid larvae found to be common the lagoon mudflats during summer (Tables 10 and 12).

(5) Dabbling ducks fed by taking plant tubers from the mud while flood waters covered it during May. The tubers are a favorite waterfowl food common in the lagoon in late summer (W. R. Uhl, pers. comm.).

These last observations in particular indicate strongly that the deposit found on the lagoon ice surface in spring was the benthic sediment in the lagoon during the previous summer.[1]

Most of the shorebirds feeding in this situation were still migrating rather than settled on adjacent tundra territories. Bar-tailed Godwits and Red Knots were common on the ice, but absent from surrounding littoral habitats (Table 9). Neither species nests commonly in the area. Semipalmated and Western Sandpipers both occurred in high densities on the ice, but only Semipalmated Sandpipers were common in adjacent habitats. This species nests at the site in these habitats; Westerns do not.

B. Shorebird diets in saltmarsh-mudflat habitats

The focus of shorebird activity in littoral areas of the southern Chukchi coast is the extensive saltmarsh and mudflat habitat scattered around Kotzebue Sound and the north shore of Seward Peninsula. This contrasts with the heavy dependence of late summer migrants on the gravel shorelines, especially of spits and barrier islands, along the Beaufort and northern Chukchi coasts (Connors and Risebrough 1978). A marked change in diet accompanies this change in habitat activity, from marine zooplankton in the north to heavier dependence on insects in the southern areas (Table 12). Diptera were the most common animal prey taken by 5 of 6 species investigated in these habitats near

---

[1] Furthermore, these observations indicate that P. Craig owes P. Connors one beer.

Table 10. Diets of shorebirds foraging on mud-on-ice, Sisualik, 25 May 1978.

Species	Number of stomachs	Contents (in order of decreasing average % volume)
Bar-tailed Godwit	1	plant matter
Red Knot	1	plant matter adult diptera seeds
Long-billed Dowitcher	4	chironomid larvae plant matter seeds
Dunlin	2	chironomid larvae seeds
Semipalmated Sandpiper	4	chironomid larvae seeds
Western Sandpiper	4	chironomid larvae seeds

Table 11. Diets of shorebirds foraging in saltmarsh, Sisualik, 25 May 1978.

Species	Number of stomachs	Contents (in order of decreasing average % volume)
Long-billed Dowitcher	2	diptera larvae seeds
Semipalmated Sandpiper	2	adult diptera diptera larvae coleoptera plant matter seeds

Table 12. Diets of shorebirds foraging in saltmarsh and mudflats at two locations in late July and August 1978.

Species	Number of stomachs with identifiable prey	Number of stomachs containing more than trace amounts of:						
		Diptera: larvae and adults	Coleoptera	Arachnida	Amphipoda Isopoda	Polychaeta	Fish	Plant matter
A. Sisualik and Noatak Delta								
Golden Plover	3	3	0	1	1	0	0	0
Dunlin	12	9	0	1	1	0	0	8
Western Sandpiper	5	5	0	0	0	0	0	5
Pectoral Sandpiper	3	3	0	0	0	0	0	1
Sharp-tailed Sandpiper	4	1	1	3	0	0	0	4
Long-billed Dowitcher	3	3	0	0	0	1	0	3
B. Shishmaref								
Golden Plover	3	1	2	0	0	0	1	0
Dunlin	6	6	1	0	1	0	0	2
Western Sandpiper	5	5	0	0	0	0	0	5
Long-billed Dowitcher	5	5	0	0	0	0	0	6

Sisualik and Shishmaref, and chironomid larvae were most frequently encountered. Only Sharp-tailed Sandpipers showed a preference for another category, foraging on small mites in the saltmarsh.

C. Seasonal shorebird population changes

Except for scattered gull and tern colonies (see below), shorebird use of saltmarsh-mudflat habitats is low during the breeding season, increasing sharply in late summer. In Figure 13A we present the results of 5 brief visits in 1977 and 1978 to 7 sites on the barrier strip east and west of Shishmaref. The strip is 160 km in length, averaging 1.12 km in width. Typically, the ocean beach is backed by irregular dunes, grading to a sandy tundra and then to saltmarsh, pools, and occasional mudflats. Few species nest in any of these habitats. Waves of post-breeding adults and juveniles, however, forage here in late July, August and September, with average densities increasing more than 10-fold between late June and late August. The peak densities during both years extrapolate to total shorebird populations for the Northern Seward Peninsula barrier strip alone of 250,000 to 350,000 birds. Other bird species noted on our transects showed the same seasonal patterns, with densities averaging about 20% of shorebird densities during each period. In late August and September, the area is heavily used by flocks of Brant, not often recorded on our walking transects. Our estimate from an aerial survey on 6 September 1978 was at least 15,000 Brant on the barrier strip.

Figure 13B compares the seasonal densities recorded on saltmarsh transects and tundra transects along the Sisualik spit. Use of saltmarsh greatly exceeded the tundra densities during all periods, peaking in August.

D. Golden Plover movements

In Connors and Risebrough (1978) we reported on the heavy use of saltmarsh habitats by Golden Plovers in the southern Chukchi study areas, surprising in view of the almost total restriction of this species to tundra habitats near Barrow. Part of the explanation probably relates to the greater availability of saltmarsh in the southern areas. We suspect, however, that some of the habitat use differences may be racial. At Barrow and eastward, the nesting race is *Pluvialis dominica dominica*, while at Wales and in Siberia it is *P. d. fulva* (Bailey 1948). Between these points the ranges are undetermined and may overlap. Measurements of specimens separate the two races easily, and we have learned to separate the juveniles by plumage in the field in most cases. In this manner we observe that almost all Golden Plovers at Cape Krusenstern, Sisualik, and near Shishmaref in August and early September were juveniles of *P. d. fulva*, the Siberian race. Juveniles collected near Barrow belong to *P. d. dominica*. Thus a difference in arctic habitat preferences accompanies a difference in late summer ranges of the races.

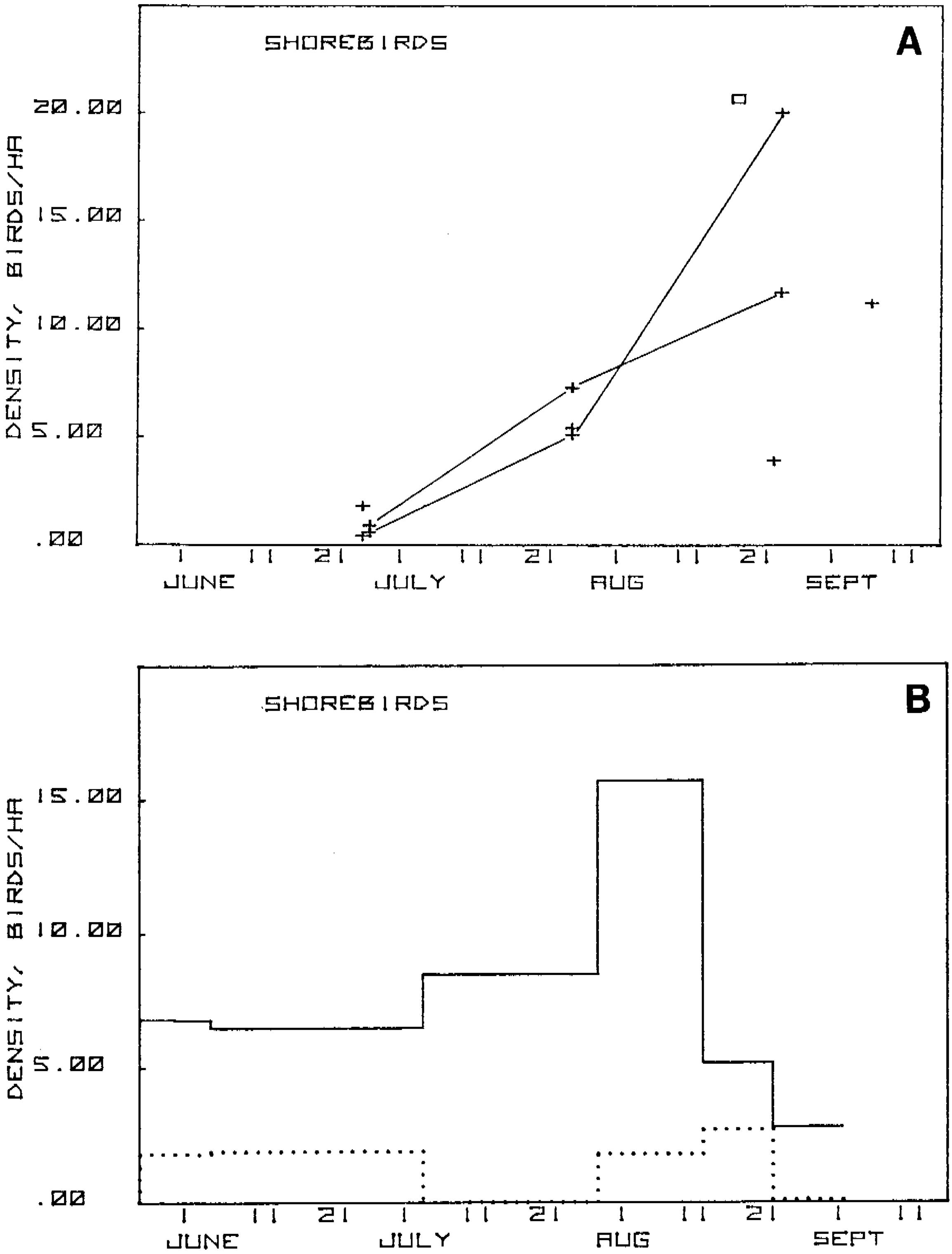


Figure 13. A. Shorebird densities at sites on barrier strip east and west of Shishmaref. (□) 1977, (+) 1978. Lines connect successive visits to 2 principal study sites.
B. Shorebird densities on transects on Sisualik Spit. Saltmarsh (solid line) and tundra (dotted line).

Furthermore, the rather high numbers of juvenile plovers seen at the southern Chukchi sites (we estimate 14,000 along the Shishmaref barrier strip on 25 August 1978) is surprising in view of the low densities of breeding *fulva* on Seward Peninsula (Brina Kessel, pers. comm.). We suggest, therefore, that these juveniles may be Siberian in origin, migrating to the Shishmaref and Kotzebue Sound area to take advantage of the saltmarsh and mudflat foraging available there. By this hypothesis, the juveniles would be following a circuitous migration route in order to increase their fat reserves before beginning the southward flights throughout the Pacific.

There is a more easily interpreted example of a late summer migration from Siberia to North America by a species which will subsequently fly back to the western side of the Pacific to wintering grounds. Juvenile Sharp-tailed Sandpipers become fairly common as far east as Kotzebue at the end of August and in early September. Since the species does not nest or winter in North America, we know these birds fly east from breeding grounds, returning southwest to wintering areas. They are not just a few stragglers; the total movement probably involves several thousand or tens of thousands of birds. Both Sharp-tailed Sandpipers and the *fulva* race of Golden Plovers may be dependent on the saltmarsh and mudflat resources of Kotzebue Sound and the Seward Peninsula, in spite of their Siberian breeding and Pacific wintering areas.

Comparative Phenologies

Phenologies for Cape Krusenstern, Prudhoe Bay, and Barrow are presented in Appendix 2. The timing of early season events showed greater than normal disparity between Beaufort and southern Chukchi sites in 1978. Areas near Kotzebue experienced one of the earliest springs within memory (W. R. Uhl, pers. comm.), while North Slope areas faced an extremely late melt-off. The difference between Cape Krusenstern and Prudhoe Bay melting dates and flowering dates averaged 3 to 4 weeks, and other sites along the Beaufort coast were even later than Prudhoe Bay (Appendix 2). Deposition of dust on the snow arising from the extensive gravel road system and high activity at the Prudhoe Bay oil field promotes earlier melting at that site than at other Beaufort sites. Bird phenology dates differed by much less, however, averaging only 5 to 10 days earlier (less for some species) at Cape Krusenstern. This delay is similar to our observations in 1977, in spite of a much greater lag in meltoff dates in 1978. Birds apparently do not respond simply to differences in meltoff dates between sites. Instead, bird nesting dates are set partly by other requirements (schedules and conditions at other sites during migration, hormonal schedules, etc.) and adjusted by local breeding ground conditions. In 1978, Beaufort coast birds were delayed in nest initiation, but apparently began quickly when conditions improved. At Cape Krusenstern, the early spring allowed some individuals to nest very early, but many delayed nesting until nearer the normal dates, resulting in a less synchronous nesting season for some species. Of 20 Western Sandpiper nests, the earliest clutch completion was 24 May, the latest 22 June.

Breeding Densities

Table 13 compares breeding bird densities at 3 sites in 1977 and 1978: Barrow, Cape Krusenstern, and Meade River (Atkasook), inland on the coastal plain south of Barrow. In spite of the great differences in phenology between the years, the coastal sites had very similar nesting densities each year. The greater difference between years at the inland Meade River site arose from differences in densities of two common species, Semipalmated Sandpipers and Lapland Longspurs, at that site (J. P. Myers, pers. comm.).

Aleutian Tern Colonies

During the 1977 field season, we located 4 very small colonies which represented northward range extensions of this species. In 1978 we found that 3 of these colonies were greatly expanded (Table 14). Observations of local residents (Carrie and W. R. Uhl, pers. comm.) suggest that this species has expanded its range into the area within the last 10 years. The marked increase between 1977 and 1978 may be further evidence of this expansion, or it may reflect differences between years in other factors such as food supply or predation by foxes and humans.

Table 14. Size of four northern colonies of Aleutian Terns (number of active nests).

Location Map no.[1]	Qikiqtaichaik Is. 128-001	Uhl-Williams Camp 128-002	Krusenstern North Flats 128-005	Tasaychek Lagoon 128-006
1977	5-20	c. 10	c. 2	c. 12
1978	c. 90	?	c. 29	c. 38

[1] Sowls *et al.* 1978

Habitat Use Patterns

Appendix 1 provides an avifaunal list for 1977 and 1978 for Cape Krusenstern. In general, densities and timing of movements of most species were similar in both years. Descriptions of the status of common species at this site, as well as at Barrow, were given in Connors and Risebrough (1977) and (1978). Additional data for a few species are presented here.

Table 13. Comparison of breeding densities at arctic tundra sites, 1977 and 1978.

	Number of species nesting		Total pairs per hectare		Reference
	1977	1978	1977	1978	
Barrow Plot 1	10	10	1.10	1.09	Myers *et al*. 1978a, 1979a
Barrow Plot 2	11	12	1.10	1.29	Myers *et al*. 1978b, 1979b
Meade River	18	16	2.72	1.88	Myers *et al*. 1978c, 1979c
Cape Krusenstern	14	13	1.33	1.55	Connors and Connors 1978, Connors *et al*. 1979

Figure 14 shows seasonal habitat use graphs for the phalarope species, comparing densities on littoral and tundra transects at Cape Krusenstern. Red Phalaropes were common along ocean shorelines for a few days in early June in 1978. These birds were probably northward migrants, but were not encountered in 1977 because of the difference in ice conditions. We expect that in most years, shoreline conditions do not allow spring migrant phalaropes to forage on marine zooplankton as they did in 1978 (Table 15). However, when the ice moves out sufficiently early, phalaropes will use the habitat, exposing themselves to the potential dangers of spilled oil before nesting begins.

Northern Phalaropes nest commonly at Cape Krusenstern, using tundra and adjacent saltmarsh and lagoon habitats (Figure 14B; Table 15). Both species exhibit a pattern contrasting sharply with phalarope habitat use in the Beaufort (Connors and Risebrough 1978). At Barrow and Prudhoe Bay, these species are almost confined to tundra sites until mid-July, and the highest densities in any habitats are reached by juveniles along gravel shorelines in August.

Western and Semipalmated Sandpipers (Figure 15) showed similar patterns in both years, with the peak densities of Westerns occurring after Semipalmated Sandpipers had left the site. Both species occurred in lower densities in 1978. The peak of the juvenile migration of Semipalmated Sandpipers is compared at Cape Krusenstern, Barrow, and Prudhoe Bay in Figure 16A. As in 1977, the peak is earlier and less intense at the southern site. The data for all shorebirds combined along shoreline transects showed a similar site comparison (Figure 16B). Only Krusenstern had high densities in June, but the late summer migration peak was earlier and much lower than the movements at both Beaufort sites. Red and Northern Phalaropes accounted for most of the peak activity.

Fat Accumulation by Phalaropes

Additional Red Phalarope juveniles collected in 1978 strengthened a correlation reported previously (Connors and Risebrough 1978). Combining all 56 specimens collected over 4 years (juveniles only, 8 August - 2 September), a Spearman rank correlation analysis shows a significant correlation between fat code, on a scale of 1 to 5, and date ($p<.01$). Juvenile Red Phalaropes build up their fat stores during the long post-fledging period when they forage along Beaufort shorelines. Adult females and adult males, freed from nesting duties in late June and late July, respectively, begin their southward migrations without a long post-breeding foraging period in the arctic. If juveniles require the long foraging period to build up energy reserves necessary for migration, have adults already achieved similar fat levels when they leave the tundra and depart southward? We compared fat levels in 14 adult male Red Phalaropes, collected along shorelines from 15 July through 3 August, 1975-1978, with 20 juveniles taken 8 through 12 August, 1975-1978. The adult fat levels were significantly higher ($p<.02$, Mann-Whitney test). We believe this supports the argument that juveniles require the late summer shoreline foraging

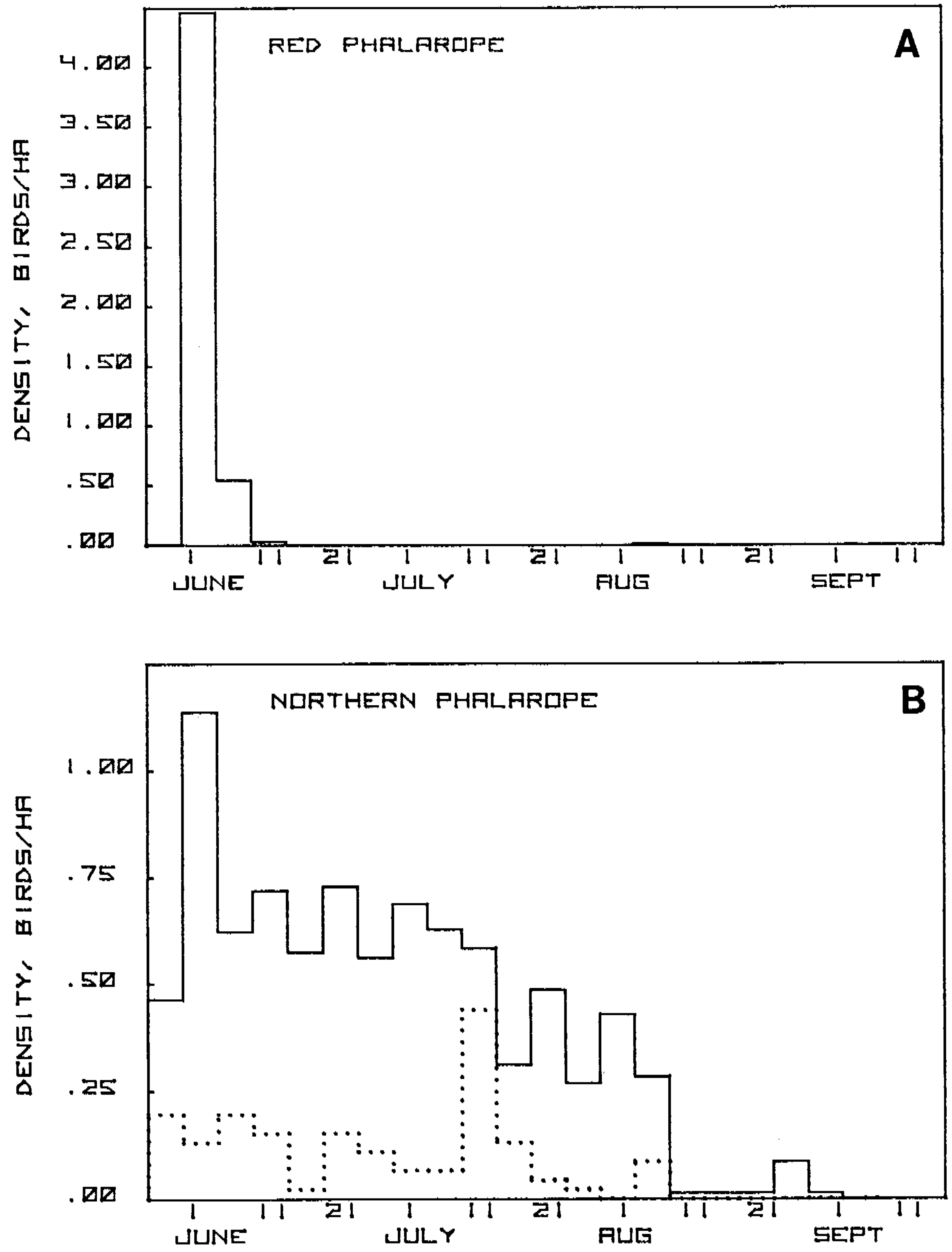


Figure 14. Phalarope densities at Cape Krusenstern. Littoral transects (solid line) compared with tundra transects (dotted line).

Table 15. Principal food items of Phalaropes at Cape Krusenstern (in order of decreasing frequency).

3 Northern Phalaropes Tundra marsh, 2 June 1978	3 Northern Phalaropes Lagoon shore, 12 June 1978	9 Red Phalaropes Ocean shore, 3-7 June 1978
chironomid larvae	mysids	copepods
other dipteran larvae	arachnids	amphipods
coleoptera	seeds	adult diptera
tiny eggs		arachnids
seeds		coleoptera
		seeds

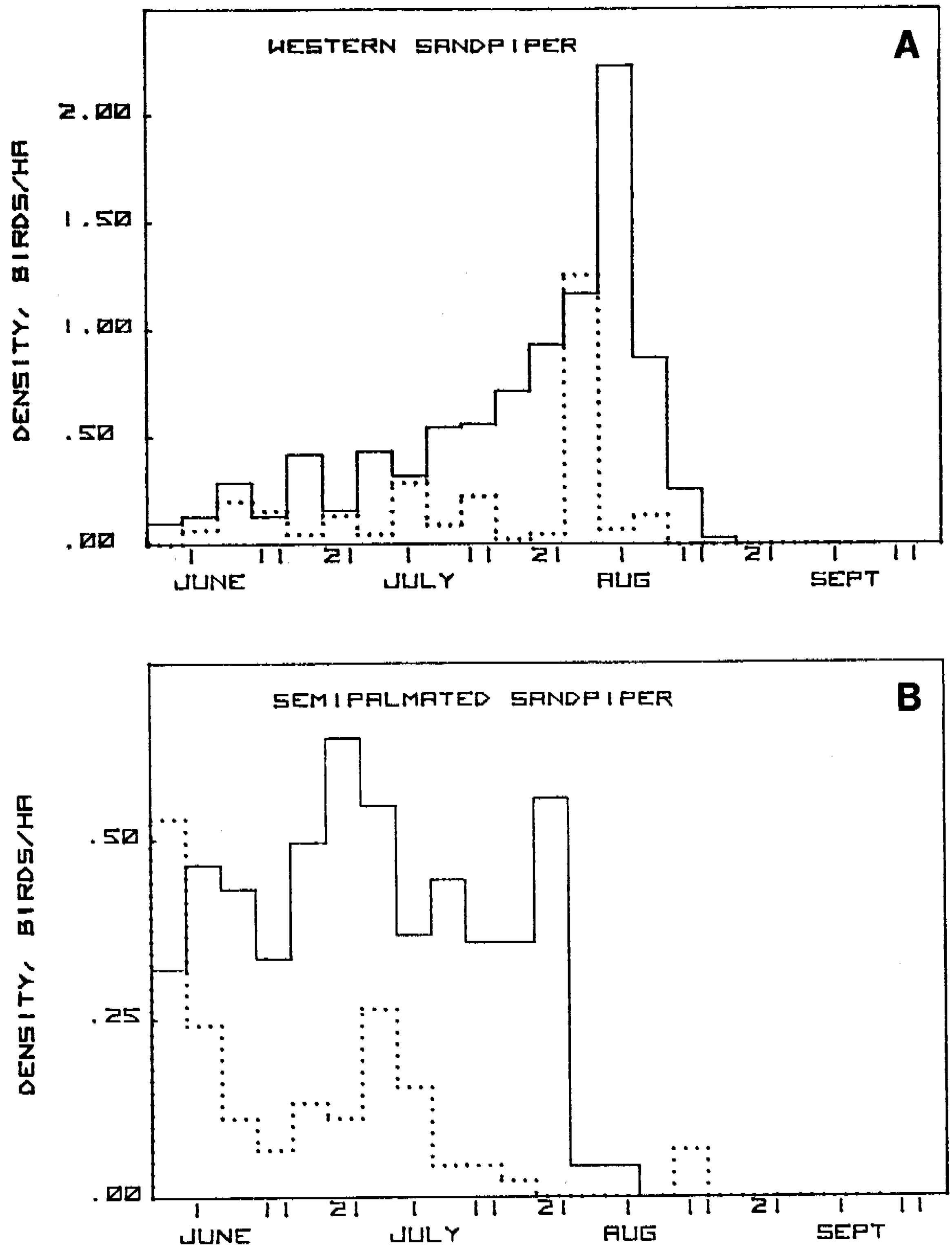
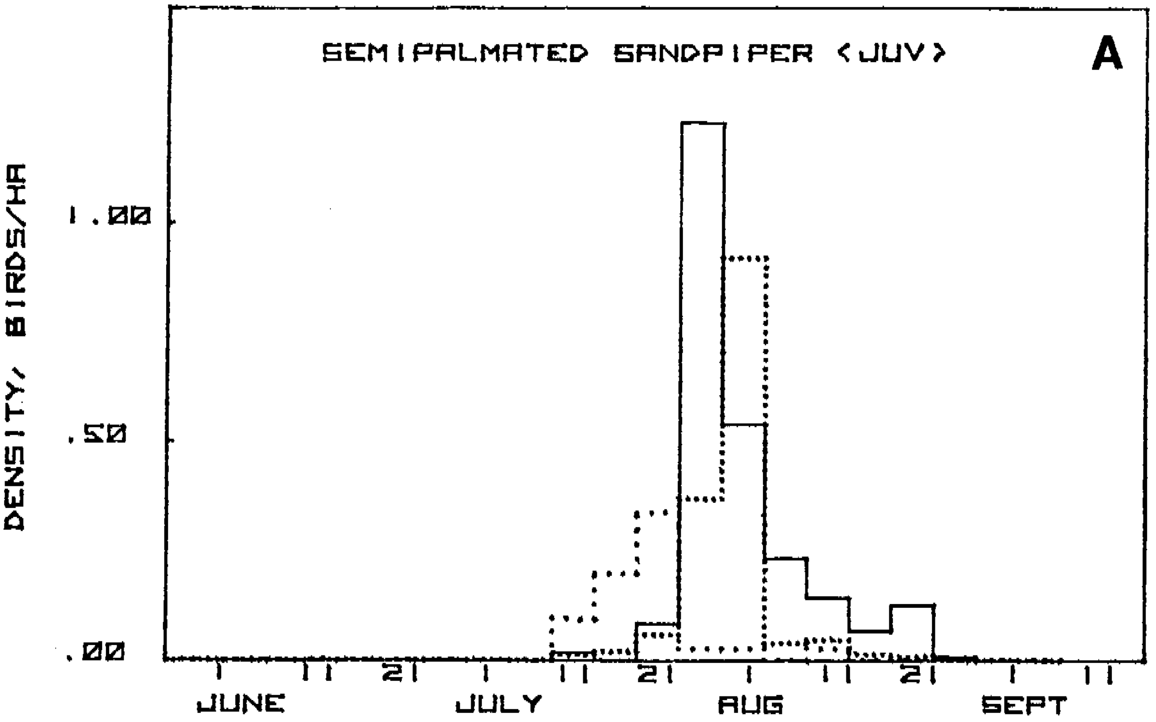


Figure 15. Sandpiper densities at Cape Krusenstern. Littoral transects (solid line) compared with tundra transects (dotted line).



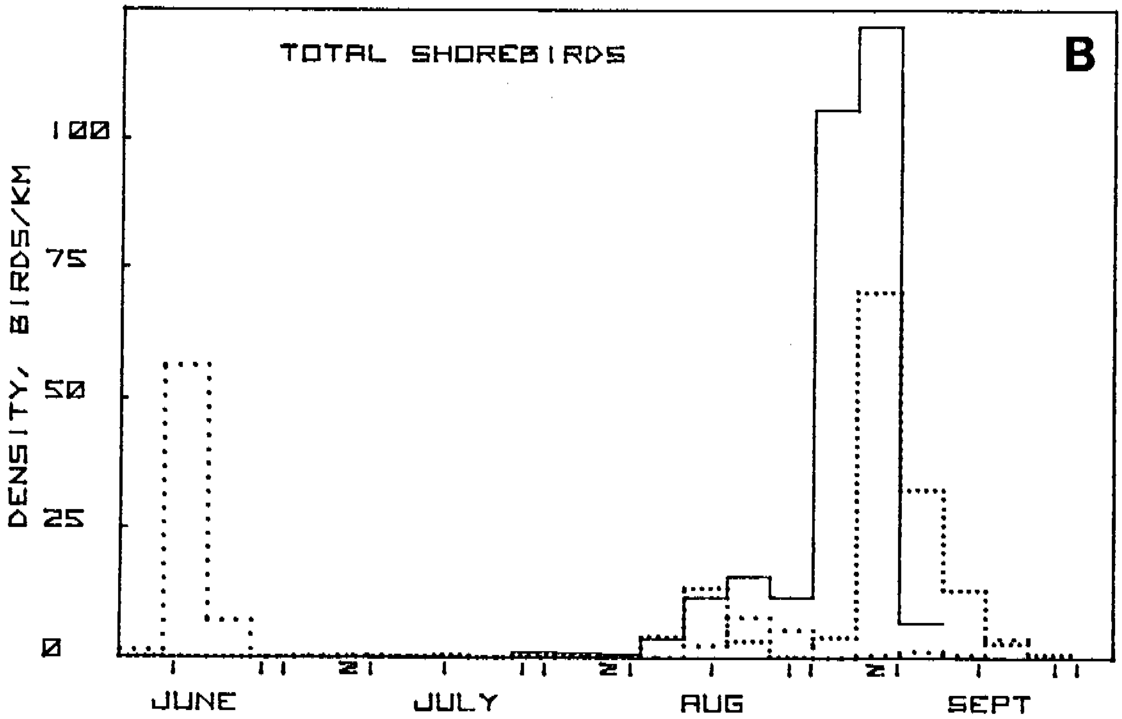


Figure 16. Shorebird densities at 3 sites: Barrow (solid line), Prudhoe Bay (short dot line), Cape Krusenstern (long dot line).

A. Juvenile Semipalmated Sandpipers on littoral transects.

B. Total shorebirds along ocean shorelines.

period to build fat reserves necessary for migration.

We have limited data which suggest that juveniles of the two phalarope species may follow very different fat accumulation schedules. Three Northern Phalarope juveniles collected at Barrow over 2 years on 8 and 9 August had significantly higher fat code levels than 20 Red Phalarope juveniles taken over 4 years, 8 through 12 August (Mann-Whitney test, $p<.01$). This tentative conclusion requires more data. It is surprising, and implies that Northern Phalaropes are capable of accumulating fat more quickly than the Red Phalaropes foraging in the same areas.

VIII. Conclusions

1. Our studies of bird use of disturbed habitats indicate that coastal oil development will affect arctic shorebird populations. We anticipate a loss in local bird populations due to destruction of habitat associated with any construction on land, and an additional loss due to changes in the quality of habitat associated with any construction: from dust effects, activity disturbance, scarring of tundra, local on-land pollution, and from deposited oil spills. We expect decreases or increases in bird densities in areas subject to drainage changes. We expect attraction of zooplankton-foraging birds to artificial gravel spits and islands, and an accompanying increase in their susceptibilities to potential oil spills.

Whether these construction effects, or the direct effects of potential oil spills, will have a meaningful impact on species populations will depend on the areal extent of the development or oil spill, in combination with the particular biological and geographical features of the site.

2. In the Beaufort and northern Chukchi, and in saltmarsh regions of the southern Chukchi, the general pattern of seasonality in habitat use by shorebirds, gulls, and terns in 1978 was similar to that of previous years, with heavy use of littoral areas developing in August and September.

3. The trophic system of principal activity in the Beaufort littoral zone involves foraging by many species on marine zooplankton along shorelines. In the southern Chukchi, the greatest activity centers on mudflats and saltmarsh areas, where high concentrations of several shorebird species forage on benthic invertebrates, especially the larvae of chironomid flies. This difference between areas implies corresponding differences in the sensitivity of bird populations to environmental disturbances. The bulk of the shorebird population in Kotzebue Sound and along the north shore of Seward Peninsula from mid-July through mid-September is probably concentrated in littoral habitats. These birds might easily be affected by the direct effects of oil spills or by indirect effects on habitat and prey resources.

4. During spring migration, shorebirds feed in very high densities in areas of the Noatak Delta where lagoon benthic sediments occur on top of the lagoon ice. The sediments are lifted during the autumn freeze-up and locked into the floating ice. At this time shorebirds feed on the same prey as are available on the late summer mudflats of these lagoons. Oil spilled during the summer would probably be similarly locked into lagoon ice and might attract birds during the following spring.

5. Juvenile Golden Plovers in southern Chukchi areas forage in saltmarshes, in contrast to their tundra habits along the Beaufort coast. We suggest that these are mainly Siberian-bred Golden Plovers of the fulva race, performing a migratory detour similar to that of the juvenile Siberian Sharp-tailed Sandpipers. Both species may fly to these North American saltmarsh areas to build fat reserves before migrating southward through the Pacific. Thus we add these Old World birds to the list of species dependent on resources in the Alaskan arctic littoral zone.

6. Spring melt-off and plant phenologies were unusually early at Cape Krusenstern and unusually late at Beaufort sites. Nesting densities were not much different from 1977, however, and the differences in bird phenologies between sites were much less than the differences in snow and flower phenologies. The greatest bird effect of the unusual seasons was probably a decrease in nesting synchrony at Cape Krusenstern and an increase at northern sites.

7. Juvenile Red Phalaropes move to the shorelines after fledging with significantly lower fat reserves than adult male Red Phalaropes just prior to southward migration. Fat levels increase during the 4 weeks of juvenile phalarope presence along the shorelines at Barrow. This pattern suggests that the shoreline foraging period may be very important to the survival of juvenile Red Phalaropes during their subsequent migration.

IX. Needs for Further Study

After four seasons of OCS work, we now have a substantial outline of the seasonality of shorebird events in the littoral zone of much of the Beaufort and Chukchi coasts. Geographically, areas in the eastern Beaufort and parts of Kotzebue Sound retain the largest question marks. Trophically, we have only a rough understanding of the dependencies of different species in different regions. We know that some species are quite flexible in their responses to changing prey conditions; a better appreciation of this flexibility for key species is required if we are to predict any indirect effects of oil pollution through changes in prey conditions.

For some species and locations we can now make valuable estimates of the probabilities of encounters between birds and a hypothetical oil spill. In most cases, however, we cannot predict the behavior of birds confronted by the oil spill, and this step is critical to evaluating the eventual impact. For example, phalaropes may be attracted to or repulsed by an oil slick. A combination of laboratory and field experiments may answer these questions for some species.

Finally, in all areas where significant populations may face disturbances, we need to know specifically what the disturbances will be and how severe will be the resultant population effects. Comparison of bird use in disturbed and undisturbed habitats, as well as study of the impact of actual environmental results, planned or unplanned, and of the recovery of populations following such impacts promises to be extremely useful in meeting OCSEAP objectives.

X. Fourth Quarter Operations

1. Field Schedule.

No field activities during this quarter.

2. Scientific party.

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

Katherine A. Breyer, Bodega Marine Laboratory, research assistant.

Carolyn S. Connors, Bodega Marine Laboratory, research assistant.

Franklin Gress, Bodega Marine Laboratory, research assistant.

3. Methods.

Laboratory analysis:

(1) Summary and computer plotting of shorebird seasonal distributions.

(2) Continuing analysis of bird 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 and identification of 130 bird stomach samples.
    (2) Analysis of 1100 transect censuses.
6. No serious problems encountered.
7. Total funds expended, 1 April 1975 - 28 February 1979: $157,205.

Appendix 1 Birds of Cape Krusenstern, Alaska, 1977-78.

The following list presents the status of bird species observed in the vicinity of Cape Krusenstern, Alaska (see map, Figure 1) in 1977 between 26 May and 7 September and in 1978 between 26 May and 4 September.

RB, rare breeder: 1 or 2 nests (or broods) located in one year.
CB, common breeder: 3 or more nests or territories located in one year.
PB, probable breeder: breeding suspected, but no nests located.
CM, common migrant: present on at least 5 days; at least 10 individuals.
V, visitor: includes less common migrants and stragglers.
*: nested near Krusenstern Lagoon on Ingitkalik Mountain.

The second column lists additional species reported as nesting occasionally at Cape Krusenstern in other years (W. R. Uhl and C. K. Uhl 1977).

	1977 Status	Additional breeders Other years (Uhl 1977)
Common Loon, *Gavia immer*	V	
Yellow-billed Loon, *G. adamsii*	V	
Arctic Loon, *G. arctica*	CB	
Red-throated Loon, *G. stellata*	CB	
Horned Grebe, *Podiceps auritus*	V	
Red-necked Grebe, *P. grisegena*	V	X
Pelagic Cormorant, *Phalacrocorax pelagicus*	V	
Whistling Swan, *Olor columbianus*	RB	
Canada Goose, *Branta canadensis*	CM	X
Brant, *B. bernicta*	CM	X
Emperor Goose, *Philacte canagica*	V	
White-fronted Goose, *Anser albifrons*	CM	X
Snow Goose, *Chen caerulescens*	CM	
Mallard, *Anas platyrhynchos*	CM	X
Pintail, *A. acuta*	CB	
Green-winged Teal, *A. crecca*	CM	X
American Wigeon, *A. americana*	CM	
Northern Shoveler, *A. clypeata*	CM	
Redhead, *Aythya americana*	V	
Ring-necked Duck, *A. collaris*	V	
Canvasback, *A. valisineria*	RB,CM	
Greater Scaup, *A. marila*	CB	
Oldsquaw, *Clangula hyemalis*	CB	
Harlequin Duck, *Histrionicus histrionicus*	V	
Steller's Eider, *Polysticta stelleri*	V	
Common Eider, *Somateria mollissima*	CB	

King Eider, *Somateria spectabilis*	V	
Spectacled Eider, *S. fischeri*	V	
White-winged Scoter, *Melanitta deglandi*	CM	
Surf Scoter, *M. perspicillata*	CM	
Black Scoter, *M. nigra*	V	X
Red-breasted Merganser, *Mergus serrator*	CM	X
Sharp-shinned Hawk, *Accipiter striatus*	V	
Red-tailed Hawk, *Buteo jamaicensis*	V	
Rough-legged Hawk, *B. lagopus*	V*	
Marsh Hawk, *Circus cyaneus*	CM	X
Gyrfalcon, *Falco rusticolus*	V	
Peregrine Falcon, *F. peregrinus*	V*	
Willow Ptarmigan, *Lagopus lagopus*	CB	
Sandhill Crane, *Grus canadensis*	CB	
Semipalmated Plover, *Charadrius semipalmatus*	RB	
Killdeer, *C. vociferus*	V	
American Golden Plover, *Pluvialis dominica*	CB	
Black-bellied Plover, *P. squatarola*	RB	
Ruddy Turnstone, *Arenaria interpres*	V	
Black Turnstone, *A. melanocephala*	CM	
Common Snipe, *Capella gallinago*	CB	
Whimbrel, *Numenius phaeopus*	RB,CM	
Bristle-thighed Curlew, *N. tahitiensis*	V	
Wandering Tattler, *Heteroscelus incanus*	V	
Red Knot, *Calidris canutus*	CM	
Rock Sandpiper, *C. ptilocnemis*	V	
Sharp-tailed Sandpiper, *C. acuminata*	V	
Pectoral Sandpiper, *C. melanotos*	RB,CM	
Baird's Sandpiper, *C. bairdii*	RB	
Least Sandpiper. *C. minutilla*	V	
Rufous-necked Sandpiper, *C. ruficollis*	V	
Dunlin, *C. alpina*	CB	
Sanderling, *C. alba*	CM	
Semipalmated Sandpiper, *C. pusilla*	CB	
Western Sandpiper, *C. mauri*	CB	
Stilt Sandpiper, *Micropalama himantopus*	V	
Buff-breasted Sandpiper, *Tryngites subruficollis*	CM	
Long-billed Dowitcher, *Limnodromus scolopaceus*	CB	
Bar-tailed Godwit, *Limosa lapponica*	PB,CM	
Hudsonian Godwit, *L. haemastica*	V	
Red Phalarope, *Phalaropus fulicarius*	CM	
Northern Phalarope, *Lobipes lobatus*	CB	
Pomarine Jaeger, *Stercorarius pomarinus*	CM	
Parasitic Jaeger, *S. parasiticus*	CM	
Long-tailed Jaeger, *S. longicaudus*	PB,CM	X
Glaucous Gull, *Larus hyperborea*	CB	
Glaucous-winged Gull, *L. glaucescens*	V	
Herring Gull, *L. argentatus*	V	
Thayer's Gull, *L. thayeri*	V	
Mew Gull, *L. canus*	PB,CM	X
Black-legged Kittiwake, *Rissa tridactyla*	CM	
Sabine's Gull, *Xema sabini*	CM	
Arctic Tern, *Sterna paradisaea*	CB	
Aleutian Tern, *S. aleutica*	CB	
Common Murre, *Uria aalge*) --	CM	
Thick-billed Murre, *U. lomvia*)		

Black Guillemot, *Cepphus grylle*	V	
Horned Puffin, *Fratercula corniculata*	V	
Snowy Owl, *Nyctea scandiaca*	V	
Short-eared Owl, *Asio flammeus*	V	X
Common Flicker, *Colaptes auratus*	V	
Eastern Kingbird, *Tyrannus tyrannus*	V	
Say's Phoebe, *Sayornis saya*	V*	
Horned Lark, *Eremophila alpestris*	V*	
Tree Swallow, *Iridoprocne bicolor*	RB	
Bank Swallow, *Hirundo rustica*	V	
Cliff Swallow, *Petrochelidon pyrrhonota*	V	
Common Raven, *Corvus corax*	CM*	
Gray-headed Chickadee, *Parus cinctus*	V	
Swainson's Thrush, *Catharus ustulatus*	V	
Gray-cheeked Thrush, *C. minimus*	V	
Wheatear, *Oenanthe oenanthe*	CM	
Bluethroat, *Luscinia svecica*	V	
Arctic Warbler, *Phylloscopus borealis*	V	
White Wagtail, *Motacilla alba*	V	
Yellow Wagtail, *M. flava*	CB	
Water Pipit, *Anthus spinoletta*	V	
Red-throated Pipit, *A. cervinus*	V	
Yellow Warbler, *Dendroica petechia*	V	
Wilson's Warbler, *Wilsonia pusilla*	V	
Redpoll, *Acanthis* sp.	CB	
Savannah Sparrow, *Passercula sandwichensis*	CB	
Tree Sparrow, *Spizella arborea*	V	
White-crowned Sparrow, *Zonotrichia leucophrys*	PB	
Fox Sparrow, *Passerella iliaca*	V	
Lapland Longspur, *Calcarius lapponicus*	CB	
Snow Bunting, *Plectrophenax nivalis*	CM	

Total species recorded, 1977-1978: 113

Appendix 2. Arctic Phenology, 1978.

Event	Date Cape Krusenstern	Date Prudhoe Bay	Date Barrow
Tundra 10% snow free		before 31 May	
Tundra 50% snow free		4 June	
Tundra 90% snow free	18-24 May	11 June	
Ponds (<1 hectare) ice free	before 23 May	25 June	
First cracking of shore-fast ice	1 June	5-7 June	
First time shoreline ice cover <25% (out to 1 km)	4 June	5 July	
First date ice pack not visible from shoreline (2 m elevation)	18 June	13 July	
First *Pedicularis kanei* flowering	25 May	23 June	
First *Papaver* sp. flowering	31 May	30 June	12 July
First *Potentilla villosa* flowering	27 May	17 June	
First *Silene acaulis* flowering	17 June	8 July	
First adult chironomid	9 June	28 June	
First bad mosquito day	14 June	5 July	7 July
Last bad mosquito day	14 August	29 August	
First shorebird clutches:			
Baird's Sandpiper		12 June	
Buff-breasted Sandpiper		9 June	
Golden Plover	19 June		
Northern Phalarope	12 June		
Pectoral Sandpiper		7 June	
Red Phalarope		5 June	
Semipalmated Sandpiper	31 May	5 June	
Western Sandpiper	27 May		
First date with most shorebirds on complete clutches	13 June	15 June	
First Pintail eggs		15 June	

Appendix 2, continued

Event	Date Cape Krusenstern	Date Prudhoe Bay	Date Barrow
First Pintail chicks	12 June		
First Lapland Longspur chicks	13 June	17-21 June	
First shorebird chicks:			
Semipalmated Sandpiper		25-30 June	
Western Sandpiper	13 June		
Peak of semipalmated Sandpiper juvenile movement	21 July	29 July	28 July
Peak of Long-billed Dowitcher juvenile movement	15 August	19 August	21 August
First day with 100 phalarope juveniles along shorelines		19 August (Northern)	10 August (Red)
First day with 1000 phalarope juveniles along shorelines		20 August (Northern)	18 August (Red)

XII. Literature Cited

Bengtson, S.-A. 1970. Breeding behavior of the Purple Sandpiper *Calidris maritima* in West Spitsbergen. Ornis Scand. 1(1):17-25.

Connors, P. G. and C. S. Connors. 1978. Breeding bird census: wet coastal tundra, Cape Krusenstern, Alaska. American Birds 32:118.

Connors, P. G., D. Woodby, and C. S. Connors. 1979. Breeding bird census: wet coastal tundra, Cape Krusenstern, Alaska. Submitted to American Birds.

Connors, P. G., J. P. Myers, and F. A. Pitelka. 1979. Seasonal patterns of habitat use by coastal plain shorebirds in arctic Alaska. In *Shorebirds in the Marine Environment*, Pacific Coast Avifauna Series (in press).

Connors, P. G. and R. W. Risebrough. 1976. Shorebird dependence on arctic littoral habitats. In *Environmental Assessment of the Alaskan Continental Shelf* (Annual Reports from Principal Investigators), Volume 2:401-456.

Connors, P. G. and R. W. Risebrough. 1977. Shorebird dependence on arctic littoral habitats. In *Environmental Assessment of the Alaskan Continental Shelf* (Annual Reports of Principal Investigators for the year ending March 1977), Volume 3:402-524.

Connors, P. G. and R. W. Risebrough. 1978. Shorebird dependence on arctic littoral habitats. In *Environmental Assessment of the Alaskan Continental Shelf* (Annual Reports of Principal Investigators). In press.

Holmes, R. T. 1966a. Breeding ecology and annual cycle adaptations of the red-backed sandpiper (*Calidris alpina*) in northern Alaska. Condor 68:3-46.

Holmes, R. T. 1966b. Feeding ecology of the red-backed sandpiper (*Calidris alpina*) in arctic Alaska. Ecology 47:32-45.

Mickelson, P. G., D. Schamel, D. Tracy and A. Ionson. 1977. Avian community ecology at two sites on Espenberg Peninsula in Kotzebue Sound, Alaska. In *Environmental Assessment of the Alaskan Continental Shelf* (Annual Reports of Principal Investigators for the year ending March 1977), Volume 5:1-74.

Myers, J. P. and F. A. Pitelka. 1975. Breeding bird census: wet coastal plain tundra (I) and (II). American Birds 29(6):1135-1136.

Myers, J. P., R. S. Greenberg, and F. A. Pitelka. 1977. Breeding bird census: wet coastal plain tundra (I) and (II). American Birds 31(1):82-83.

Myers, J. P., R. P. ERickson, and F. A. Pitelka. 1978a. Breeding bird census: wet coastal plain tundra (I), Barrow Alaska. American Birds Volume 32.

Myers, J. P., W. D. Shuford, and F. A. Pitelka. 1978b. Breeding bird census: wet coastal plain tundra (II), Barrow, Alaska. American Birds Volume 32.

Myers, J. P., L. E. Stenzel, and F. A. Pitelka. 1978c. Breeding bird census: arctic low foothills tundra, Atkasook, Alaska. American Birds 32:115-116.

Myers, J. P., B. J. McCaffery, and F. A. Pitelka. 1979a. Breeding bird census: wet coastal plain tundra (I), Barrow, Alaska. Submitted to American Birds.

Myers, J. P., W. D. Shuford, and F. A. Pitelka. 1979b. Breeding bird census: wet coastal plain tundra (II), Barrow, Alaska. Submitted to American Birds.

Myers, J. P., W. D. Shuford, S. Johnston, and F. A. Pitelka. 1979c. Breeding bird census: arctic low foothills tundra, Atkasook, Alaska. Submitted to American Birds.

Pitelka, F. 1974. An avifaunal review for the Barrow region and North Slope of arctic Alaska. Arctic and Alpine Research 6(2):161-184.

Redburn, D. R. 1974. The ecology of the inshore marine zooplankton of the Chukchi Sea near Point Barrow, Alaska. M.S. thesis, University of Alaska, Fairbanks.

Sowles, A. L., S. A. Hatch, and C. J. Lensink. 1978. Catalog of Alaska Seabird Colonies. Fish and Wildlife Service, U.S. Dept. of the Interior, vi + 32 pp. + 153 maps.

Ugolini, F. C. 1975. Ice-rafted sediments as a cause of some thermokarst lakes in the Noatak River Delta, Alaska. Science 188: 51-53.

Uhl, William R. and Carrie K. Uhl. 1977. Tagiumsinaaqmiit: Ocean Beach Dwellers of the Cape Krusenstern area: Subsistence Patterns. Anthropology and Historic Preservation, Cooperative Park Studies Unit, University of Alaska, Fairbanks, Alaska. Occasional Paper 14:vi + 227 pp.

Vermeer, K. and G. G. Anweiler. 1975. Oil threat to aquatic birds along the Yukon coast. Wilson Bull. 87:467-480.

Walker, D. A., P. J. Webber, K. R. Everett, and J. Brown. 1977. The effects of low-pressure wheeled vehicles on plant communities and soils at Prudhoe Bay, Alaska. U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire. Special Report 77-17, iii + 49 pp.

Weller, G., D. Norton, and T. Johnson, eds. 1978. Environmental Assessment of the Alaskan Continental Shelf, Interim Synthesis: Beaufort/Chukchi. ix + 362 pp.

XIII. Research Personnel, 1978 Season

Research Coordinator

- Peter G. Connors

Research assistants

- Katharine A. Breyer
- Carolyn S. Connors
- Frank Gress
- Katherine Hirsch
- Craig Hohenberger
- Douglas Woodby

Consultants

- J. P. Myers
- F. A. Pitelka
- R. W. Risebrough
- Carrie Uhl
- W. Robert Uhl

Annual Report

Contract #: 02-7-022-35410
Research Unit: 196
Number of pages: 258

The distribution, abundance and feeding ecology of birds associated with pack ice

George J. Divoky
Principal Investigator

Assisted by:
Robert Boekelheide
Kate Darling
Deborah M. Ford
Doug Forsell
A. Edward Good
Tom Harvey
Katie Hirsch
Karen Oakley
Colleen Monahan
Tom Scharffenberger
Kenneth Wilson
Doug Woodby

Report prepared by:
George J. Divoky
A. Edward Good

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

1 April 1979

Table of Contents

List of Tables

List of Tables (Continued)

List of Tables (Continued)

List of Tables (Continued)

List of Figures

List of Figures (Continued)

List of Figures (Continued)

List of Figures (Continued)

List of Figures (Continued)

List of Figures (Continued)

List of Figures (Continued)

List of Figures (Continued)

Acknowledgements

The data presented here is in large part the result of a huge field effort conducted in 1976. The attempt at censusing the 1200 km of northern Alaska coastline would not have been possible without the dedication and enthusiasm of all those listed on the title page. The logistical support provided by the Naval Arctic Research Laboratory was central to our effort. OCS logistics coordinators, David Kennedy, Ted Flesher and Daniel Brooks did much to ensure the success and safety of field operations. David Norton, Arctic Project Office Biologist, provided moral and scientific support.

The data processing which is just now being completed and will provide the analyses that will result in the final products was largely the work of Michael Crane and his staff.

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

As part of the environmental assessment of the outer continental shelf of Alaska the distribution, abundance and feeding ecology of seabirds associated with pack ice are being studied. An attempt is being made to determine the critical species and habitat associated with the pack ice. This report reports primarily on the Beaufort Sea where oil leases will be conducted in late 1979.

Observations of birds in marine habitats show that densities are low until late July. Oldsquaw then begin to concentrate in lagoons and surface feeders such as phalaropes, gulls and Arctic Terns become abundant along islands, spits and bars. Islands and spits continue to have high densities until late September. Lagoons are less important in September as Oldsquaw complete their molt and then occupy a wide variety of littoral habitats on the Beaufort coast. The nearshore waters within 20 km of land are the most important with offshore areas having low densities except for the area north of the Plover Islands. Drifting pack ice provides a major food source for surface feeders in the nearshore Beaufort and the presence of ice may affect Oldsquaw numbers also.

Terrestrial habitats adjacent to the Beaufort Sea were found to support large numbers of breeding birds in June and July. Wet and moist tundra had the highest densities and areas near river deltas and mouths were found to be more important than other areas.

This report documents bird use of the nearshore Beaufort Sea from June through October and provides information on where and when oil development will have the most detrimental impacts on bird populations.

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. Sea ice creates a dynamic environment that can both increase and decrease bird numbers. 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.

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, ice cover and distance from ice edge.

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 primary prey species consumed by seabirds associated with the pack ice.

C. Relevance to problems of petroleum development

The ice environment of the Bering, Chukchi and Beaufort seas will present unique problems to those involved in the exploitation of oil and gas reserves. The dynamic aspects of pack ice and the severe temperatures associated with it increase the chances of mechanical and human error causing incidents which could prove harmful to biological systems. In the pack ice the biological systems that will be impacted by such incidents could be expected to be less resilient than those in areas further south. This is due both to the slow rate of biodegradation of oil in Arctic waters and the low species diversity of biological systems in the Arctic.

Birds found in and next to the pack ice can be expected to be severely impacted by oil spills and other perturbations associated with oil and gas exploitation. 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. Oil spilled in the pack ice will spread out in areas of open water such as leads and polynas. Because these are the areas where birds are concentrated in the ice the chances of birds coming in contact with spilled oil are greater in the ice than in open water.

The data obtained through this research unit are applicable to problems of petroleum development in a number of ways. Areas that support high densities of birds can be designated as critical areas so that little or no human disturbance will occur in the area. Alternatively, human activity can be planned so that it occurs at a time when bird use of the area is low. Because of the dynamic nature of the pack ice critical areas and the times when they are critical vary greatly. Unlike delineating critical areas on or near the mainland where specific geographic areas can be described, critical areas in the pack ice are frequently defined in terms of ice cover, distance to shelfbreak, water temperature, etc. These factors are constantly changing during ice formation and deformation. Thus the designation of critical areas and species has to develop slowly and requires a large data base.

This project will provide a pre-development data base on bird distribution and abundance in relation to these parameters. Thus specific questions that government or industry seeks to address can be answered by using the data set. The question of age ratios in Glaucous Gulls is an example of such a question. Ultimately it is hoped that future studies will be able to compare their data with that of this research unit so that the effects of petroleum development can be quantified.

III. Current state of knowledge

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. Because followers in the Beaufort are directly related to the type of ice-breaking being done, his observations do not provide accurate estimates of densities. 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 areas

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 areas.

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 as does the ice in the northern Chukchi and Beaufort.

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 Burns 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 little is known about the winter situation. This will no longer be the case after OCSEAP's winter studies in the Beaufort Sea.

The water flowing north through the Bering Strait is a major influence on the Chukchi Sea. The 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 on 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 are present from approximately June to October; their 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 Chukchi and Beaufort seas 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 biologically productive of the three seas studied by this project.

V. Sources, methods and rationale of data collection

A. Methods

1. Pelagic censusing

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, meterologic and ice conditions are recorded for each observation period.

1978 was the first year in which all data gathered by this project were processed using the SOL-20 microprocessor. All observations were put on coded sheets and then entered onto micro-floppy discs on board ship. A conversion from the micro-floppy discs to "033" format, IBM compatible large discs, has just been completed and data can now be sent to NODC directly after a cruise.

Further processing of this data has been delayed until the arrival of the Texas Instrument terminal which is part of a system Hal Petersen of R.U. 527 is developing for OCSEAP. We anticipate using the terminal and the University of Rhode Island computer for further editing and analysis of data.

The maps and tables of pelagic data presented in this report are the result of computing birds per km^2 by hand.

2. Coastal habitat utilization -- foot surveys

In 1976 surveys on foot were conducted to obtain information on bird utilization of specific coastal habitats. The transects walked to census coastal habitats are present in Figures 112 through 122.

Censusing was conducted with the aid of USGS or Coast and Geodetic Survey charts. After locating his exact position the observer would walk on a transect paralleling the coast. In most cases a team of two people censused together: one walking on the beach or bluff adjoining the beach, the other walking 20 to 200 meters inland. All birds encountered during a transect were recorded. All birds observed, their activities and associated habitat were recorded. Additional information on sex, plumage, age, etc., was collected whenever possible. Birds flying in a direct manner and assumed to be not utilizing the habitat in a strict sense, were not recorded as being associated with a given habitat. Such sightings will be included in the data being analyzed for movements and migration but are not included in habitat utilization. Weather conditions were recorded periodically throughout the day. Wind, glare, fog and rain were major factors in hindering observations. Whenever these conditions caused a substantial drop in the quality of observations the transect was terminated. At the end of a transect the observer would locate his position on a chart and compute the kilometers of a habitat censused. Because the coastal mainland has a number of closely juxtaposed habitats a number of habitats can be sampled simultaneously. A transect along 20 km of bluff would allow the censusing of 20 km of ocean or lagoon, 20 km of beach, and 20 km of the habitat present on the bluff. If patches of wet and moist tundra occurred on the bluff the distance walked in each would be computed. After each visit to an area the number of birds per kilometer per habitat for each species was computed. This gives a birds per linear distance figure and appears to be the best way of presenting bird densities in coastal linear habitats.

Descriptions of the habitat types used in the course of the mainland work are given below.

Alpine tundra -- Characterized by well-drained soil, extensive bare ground and prostrate vegetation. This habitat is equivalent to Kessel anc Cade's (1958) Dry Tundra. Alpine tundra was encountered only in the Cape Lisburne area where it was generally found over 100 m elevation.

Wet tundra -- Characterized by extensive standing water with emergent vegetation, usually grasses and sedges. Ponds are frequently scattered throughout this habitat. Wet tundra is analagous with Kessel and Cade's (1958) sedgegrass marsh and Bergman's (1974) flooded tundra.

Moist tundra -- Any moderately well-drained area covered by vegetation, sometimes including small ponds or wet areas. The determining factor is the amount of standing water. Vegetative components vary from area to area. Moist tundra as defined for purposes of this study includes Kessel and Cade's (1958) Tussock-Heath, Tundra-Lacustrine water edge and Lacustrine water habitat types. However, since this study was done in a variety of areas vegetation other than Tussock-Heath were encountered.

Moist tundra with ponds -- This habitat is similar to moist tundra except that it contains more ponds. A straight course in this habitat would cross a pond or lake every 200 m. The distinction between moist tundra and moist tundra with ponds is not always definite. Because bird densities appeared to be related to the presence of ponds we felt it important to attempt to show this correlation.

Brackish tundra -- This habitat includes tundra areas influenced by salt water. The substrate is typically mud and vegetation, usually *Puccinellia* or *Carex*. This habitat is analogous to Bergman's Coastal Wetlands (Class VII) except that our classification is not dependent on the presence of ponds, as his is.

River delta -- An area where a river meets the ocean, lagoon or bay waters. It is characterized by salt to brackish water, the division of the river into several channels, delta islands and extensive mudflats.

River mouth -- An area where a small or medium sized river enters a lagoon, bay or the ocean. It is different from a river delta in that there is no branching into channels nor are there delta islands.

Beach -- The strip of bare ground along the edge of the ocean or lagoon. Substrate can be sand, gravel, mud, peat or some combination.

Spits and Bars -- Any narrow peninsula of land jutting into the sea or enclosing a lagoon is included in this category. A wide size range is included in this grouping from spits of a few hundred meters to a land form the size of Point Franklin.

Lagoon -- Areas of salt or brackish water partially or entirely enclosed by barrier islands, bars or spits.

Bay -- Any area of salt or brackish water that is partially enclosed by the mainland shoreline or spits and bars.

Ocean -- Any salt or brackish water that is not enclosed, as in lagoons and bays.

An attempt was always made to identify the primary habitat being utilized by a bird. Birds found in the ocean in close proximity to the beach were recorded as using the beach rather than the ocean. The data format for this project allows two habitats to be entered for each bird sighting. Thus when computer analysis of the data is possible a more detailed habitat utilization study can be done.

Dates and localities of mainland censusing are presented in the list of field trips on page 10. Areas censused in this way are presented in Figures 112-122.

3. Aerial surveys

Aerial surveys of the Alaskan Beaufort sea coast and the northern Chukchi coast south to Cape Lisburne were conducted in 1976. The shoreline was divided into 15 coastal sections (A-Q) based on habitat and land forms. Table 8 describes each of these sections. Censusing was conducted from aircraft flying at 150 feet. In general the flight path was 300 m seaward of the beach. An ice and position observer and one to two bird observers were on each flight. The ice and position observer would draw the flight path, ice conditions and time on maps. The bird observers recorded all birds out to 300 m from either side of the plane. When only one bird observer was aboard only one side of the plane was censused. Bird observers recorded the species, number, and habitat of all species seen. After the flight all information was entered into OCSEAP's "033" format.

The distance of each habitat censused for each flight was computed and the number of birds per linear kilometer of habitat was computed for each flight over each coastal section.

4. Cooper Island

Field work on Cooper Island was conducted from 1 July to 12 September 1978.

a. Breeding birds

The chronology, hatching success, fledging success and growth rates of Arctic Terns (*Sterna paradisaea*) and Black Guillemots (*Cepphus grylle*) breeding on Cooper Island were studied in order to compare 1978 with previous years and examine how ice conditions affect these parameters. Chicks were weighed and measured every other day after hatching until fledging. All chicks were banded with USFWS bands and green plastic bands. Adult Black Guillemots were captured at the nest and banded with USFWS bands.

b. Shoreline transects

The north and south shores of Cooper Island were divided into six transects. These transects were walked every other day. The species, number, age, sex, plumage, behavior, flight direction and habitat of all birds were recorded. Ice conditions were mapped for each transect. The number of birds by species per km were computed.

Whenever feeding birds were observed an attempt was made to locate and identify prey organisms. Plankton tows were conducted every other day to supplement our observations of plankton on transects.

VI. Results

A. Pelagic censusing

During the past year bird observations were conducted on the four cruises listed below:

Ship	Dates	Location	No. of 15 min. Observations	Figures
NOAA SURVEYOR	2 May to 15 May	Bering Sea	254	84-95
NOAA SURVEYOR	25 May to 12 June	Bering Sea	308	96-110
USCGC NORTHWIND	26 Aug. to 15 Sept.	Beaufort Sea	188	19-31
R/V ALUMIAK and M/V NATCHIK	5 Aug. to 29 Aug.	Beaufort Sea	261	1-17

In addition the following data from previous years is presented:

Ship	Dates	Location	No. of 15 min. Observations	Figures
USCGC GLACIER	31 July to 25 Aug. 1975	Chukchi Sea	403	32-67
USCGC GLACIER	28 to 29 Sept. 1976	Chukchi Sea	41	68-83

1. Beaufort Sea

A primary area of interest in 1978 was the nearshore area of the Beaufort Sea between Harrison Bay and Camden Bay. This area will be leased for oil and gas exploitation in the fall of 1979. A series of transects were selected in spring 1978 in order to systematically sample the area.

Mechanical problems with vessels and ice conditions prevented the completion of the planned grid. The USCGC NORTHWIND had a number of problems culminating in the loss of a generator. Because the ship was then forced to steam to Kodiak for repairs, the total number of transects obtained in the offshore waters of the Beaufort Sea was disappointingly low. In the nearshore waters few preselected transects were conducted due to time spent in repairing a winch on the R.V. ALUMIAK. When the M.V. NATCHIK was brought in as a replacement, ice prevented the completion of the grid. The M.V. NATCHIK proved to be an excellent vessel for nearshore observations. We strongly urge that future nearshore censusing be conducted from her rather than the ALUMIAK. The NATCHIK has the benefit of being used for one study at a time thus avoiding the problems of multi-disciplinary cruises. Some changes need to be made in the NATCHIK, however, so that an observer can stand on top of the cabin and make observations while the radar is functioning. This could be accomplished by mounting the radar on a superstructure.

Ice conditions in the Beaufort Sea were relatively moderate in 1978. Less ice was present than in 1975 and 1976, but more ice was present than in 1977 when open water extended out to the shelf break. Maps showing the cruise tracks, birds per km^2 and ice conditions for the Beaufort Sea in 1978 are presented in Figures 1 through 31.

2. Bering Sea

The two Bering Sea cruises in 1978 filled a major gap in our censusing of the Bering Sea ice edge. While we have good data from March through April we lacked observations for May and early June. Birds begin to move to breeding colonies in May and it is important to see how densities in the ice change as breeding begins. All of the observations obtained on these two cruises have been entered onto magnetic discs.

The cruise tracks, birds per km^2 and ice conditions for the two 1978 Bering Sea cruises are presented in Figures 84 through 110.

B. Aerial censuses of coastal habitat

The results of the aerial surveys flown in 1976 are presented in Tables 9 through 23 and summarized by month in Tables 25-29 for the Beaufort. The coastal sections are described in Table 8 and identified in Figure 111.

C. Mainland tundra, beach and littoral zone utilization

The results of the land-based coastal surveys are presented in the tables listed below.

Table	Location	Dates	Figure
A	Cape Lisburne	25 - 28 June	118
B	Cape Lisburne	13 - 18 August	118
C	Cape Beaufort	13 - 15 July	119
D	S. Kasegaluk Spit	12 - 13 July	119
E	Icy Cape	21 - 28 June	120
F	Icy Cape	7 - 11 July	120
G	Icy Cape	9 - 12 September	120
H	Wainwright	30 June - 4 July	121
I	Wainwright	30 July - 4 August	121
J	Wainwright	13 - 15 September	121
K	Peard Bay	17 - 20 June	122
L	Peard Bay	31 July - 4 August	122
M	Peard Bay	14 - 16 September	122
N	Barrow	18 - 19 July	123
O	Pitt Point	8 - 11 July	124
P	Pitt Point	30 August - 2 September	124
Q	Colville River	13 - 15 July	125
R	Oliktok Point	12 - 15 June	125
S	Oliktok Point	16 - 19 July	125
T	Oliktok Point	4 - 6 September	125
U	Kuparuk River	30 June	
V	Sagavanirktok River	23 - 24 June and 3 July	
W	Bullen to Brownlow Pt.	21 - 24 July	127
X	Barter Island	24 June	128
Y	Bernard Spit	24 June	128

The total birds per kilometer per habitat for each month are given in Table Z. The data for each habitat per month is summarized in Figures 123 through 126.

VII. Discussion

A. Pelagic censusing

All of the data from the 20 cruises conducted in the ice have been put on magnetic discs. In the very near future we will begin to analyze the data with the aid of the Texas Instrument 771 and the programs being written by Hal Petersen (R.U. 527) for analyzing data in the "033" data format. For this annual report we have focused our attention on the Beaufort Sea since part of it will be leased in the fall of 1979.

Beaufort Sea

Observations made outside the 10-fathom contour in 1978 confirmed the findings of past cruises in the offshore Beaufort. Overall densities of more than 10 birds per km^2 were uncommon. The only area supporting high densities was the area directly east of Barrow and north of the Plover Islands (Figure 20). This area typically has higher densities than the rest of the Beaufort which is apparently due to the Bering Sea water that moves through the Chukchi Sea and into the extreme western Beaufort (Johnson, 1956). High densities of surface feeders are usually associated with this water mass (Divoky, 1978). In 1978 we found large numbers of Short-tailed Shearwaters (Puffinus tenuirostris) in this area (Figure 25).

Aside from the Bering Sea water mass mentioned above, the offshore Beaufort Sea has no major oceanographic feature that concentrates seabirds. Because shoreline migrants constitute the bulk of all species seen in the Beaufort we have stratified the data with regard to distance from shore (Table 1). When the shearwaters are excluded from the total the average density for strata outside of 15 km from shore does not exceed an average of 5 birds per km^2. Densities inside 19 km averaged 25 birds per km^2. This is due primarily to large Oldsquaw (Clangula hyemalis) and eider (Somateria spp.) flocks seen just north of Flaxman Island and Camden Bay. The presence of ice played no discernible role in offshore distributions. While the offshore Beaufort is a rather homogeneous unit characterized by uniformly low biological productivity and resulting low bird densities, the nearshore Beaufort is a conglomeration of a large number of habitats that vary greatly in the bird species and densities they support. In order to discuss bird distribution in the nearshore Beaufort we have divided the coast into ten sections. The divisions are based primarily on coastal features such as barrier islands, river mouths and bays. While the principal reason for these divisions is to stratify by habitat they also serve the purpose of providing information on areas that fall under certain political jurisdictions. These sections are shown in Figure 18. They are unfortunately (but for a good reason) not exactly the same as the sections used in the discussion of aerial surveys.

Before discussing the coastal divisions some general comments on densities in the nearshore Beaufort in relation to shore can be made. Table 2 shows average densities and frequencies of occurrence in relation to distance from the mainland shore. To present a more accurate picture of the actual densities and frequencies certain species have a total density and frequency and also a density and frequency excluding migrants. "Migrants" as referred to in Table 2 describes all birds flying in a general westerly direction. The densities that exclude migrants provide a more accurate picture of the number of birds actually being supported by the habitat as opposed to those just flying over it.

Table 2 confirms the observations made outside of the ten-fathom curve. Outside of 15 km from shore densities are low except for migrating eiders. Migrating eiders are closely associated with the mainland shore as is seen by their high densities within 3 km from shore. Nowhere are non-migrating eiders found in high densities. This will be discussed in greater detail later.

When migrating eiders are subtracted from total densities it is apparent that the dominant species in the nearshore Beaufort is the Oldsquaw. Their distribution within 11 km from shore, where our sampling was most intensive, is rather uniform. A high average density in the 4 and 5 km from shore range will not be explainable without further analysis. All the other species in Table 2 were seen in low densities.

Table 6 shows the average total density of birds observed in each of the coastal sections shown in Figure 18. Tables 3-5 show the average density for Oldsquaw, eider and phalaropes (Phalaropus fulicarus and/or Lobipes lobatus), respectively. These three species comprised over 80 percent of all birds seen on inshore cruises in 1976 and 1977 and over 90 percent of all birds seen in 1978. Thus an analysis of their distribution does much to explain total densities inshore.

Table 6 shows that the Plover Island area had the highest average density of any coastal section in 1976 and the second highest average density in 1977. In 1978 the densities encountered in the Plovers were comparable to densities in other years but much less than the high densities encountered in lagoon areas that same year. In 1978 unlike other years there were few large flocks of surface feeders encountered north of the Plovers. Instead Oldsquaw were present in numbers in both early and late August.

Elson Lagoon

Elson Lagoon was sampled only in 1978 and only on 2 August. The ten transects conducted found high densities of Oldsquaw from the base of the Pt. Barrow spit to the pass just west of Cooper Island. Migrating eiders were found in moderate numbers as they crossed the lagoon on their way to the base of Pt. Barrow spit.

Plover Islands

The Plover Island area encompasses the nearshore waters from Barrow to Tangent Point that lie north of the Plover Islands. The area differs from other sections of the Beaufort coast due to its proximity to the Bering Sea water that flows east past Pt. Barrow. The warmer water apparently is the reason why zooplankton and surface feeding bird species are more abundant in this area than in other areas of the Beaufort.

The best information for inshore bird densities for this area comes from the Cooper Island field camp. In late July and early August the waters around Cooper support large multi-species feeding flocks of surface feeders. Red Phalaropes (Phalaropus fulicarius), Arctic Terns (Sterna paradisaea), Black-legged Kittiwakes (Rissa tridactyla) and Sabine's Gulls (Xema sabini) are the primary species found in these flocks. The primary prey species being consumed by the flocks are Apherusa glacialis and Thysanoessa raschii. Zooplankton associated with ice apparently play a major role in supporting the large feeding flocks. Surface feeders decline during August while Oldsquaw increase in number.

Smith Bay

Sampling in Smith Bay has been light and all observations have been made in the last week of August. Oldsquaw were found in high densities in both 1977 and 1978 and comprised over 90 percent of the birds in both years. It is unlikely that the area supports large numbers of birds earlier in the year since it lacks the islands and spits that concentrate surface feeders and Oldsquaw in early August.

Pitt Point

The Pitt Point section lacks barrier islands, rivers and spits and is in general a featureless section of coastline whose main purpose appears to be the separating of Smith Bay from Harrison Bay. Censusing in early August was conducted only in 1978. These transects had high total densities (over 500 birds per km^2) but 95 percent of these were migrating eiders so the total density of birds actually occupying the habitat was very low.

The average densities on late August transects in this area have varied over the three sampling years. In 1976 phalaropes were found in the area in large numbers. This is surprising since 20 August is a rather late date for high densities of phalaropes. The pelagic distribution of phalaropes in the Beaufort in 1976 (Divoky, 1978) shows that high densities were present just east of Pt. Barrow and the birds seen in the Pitt Point area appear to be the eastern edge of that concentration. In late August 1977 migrating eiders constituted 41 percent and Oldsquaw 24 percent of the birds seen in the area. Densities for total species during that year were less than 30 birds per km^2. In late 1978 large flocks of Oldsquaw (280 per km^2) were present.

Harrison Bay

Harrison Bay contains a wide variety of habitats and thus densities vary greatly depending on which area is sampled. The extreme eastern edge of the bay lies next to Simpson Lagoon and contains Thetis Island. The area is shallower than the western part of the bay and is used extensively by Oldsquaw. The western side of the bay usually has low densities.

Our censusing of Harrison Bay showed high average densities in 1976 and 1978 (77 and 92 birds per km^2 respectively) and low densities in 1977 (16 birds per km^2). In 1976 over half of the birds seen were migrant eiders. Almost 40 percent were Oldsquaw. The low densities in 1977 were low because no major eider migration was encountered and Oldsquaw densities were low. In 1978 intensive censusing took place in the eastern part of the bay where Oldsquaws are abundant. Oldsquaws are the primary reason for the high density that year.

Jones Islands

The Jones Island area includes the waters seaward of the Jones Islands. The area is of interest because it will be included in the 1979 lease sale and because it lies next to Simpson Lagoon which is known to be a major concentration area for Oldsquaw.

Total densities for the three years are rather uniformly low with between 20 and 30 birds per km^2 being encountered. The percentage of Oldsquaws varies greatly from year to year. The high densities in 1976 are apparently due to the calm weather and ice north of the islands that permitted birds to move north from Simpson Lagoon. Sampling in 1977 when no Oldsquaw were seen north of the islands was conducted in windy weather when birds would be more inclined to seek out the protection of lagoons. There was also more ice present in 1976 which would provide prey items north of the islands. The complete lack of Oldsquaws in 1977 is very hard to explain, however.

Phalaropes comprised over half the birds seen in 1977. They were more abundant in this section than elsewhere on the coast. The area does offer many islands and spits where migrant phalaropes are known to concentrate in the Beaufort.

Simpson Lagoon

Our sampling in Simpson Lagoon is light due to the shallowness of the lagoon. The area is known to support large numbers of molting Oldsquaw in August. Our data only shows this for 1978 when very high densities of Oldsquaw were found.

Prudhoe-Flaxman

The Prudhoe-Flaxman area includes the waters from the west dock of Prudhoe Bay east to the eastern tip of Flaxman Island. The barrier islands in this area are in general further offshore than in other areas such as Elson and Simpson Lagoons and the islands are spaced further apart than in the Plover or Jones Islands. We have separated the densities for this section into "inside" and "outside" the barrier islands. In general the "inside" habitat is comparable to other lagoons and the "outside" habitat is comparable to areas seaward of barrier islands.

In 1976 and 1977 total densities inside the barrier islands were less than those outside. In 1978 there was much less of a difference between the two habitats with the higher densities being found outside of the islands.

The high densities outside of barrier islands in 1976 and 1977 were due to different events in the two years. In 1976 large flocks of Oldsquaw were encountered just north of Flaxman Island. The number of Oldsquaws dropped drastically in 1977 when densities of 1.5 birds per km^2 were present. The high densities outside of the barrier islands in 1977 were due to large eider flocks. Eiders were not even encountered inside the barrier islands in this area in 1976. In 1978 eiders again constituted the bulk of the birds outside the islands but densities were much less than in 1977. The area inside the islands had a high percentage of eiders in 1977 but in other years no one species predominated.

Camden Bay

Total bird densities in Camden Bay were moderate in 1976 and 1978 and low in 1977. The high densities in 1976 were due to high numbers of Oldsquaw. In 1977 no Oldsquaw were seen in the bay and the few birds that were seen were almost all eiders. Oldsquaw densities remained low in 1978 but eider densities increased greatly.

Barter Island

Sampling in the area east of Camden Bay has been spotty due to heavy ice and the distance from Barrow. In 1976 densities were moderate with Oldsquaw and Brant comprising 55 and 39 percent, respectively, of the total birds. In 1977 and 1978 densities were low.

Summary of Beaufort Sea pelagic observations

The low densities of birds outside of the 10-fathom contour has now been well documented. Only the area north of the Plover Islands has been found to support high densities of pelagic birds and they appear to be associated with Bering Sea water that has passed through the Chukchi. The low densities of birds in the Beaufort is somewhat surprising since shipboard observations show Arctic Cod (*Boreogadus saida*) to be abundant under the ice. The Black Guillemot which consumes primarily fish and is common offshore in the Chukchi Sea is rare throughout most of the Beaufort. It appears that the low numbers of zooplankton in the water column of the offshore Beaufort reduces the number of birds offshore.

While densities outside of 10 fathoms are rarely more than 10 birds per km yearly averages for observations from inside 10 fathoms in 1976, 1977 and 1978 are 60, 33 and 107 birds per km^2 respectively. Our observations cover only August and early September but this is the time of maximum abundance for birds in the Beaufort. During this period three species comprise over 80 percent of all birds seen.

Whie eiders are seen in large numbers they almost all are migrating. Table shows that only in the area between Prudhoe Bay and Flaxman Island are non-migrating eiders regularly encountered. This area is the center of Common Eider (*Somateria mollissima*) breeding abundance with approximately 400 nests being present. It appears likely that many of the birds we observed are associated with these breeding colonies.

There is no reason to believe that this is the one area in the nearshore Alaskan Beaufort where migrating eiders stop.

Phalaropes (primarily Phalaropus fulicarius but some Lobipes lobatus) were found throughout the nearshore Beaufort but usually in low densities. This research unit as well as R.U. 172 has shown that phalaropes are most concentrated within one to two meters of the beaches of spits and bars and our observations from vessels would miss most of the large concentrations.

Our observations for Oldsquaw show that they comprised over half of all birds seen inshore in 1976 and 1978 but only 20 percent in 1977. We have as of yet no analysis to explain the low numbers in 1977. It is important that we encountered the low densities in order to observe the yearly variation that can occur. If densities as low as 1977 were encountered after oil development began the impact of the oil industry would almost certainly be blamed.

Few patterns of Oldsquaw distribution can be discerned from Table 3. Oldsquaws can be expected to occur in moderate densities in all areas of the inshore Beaufort. Lagoons were found to have extremely high densities in 1978. After Oldsquaw complete their molt, however, they move to unprotected areas as the densities for Smith Bay and Pitt Point for 1978 show.

B. Aerial surveys

Tables 26 through 29 summarize by month the aerial surveys done in the Beaufort Sea in 1976. These tables give the total birds per kilometer per habitat in each section. Because the Beaufort Sea will be leased in late 1979 we have centered our discussion of results on that sea.

A few words need to be said about the quality of aerial surveys. Observing birds from a plane at 150 feet at a speed of between 80 and 120 miles per hour gives one a very rough picture of what is happening on the ground. Aerial surveys have the benefit of being able to cover a very large area in a short period of time. They seem best suited to locating large flocks of birds such as shearwaters in the Bering Sea. Birds not concentrated into flocks can be best censused when the survey is done over an area that provides a standard visual field such as a calm ocean or one with moderate swells. The observer can then scan for atypical objects that stand out against the background. Without such a background the observer has to work much harder to locate, identify and count birds. Almost all of our aerial surveys were conducted over a mosaic of ice, water, gravel, tundra vegetation, etc. Individual birds are easily missed when censusing such a visual conglameration and even large flocks have to fly or dive in order to be obvious. For this reason the reader should approach the aerial data cautiously. While changes in densities through time and in habitats are obvious the actual numbers provide only the roughest indices of actual birds present.

June

Our aerial surveys probably best show bird utilization of marine habitats and land/water interfaces throughout the summer with only marginal information on terrestrial habitats. Because ice cover is complete or nearly complete for most of June bird densities in the Beaufort Sea were extremely low. The sole exception is the river mouth/ delta habitat in Section L where a flock of Brant were encountered on the Colville River delta on 17 June. All other habitats had less than .1 bird per kilometer.

July

Densities in all habitats increased in July. Lagoons had the highest densities with ocean/spits and islands having the next highest abundance. Densities in all other habitats were two or less than two birds per linear kilometer.

August

For most habitats densities remained much the same in August as they were in July. Section H, the Plover Islands and Elson Lagoon had very high densities for ocean, pass, and spits and islands habitats. This trend continued for the rest of the year with large numbers of surface feeding species found on and near the Plover Islands.

September

Most habitats reached their maximum abundance in September. Spits and islands again had the highest linear density.

October

Our October aerial surveys document the few birds present in the Beaufort during this month. The large number of birds on Section H were flocks of Ross' Gulls (Rhodostethia rosea).

C. Mainland tundra, beach and littoral zone utilization

The following is a discussion of the data presented in Tables A through Z and Figures 123 through 126.

June

Wet tundra

Numbers of birds on wet tundra were found to be rather consistent with four of the areas having between 19 and 26 birds per km. The Oliktok area had 54 birds per km due to the large number of waterfowl at that locality. Snow cover at Oliktok played a role in concentrating the birds in wet tundra.

Loons (Gavia spp) when present comprised only a small percentage of total bird numbers. Geese were found in numbers only at Icy Cape and Oliktok. Ducks were most abundant at localities from Peard Bay to the east. Oldsquaw was usually the most abundant species but at Oliktok King Eiders (Somateria spectabilis) were more frequently encountered. Shorebirds usually comprised more than 50 percent of all birds seen. Red Phalaropes were usually the most abundant species. Semipalmated Sandpipers (Calidris pusilla) and Dunlin (C. alpina) were regularly encountered but in lesser numbers than Red Phalaropes. At Cape Lisburne Western Sandpipers (C. mauri) and Long-billed Dowitchers (Limnodromus scolopacous) were the most abundant species. Gulls and Arctic Terns when present were found in small numbers. Passerines were present at all localities but were most numerous at Peard Bay where Lapland Longspurs (Calcarius lapponicus) and Snow Buntings (Plectrophenax nivalis) comprised nearly a third of all birds seen.

Moist tundra

The average numbers of birds per km on moist tundra was half the average for wet tundra. Highest densities were found on delta islands.

Loons again comprised a small percentage of all birds seen. Ducks and geese were found in small numbers except at Oliktok. Shorebirds were less common than on wet tundra and comprised approximately 30 percent of all birds seen. No one species comprised the bulk of this percentage. Gulls and terns were found in low numbers. Passerines, primarily Lapland Longspurs and Snow Buntings, were abundant in this habitat at a number of localities. At Icy Cape and Peard Bay over 60 percent of the total birds were passerines.

Moist tundra with ponds

This habitat was found only at Cape Lisburne and bird numbers were comparable to those found in moist tundra. Shorebirds and passerines were the only two troups found in this habitat. The American Golden Plover (Pluvialis dominica) was the most abundant shorebird.

Brackish tundra

This habitat was encountered only at Icy Cape. The total number of birds encountered was similar to wet tundra. Species composition was also similar to wet tundra.

River delta

This habitat was encountered only at Icy Cape. Bird numbers were comparable to moist tundra. Together Semipalmated Sandpipers and Dunlin comprised approximately 50 percent of all birds seen.

River mouth

This habitat had the largest range of any habitat censused in June. Cape Lisburne had one large flock of Black Brant (*Branta bernicla*) that comprised over 50 percent of all birds seen. Western Sandpipers were also abundant in this habitat at Cape Lisburne. At Peard Bay Oldsquaw and Western Sandpipers were the most abundant birds. In the Sagavanirktok River delta Black Brant and Pintail (*Anas acuta*) were the most abundant species.

Beach

Bird numbers on and near beaches in June were usually less than 10 birds per km. The one exception was Cape Lisburne where Black-legged Kittiwakes (*Rissa tridactyla*) comprised 90 percent of all birds seen. These birds were from the colony at the Cape. At other localities shorebirds comprised the bulk of all birds seen. At Bernard Spit waterfowl were also important.

Spits and bars

Bird use of spits and bars was low at all localities except Cape Lisburne where one flock of Greater Scamp (*Aythya marila*) greatly increased the total.

Lagoon

Bird use of lagoons was high at Cape Lisburne and the Sagavanirktok River but low at Icy Cape and Bernard Spit. This is due to the presence of ice at the latter localities. Black Brant and Oldsquaw were the two most important species at Cape Lisburne. Oldsquaw and Red-throated Loons (*Gavia stellata*) were most important at the Sagavanirktok Tiver.

Bay

The two bays censused in June had negligible numbers of birds.

Ocean

As with lagoons ice played a role in decreasing bird numbers on the ocean in June. At Cape Lisburne Oldsquaw and murres (*Uria* spp.) were the most abundant species. At Oliktok Arctic Loons (*Gavia arctica*), Oldsquaw and King Eiders were abundant.

July

Wet tundra

In July bird numbers on wet tundra generally remained the same as in June. The average birds per km was the same as the preceding month.

The Pitt Point area was found to have low numbers of birds. Species composition was much the same as wet tundra in June, however. Shorebirds comprised 50 percent and ducks 20 percent of the total. Wet tundra at Cape Beaufort was found to be extremely atypical with only one flock of Arctic Terns being seen. At the other extreme an island in the Colville River supported 85 birds per kilometer of wet tundra. This high figure is due largely to the number of shorebirds seen (57 per km). Semipalmated Sandpipers were especially abundant with 25 per km being seen.

At Icy Cape bird numbers dropped slightly from June. The composition remained roughly the same as in June with shorebirds comprising 50 percent, geese 15 percent and ducks 10 percent of the total. The shorebird species composition changed drastically, however, with Pectoral Sandpipers (*Calidris melanotos*) being most abundant and other species being found in low numbers.

Wainwright had a typical wet tundra situation. Shorebirds comprised 40 percent of all birds seen with 12 per km being encountered. Red Phalaropes were abundant (7.5 per km). Lapland Longspurs comprised 33 percent of all birds seen.

At Oliktok Point bird numbers dropped greatly from June figures due to a decrease in geese and ducks. More shorebird species were present than in June. Semipalmated and Pectoral Sandpipers increased in numbers while Red Phalaropes declined.

Between Bullen and Brownlow Point bird numbers were found to be typical. Ruddy Turnstones and Golden Plovers were the most abundant shorebirds. No Red Phalaropes were seen in wet tundra.

Moist tundra

The total birds per km for moist tundra averaged the same in July as it did in June. Two areas, Cape Beaufort and Bullen-Brownlow, had approximately 6 birds per km. At Cape Beaufort Lapland Longspurs made up the bulk of the birds seen. At Bullen-Brownlow low numbers of shorebirds, jaegers and passerines were found. At Icy Cape species and numbers remained much the way they were in June. Pectoral Sandpipers were more common than in June, however. At Wainwright low numbers of shorebirds were seen. Lapland Longspurs were abundant (9.2 per km). In the vicinity of Barrow the moist tundra had large numbers of birds. Shorebirds were low in numbers. Passerines comprised over 33 percent of all birds seen.
At Pitt Point bird numbers in moist tundra were higher than in wet tundra

from the same area. This is due primarily to the higher numbers of passerines in moist tundra. In the Colville River delta low numbers of a variety of species were encountered. Semipalmated Sandpipers were the most abundant shorebird (5.7 per km) and Lapland Longspurs comprised over a third of all birds seen (9.5 per km). Bird numbers and species at Oliktok were much the same as found in June.

Moist tundra with ponds

Extremely low densities were encountered in this habitat at Pitt Point with only passerines being present. At Bullen-Brownlow bird numbers in this habitat were much the same as they were in moist tundra but with loons and waterfowl being more common.

Brackish tundra

In July brackish tundra continued to support numbers of birds comparable to those on wet tundra. At Icy Cape Western Sandpipers were the most common species with Glaucous Gulls (*Larus hyperboreus*), Lapland Longspurs and Black Brant also being present in numbers. At Pitt Point Pintails and Pectoral Sandpipers were the most abundant species each having more than 7 birds per km. The large number of birds seen on brackish tundra at Oliktok was due to Black Brant being numerous (36 per km).

Mud flats

Bird use of mud flats at Pitt Point was negligible.

River delta

At Icy Cape Western Sandpipers comprised more than 50 percent of all birds seen. Dunlin, Glaucous Gulls and Lapland Longspurs were common. At Oliktok Black Brant were common. Between Bullen and Brownlow Point Low numbers of birds were seen.

River mouth

A wide range of bird numbers occurred in this habitat in July. At Cape Beaufort bird numbers were high with Red and Northern Phalaropes and Long-tailed Jaegers (*Stercorarius longicaudus*) being the most abundant species. At Oliktok Black Brant were abundant (38.3 per km) with all other species being present in negligible numbers. Wainwright had no birds using river mouths and Pitt Point had low numbers.

Beach

Bird numbers on beaches remained low in July. At Icy Cape where numbers were high shorebirds comprised most of the birds seen. Western Sandpipers were abundant (11.8 per km). At all other localities bird numbers were negligible.

Spits and bars

Birds using spits and bars increased in July. At most sites shorebirds and gulls were the most abundant birds but between Bullen and Brownlow Point Oldsquaw were abundant with 27 per km.

Lagoons

Bird use of lagoons declined in July. Between Bullen and Brownlow Point Oldsquaw were common, however (8.1 per km).

Bay

The only bay censused had moderate bird numbers due to Oldsquaw being common (5.3 per km).

Ocean

With the exception of Barrow only moderate numbers of birds were seen in the ocean in July. The high figure for Barrow is due to Oldsquaw being abundant (134.5 km). This is also true at Bullen-Brownlow where 25.5 Oldsquaw per km were seen.

August

Wet tundra

At the three localities censused in August wet tundra supported the same number of birds as in June and July. At Wainwright only a small section of wet tundra was censused and a single flock of Red Phalaropes comprised the majority of birds seen. At Peard Bay low numbers of a variety of tundra species were encountered. At Pitt Point White-fronted Geese (*Anser albifrons*) (15.4 per km) and Dunlin (9.2 per km) were the most abundant species.

Moist tundra

Moist tundra continued to support approximately the same number of birds as it did in June and July. At Cape Lisburne passerines again comprised a large percentage of the total. Rock Ptarmagin (*Lagopus mutus*) were common and shorebird species diversity was lower than on previous visits. At Wainwright Lapland Longspurs were abundant (8 per km) and Dunlins were the most common shorebird (5.1 per km). At Peard Bay passerines comprised over 75 percent of all birds seen. At Pitt Point bird numbers were lower but this is due in large part to low numbers of passerines.

Moist tundra with ponds

This habitat was censused only at Wainwright where bird numbers approximated those found on wet tundra. Lapland Longspurs were abundant (8.0 per km) and Red Phalaropes were common (4.6 per km).

Brackish tundra

This habitat was censused only at Pitt Point where moderate bird numbers were found. Dunlin and Short-billed Dowitchers were the most abundant.

Mud flat

Although a rather large mud flat was censused at Pitt Point no birds were seen.

River delta

On the small section of river delta censused at Pitt Point large numbers of Black Brant and Dunlin were seen.

River mouth

At river mouths near Cape Lisburne bird numbers were high. Western Sandpipers were abundant (198 per km) and Dunlin and Bar-tailed Godwits (*Limosa lapponica*) were common. At Peard Bay bird numbers were lower with Western Sandpipers comprising 50 percent of the total.

Beach

The number of birds using the beach increased greatly in August. At Cape Lisburne Northern Phalaropes comprised over 50 percent of all birds seen. In the Wainwright-Pt. Franklin area bird densities on the beach were exceptionally high with 71.9 Red Phalaropes per km. At Peard Bay bird numbers were low. At Pitt Point moderate numbers of shorebirds associated with the beach.

Spits and bars

Spits and bars averaged over 200 birds per km in August. At Cape Lisburne Northern Phalaropes were the most abundant species (107 per km). At Wainwright bird numbers were exceptionally high with 258 Red Phalaropes and 121 Arctic Terns per km. At Peard Bay numbers were lower with 50 Red Phalaropes per km. At Pitt Point a small spit had high numbers of Sanderlings, Long-billed Dowitchers and Glaucous Gulls.

Lagoon

Lagoon use rose some from July levels but still was not high. At Cape Lisburne Pintails comprised over 50 percent of all birds. At Wainwright unidentified eiders (19.5 per km) and Oldsquaw (10.5 per km) were the most abundant species in lagoons.

Bay

Both bays censused in August had Oldsquaw as the principal species. Bird numbers were much higher at Pitt Point than at Peard Bay.

Ocean

Bird numbers on the ocean remained low at most localities with the exception of Peard Bay and Pitt Point where Oldsquaw were common.

September

Wet tundra

Bird numbers in wet tundra dropped drastically from June to August levels. At Icy Cape shorebird numbers were greatly reduced and Black Brant was the most abundant species. At Oliktok Long-billed Dowitchers were the most abundant shorebirds.

Moist tundra

Bird numbers on moist tundra were also greatly reduced in September. Only Oliktok had a moderate number of birds. Lapland Longspurs and Dunlin were the two commonest species at these sites.

Moist tundra with ponds

At both localities censused bird numbers were low to moderate. At Peard Bay Glaucous Gulls were the only birds seen. At Oliktok a number of species were seen with Dunlin and Long-billed Dowitchers being the most important.

Brackish tundra

Low numbers of birds were found at the two areas recensused. Black Brant was the commonest species at both sites.

River delta

At Oliktok bird use of river deltas was moderately high with Glaucous Gulls comprising over 70 percent of all birds seen.

D. Glaucous Gull age ratios

At the 1978 fall workshop for OCS investigators of vertebrate consumers, William Drury (R.U. 237 and 447) discussed the results of an aerial survey he conducted from Wainwright to Norton Sound. Drury's census showed that the percentage of subadult Glaucous Gulls on the coast was remarkably high. He expressed concern that if his census dealt with a valid sample, the population appeared to be undergoing a rapid increase.

Drury's concerns are based in large part on his experience with Herring Gulls on the east coast of North America (Kadlec and Drury, 1968) where decreased mortality of immature birds has caused the population to increase. The availability of human garbage is a major factor in the increase. As a result of discussions at the fall meeting a program was written to extract Glaucous Gull age information from the data files of R.U. 196 and 3/4. Summaries of these extractions are presented in Tables 30 and 31.

Table 30 shows the age ratios of Glaucous Gulls observed on land-based surveys on the northern Chukchi and Beaufort sea coasts. Most of these surveys were conducted in 1976. Detailed analysis of the age ratios is not yet available. General comments can be made on some trends. In 1976 the percentages of immature birds (immature is defined here as all subadult birds excluding hatching year birds) were low at most locations on the coast. Rarely were immatures more than 15 percent of all birds observed. If the Glaucous Gull has life table parameters similar to the Herring Gull, immatures should make up twelve percent of the population in a stable situation (W. Drury pers comm). Our only comprehensive land based data set since 1976 is from Cooper Island. Our observations in the summer of 1978 show that the age composition of Glaucous Gulls at Cooper Island has changed greatly since 1978. The percent of adult birds was not more than 50 percent for any month. Our data also shows that the number of Glaucous Gulls present on Cooper Island was much higher in 1978 than it was in 1976.

Table 31 presents the age ratios of Glaucous Gulls observed on cruises in the Bering, Chukchi and Beaufort Seas. This data also shows a high percentage of immature birds. The fact that young birds may be more attracted to ships than adult birds makes the shipboard data somewhat biased.

If the Glaucous Gull population is increasing due to decreased mortality of young birds the cause may be the food available at factory ships in the ice in the Bering Sea in winter. Dumps present along the coast might also provide an important food source in fall. Because Glaucous Gulls are a predator/scavenger that frequently eat eggs and young of other species the results of a population increase could adversely affect other tundra and island nesting species. The data on Glaucous Gull age ratios that has been gathered by R.U.3/4 and R.U. 196 will be processed further and analyzed with William Drury and Sam Patten who have both dealt with the problem of commensalism in gulls. In the summer of 1979 the Glaucous Gull colonies on the coast will be recensused to see if any increase has occurred over the totals found in 1976 by R.U. 3/4.

Little is known about Glaucous Gull population dynamics. Because food sources in the arctic vary greatly from year to year one would expect Glaucous Gull reproductive success to have a good amount of annual variation. What we might be seeing now is a pulse of immatures moving through the population.

VIII. Conclusions

Because the largest data base gathered by this research unit is for the Beaufort Sea and because the Beaufort will be leased in the near future the following conclusions will deal primarily with that sea and the potential impacts of oil development.

For almost nine months of the year the impact of the ice cover on birds in the Beaufort Sea is complete or nearly complete. Ice cover is complete or nearly complete from approximately the end of October until mid-June. While fish and zooplankton populations are present under the ice during this period the ice acts as a barrier preventing birds from preying on these populations. The only area where birds could be expected to regularly occur in the Beaufort in winter is in the chronic lead system that occurs from Wainwright to north of Pt. Barrow. Black Guillemots are known to occur in these leads during the winter (Gabrielson and Lincoln 1958) in the Chukchi and it seems likely that they are found in those parts of the lead system that enter the Beaufort just north of the Plover Islands. No other seabird species could be expected to be encountered in the Beaufort on a regular basis. The only food source available in areas where ice cover is complete is the carrion and feces of mammals found on the pack ice. While scavenging opportunities of this sort could be exploited by gulls the only birds associated with Polar Bear (_Thalarctos maritimus_) kills in March are Ravens (_Corvus corvax_) (T. J. Eley, pers. comm.).

In early May a flow lead (a lead formed by the free floating pack ice separating from the more stable land fast ice) forms in the Chukchi Sea from the Bering Strait to Pt. Barrow. The lead extends into the Beaufort not as a flow lead but as a series of leads fanning out into the Beaufort Sea pack ice. It is likely that most of the million eiders that migrate through the Beaufort (Barry 1968) pass Pt. Barrow in spring. Observations made by part of this study show that in 1976 the peak of King Eider migration was in late May with almost half a million birds passing on 26 May. In the Chukchi where the flow lead is a well defined structure, eiders will stop and sit in the water, especially if the lead is not open further north. In the Beaufort the lack of a well defined lead can be a problem for the eiders. A late cold spell can cause small leads to freeze over. In the Beaufort eiders can thus lose their migratory pathway and a place to rest on the water. When this happens large numbers of eiders may perish (Barry 1968).

Other species use the flow lead as a migratory pathway in spring. These include Oldsquaw, Glaucous Gulls (_Larus hyperboreus_), and murres (_Uria_ spp.). Those species are present in far fewer numbers than eider. In general most species found breeding on the mainland tundra adjacent to the Beaufort Sea complete the final part of their spring migration by flying over land. Thus for many of these species there is no contact with the marine system until after breeding is completed.

Aside from the birds that migrate along the leads in the Beaufort in spring the first use of the Beaufort Sea in the spring and early summer is by birds using barrier islands for breeding. The total number of seabirds breeding on barrier islands in the Alaskan Beaufort was 1,086 in 1976 (Divoky 1978) with Common Eiders and Glaucous Gulls being the two most numerous species. Both of these species are found on islands that are affected early by river runoff. Arctic Terns (Sterna paradisaea) and Black Guillemots (Cepphus grylle) are more common on islands away from rivers. The area from Oliktok Point to Flaxman Island has the most intense use of barrier islands and thus of their surrounding waters by breeding birds.

During June when the bird densities in the nearshore and offshore Beaufort are extremely low, densities on the adjacent mainland are extremely high. Figure 123 shows which habitats are most important during this time. Wet tundra and moist tundra have high concentrations of breeding birds. River mouths concentrate large flocks of non-breeders. Our aerial surveys for June (Table 25) show that in the nearshore waters and littoral habitats there are few birds. Our June transects from Cooper Island also demonstrate the lack of birds in nearshore areas (Divoky 1978). During most of June the open water in the nearshore Beaufort consists of moats next to the mainland beach and around barrier islands. Oldsquaw and loons (Gavia spp.) are the primary species found in these moats.

During July many species complete their breeding activities on the tundra and begin to occupy littoral habitats. The increase of birds on the ocean near shore is best demonstrated by comparing Figures 123 and 124. The ice undergoes its most rapid decomposition during this month and large areas of the nearshore Beaufort become ice-free. Oldsquaw begin to concentrate in large numbers on the south side of barrier islands.

In August bird densities in littoral habitats immediately adjacent to the shoreline reach their peak as shown in Figure 125. Spits and bars and barrier islands have the highest densities during this time due to large numbers of phalaropes, Arctic Terns, and Sabine's Gulls feeding on and next to the beaches and the large numbers of molting Oldsquaw found roosting on the south side of the islands.

Ovservations from vessels show that the nearshore Beaufort within the 10-fathom curve regularly supports densities of over 30 birds per sq. km with densities of over 500 birds per sq. km in lagoons and other areas where Oldsquaw concentrate. Oldsquaw have accounted for over 50 percent of all birds seen in the nearshore Beaufort. The importance of Oldsquaw in the nearshore Beaufort avifauna is even greater than the figures indicate since eiders, which constitute a high percentage of birds seen in the Beaufort (Table 4), are almost all migrants passing over the Beaufort.

Observations from outside the 10-fathom curve demonstrate that densities in the offshore Beaufort are rarely more than 10 birds per square kilometer. The only exception is the area north of the Plover Islands where Bering Sea water causes zooplankton and birds to be abundant in August and September.

An interesting aspect of our September data is the fact that densities seen in littoral habitats from the mainland (Figure 125) are much less than the August figures whereas aerial surveys show an increase in most littoral habitats (Table 28). This is because most of the species that concentrate to feed near beaches are surface feeders that usually leave the Beaufort by the first of September. Large flocks of Oldsquaw are present in the nearshore Beaufort in September and since they have completed their molt they are much less dependent on lagoons than they were in August. Glaucous Gulls also move from the mainland tundra to littoral habitats in September and in certain areas are found in very larger flocks.

Most Oldsquaw migrate southward in September and our October aerial surveys demonstrate the low densities present in the Beaufort. The only area where high densities were encountered was in the Plover Islands where large flocks of Ross' Gulls were present.

IX. Summary of January - March Quarter

A. Ship or field trip schedule

No field work was conducted during this quarter

B. Laboratory operations and data analyzed

All data gathered by R.U. 196 and R.U. 3/4 in 1976 have been keypunched, put on tape, and subsequently put on magnetic discs. These 78 data files containing over 90,000 entries have been run through Hal Petersen's (R.U. 527) check programs which search for taxonomic code errors as well as logical errors in other fields. During this quarter the errors found by these programs were corrected by personnel from R.U. 196. After the corrections are made on the magnetic tapes the data will be ready to be entered into the NODC data bank. In addition, the three data files of 1977 data have been keypunched by Mike Crane's office.

All data gathered since August 1977 has been entered onto mini-floppy discs using the SOL-20 and the "PELAGICB" entry program. The program contains a number of edits that prevent the entry of invalid data. During this quarter a program was written by Leo Karl of Custom Computing to convert the data from mini-floppy disc ASCII format to large floppy disc EBCDIC format. A test of the conversion conducted by Michael Crane showed that it is functional. The six data files on mini-floppy discs will be converted to large discs and sent to Michael Crane so that the data can be put on magnetic tape and sent to NODC.

In addition to the above Mr. Karl has completed a program to extract data on age by day for any species or group of species by cruise. The program converts easily to analyze sex, plumage, and color phase. The results of the extraction of Glaucous Gull data are presented in this report.

X. Literature Cited

Barry, T. W. 1968. Observations on natural mortality and native use of eider ducks along the Beaufort Sea coast. Canadian Field-Naturalist 82(2):140-144.

Bergman, R. D., Howard, R. L., Abraham, K. F., and Weller, M. W. 1977. Water birds and their wetland resourses in relation to oil development at Storkerson Point, Alaska. USFWS Resource Publication: 129. 38 p.

Divoky, G. J. 1976. The pelagic feeding habits of Ivory and Ross' Gulls. Condor 78:85-90.

_____. 1978. The distribution, abundance and feeding ecology of birds associated with pack ice. Annual Report to BLM/NOAA. 327 pp.

Fay, F. H. 1974. The role of ice in the ecology of marine mammals of the Bering Sea. Pages 383-399 in D. W. Hood and E. J. Kelly, eds. Oceanography of the Bering Sea. Univ. Alaska Inst. Mar. Sci. Occas. Publ. 2:1-623.

Frame, G. W. 1973. Occurrence of birds in the Beaufort Sea, summer 1969. Auk 90:552-563.

Hays, H., and M. LeCroy. 1971. Field criteria for determining incubation stage in eggs of the Common Tern. Wilson Bulletin 83:425-429.

Irving, L., C. P. McRoy, and J. J. Burns. 1970. Birds observed during a cruise in the ice-covered Bering Sea in March 1968. Condor 72: 110-112.

Johnson, M. W. 1956. The plankton of the Beaufort and Chukchi sea area of the Arctic and its relation to the hydrography. Arctic Inst. of N. America, Technical Paper No. 1, 32 pp.

Jacques, F. L. 1930. Water birds observed on the Arctic Ocean and Bering Sea in 1928. Auk 47:353-366.

Kessel, B., and T. J. Cade. 1958. Birds of the Colville River, northern Alaska. Univ. Alaska Biol. Pap. 2. 83 pp.

MacGinitie, G. E. 1955. Distribution and ecology of the marine invertebrates of Point Barrow, Alaska. Smithson. Misc. Collect. 128:1-201.

McRoy, C. P., J. J. Goering, and W. E. Shiels. 1972. Studies of primary production in the eastern Bering Sea. In A. Y. Takenouti et al. (Eds.). Biol. Oceanogr. of the northern Pacific Ocean. Pp. 200-218.

_____, and S. R. Goering. 1974. The influence of ice on the primary productivity of the Bering Sea. Pages 403-421 in D. W. Hood and E. J. Kelly, eds. Oceanography of the Bering Sea. Univ. Alaska Inst. Mar. Sci. Occas. Publ. 2:1-623.

Mohr, J. L., and S. R. Geiger. 1968. Arctic basin faunal precis - animals taken mainly from arctic drifting stations and their significance for biogeography and water-mass recognition. Pages 297-313 in J. E. Sater, coordinator. Arctic drifting stations. Arctic Inst. N. Am.

Nelson, E. W. 1883. Birds of the Bering Sea and the Arctic Ocean. Cruise of the Revenue Steamer Corwin in Alaska and the N. W. Arctic Ocean in 1881. Govt. Printing Off., Washington, D. C.

Shapiro, L. H., and J. J. Burns. 1975. Major late-winter features of ice in northern Bering and Chukchi seas as determined from satellite imagery. Univ. of Alaska Geophysical Inst. Rept. 75-8.

Swartz, L. G. 1966. Sea-cliff birds. Pages 611-678 in N. J. Wilinovsky and J. N. Wolfe, eds. Environment of the Cape Thompson region, Alaska. U.S.A.E.C., Div. Tech. Inf., Oak Ridge, Tennessee.

Watson, G. E., and G. J. Divoky. 1972. Pelagic bird and mammal observations in the eastern Chukchi Sea, early fall 1970. U.S. Coast Guard Oceanogr. Rep. 50:111-172.

_____, and _____. 1974. Marine birds of the western Beaufort Sea. In J. C. Reed and J. E. Sater (Eds.) The coast and shelf of the Beaufort Sea. Arctic Inst. of N. Am. pp. 681-695.

3NW878

Distance from land	Km	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100	101-105	106-110	111-115	116-120
Number of transects	n	0	18	35	21	7	5	11	12	14	8	2	4	8	12	5	7	5	2	0	5	0	5	0	2
All *Gavia*	$\bar{x}$	-	1.2	0.6	0.5	0.2	0.3	0.2	0.5	0.3	0.2	0.0	1.7	1.5	2.2	7.0	1.6	0.7	0.8	-	0.0	-	0.4	-	0.0
	% freq	-	50	31	19	14	20	9	33	29	13	0	25	25	42	40	57	60	50	-	0	-	20	-	0
Puffinis tenurostris	$\bar{x}$	-	0.0	0.0	0.0	4.9	81.9	7.1	0.0	171.9	0.0	0.0	0.0	6.1	0.1	0.0	0.0	0.0	0.0	-	0.0	-	0.0	-	0.0
	% freq	-	0	0	0	29	40	18	0	50	0	0	0	8	8	0	0	0	0	-	0	-	0	-	0
Clangula hyemalis	$\bar{x}$	-	6.9	1.6	0.7	3.7	0.2	0.1	0.6	1.7	1.9	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0	-	0.0	-	0.0
	% freq	-	56	26	10	43	20	9	8	36	13	50	25	0	0	0	0	0	0	-	0	-	0	-	0
All Eiders	$\bar{x}$	-	10.1	24.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0	-	0.0	-	0.0
	% freq	-	33	6	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	-	0	-	0
All Phalaropes	$\bar{x}$	-	1.3	0.3	0.1	0.2	0.0	0.0	0.9	1.6	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	-	0.0	-	0.0	-	0.0
	% freq	-	17	11	5	14	0	0	17	29	0	0	0	0	0	20	0	0	0	-	0	-	0	-	0
All *Stercorarius*	$\bar{x}$	-	0.2	0.2	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0	-	0.0	-	0.0
	% freq	-	11	14	10	0	0	0	17	7	0	0	0	0	0	0	0	0	0	-	0	-	0	-	0
Larus hyperboreus	$\bar{x}$	-	0.8	0.6	0.9	0.6	0.2	0.4	0.4	1.5	0.0	0.0	0.3	1.0	1.3	0.0	0.2	0.3	0.0	-	0.4	-	0.4	-	0.9
	% freq	-	50	34	43	57	20	27	17	43	0	0	25	50	58	0	14	20	0	-	20	-	20	-	50
Rissa tridactyla	$\bar{x}$	-	0.0	0.0	0.2	0.9	0.5	0.5	0.0	0.9	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0	-	0.0	-	0.0	-	0.0
	% freq	-	0	0	10	29	40	9	0	36	0	0	0	13	0	0	14	0	0	-	0	-	0	-	0
Sterna paradisaea	$\bar{x}$	-	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0	-	0.0	-	0.0
	% freq	-	11	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	-	0	-	0
Total	$\bar{x}$	-	22.1	27.5	3.1	10.3	83.1	8.2	2.6	177.3	2.2	0.6	2.5	8.8	3.5	8.1	2.0	1.0	0.8	-	0.4	-	0.7	-	0.9
	% freq	-	83	69	71	100	60	36	67	86	38	50	75	75	75	60	71	80	50	-	20	-	40	-	50

Table 1. Densities of birds in relation to distance from land in the Beaufort Sea in August and September 1978.

3AL878

Distance from land	Km	≤ 1	2+3	4+5	6+7	8+9	10+11	12+13	14+15	16+17	18+19
Number of transects	n	19	48	47	59	44	25	8	4	3	4
Gavia arctica	$\bar{x}$ (excluding migrants)	1.1	1.0 (0.9)	0.7 (0.7)	1.0 (1.0)	0.8	0.9	1.6 (1.0)	0.0	0.9	0.6
	% freq	53	44 (40)	32 (30)	39 (37)	45	40	38 (25)	0	67	25
Gavia stellata	$\bar{x}$ (excluding migrants)	0.1	0.1 (<0.1)	<0.1	0.1	0.2	0.1	0.2	0.0	0.0	0.0
	% freq	5	6 (2)	2	2	11	4	13	0	0	0
All *Gavia*	$\bar{x}$	1.5	1.4 (1.2)	1.2 (1.0)	2.0 (1.3)	1.4 (1.3)	1.7 (1.6)	2.8 (2.1)	2.0 (0.0)	0.9	0.6
	% freq	58	58 (54)	40 (36)	56 (49)	61 (59)	56 (52)	63 (50)	50 (0)	67	25
Branta bernicla	$\bar{x}$	0.0	17.5 (0.0)	0.0	1.3 (0.0)	0.9 (0.0)	0.0	0.0	0.0	0.0	0.0
	% freq	0	4 (0)	0	2 (0)	2 (0)	0	0	0	0	0
Clangula hyemalis	$\bar{x}$	67.1	52.2	133.1	74.2	36.8	64.7	26.6	80.6	0.0	0.0
	% freq	84	73	68	63	52	64	50	25	0	0
All Eiders	$\bar{x}$ (excluding migrants)	226.2 (3.1)	67.7 (4.4)	6.3 (1.4)	4.8 (0.5)	3.0 (0.3)	15.4 (0.5)	11.7 (1.5)	0.7	0.3 (0.0)	50.8 (2.5)
	% freq	53 (26)	35 (17)	26 (15)	20 (10)	16 (7)	24 (12)	25 (13)	25	33 (0)	50 (25)
All Phalaropes	$\bar{x}$	2.7	4.0	18.5	4.3	4.2	0.7	0.8	1.0	0.0	0.3
	% freq	26	31	32	24	27	16	25	25	0	25
All *Stercorarius*	$\bar{x}$	0.4	0.3	0.1	0.4	0.3	0.1	0.3	0.0	0.0	0.0
	% freq	11	13	6	12	11	4	25	0	0	0
Larus hyperboreus	$\bar{x}$	0.6	3.1	1.3	2.7	0.7	0.7	0.1	0.0	0.0	0.0
	% freq	26	21	21	36	30	36	25	0	0	0
Rissa tridactyla	$\bar{x}$	0.6	0.2	0.3	0.3	0.3	0.2	0.0	0.0	0.0	0.0
	% freq	11	2	4	8	7	8	0	0	0	0
Xema sabini	$\bar{x}$	0.1	0.1	0.1	<0.1	0.1	0.1	0.0	0.0	0.0	0.0
	% freq	5	4	2	2	5	4	0	0	0	0
Sterna paradisaea	$\bar{x}$	1.3	1.1	2.4	2.2	1.7	0.3	0.0	0.0	1.0	0.0
	% freq	16	10	13	10	14	8	0	0	33	0
Uria species	$\bar{x}$	0.1	1.1	0.4	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
	% freq	5	19	9	2	0	0	0	0	0	0
Total density	$\bar{x}$ (excluding migrants)	299.2(76.0)	149.0(68.1)	163.8(158.7)	92.4(86.4)	49.4(45.9)	84.5(69.6)	42.6(31.7)	84.9(83.0)	2.2(1.9)	51.7(3.4)
	% freq	100(100)	98(96)	96(96)	97(93)	91(89)	100(96)	100(100)	75(75)	100(100)	50(50)

Table 2. Densities of birds in relation to distance from land in the Beaufort Sea in August 1978.

Table 3. Densities and percent of total densities of Oldsquaw in the nearshore Beaufort Sea.

n = number of transects
$\bar{x}$ = average density in birds per km^2
% total = percentage of total density constituted by Oldsquaw

	1976			1977			1978		
	n	$\bar{x}$	% total	n	$\bar{x}$	% total	n	$\bar{x}$	% total
Plover Islands									
early August	0	-	-	26	8.5	10	21	28.6	41
late August	11	2.9	3	18	31.4	61	19	25.7	47
Elson Lagoon	0	-	-	0	-	-	10	299.1	91
Smith Bay	0	-	-	6	56.7	90	12	80.0	94
Pitt Point									
early August	0	-	-	0	-	-	13	20.3	4
late August	8	2.9	5	29	6.5	24	11	279.7	95
Harrison Bay	23	30.3	39	38	10.2	63	53	84.7	92
Jones Islands	35	22.3	73	35	0.0	0	37	8.2	30
Simpson Lagoon	2	8.3	16	5	36.0	84	7	507.4	96
Prudhoe-Flaxman (inside)	22	3.7	21	17	0.2	1	71	20.2	35
Prudhoe-Flaxman (outside)	10	168.3	99	14	1.5	1	7	2.1	6
Camden Bay	10	45.5	83	43	0.1	1	20	6.9	11
Barter Island	14	40.0	55	40	2.0	21	20	0.2	12
Total	135	32.1	54	271	6.7	20	301	60.8	57

Table 4. Densities and percent of total densities of eiders in the nearshore Beaufort Sea.

n = number of transects
$\bar{x}$ = average density in birds per km^2
% total = percentage of total density constituted by eiders

	1976			1977			1978		
	n	$\bar{x}$	% total	n	$\bar{x}$	% total	n	$\bar{x}$	% total
Plover Islands									
early August	0	-	-	26	39.0	48	21	8.8	13
late August	11	4.1	5	18	0.2	<1	19	18.7	24
Elson Lagoon	0	-	-	0	-	-	10	23.1	7
Smith Bay	0	-	-	6	0.8	1	12	0.9	1
Pitt Point									
early August	0	-	-	0	-	-	13	523.5	95
late August	8	0.2	<1	29	11.3	41	11	13.0	4
Harrison Bay	23	41.3	54	38	2.2	13	53	3.9	4
Jones Islands	35	1.5	5	35	7.0	34	37	8.1	30
Simpson Lagoon	2	0.0	0	5	0.0	0	7	4.4	1
Prudhoe-Flaxman (inside)	22	5.7	33	17	23.7	83	71	6.7	12
Prudhoe-Flaxman (outside)	10	0.0	0	14	147.9	96	7	29.2	87
Camden Bay	10	38.3	14	43	7.5	90	20	50.7	80
Barter Island	14	0.0	0	40	0.6	40	20	0.0	0
Total	135	11.5	19	271	17.0	51	301	33.1	31

Table 5. Densities and percent of total densities of phalaropes in the nearshore Beaufort Sea.

n = number of transects
$\bar{x}$ = average density in birds per km^2
% total = percentage of total density constituted by phalaropes

	1976			1977			1978		
	n	$\bar{x}$	% total	n	$\bar{x}$	% total	n	$\bar{x}$	% total
Plover Islands									
early August	0	-	-	26	16.3	20	21	4.7	7
late August	11	43.6	51	18	3.0	6	19	0.9	2
Elson Lagoon	0	-	-	0	-	-	10	0.0	0
Smith Bay	0	-	-	6	2.3	4	12	1.6	2
Pitt Point									
early August	0	-	-	0	-	-	13	1.1	<1
late August	8	52.7	87	29	5.0	18	11	0.2	<1
Harrison Bay	23	1.3	2	38	1.4	9	53	0.6	1
Jones Islands	35	4.6	15	35	10.9	53	37	8.3	31
Simpson Lagoon	2	3.6	7	5	5.0	12	7	10.1	2
Prudhoe-Flaxman (inside)	22	1.8	10	17	1.5	4	71	15.1	26
Prudhoe-Flaxman (outside)	10	0.0	0	14	0.3	<1	7	0.1	<1
Camden Bay	10	3.9	7	43	0.4	4	20	1.1	2
Barter Island	14	1.3	2	40	0.2	3	20	0.7	41
Total	135	8.9	15	271	4.1	10	301	5.4	5

Table 6. Total densities of birds in the nearshore Beaufort Sea.

n = number of transects
$\bar{x}$ = average density in birds per km^2

	1976		1977		1978	
	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
Plover Islands						
early August	0	-	26	81.8	21	69.4
late August	11	86.1	18	51.7	19	55.2
Elson Lagoon	0	-	0	-	10	329.0
Smith Bay	0	-	6	63.0	12	85.0
Pitt Point						
early August	0	-	0	-	13	555.0
late August	8	60.5	29	27.6	11	295.8
Harrison Bay	23	77.0	38	16.3	53	92.3
Jones Island	35	30.4	35	20.4	37	26.9
Simpson Lagoon	2	53.3	5	43.0	7	528.6
Prudhoe-Flaxman (inside)	22	17.5	17	34.5	71	58.0
Prudhoe-Flaxman (outside)	10	170.1	14	154.2	7	33.5
Camden Bay	10	54.8	43	8.3	20	53.6
Barter Island	14	73.3	40	2.8	20	1.7
Total	135	59.5	271	33.1	301	107.2

Table 7. Densities and percentages of migrating vs. non-migrating eiders by area in nearshore Beaufort Sea during August 1976, 1977 and 1978.

n = number of transects
$\bar{x}$ = average desnity in birds per km^2

Area	Year	n	$\bar{x}$ migrant	$\bar{x}$ non-migrant	% migrant	% non-migrant
Plover Islands	76	11	2.4	1.7	62	38
	77	44	23.4	0.2	99	1
	78	40	9.9	3.7	73	27
Elson Lagoon	78	10	22.6	0.5	98	2
Smith Bay	77	6	0.8	0.0	100	0
	78	12	0.0	0.9	0	100
Pitt Point	76	8	0.0	0.8	0	100
	77	29	2.8	8.5	25	75
	78	24	289.5	0.4	>99	1
Harrison Bay	76	23	38.2	3.1	92	8
	77	38	2.2	0.0	100	0
	78	53	3.9	0.0	100	0
Jones Islands	76	35	1.4	0.1	94	6
	77	35	5.8	1.2	83	17
	78	37	7.5	0.6	93	7
Simpson Lagoon	76	2	-	-	-	-
	77	5	-	-	-	-
	78	7	4.4	0.0	100	100
Prudhoe-Flaxman - inside islands	76	22	1.5	4.2	26	74
	77	17	0.0	28.7	0	100
	78	71	4.1	2.6	61	39
Prudhoe-Flaxman - outside islands	76	10	0.0	-	-	-
	77	14	45.9	102.4	31	69
	78	7	27.7	1.4	95	5
Camden Bay	76	10	37.3	1.0	97	3
	77	43	7.0	0.0	100	0
	78	20	14.7	36.0	29	71
Barter Island	76	14	-	-	-	-
	77	40	0.8	0.0	100	0
	78	20	-	-	-	-
Total	76	135	10.1	1.5	87	13
	77	271	10.4	9.8	51	49
	78	301	29.4	3.7	89	11

Table 8. Coastal sections in the northern Chukchi and Beaufort seas.

A -- CAPE LISBURNE TO KASEGALUK LAGOON

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
133 km	Ayugatak Spit	1.8	7.0	Ayugatak	4.7	
	Agiak Spit	0.8	3.0	Agiak	1.2	
	Omalik Spit	0.6	2.5	Omalik	1.7	
	Total	3.2	12.5	Total	7.6	

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour) 5 fathoms	 10 fathoms	Coastal Relief (avg. distance mainland shore to contour) 15 m	 30 m
None, however, has at least 25 small streams.		8-11 km	16-24 km	150 m hills	3 km inland

B -- SOUTHERN KASEGALUK LAGOON

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
45 km	Southern Spit	7.1	20.4	Kasegaluk	300	2
	Neakok - Kukpowruk Pass	4.4	23.4			
	Total	11.5	43.8			

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour) 5 fathoms	 10 fathoms	Coastal Relief (avg. distance mainland shore to contour) 15 m	 30 m
Kukpowruk R. & Epizetka R.	6.4	8 km	19 km	2-5 km	8-26 km

Table 8, cont'd.

C -- CENTRAL KASEGALUK LAGOON

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
87 km	Pt. Lay Island	7.4	31.4	Kasegaluk	300	2
	Akunik - Utukok Pass	5.3	24.0			
	Solovik Island	7.8	30.4			
	Total	20.5	85.8			

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
Kokolik R.	2.6	8 km	19 km	2-5 km	8-26 km

D -- NORTHERN KASEGALUK LAGOON

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
60 km	"Icy Cape Island"	4.2	26.2	Kasegaluk	300	2
	Akoliakatat - Pingorarok Pass	3.6	18.4			
	"Northern Spit"	2.2	15.2			
	Total	10.0	59.8			

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
None	None	8 km	19 km		

Blossom shoals (3-4 fathoms) extend 10-13 km NW of Icy Cape

Table 8, cont'd.

E -- WAINWRIGHT (Kilimantavi to Atanik)

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
60 km	None, however spits are present on each side of Wainwright Inlet	6.3	9.6	Wainwright Inlet	234	2

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
Sinaruruk R. (protected)	4.5	0.8 km	2-5 km	2-14 km	35-48 km

Kungok, Kuk, Ivisaruk & Alatakrok Rivers enter into Wainwright Inlet complex.

F -- PEARD BAY

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
45 km	"West Spit"	4.3	9.0	Peard Bay	59.8	6
	Pt. Franklin	4.7	13.1	Kugrua Bay	21.8	3-4
	Seahorse Island (largest has 20' elevation)	0.3	2.4			
	"East Spit"	0.9	8.6			
	Total	10.2	33.1			

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
Kugrua R. enters Kugrua Bay		8-11 km	16 km	0.8 km	32 km

Several small streams enter Bay

Table 8, cont'd.

G -- TACHINISOK INLET TO PT. BARROW

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
96 km	None			None		

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
Walakpa R. enters into 7 km long Walakpa Bay. 10-12 small streams.		0.8-2 km	2-8 km	Mod. bluffs (8-27 m) present, furrowed by numerous small streams. Almost no beaches adjoin bluffs. Closest 30 m elevation, 53 km inland.	

H -- PT. BARROW TO TANGENT PT.

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
85 km	Barrow Spit	2.0	15.0	Elson	260	3
	Deadman's Island	0.3	2.1	Admiralty Bay	585	2-3
	Tapkaluk Island Complex	1.8	12.5	Inaru, Meade, Topagoruk, Chipp & Alaktak R. enter Admiralty Bay		
	Cooper Island	1.6	6.1			
	Martin Island	0.7	8.0			
	Sanigarvak Island	0.2	2.6			
	Igalik Island	0.4	3.2			
	Total	7.0	49.5			

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
See: Lagoons, Admiralty Bay		8 km	26 km	69 km	96 km

Table 8, cont'd.

J -- TANGENT PT. TO DREW PT.

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
61 km	Kulgurak Island	0.5	5.2	Fatigue Bay	14.6	
	Tulimanik Island	0.4	4.0	(extensive mud flats)		
	Total	0.9	9.2			

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
Ikpikpuk R. & Piasuk R.	29.4	19 km	40 km	43 km	56 km

K -- DREW POINT TO CAPE HALKETT

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
70 km	"Pitt Pt. Island"	0.1	1.6	Pogik Bay	18.2	
	Pogik Bay Complex	1.8	4.1	Small shallow lagoon near Kokruqgarok		
	Total	1.9	5.7			

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
No rivers, few small streams.		6 km	38 km	51 km	58 km

Table 8, cont'd.

L -- HARRISON BAY

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
150 km	Eskimo Island	1.2	4.4	Kogru R. - a series of connected lakes that form a 16 km long, 47 km^2 lagoon; entrance depth 1 m, but deeper inside.		

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
Colville	51.2	13 km	35 km	6 km	19 km

Extensive bars and shoals to the E and SE of Atigaru Pt.

Pacific shoal - 13 km SE of Cape Halkett; 1-2 m deep and 8 km in N-S length.

M -- OLIKTOK PT. TO PT. MCINTYRE

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
60 km	Spy Island	0.5	5.4	Simpson Lagoon	260	2
	Leavitt Island	0.3	2.6	Gwydyr Bay		1-2
	Pingok Island	4.2	11.4			
	Bertoncini Island	0.2	0.8			
	Bodfish Island	0.7	1.3			
	Cottle Island	0.9	6.9			
	Long Island	1.0	11.2			
	Egg Island	0.1	1.9			
	Stump Island	0.4	4.4			
	Total	8.8	48.5			

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
Ugnuravik R.	-	6 km	17 km	21 km	32 km
Sakonowyak R.	-				
Kuparuk R.	10.2				

Table 8, cont'd.

N -- PART I: PT. MCINTYRE TO BULLEN

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)
74 km	Gull Island	0.03	0.5
	Reindeer Island	0.2	2.6
	Argo Island	0.05	0.8
	Niakuk Island	0.1	1.2
	Howe Island	0.8	0.5
	Duck Island	0.05	0.5
	Foggy Island	0.2	3.2
	Cross Island	0.5	4.2
	Dinkum Island	0.03	0.4
	Narwhal Island	0.3	3.5
	Jeanette - Karluk Is. Complex	0.3	5.4
	Lion Point	0.2	1.9
	Tigvariak Island	3.6	3.2
	Pole Island	0.6	4.8
	Belvedere Island	0.4	6.2
	Total	7.4	38.9

Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
Prudhoe Bay	78	
Foggy Island Bay	117	
Mikkelsen Bay	91	
Total	286	

6 km wide, 6-8 m deep channel between mainland and barrier islands.

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
Putuligayuk R.	-	18 km	27 km	10 km	16 km
Sagavanirktok R.	26.9				
Kadleroshilik R.	-				
Saviovik R.	8.8				

Table 8, cont'd.

N -- PART II: BULLEN TO BROWNLOW PT.

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
38 km	Bullen Point	0.1	1.6	"Challenge - Flaxman Lagoon"	156	3
	Point Gordon	0.2	2.8			
	Challenge Island	0.1	0.1			
	Alaska Island	0.4	5.9			
	Duchess Island	0.3	2.9			
	North Star Island	0.2	2.4			
	Flaxman Island	3.5	11.2			
	Point Thompson	0.1	2.1			
	Total	4.8	29.0			

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
Staines (branch of Canning R.)	6.4	6 km	10 km	10 km	14 km

Table 8, cont'd.

P -- BROWNLOW PT. TO JAGO RIVER

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
125 km	Canning River Complex	1.2	15.0	"Canning River Lagoon"	24.7	2
	Collinson Point	0.3	3.2	"Anderson Point"	16.9	2
	Anderson Point Complex	1.3	9.4	Arey Lagoon	39.0	2
	Arey island	1.4	11.6	Kaktovik Lagoon	18.2	3
	Barter Island	15.9	7.4			
	Bernard Spit	1.2	8.3			
	Total	21.3	54.9	Total	98.8	

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
Canning R. (excluding Staines R. branch)	5.6	6 km	9 km	3 km	5 km
Tamayariak R.	-				
Katakturuk R.	3.1				
Sadlerochit R.	1.6				
Hulahula R.	6.6				
Okpilak R.					
Numerous small streams					

Table 8, cont'd.

Q -- JAGO RIVER TO U.S./CANADA BORDER

Km. of Seaward Aspect	Barrier Islands or Spits Name	Area (km^2)	Seaward Coast (km)	Lagoons or Protected Waters Name	Area (km^2)	Depth (m)
109 km	Jago Spit	0.4	6.1	Jago	52.5	3
	Tapkaurak Spit	0.6	11.6	Tapkaurak	20.0	2
	"Pokok Lagoon Spit"	0.7	7.2	Oruktalik	8.8	2
	Angun Lagoon (Humphrey Pt. - Angun Pt.)	0.5	8.0	Pokok	143.1	2
				Pokok Bay	4.3	3
	Nuvagapak Lagoon Complex	0.6	11.2	Angun	8.8	3
	Egaksrak Lagoon Complex	0.4	5.9	Beaufort - Nuvagapak	26.3	2
	Icy Reef	1.8	26.4	Egaksrak	35.0	2
	Demarcation Point	0.4	4.0	Siku	22.5	2
				Demarcation Bay	42.5	5
	Total	5.4	80.4	Total	363.8	

Rivers	Km. of Coastline	Nearshore Bottom Topography (avg. distance mainland shore to contour)		Coastal Relief (avg. distance mainland shore to contour)	
		5 fathoms	10 fathoms	15 m	30 m
Jago R.	9.6	2 km	6 km	3 km	6 km
Aichilik - Egaksrak R.	10.2				
Kongakut R.	16.0				
Numerous small streams					

Table 9. Linear densities of birds observed on aerial surveys in 1976 between Kasegaluk Lagoon and Cape Lisburne (Section A).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
16 July								
Ocean	17	-	0.3	-	0.1	-	-	0.4
Ocean/mainland	38	<0.1	-	-	0.1	0.5	-	0.6
Lagoon	2	-	-	-	-	-	-	0.0
Spits and islands	2	-	-	-	-	-	-	0.0
Mainland beach	36	-	0.1	-	-	-	-	0.1
6 August								
Ocean	257	<0.1	1.4	-	0.2	0.3	29.9	31.8
Ocean/mainland	140	-	1.1	-	-	5.5	41.7	48.3
Lagoon	6	2.0	31.7	-	-	-	-	33.7
Spits and islands	10	-	-	-	3.1	1.3	-	4.4
Rivermouth/delta	1	-	15.0	-	16.0	-	-	31.0
Mainland beach	129	-	0.8	-	3.7	1.6	-	6.1
Dump	0.2	-	-	-	500.0	-	-	500.0
20 August								
Ocean	383	-	4.6	0.1	0.2	0.5	0.5	5.9
Ocean/mainland	133	0.1	-	0.5	0.9	0.5	-	2.0
Lagoon	6	-	6.7	-	-	-	-	6.7
Spits and islands	10	-	-	-	-	-	-	-
Mainland beach	122	-	-	-	0.8	0.8	-	1.6
11 September								
Ocean	383	<0.1	2.4	-	0.3	0.4	8.1	3.1
Ocean/mainland	133	0.1	2.9	-	0.1	0.3	-	3.4
Lagoon	6	-	9.2	-	-	-	-	9.2
Spits and islands	10	-	-	-	-	-	-	0.0
Rivermouth/delta	1	-	-	-	1.0	-	-	1.0
Mainland beach	122	-	0.1	-	1.5	0.3	-	1.8
Dump	0.2	-	-	-	2500.0	-	-	2500.0

Table 9. Linear densities of birds observed on aerial surveys in 1976 between Kasegaluk Lagoon and Cape Lisburne (Section A). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
<u>20 September</u>								
Ocean	232	<0.1	4.3	-	1.7	-	<0.1	6.0
Ocean/mainland	232	-	-	-	-	-	-	0.0
Lagoon	12	-	6.8	-	6.3	-	-	13.1
Spits and islands	20	-	-	-	-	-	-	0.0
Rivermouth/delta	2	-	-	-	15.0	-	-	15.0
Mainland beach	212	-	-	-	0.8	<0.1	-	0.8
Dump	0.2	-	-	-	1000.0	-	-	1000.0
<u>28 September</u>								
Ocean	133	<0.1	0.3	-	0.2	0.8	-	1.3
Ocean/mainland	133	-	-	-	-	-	-	-
Lagoon	6	-	-	-	-	-	-	-
Spits and islands	10	-	-	-	-	-	-	-
Rivermouth/delta	1	-	-	-	7.0	-	-	7.0
Mainland beach	122	-	-	-	3.0	-	-	3.0
Dump	0.2	-	-	-	-	-	-	0.0

Table 10. Linear densities of birds observed on aerial surveys in 1976 between Point Lay and southern Kasegaluk Lagoon (Section B).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
8 July								
Ocean	106	0.1	3.0	-	0.1	0.3	-	3.5
Ocean/spits and islands	54	0.2	0.8	-	-	0.1	-	1.0
Lagoon	54	-	1.0	-	0.1	<0.1	-	1.1
Pass	1	2.0	2.0	-	-	-	-	4.0
Spits and islands	54	-	1.2	-	1.4	0.8	-	3.4
16 July								
Ocean	48	-	22.8	-	<0.1	-	-	22.8
Ocean/spits and islands	41	0.1	-	-	-	-	-	0.1
Lagoon	54	0.1	1.9	-	-	0.2	-	2.2
Spits and islands	54	-	-	-	0.3	1.1	-	1.4
6 August								
Ocean	60	<0.1	0.2	-	-	<0.1	-	0.2
Ocean/spits and islands	41	-	0.6	-	-	0.5	-	1.1
Lagoon	153	-	1.3	-	0.2	0.1	-	1.6
Spits and islands	108	-	0.9	0.3	2.0	2.8	-	6.0
20 August								
Ocean	54	-	11.0	4.3	0.7	1.3	-	17.3
Lagoon	162	<0.1	2.5	1.8	0.1	1.4	-	5.8
Spits and islands	54	-	-	-	0.2	-	-	0.2

Table 10. Linear densities of birds observed on aerial surveys in 1976 between Point Lay and southern Kasegaluk Lagoon (Section B). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
<u>11 September</u>								
Ocean	54	0.1	4.4	-	0.1	-	-	4.6
Ocean/spits and islands	54	0.1	0.7	-	-	-	-	0.8
Lagoon	162	<0.1	6.5	-	0.3	0.3	-	7.1
Pass	1	-	8.0	-	-	-	-	8.0
Spits and islands	54	-	-	-	1.5	-	-	1.5
<u>20 September</u>								
Ocean	54	-	4.7	-	0.8	-	-	5.5
Ocean/spits and islands	54	<0.1	1.3	-	0.1	-	-	1.4
Lagoon	162	<0.1	2.7	-	0.9	-	-	3.6
Spits and islands	54	-	-	0.4	3.2	-	-	3.6
<u>28 September</u>								
Ocean	54	-	0.3	-	0.2	-	-	0.5
Lagoon	162	-	1.0	<0.1	0.8	-	-	1.8
Spits and islands	54	-	0.6	-	1.8	-	-	2.4

Table 11. Linear densities of birds observed on aerial surveys in 1976 between Icy Cape and Point Lay (Section C).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
17 June								
Ocean	73	-	-	-	-	-	-	-
Lagoon	146	-	0.7	-	0.3	0.2	<0.1	1.2
Spits and islands	73	-	0.2	-	0.6	0.2	<0.1	1.0
8 July								
Ocean	233	<0.1	1.4	-	0.1	<0.1	0.1	1.6
Ocean/spits and islands	73	0.1	2.1	-	<0.1	0.1	-	2.3
Lagoon	73	-	1.8	-	-	-	-	1.8
Pass	2	-	1.0	-	-	-	-	1.0
Spits and islands	71	-	-	-	0.6	0.6	-	1.2
16 July								
Ocean	75	0.1	0.1	-	-	-	-	0.2
Lagoon	73	0.1	3.3	-	<0.1	0.2	-	3.6
Pass	2	-	-	-	1.5	-	-	1.5
Spits and islands	71	-	3.2	-	3.5	5.5	-	12.2
6 August								
Ocean	73	<0.1	-	-	-	-	-	<0.1
Ocean/spits and islands	73	-	0.9	10.5	0.5	3.2	-	15.1
Lagoon	146	<0.1	0.4	-	0.2	1.0	-	1.6
Spits and islands	73	-	-	-	1.0	20.4	-	21.4
Rivermouth/delta	17	0.1	-	-	1.5	-	-	1.6
20 August								
Ocean	73	-	3.5	2.6	0.5	2.1	-	8.7
Lagoon	219	-	0.7	2.4	0.1	3.0	-	6.2
Spits and islands	73	-	-	0.2	0.9	2.1	-	3.2

Table 11. Linear densities of birds observed on aerial surveys in 1976 between Icy Cape and Point Lay (Section C). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
<u>11 September</u>								
Ocean	73	-	0.4	-	<0.1	-	-	0.4
Ocean/spits and islands	73	0.4	0.3	-	0.3	0.1	-	1.1
Lagoon	219	0.1	14.2	-	0.1	-	-	14.4
Pass	2	-	10.0	-	11.5	-	-	21.5
Spits and islands	71	-	0.6	-	1.2	-	-	1.8
<u>20 September</u>								
Lagoon	146	-	0.8	-	0.3	<0.1	-	1.1
Spits and islands	73	-	-	-	3.0	-	-	3.0
Mainland beach	73	-	-	-	0.6	-	-	0.6
<u>23 September</u>								
Ocean	73	-	0.9	-	0.1	-	-	1.0
Ocean/spits and islands	73	-	0.3	-	-	-	-	0.3
Lagoon	73	-	4.4	0.3	0.1	-	-	4.8
Pass	2	-	107.5	-	-	-	-	107.5
Spits and islands	71	-	0.2	-	2.5	-	-	2.7
<u>28 September</u>								
Ocean	73	-	0.5	-	-	-	-	0.5
Lagoon	219	-	1.6	-	0.5	-	-	2.1
Spits and islands	71	-	1.9	-	11.9	-	-	13.8
<u>13 October</u>								
Ocean	23	-	2.5	-	-	-	-	2.5
Spits and islands	23	-	-	-	0.1	-	-	0.1

Table 12. Linear densities of birds observed on aerial surveys in 1976 between Kilimantavi and Icy Cape (Section D).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
17 June								
Ocean	63	-	-	-	-	-	-	0.0
Lagoon	126	-	0.8	-	0.1	-	-	0.9
Spits and islands	61	-	0.2	-	3.3	-	-	3.5
Mainland beach	63	-	-	-	-	-	-	0.0
21 June								
Ocean	63	-	1.4	-	0.1	-	-	1.5
Lagoon	63	-	0.5	-	<0.1	<0.1	-	0.5
Spits and islands	61	-	<0.1	-	<0.1	<0.1	-	0.1
8 July								
Ocean	233	0.1	3.7	-	<0.1	-	-	3.8
Ocean/spits and islands	61	0.1	1.4	-	0.1	-	-	1.6
Lagoon	63	<0.1	0.1	-	-	-	-	0.1
Pass	2	2.0	-	-	-	-	-	2.0
Spits and islands	61	-	0.1	-	0.1	0.2	-	0.4
16 July								
Ocean/spits and islands	61	0.1	0.1	-	-	-	-	0.2
Spits and islands	61	-	-	-	5.2	3.7	-	8.9
25 July								
Ocean/spits and islands	52	-	0.4	-	-	-	-	0.4
Spits and islands	52	-	-	0.5	4.2	2.2	-	6.9
6 August								
Ocean	13	0.1	-	-	-	-	-	0.1
Ocean/spits and islands	61	-	0.2	80.2	0.6	21.7	-	102.7
Lagoon	163	<0.1	52.8	-	0.1	0.2	<0.1	53.1
Pass	2	-	0.5	-	-	-	-	0.5
Spits and islands	61	-	-	-	1.6	13.7	-	15.3

Table 12. Linear densities of birds observed on aerial surveys in 1976 between Kilimantavi and Icy Cape (Section D). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
20 August								
Ocean/spits and islands	126	-	1.3	1.4	1.0	0.7	-	4.4
Lagoon	189	-	12.1	0.2	0.2	0.3	-	12.8
Pass	2	-	6.0	-	-	-	-	6.0
Spits and islands	61	-	-	-	0.6	0.5	-	1.1
11 September								
Ocean	76	<0.1	0.1	-	0.2	-	-	0.3
Ocean/spits and islands	61	0.1	0.5	-	-	<0.1	-	0.6
Lagoon	100	<0.1	19.7	-	-	-	-	19.7
Spits and islands	61	-	0.3	-	0.8	-	-	1.1
20 September								
Ocean/spits and islands	61	-	-	-	0.3	-	-	0.3
Lagoon	100	0.1	2.8	-	1.2	-	-	4.1
Spits and islands	61	-	0.1	0.2	3.2	-	-	3.5
23 September								
Ocean	63	-	0.8	-	<0.1	-	-	0.8
Ocean/spits and islands	61	-	-	-	-	-	-	0.0
Lagoon	63	<0.1	4.9	-	0.2	-	-	5.1
Pass	2	-	10.0	-	7.5	-	-	17.5
Spits and islands	61	<0.1	0.1	-	0.6	-	-	0.7
Mainland beach	13	-	-	0.2	1.2	-	-	1.4
28 September								
Ocean	63	-	-	-	-	-	-	0.0
Ocean/spits and islands	63	-	-	-	-	-	-	0.0
Lagoon	189	-	3.4	-	2.4	-	-	5.8
Spits and islands	63	-	-	0.1	2.1	-	-	2.2
Mainland beach	26	-	-	-	4.0	-	-	4.0

Table 12. Linear densities of birds observed on aerial surveys in 1976 between Kilimantavi and Icy Cape (Section D). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
<u>13 October</u>								
Ocean	63	-	2.8	0.4	0.1	-	-	3.3
Lagoon	63	-	-	-	-	-	-	0.0
Spits and islands	63	-	-	0.2	-	-	-	0.2
<u>6 November</u>								
Ocean	276	-	<0.1	-	-	-	-	<0.1

Table 13. Linear densities of birds observed on aerial surveys in 1976 between Atanik and Kilimantavi (Section E).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
17 June								
Ocean/mainland	84	0.1	0.4	<0.1	0.1	0.1	< 0.1	0.7
6 July								
Ocean/mainland	37	0.3	1.9	-	0.1	-	-	2.3
Mainland beach	37	-	-	-	<0.1	-	-	<0.1
8 July								
Ocean	126	<0.1	0.6	-	-	-	<0.1	0.6
Ocean/spits and islands	9	-	-	-	-	-	-	0.0
Ocean/mainland	47	1.7	6.1	-	-	-	-	7.8
Pass	2	1.5	-	-	-	-	-	1.5
Spits and islands	9	0.6	4.6	-	0.1	-	-	5.3
Mainland beach	47	-	-	-	1.3	-	-	1.3
Dump	0.5	-	-	-	400.0	-	-	400.0
16 July								
Ocean/spits and islands	9	-	-	-	-	-	-	0.0
Ocean/mainland	47	1.9	6.4	-	-	-	-	8.3
Spits and islands	9	-	-	-	1.7	-	-	1.7
Mainland beach	47	-	-	-	3.9	1.7	-	5.6
6 August								
Ocean	56	1.0	1.1	1.4	0.8	1.4	-	5.7
Ocean/spits and islands	9	-	-	83.3	-	6.4	-	89.7
Ocean/mainland	47	<0.1	-	399.2	0.1	22.1	-	421.4
Spits and islands	9	-	-	-	1.7	11.2	-	12.9
Mainland beach	47	-	-	-	1.8	-	-	1.8

Table 13. Linear densities of birds observed on aerial surveys in 1976 between Atanik and Kilimantavi (Section E). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
20 August								
Ocean/spits and islands	9	-	22.2	2.3	0.1	-	-	24.6
Ocean/mainland	47	<0.1	0.1	0.9	0.3	0.2	-	1.5
Pass	2	-	15.5	-	-	-	-	15.5
Spits and islands	9	-	-	-	-	-	-	0.9
Mainland beach	47	<0.1	1.1	4.9	0.5	0.1	-	6.6
11 September								
Ocean	168	0.1	1.2	-	<0.1	-	-	1.2
Ocean/spits and islands	18	-	-	-	-	-	-	0.0
Ocean/mainland	94	-	1.8	-	0.4	<0.1	-	2.2
Spits and islands	18	-	-	-	0.2	-	-	0.2
Mainland beach	94	-	-	-	3.1	-	-	3.1
20 September								
Ocean	112	<0.1	0.7	-	1.1	-	-	1.8
Ocean/spits and islands	9	-	-	-	-	-	-	0.0
Ocean/mainland	94	0.6	-	-	0.6	-	-	1.2
Pass	2	-	-	-	15.5	-	-	15.5
Spits and islands	9	-	-	-	2.2	-	-	2.2
Mainland beach	47	-	-	-	3.4	-	-	3.4
23 September								
Ocean	56	0.1	0.6	-	0.6	-	-	1.3
Ocean/spits and islands	9	-	-	-	110.2	-	-	110.2
Ocean/mainland	47	-	-	-	-	-	-	0.0
Pass	2	-	-	-	17.5	-	-	17.5
Spits and islands	9	-	-	-	-	-	-	0.0
Mainland beach	47	-	-	-	32.0	-	-	32.0

Table 13. Linear densities of birds observed on aerial surveys in 1976 between Atanik and Kilimantavi (Section E). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
28 September								
Ocean/spits and islands	9	-	-	-	0.1	-	-	0.1
Ocean/mainland	68	0.1	0.4	-	0.2	-	-	0.7
Spits and islands	9	-	-	-	-	-	-	0.0
Mainland beach	68	-	-	-	5.5	<0.1	-	5.5
13 October								
Ocean	120	-	0.2	-	<0.1	-	-	0.2
6 November								
Ocean	240	-	0.1	-	-	-	-	0.1

Table 14. Linear densities of birds observed on aerial surveys in 1976 between Peard Bay and Atanik (Section F).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
17 June								
Ocean	38	-	0.3	-	0.4	-	-	0.7
Ocean/spits and islands	38	-	-	-	-	-	-	0.0
Bay	41	-	-	-	0.1	0.1	-	0.2
Spits and islands	38	-	-	-	-	-	-	0.0
21 June								
Bay	39	-	-	-	<0.1	-	-	<0.1
6 July								
Ocean/spits and islands	41	2.0	73.1	-	0.1	<0.1	-	75.2
Bay	41	<0.1	-	-	-	-	-	<0.1
Spits and islands	41	-	-	-	-	-	-	0.0
Mainland beach	41	-	-	-	-	-	-	0.0
8 July								
Ocean	138	<0.1	3.4	-	-	-	-	3.4
Ocean/spits and islands	42	0.7	17.3	-	0.6	-	-	18.6
Bay	41	0.2	4.9	-	-	-	-	5.1
Pass	4	0.8	2.5	-	-	-	-	3.3
Spits and islands	38	-	-	-	-	-	-	0.0
16 July								
Ocean/spits and islands	42	0.1	3.5	-	1.5	1.1	-	6.2
Spits and islands	42	-	0.1	-	0.4	4.4	-	4.9
25 July								
Spits and islands	9	-	-	-	0.8	0.3	-	1.2
Ocean/spits and islands	9	-	-	-	-	-	-	0.0
Bay	86	0.1	0.4	-	<0.1	<0.1	-	0.5
Mainland beach	42	-	-	-	0.4	-	-	0.4

Table 14. Linear densities of birds observed on aerial surveys in 1976 between Peard Bay and Atanik (Section F). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
6 August								
Spits and islands	2	-	-	-	-	-	-	0.0
Ocean/spits and islands	2	-	-	-	17.5	6.0	-	23.5
Bay	86	<0.1	-	0.4	0.7	1.3	-	2.4
Mainland beach	42	-	-	-	0.2	-	-	0.2
20 August								
Ocean/spits and islands	42	-	3.8	23.8	1.0	0.3	-	28.9
Bay	80	-	1.4	1.3	2.5	-	-	5.2
Spits and islands	38	-	8.1	92.3	2.5	11.8	-	114.7
Mainland beach	42	-	-	-	0.1	0.1	-	0.2
11 September								
Ocean/spits and islands	42	-	0.8	-	-	-	-	0.8
Bay	80	<0.1	23.1	-	0.1	0.2	-	23.4
Spits and islands	38	-	-	-	6.2	0.9	-	7.1
20 September								
Bay	122	-	1.3	-	0.3	-	-	1.6
Spits and islands	48	-	-	0.2	55.2	<0.1	-	55.4
23 September								
Ocean/spits and islands	42	-	0.6	-	-	-	-	0.6
Bay	41	-	14.9	-	0.9	-	-	15.8
Spits and islands	38	-	1.3	-	38.4	-	-	39.7

Table 14. Linear densities of birds observed on aerial surveys in 1976 between Peard Bay and Atanik (Section F). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
<u>28 September</u>								
Ocean/spits and islands	42	-	<0.1	-	<0.1	-	-	<0.1
Bay	43	-	1.9	-	2.3	-	-	4.2
Spits and islands	38	-	-	-	32.5	-	-	32.5
<u>13 October</u>								
Ocean	90	-	1.0	<0.1	<0.1	<0.1	-	1.0

Table 15. Linear densities of birds observed on aerial surveys in 1976 between Barrow and Peard Bay (Section G).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
17 June								
Ocean	286	-	0.3	-	0.1	-	-	0.4
21 June								
Ocean/mainland	340	<0.1	<0.1	-	0.1	<0.1	<0.1	0.1
6 July								
Ocean/mainland	340	0.7	9.3	<0.1	0.1	<0.1	-	11.3
Mainland beach	170	-	<0.1	-	-	-	-	<0.1
8 July								
Ocean	224	<0.1	0.1	-	<0.1	<0.1	-	0.1
Ocean/mainland	90	2.4	6.1	-	0.1	-	-	8.6
Mainland beach	90	-	-	-	0.3	-	-	0.3
Dump	0.5	-	-	-	1600.0	-	-	1600.0
16 July								
Ocean/mainland	85	0.1	1.2	-	2.5	-	-	3.8
Mainland beach	85	-	-	0.1	-	0.1	-	0.2
25 July								
Ocean/mainland	170	<0.1	0.6	-	0.1	-	-	0.7
Rivermouth/delta	1	-	-	-	16.0	-	-	16.0
Mainland beach	85	-	-	-	0.3	-	-	0.3
6 August								
Ocean	85	<0.1	0.5	<0.1	1.9	1.3	-	3.7
Ocean/mainland	85	0.1	2.2	0.5	0.1	0.5	-	3.4
Rivermouth/delta	1	-	-	35.0	-	-	-	35.0
Mainland beach	85	-	-	-	1.6	-	-	1.6

Table 15. Linear densities of birds observed on aerial surveys in 1976 between Barrow and Peard Bay (Section G). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
20 August								
Ocean	85	0.1	<0.1	0.1	0.3	1.0	-	1.5
Ocean/mainland	85	<0.1	3.4	2.5	<0.1	0.3	-	6.2
Mainland beach	85	-	-	0.6	0.1	0.3	-	1.0
11 September								
Ocean	255	<0.1	0.7	-	0.1	<0.1	-	0.8
Ocean/spits and islands	5		10.0	-	-	-	-	10.0
Ocean/mainland	85	<0.1	9.9	-	2.0	0.7	-	12.6
Spits and islands	5	-	-	-	1.0	-	-	1.0
Mainland beach	85	-	-	-	0.6	<0.1	-	0.6
20 September								
Ocean	170	-	11.1	-	0.9	-	-	12.0
Ocean/mainland	85	<0.1	4.3	-	-	-	-	4.3
Mainland beach	85	-	-	-	3.3	-	-	3.3
28 September								
Ocean	113	<0.1	0.1	-	<0.1	-	-	0.1
Ocean/mainland	57	-	<0.1	-	-	0.4	-	0.4
Mainland beach	57	-	-	-	2.0	-	-	2.0
13 October								
Ocean	156	-	7.1	-	0.2	<0.1	-	7.3
6 November								
Ocean	170	-	0.1	-	-	-	-	0.1

Table 16. Linear densities of birds observed on aerial surveys in 1976 between Barrow and Tangent Point (Section H).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
<u>17 June</u>								
Ocean	66	-	-	-	-	-	-	0.0
Ocean/spits and islands	57	-	-	-	-	-	-	0.0
Lagoon	204	-	-	-	-	-	-	0.0
Spits and islands	54	-	0.2	-	0.1	-	-	0.3
Mainland beach	69	-	-	-	-	-	-	0.0
<u>7 July</u>								
Ocean	66	-	-	-	-	-	-	0.0
Ocean/spits and islands	57	-	-	-	-	-	-	0.0
Lagoon	66	0.1	9.3	-	-	-	-	9.4
Pass	14	-	-	-	-	-	-	0.0
Spits and islands	54	-	-	-	0.2	<0.1	-	0.2
<u>15 July</u>								
Ocean	10	-	-	-	-	-	-	0.0
Ocean/spits and islands	57	-	-	-	-	-	-	0.0
Bay	163	-	<0.1	-	<0.1	-	-	0.1
Lagoon	129	<0.1	4.0	-	<0.1	0.1	-	4.1
Spits and islands	54	-	7.1	-	0.3	0.2	-	7.6
<u>20 July</u>								
Ocean	10	-	0.5	-	-	-	-	0.5
Ocean/spits and islands	57	-	-	-	-	-	-	0.0
Bay	63	0.1	0.8	-	-	-	-	0.9
Lagoon	129	0.3	4.5	-	0.1	-	-	4.9
Spits and islands	54	-	6.2	-	0.4	0.2	-	6.8
Mainland beach	192	-	-	-	-	-	-	0.0
<u>28 July</u>								
Ocean	208	<0.1	<0.1	-	<0.1	<0.1	-	0.1
Spits and islands	5	-	-	-	0.6	-	-	0.6

Table 16. Linear densities of birds observed on aerial surveys in 1976 between Barrow and Tangent Point (Section H). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
30 July								
Ocean	10	-	-	-	-	-	-	0.0
Ocean/spits and islands	73	0.2	12.0	-	0.4	2.8	0.3	15.7
Bay	63	<0.1	0.1	-	0.4	0.1	-	0.6
Lagoon	66	0.1	24.2	-	0.2	1.2	-	25.7
Spits and islands	57	-	-	0.2	0.3	0.5	-	1.0
Mainland beach	124	-	-	-	0.4	-	-	0.4
12 August								
Ocean/spits and islands	57	0.1	3.0	-	<0.1	3.8	-	6.9
Lagoon	218	<0.1	1.2	< 0.1	<0.1	0.1	-	1.4
Pass	14	0.2	5.7	-	0.1	20.5	-	26.6
Spits and islands	54	-	-	27.9	4.6	40.9	-	73.4
19 August								
Ocean	63	-	5.8	6.4	0.7	2.5	-	15.4
Ocean/spits and islands	57	-	1.6	1.5	0.1	1.3	-	4.5
Lagoon	63	-	3.1	-	-	0.9	-	4.0
Pass	10	-	3.7	-	1.0	5.0	-	9.7
Spits and islands	47	-	-	6.4	0.2	2.7	-	9.3
7 September								
Ocean	10	-	3.1	-	-	-	-	3.1
Ocean/spits and islands	90	-	0.1	1.6	0.1	0.2	-	2.0
Lagoon	161	-	0.2	-	<0.1	-	-	0.2
Spits and islands	90	-	<0.1	56.8	14.2	62.6	-	133.6

Table 16. Linear densities of birds observed on aerial surveys in 1976 between Barrow and Tangent Point (Section H). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
18 September								
Ocean	10	-	1.5	-	-	0.2	-	1.7
Ocean/spits and islands	57	0.1	5.9	-	-	-	-	6.0
Lagoon	63	-	0.7	-	-	-	-	0.7
Spits and islands	54	-	-	-	39.5	2.0	-	41.5
23 September								
Ocean	10	-	0.6	-	-	-	-	0.6
Ocean/spits and islands	57	<0.1	6.8	-	12.1	0.8	-	19.7
Lagoon	63	0.2	4.1	-	17.6	-	-	21.9
Spits and islands	54	-	9.9	0.1	71.3	11.8	-	93.1
4 October								
Ocean	160	<0.1	0.1	-	<0.1	0.1	-	0.2
Ocean/spits and islands	57	-	0.4	-	0.4	-	-	0.8
Lagoon	63	-	1.7	0.1	0.2	0.1	<0.1	2.1
Pass	10	-	-	-	2.0	-	-	2.0
Spits and islands	54	-	0.4	-	2.8	28.2	-	31.4
13 October								
Ocean	352	-	0.8	-	0.2	0.1	-	1.1

Table 17. Linear densities of birds observed on aerial surveys in 1976 between Tangent Point and Drew Point (Section J).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
17 June								
Ocean	44	-	-	-	0.1	-	-	0.1
Ocean/spits and islands	13	-	-	-	-	-	-	0.0
Ocean/mainland	33	-	-	-	-	-	-	0.0
Lagoon	13	-	0.2	-	0.1	-	-	0.3
Spits and islands	13	-	-	-	-	-	-	0.0
Rivermouth/delta	60	-	0.3	-	-	-	-	0.3
Mainland beach	33	-	-	-	-	-	-	0.0
7 July								
Ocean/spits and islands	11	-	5.7	-	0.3	-	-	6.0
Ocean/mainland	14	-	-	-	-	-	-	0.0
Lagoon	13	-	0.5	-	-	-	-	0.5
Spits and islands	11	-	5.6	-	1.5	-	-	7.1
Mainland beach	14	-	-	-	-	-	-	0.0
15 July								
Ocean	33	1.2	2.2	-	0.1	-	-	3.5
Ocean/mainland	33	<0.1	1.9	-	-	0.3	-	2.2
Lagoon	13	-	-	-	-	-	-	0.0
Spits and islands	13	-	-	-	-	-	-	0.0
Rivermouth/delta	20	-	0.2	-	0.1	-	-	0.3
Mainland beach	33	-	-	-	-	-	-	0.0
20 July								
Ocean	109	0.1	0.5	-	-	-	-	0.6
Ocean/mainland	46	0.3	1.7	-	>0.1	>0.1	-	2.0
Rivermouth/delta	20	0.2	1.2	-	-	-	-	1.4
Mainland beach	46	-	-	-	-	-	-	0.0
28 July								
Ocean	30	-	-	-	-	-	-	0.0

Table 17. Linear densities of birds observed on aerial surveys in 1976 between Tangent Point and Drew Point (Section J). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
30 July								
Ocean/spits and islands	26	0.7	27.2	-	-	-	-	27.9
Ocean/mainland	66	<0.1	9.0	-	0.3	0.2	-	10.4
Lagoon	26	-	0.2	-	-	-	-	0.2
Spits and islands	26	-	-	-	0.2	0.2	-	0.4
Rivermouth/delta	40	0.1	<0.1	-	0.5	0.2	-	0.8
Mainland beach	66	-	-	-	0.1	-	-	0.1
12 August								
Ocean	132	0.1	5.3	0.2	<0.1	1.6	-	7.2
Mainland tundra	30	0.1	-	-	0.2	0.1	-	0.4
19 August								
Ocean	132	-	0.3	-	0.1	1.1	-	1.5
Ocean/spits and islands	18	-	6.9	-	-	-	-	6.9
Ocean/mainland	26	-	5.2	-	1.0	0.5	-	5.7
7 September								
Ocean	49	-	<0.1	-	-	-	-	<0.1
Ocean/mainland	75	0.1	29.8	0.3	<0.1	0.1	-	30.3
Spits and islands	5	-	-	-	0.2	-	-	0.2
Rivermouth/delta	20	-	0.1	-	0.1	-	-	0.2
Mainland beach	29	-	0.7	1.0	9.6	0.7	-	12.0
23 September								
Ocean	111	-	1.9	-	0.1	-	-	2.0
Ocean/spits and islands	10	-	-	-	1.0	-	-	1.0
Ocean/mainland	59	-	15.5	-	7.3	-	-	22.8
Lagoon	26	-	0.6	-	-	-	-	0.6
Spits and islands	10	-	-	-	5.5	-	-	5.5
Mainland beach	13	-	-	0.1	47.9	0.1	-	48.1

Table 17. Linear densities of birds observed on aerial surveys in 1976 between Tangent Point and Drew Point (Section J). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
4 October								
Ocean	74	-	1.1	-	-	-	-	1.1

Table 18. Linear densities of birds observed on aerial surveys in 1976 between Drew Point and Cape Halkett (Section K).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
<u>17 June</u>								
Ocean/mainland	126	-	-	-	-	-	-	0.0
Spits and islands	6	-	-	-	-	-	-	0.0
Mainland beach	57	-	-	-	<0.1	-	-	<0.1
<u>7 July</u>								
Ocean/mainland	126	-	-	-	-	-	-	0.0
Spits and islands	6	-	-	-	-	-	-	0.0
Mainland beach	57	-	1.1	-	0.5	-	-	1.6
<u>15 July</u>								
Ocean/mainland	63	0.1	1.5	-	-	-	-	1.6
Lagoon	6	-	2.0	-	-	-	-	2.0
Spits and islands	6	-	-	-	-	-	-	0.0
Mainland beach	57	-	-	-	0.1	-	-	0.1
<u>20 July</u>								
Ocean	72	<0.1	3.4	-	-	-	-	3.4
Ocean/mainland	63	0.3	0.8	-	-	-	-	1.2
Spits and islands	6	-	3.3	-	-	-	-	3.3
Mainland beach	57	-	-	-	<0.1	-	-	<0.1
<u>28 July</u>								
Ocean	170	<0.1	1.2	-	-	-	-	1.2
<u>30 July</u>								
Ocean/mainland	48	-	1.2	-	<0.1	-	-	1.2
Mainland beach	48	-	-	-	-	-	-	0.0
<u>12 August</u>								
Ocean	111	0.2	1.7	0.1	<0.1	-	-	2.0
Ocean/mainland	44	-	0.3	-	-	0.1	-	0.4
Mainland beach	44	-	1.7	-	0.2	0.2	-	2.1

Table 18. Linear densities of birds observed on aerial surveys in 1976 between Drew Point and Cape Halkett (Section K). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
<u>7 September</u>								
Ocean	80	<0.1	1.4	-	0.1	-	-	1.5
Ocean/mainland	80	0.1	23.7	-	0.1	0.3	-	24.2
Mainland beach	80	-	0.8	3.6	3.9	<0.1	-	8.3
Mainland tundra	110	-	0.2	-	-	-	-	0.2
<u>18 September</u>								
Ocean	63	-	-	-	-	-	-	0.0
Ocean/mainland	63	0.2	14.3	-	-	-	-	14.5
Mainland beach	63	<0.1	-	<0.1	0.6	<0.1	-	0.6
<u>23 September</u>								
Ocean	207	<0.1	13.0	-	5.3	0.1	-	18.4
Ocean/mainland	63	-	1.5	-	-	-	-	1.5
Spits and islands	6	-	-	-	2.8	-	-	2.8
Mainland beach	57	-	-	-	1.7	0.2	-	1.9
<u>4 October</u>								
Ocean	193	-	-	-	-	<0.1	-	<0.1
Ocean/mainland	63	-	-	-	-	-	-	0.0
Mainland beach	63	-	-	-	-	-	-	0.0

Table 19. Linear densities of birds observed on aerial surveys in 1976 between Cape Halkett and Oliktok Point (Section L).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
17 June								
Rivermouth/delta	33	-	2.1	-	0.2	<0.1	-	2.3
7 July								
Ocean	156	-	-	-	-	-	-	0.0
Mainland tundra	18	-	3.2	-	0.2	0.1	-	3.5
15 July								
Ocean/mainland	35	-	0.2	1.4	-	-	-	1.6
Mainland beach	35	-	1.4	-	-	-	-	1.4
20 July								
Ocean	86	0.1	1.9	-	-	-	-	2.0
Ocean/mainland	76	0.1	1.6	-	0.1	-	-	1.8
Lagoon	2	0.1	1.4	-	0.7	-	-	2.2
Rivermouth/delta	33	-	-	-	1.5	-	-	1.5
Mainland beach	76	-	-	-	-	-	-	0.0
28 July								
Ocean	214	<0.1	-	-	-	-	-	<0.1
Ocean/mainland	152	0.1	2.2	-	<0.1	-	-	2.3
Rivermouth/delta	33	0.1	1.7	3.0	0.3	0.2	-	5.3
Mainland beach	76	-	-	-	0.9	-	-	0.9
Mainland tundra	3	0.7	-	-	-	-	-	0.7
12 August								
Ocean	286	<0.1	-	-	-	-	-	<0.1
Ocean/mainland	92	-	0.6	-	0.1	-	-	0.7
Lagoon	3	0.3	8.7	-	0.7	-	-	9.7
Mainland beach	4	-	-	-	1.0	0.5	-	1.5
Mainland tundra	1	-	-	-	2.0	-	-	2.0

Table 19. Linear densities of birds observed on aerial surveys in 1976 between Cape Halkett and Oliktok Point (Section L). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
19 August								
Ocean/mainland	190	-	0.7	-	<0.1	-	-	0.7
Lagoon	3	-	-	-	1.0	-	-	1.0
Rivermouth/delta	33	0.1	0.1	-	0.7	-	-	0.9
Mainland beach	62	-	-	-	-	-	-	0.0
7 September								
Ocean	50	0.1	0.3	-	-	-	-	0.4
Ocean/mainland	77	-	0.2	-	-	-	-	0.2
Rivermouth/delta	33	-	1.9	2.7	2.0	0.1	-	6.7
Mainland beach	22	-	-	0.2	0.1	-	-	0.2
23 September								
Ocean	144	<0.1	0.6	-	-	-	-	0.6
Ocean/spits and islands	0.5	-	-	-	6.0	-	-	6.0
Ocean/mainland	208	<0.1	4.8	-	0.1	-	-	4.9
Rivermouth/delta	33	-	-	-	1.2	-	-	1.2
Mainland beach	104	-	-	-	0.4	-	-	0.4
4 October								
Ocean	172	-	0.2	-	-	-	-	0.2
Ocean/mainland	135	-	-	-	-	-	-	0.0
Rivermouth/delta	33	-	-	-	-	-	-	0.0
Mainland beach	103	-	-	-	-	-	-	0.0

Table 20. Linear densities of birds observed on aerial surveys in 1976 between Oliktok Point and Point McIntyre (Section M).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
<u>17 June</u>								
Ocean	10	-	-	-	-	-	-	0.0
Lagoon	82	-	0.1	-	<0.1	-	-	0.1
Spits and islands	50	-	<0.1	-	-	-	-	<0.1
Mainland beach	32	-	0.1	-	-	-	-	0.1
<u>7 July</u>								
Ocean/spits and islands	50	-	-	-	-	-	-	0.0
Lagoon	65	<0.1	3.7	-	0.1	-	-	3.8
Pass	10	-	-	-	-	-	-	0.0
Spits and islands	50	-	-	-	0.1	<0.1	-	0.1
<u>15 July</u>								
Lagoon	60	-	13.0	-	-	-	-	13.0
Pass	10	-	-	-	-	-	-	0.0
Spits and islands	50	-	5.8	-	0.2	0.1	-	6.1
<u>20 July</u>								
Lagoon	160	<0.1	7.2	-	<0.1	-	-	7.2
Pass	10	-	0.4	-	0.2	0.2	-	0.8
Spits and islands	50	-	0.1	-	0.1	-	-	0.2
Rivermouth/delta	4	-	0.3	-	1.0	-	-	1.3
Mainland beach	76	-	-	-	0.2	-	-	0.2
Mainland tundra	2	-	2.5	-	-	-	-	2.5
<u>28 July</u>								
Ocean	250	-	0.8	-	<0.1	-	-	0.8
Lagoon	46	-	0.2	-	-	-	-	0.2
Spits and islands	10	-	-	-	<0.1	-	-	<0.1

Table 20. Linear densities of birds observed on aerial surveys in 1976 between Oliktok Point and Point McIntyre (Section M). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
12 August								
Ocean/spits and islands	57	<0.1	4.7	-	-	-	-	4.7
Lagoon	220	<0.1	1.8	-	-	0.1	-	1.9
Pass	10	-	3.7	-	-	-	-	3.7
Spits and islands	57	-	0.1	0.8	1.3	0.6	-	2.8
Mainland beach	79	-	-	-	0.4	0.1	-	0.5
19 August								
Lagoon	120	<0.1	5.0	0.1	<0.1	<0.1	-	5.1
Mainland tundra	3	-	-	-	1.0	-	-	1.0
7 September								
Ocean/spits and islands	57	<0.1	0.7	8.1	0.6	-	-	9.4
Lagoon	106	-	3.3	1.2	-	-	-	4.5
Spits and islands	57	-	0.1	8.0	2.7	0.1	-	10.9
Mainland beach	23	-	-	0.1	0.4	-	-	0.5
23 September								
Ocean/spits and islands	57	0.1	10.0	-	-	-	-	10.1
Lagoon	180	-	3.9	0.7	0.4	0.3	-	4.3
Spits and islands	57	-	-	1.4	0.8	<0.1	-	2.2
Mainland beach	15	-	-	-	0.3	-	-	0.3
4 October								
Ocean	104	-	-	-	-	-	-	0.0
Lagoon	50	-	0.2	-	<0.1	-	-	0.2
Spits and islands	50	-	-	-	0.3	-	-	0.3

Table 21. Linear densities of birds observed on aerial surveys in 1976 between Point McIntyre and Brownlow Point (Section N).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
15 July								
Ocean	20	-	-	-	-	-	-	0.0
Ocean/spits and islands	3	-	11.7	-	-	-	-	11.7
Bay	20	-	0.4	-	-	-	-	0.4
Lagoon	50	-	0.1	-	-	-	-	0.1
Spits and islands	5	-	-	-	2.2	-	-	2.2
Rivermouth/delta	5	-	-	-	0.2	-	-	0.2
Mainland beach	68	-	-	-	0.1	-	-	0.1
20 July								
Ocean/spits and islands	28	-	1.7	-	-	-	-	1.7
Bay	20	0.1	1.9	-	0.1	-	-	2.1
Lagoon	43	-	13.8	-	<0.1	-	-	13.8
Spits and islands	28	-	-	-	0.2	<0.1	-	0.2
Rivermouth/delta	30	-	-	-	2.5	0.1	-	2.6
Mainland beach	35	-	-	-	<0.1	-	-	<0.1
28 July								
Ocean	17	0.1	1.9	-	-	-	-	2.0
Ocean/spits and islands	28	-	3.5	-	-	-	-	3.5
Bay	27	-	-	-	-	-	-	0.0
Lagoon	86	-	0.4	-	<0.1	-	-	0.4
Pass	3	-	2.0	-	-	-	-	2.0
Spits and islands	28	-	-	-	-	1.3	-	1.3
Rivermouth/delta	31	-	-	-	4.3	0.1	-	4.4
12 August								
Ocean	30	-	-	-	-	-	-	0.0
Ocean/spits and islands	50	<0.1	10.5	-	-	-	-	10.5
Bay	40	-	-	-	-	-	-	0.0
Lagoon	150	-	6.8	-	0.2	<0.1	-	7.0
Pass	26	-	0.6	-	0.1	7.2	-	7.9
Spits and islands	50	-	-	17.4	0.9	20.0	-	38.3
Rivermouth/delta	66	-	<0.1	-	0.6	0.6	-	1.2

Table 21. Linear densities of birds observed on aerial surveys in 1976 between Point McIntyre and Brownlow Point (Section N). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
19 August								
Bay	10	-	3.0	1.5	0.6	-	-	5.1
Rivermouth/delta	70	-	0.2	0.5	2.5	-	-	3.2
7 September								
Ocean	33	-	-	-	-	-	-	0.0
Ocean/spits and islands	8	0.1	-	-	-	-	-	0.1
Bay	40	0.1	21.2	1.8	-	-	-	23.1
Lagoon	158	-	2.5	2.2	-	-	-	4.7
Spits and islands	8	-	2.8	11.1	10.8	0.3	-	25.0
Rivermouth/delta	75	-	-	-	1.4	-	-	1.4
Mainland beach	86	-	0.4	0.6	0.7	<0.1	-	1.7
23 September								
Ocean	20	-	2.0	-	-	-	-	2.0
Ocean/spits and islands	37	-	5.9	-	0.1	-	-	6.0
Ocean/mainland	11	-	-	-	-	-	-	0.0
Bay	41	-	1.2	-	1.0	-	-	2.2
Lagoon	37	-	26.9	-	0.6	1.1	-	28.6
Spits and islands	17	-	-	13.4	3.9	-	-	17.3
Rivermouth/delta	40	-	-	-	0.2	-	-	0.2
Mainland beach	27	-	-	-	0.7	-	-	0.7
4 October								
Ocean	310	-	0.6	-	-	-	-	0.6
Ocean/spits and islands	50	-	-	-	-	-	-	0.0
Lagoon	50	-	-	0.7	0.2	-	-	0.9
Spits and islands	50	-	-	<0.1	0.3	-	-	0.3

Table 22. Linear densities of birds observed on aerial surveys in 1976 between Brownlow Point and the Jago RIver (Section P).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
15 July								
Ocean/spits and islands	43	-	-	-	-	-	-	0.0
Ocean/mainland	25	-	0.3	-	-	-	<0.1	0.3
Lagoon	50	-	<0.1	-	<0.1	-	-	<0.1
Pass	7	-	1.4	-	-	-	-	1.4
Spits and islands	43	-	-	-	0.5	0.1	-	0.6
Rivermouth/delta	13	-	-	-	-	-	-	0.0
Mainland beach	25	-	-	-	-	-	-	0.0
20 July								
Ocean/spits and islands	73	<0.1	2.0	-	-	-	-	2.0
Ocean/mainland	45	-	0.6	-	-	-	-	0.6
Lagoon	90	0.1	5.2	-	<0.1	-	-	5.3
Pass	12	-	-	-	-	-	-	0.0
Spits and islands	73	-	-	-	<0.1	-	-	<0.1
Rivermouth/delta	21	-	1.9	-	0.4	-	-	2.3
Mainland beach	33	0.2	0.8	-	-	-	-	1.0
Mainland tundra	4	-	3.0	-	-	-	-	3.0
28 July								
Ocean	178	-	<0.1	-	-	-	-	<0.1
Ocean/mainland	25	-	1.4	-	-	-	-	1.4
Lagoon	63	<0.1	0.8	-	-	-	-	0.8
Spits and islands	49	-	-	-	-	-	-	0.0
Rivermouth/delta	13	-	-	0.5	0.2	-	-	0.7
Mainland beach	25	-	-	-	-	-	-	0.0
Mainland tundra	4	0.3	-	-	-	-	-	0.3

Table 22. Linear densities of birds observed on aerial surveys in 1976 between Brownlow Point and the Jago River (Section P). (Continued)

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
12 August								
Ocean/mainland	50	0.1	12.8	-	<0.1	-	-	12.9
Ocean/spits and islands	72	-	0.4	-	-	-	-	0.4
Lagoon	120	<0.1	2.7	-	<0.1	<0.1	-	2.7
Pass	12	-	0.4	-	-	-	-	0.4
Spits and islands	72	-	-	0.1	0.3	-	-	0.4
Rivermouth/delta	21	-	-	-	0.9	-	-	0.9
Mainland beach	21	-	-	-	-	0.1	-	0.1
7 September								
Ocean/mainland	50	-	<0.1	0.8	-	-	-	0.8
Ocean/spits and islands	72	-	-	0.5	-	-	-	0.5
Lagoon	120	-	1.7	2.4	0.3	<0.1	-	4.4
Pass	12	-	-	-	-	-	-	0.0
Spits and islands	72	-	-	0.1	0.7	-	-	0.8
Rivermouth/delta	21	-	<0.1	-	1.3	-	-	1.3
Mainland beach	21	-	1.0	1.4	2.0	-	-	4.4
Mainland tundra	5	-	-	-	1.0	-	-	1.0
4 October								
Ocean	220	-	-	-	0.1	-	-	0.0
Ocean/spits and islands	72	-	0.4	-	-	-	-	0.4
Lagoon	50	-	0.1	-	0.5	-	-	0.6
Spits and islands	72	-	0.3	-	0.1	-	-	0.4

Table 23. Linear densities of birds observed on aerial surveys in 1976 between the Jago River and Demarcation Point (Section Q).

	Km	Loons	Waterfowl	Shorebirds	Large gulls	Small gulls and terns	Alcids	TOTAL
20 July								
Ocean/spits and islands	164	<0.1	0.4	-	<0.1	-	-	0.4
Ocean/mainland	20	0.6	1.9	-	0.1	0.1	-	2.6
Lagoons	176	0.3	8.9	-	0.7	<0.1	-	9.9
Pass	12	0.2	3.0	-	-	-	-	3.2
Spits and islands	164	-	0.1	0.1	0.2	0.1	-	0.5
Rivermouth/delta	44	0.1	0.3	-	-	-	-	0.4
Mainland beach	20	-	-	-	0.6	-	-	0.6
Mainland tundra	20	-	0.1	-	0.1	-	-	0.2
28 July								
Ocean	280	<0.1	-	-	-	-	-	<0.1
Ocean/mainland	7	-	-	-	-	-	-	0.0
Lagoon	44	-	1.8	-	0.1	0.1	-	2.0
Pass	2	0.5	-	-	-	-	-	0.5
Rivermouth/delta	2	-	-	-	-	0.5	-	0.5
Mainland beach	7	-	-	-	-	-	-	0.0
12 August								
Ocean/spits and islands	328	<0.1	1.6	-	-	-	-	1.6
Ocean/mainland	20	0.1	3.7	-	-	-	-	3.8
Lagoon	176	<0.1	4.4	<0.1	-	0.1	-	4.6
Pass	12	-	0.1	-	-	-	-	0.1
Spits and islands	164	-	-	<0.1	0.3	0.1	-	0.4
Rivermouth/delta	44	-	-	-	0.1	-	-	0.1
Mainland beach	20	-	-	-	0.1	-	-	0.1
Mainland tundra	20	-	-	0.1	-	-	-	0.1
7 September								
Ocean/spits and islands	164	-	1.2	0.1	-	-	-	1.3
Ocean/mainland	20	-	2.5	-	-	-	-	2.5
Lagoon	176	0.1	4.4	0.6	0.1	-	-	5.2
Pass	12	-	2.7	-	-	-	-	2.7
Spits and islands	164	-	0.1	0.9	0.2	<0.1	-	1.2
Rivermouth/delta	44	-	-	-	-	-	-	0.0
Mainland beach	20	-	-	-	-	-	-	0.0

Table 24. Explanation of habitats in Tables 9 through 23.

The following list of habitats are used in Tables 9 through 23. The abbreviations at right are used in Tables 25 through 29. Habitats containing a slash between two habitats indicate birds utilizing an interface of two habitats.

Habitat	Abbreviation
Ocean	Oce
Ocean/spits and islands	O/SI
Ocean/mainland	O/M
Bay	Bay
Lagoon	Lag
Pass	Pass
Spits and islands	S&I
River mouth/delta	RmD
Mainland beach	Bea
Mainland tundra	Tun

Table 25. Total birds per kilometer by habitat in June 1976 on aerial surveys presented in Tables 16 through 23.

$\bar{x}$ = density per linear kilometer
km = kilometers of trackline

Location		Habitat									
		Oce	O/SI	O/M	Bay	Lag	Pass	S&I	RmD	Bea	Tun
Barrow – Tangent Pt. (H)	$\bar{x}$	0.6	0.0	-	-	0.3	-	0.3	-	0.0	-
	km	66	57	-	-	204	-	13	-	69	-
Tangent Pt. – Drew Pt. (J)	$\bar{x}$	0.1	0.0	0.0	-	0.3	-	0.0	0.3	0.0	-
	km	44	57	33	-	13	-	13	60	33	-
Drew Pt. – Cape Halkett (K)	$\bar{x}$	-	-	0.0	-	-	-	0.0	-	<0.1	-
	km	-	-	126	-	-	-	6	-	57	-
Cape Halkett – Oliktok Pt. (L)	$\bar{x}$	-	-	-	-	-	-	-	2.3	-	-
	km	-	-	-	-	-	-	-	33	-	-
Oliktok Pt. – Pt. McIntyre (M)	$\bar{x}$	0.0	-	-	-	0.1	-	0.1	-	0.1	-
	km	10	-	-	-	82	-	50	-	32	-
Pt. McIntyre – Brownlow Pt. (N)	$\bar{x}$	-	-	-	-	-	-	-	-	-	-
	km	-	-	-	-	-	-	-	-	-	-
Brownlow Pt. – Jago River (P)	$\bar{x}$	-	-	-	-	-	-	-	-	-	-
	km	-	-	-	-	-	-	-	-	-	-
Jago River – Demarcation (Q)	$\bar{x}$	-	-	-	-	-	-	-	-	-	-
	km	-	-	-	-	-	-	-	-	-	-
Total km		120	70	159	-	299	-	123	93	191	-
Mean		<0.1	0.0	0.0	-	<0.1	-	0.1	1.0	<0.1	-
Range		0.0–0.6	-	-	-	0.1–0.3	-	0.0–0.3	0.3–2.3	0.0–0.1	-

Table 26. Total birds per kilometer by habitat in July 1976 on 23 aerial surveys presented in Tables 16 through 23.

$\bar{x}$ = density per linear kilometer
km = kilometers of trackline

		Habitat									
Location		Oce	O/SI	O/M	Bay	Lag	Pass	S&I	RmD	Bea	Tun
Barrow -	$\bar{x}$	0.1	4.6	-	0.4	8.9	0.0	3.8	-	0.2	-
Tangent Pt. (H)	km	304	249	-	289	390	14	224	-	316	-
Tangent Pt. -	$\bar{x}$	1.1	21.4	-	5.4	0.2	-	1.8	0.8	<0.1	-
Drew Pt. (J)	km	172	37	-	159	52	-	50	80	159	-
Drew Pt. -	$\bar{x}$	1.9	-	1.3	-	2.0	-	0.2	-	0.7	-
Cape Halkett (K)	km	242	-	174	-	6	-	18	-	219	-
Cape Halkett -	$\bar{x}$	0.4	-	1.5	-	2.2	-	-	1.2	0.6	0.7
Oliktok Pt. (L)	km	456	-	374	-	2	-	-	66	187	3
Oliktok Pt. -	$\bar{x}$	0.8	0.0	-	-	6.6	0.3	2.0	1.3	0.2	2.5
Pt. McIntyre (M)	km	250	50	-	-	331	30	160	4	76	2
Pt. McIntyre -	$\bar{x}$	0.9	3.1	-	0.8	3.5	2.0	0.9	3.3	0.1	-
Brownlow Pt. (N)	km	37	59	-	64	179	3	61	66	103	-
Brownlow Pt. -	$\bar{x}$	<0.1	1.3	0.7	-	2.6	0.5	0.2	1.2	0.4	1.8
Jago River (P)	km	178	116	95	-	203	19	165	47	83	8
Jago River -	$\bar{x}$	<0.1	0.4	1.9	-	8.3	2.8	0.5	0.6	0.4	0.2
Demarcation (Q)	km	280	164	27	-	220	14	164	46	27	20
Total km		1919	675	670	512	1383	99	842	309	1170	33
Mean		0.6	3.5	1.4	2.0	6.3	0.7	1.7	1.5	0.3	0.8
Range		<0.1- 1.9	0.0- 21.4	0.7- 1.9	0.4- 5.4	0.2- 8.9	0.0- 2.8	0.2- 3.8	0.6- 3.3	<0.1- 0.7	0.2- 1.8

Table 27. Total birds per kilometer by habitat in August 1976 on aerial surveys presented in Tables 16 through 23.

$\bar{x}$ = density per linear kilometer
km = kilometers of trackline

		Habitat									
Location		Oce	O/SI	O/M	Bay	Lag	Pass	S&I	RmD	Bea	Tun
Barrow -	$\bar{x}$	15.4	5.7	-	-	2.0	19.6	43.6	-	-	-
Tangent Pt. (H)	km	63	114	-	-	281	24	101	-	-	-
Tangent Pt. -	$\bar{x}$	4.4	6.9	5.7	-	-	-	-	-	-	0.4
Drew Pt. (J)	km	264	18	26	-	-	-	-	-	-	30
Drew Pt. -	$\bar{x}$	2.0	-	0.4	-	-	-	-	-	2.1	-
Cape Halkett (K)	km	111	-	44	-	-	-	-	-	44	-
Cape Halkett -	$\bar{x}$	<0.1	-	0.7	-	5.4	-	-	0.9	0.1	2.0
Oliktok Pt. (L)	km	286	-	282	-	6	-	-	33	64	1
Oliktok Pt.	$\bar{x}$	-	4.7	-	-	3.0	3.7	2.8	-	0.5	1.0
Pt. McIntyre (M)	km	-	57	-	-	340	10	57	-	79	3
Pt. McIntyre -	$\bar{x}$	0.0	10.5	-	1.0	7.0	7.9	38.3	2.2	-	-
Brownlow Pt. (N)	km	30	50	-	50	150	26	50	136	-	-
Brownlow Pt. -	$\bar{x}$	-	0.4	9.1	-	2.1	0.4	0.5	0.8	0.1	0.3
Jago River (P)	km	-	72	75	-	183	12	121	34	46	4
Jago River -	$\bar{x}$	-	1.6	3.8	-	4.6	0.1	0.4	0.1	0.1	0.1
Demarcation (Q)	km	-	328	20	-	176	12	164	44	20	20
Total km		754	639	447	50	1136	162	448	247	253	58
Mean		3.1	3.3	2.5	1.0	3.4	6.7	10.9	1.6	0.6	0.4
Range		0.0-	0.4-	0.4-	-	2.0-	0.1-	0.4-	0.1-	0.1-	0.1-
		15.4	10.5	9.1		7.0	19.6	43.6	2.2	2.1	2.0

Table 28. Total birds per kilometer by habitat in September 1976 on aerial surveys presented in Tables 16 through 23.

$\bar{x}$ = density per linear kilometer
km = kilometers of trackline

Location		Habitat									
		Oce	O/SI	O/M	Bay	Lag	Pass	S&I	RmD	Bea	Tun
Barrow - Tangent Pt. (H)	$\bar{x}$	1.8	8.1	-	-	5.1	-	76.6	-	-	-
	km	30	30	204	-	287	-	201	-	-	-
Tangent Pt. - Drew Pt. (J)	$\bar{x}$	1.4	1.0	27.0	-	0.6	-	3.7	0.2	23.2	-
	km	160	10	134	-	26	-	15	20	42	-
Drew Pt. - Cape Halkett (K)	$\bar{x}$	11.2	-	14.3	-	-	-	2.8	-	4.1	0.2
	km	350	-	206	-	-	-	6	-	200	110
Cape Halkett - Oliktok Pt. (L)	$\bar{x}$	0.6	6.0	3.6	-	-	-	-	4.0	0.4	-
	km	194	0.5	285	-	-	-	-	66	126	-
Oliktok Pt. - Pt. McIntyre (M)	$\bar{x}$	-	9.8	-	-	4.4	-	6.6	-	0.4	-
	km	-	114	-	-	286	-	114	-	38	-
Pt. McIntyre - Brownlow Pt. (N)	$\bar{x}$	0.8	5.0	0.0	12.5	9.2	-	11.7	1.0	1.5	-
	km	53	45	11	81	195	-	42	115	113	-
Brownlow Pt. - Jago River (P)	$\bar{x}$	-	0.8	0.5	-	4.4	0.0	0.8	1.3	4.4	1.0
	km	-	50	72	-	120	12	72	21	21	5
Jago River - Demarcation (Q)	$\bar{x}$	-	1.3	2.5	-	5.2	2.7	1.2	0.0	0.0	-
	km	-	164	20	-	176	12	164	44	20	-
Total km		787	587.5	728	81	1090	24	614	266	560	115
Mean		5.5	5.6	10.5	12.5	5.5	1.4	27.6	1.5	3.8	0.2
Range		0.6-11.2	0.8-9.8	0.0-27.0	-	0.6-9.2	0.0-2.7	0.8-76.6	0.0-4.0	0.0-23.2	0.2-1.0

Table 29. Total birds per kilometer by habitat in October 1976 on aerial surveys presented in Tables 16 through 23.

$\bar{x}$ = density per linear kilometer
km = kilometers of trackline

		Habitat									
Location		Oce	O/SI	O/M	Bay	Lag	Pass	S&I	RmD	Bea	Tun
Barrow -	$\bar{x}$	0.8	0.8	-	-	2.1	2.0	31.4	-	-	-
Tangent Pt. (H)	km	512	57	-	-	63	10	54	-	-	-
Tangent Pt. -	$\bar{x}$	1.1	-	-	-	-	-	-	-	-	-
Drew Pt. (J)	km	74	-	-	-	-	-	-	-	-	-
Drew Pt. -	$\bar{x}$	<0.1	-	0.0	-	-	-	-	-	0.0	-
Cape Halkett (K)	km	193	-	63	-	-	-	-	-	63	-
Cape Halkett -	$\bar{x}$	0.2	-	0.0	-	-	-	-	0.0	0.0	-
Oliktok Pt. (L)	km	172	-	135	-	-	-	-	33	103	-
Oliktok Pt. -	$\bar{x}$	0.0	-	-	-	0.2	-	0.3	-	-	-
Pt. McIntyre (M)	km	104	-	-	-	50	-	50	-	-	-
Pt. McIntyre -	$\bar{x}$	0.6	0.0	-	-	0.9	-	0.3	-	-	-
Brownlow Pt. (N)	km	310	50	-	-	50	-	50	-	-	-
Brownlow Pt. -	$\bar{x}$	0.0	0.4	-	-	0.6	-	0.4	-	-	-
Jago River (P)	km	220	72	-	-	50	-	72	-	-	-
Jago River -	$\bar{x}$	-	-	-	-	-	-	-	-	-	-
Demarcation (Q)	km	-	-	-	-	-	-	-	-	-	-
Total km		1585	179	198	-	213	10	226	33	166	-
Mean		0.5	0.4	0.0	-	1.0	2.0	7.8	0.0	0.0	-
Range		0.0- 1.1	0.0- 0.8	-	-	0.2- 2.1	-	0.3- 31.4	-	-	-

Table 30. Percentages of age classes of Glaucous Gulls observed on foot surveys in 1976.

Area	Percent adult	Percent immature	Percent hatching year	Total aged
Cape Lisburne				
June	100	0	0	21
August	78	21	1	465
September	40	21	40	163
Kasegaluk Lagoon				
July	86	14	-	189
Utukok Pass				
July	90	-	10	107
Icy Cape				
June	100	-	-	82
August	99	1	-	122
September	78	1	21	110
Wainwright				
June	80	20	-	78
July	91	9	-	353
September	41	7	52	29
Peard Bay				
June	100	-	-	22
July	94	6	-	214
September	73	2	25	261
Barrow				
May	99	1	-	652
July	89	11	-	83
October	37	8	55	1408
Plover Islands				
July	83	17	-	124
Cooper Island				
June	80	20	-	111
July	80	20	-	200
August	77	21	2	279
Pitt Point				
July	100			69
August	91	1	8	78

Table 30. Percentages of age classes of Glaucous Gulls observed on foot surveys in 1976. (Continued)

Area	Percent adult	Percent immature	Percent hatching year	Total aged
Oliktok				
June	96	4	-	100
July	98	2	-	149
September	62	38	-	92
Bullen - Brownlow				
July	97	3	-	222
Beaufort Lagoon				
June	95	5	-	149

Table 31. Percentagesof age classes of Glaucous Gulls observed on cruises in Beaufort, Chukchi and Bering Seas.

Area	Percent adult	Percent immature	Percent hatching year	Total aged
Beaufort Sea				
August 1976 (nearshore)	91	9	-	33
August 1977 (nearshore)	60	40	-	102
August 1977 (offshore)	76	23	1	383
August 1978 (nearshore)	67	31	2	133
September 1978 (offshore)	74	26	-	295
Chukchi Sea				
August 1975	76	24	-	2100
July 1976	80	20	-	2309
August 1976	81	18	1	2217
September 1976 (northern)	50	26	24	187
October	44	18	38	34
Bering Strait - Kotzehue Sound				
September 1976	51	18	31	156
Bering Sea				
March 1976	58	42	-	79
April 1976	73	27	-	99
March 1977	74	26	-	223
April 1977	80	20	-	477
May 1977	27	73	-	149
May 1978	53	47	-	513
June 1978	60	40	-	45

Table A. Indices of abundance of species encountered in the vicinity of Cape Lisburne from 25 June to 28 June.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	0.9	10.5	4.7			1.5	10.6	2.5	6.0		12.2
Min. per habitat	40	435	230			80	355	90	200		435
Species											
Red-throated Loon	-	0.4	-			-	-	-	0.1*		0.4
Pelagic Cormorant	-	-	-			-	-	-	-		0.1*
Black Brant	-	-	-			73.3*	-	-	6.2*		-
Pintail	-	0.2	-			5.3*	-	-	0.3		-
Green-winged Teal	-	-	-			-	-	-	-		0.3
Greater Scaup	-	-	-			-	-	-	4.7		-
Oldsquaw	-	0.2	-			-	0.1*	10.8*	9.1		3.3
Harlequin Duck	-	-	-			-	-	-	-		0.2*
Common Eider	-	-	-			-	-	-	-		1.8
Rock Ptarmigan	-	0.2	0.6			-	0.2	-	-		-
Ruddy Turnstone	-	0.1*	-			-	-	-	-		-
American Golden Plover	3.3	0.9	2.3			-	-	-	-		-
Semipalmated Sandpiper	2.2	0.9	0.1*			1.3	0.2	-	-		-
Western Sandpiper	5.5	1.0	-			31.3	0.8	-	-		-
Baird's Sandpiper	-	-	0.9			-	-	-	-		-
Knot	-	0.1*	1.1			-	0.1*	-	-		-
Long-billed Dowitcher	4.4	0.1*	-			-	0.1*	-	-		-
Red Phalarope	-	0.2	-			-	-	-	-		-
Northern Phalarope	-	0.4	-			1.3	-	-	-		-
Pomarine Jaegar	-	0.1*	-			-	-	-	-		-
Parasitic Jaeger	-	0.2*	-			1.3	-	-	-		0.1*
Long-tailed Jaeger	-	0.9	-			-	-	-	-		-
Glaucous Gull	-	-	-			1.3	0.5	1.6	-		-
Black-legged Kittiwake	-	-	-			-	37.7	-	-		-
Arctic Tern	-	-	-			-	0.2	4.8	0.2*		0.2
Uria sp.	-	-	-			-	-	-	-		3.1

Table A. (Continued).

Black Guillemot	-	-	-	-	-	-	-	0.9
Red-throated Pipit	-	0.5	0.4	-	-	-	-	-
Redpoll	-	-	1.1	-	-	-	-	-
Savannah Sparrow	-	1.0	0.1*	-	0.1*	-	-	-
Golden-crowned Sparrow	-	0.1*	-	-	-	-	-	-
Lapland Longspur	2.2	6.2	1.9	-	0.1*	-	-	-
Snow Bunting	1.1*	0.1*	1.9	-	-	-	-	-

*Denotes single sighting.

Table B. Indices of abundance of species encountered in the vicinity of Cape Lisburne from 13 August to 18 August.

Habitat	WT	MT	MTWP	AT	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat		23.2		1.6			0.5	40.8	11.4	17.6		46.7
Min. per habitat		860		60			20	1185	360	350		1365
Species												
Yellow-billed Loon		-		-			-	-	-	-		0.1*
Arctic Loon		-		-			-	-	-	-		0.2
Red-throated Loon		-		-			-	-	-	0.1		0.2
Gavia sp.		-		-			-	-	-	0.1		-
Pelagic Cormorant		-		-			-	-	-	-		0.5
Canada Goose		-		-			-	-	-	2.4*		-
Black Brant		-		-			-	-	-	0.2		-
Pintail		-		-			-	-	-	0.1		-
Oldsquaw		-		-			-	-	-	8.3		5.78
Common Eider		-		-			-	-	-	-		0.5
King Eider		-		-			-	-	-	-		0.1*
Spectaded Eider		-		-			-	-	-	-		0.1*
Large Eider		-		-			-	-	-	-		1.3
Surf Scoter		-		-			-	-	-	-		0.7*
Unid. Duck		-		-			-	-	-	-		5.7*
Rock Ptarmigan		2.6		12.9			-	-	-	-		-
American Golden Plover		-		8.8			-	-	-	-		-
Western Sandpiper		1.1		-			198	1.0	4.2	-		-
Dunlin		0.7		-			52	0.5	2.1	-		-
Pectoral Sandpiper		-		2.5			-	-	-	-		-
Sanderling		-		-			-	-	0.8	-		-
Long-billed Dowitcher		1.8		-			-	-	-	-		-
Bar-tailed Godwit		-		-			14	0.3	1.0	-		-
Red Phalarope		-		-			-	1.2	3.0	-		-
Northern Phalarope		-		-			-	13.5	107.3	-		-

Table B. (Continued).

Unid. Phalarope	-	-	-	3.8	13.8	-	-
Pomarine Jaeger	0.1	-	-	0.1	-	-	-
Parasitic Jaeger	-	-	-	0.1	-	-	-
Long-tailed Jaeger	0.6	0.1	-	-	-	-	-
Glaucous Gull	0.2	-	-	2.0	2.4	0.6	-
Herring Gull	-	-	-	0.1*	-	-	-
Black-legged Kittiwake	-	-	-	-	-	2.2	4.2
Arctic Tern	0.3	-	-	0.3	6.2	-	-
Uria sp.	-	-	-	-	-	-	1.0
Black Guillemot	-	-	-	-	-	-	0.8
Horned Puffin	-	-	-	-	-	-	0.2
Tree Swallow	0.3	-	-	-	-	-	-
Wheatear	0.3	-	-	-	-	-	-
Yellow Wagtail	0.3	-	-	-	-	-	-
Lapland Longspur	4.1	-	-	-	-	-	-
Snow Bunting	1.3	-	-	-	-	-	-

*Denotes single sighting.

Table C. Indices of abundance of species encountered in the vicinity of Cape Beaufort from 13 July to 15 July.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	4.3	17.9				3.6	27.6	1.0			32.3
Min. per habitat	56	314				95	420	35			445
Species											
Arctic Loon	-	-				-	-	-			0.1*
Red-throated Loon	-	-				1.1	-	-			0.1*
Gavia sp.	-	-				-	-	-			1.0*
White-fronted Goose	-	-				4.2*	-	-			0.7*
Snow Goose	-	-				1.4*	-	-			-
Pintail	-	-				5.8	-	-			0.2
Greater Scaup	-	-				1.1*	-	-			-
Oldsquaw	-	-				7.5	0.1*	-			1.0
Red-breasted Merganser	-	-				-	-	-			0.2
Marsh Hawk	-	0.1				-	-	-			-
American Golden Plover	-	-				0.8	-	-			-
Ruddy Turnstone	-	-				5.6	0.7	-			-
Black Turnstone	-	-				0.3*	-	-			-
Semipalmated Sandpiper	-	0.7				0.6*	1.0*	-			-
Western Sandpiper	-	-				1.9	-	-			-
Dunlin	-	-				0.6*	-	-			-
Calidris sp.	-	-				1.9	-	-			-
Bar-tailed Godwit	-	-				3.3*	-	-			-
Red Phalarope	-	-				18.1	-	-			-
Northern Phalarope	-	-				13.4	-	-			-
Parasitic Jaeger	-	-				0.6*	-	-			-
Long-tailed Jaeger	-	0.3				18.7*	-	-			-
Glaucous Gull	-	-				0.8	0.1	-			-
Mew Gull	-	-				1.1*	-	-			-
Blacked-legged Kittiwake	-	-				-	-	-			-
Sabine's Gull	-	-				-	-	4.0*			-

Table C. (Continued).

Arctic Tern	1.4*	-	3.9	0.1*	9.0*	0.6
Savannah Sparrow	-	-	0.3*	-	-	-
Yellow Wagtail	-	-	0.6	-	-	-
Lapland Longspur	-	5.4	-	0.1*	-	-

*Denotes single sighting.

Table D. Indices of abundance of species encountered in the vicinity of South Kasegaluk Spit from 12 July to 13 July.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat								26.3	15.4		15.4
Min. per habitat								490	290		290
<u>Species</u>											
Arctic Loon								-	-		0.1*
Red-throated Loon								0.1*	-		0.2
Black Brant								0.1	0.7*		-
Pintail								0.5	-		-
Oldsquaw								0.4	0.3*		1.5
Common Eider								0.2	-		-
American Golden Plover								0.2	-		-
Ruddy Turnstone								0.3	-		-
Semipalmated Sandpiper								1.2	-		-
Western Sandpiper								0.1*	-		-
Pectoral Sandpiper								0.2	-		-
<u>Calidris</u> sp.								0.5	-		-
Red Phalarope								0.3*	-		-
Northern Phalarope								3.1*	-		-
Unid. Phalarope								-	0.3*		-
Long-tailed Jaeger								1.3*	-		-
Glauous Gull								0.5	0.5*		0.5
Arctic Tern								1.3	1.2		0.5
Savannah Sparrow								0.2	-		-
Lapland Longspur								0.8	-		-

*Denotes single sighting.

Table E. Indices of abundance of species encountered in the vicinity of Icy Cape from 21 June to 28 June.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	14.3	44.3		3.9	9.3		27.0		27.0		
Min. per habitat	590	1515		165	305		930		930		
Species											
Yellow-billed Loon	-	-		-	0.1*		-		0.1		
Arctic Loon	0.1	0.1		0.5	-		-		0.1		
Red-throated Loon	0.1	0.1		0.5	-		-		0.1		
Whistling Swan	0.6	-		-	-		-		-		
Black Brant	-	-		4.1	-		-		-		
White-fronted Goose	1.9	0.1		1.8	-		-		-		
Snow Goose	1.9	0.2		-	-		-		-		
Pintail	0.6	-		-	0.1*		-		0.1		
Oldsquaw	1.7	0.2		1.8	1.7		-		2.0		
Common Eider	-	0.1		-	-		-		0.1*		
Spectacled Eider	-	-		-	-		-		0.1*		
Steller's Eider	0.1*	-		-	-		-		-		
Unid. Ptarmigan	-	0.2		-	-		-		-		
American Golden Plover	-	0.3		0.3*	0.3		0.1		-		
Black-bellied Plover	0.1	0.1*		-	0.2		-		-		
Ruddy Turnstone	-	-		0.3*	-		-		-		
Semipalmated Sandpiper	3.3	0.2		0.7	4.1		-		-		
Western Sandpiper	0.9	0.1		-	-		-		-		
Baird's Sandpiper	0.1*	0.2		1.3	0.2		-		-		
Pectoral Sandpiper	0.3	0.1		0.5	-		0.1		-		
Dunlin	1.0	0.8		2.8	2.4		0.4		-		
Knot	-	0.1*		-	-		-		-		
Long-billed Dowitcher	0.3	-		-	-		-		-		
Red Phalarope	8.7	0.3		4.4	0.8		-		-		
Northern Phalarope	0.6	0.1		0.5	-		0.1		-		
Pomarine Jaeger	0.2	0.1		-	-		-		-		

Table E. (Continued).

Parasitic Jaeger	0.3	0.1	0.5	-	-	-
Glaucous Gull	0.2	-	0.5	0.3	0.4	0.1
Arctic Tern	0.6	0.2	0.5	-	0.6	-
Short-eared Owl	0.1*	0.1	-	-	-	-
Savannah Sparrow	-	-	-	-	0.1*	-
Lapland Longspur	2.7	6.1	6.1	1.0	0.1	-
Snow Bunting	-	0.5	0.5	-	0.1	-

*Denotes single sighting.

Table F. Indices of abundance of species encountered in the vicinity of Icy Cape from 7 July to 11 July.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	12.3	30.2		6.6	4.5		99.0		99.0		
Min. per habitat	410	875		180	170		1690		1690		
<u>Species</u>											
Arctic Loon	0.2	0.4		0.2*	-		-		0.1		
Red-throated Loon	0.6	0.2		-	-		-		0.1		
White-fronted Goose	1.7	1.0		-	-		0.1		-		
Black Brant	1.8*	0.1		2.1	-		0.1		-		
Pintail	-	0.3		-	-		-		-		
Oldsquaw	2.1	0.1		-	-		-		-		
Spectacled Eider	0.5*	-		-	-		-		-		
American Golden Plover	-	0.3		-	0.2*		0.2		-		
Ruddy Turnstone	-	-		-	-		0.1				
Semipalmated Sandpiper	-	0.1		0.2*	-		0.1		-		
Baird's Sandpiper	-	0.1*		-	-		-		-		
Western Sandpiper	1.2	1.1		4.6	9.1		11.8		-		
Pectoral Sandpiper	7.7	2.9		1.6	1.5		2.1		-		
Dunlin	1.7	1.4		1.1	2.8		6.5		-		
<u>Calidris</u> sp.	0.5*	-		-	-		0.4		-		
Buff-breasted Sandpiper	-	-		0.2*	-		-		-		
Long-billed Dowitcher	0.1*	-		-	-		-		-		
Bar-tailed Godwit	0.5*	-		-	-		0.3		-		
Red Phalarope	0.7	0.8		-	0.9		1.5		-		
Northern Phalarope	0.1	-		0.3	-		0.4		-		
Unid. Phalarope	-	-		-	-		0.6		-		
Pomarine Jaeger	-	0.1		-	-		-		-		
Parasitic Jaeger	0.2	0.1		-	-		-		-		
Long-tailed Jaeger	0.1*	0.1		0.2*	-		-		-		
<u>Stercorarius</u> sp.	-	0.1		-	-		-		-		

Table F. (Continued).

Glaucous Gull	0.9	0.4	3.8*	-	0.5	-
Arctic Tern	0.2	0.4	0.9	0.4	0.6	-
Savannah Sparrow	0.2	-	-	-	-	-
Lapland Longspur	1.8	1.4	3.0	-	0.1	-
Snow Bunting	-	0.4	-	-	0.1	-

*Denotes single sighting.

Table G. Indices of abundance of species encountered in the vicinity of Icy Cape from 9 September to 12 September.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	11.6	4.1	9.8	5.9	7.8		34.9		34.9		
Min. per habitat	280	185	225	140	250		1100		1100		
<u>Species</u>											
Arctic Loon	-	-	-	-	1.0		-		1.6		
Red-throated Loon	0.1	-	-	-	-		-		0.3		
Black Brant	3.5	-	-	4.4	8.9		0.5		0.4		
Oldsquaw	-	-	-	-	-		-		34.9		
Red-breasted Merganser	-	-	-	-	-		-		0.3		
American Golden Plover	0.3	-	-	-	-		-		-		
Black-bellied Plover	0.1	-	-	-	1.3		0.7		-		
Pectoral Sandpiper	-	-	-	-	-		0.1		-		
Dunlin	0.3	0.3	-	0.4	2.9		4.1		-		
Calidris sp.	-	-	-	-	-		0.1		-		
Bar-tailed Godwit	-	-	-	-	-		0.1		-		
Northern Phalarope	0.3	-	-	-	-		-		-		
Glaucous Gull	-	-	-	0.1	1.1		1.3		0.2		
Black-legged Kittiwake	-	-	-	-	-		0.1		-		
Sabine's Gull	-	-	-	-	-		0.1		-		
Arctic Tern	-	-	-	-	-		-		1.4		
Pomarine Jaeger	-	-	-	0.1	-		-		-		
Short-eared Owl	-	0.1	-	-	-		-		-		
Snowy Owl	-	0.1	-	-	-		-		-		
Lapland Lonspur	-	-	-	0.1	-		-		-		
Snow Bunting	-	0.1	-	-	-		0.1		-		

*Denotes single sighting.

Table H. Indices of abundance of species encountered in the vicinity of Wainwright from 30 June to 4 July.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	12.9	32.7				2.3	33.0	6.9	10.4		35.7
Min. per habitat	47	1040				90	1060	180	320		1080
<u>Species</u>											
Yellow-billed Loon	-	-				-	-	-	-		0.1
Arctic Loon	0.2	0.1				-	-	-	-		0.4
Red-throated Loon	0.2	-				-	-	-	-		-
Gavia sp.	-	0.1				-	-	-	-		0.8
Black Brant	1.6	-				-	-	-	-		-
White-fronted Goose	0.2	-				-	-	-	-		-
Snow Goose	-	-				-	-	-	-		0.1*
Pintail	1.5	0.1*				-	-	-	-		-
Oldsquaw	1.9	1.6				-	0.1*	-	1.8		2.3
Steller's Eider	-	-				-	-	-	0.6		-
Spectaded Eider	0.2	-				-	-	-	-		-
King Eider	0.1*	-				-	-	-	-		0.2
Red-breasted Merganser	-	-				-	-	-	-		0.1*
American Golden Plover	0.1	0.2				-	-	-	-		-
Ruddy Turnstone	-	0.1*				-	-	-	-		-
Semipalmated Sandpiper	1.2	0.6				-	0.1	0.8	-		-
Western Sandpiper	-	-				-	0.1*	0.1*	-		-
Baird's Sandpiper	0.2	0.9				-	-	-	-		-
Pectoral Sandpiper	0.5	0.1				-	-	-	-		-
Dunlin	2.0	1.0				-	0.2	-	-		-
Long-billed Dowitcher	0.4	-				-	-	-	-		-
Whimbrel	0.1*	0.1*				-	-	-	-		-
Red Phalarope	7.5	0.7				-	0.2	0.3	-		-
Pomarine Jaeger	0.6	0.1				-	0.1	-	-		-
Parasitic Jaeger	0.6	0.4				-	-	-	-		-

Table H. (Continued).

Long-tailed Jaeger	-	0.1	-	-	-	-	-
Glaucous Gull	0.6	0.1	-	-	-	-	-
Sabine's Gull	-	0.1*	-	-	0.1*	-	-
Arctic Tern	-	0.2	-	0.1*	1.6	0.1*	0.2
Snowy Owl	-	0.1	-	-	-	-	-
Lapland Longspur	10.9	9.2	-	0.1	-	-	-
Snow Bunting	0.9	0.4	-	0.1	0.3	-	-

*Denotes single sighting.

Table I. Indices of abundance of species encountered in the vicinity of Wainwright to Pt. Franklin from 30 July to 4 August.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	1.8	17.9	15.3				37.3	46.8	26.9		59.7
Min. per habitat	80	685	460				1380	1473	790		2005
Species											
Yellow-billed Loon	-	-	-				-	-	0.1		0.1
Arctic Loon	-	-	0.3				-	-	0.3		0.3
Red-throated Loon	-	0.1*	0.5				-	-	1.0		0.1
Unid. Small Loon	-	-	0.1				-	-	-		0.2
Black Brant	-	-	-				-	-	0.4		-
Pintail	-	0.6	-				-	0.1	0.1*		-
Oldsquaw	-	-	0.5				-	-	10.5		1.0
Steller's Eider	-	-	-				-	3.6	-		-
Common Eider	-	-	-				-	3.9	-		0.7
King Eider	-	-	-				-	-	0.1*		-
Spectacled Eider	-	-	-				-	0.2	0.3*		-
Unid. Eider	-	-	-				-	4.3	19.5		0.1*
Unid. Duck	-	-	0.1				-	0.6	-		-
Ruddy Turnstone	-	-	-				0.1*	-	-		-
American Golden Plover	-	0.2	0.3				-	-	-		-
Semipalmated Sandpiper	-	0.1	2.1				4.0	0.6	-		
Baird's Sandpiper	0.6*	-	-				-	-	-		-
Western Sandpiper	-	0.2	1.0				5.0	1.0	-		-
Pectoral Sandpiper	1.1	0.1	0.3				-	0.1	-		-
Dunlin	3.3	5.1	1.7				2.9	2.1	-		-
Sanderling	-	-	-				0.2	0.1	-		-
Red Phalarope	17.7*	0.3	4.6				71.9	258.8	-		-
Northern Phalarope	-	-	-				0.1	0.1	-		-
Pomarine Jaeger	-	-	-				0.1	-	-		-
Parasitic Jaeger	1.6	-	0.2				-	0.1	-		-

Table I. (Continued).

Long-tailed Jaeger	0.1	0.4	0.2	-	1.0	-	-
Glaucous Gull	-	0.2	0.2	0.1	3.2	0.8	0.5
Black-legged Kittiwake	-	-	-	0.3	2.9	-	-
Sabine's Gull	-	-	-	-	17.1	-	-
Arctic Tern	-	-	0.1	0.4	121.0	0.1	-
Uria sp.	-	-	-	-	-	-	0.4
Black Guillemot	-	-	-	-	0.3	-	0.1
Snowy Owl	-	0.1*	0.1*	-	-	-	-
Savannah Sparrow	-	-	0.3	-	-	-	-
Lapland Longspur	2.2	8.0	8.4	-	-	-	-
Snow Bunting	-	0.5	-	0.3	-	-	-

*Denotes single sighting.

Table J. Indices of abundance of species encountered in the vicinity of Wainwright from 13 September to 15 September.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	0.8	2.4				0.2	17.6	5.4	0.3		22.7
Min. per habitat	20	40				5	440	170	10		600
Species											
Arctic Loon	-	-				-	-	-	-		0.2
Red-throated Loon	2.5	-				-	-	-	-		0.1*
Govia sp.	-	-				-	-	-	-		0.4
Black Brant	-	-				-	0.6*	-	-		-
Oldsquaw	-	-				-	-	-	-		14.4
Steller's Eider	-	-				-	-	-	-		0.5
Dunlin	-	-				-	0.1	-	-		-
Sanderling	-	-				-	0.1*	0.4	-		-
Red Phalarope	-	-				-	0.2	-	-		-
Long-tailed Jaegar	-	0.4				-	-	-	-		-
Glaucous Gull	-	-				-	11.1	14.6	-		5.3
Blacked-legged Kittiwake	-	-				-	-	-	-		0.2
Sabine's Gull	-	-				20*	-	0.1*	-		0.1

*Denotes single sighting.

Table K. Indices of abundance of species encountered in the vicinity of Peard Bay from 17 June to 20 June.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	4.8	24.3				2.3	12.1	9.0		21.0	9.0
Min. per habitat	90	860				90	365	60		425	60
<u>Species</u>											
White-fronted Goose	-	0.1*				-	-	-		-	-
Oldsquaw	2.9	0.5				3.0	-	-		0.1*	-
Common Eider	-	-				-	-	-		-	0.1*
King Eider	0.8*	-				-	-	-		-	-
Steller's Eider	0.2*	-				-	-	-		-	-
Willow Ptarmigan	0.2*	0.2				-	-	-		-	-
Semipalmated Plover	-	0.1*				-	-	-		-	-
American Golden Plover	0.4	0.1				-	-	-		-	-
Ruddy Turnstone	0.4	-				-	-	-		-	-
Semipalmated Sandpiper	1.3	1.2				1.4	-	-		-	-
Western Sandpiper	-	-				2.6	-	-		-	-
Baird's Sandpiper	-	0.7				-	0.2	-		-	-
Pectoral Sandpiper	1.0	0.4				1.7	-	-		-	-
Dunlin	2.9	1.0				1.3	0.2	-		-	-
Long-billed Dowitcher	-	0.1*				-	-	-		-	-
Common Snipe	0.2*	-				-	-	-		-	-
<u>Calidris</u> sp.	-	0.2				-	-	-		-	-
Red Phalarope	2.7	0.7				1.7	-	-		-	-
Northern Phalarope	0.4	0.1				0.3*	-	-		-	-
Pomarine Jaeger	-	0.2				-	0.2	-		-	-
Parasitic Jaeger	-	-				-	0.1*	-		-	-
Long-tailed Jaeger	0.2*	0.2				-	-	-		-	-
Glaucous Gull	0.2*	0.2				-	0.2	-		-	-
Arctic Tern	-	-				-	-	1.2		-	-
Redpoll	-	0.1				-	-	-		-	-
Savannah Sparrow	-	0.7				-	-	-		-	-
Lapland Longspur	4.2	8.8				-	0.2	-		-	-
Snow Bunting	1.6	0.2				-	0.3	0.1*		-	-

*Denotes single sighting.

Table L. Indices of abundance of species encountered in the vicinity of Peard Bay from 31 July to 4 August.

Habitat	WT	MT	Rm	Bea	S&B	Bay	Oce	Lake	Lake Shore
Km Per Habitat	5.4	9.7	5.2	63.7	3.4	59.3	7.3	2.6	2.6
Min. Per Habitat	120	210	141	1100	100	1050	193	40	40
Species									
Yellow-billed Loon	-	-	-	-	-	-	0.3	-	-
Arctic Loon	0.9	-	-	-	-	0.2	0.6	1.2	-
Red-throated Loon	0.2	-	-	-	-	0.5	0.3	1.5	-
Loon sp.	0.9	-	-	-	-	-	-	-	-
Pintail	2.0	-	4.0*	2.9*	-	1.3*	-	-	-
Oldsquaw	0.2	-	2.7*	-	-	15.3	37.8*	8.9*	-
Common Eider	-	-	-	-	-	0.2	3.7	-	-
King Eider	-	-	0.2*	0.1*	-	-	-	-	-
Eider sp.	-	-	-	-	-	1.0	-	-	-
Red-breasted Merg.	-	-	-	-	-	-	-	-	-
Duck sp.	-	-	-	-	-	2.2*	-	-	-
Golden Eagle	-	0.1*	-	-	-	-	-	-	-
Golden Plover	-	1.2	0.6	0.1*	-	-	-	-	-
Black-bellied Plover	-	0.2	-	-	-	-	-	-	-
Ruddy Turnstone	-	-	-	0.1	-	-	-	-	-
Semipalmated Sand.	-	-	4.2	0.9	4.8	-	-	-	-
Western Sandpiper	0.9	-	25.0	0.2	4.2	-	-	-	-
Bairds Sandpiper	1.3	-	3.8	0.9	6.9	-	-	-	-
Pectoral Sandpiper	0.8	-	-	-	-	-	-	-	0.4*
Dunlin	0.9	0.4	2.3	0.1	-	-	-	-	1.5
Calidris sp.	-	0.1*	1.3	0.1	-	-	-	-	-
Red Phalarope	1.3	-	-	1.4	50.8	-	1.0	-	2.7
Northern Phalarope	-	-	-	-	1.2	-	-	-	-
Pomarine Jaeger	-	-	-	-	-	-	0.1*	-	-
Parasitic Jaeger	-	-	-	-	-	-	0.2	-	-

Table L. (Continued).

Long-tailed Jaeger	0.9*	1.0	-	-	0.6*	-	-	-	-
Glaucous Gull	1.9	-	2.1	0.6*	-	0.3	0.3	-	-
Black-legged Kitt.	-	-	-	-	-	-	-	-	-
Sabines Gull	-	-	-	-	-	-	-	-	-
Arctic Tern	-	-	-	-	3.9	0.2	0.8	-	-
Lapland Longspur	5.2	7.4	1.0	0.5	-	-	-	-	-
Snow Bunting	0.4	1.8	-	0.3	-	-	-	-	-

*Denotes single sighting.

Table M. Indices of abundance of species encountered in the vicinity of Peard Bay from 14 September to 16 September.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	1.8	23.0	1.3			1.9	24.9			24.9	
Min. per habitat	60	620	30			50	630			630	
Species											
Black Brant	-	-	-			0.5	-			2.5	
Steller's Eider	-	-	-			-	-			0.5	
Red-breasted Merganser	-	-	-			8.9	-			-	
Willow Ptarmigan	-	1.0*	-			-	-			-	
Glaucous Gull	-	-	4.6			-	5.8			-	

*Denotes single sighting.

Table N. Indices of abundance of species encountered in the vicinity of Barrow from 18 July to 19 July.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat		33.2					33.2				33.2
Min. per habitat		730					688				688
Species											
Red-throated Loon		0.1*					-				-
Arctic Loon		0.2					-				1.1
Oldsquaw		0.8					-				134.5
Common Eider		-					-				0.1
King Eider		2.0					-				-
Steller's Eider		-					1.2				0.2
American Golden Plover		0.3					-				-
Pectoral Sandpiper		1.8					-				-
Dunlin		1.5					-				-
Red Phalarope		0.8					-				-
Pomarine Jaeger		1.7					-				-
Parasitic Jaeger		0.2					-				-
Long-tailed Jaeger		0.5					-				-
Glaucous Gull		0.8					-				0.3
Sabine's Gull		1.1					-				-
Arctic Tern		0.3					-				0.2
Snowy Owl		1.5					-				-
Savannah Sparrow		0.1					-				-
Lapland Longspur		6.9					-				-
Snow Bunting		2.4					-				-

*Denotes single sighting.

Table O. Indices of abundance of species encountered in the vicinity of Pitt Pt. from 8 July to 11 July.

Habitat	WT	MT	MTWP	BT	DMF	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	12.5	56.6	5.1	7.6	9.0		2.7	40.4	1.5		21.2	25.9
Min. per habitat	370	1490	165	240	220		70	1090	50		600	725
<u>Species</u>												
Arctic Loon	-	-	-	0.3	-		0.4	-	-		0.4	0.8
Red-throated Loon	0.1	-	-	-	-		-	-	-		0.1	-
Whistling Swan	-	-	-	-	-		0.7	-	-		-	-
Black Brant	-	0.1	-	2.1	-		-	-	-		0.1	-
White-fronted Goose	0.4	-	-	-	-		-	-	-		-	-
Snow Goose	-	0.1	-	-	-		-	-	-		-	-
Pintail	0.3	0.1	-	7.6	-		-	-	-		0.1	0.1
Greater Scaup	-	-	-	-	-		-	-	-		0.5*	-
Oldsquaw	0.8	-	-	1.3	-		-	0.1	-		5.3	5.5
King Eider	0.2	-	-	-	-		-	-	-		-	-
Spectaded Eider	-	-	-	0.1	-		-	-	-		-	0.1
Red-breasted Merganser	-	-	-	-	-		-	0.1	-		0.6	-
Peregrine Falcon	-	0.1*	-	-	-		-	-	-		-	-
Ptarmigan sp.	-	0.1	-	-	-		-	-	-		0.5	-
American Golden Plover	-	0.1	-	-	-		-	-	-		-	-
Ruddy Turnstone	-	0.1	-	-	-		-	-	-		-	-
Semipalmated S.	0.9	0.1	-	0.5	-		-	0.1	-		-	-
Baird's Sandpiper	0.2	0.9	-	0.5	-		-	-	0.6		-	-
Pectoral Sandpiper	0.6	1.6	-	7.1	0.1		-	0.1	-		-	-
Dunlin	0.9	2.0	-	2.9	-		-	-	-		-	-
Long-billed Dowitcher	-	0.2	-	-	-		-	-	-		-	-
Red Phalarope	1.0	0.4	-	-	-		-	-	-		-	-
Northern Phalarope	0.1	0.1	-	0.1	-		-	-	-		-	-

Table O. (Continued).

Pomarine Jaeger	-	0.1	-	-	-	-	-	-	-	-
Parasitic Jaeger	-	0.2	-	-	-	-	-	-	-	-
Long-tailed Jaeger	-	0.1	-	-	-	-	-	-	-	-
Glaucous Gull	0.2	-	-	0.4	-	-	0.5	14.0	-	-
Sabine's Gull	-	0.1	-	0.9	-	-	0.1	1.3	-	-
Arctic Tern	0.1	-	-	-	-	-	1.1	0.6	-	-
Snowy Owl	-	0.1*	-	-	-	-	-	-	-	-
Savannah Sparrow	-	0.1	-	-	-	-	-	-	-	-
Lapland Longspur	0.9	4.6	0.1	0.1	-	-	0.1	-	-	-
Snow Bunting	0.2	0.9	0.1	0.1	-	-	0.2	-	-	-

*Denotes single sighting.

Table P. Indices of abundance of species encountered in the vicinity of Pitt Pt. from 30 August to 2 September.

Habitat	WT	MT	MTWP	BT	DMF	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	3.7	28.1		8.7	6.3	0.9		41.2	0.5		23.7	28.3
Min. per habitat	85	665		250	180	50		1045	15		670	670
Species												
Arctic Loon	0.81	0.1		-	-	-		-	-		1.5	-
Red-throated Loon	0.3	-		-	-	-		-	-		0.9	0.2
Black Brant	-	-		0.2*	-	233.3*		-	-		0.6	-
White-fronted Goose	15.4	1.4		-	-	-		-	-		-	-
Pintail	-	0.2*		-	-	-		-	-		-	-
Oldsquaw	-	0.9		-	-	-		-	-		239.5	207.5
Spectacled Eider	-	-		-	-	-		-	-		-	0.1*
King Eider	-	-		-	-	-		-	-		-	0.1*
Red-breasted Merganser	-	-		-	-	-		-	-		0.1*	-
Willow Ptarmigan	-	0.2*		-	-	-		-	-		-	-
Black-bellied P.	2.4	0.2		0.3	-	4.4		1.3	18		-	-
Ruddy Turnstone	-	-		-	-	-		0.7	-		-	-
Pectoral Sandpiper	0.8	0.3		0.7	-	-		0.1	-		-	-
Dunlin	9.2	0.8		7.3	-	362.2		7.9	4		-	-
Sanderling	-	-		-	-	-		0.1	-		-	-
Long-billed Dowitcher	0.5	0.2		3.7	-	22.2		0.5	70*		-	-
Red Phalarope	1.9	0.1		-	-	-		4.7	48*		-	-
Northern Phalarope	0.5	-		-	-	-		0.1	2*		-	-
Parasitic Jaeger	0.5	0.1		-	-	-		-	-		-	-
Glaucous Gull	0.5	-		-	-	11.1		0.2	60*		0.2	1.0
Sabine's Gull	-	-		-	-	-		-	2.0*		-	-
Lapland Longspur	-	1.3		-	-	-		0.2	-		-	-
Snow Bunting	-	0.6		-	-	-		0.3	-		-	-

*Denotes single sighting.

Table Q. Indices of abundance of species encountered in the Colville River delta from 13 to 15 July.

Habitat	WT	MT	Lake	River Shore	River
Km per habitat	7.2	10.2	1.8	6.9	6.9
Min per habitat	580	455	160	290	290
Species					
Yellow-billed Loon	0.3	-	1.6	-	-
Arctic Loon	-	-	-	-	0.1
Red-throated Loon	1.6	-	1.6	-	0.3
Black Brant	5.1	0.6	8.9	-	-
Pintail	0.3	0.4	-	2.1	-
Oldsquaw	3.9	0.2	-	-	0.3*
Spectacled Eider	1.4	-	-	-	-
Eider sp.	-	-	-	-	0.1*
Willow Ptarmigan	-	0.1*	-	-	-
Golden Plover	-	0.2	-	-	-
Black-bellied Plover	0.3	0.2	-	-	-
Ruddy Turnstone	0.7	0.3	-	-	-
Semipalmated Sandpiper	25.1	5.7	-	-	-
Baird's Sandpiper	-	0.4	-	-	-
Pectoral Sandpiper	6.9	2.3	-	-	-
Dunlin	5.7	1.2	-	0.1*	-
Long-billed Dowitcher	3.2	-	-	-	-
Red Phalarope	7.9	1.5	-	-	-
Northern Phalarope	7.2	-	-	-	-
Pomarine Jaeger	0.1*	0.1*	-	-	-
Parasitic Jaeger	0.1*	0.3	-	-	-
Sabine's Gull	3.2	0.8*	-	-	-
Arctic Gull	1.6	0.2	-	-	-
Glaucous Gull	3.1	0.1*	-	1.0*	0.6*
Redpoll	0.1*	0.1*	-	-	-
Savannah Sparrow	-	1.0	-	-	-
Lapland Longspur	8.1	9.5	-	-	-
Snow Bunting	0.3	0.7	-	-	-

*Denotes Single sighting.

Table R. Indices of abundance of species encountered in the vicinity of Oliktok from 12 June to 15 June.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	4.3	55.6					34.0				34.0
Min. per habitat	210	1870					1150				1150
Species											
Arctic Loon	-	-					-				2.9
Red-throated Loon	-	0.1*					-				-
Whistling Swan	0.2*	-					-				-
Black Brant	-	-					-				0.2*
White-fronted Goose	11.9	0.9					-				-
Pintail	0.2*	0.1*					-				-
Oldsquaw	9.1	1.3					-				2.8
Common Eider	-	-					-				0.1
King Eider	10.2	0.6					-				4.5
Spectaded Eider	0.2*	-					-				0.3
Unid. Ptarmigan	-	0.2					-				-
American Golden Plover	0.2*	0.7					-				-
Semipalmated Sandpiper	2.8	1.6					-				-
Baird's Sandpiper	-	0.2					-				-
Pectoral Sandpiper	0.2*	0.1*					-				-
Dunlin	2.6	0.6					-				-
Stilt Sandpiper	0.2*	-					-				-
Red Phalarope	6.7	0.1					-				-
Northern Phalarope	1.2	-					-				-
Pomarine Jaeger	0.7	0.3					-				-
Parastic Jaeger	-	0.1					-				-
Long-tailed Jaeger	-	0.1					-				-
Glaucous Gull	0.4	0.1					-				0.2
Sabine's Gull	0.9	-					-				-
Arctic Tern	0.7	-					-				-
Snowy Owl	-	0.1*					-				-

Table R (Continued).

Short-eared Owl	0.2*	-	-	-
Hoary Redpoll	0	0.1	-	-
Savannah Sparrow	-	0.1	-	-
Lapland Longspur	6.0	3.0	-	-
Snow Bunting	-	1.1	-	-

*Denotes single sighting.

Table S. Indices of abundance of species encountered in the vicinity of Oliktok from 16 July to 19 July.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	4.3	55.5		12.0	5.1	13.8	31.9				16.1
Min. per habitat	165	1740		320	180	365	910				490
<u>Species</u>											
Yellow-billed Loon	-	-		-	-	-	-				0.3
Arctic Loon	0.7	0.1		-	0.4	-	-				0.8
Red-throated Loon	-	0.1		-	-	-	-				-
<u>Gavia</u> sp.	-	-		-	-	-	-				0.5
Whistling Swan	-	0.1		-	-	-	0.1				0.1*
Black Brant	-	0.5		36.2	5.4	38.8	1.9				6.9
White-fronted Goose	1.4*	0.1*		-	-	0.3	-				-
Snow Goose	-	0.1*		-	-	-	-				-
Pintail	-	-		-	-	2.7	-				-
Greater Scaup	-	-		-	-	-	-				0.4*
Oldsquaw	0.7	0.2		-	-	2.7	-				0.7
Common Eider	-	-		-	-	-	-				0.1
King Eider	-	0.1*		-	1.2	-	-				0.4
Unid. Eider	0.7	0.1*		-	-	-	-				1.6
Red-breasted Merganser	-	-		-	-	-	-				0.1*
Willow Ptarmigan	-	0.1		-	-	-	-				-
American Golden Plover	-	0.8		0.3	-	-	-				-
Black-bellied Plover	-	0.1		-	-	-	-				-
Ruddy Turnstone	0.7	0.1		-	-	-	-				-
Semipalmated Sandpiper	5.8	1.8		0.8	-	2.7	0.1*				-
Western Sandpiper	-	0.1		-	-	-	-				-
Baird's Sandpiper	-	0.3		0.2	-	0.1*	0.1*				-
Pectoral Sandpiper	2.8	0.6		1.8*	-	-	-				-
Dunlin	1.9	0.8		0.2	-	-	0.1*				-
Long-billed Dowitcher	0.2*	-		-	-	-	-				-

Table S (Continued).

Stilt Sandpiper	0.6	-	-	-	-	-	-
Whimbrel	-	0.1*	-	-	-	-	-
Red Phalarope	3.0	0.7	0.2	-	0.2	-	-
Northern Phalarope	0.5	0.1	-	-	-	-	-
Pomarine Jaeger	-	0.1	-	-	-	-	-
Parastic Jaeger	0.2*	0.2	-	-	-	-	-
Long-tailed Jaeger	0.5	0.1	-	-	-	-	-
Glaucous Gull	-	0.1	-	1.6	1.3	1.5	3.2
Sabine's Gull	2.3*	0.1	-	-	-	-	-
Arctic Tern	1.6	0.2	-	-	0.1*	-	-
Snowy Owl	-	0.1	-	-	-	-	-
Common Raven	-	0.1*	-	-	-	-	-
Hoary Redpoll	-	0.1*	-	-	-	-	-
Savannah Sparrow	-	0.2	-	-	-	-	-
Lapland Longspur	1.4	3.9	1.6	-	-	0.1*	-
Snow Bunting	-	0.3	-	-	-	0.1	-

*Denotes single sighting.

Table T. Indices of abundance of species encountered in the vicinity of Oliktok from 4 September to 6 September.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	5.2	17.6	9.9	4.6	6.0	7.6	15.4				15.4
Min. per habitat	175	490	255	85	190	215	370				370
<u>Species</u>											
Arctic Loon	0.2	0.1	1.2	-	3	0.8	-				0.2
Red-throated Loon	0.2	-	0.5	-	0.2*	-	-				-
Gavia sp.	-	-	-	-	0.2*	-	-				-
Whistling Swan	-	-	-	-	0.2*	-	-				-
Black Brant	-	-	-	3.7	-	8.7	2.1*				-
Pintail	-	0.1	-	-	-	-	-				-
Gyrfalcon	-	0.1*	-	-	-	-	-				-
American Golden Plover	0.2*	0.1	-	-	-	-	-				-
Black-bellied Plover	0.9	0.6	0.4	-	-	0.1*	-				-
Western Sandpiper	-	-	-	-	0.3	-	0.1*				-
Pectoral Sandpiper	1.3	-	0.2	-	-	0.5	-				-
Dunlin	2.7	2.1	2.6	0.1*	2.5	3.0	1.6				-
Sanderling	-	-	-	-	-	-	0.9				-
Long-billed Dowitcher	3.0	0.2	1.9	-	-	0.3*	0.2				-
Red Phalarope	-	-	0.7	-	-	-	3.1				-
Parastic Jaeger	0.4	-	-	-	-	-	-				-
Glaucous Gull	0.4	-	0.2	-	16.5	2.6	0.5				-
Arctic Tern	-	-	-	-	-	-	0.5				1.5
Snowy Owl	0.2*	0.2	-	-	-	-	-				-
White-crowned Sparrow	-	0.1*	-	-	-	-	-				-
Lapland Longspur	0.6	3.0	0.6	0.4	0.3	-	-				-
Snow Bunting	-	0.5	0.2	-	-	-	1.3				-

*Denotes single sighting.

Table U. Indices of abundance of species encountered on islands in the Kuparuk River delta on 30 June.

Habitat	WT
Km per habitat	7.1
Min per habitat	160
Species	
Arctic Loon	1.0
Whistling Swan	0.3
Black Brant	2.1
White-fronted Goose	0.8*
Pintail	5.2
Oldsquaw	1.4
Common Eider	0.3*
King Eider	1.3
Ruddy Turnstone	0.6
Baird's Sandpiper	0.1*
Pectoral Sandpiper	2.1
Dunlin	0.3*
Red Phalarope	3.5
Northern Phalarope	1.7
Parasitic Jaeger	0.8
Glaucous Gull	1.5
Sabine's Gull	0.1*
Lapland Longspur	2.1

*Denotes single sighting.

Table V. Indices of abundance of species encountered on islands in the Sagavanirktok River delta on 23-24 June and 3 July.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat		21.7				0.5		1.5	1.5	4.5	1.3
Min per habitat		494				10		40	40	85	80
<u>Species</u>											
Arctic Loon		0.1*				-		-	1.3*	-	1.3
Red-throated Loon		0.1*				-		-	4.0	-	0.3*
Gavia sp.		0.1*				-		-	-	0.4	-
Whistling Swan		0.3				-		-	-	-	-
Canada Goose		0.5				-		-	-	-	-
Black Brant		3.4				18.0		-	-	-	-
Pintail		-				10.0		-	-	-	-
Oldsquaw		0.2				-		-	20.0	-	0.6
Common Eider		-				-		-	-	0.4*	-
King Eider		0.4				-		-	1.3*	-	-
Pluvialis sp.		0.1*				-		-	-	-	-
Ruddy Turnstone		1.0				2.0		-	-	-	-
Semipalmated Sandpiper		0.3				-		-	-	-	-
Baird's Sandpiper		0.9				-		-	-	-	-
Pectoral Sandpiper		0.7				-		-	-	-	-
Buff-breasted Sandpiper		0.6				-		-	-	-	-
Red Phalarope		1.2				4.0		-	-	-	-
Pomarine Jaeger		0.1*				-		-	-	-	-
Parasitic Jaeger		0.1*				-		-	-	-	-
Long-tailed Jaeger		0.3*				-		-	-	-	-
Glaucous Gull		4.1				-		0.6*	-	0.2*	-
Arctic Tern		0.2				-		-	-	-	0.6
Snowy Owl		0.1				-		-	-	-	0.3*
Lapland Longspur		0.8				-		-	-	-	-
Snow Bunting		0.2				-		-	-	-	-

*Denotes single sighting.

Table W. Indices of abundance of species encountered in the vicinity of Bullen to Brownlow from 21 July to 24 July.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	3.9	38.1	28.1		5.5		29.5	20.3	49.5		31.2
Min. per habitat	120	1050	795		195		930	655	1435		1010
<u>Species</u>											
Arctic Loon	-	-	0.3		-		-	-	0.3		0.2
Red-throated Loon	-	-	0.4		-		-	-	0.1		0.2
Whistling Swan	-	0.1	0.3		-		-	-	0.1		-
Canada Goose	-	-	0.4*		-		-	-	2.5		-
Pintail	-	-	0.4		-		-	-	0.1*		0.1*
Oldsquaw	4.3	-	0.1*		0.4*		0.2	27.1	8.1		25.5
Common Eider	0.5*	-	-		-		-	-	0.2		-
King Eider	-	-	0.2*		-		-	0.1*	-		0.1*
Unid. Eider	-	-	0.1*		-		-	1.0	0.6		0.3
White-winged Scoter	-	-	-		-		-	-	-		0.1*
Red-breasted Merganser	-	-	-		-		-	0.2*	-		0.1*
Unid. Duck	-	-	-		-		-	2.3*	-		-
Rough-legged Hawk	-	0.1*	-		-		-	-	-		-
Rock Ptarmigan	-	-	0.4		-		-	-	-		-
Unid. Ptarmigan	-	0.2	0.7		-		-	-	-		-
American Golden Plover	4.1	1.6	1.5		-		0.6*	0.7*	-		-
Black-bellied Plover	1.5*	0.2	-		-		-	-	-		-
Ruddy Turnstone	8.2	0.2	0.5		-		-	-	-		-
Semipalmated Sandpiper	2.8	0.2	0.5		1.8		0.5*	0.6*	-		-
Baird's Sandpiper	-	0.1	0.5		-		-	-	-		-
White-rumped Sandpiper	0.3	-	-		-		-	-	-		-
Pectoral Sandpiper	1.8	0.7	0.3		-		-	-	-		-
Dunlin	1.0	0.1	0.3		-		-	-	-		-
Red Phalarope	-	0.1	0.3		0.2*		0.1	-	-		-
Northern Phalarope	-	-	0.1*		-		-	-	-		-

Table W (Continued).

Pomarine Jaeger	-	0.1	0.1*	-	-	0.1*	-	-
Parasitic Jaeger	1.0	0.1	0.1	-	-	-	-	-
Long-tailed Jaeger	-	0.1	0.1	-	0.1	0.1	0.1*	-
Glaucous Gull	0.3*	-	0.2	0.7*	0.2	2.7	0.3	0.2
Sabine's Gull	1.0	-	-	-	-	0.8*	-	-
Arctic Tern	1.0	-	0.2	0.2*	-	0.2*	0.1	-
Snowy Owl	-	0.1	0.1	-	-	-	-	-
Lapland Longspur	0.3*	1.1	1.8	-	0.1*	-	-	-
Snow Bunting	-	1.1	0.1	-	0.1*	-	-	-

*Denotes single sighting.

Table X. Indices of abundance of species encountered in the vicinity of Barter Island on 24 June.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat	2.9	3.3					3.1				
Min per habitat	100	100					73				
Species											
Pintail	0.3*	0.3*					-				
Oldsquaw	2.8	0.3*					-				
Eider sp.	0.3*	-					-				
King Eider	0.7*	-					-				
Willow Ptarmigan	-	0.3*					-				
American Golden Plover	1.7	0.6*					-				
Semipalmated Sandpiper	4.5	0.3*					0.3*				
Baird's Sandpiper	-	0.6					1.0				
Pectoral Sandpiper	6.6	0.3*					-				
Buff-breasted Sandpiper	-	0.9*					-				
Red Phalarope	5.5	0.3*					-				
Northern Phalarope	1.7	-					-				
Pomarine Jaeger	0.3	0.3*					-				
Parasitic Jaeger	-	0.3*					-				
Arctic Tern	0.7*	-					-				
Common Raven	-	2.4*					-				
Lapland Longspur	0.3*	2.1					0.3*				
Snow Bunting	-	0.3*					1.0				

*Denotes single sighting.

Table Y. Indices of abundance of species encountered in the vicinity of Bernard Spit on 24 June.

Habitat	WT	MT	MTWP	BT	RD	RM	Bea	S&B	Lag	Bay	Oce
Km per habitat							8.3	8.3	8.3		
Min per habitat							218	218	218		
Species											
Arctic Loon							0.1*	-	-		
Red-throated Loon							1.2*	-	-		
Pintail							-	1.5	-		
Oldsquaw							0.7	0.7	-		
Common Eider							3.8	0.5	0.4		
Spectacled Eider							-	0.2	-		
Surf Scoter							3.7*	-	-		
Baird's Sandpiper							-	0.8	-		
Red Phalarope							-	0.1*	-		
Redpoll							-	0.1*	-		
Snow Bunting							-	0.1*	-		

*Denotes single sighting

Table Z. Total birds per kilometer per habitat for census areas presented in Tables A-Y.

	WT	MT	MTWP	RD	RM	BT	MF	BEA	S&B	LAG	BAY	OCE	ALP TUNDRA
June													
Cape Lisburne	18.7	13.8	10.4	-	115.1	-	-	40.1	17.2	20.6	-	10.4	
Icy Cape	26.4	10.4	-	11.2	-	27.6	-	2.0	-	2.7	-	-	
Peard Bay	19.6	15.8	-	-	12.0	-	-	1.4	1.3	-	0.1	0.1	
Oliktok	54.6	11.5	-	-	-	-	-	0	-	-	-	11.0	
Kuparuk River	-	25.2	-	-	-	-	-	-	-	-	-	-	
Sagavanirktok River	-	16.0	-	-	34.0	-	0	-	0.6	26.6	1.0	3.1	
Bernard Spit	-	-	-	-	-	-	-	9.5	4.0	0.4	-	-	
Barter Is.	25.4	9.3	-	-	-	-	-	2.6	-	-	-	-	
Total	144.7	102.0	10.4	11.2	161.1	27.6	0	55.6	23.1	50.3	1.1	24.6	
Mean	28.9	14.6	-	-	53.7	-	-	9.3	5.8	12.6	0.6	6.2	
Range	(18.7- 54.6)	(9.3- 25.2)	- -	- -	(12- 115.1)	- -	- -	(0- 40.1)	(0.6- (17.2)	(0.4- 26.6)	(0.1- 1.0)	(0.1- 10.4)	
July													
Cape Beaufort	1.4	6.5	-	-	93.6	-	-	2.1	13.0	-	-	3.9	
South Kasegaluk Spit	-	-	-	-	-	-	-	-	11.3	3.0	-	2.8	
Icy Cape	22.8	11.8	-	14.9	-	18.2	-	25.5	-	0.2	-	-	
Wainwright	31.5	16.3	-	-	0	-	-	1.1	3.2	2.5	-	4.2	
Barrow	-	23.0	-	-	-	-	-	1.2	-	-	-	136.4	
Pitt Point	6.9	12.2	0.2	-	1.1	24.0	0.1	2.4	16.5	-	7.6	6.5	
Colville R.	85.1	25.9	-	-	-	-	-	-	-	-	-	-	
Oliktok	25.0	12.5	-	8.6	48.9	41.3	-	4.0	-	-	-	15.1	
Bullen-Brownlow	28.1	6.2	10.0	3.3	-	-	-	1.9	35.9	12.5	-	26.8	
Total	200.8	114.4	10.2	26.8	143.6	83.5	0.1	38.2	79.9	18.2	7.6	195.7	
Mean	28.7	14.3	5.1	8.9	35.9	27.8	-	5.5	16.0	4.6	-	28.0	
Range	(1.4- 85.1)	(6.2- 25.9)	(0.2- 10.0)	(3.3- 14.9)	(0- 93.6)	(18.2- 41.3)	- -	(1.1- 25.5)	(3.2- 35.9)	(0.2- 12.5)	- -	(2.8- 136.4)	

Table Z (Continued).

	WT	MT	MTWP	RD	RM	BT	MF	BEA	S&B	LAG	BAY	OCE	ALP TUNDRA
August													
Cape Lisburne	-	13.7	-	-	264	-	-	22.9	140.8	14.0	-	21.4	24.3
Wainwright	26.6	15.9	21.0	-	-	-	-	85.4	421.1	33.2	-	3.5	-
Peard Bay	17.8	12.2	-	-	47.2	-	-	8.2	72.4	-	21.2	45.1	-
Pitt Point	32.8	6.5	-	633.2	-	12.2	0	16.1	204.0	-	242.8	208.9	-
Total	77.2	48.3	21.0	633.2	311.2	12.2	0	132.6	838.3	47.2	264.0	278.9	24.3
Mean	25.7	12.1	-	-	155.6	-	-	33.2	209.6	23.6	132	69.7	-
Range	(17.8-	(6.5-	-	-	(264-	-	-	(8.2-	(72.4-	(14-	(21.2-	(3.5-	-
	32.8)	15.9)	-	-	47.2)	-	-	85.4)	421.4)	33.2)	242.8)	208.9)	-
September													
Icy Cape	4.6	0.6	0	-	-	5.1	-	7.2	-	39.1	-	-	-
Wainwright	2.5	0.4	-	-	20.0	-	-	12.1	-	0	-	21.2	-
Peard Bay	-	1.0	4.6	-	9.4	-	-	5.8	-	-	3.0	-	-
Oliktok	10.1	7.1	8.5	23.2	16.0	4.2	-	10.3	-	-	-	1.7	-
Total	17.2	9.1	13.1	23.2	45.4	9.3	-	35.4	-	39.1	3.0	22.9	-
Mean	5.7	2.3	4.4	-	15.1	4.7	-	8.9	-	19.6	-	11.5	-
Range	(2.5-	(0.6-	(0-	-	(9.4-	(4.2-	-	(5.8-	-	(0-	-	(1.7-	
	10.1)	7.1)	8.5)	-	16.0)	5.1)	-	10.3)	-	39.1)	-	21.2)	-

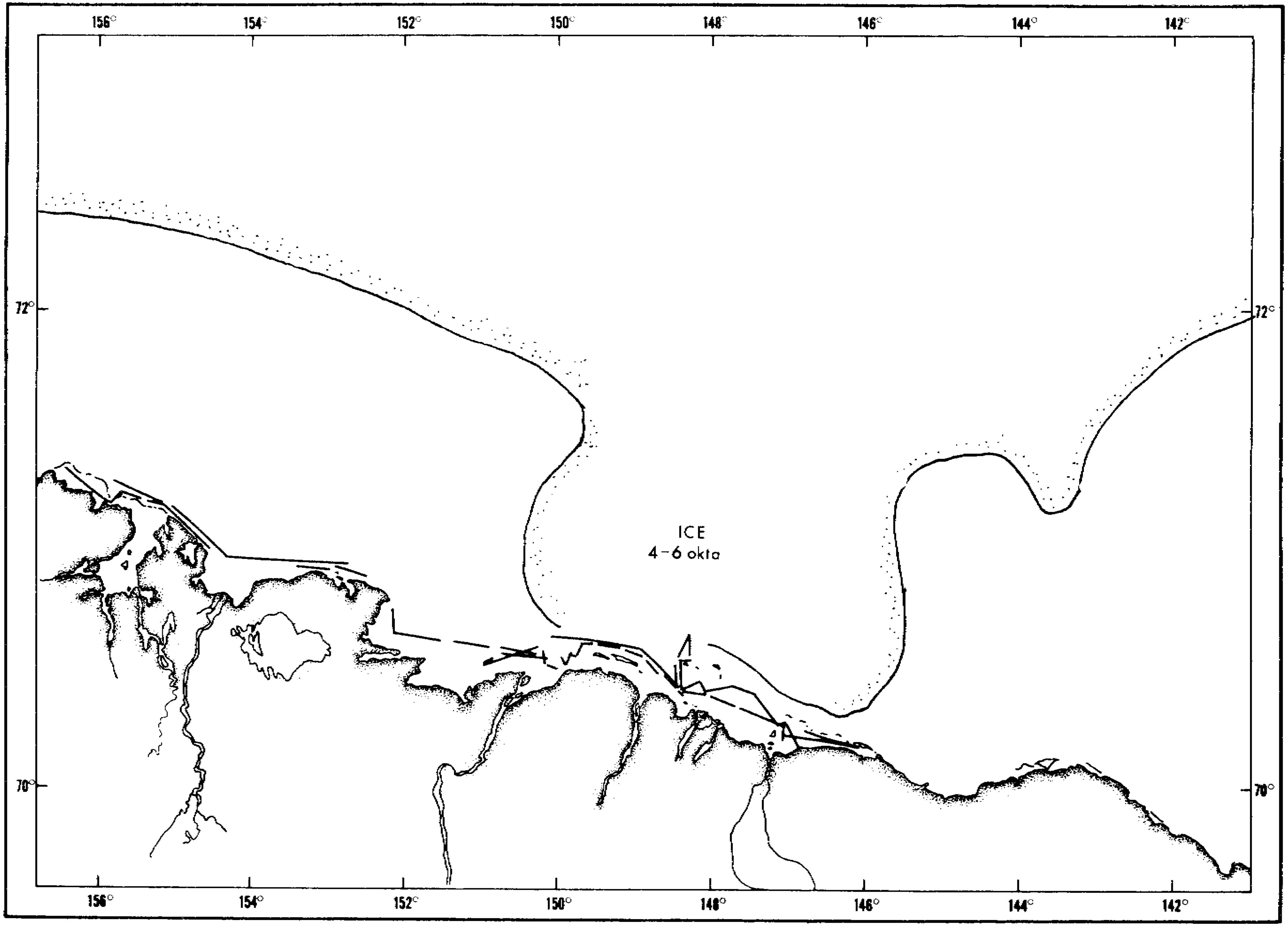


Figure 1. Cruise track during periods of observation in Beaufort Sea from 5 to 29 August 1978. (3AL878)

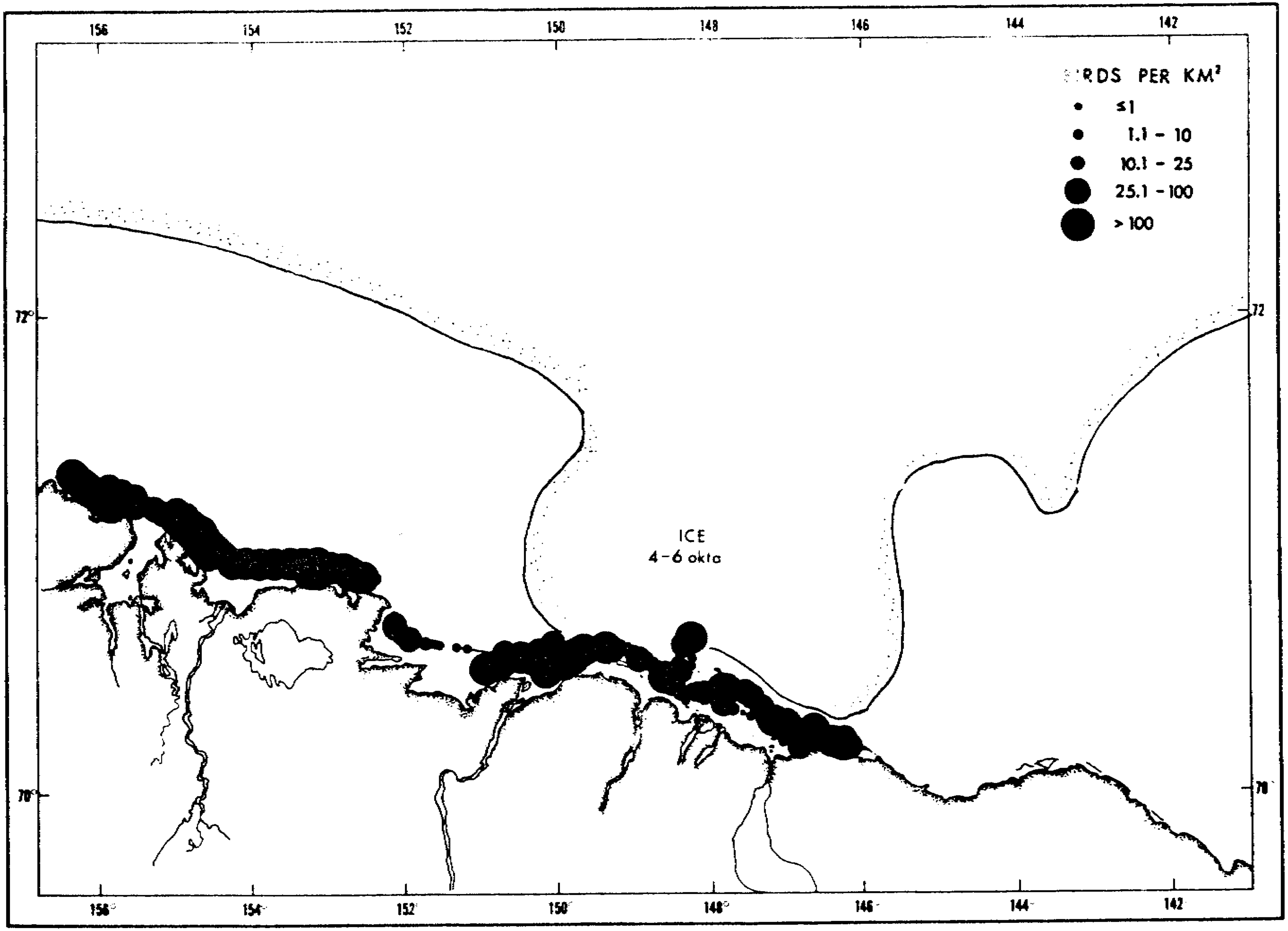


Figure 2. Distribution and abundance of seabirds in Beaufort Sea from 5 to 29 August 1978. (3AL878)

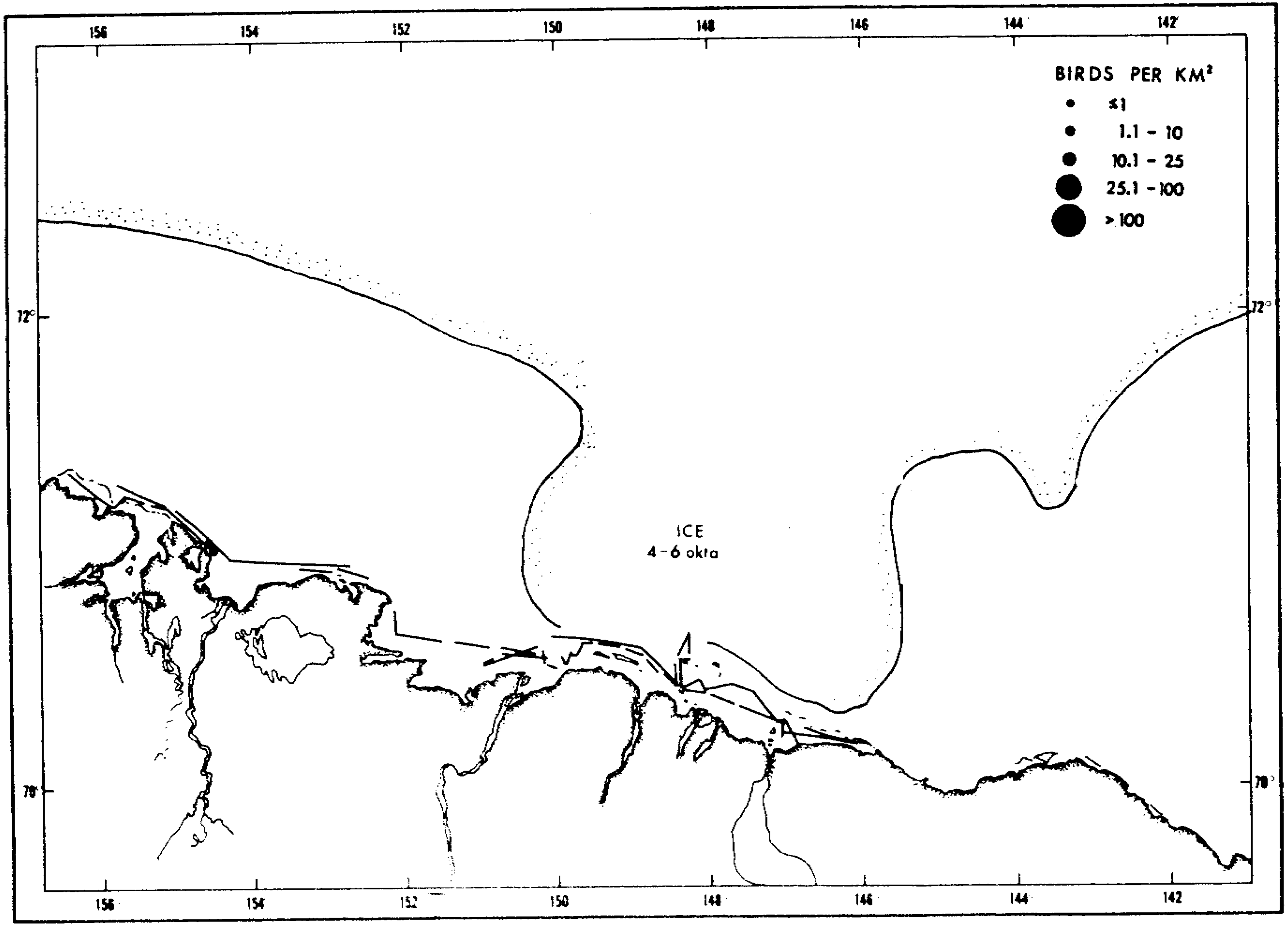


Figure 3. Distribution and abundance of Yellow-billed Loons in Beaufort Sea from 5 to 29 August 1978. (3AL878)

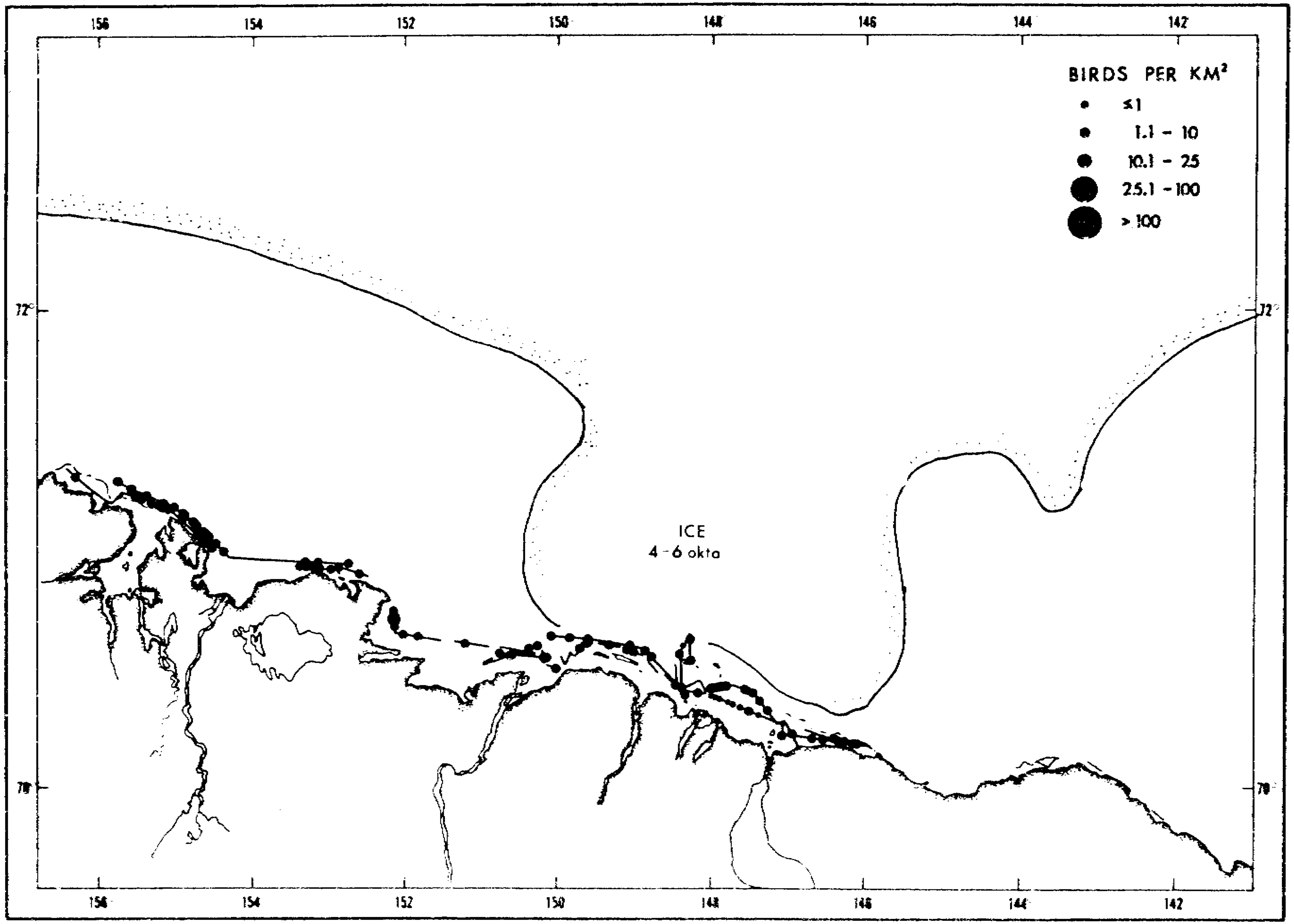


Figure 4. Distribution and abundance of Arctic Loons in Beaufort Sea from 5 to 29 August 1978. (3AL878)

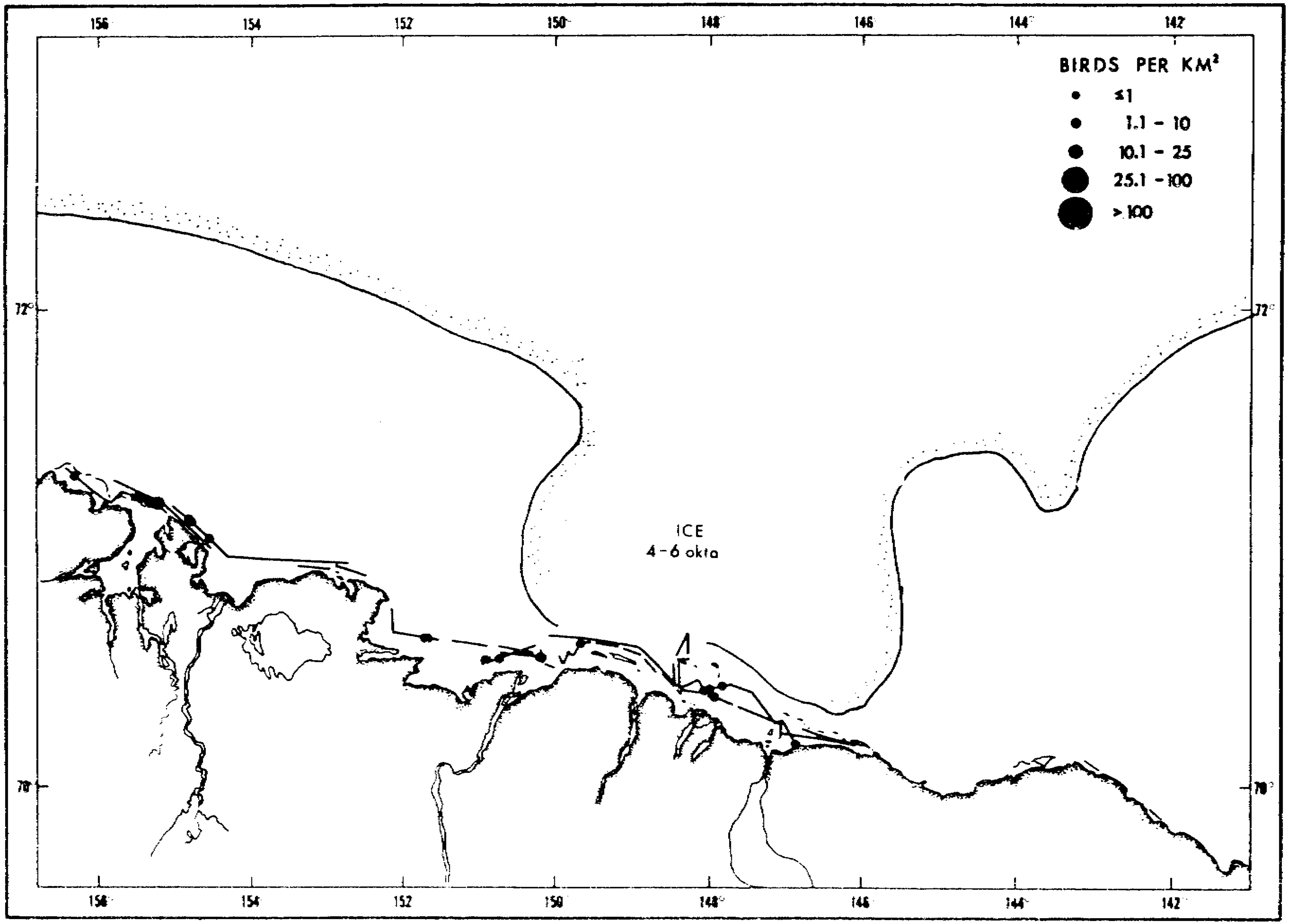


Figure 5. Distribution and abundance of Red-throated Loons in Beaufort Sea from 5 to 29 August 1978. (3AL878)

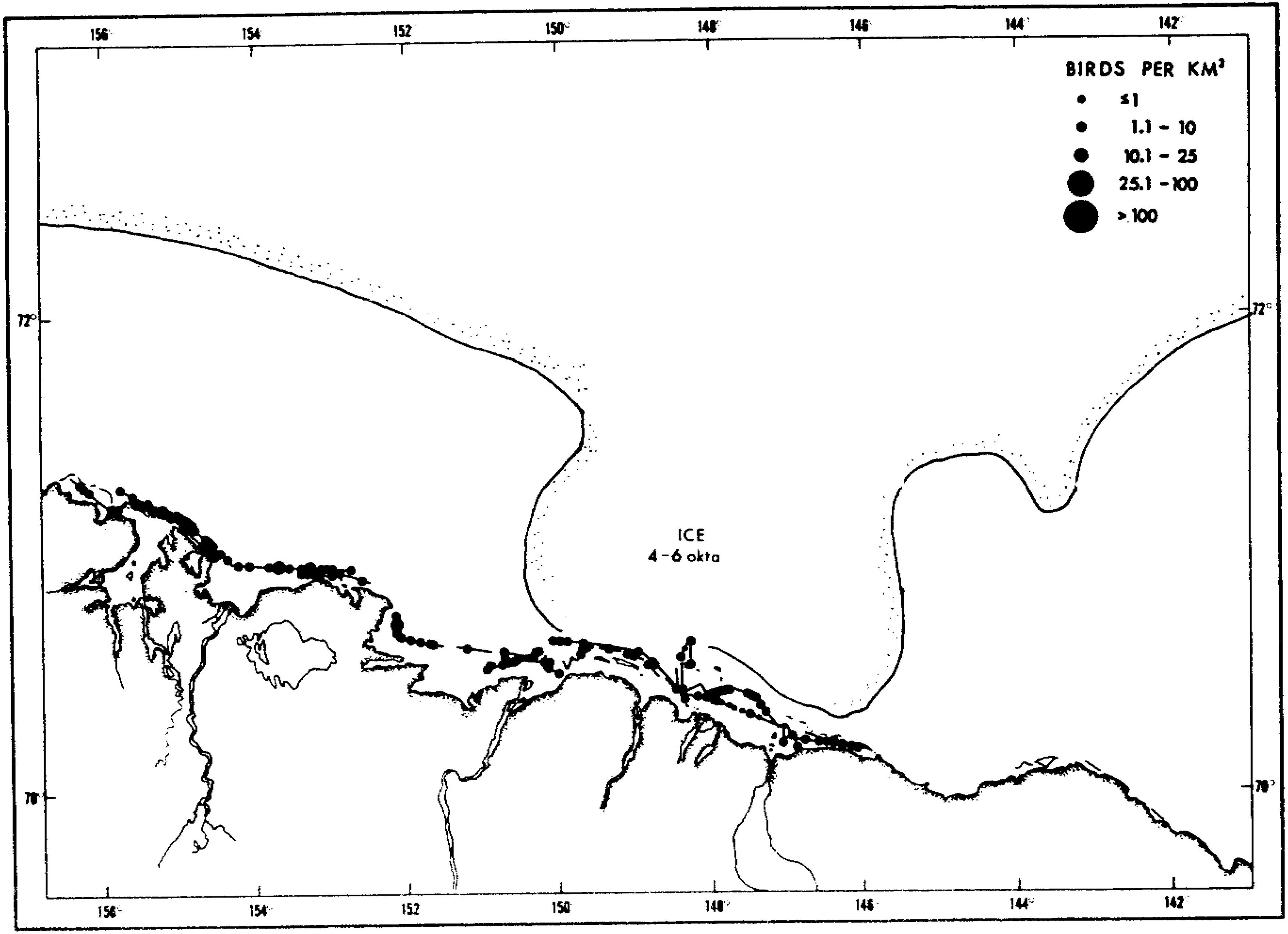


Figure 6. Distribution and abundance of all loons in Beaufort Sea from 5 to 29 August 1978 (3AL878)

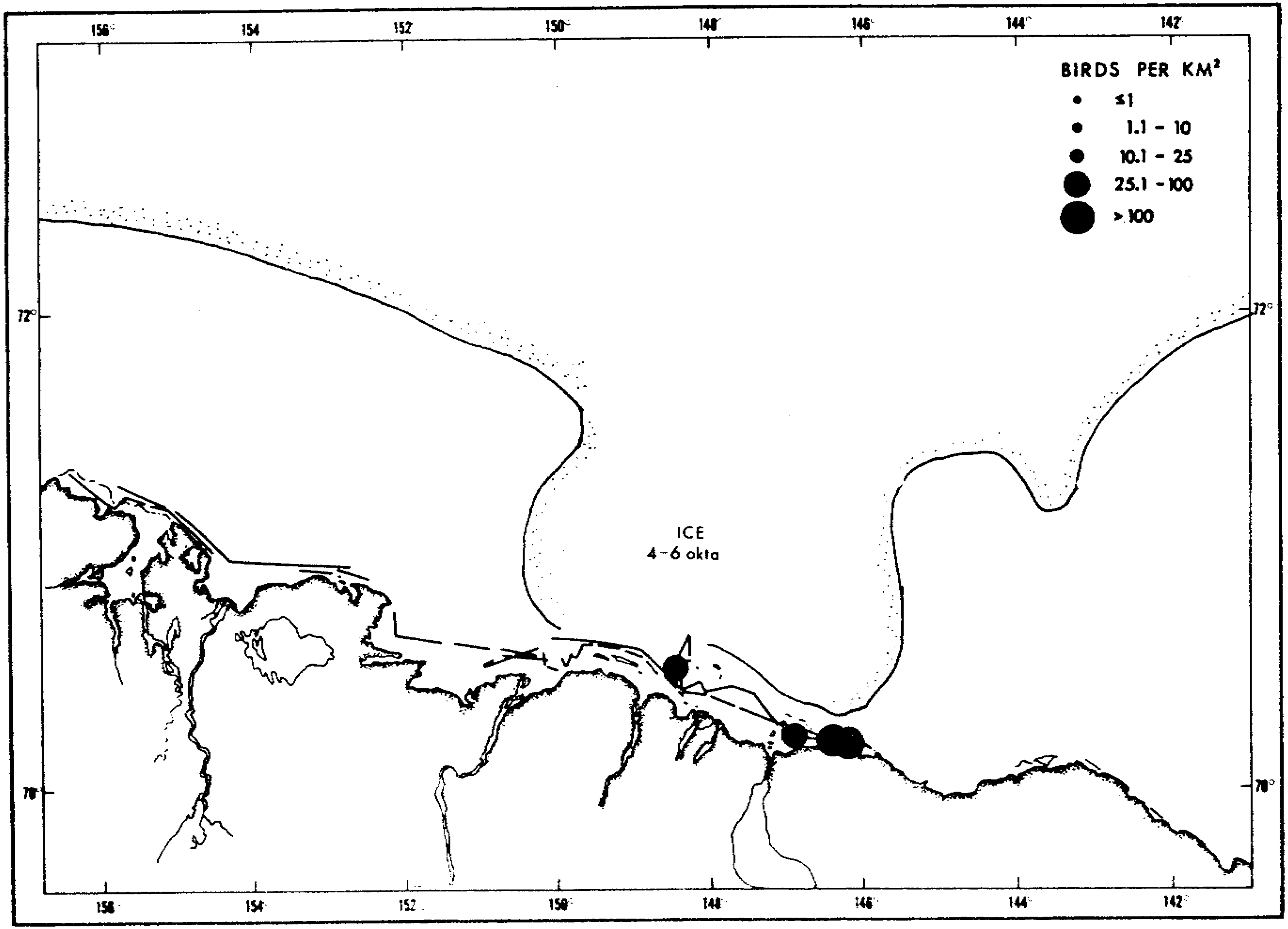


Figure 7. Distribution and abundance of Black Brant in Beaufort Sea from 5 to 29 August 1978. (3AL878)

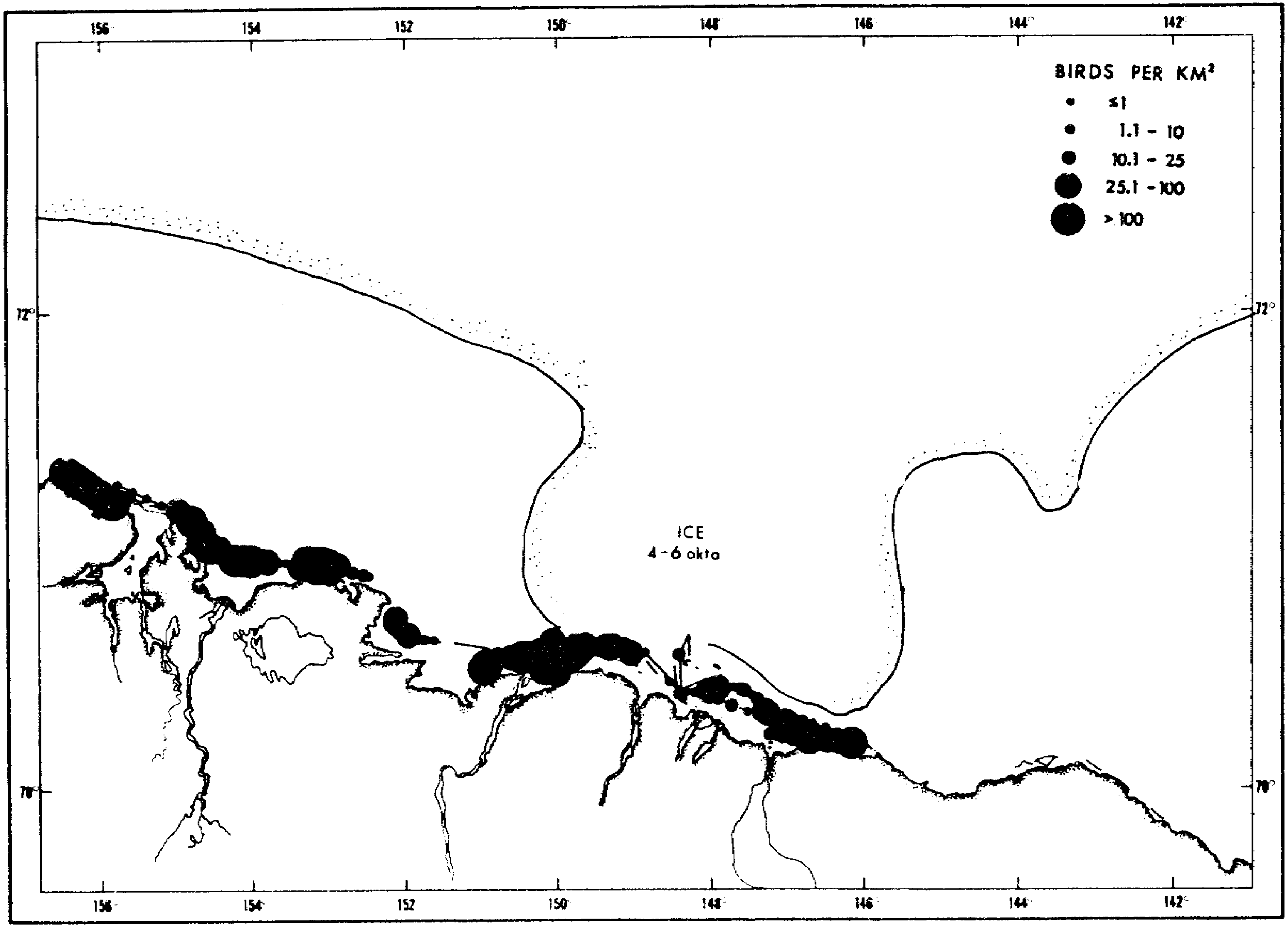


Figure 8. Distribution and abundance of Oldsquaws in Beaufort Sea from 5 to 29 August 1978. (3AL878)

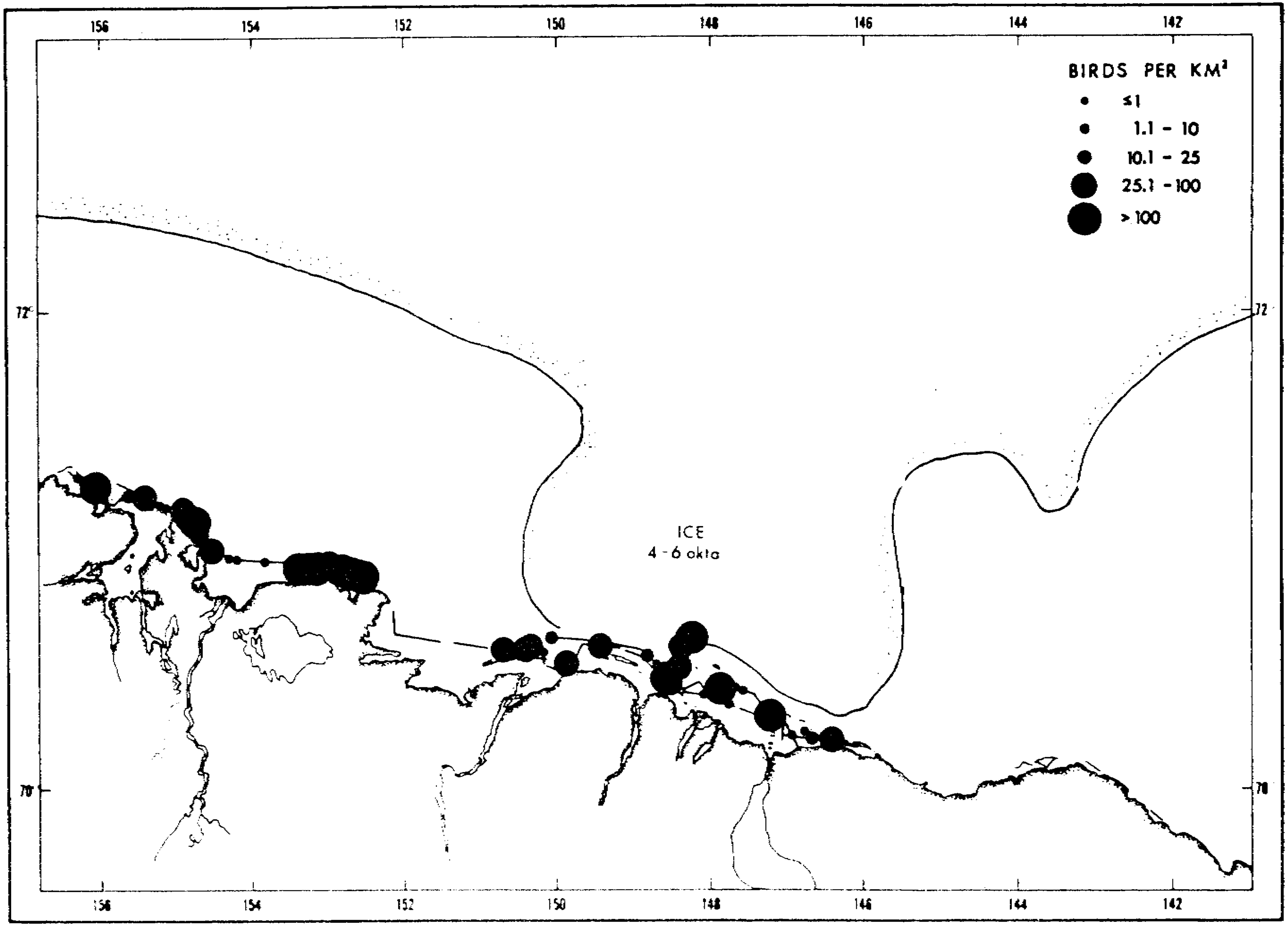


Figure 9. Distribution and abundance of eiders in Beaufort Sea from 5 to 29 August 1978. (3AL878)

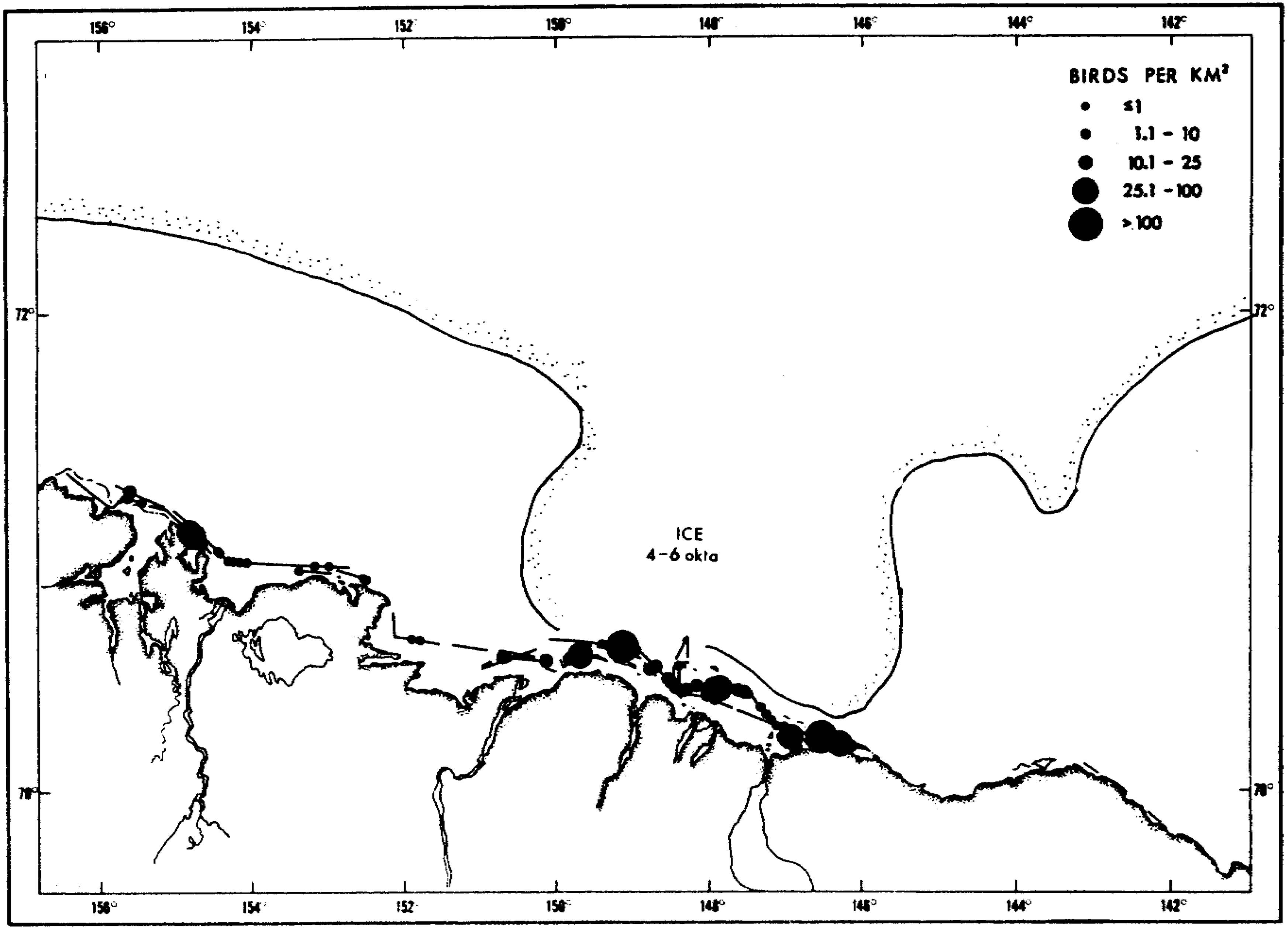


Figure 10. Distribution and abundance of phalaropes in Beaufort Sea from 5 to 29 August 1978. (3AL878)

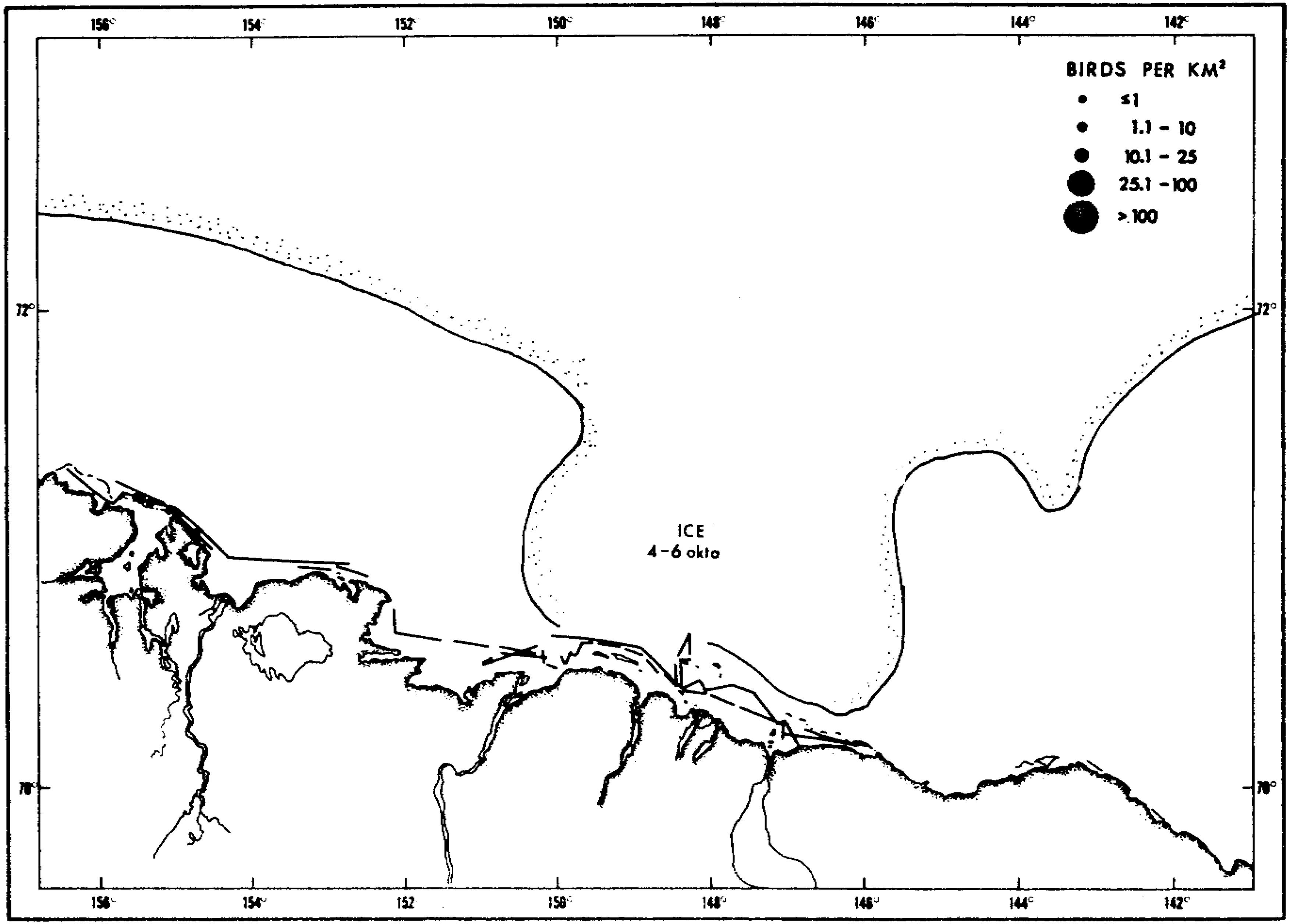


Figure 11. Distribution and abundance of Pomarine Jaegers in Beaufort Sea from 5 to 29 August 1978. (3AL878)

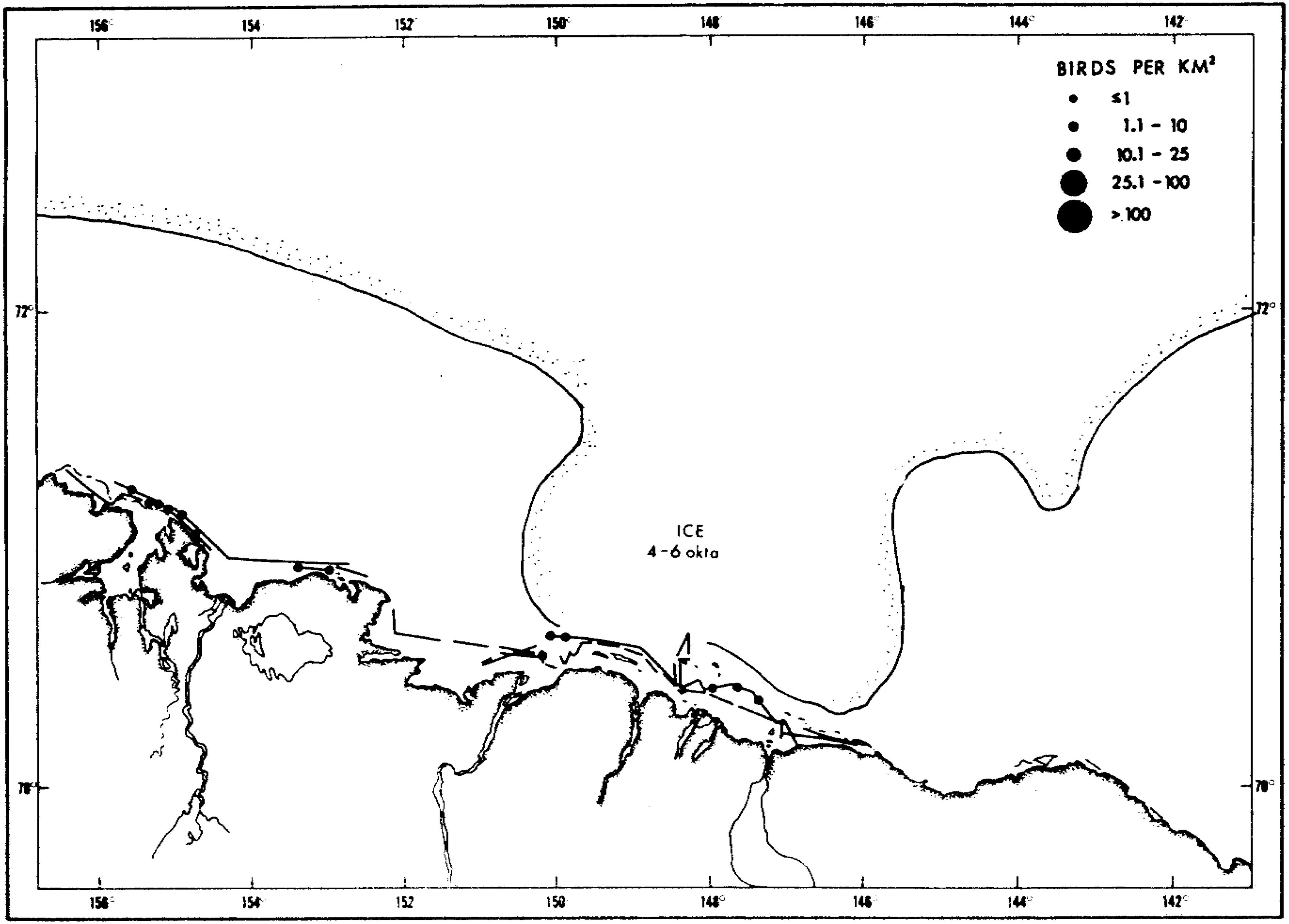


Figure 12. Distribution and abundance of Parasitic Jaegers in Beaufort Sea from 5 to 29 August 1978. (3AL878)

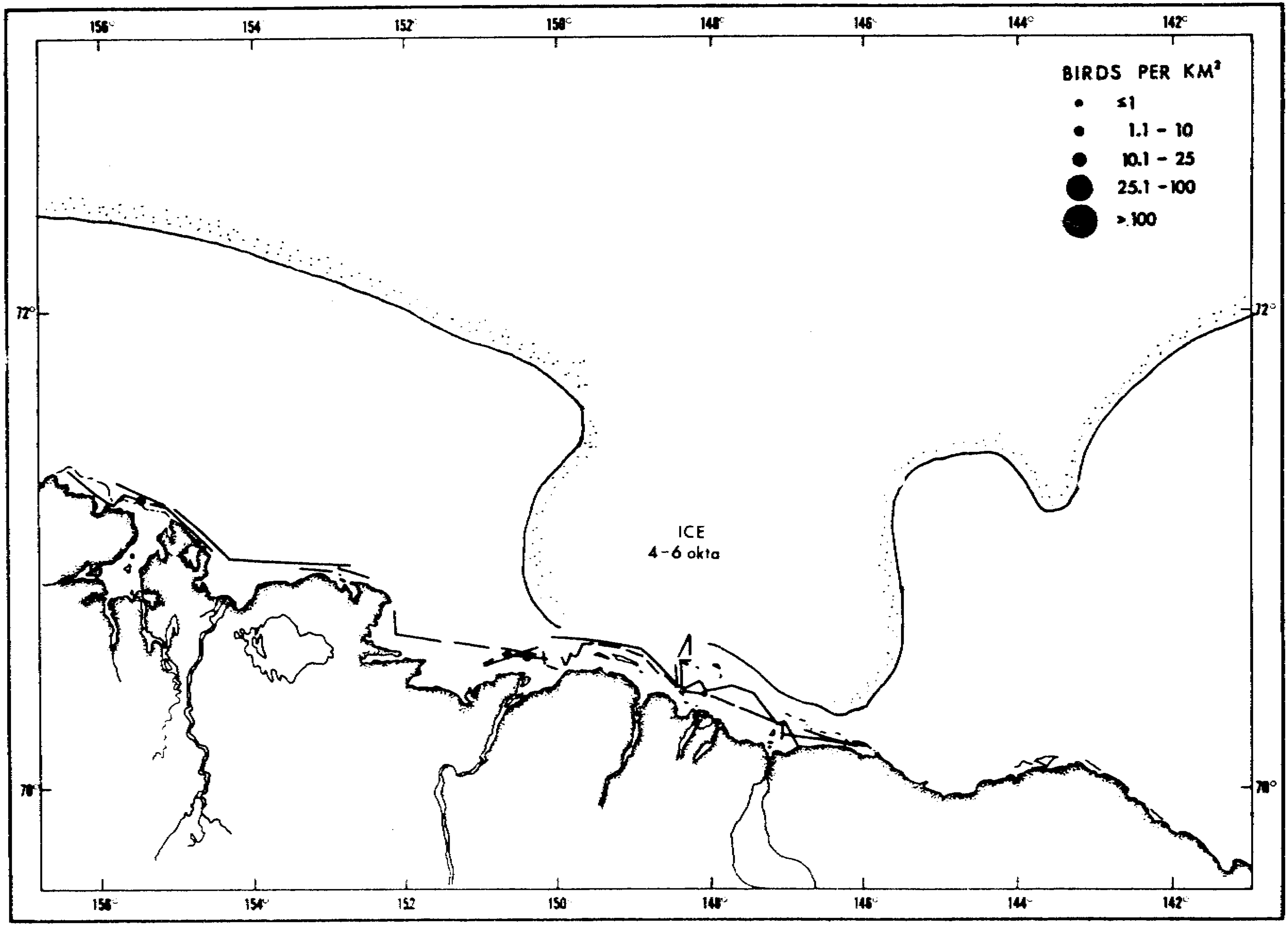


Figure 13. Distribution and abundance of Long-tailed Jaegers in Beaufort Sea from 5 to 29 August 1978. (3AL878)

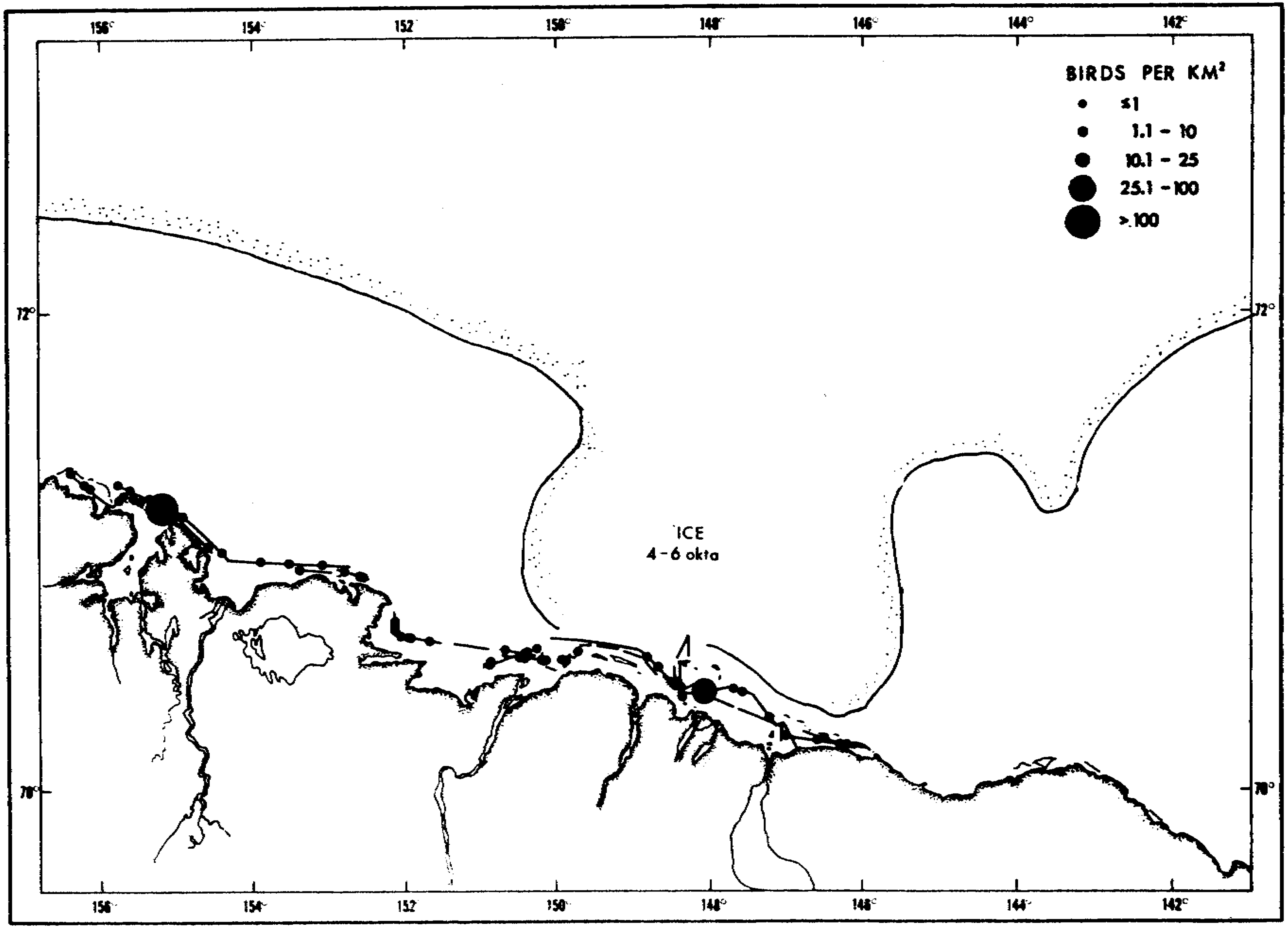


Figure 14. Distribution and abundance of Glaucous Gulls in Beaufort Sea from 5 to 29 August 1978. (3AL878)

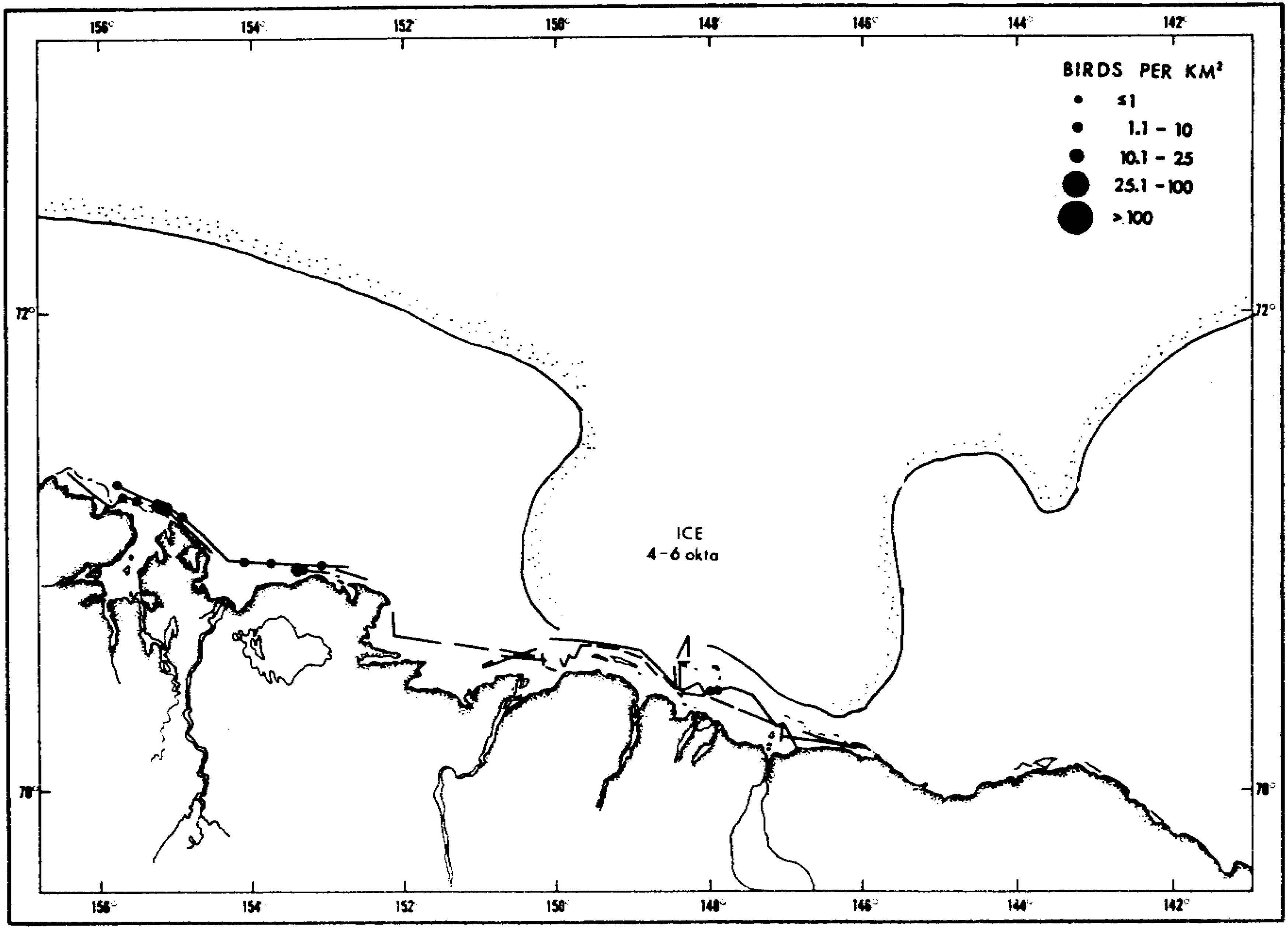


Figure 15. Distribution and abundance of Black-legged Kittiwakes in Beaufort Sea from 5 to 29 August 1978. (3AL878)

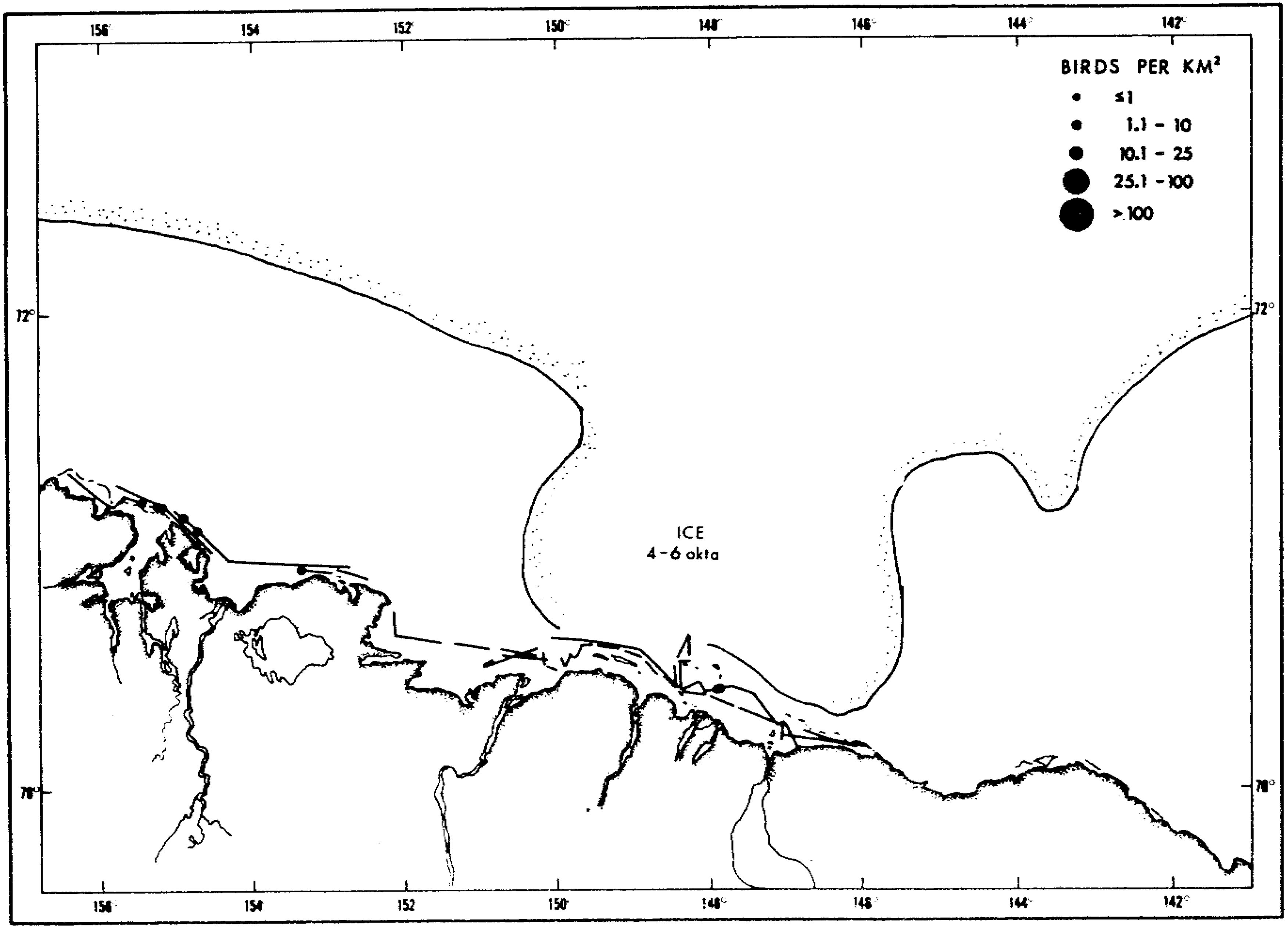


Figure 16. Distribution and abundance of Sabine's Gulls in Beaufort Sea from 5 to 29 August 1978. (3AL878)

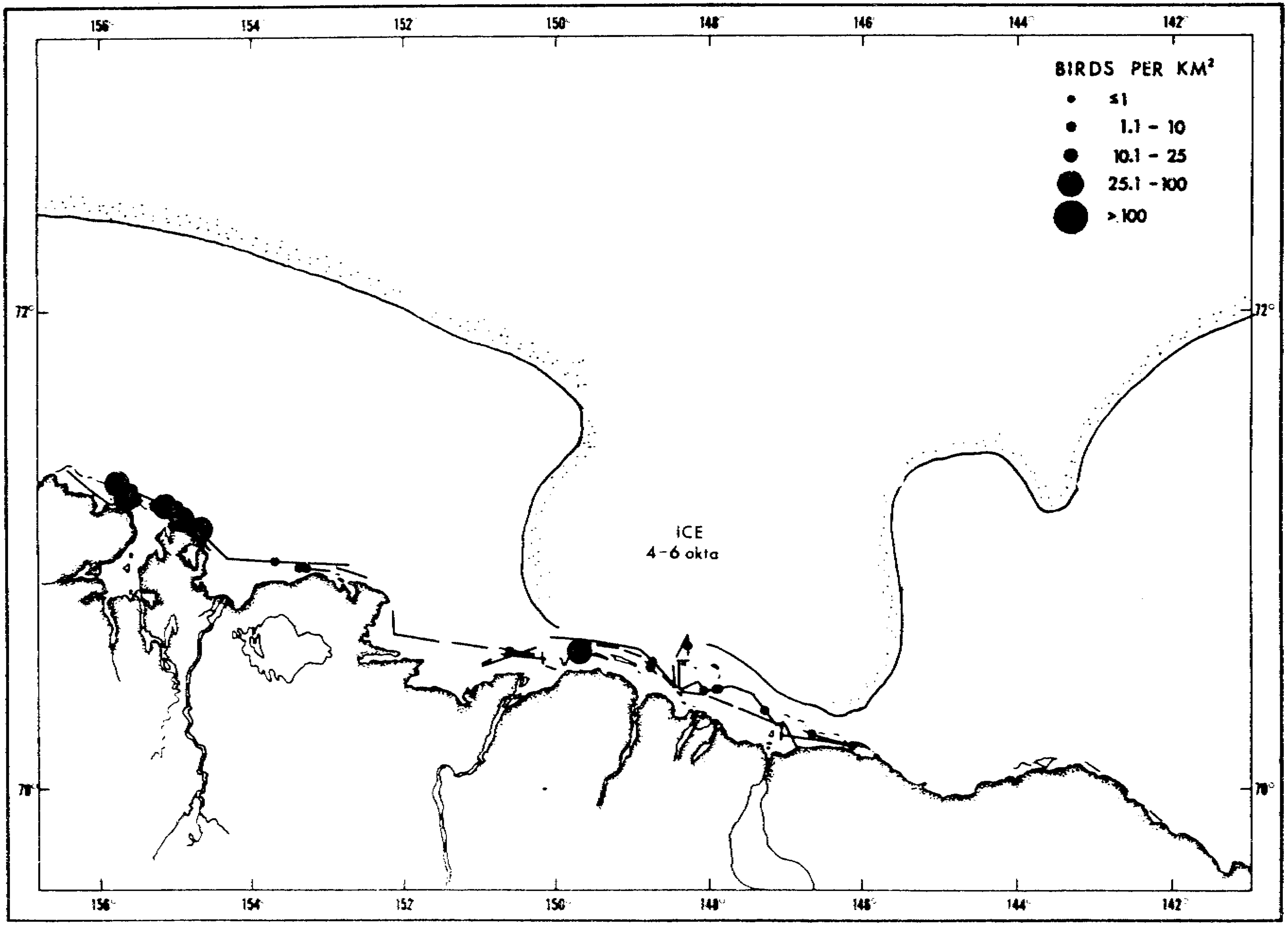


Figure 17. Distribution and abundance of Arctic Terns in Beaufort Sea from 5 to 29 August 1978. (3AL878)

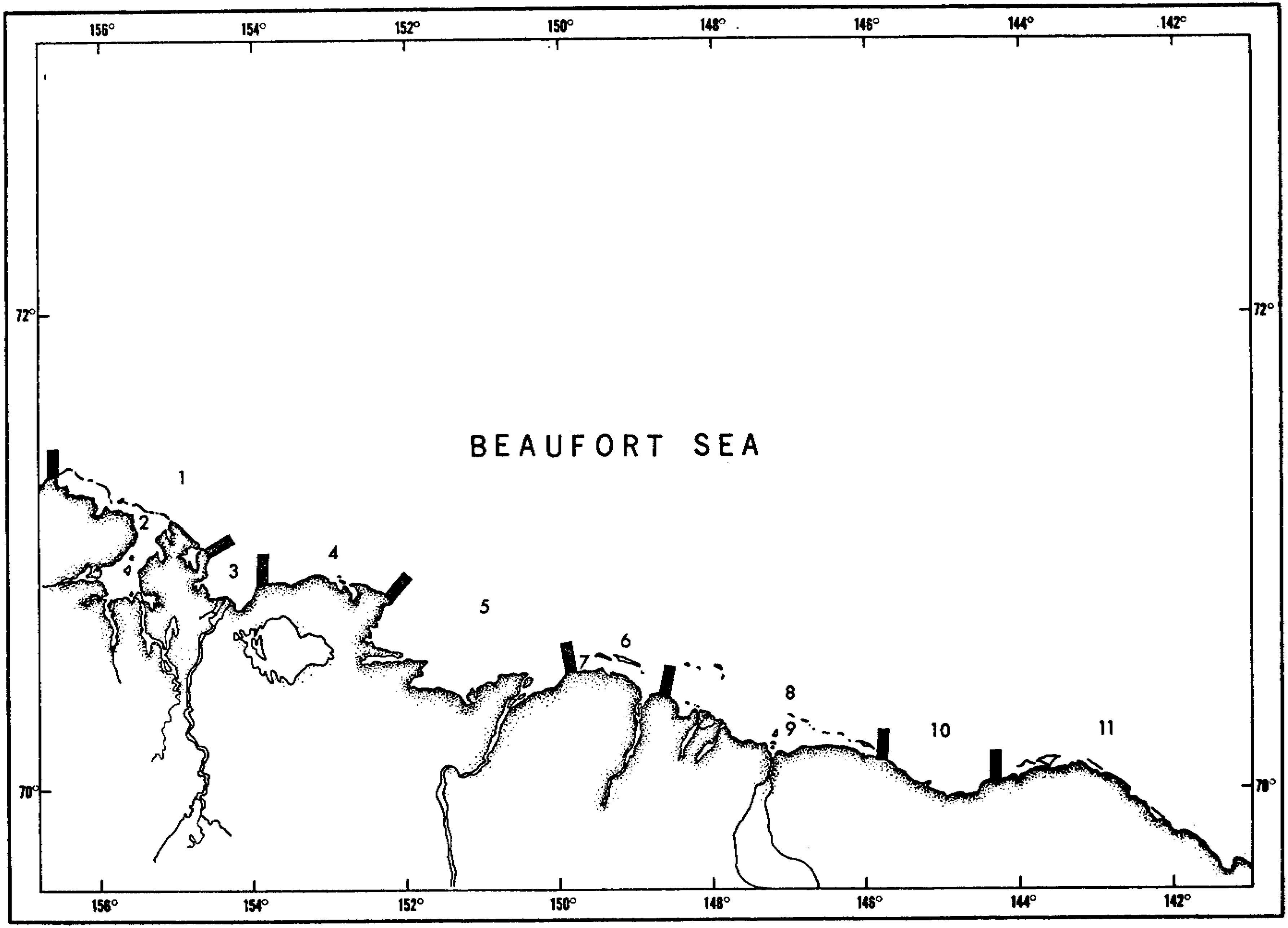


Figure 18. Beaufort Sea showing coastal divisions refered to in tables 3 through 6.

Figure 18 (Continued). Descriptions of coastal sections shown in accompanying map.

Coastal Section

1 - Plover Islands: Nearshore waters seaward of Plover Islands from Pt. Barrow to Tangent Point and from Tangent Point to Cape Simpson.

2 - Elson Lagoon: Lagoonal waters inside Plover Islands.

3 - Smith Bay: Nearshore waters from Cape Simpson to Drew Point.

4 - Pitt Point: Nearshore waters from Drew Point to Cape Halkett.

5 - Harrison Bay: Nearshore waters from Cape Halkett to Oliktok Pt.

6 - Jones Islands: Nearshore waters seaward of the Jones Islands from Spy Island to west dock, Prudhoe Bay.

7 - Simpson Lagoon: Lagoonal waters from Oliktok Point to Beechy Point.

8 - Prudhoe-Flaxman (outside islands): Nearshore waters seaward of barrier islands from Prudhoe Bay to Brownlow Point.

9 - Prudhoe-Flaxman (inside islands): Nearshore waters south of barrier islands from Prudhoe Bay to Brownlow Point.

10 - Camden Bay: Nearshore waters from Brownlow Point to Anderson Point.

11 - Barter Island: Nearshore waters seaward of barrier islands from Anderson Point to Demarcation Point.

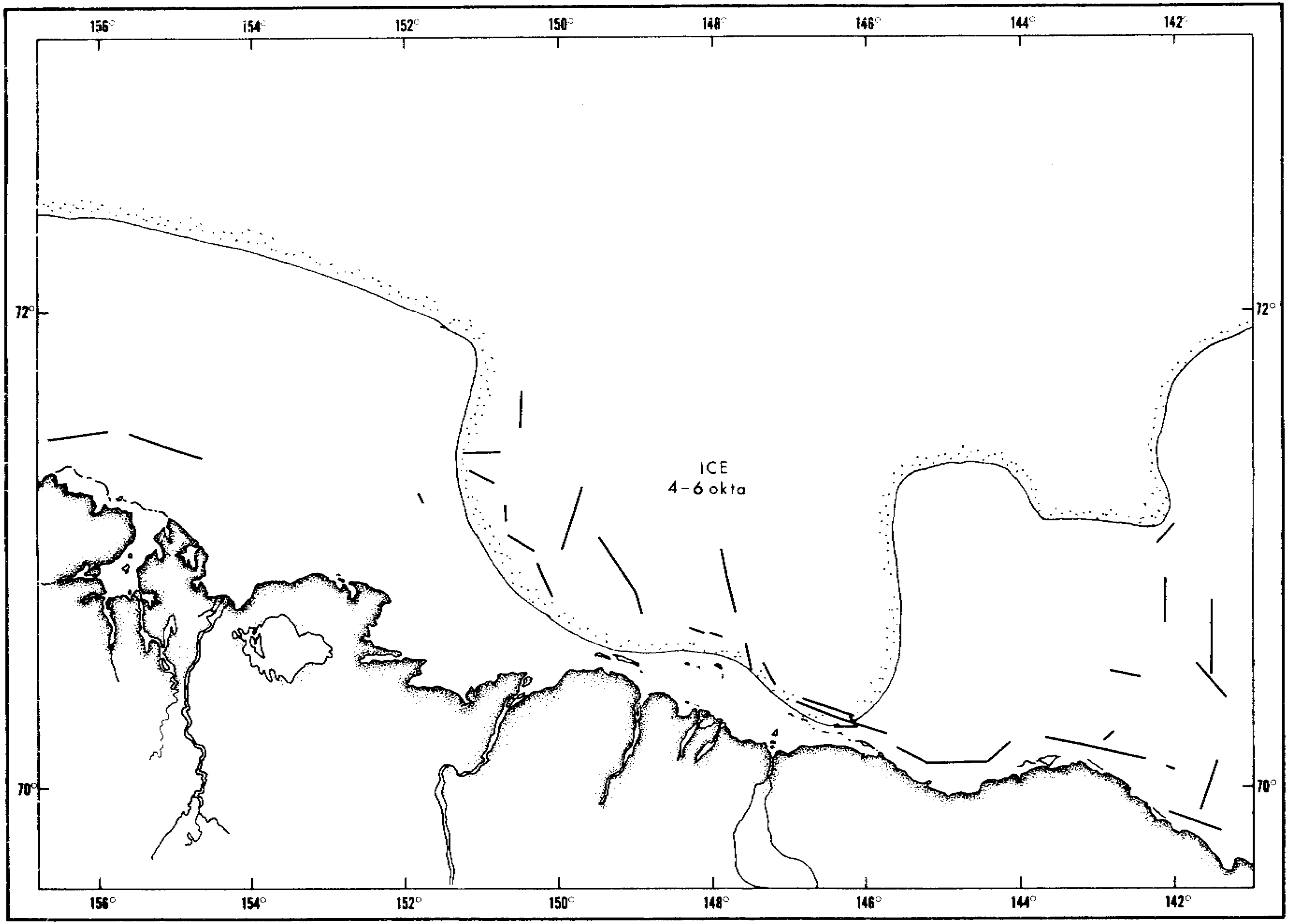


Figure 19. Cruise track during periods of observation in Beaufort Sea from 26 August to 15 September. (3NW878)

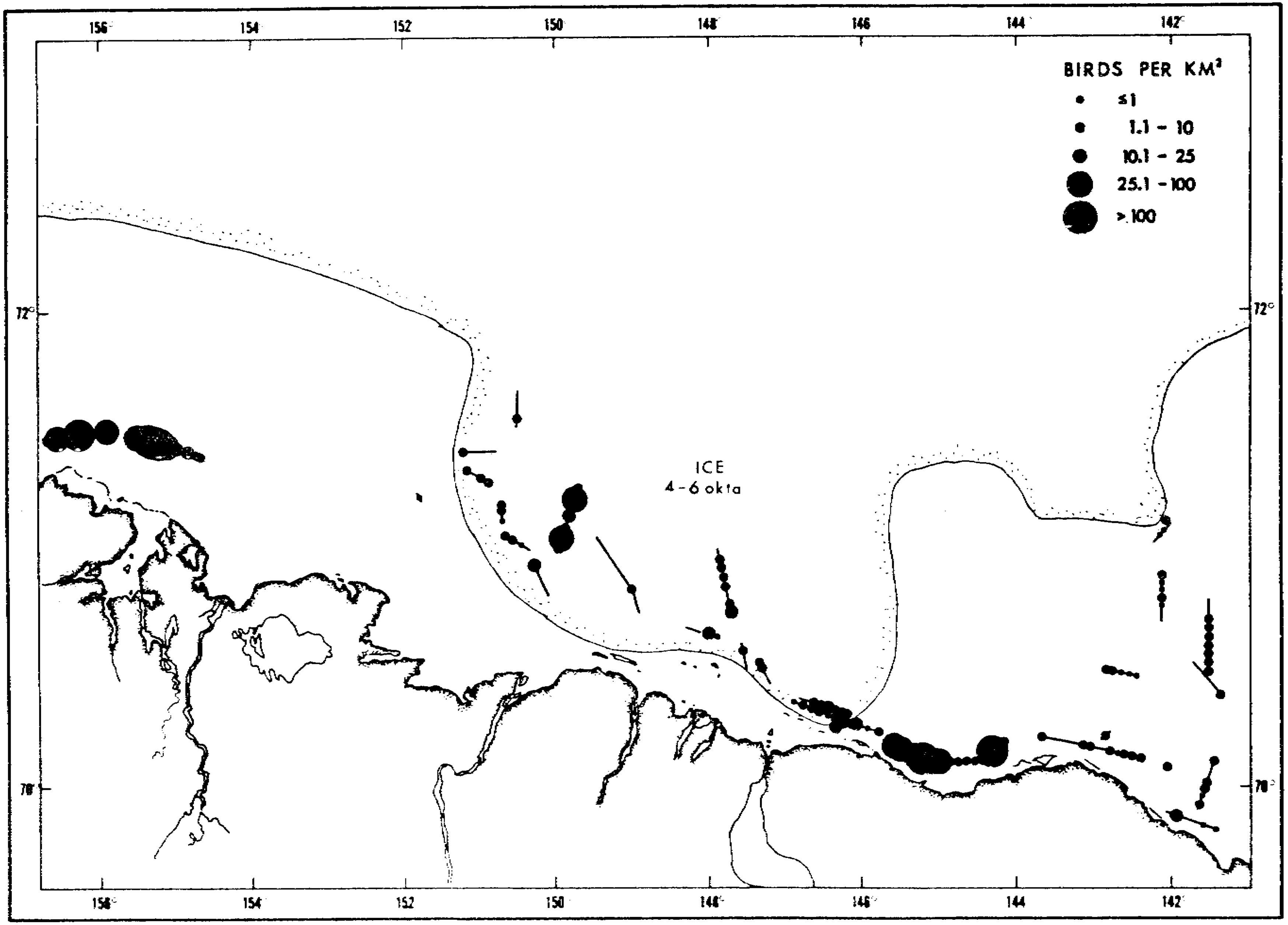


Figure 20. Distribution and abundance of seabirds in Beaufort Sea from 26 August to 15 September 1978. (3NW878)

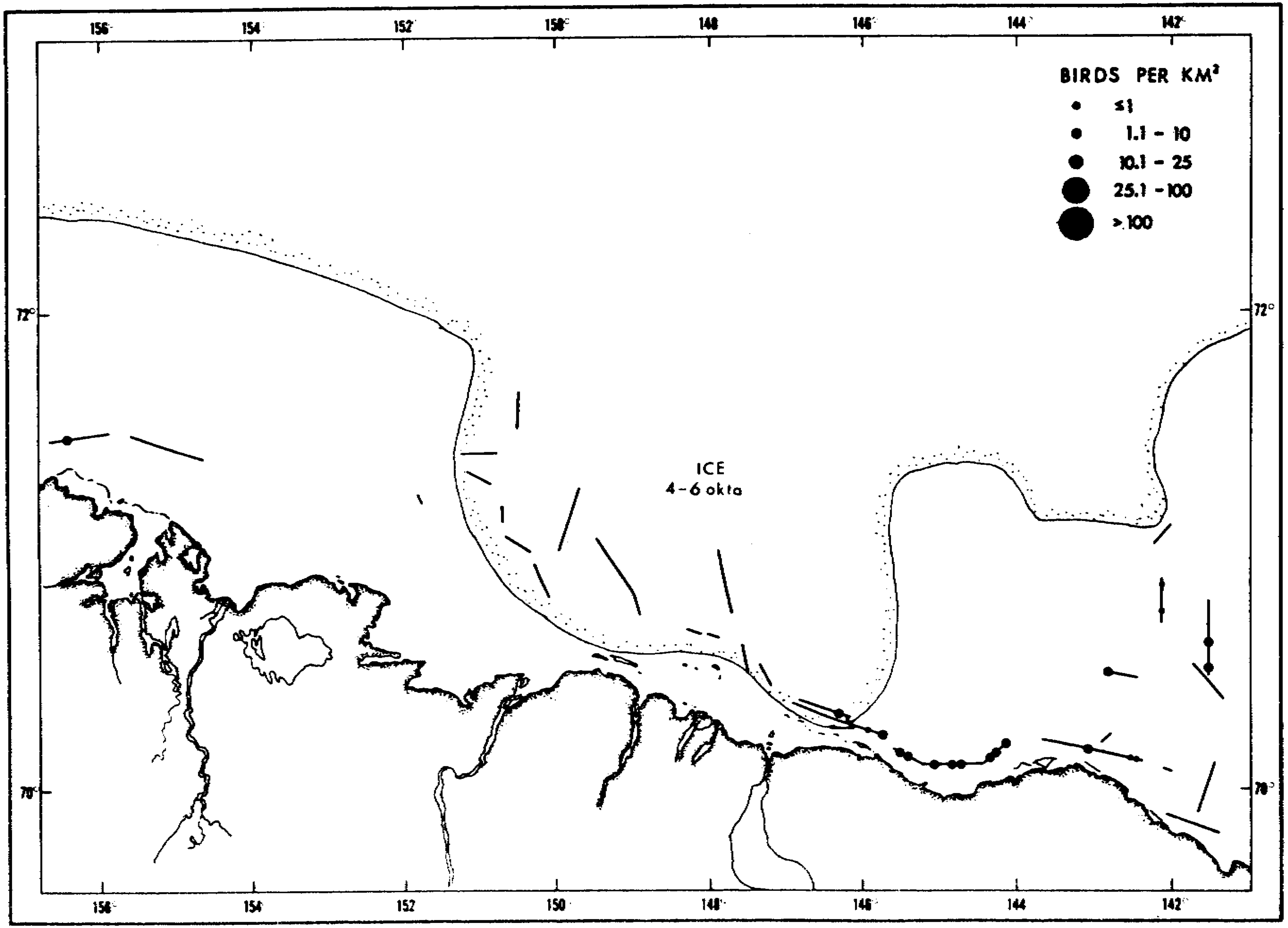


Figure 21. Distribution and abundance of Arctic Loons in Beaufort Sea from 26 August to 15 September 1978. (3NW878)

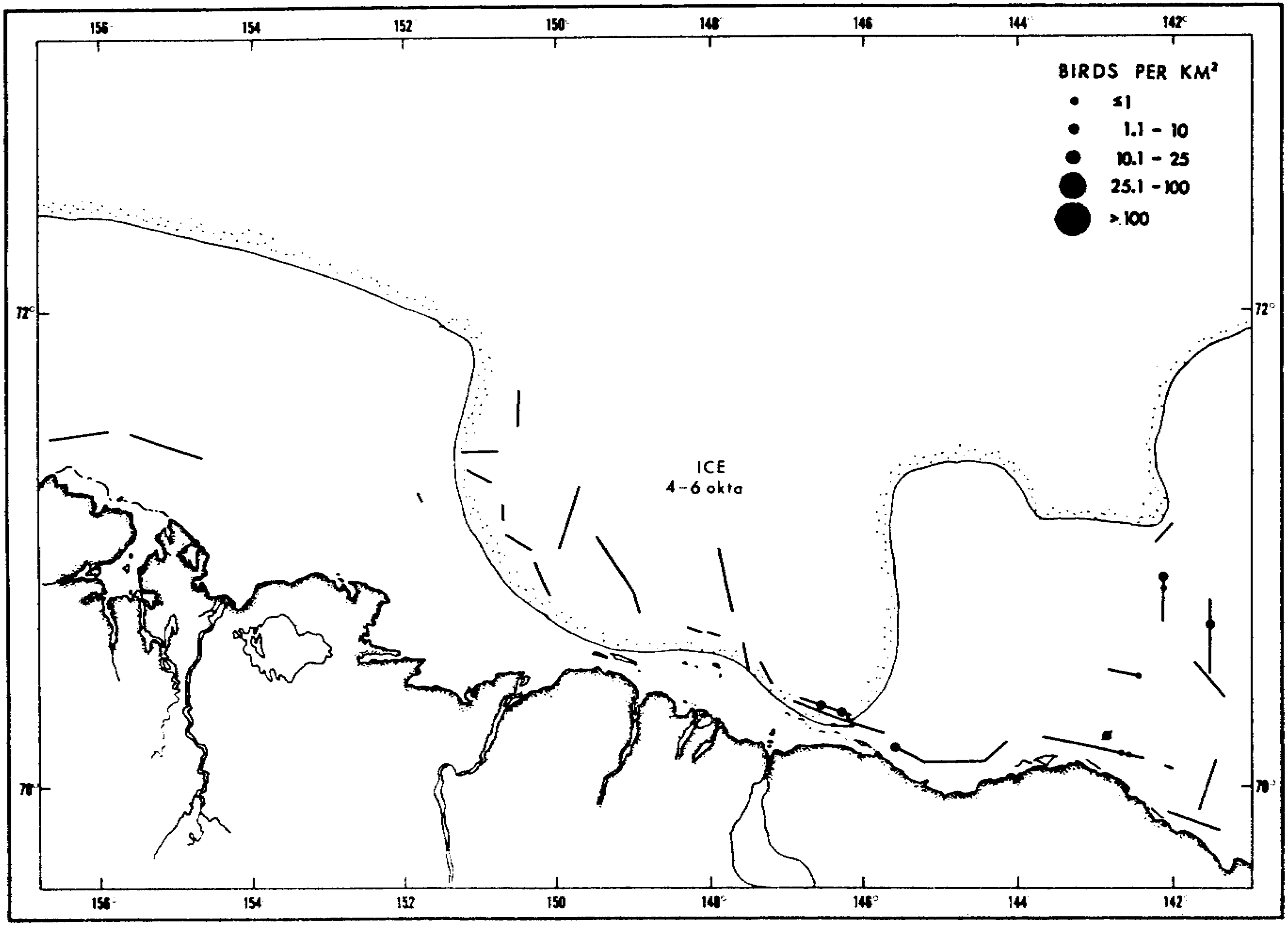


Figure 22. Distribution and abundance of Red-throated Loons in Beaufort Sea from 26 August to 15 September 1978. (3NW878)

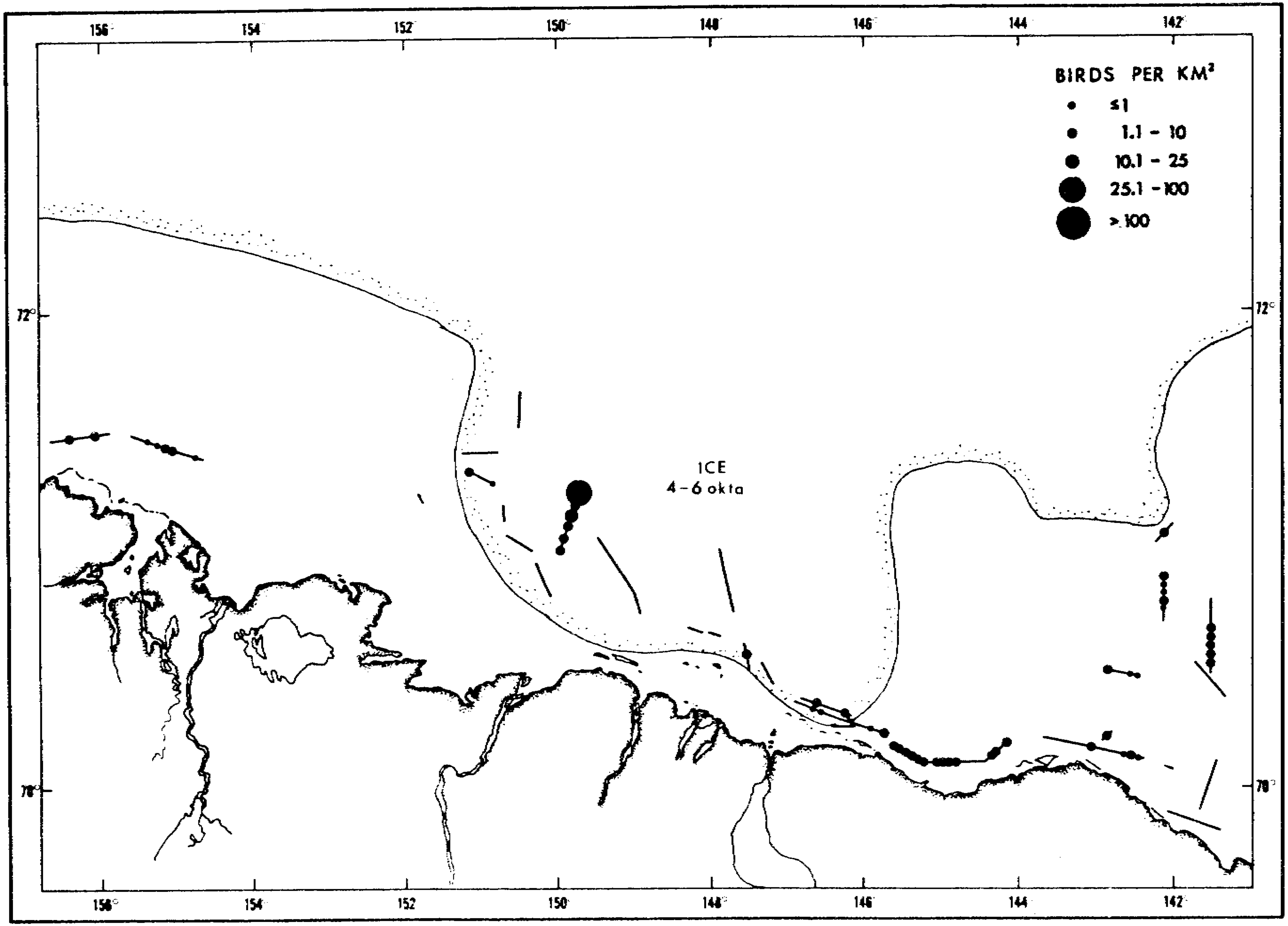


Figure 24. Distribution and abundance of all loons in Beaufort Sea from 26 August to 15 September 1978. (3NW878)

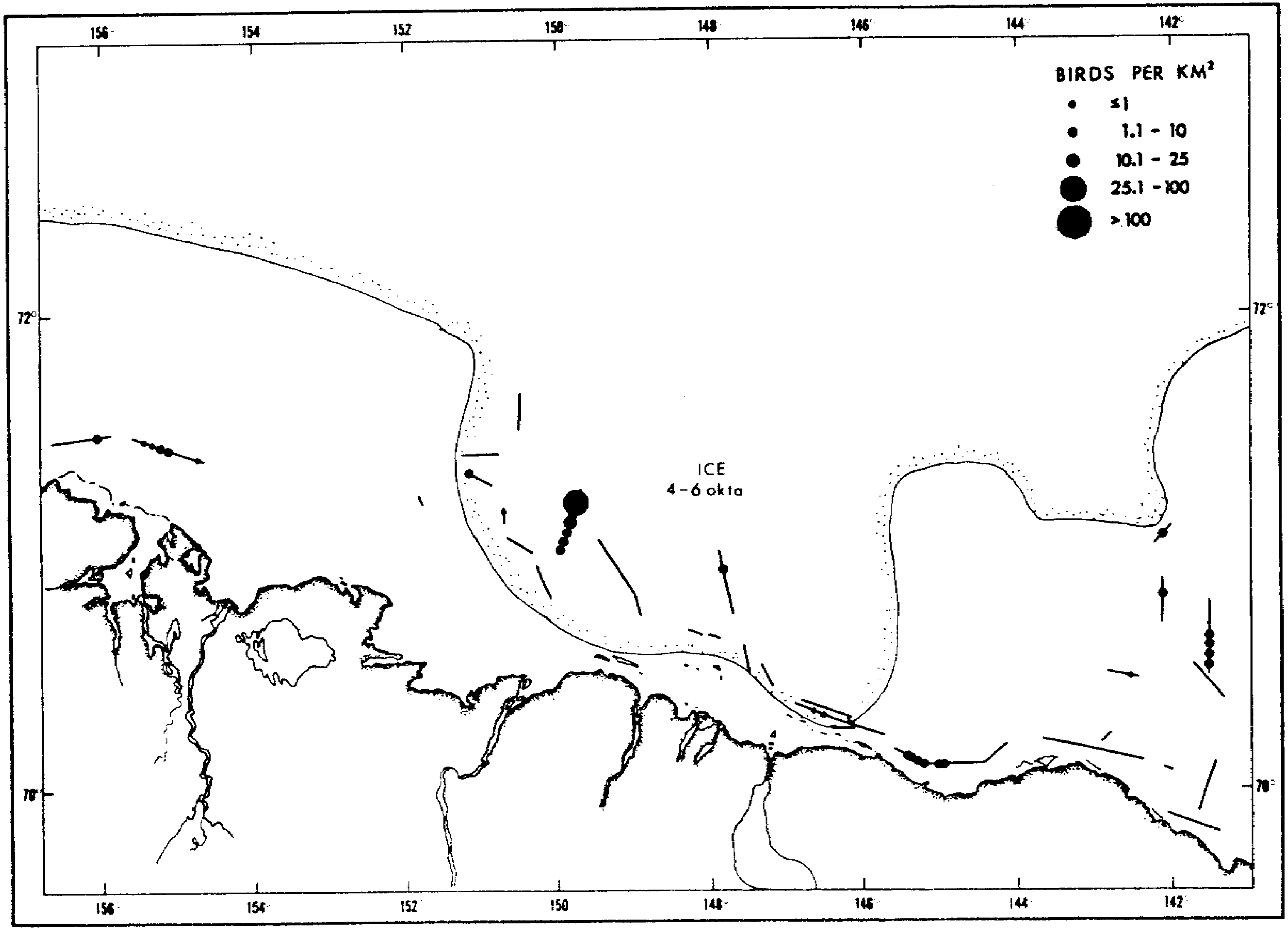


Figure 23. Distribution and abundance of unidentified loons in Beaufort Sea from 26 August to 15 September 1978. (3NW878)

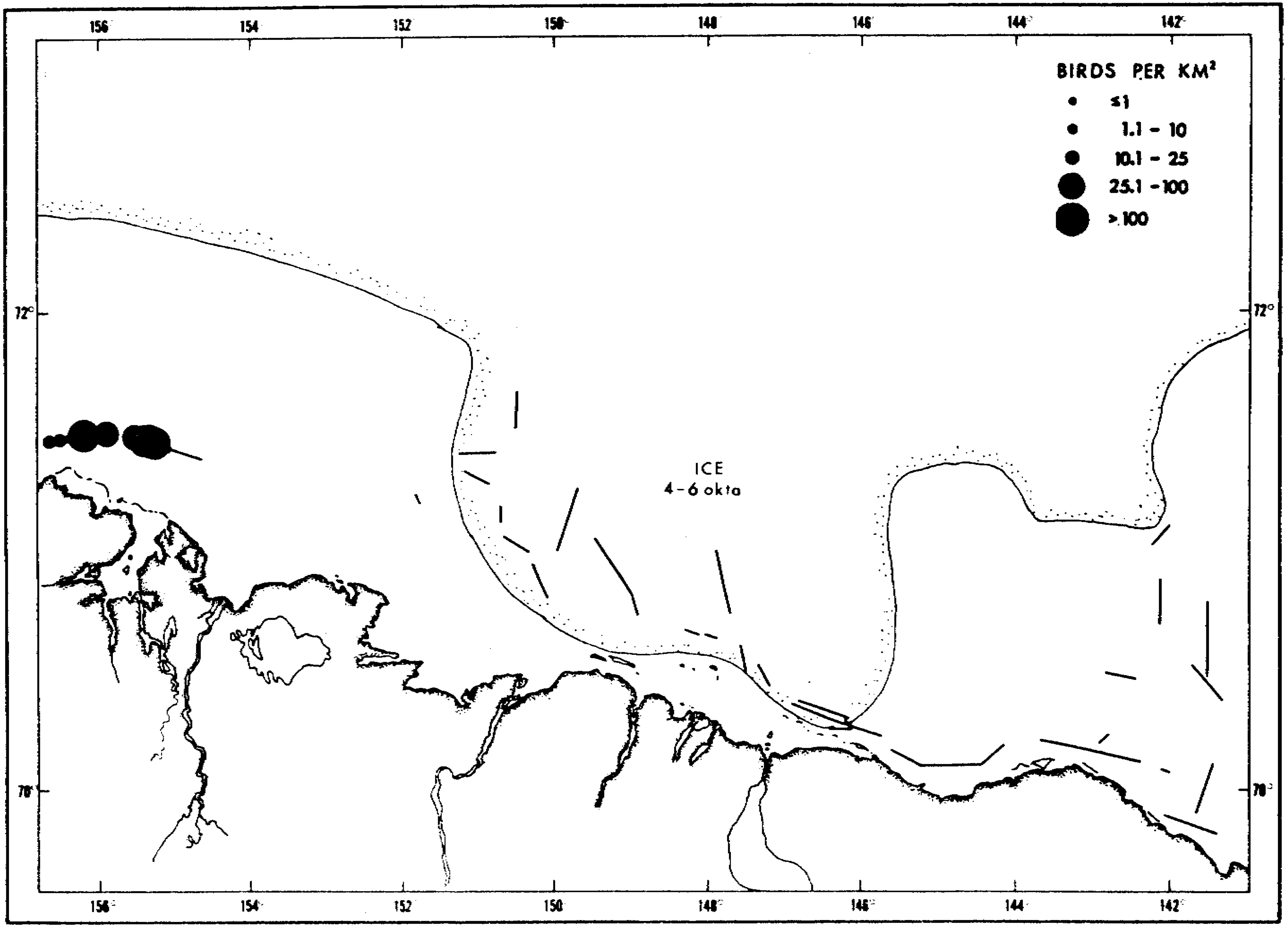


Figure 25. Distribution and abundance of Short-tailed Shearwaters in Beaufort Sea from 26 August to 15 September 1978 (3NW878)

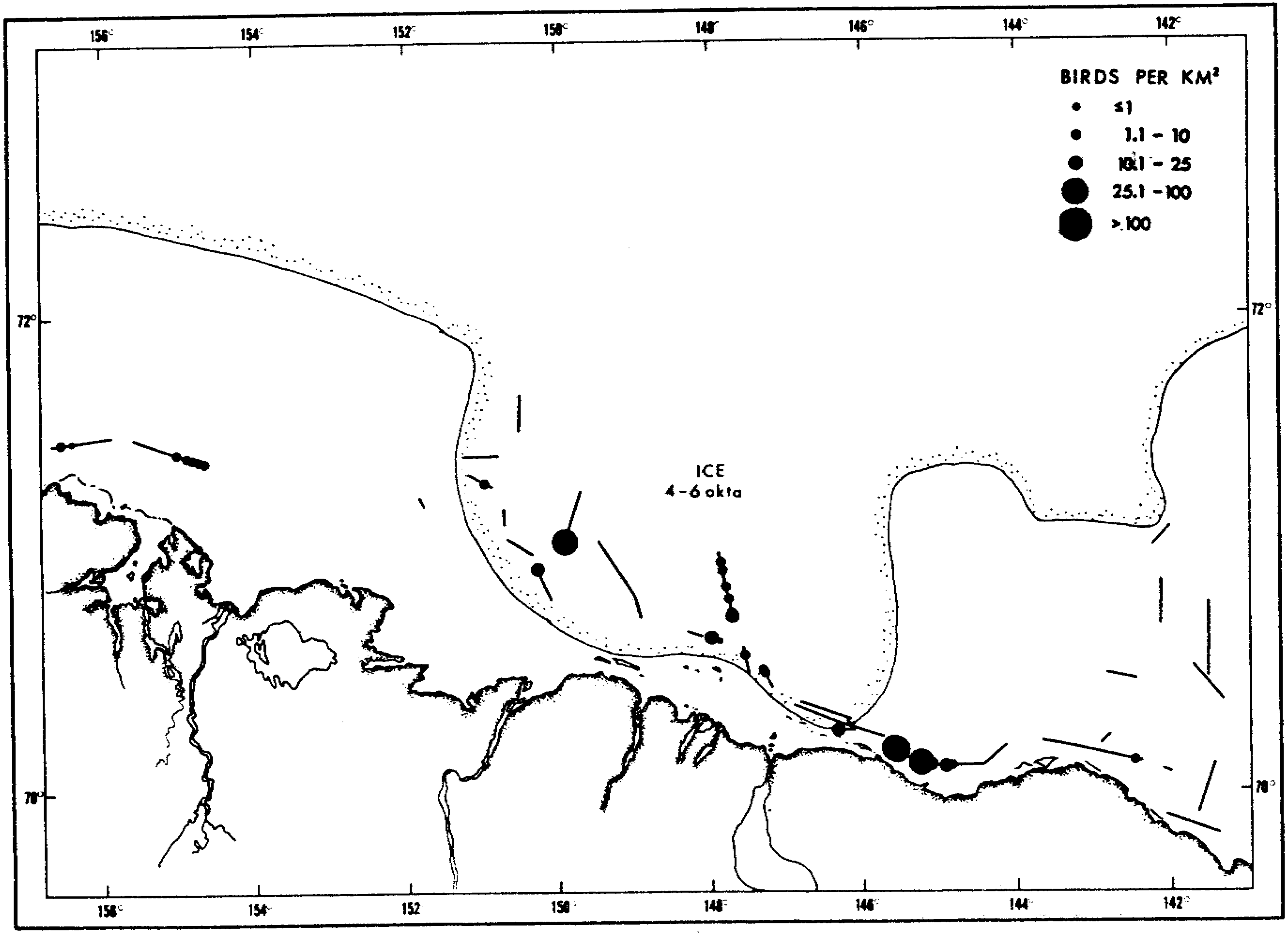


Figure 26. Distribution and abundance of Oldsquaws in Beaufort Sea from 26 August to 15 September 1978. (3NW878)

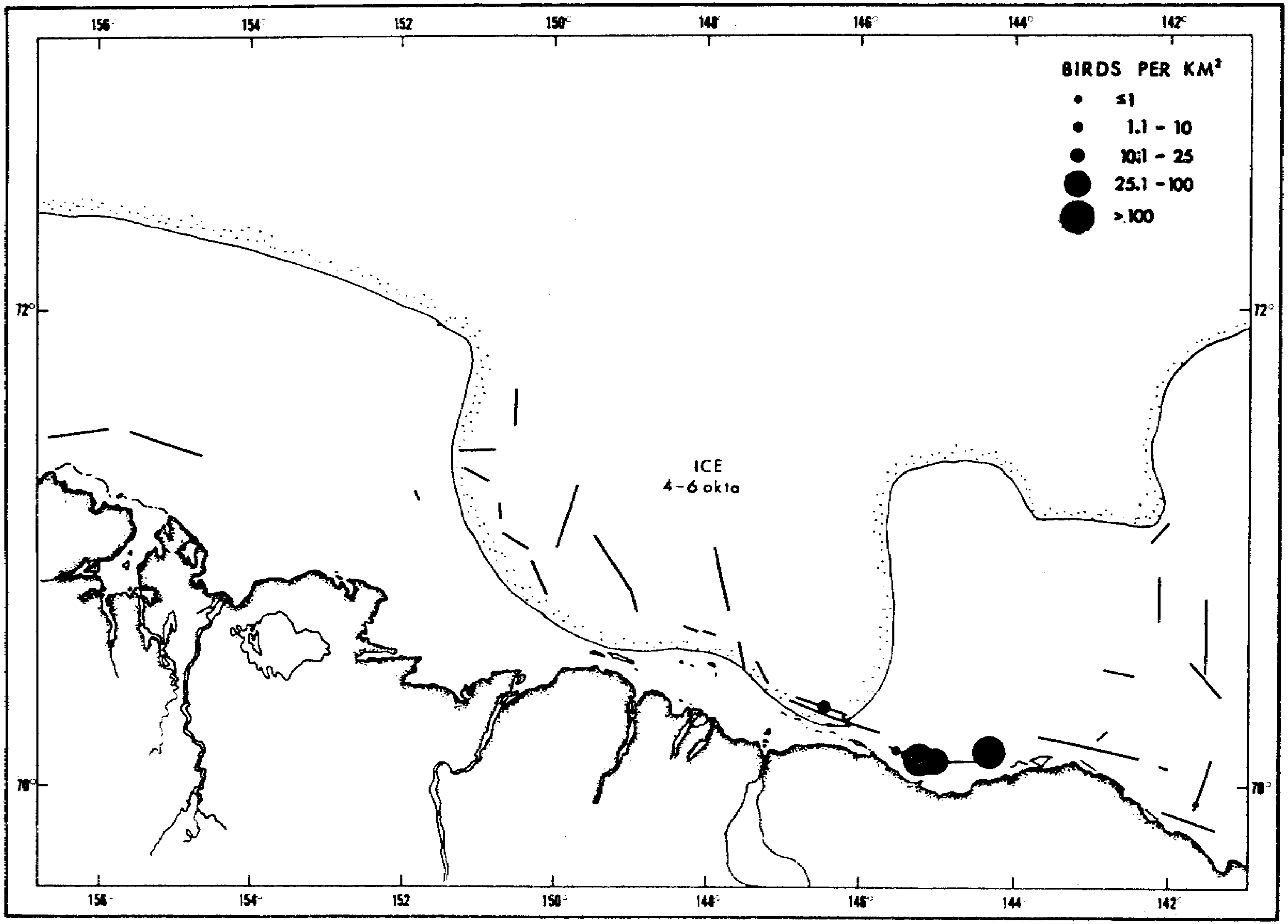


Figure 27. Distribution and abundance of eiders in Beaufort Sea from 26 August to 15 September 1978. (3NW878)

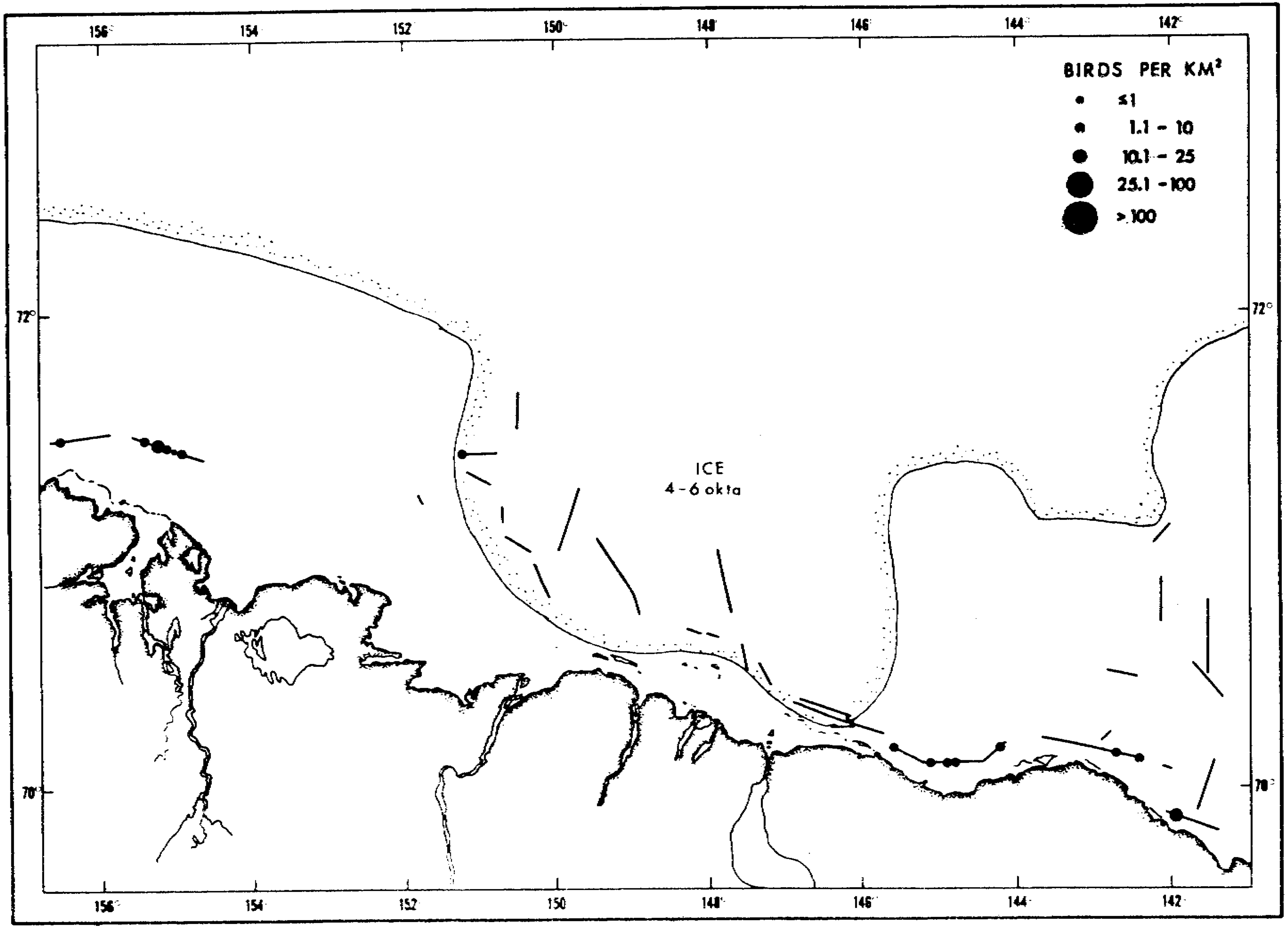


Figure 28. Distribution and abundance of phalaropes in Beaufort Sea from 26 August to 15 September 1978. (3NW878)

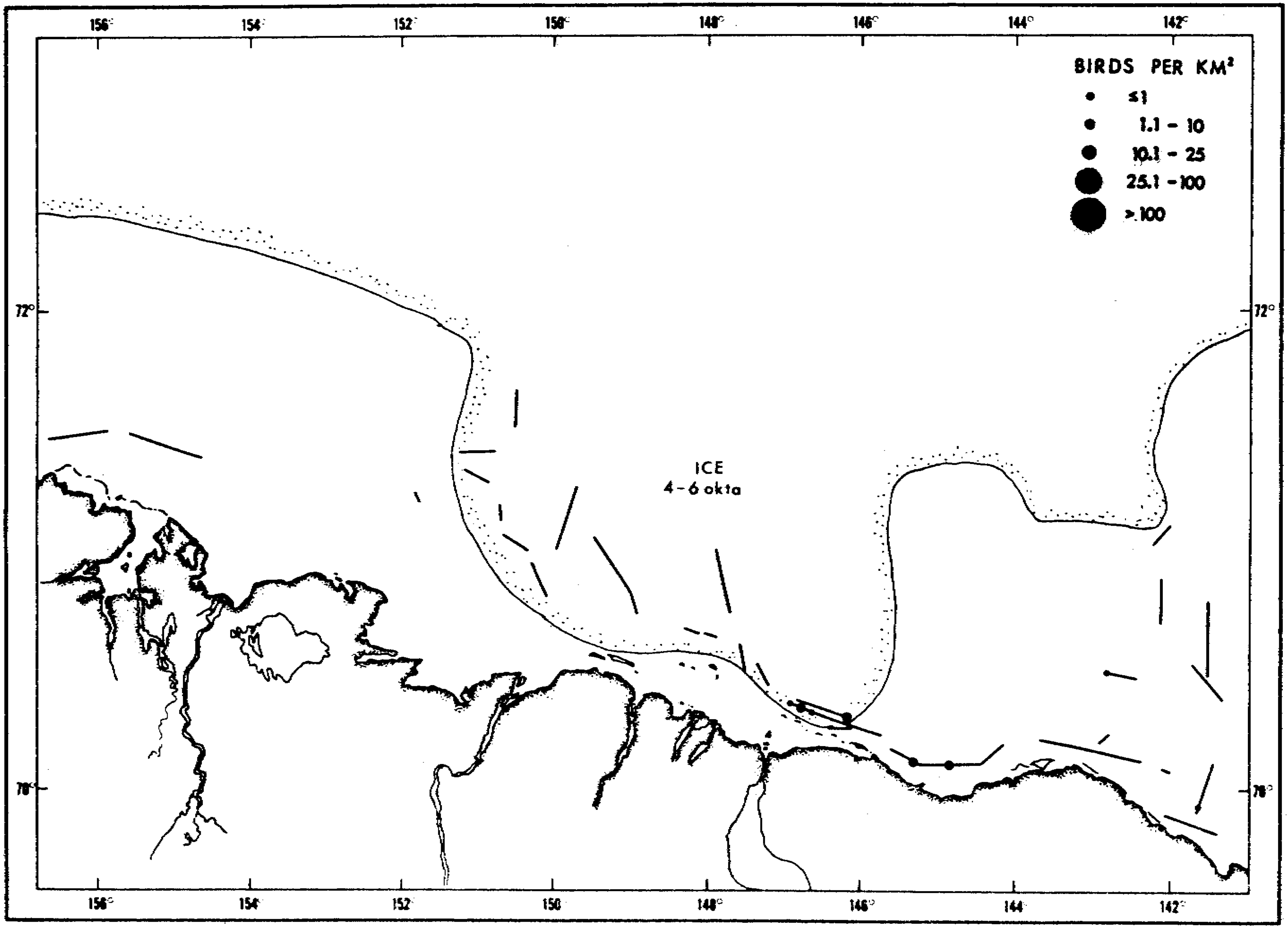


Figure 29. Distribution and abundance of Parasitic Jaegers in Beaufort Sea from 26 August to 15 September 1978. (3NW878)

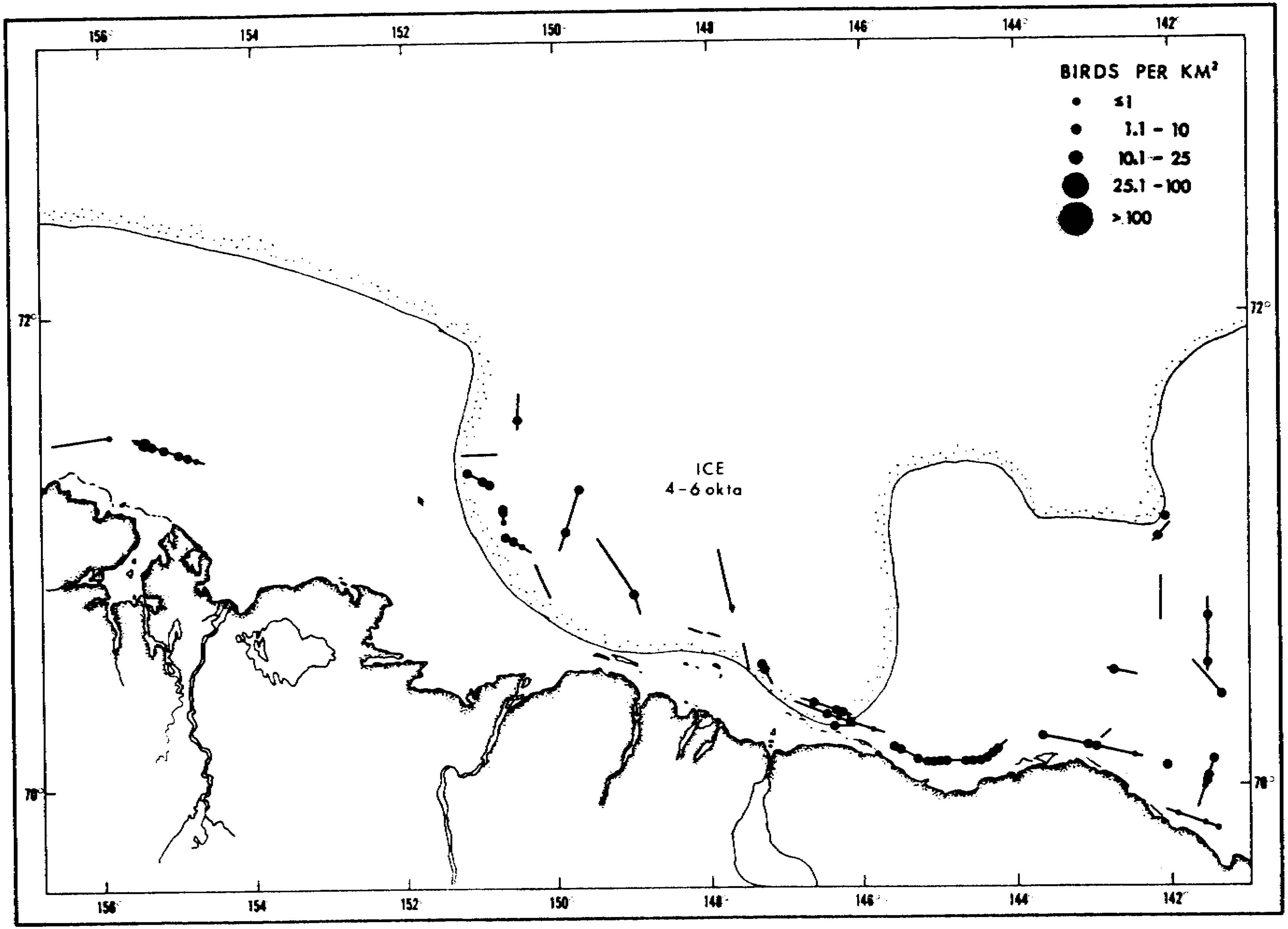


Figure 30. Distribution and abundance of Glaucous Gulls in Beaufort Sea from 26 August to 15 September 1978. (3NW878)

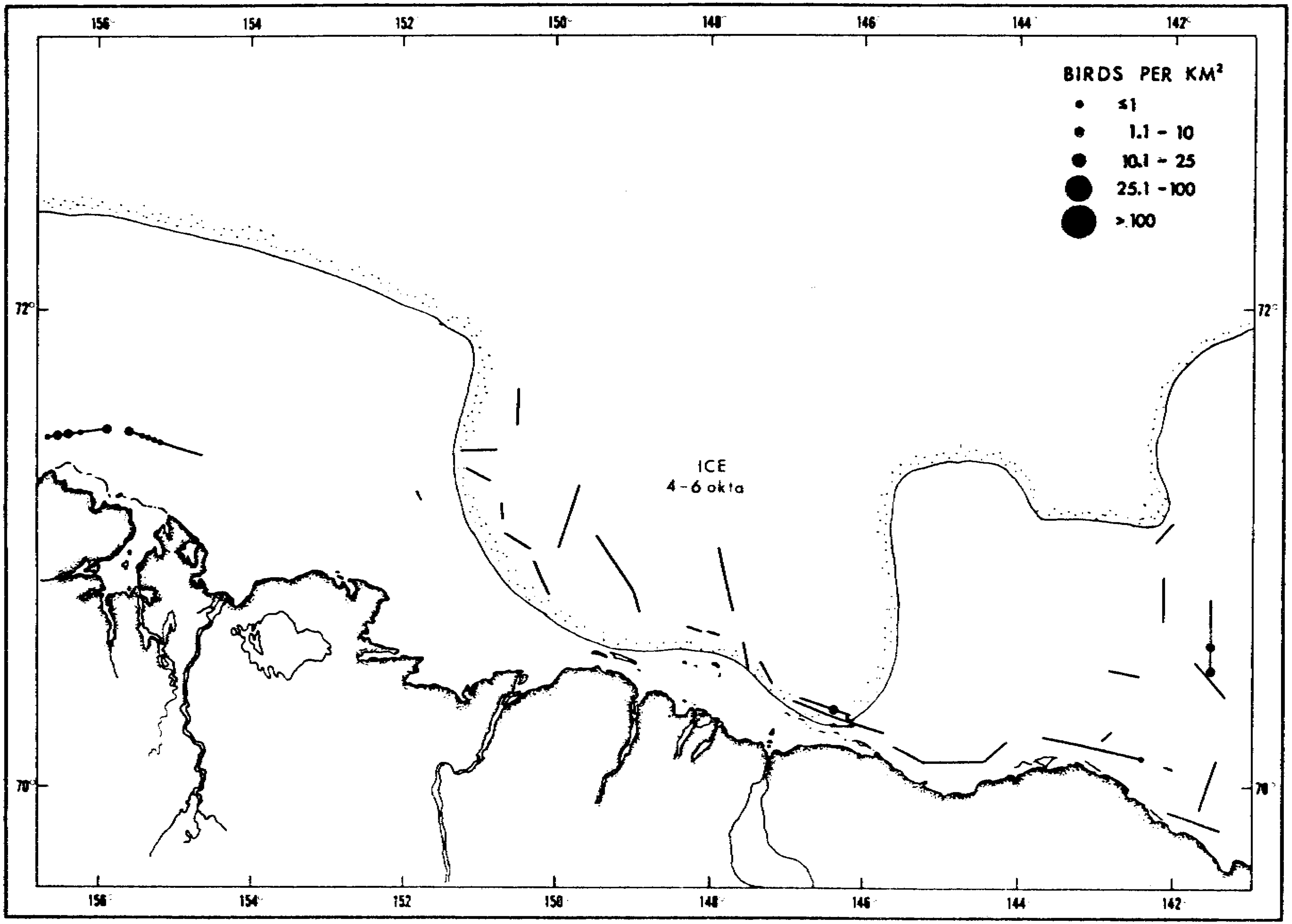


Figure 31. Distribution and abundance of Black-legged Kittiwakes in Beaufort Sea from 26 August to 15 September 1978. (3NW878)

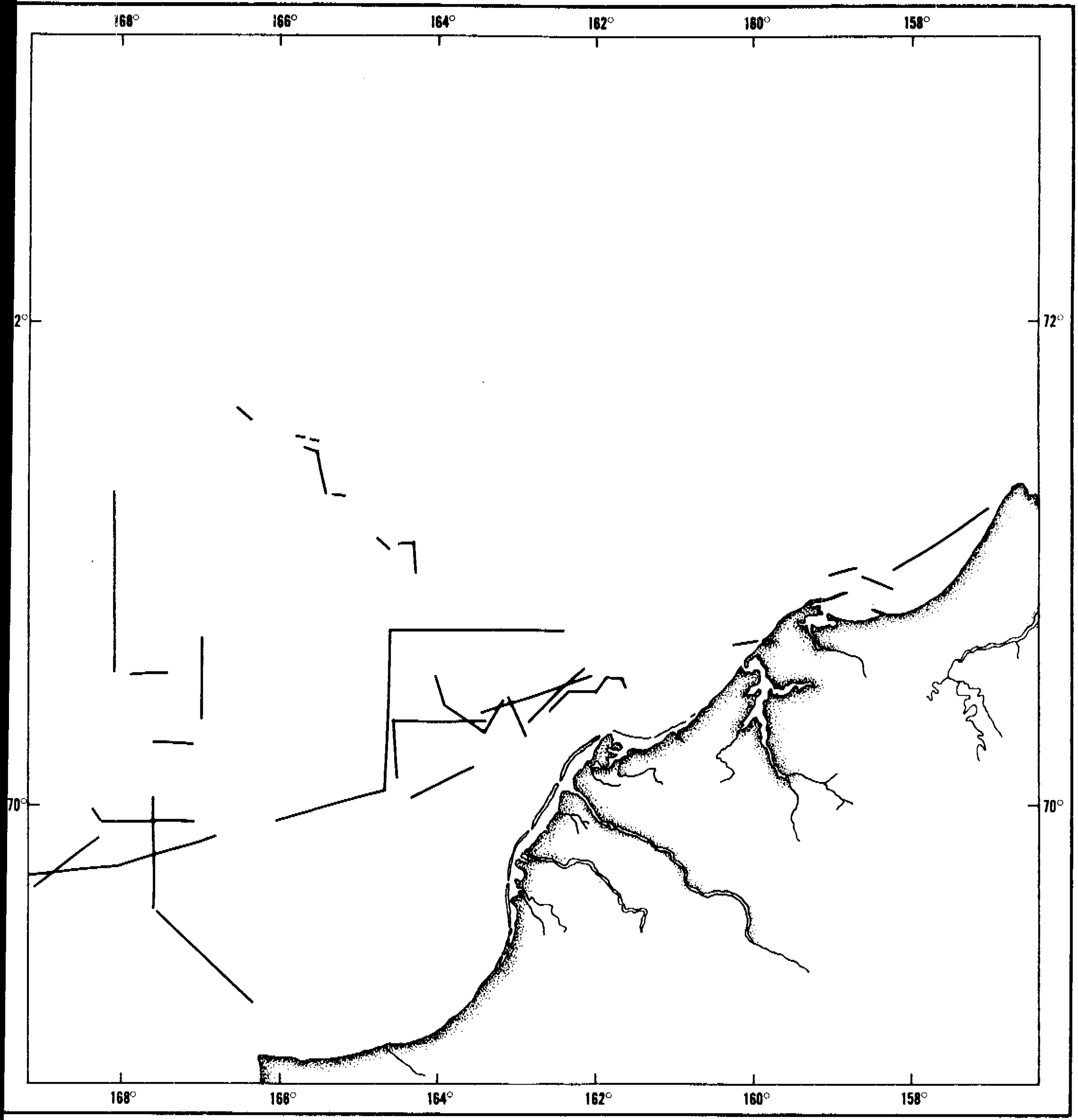


Figure 32. Cruise track during periods of observation in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

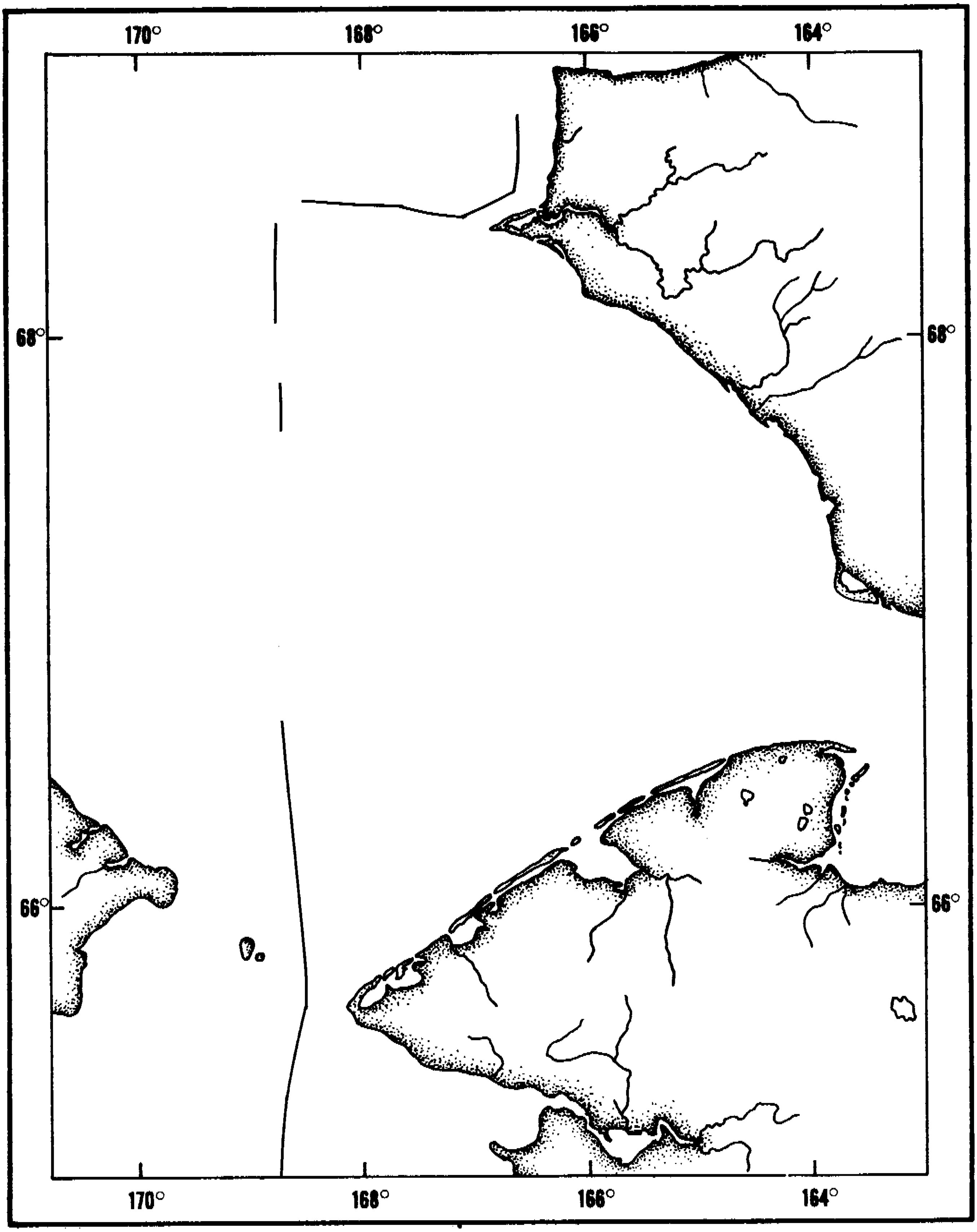


Figure 33. Cruise track during periods of observation in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

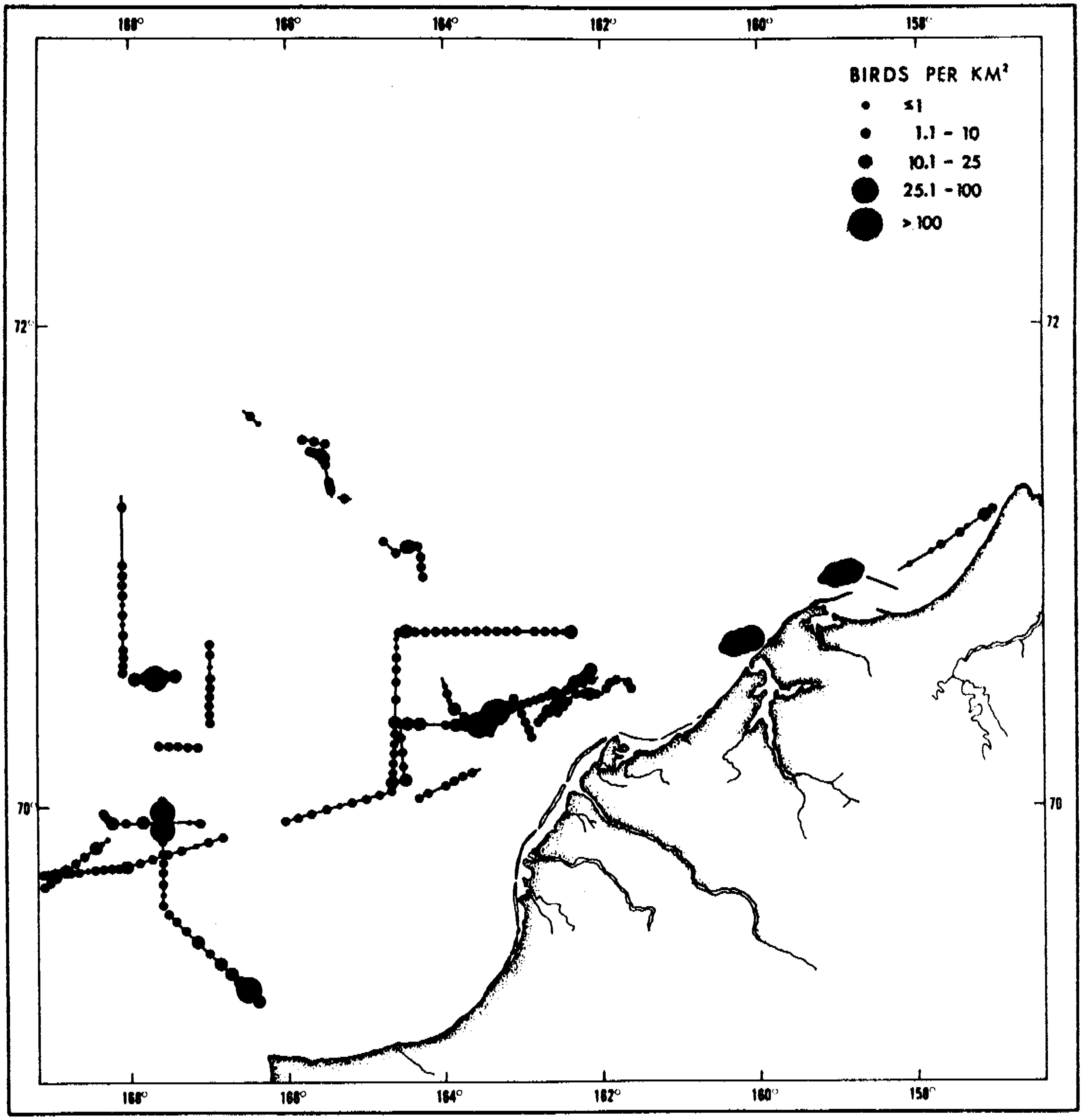


Figure 34. Distribution and abundance of seabirds in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

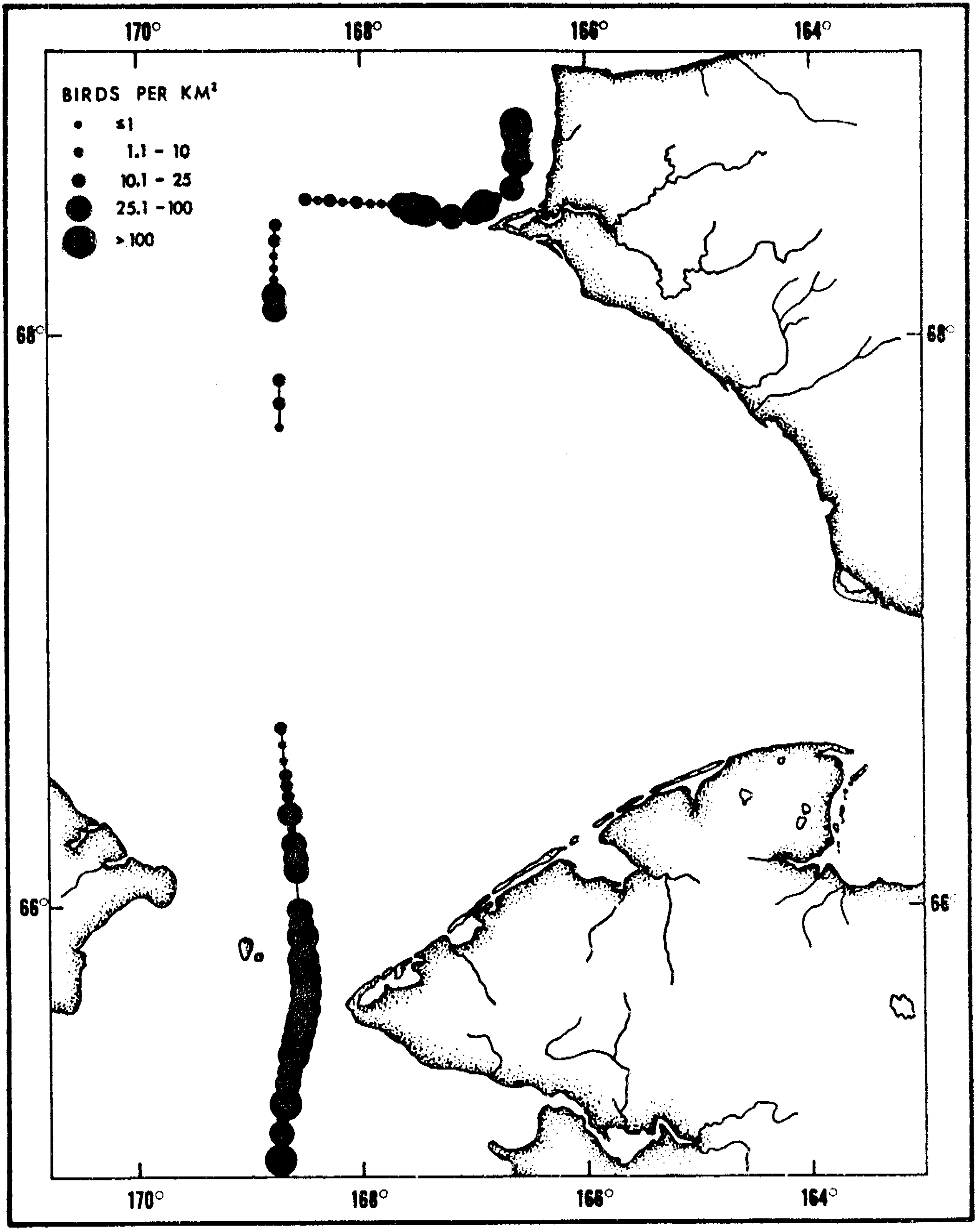


Figure 35. Distribution and abundance of seabirds in Bering Strait and southern Chukchi Sea between 31 July and 1 August 1975. (2GL875)

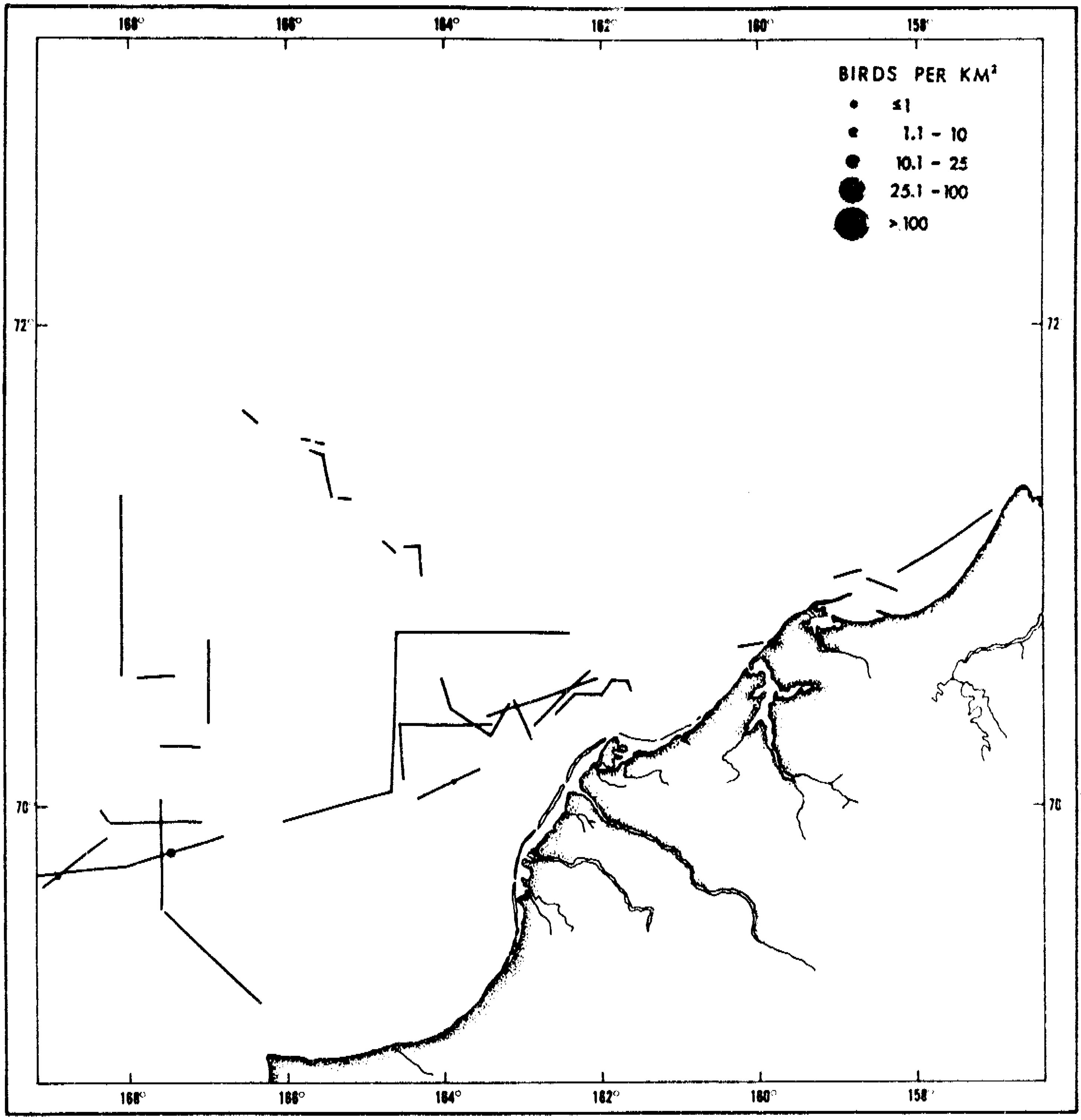


Figure 36. Distribution and abundance of Northern Fulmars in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

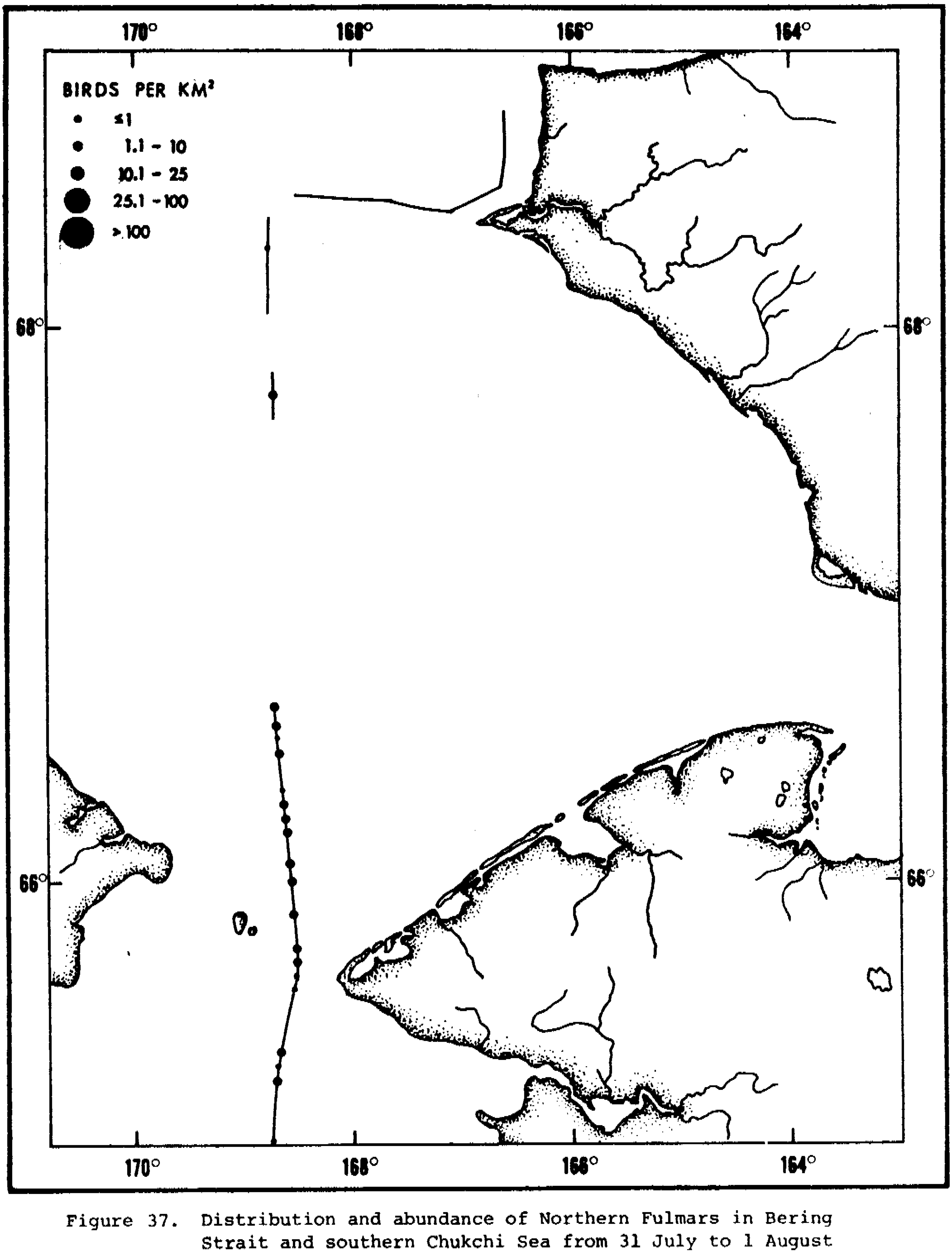


Figure 37. Distribution and abundance of Northern Fulmars in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

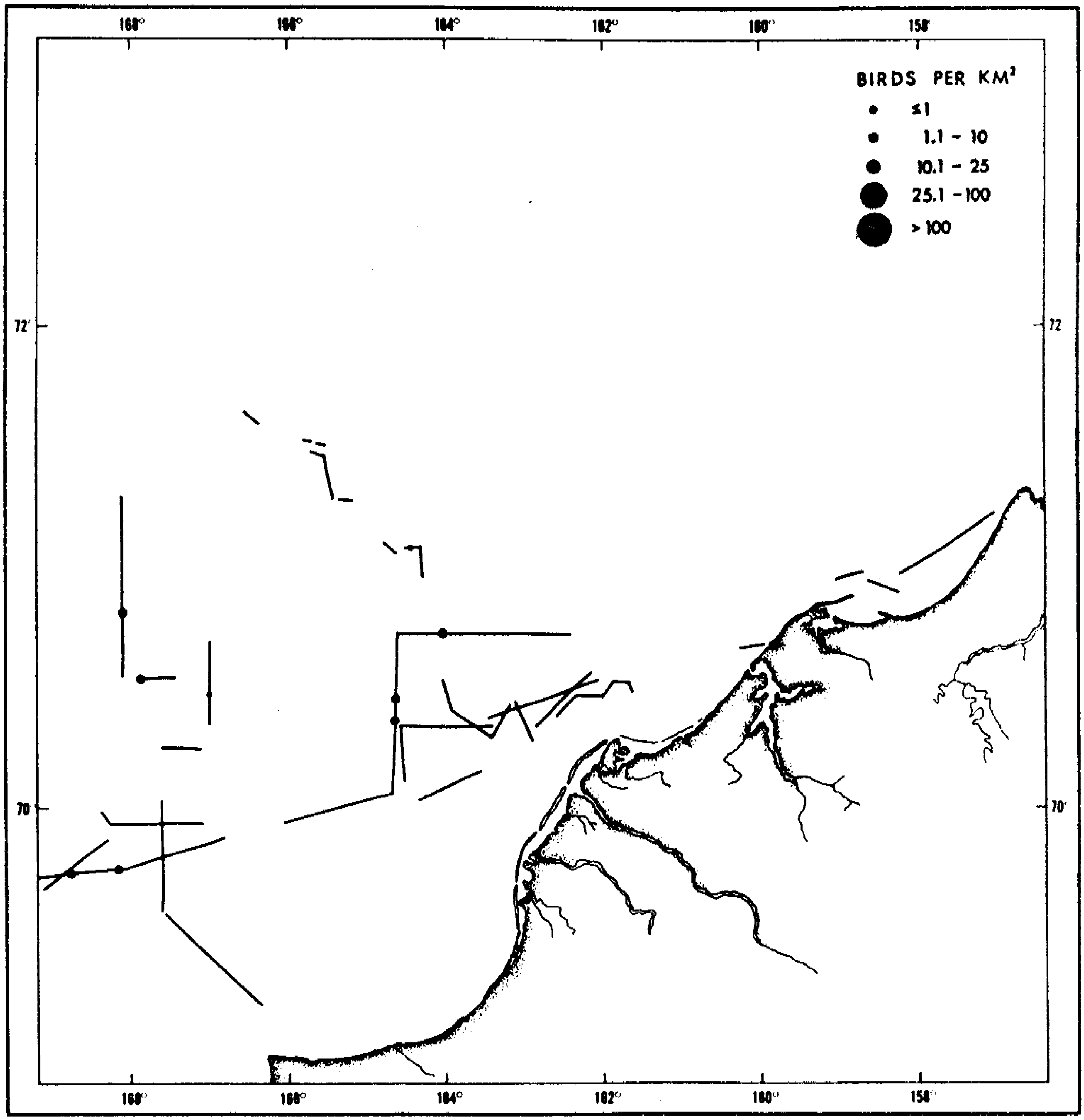


Figure 38. Distribution and abundance of phalaropes in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

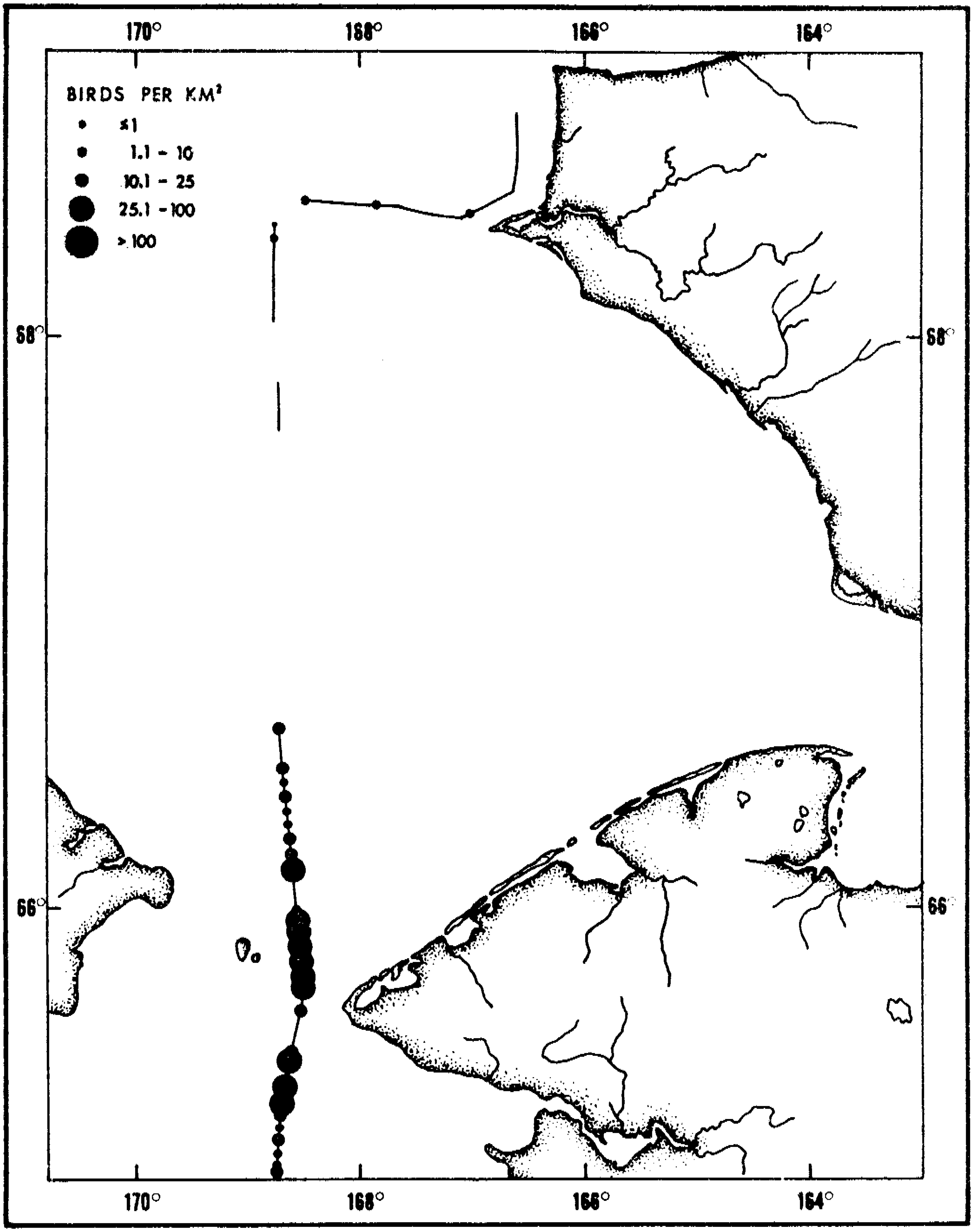


Figure 39. Distribution and abundance of phalaropes in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

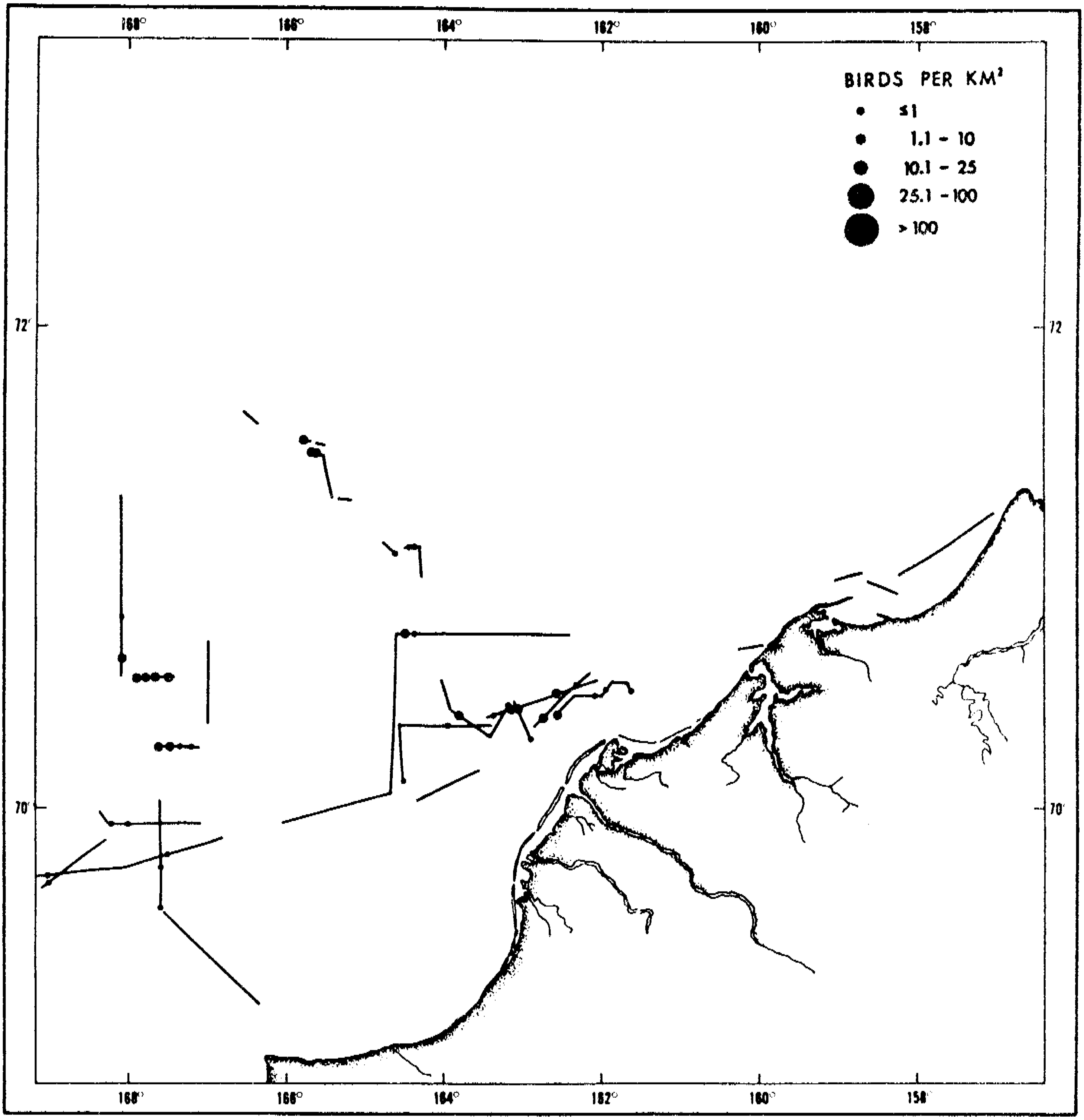


Figure 40. Distribution and abundance of Pomarine Jaegers in northern Chukchi Sea from 2 to 25 August 1975. (3GL875)

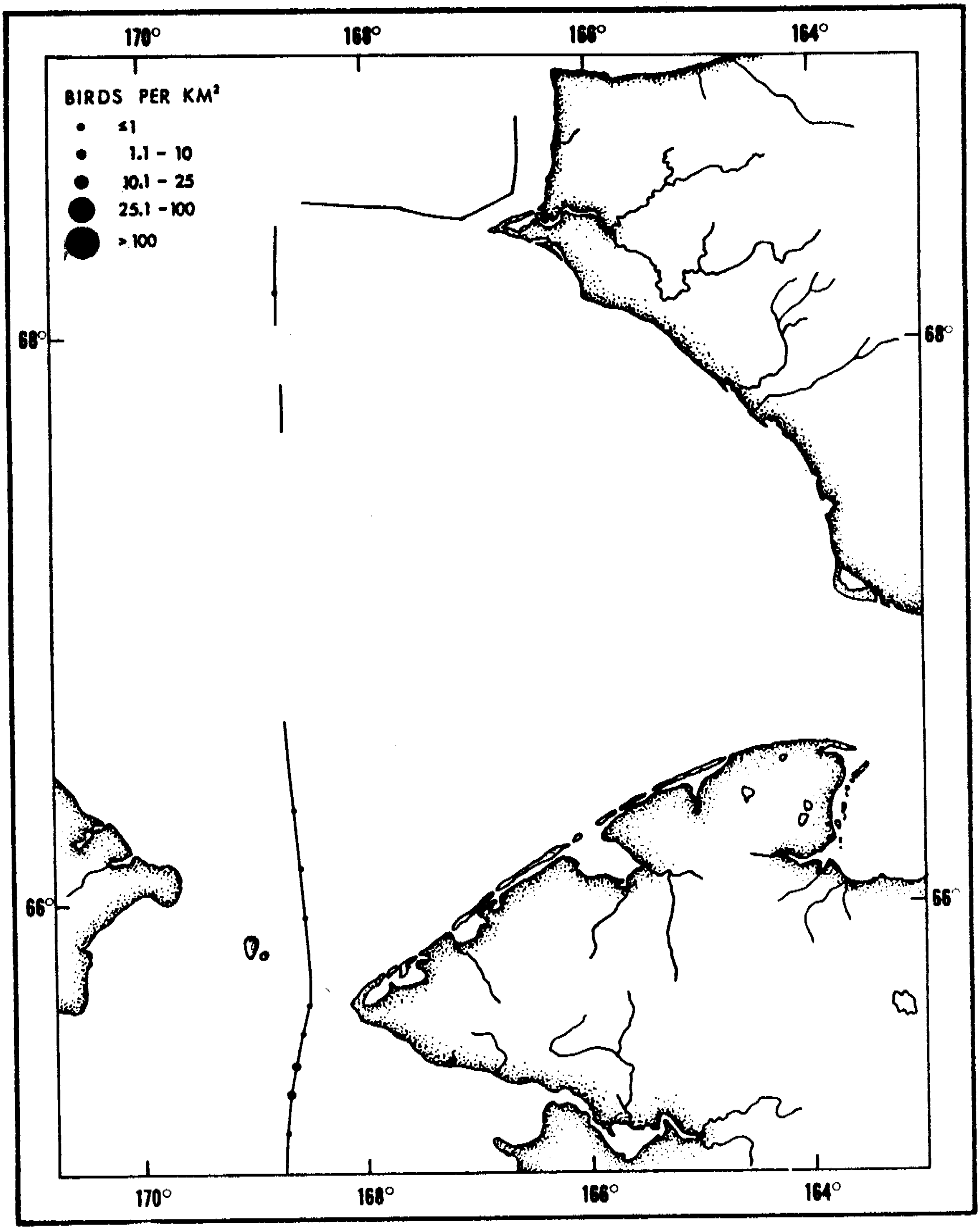


Figure 41. Distribution and abundance of Pomarine Jaegers in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

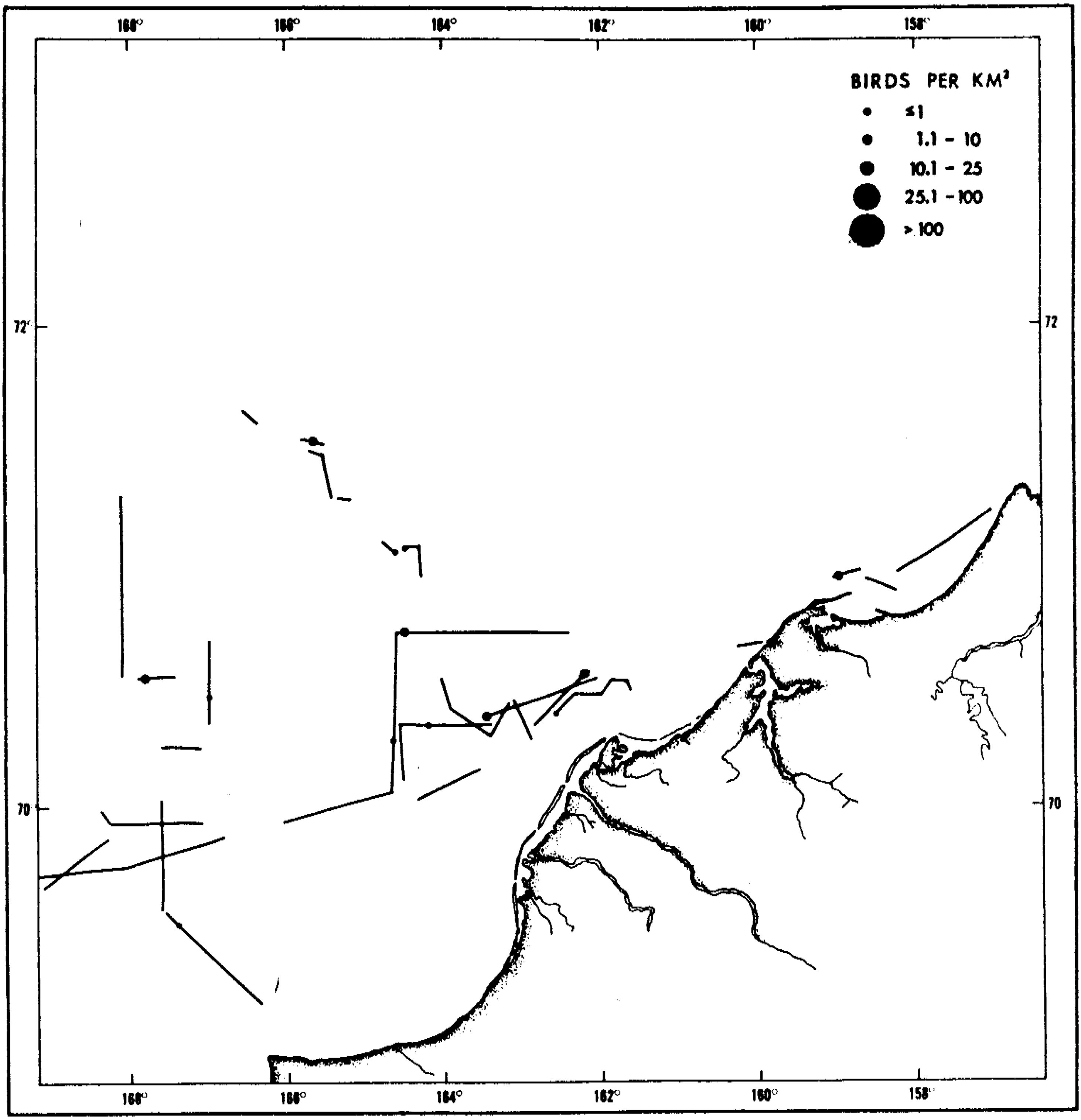


Figure 42. Distribution and abundance of Parasitic Jaegers in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

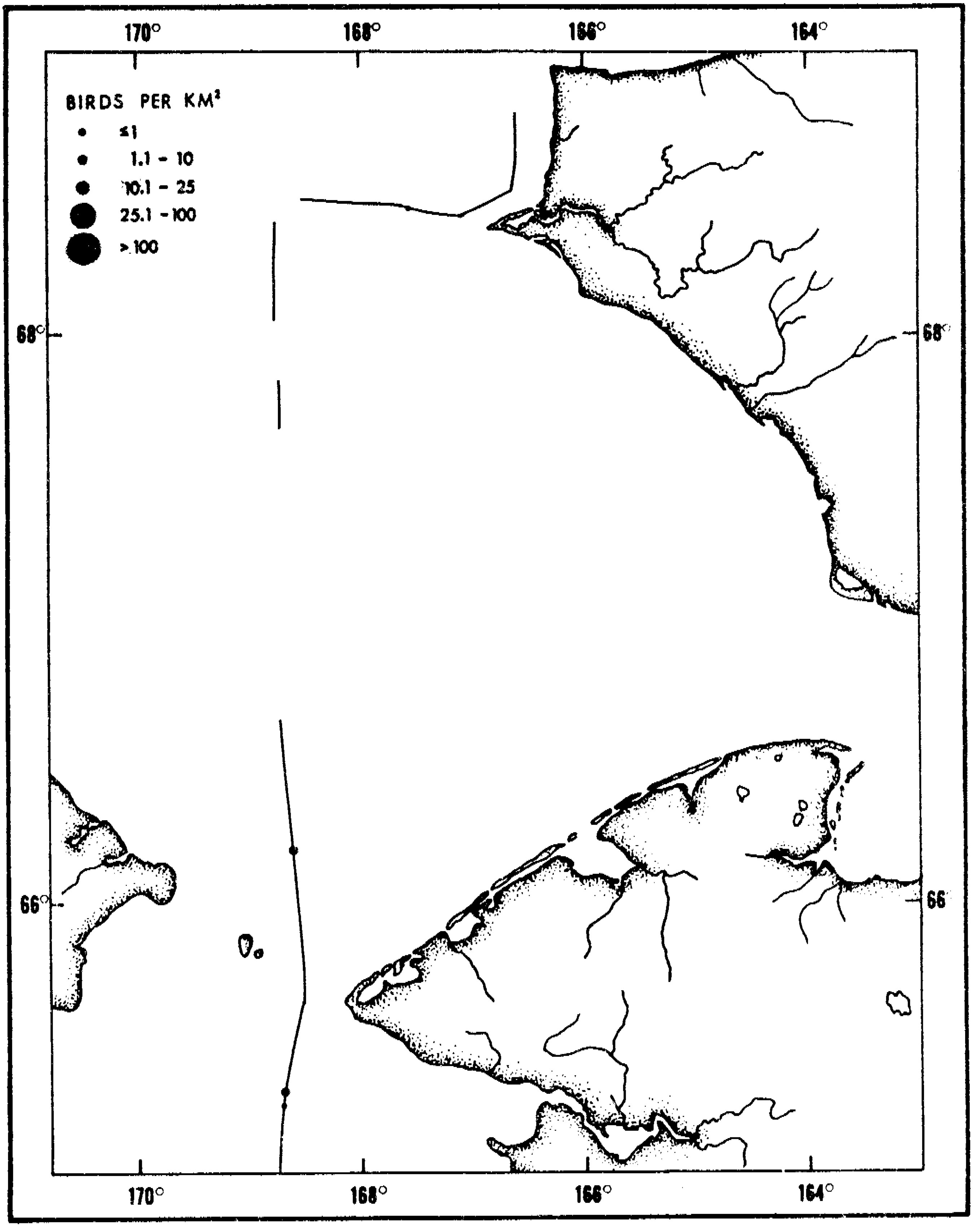


Figure 43. Distribution and abundance of Parasitic Jaegers in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

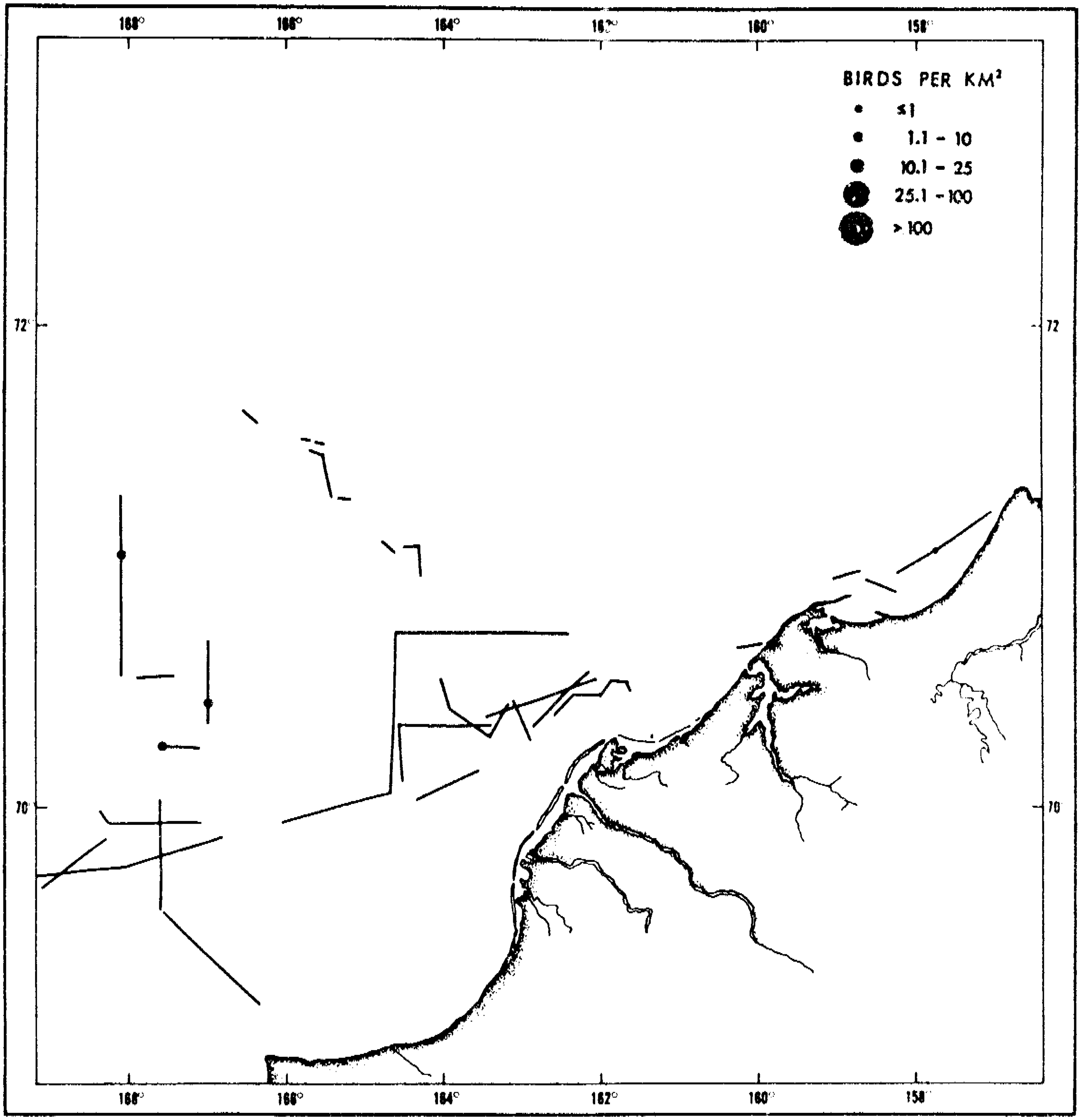


Figure 44. Distribution and abundance of Long-tailed Jaegers in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

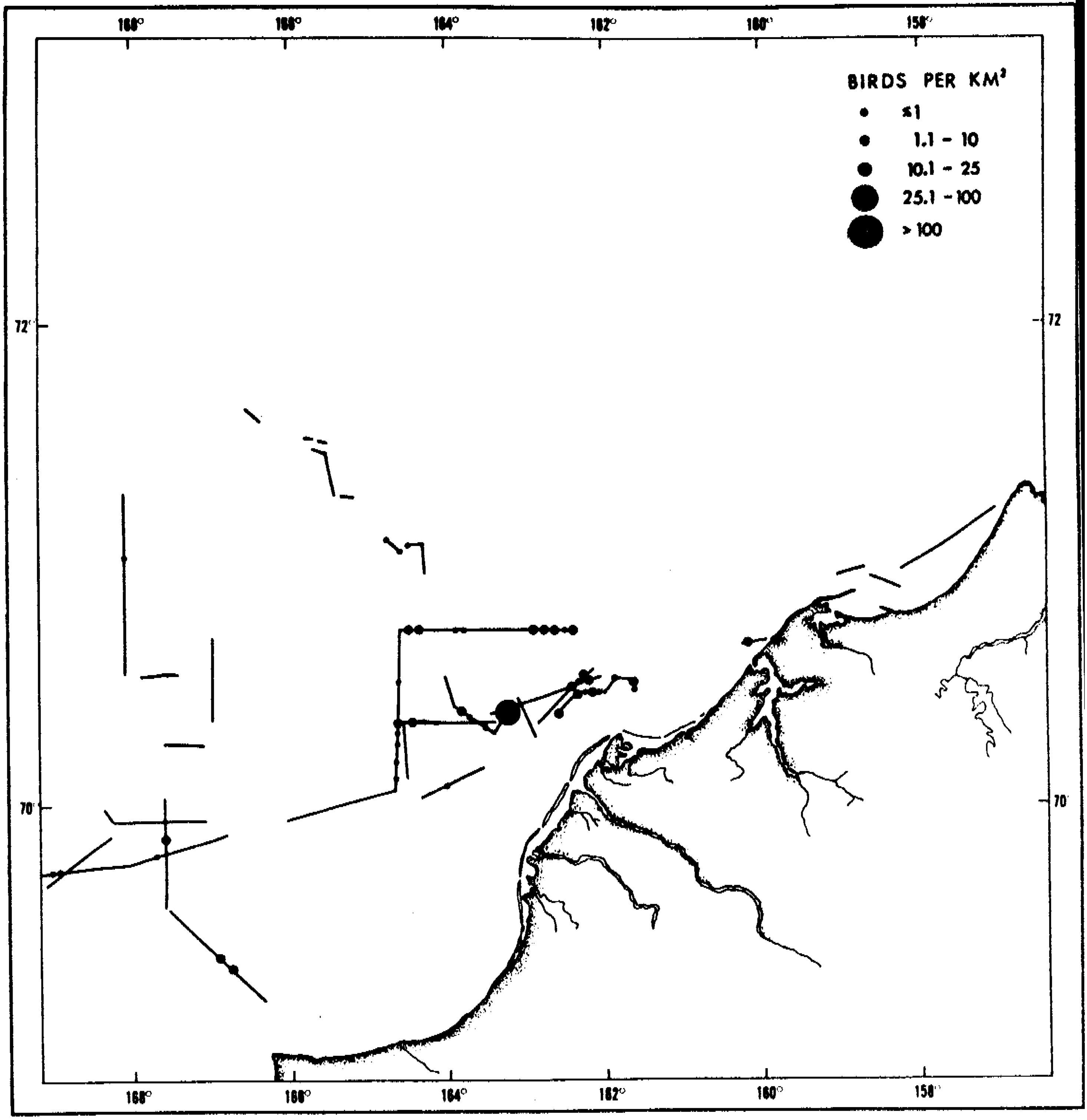


Figure 45. Distribution and abundance of Glaucous Gulls in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

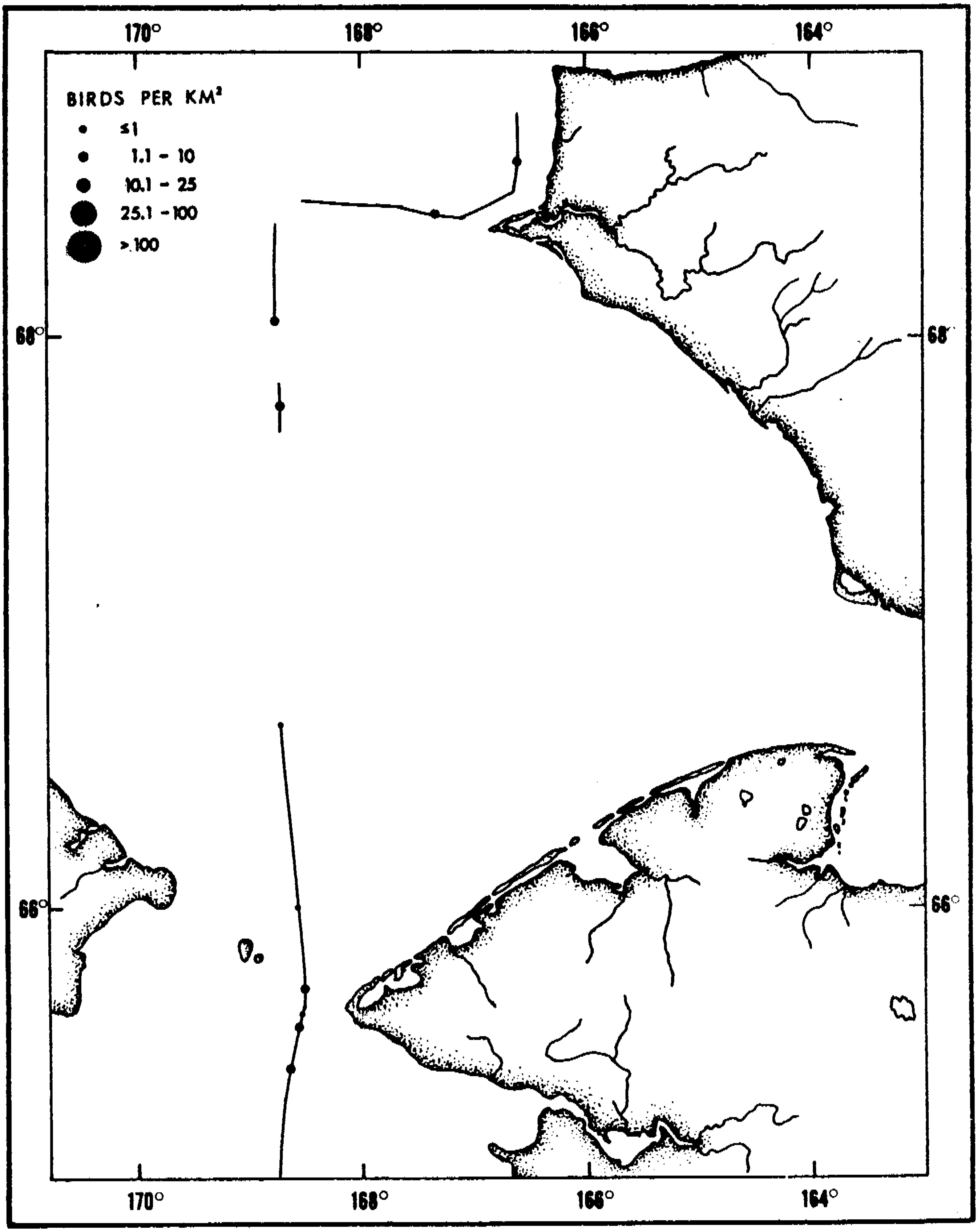


Figure 46. Distribution and abundance of Glaucous Gulls in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

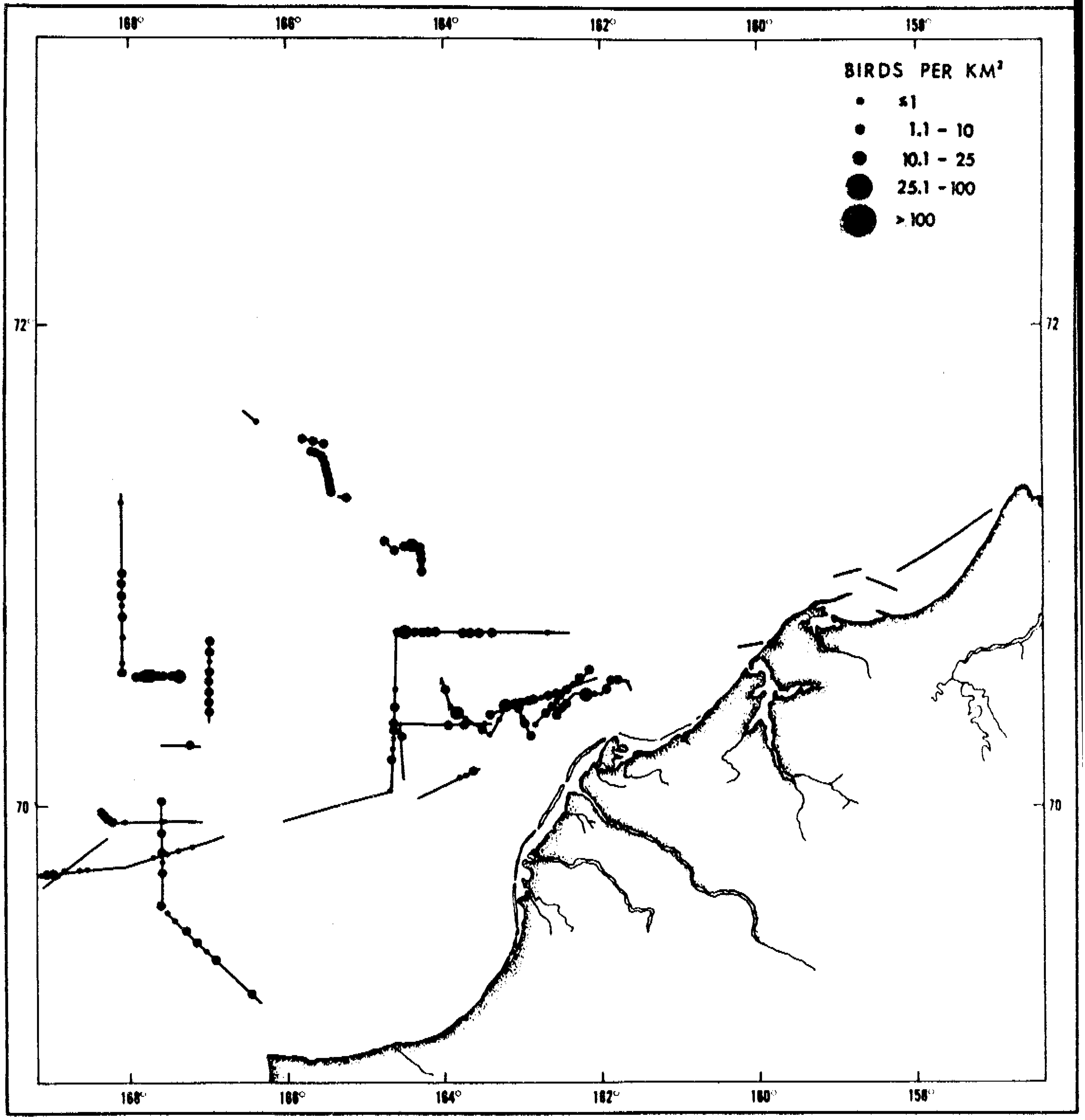


Figure 47. Distribution and abundance of Black-legged Kittiwakes in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

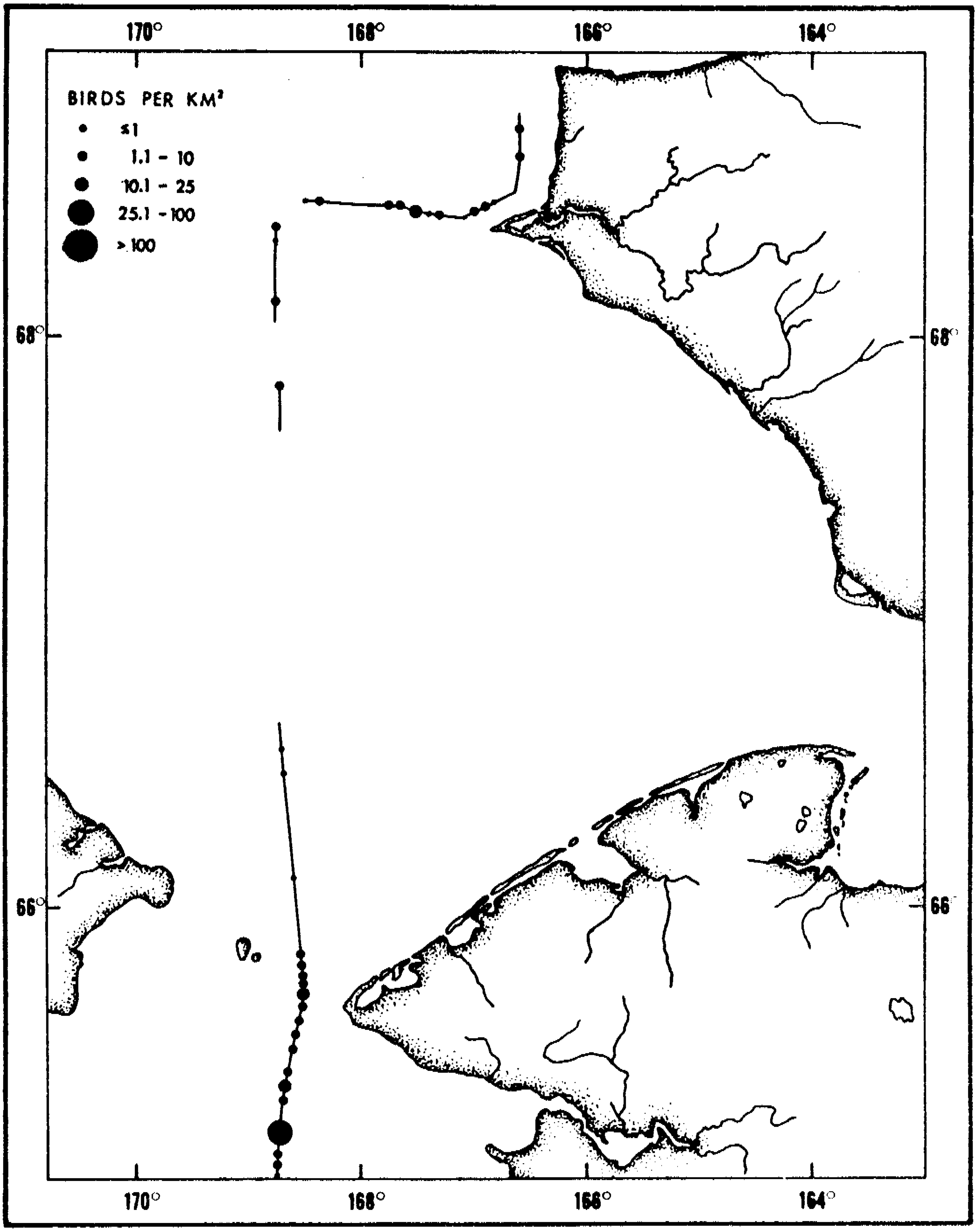


Figure 48. Distribution and abundance of Black-legged Kittiwakes in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

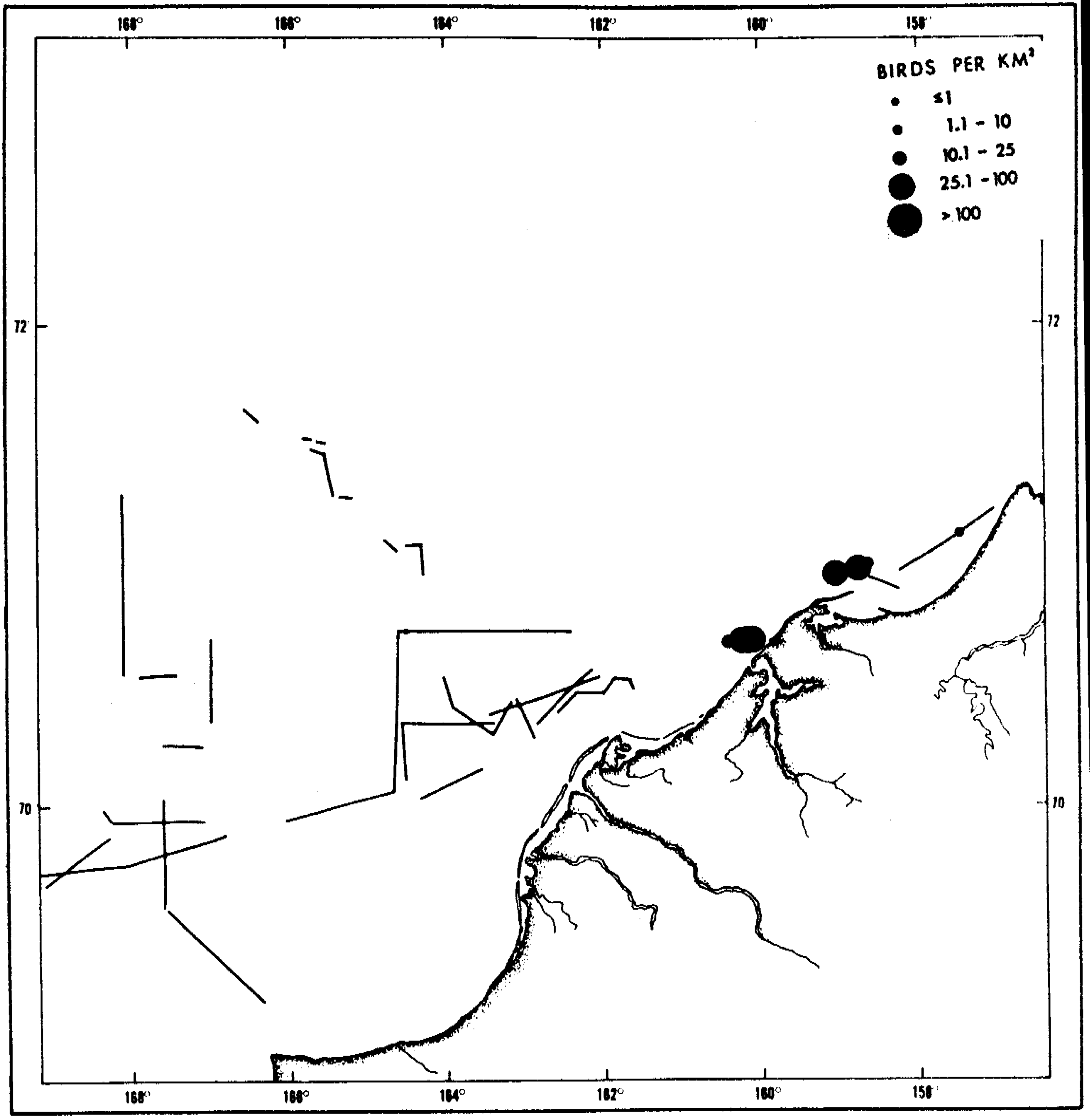


Figure 49. Distribution and abundance of Arctic Terns in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

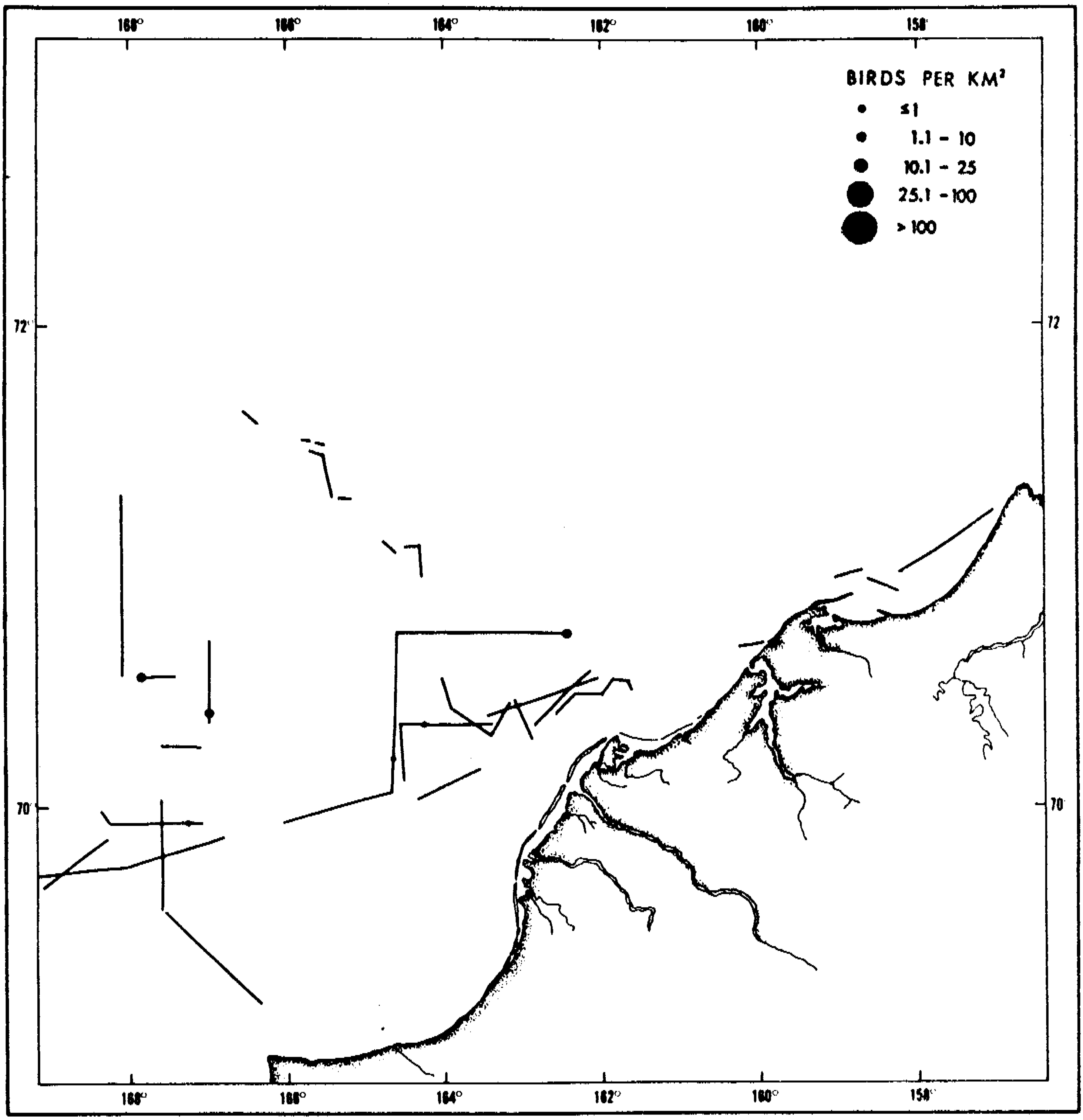


Figure 51. Distribution and abundance of Common Murres in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

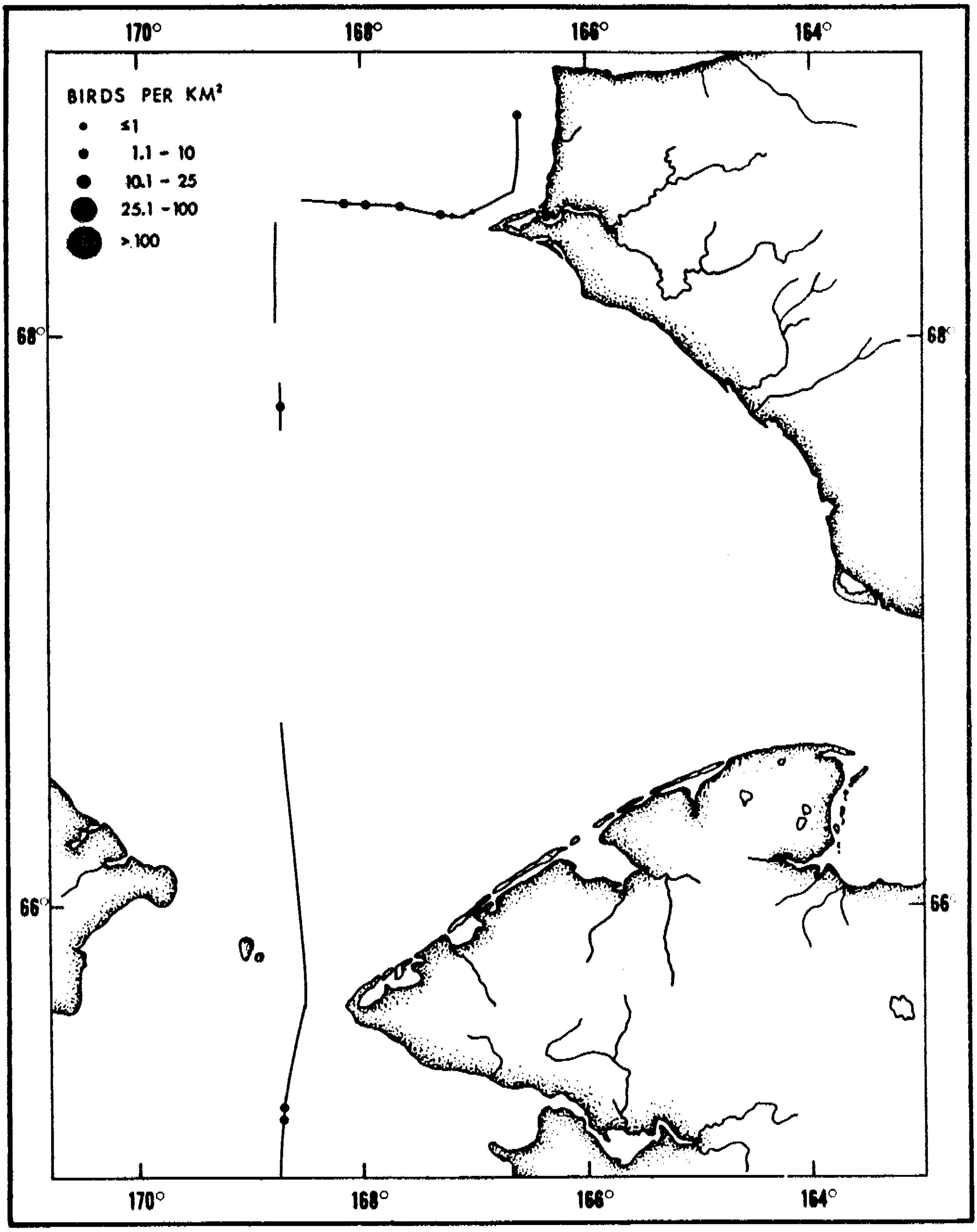


Figure 52. Distribution and abundance of Common Murres in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

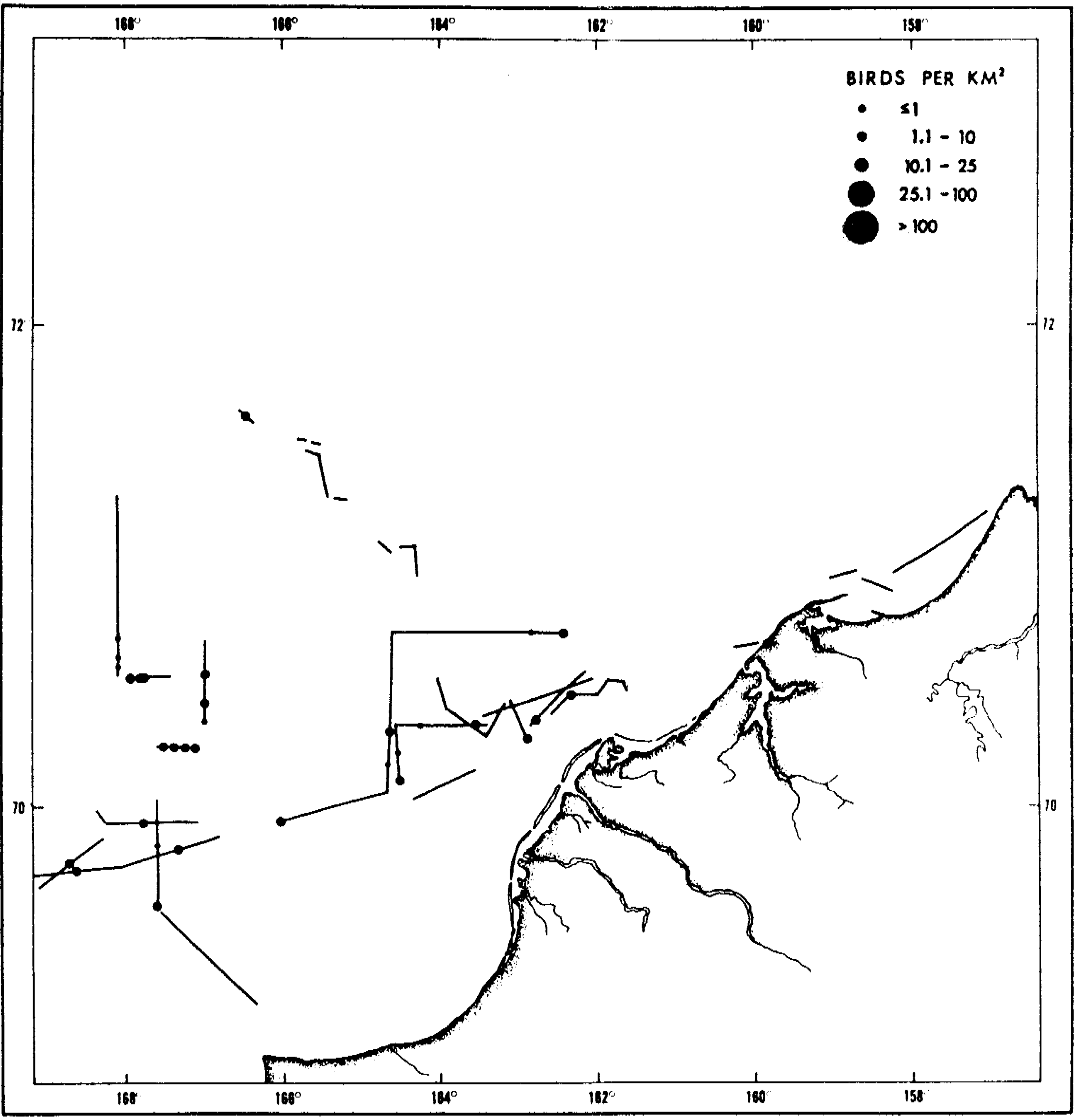


Figure 53. Distribution and abundance of Thick-billed Murres in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

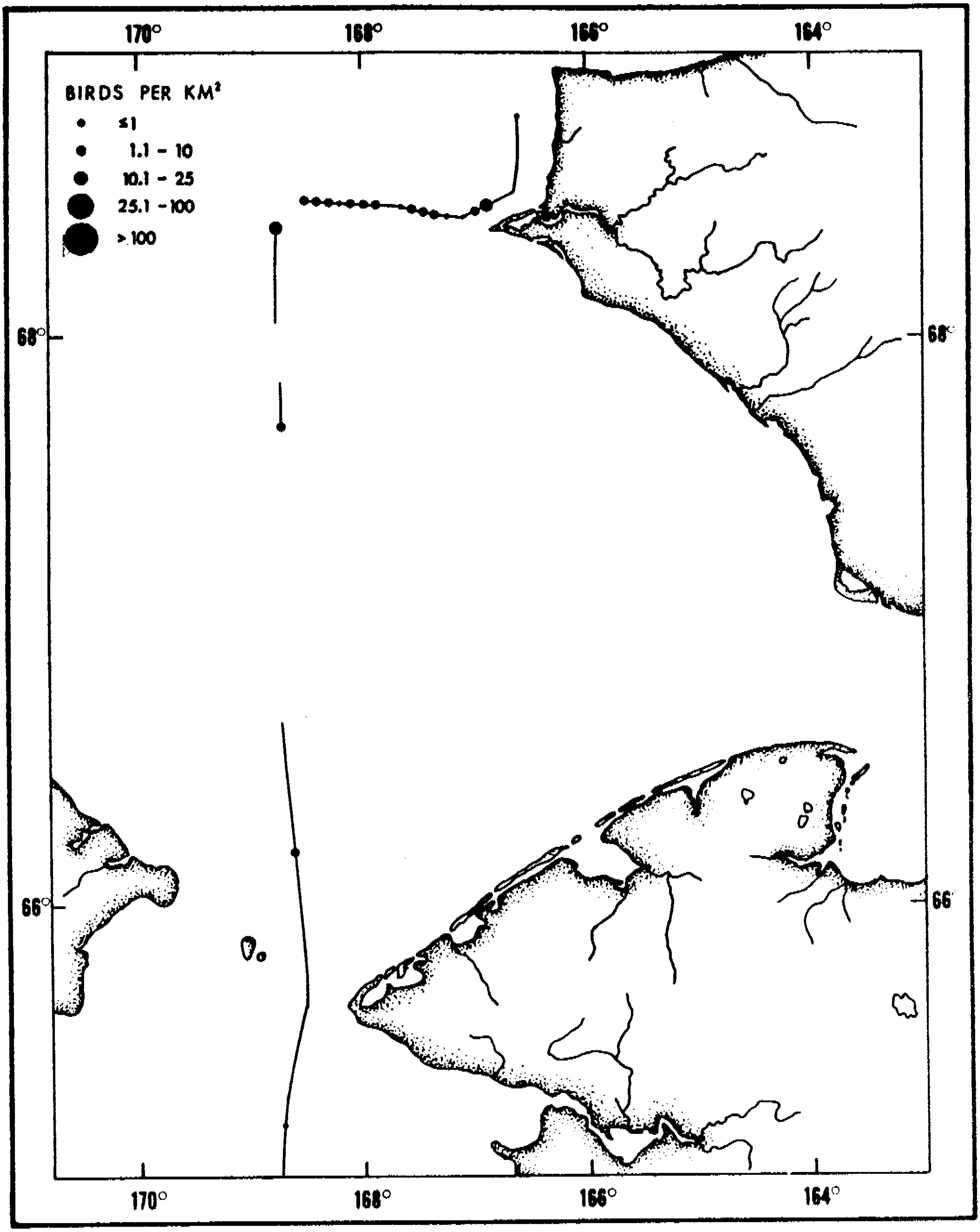


Figure 54. Distribution and abundance of Thick-billed Murres in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

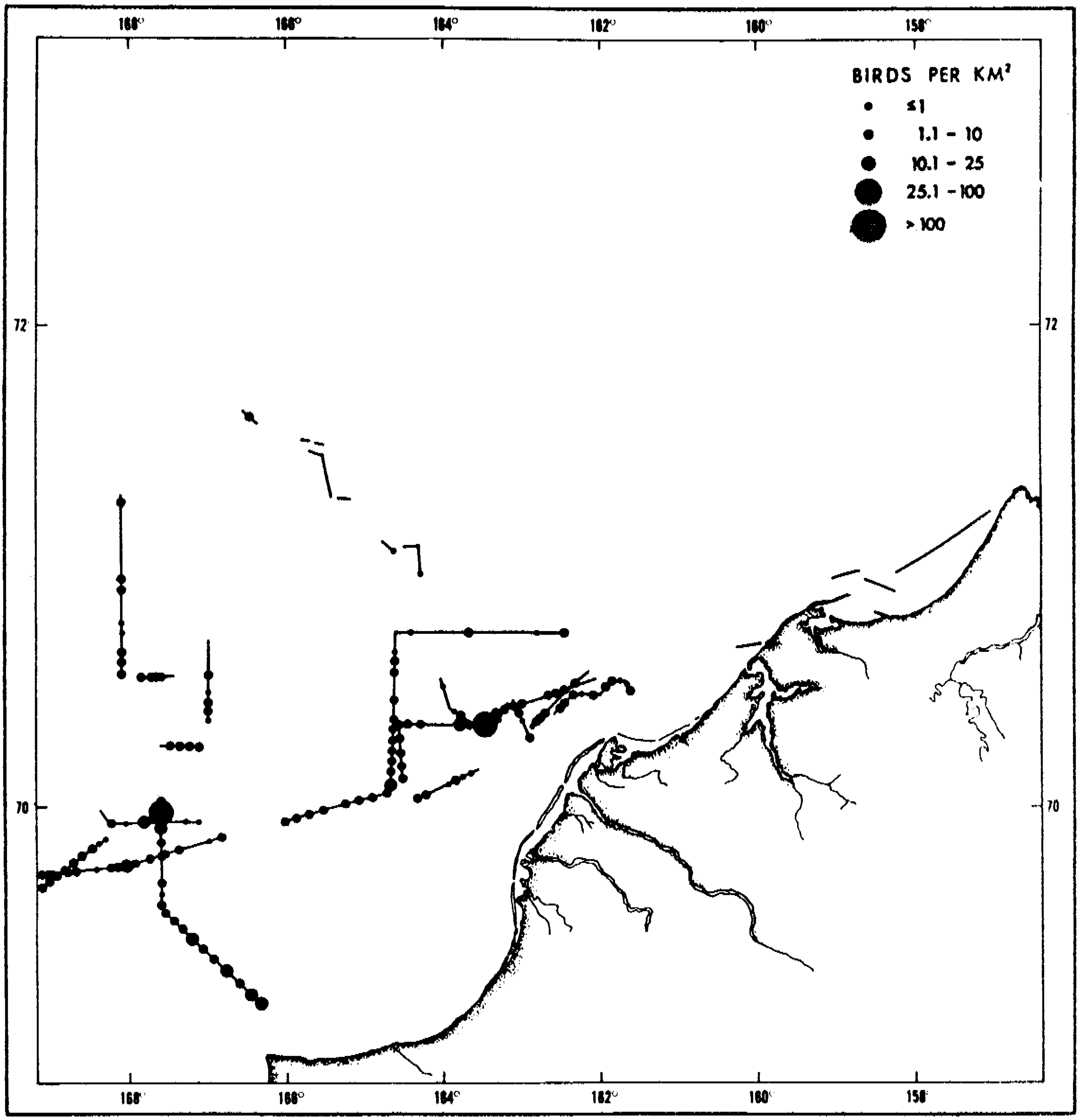


Figure 55. Distribution and abundance of all murres in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

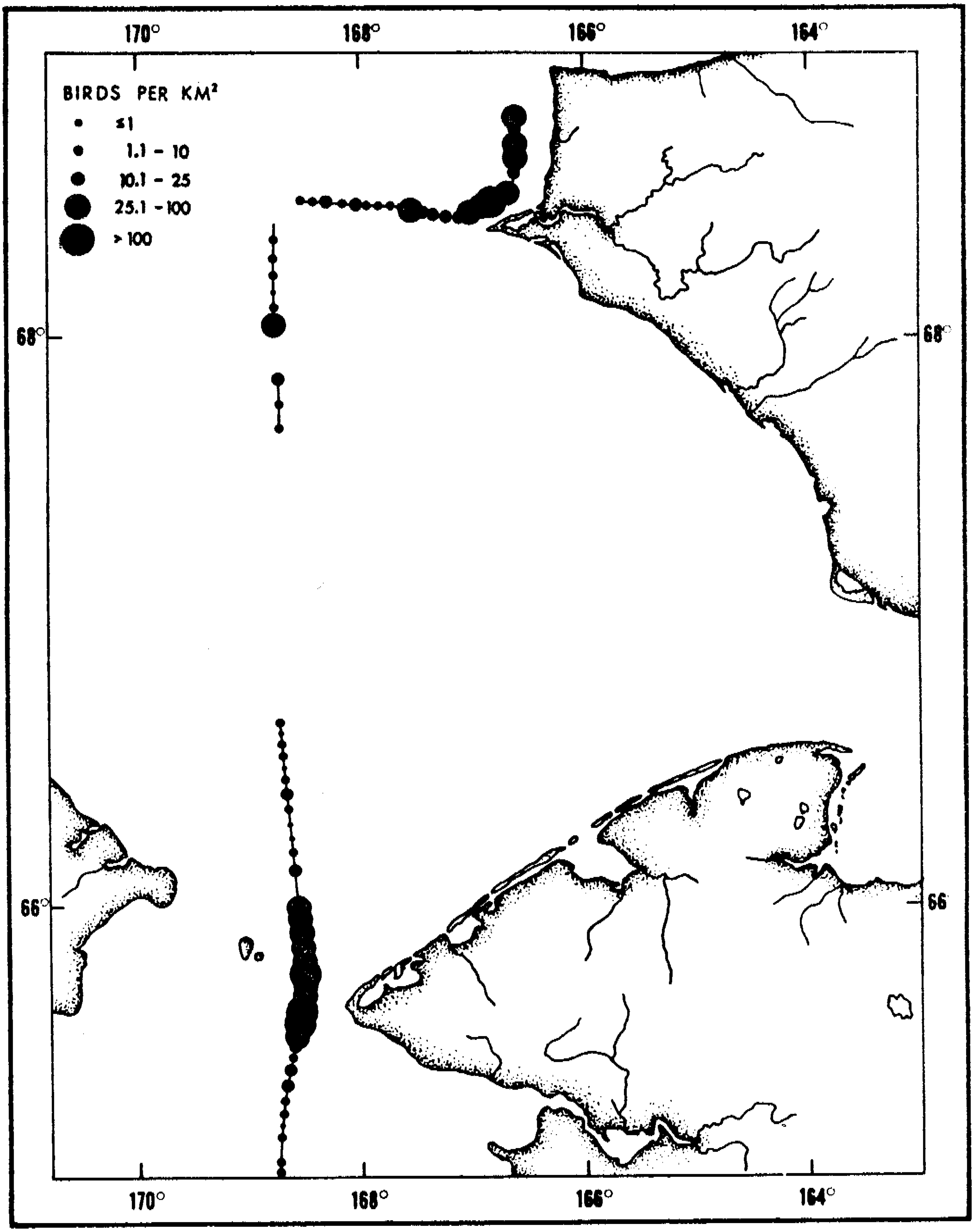


Figure 56. Distribution and abundance of all murres in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

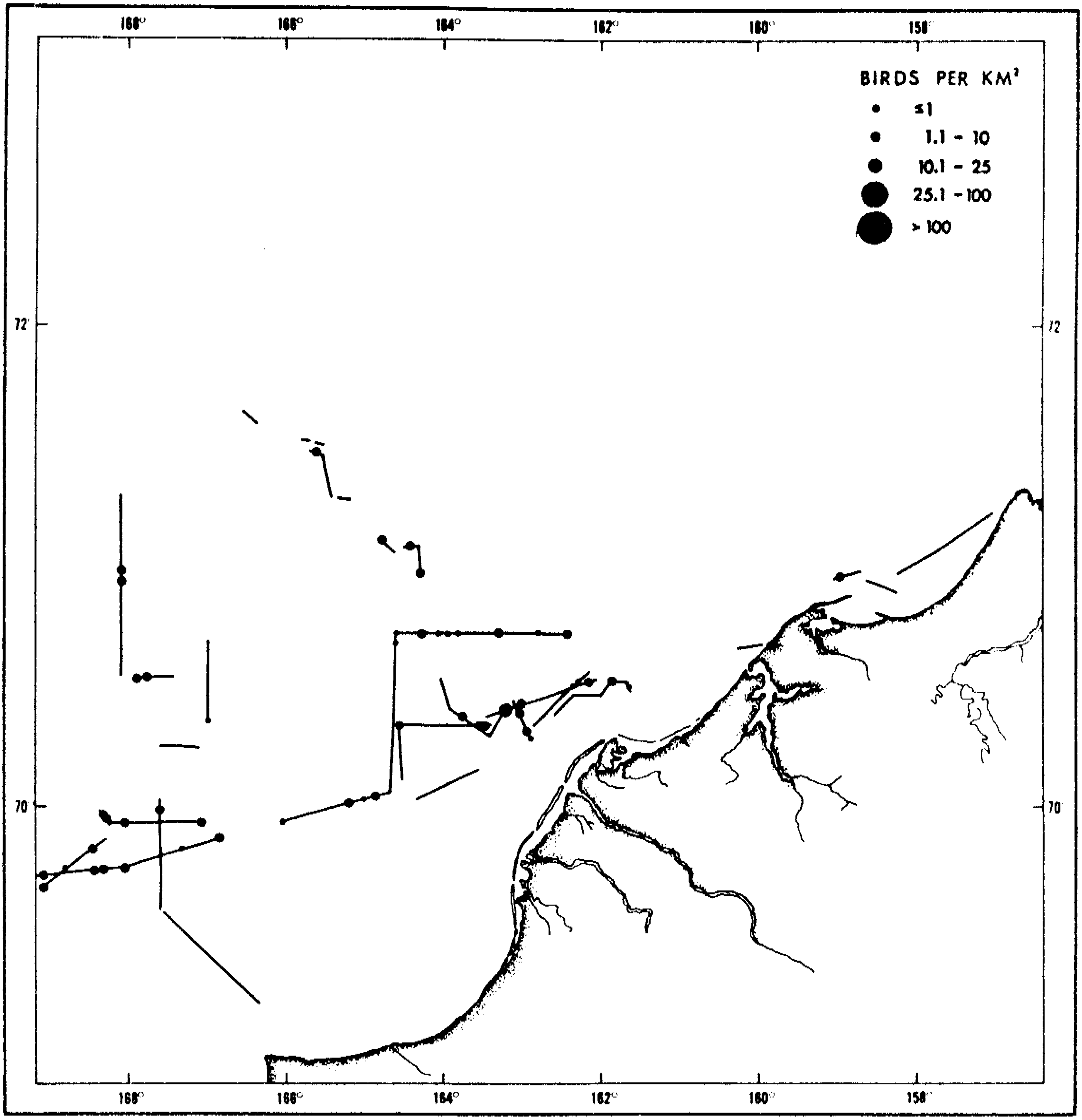


Figure 57. Distribution and abundance of Black Guillemots in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

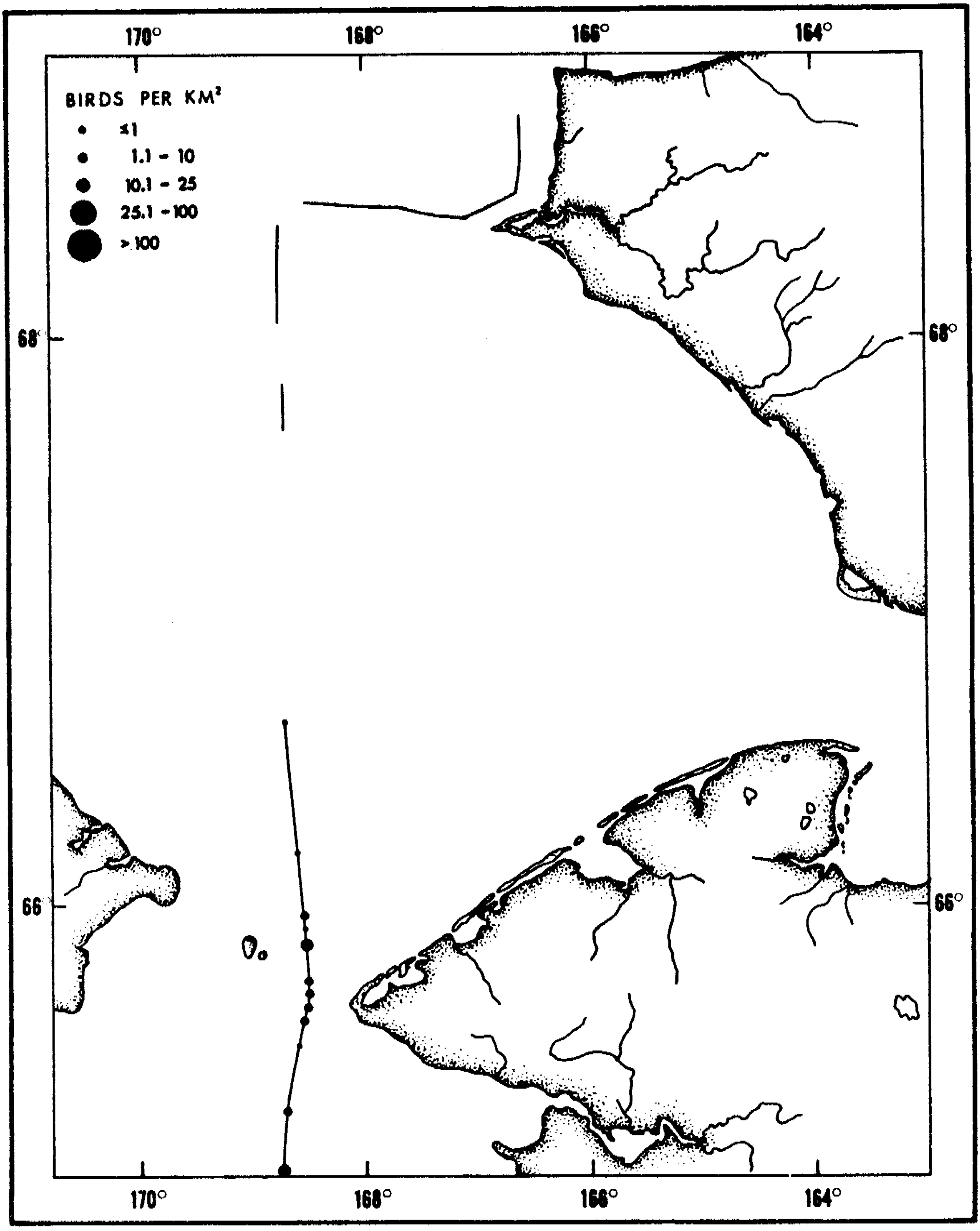


Figure 59. Distribution and abundance of Parakeet Auklets in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

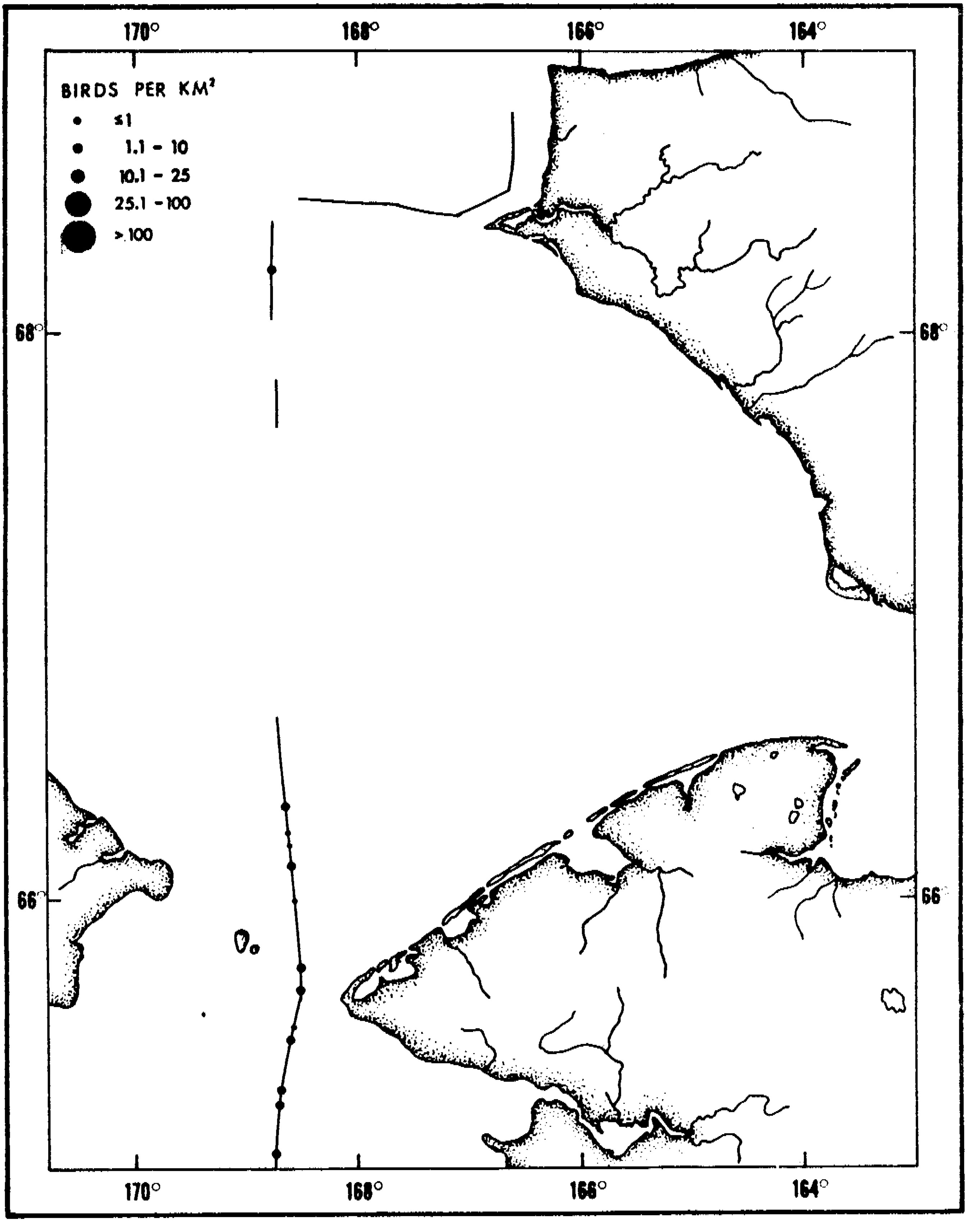


Figure 60. Distribution and abundance of Crested Auklets in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

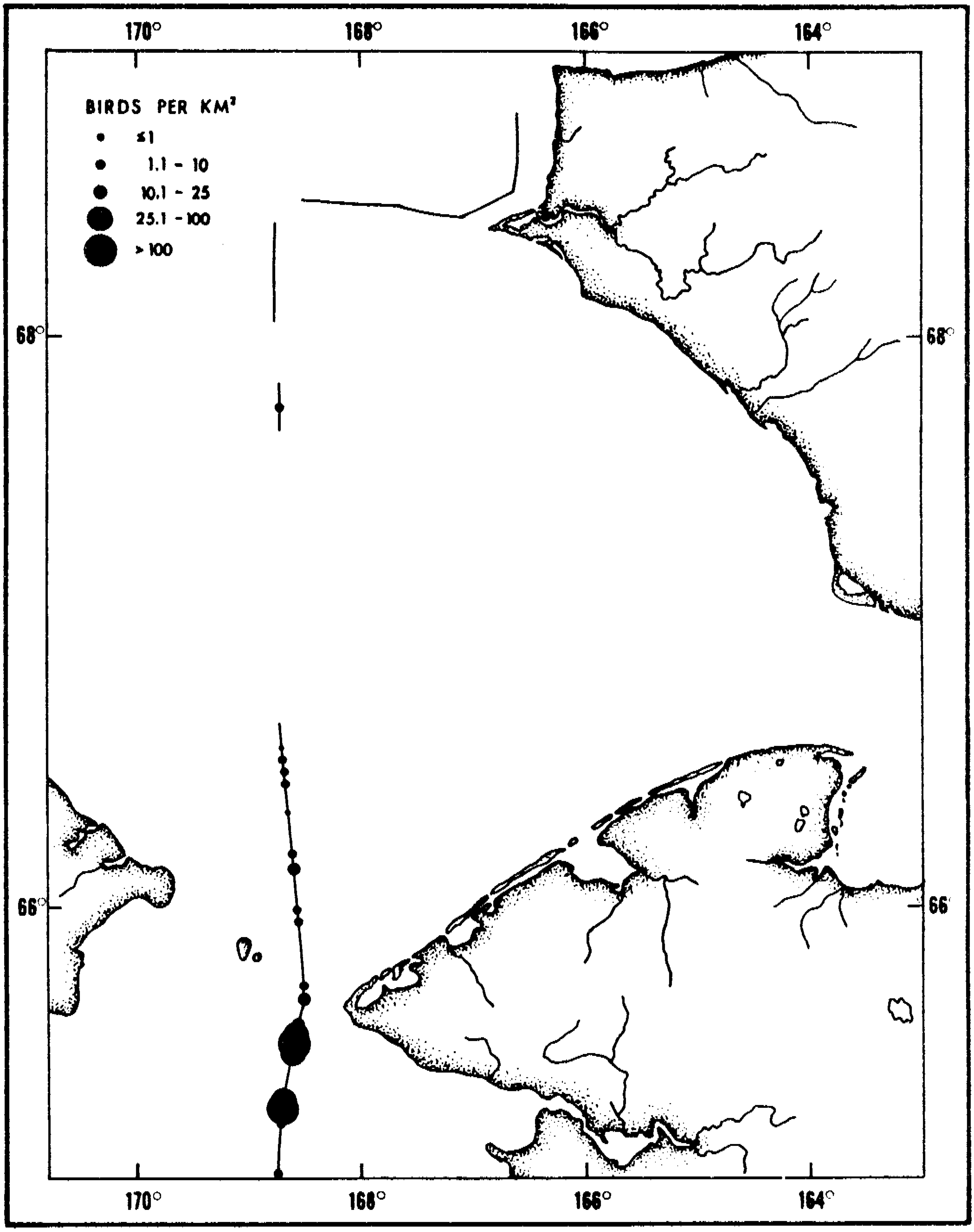


Figure 61. Distribution and abundance of Least Auklets in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

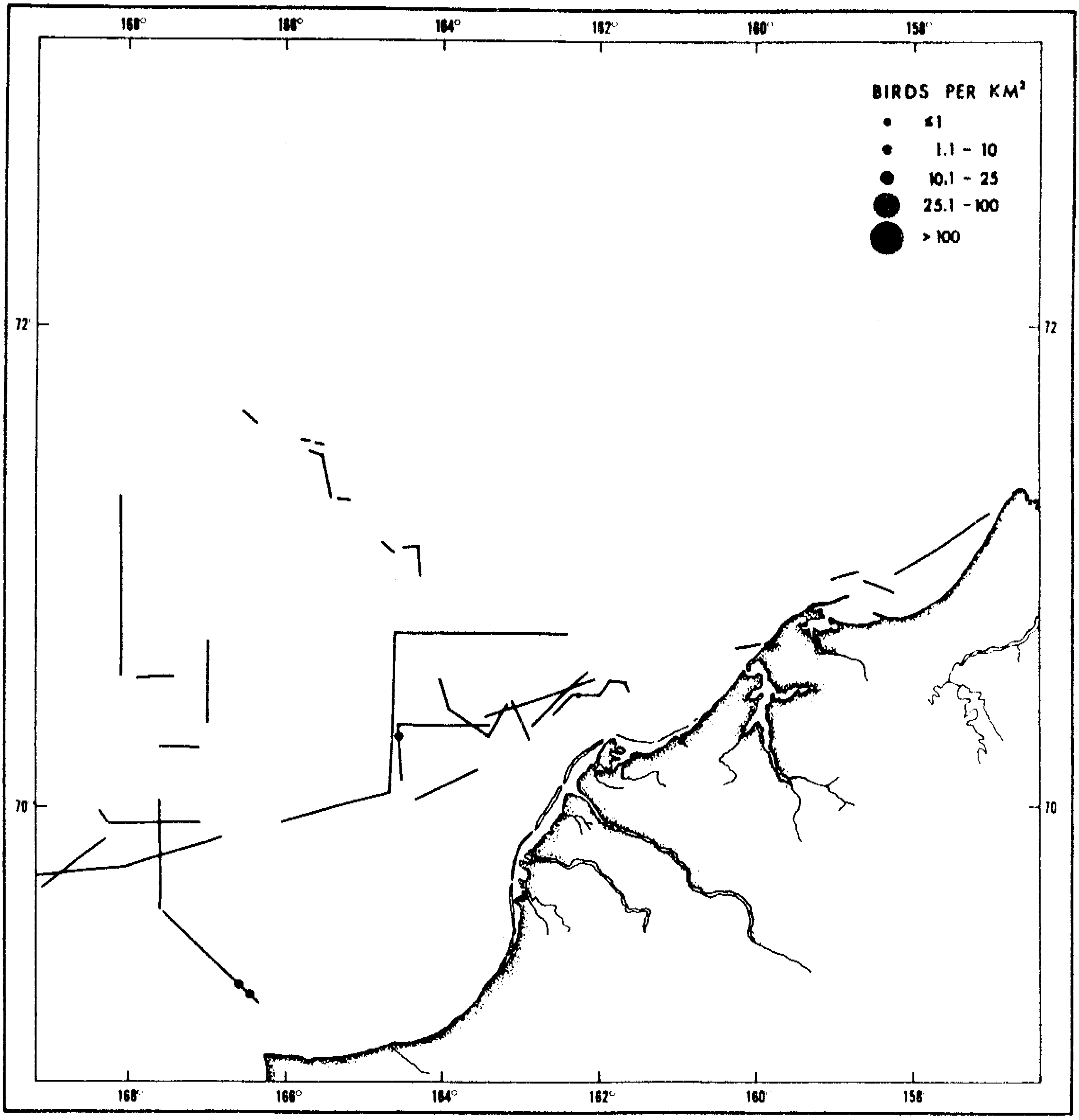


Figure 62. Distribution and abundance of Horned Puffins in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

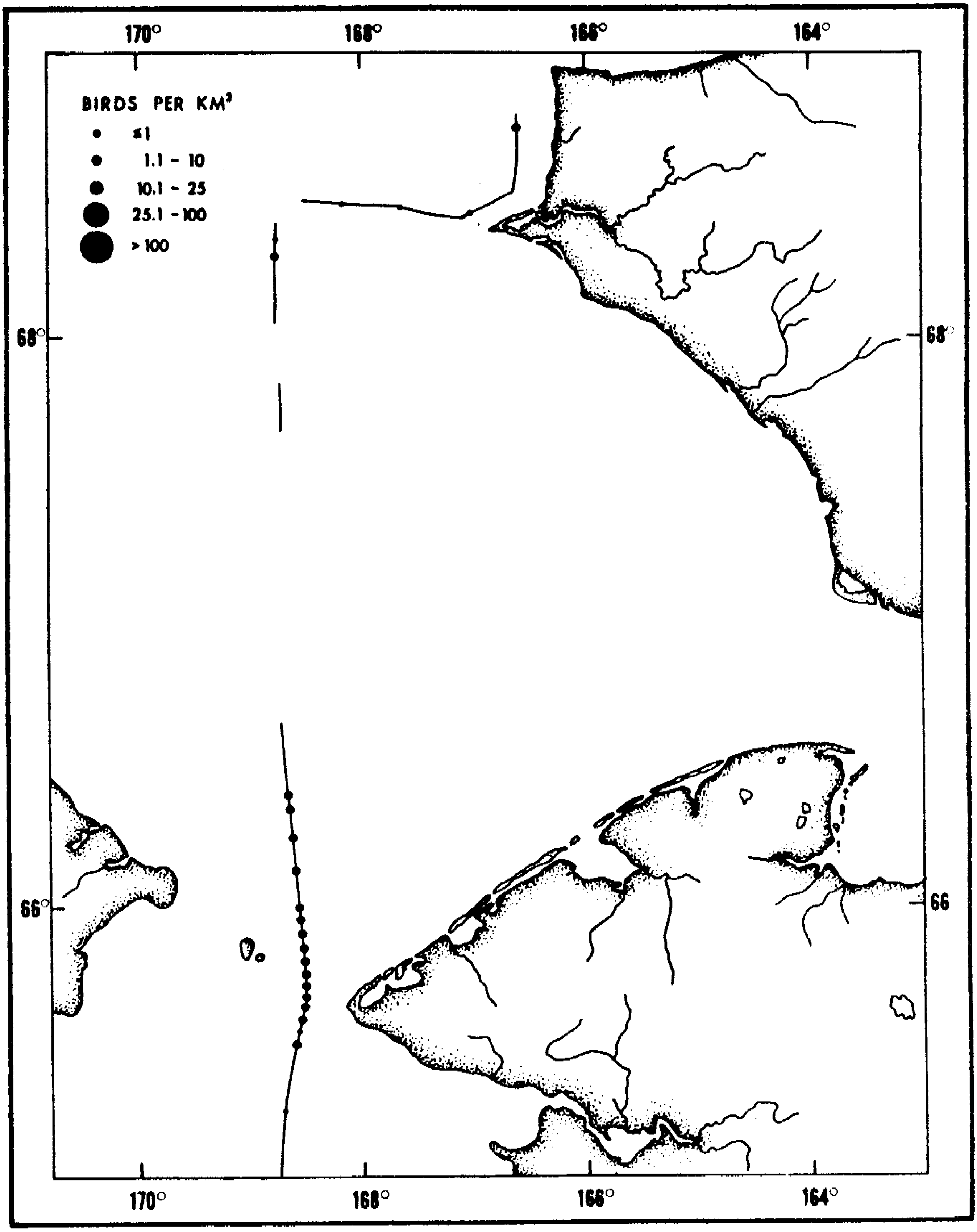


Figure 63. Distribution and abundance of Horned Puffins in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

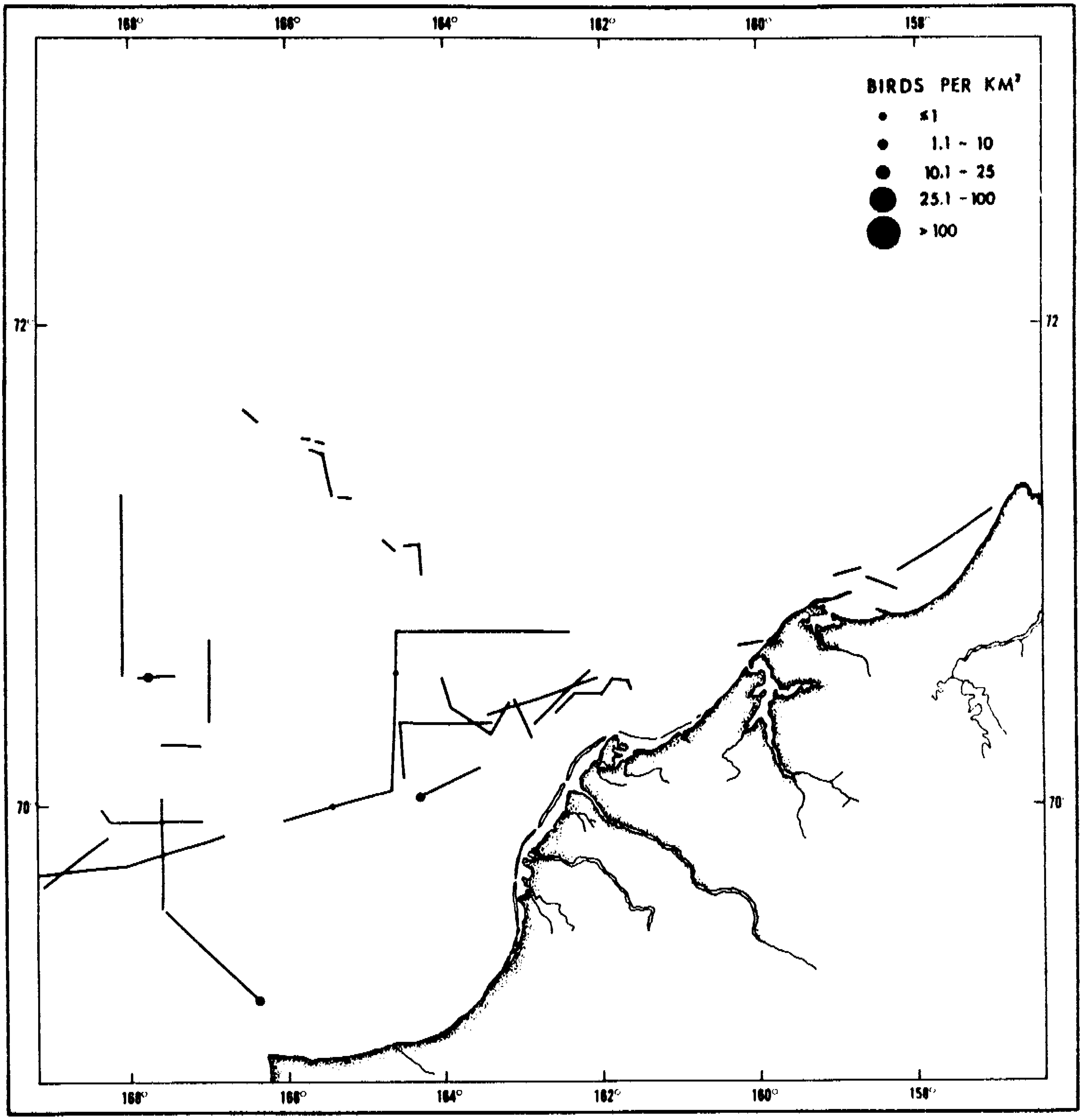


Figure 64. Distribution and abundance of Tufted Puffins in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

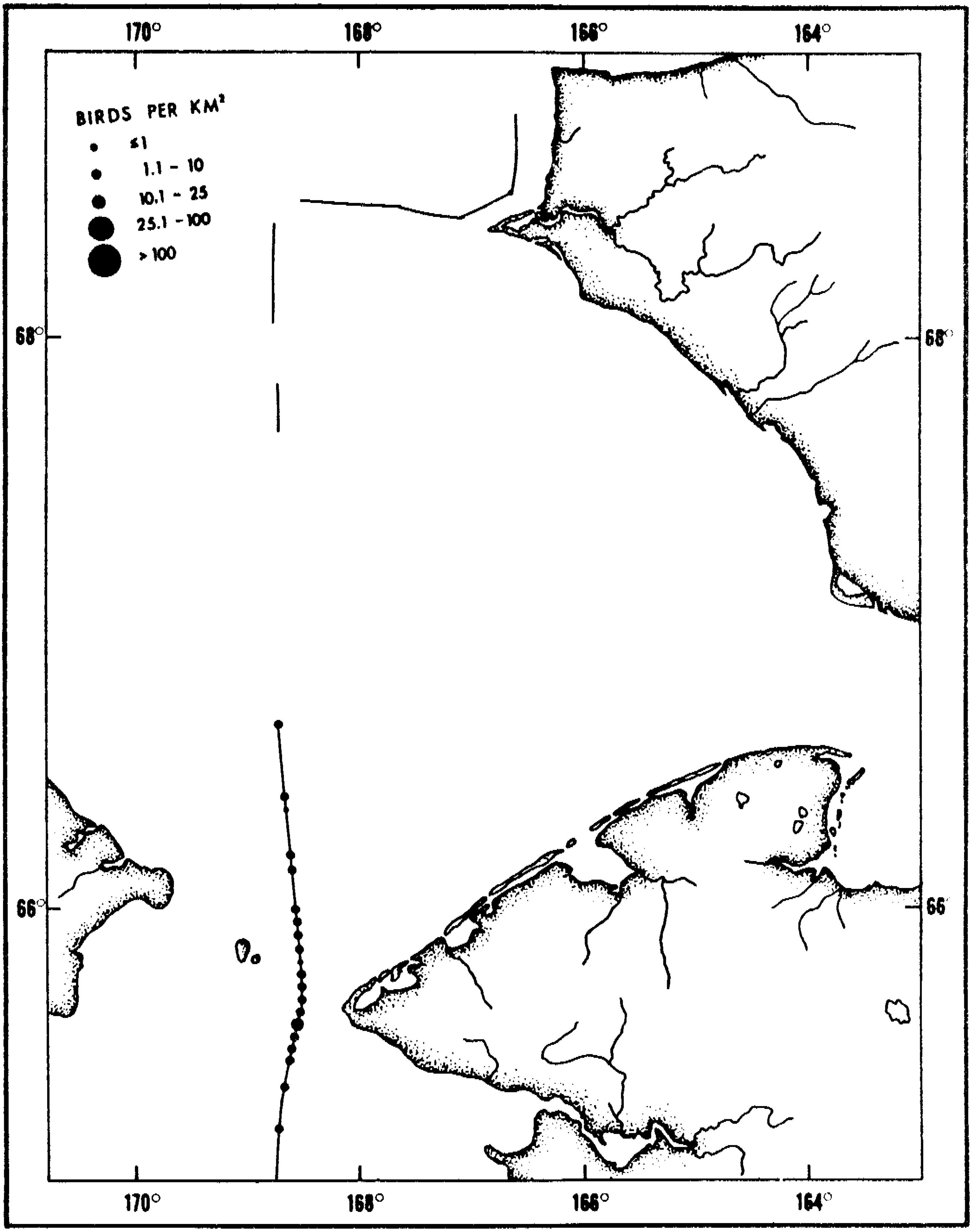


Figure 65. Distribution and abundance of Tufted Puffins in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

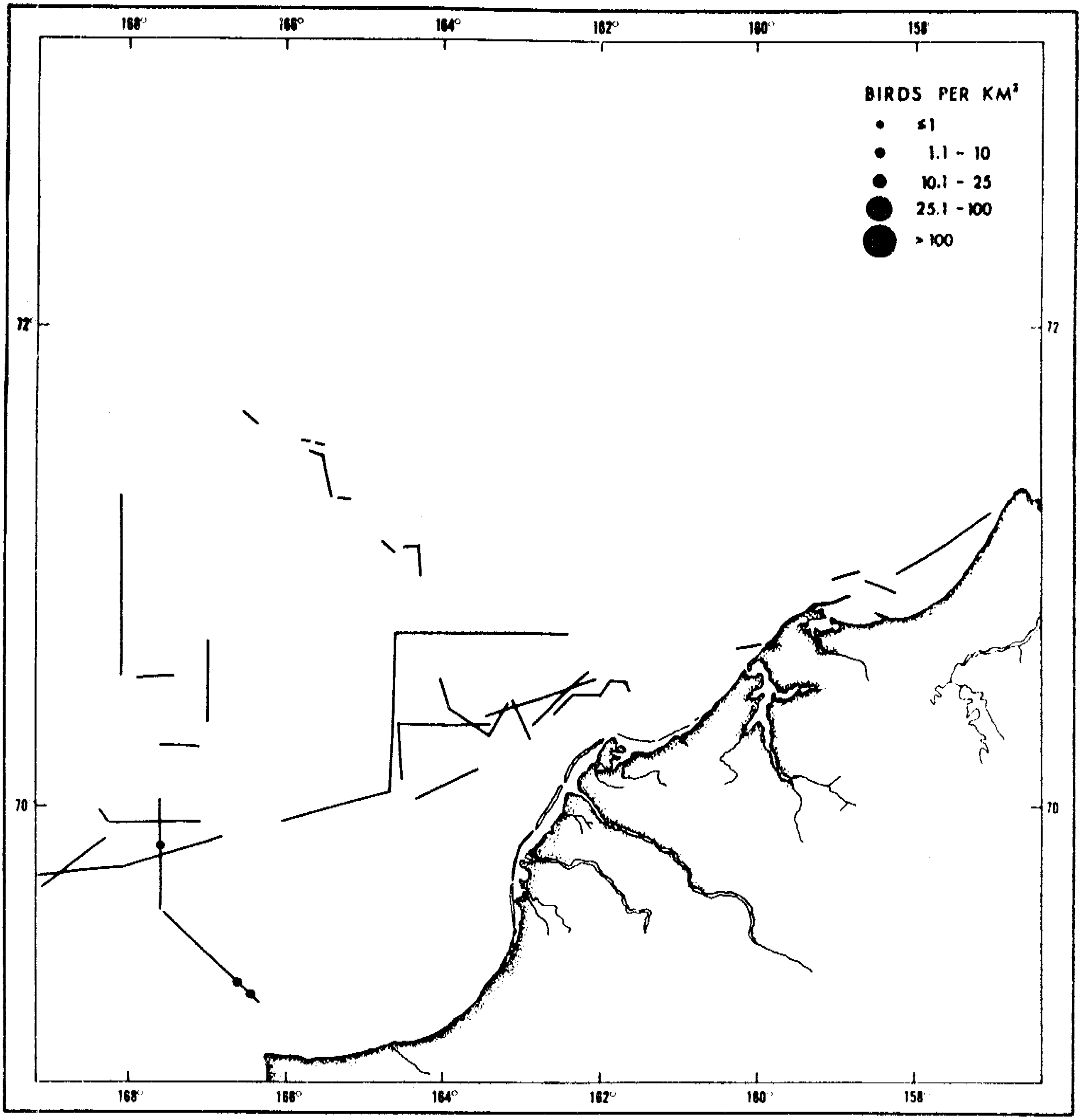


Figure 66. Distribution and abundance of large alcids in northern Chukchi Sea from 2 to 25 August 1975. (2GL875)

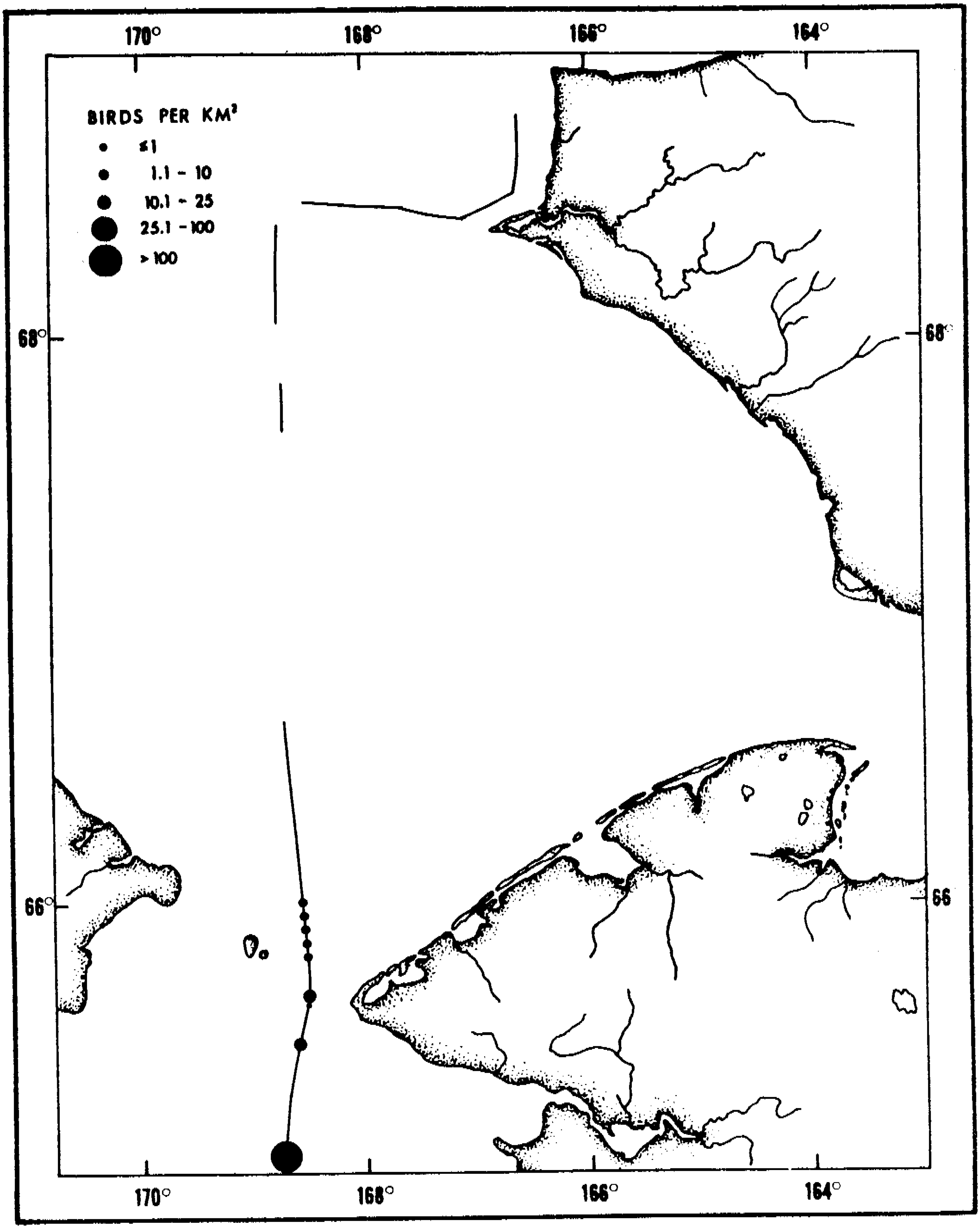


Figure 67. Distribution and abundance of large alcids in Bering Strait and southern Chukchi Sea from 31 July to 1 August 1975. (2GL875)

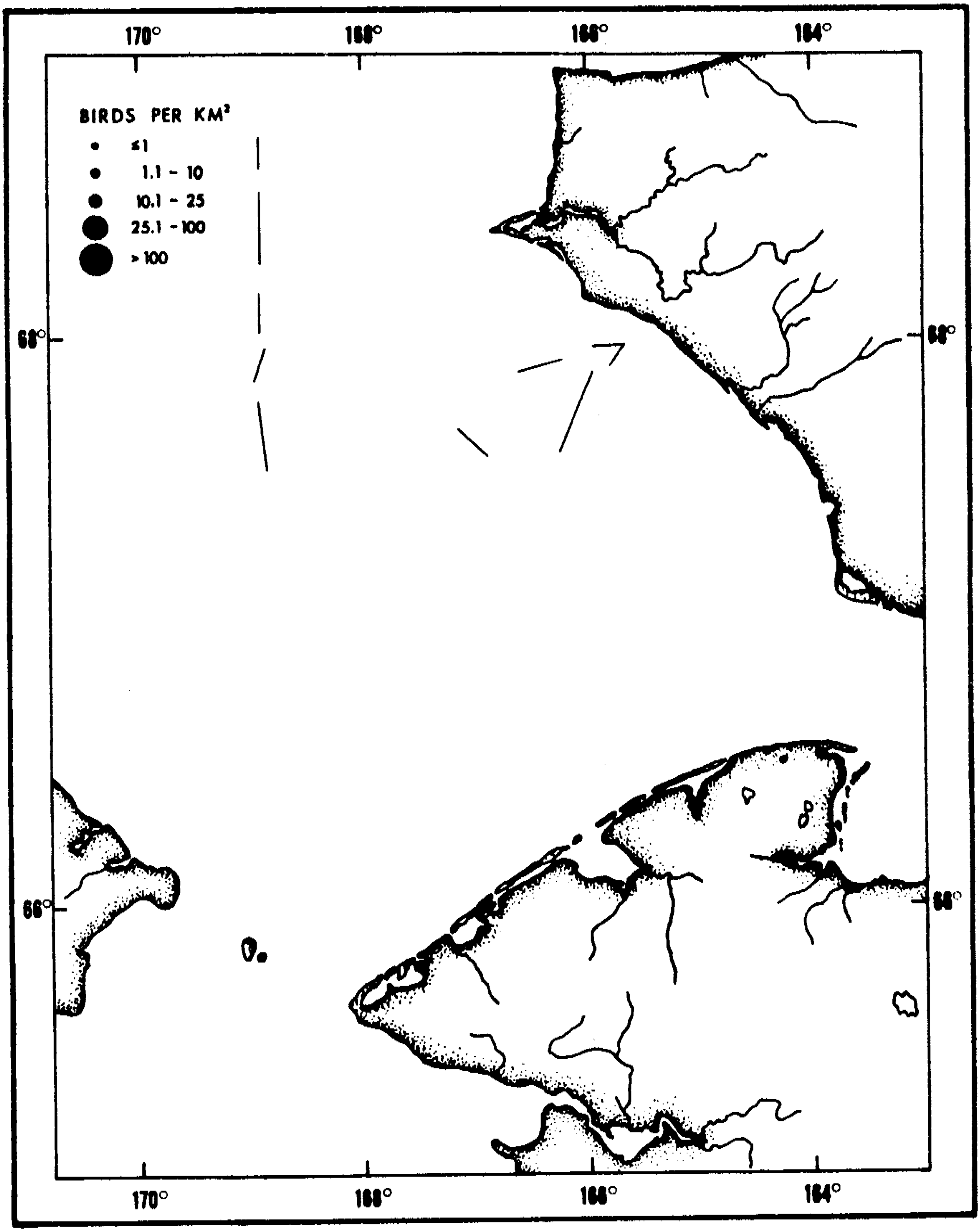


Figure 68. Cruise track during periods of observation in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

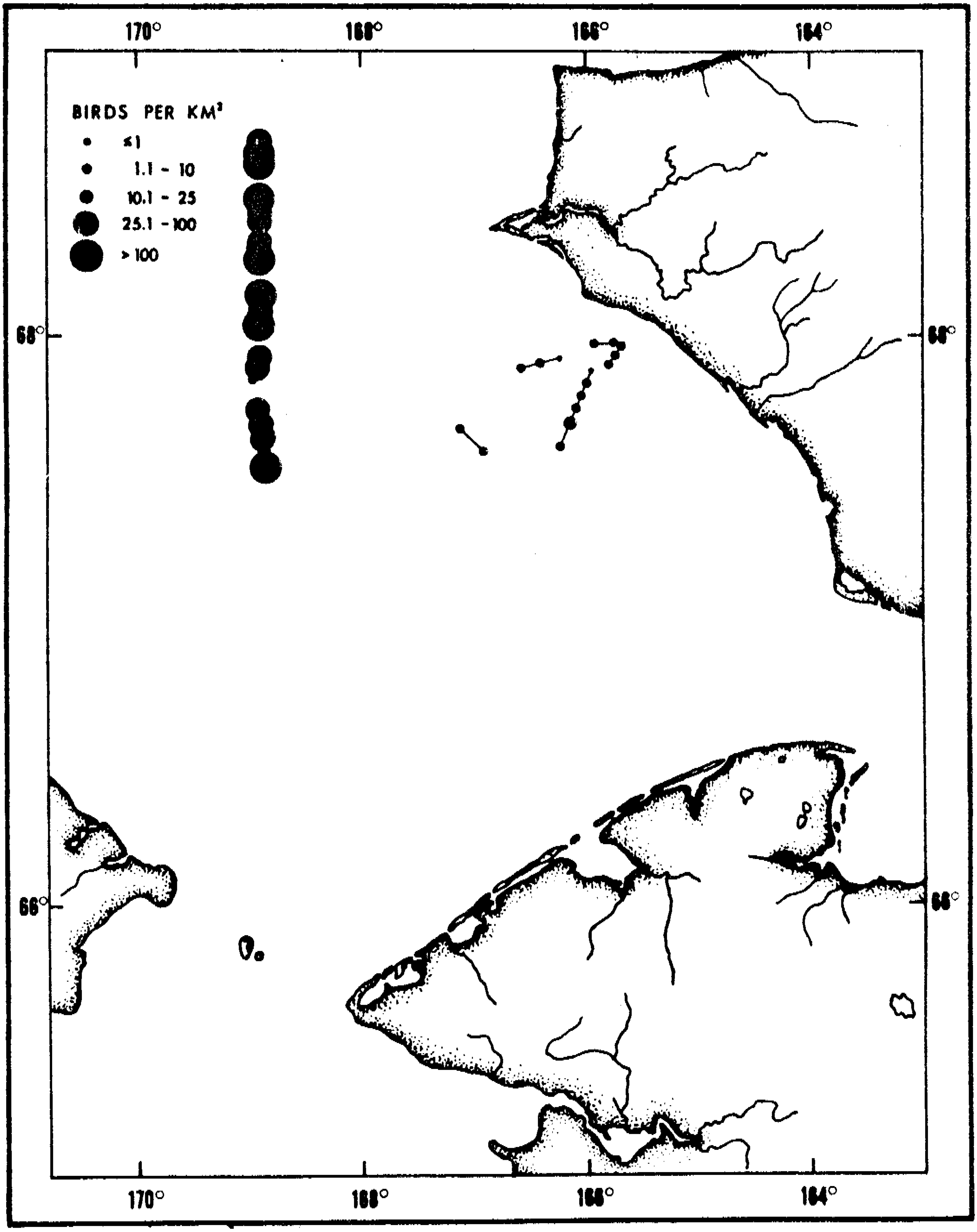


Figure 69. Distribution and abundance of seabirds in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

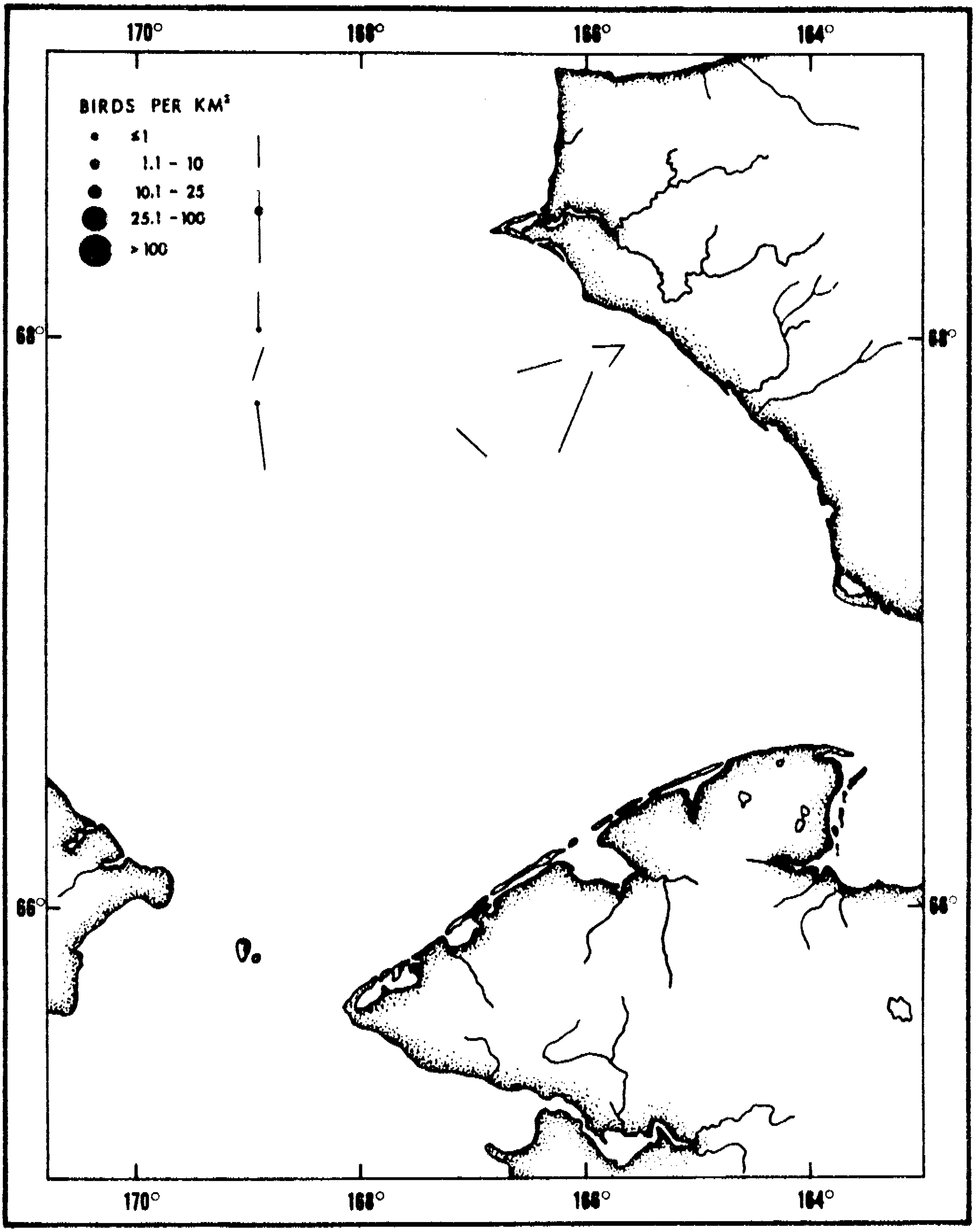


Figure 70. Distribution and abundance of loons in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

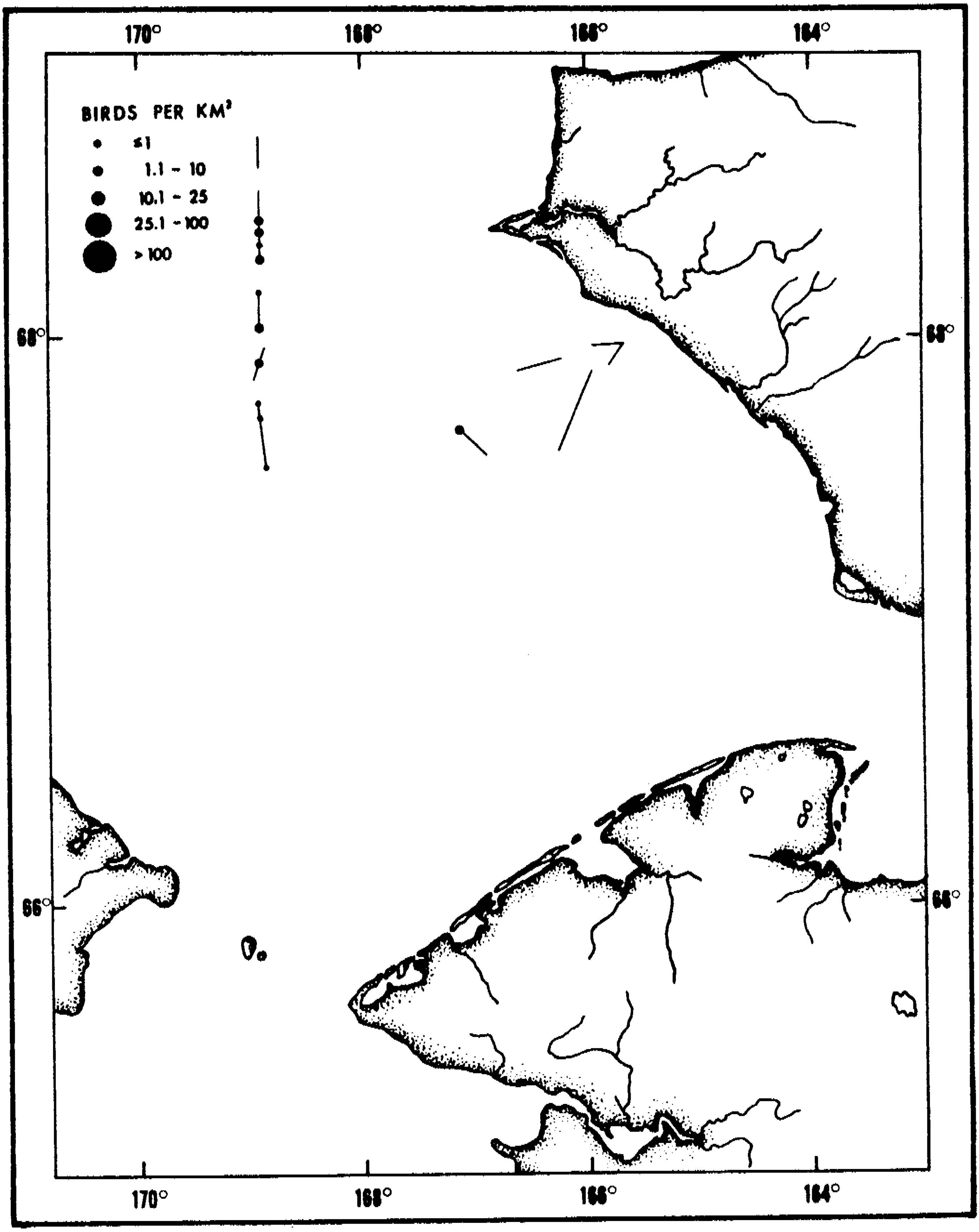


Figure 71. Distribution and abundance of Northern Fulmars in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

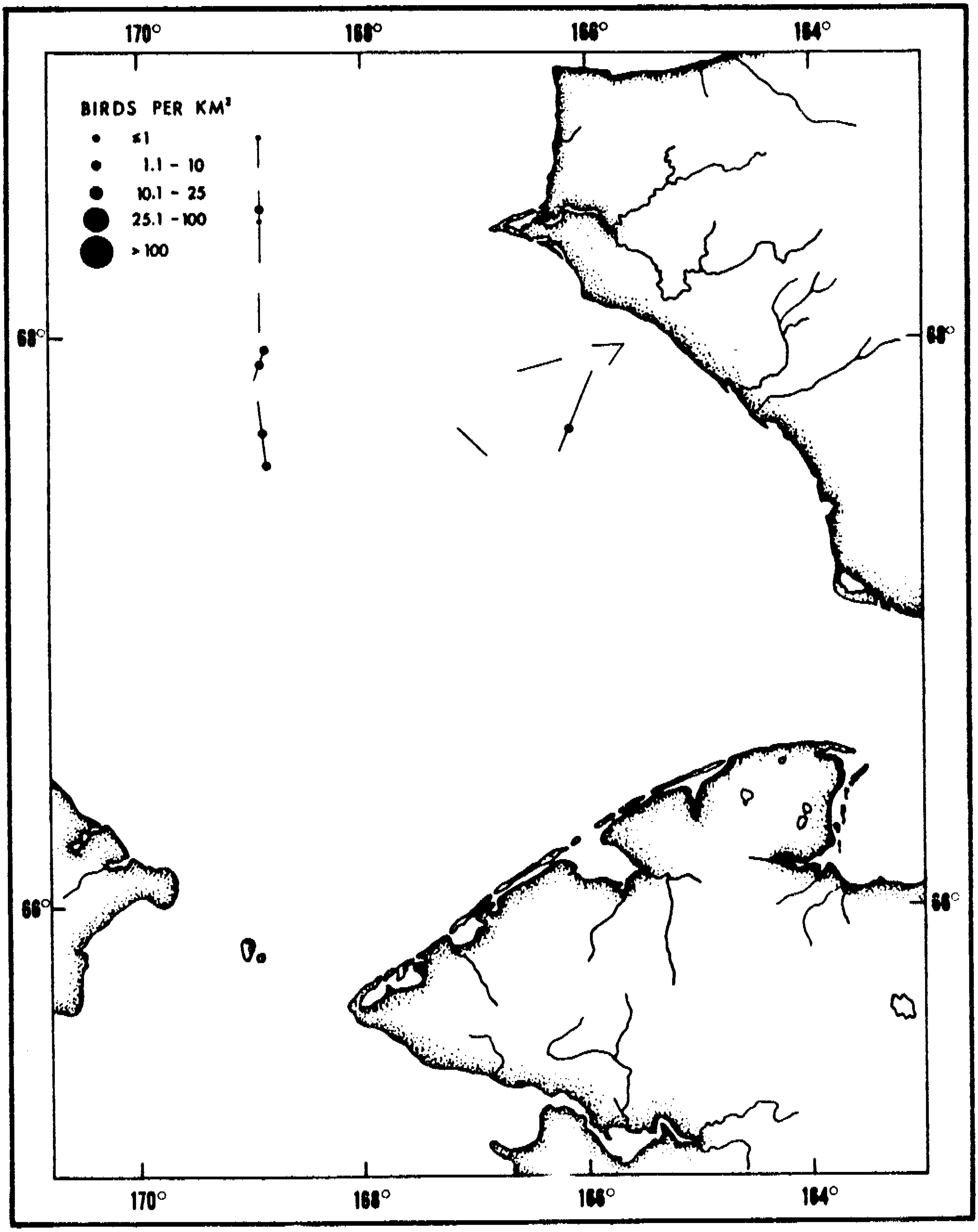


Figure 72. Distribution and abundance of shearwaters in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

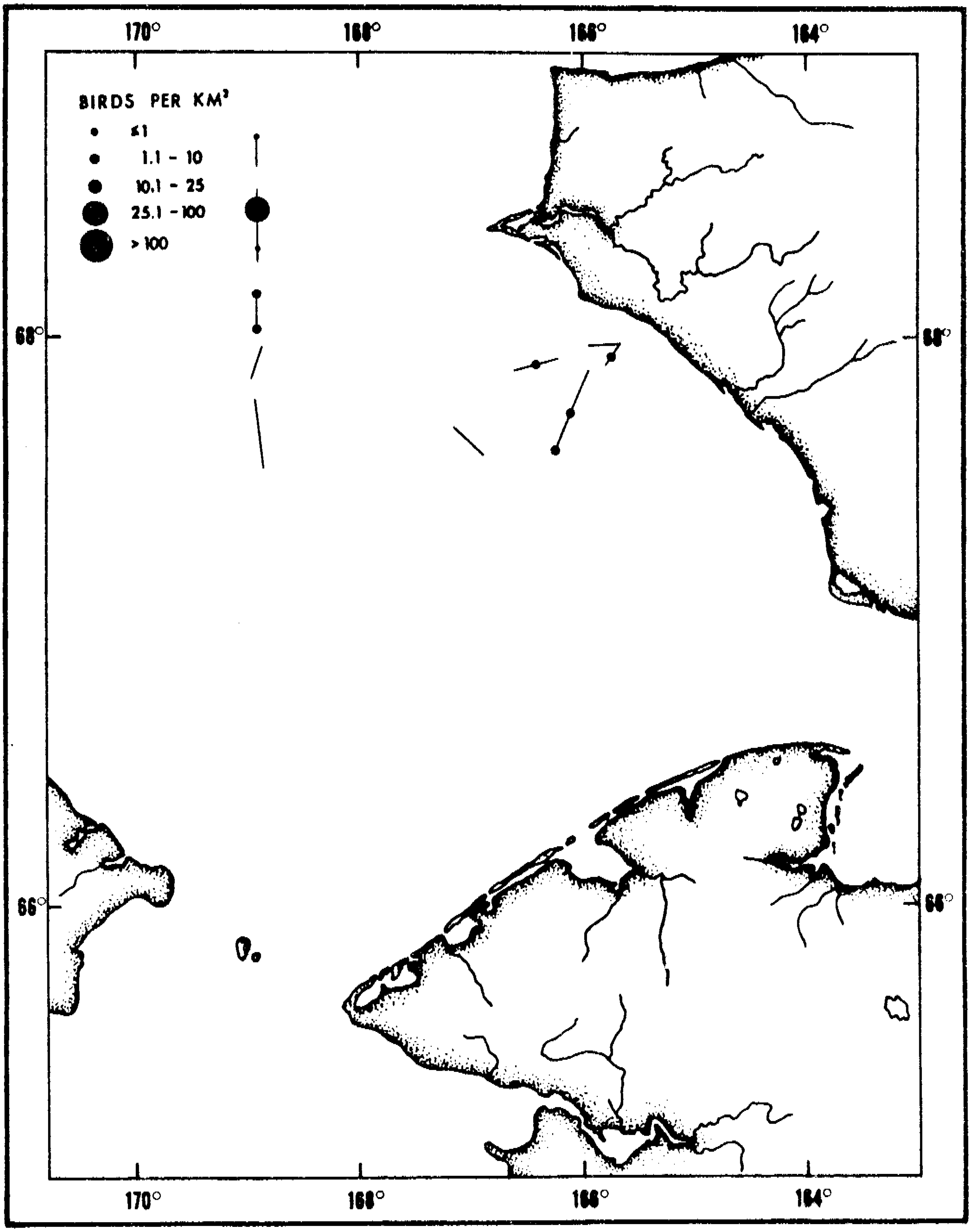


Figure 73. Distribution and abundance of Oldsquaws in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

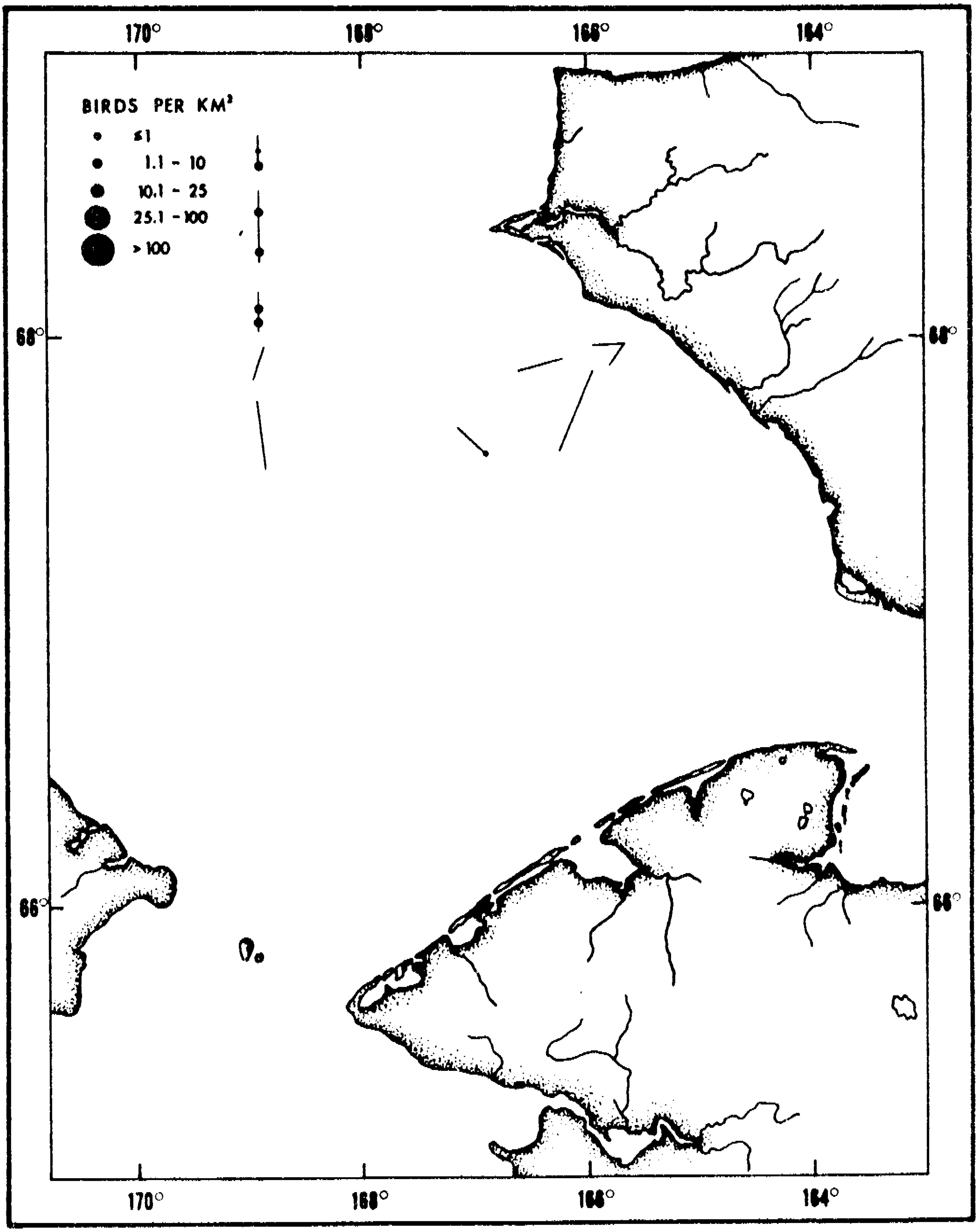


Figure 74. Distribution and abundance of eiders in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

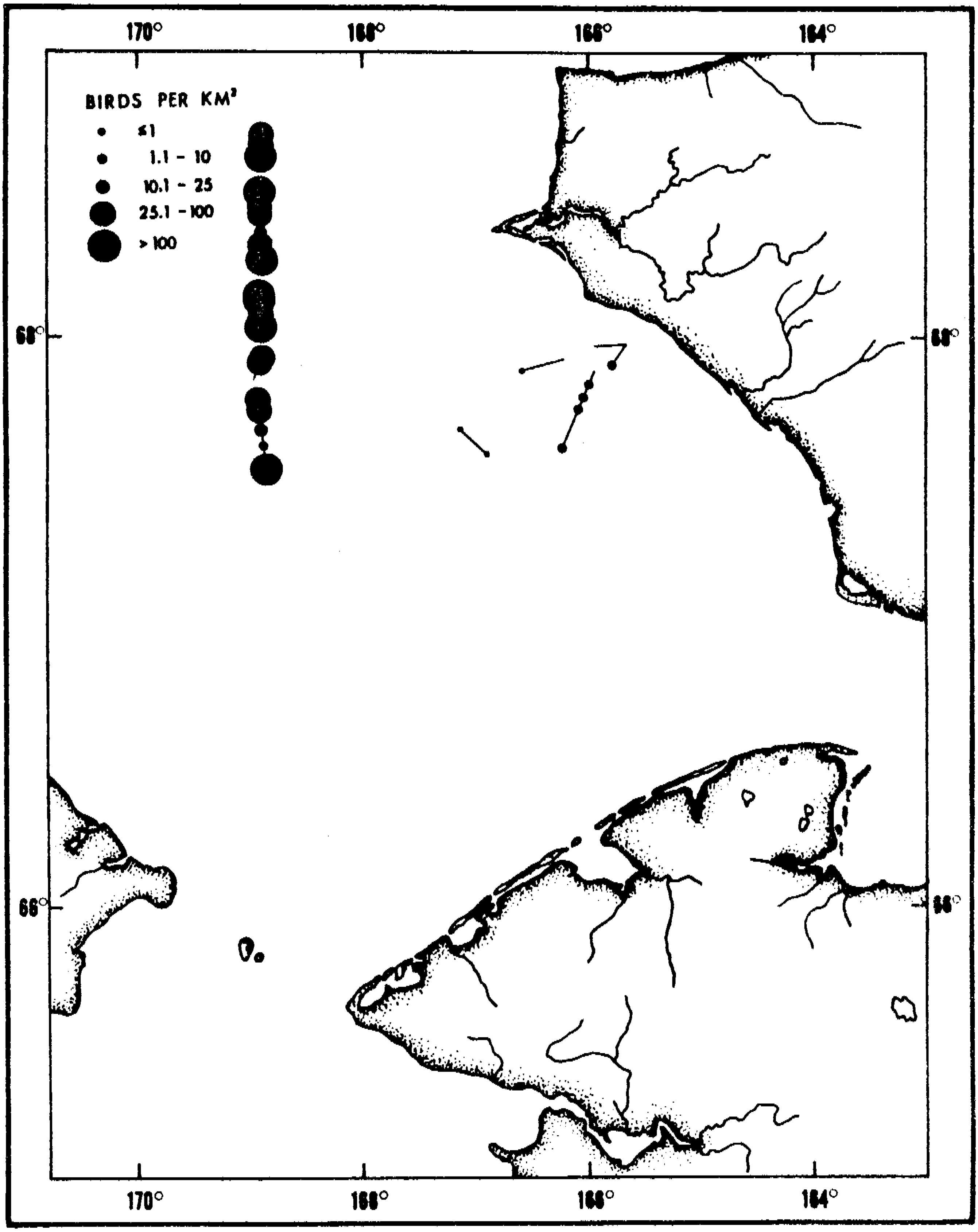


Figure 75. Distribution and abundance of phalaropes in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

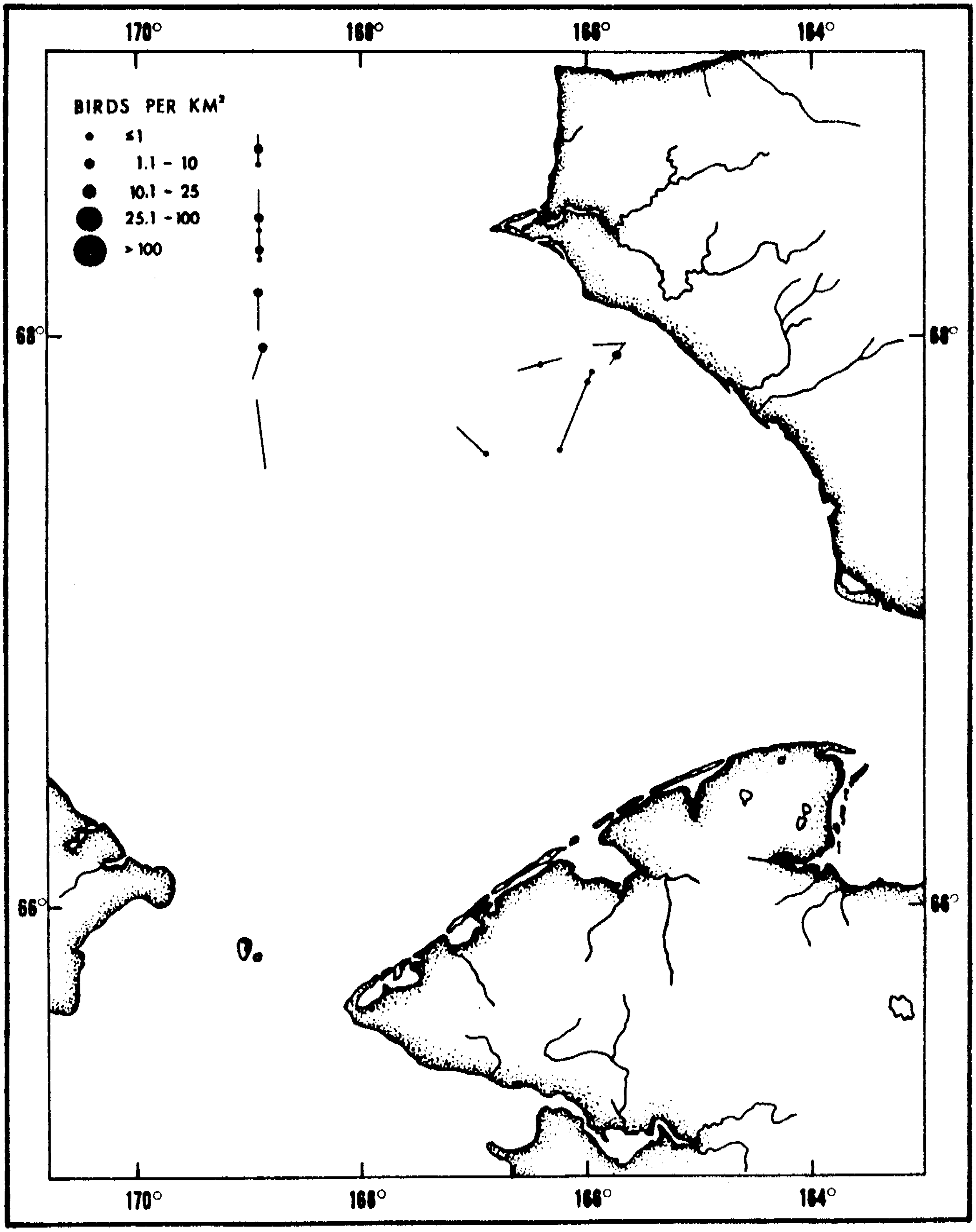


Figure 76. Distribution and abundance of Glaucous Gulls in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

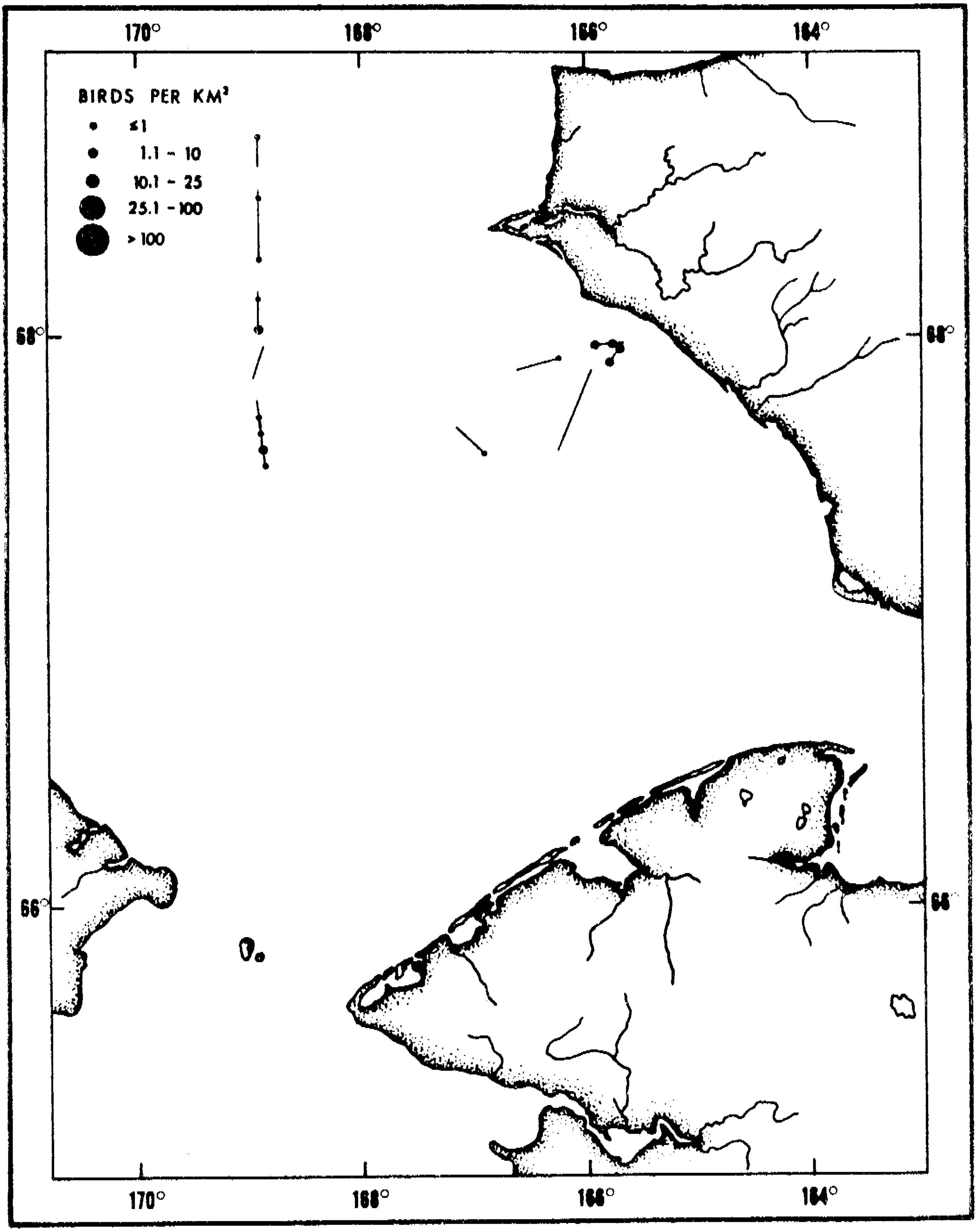


Figure 77. Distribution and abundance of Black-legged Kittiwakes in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

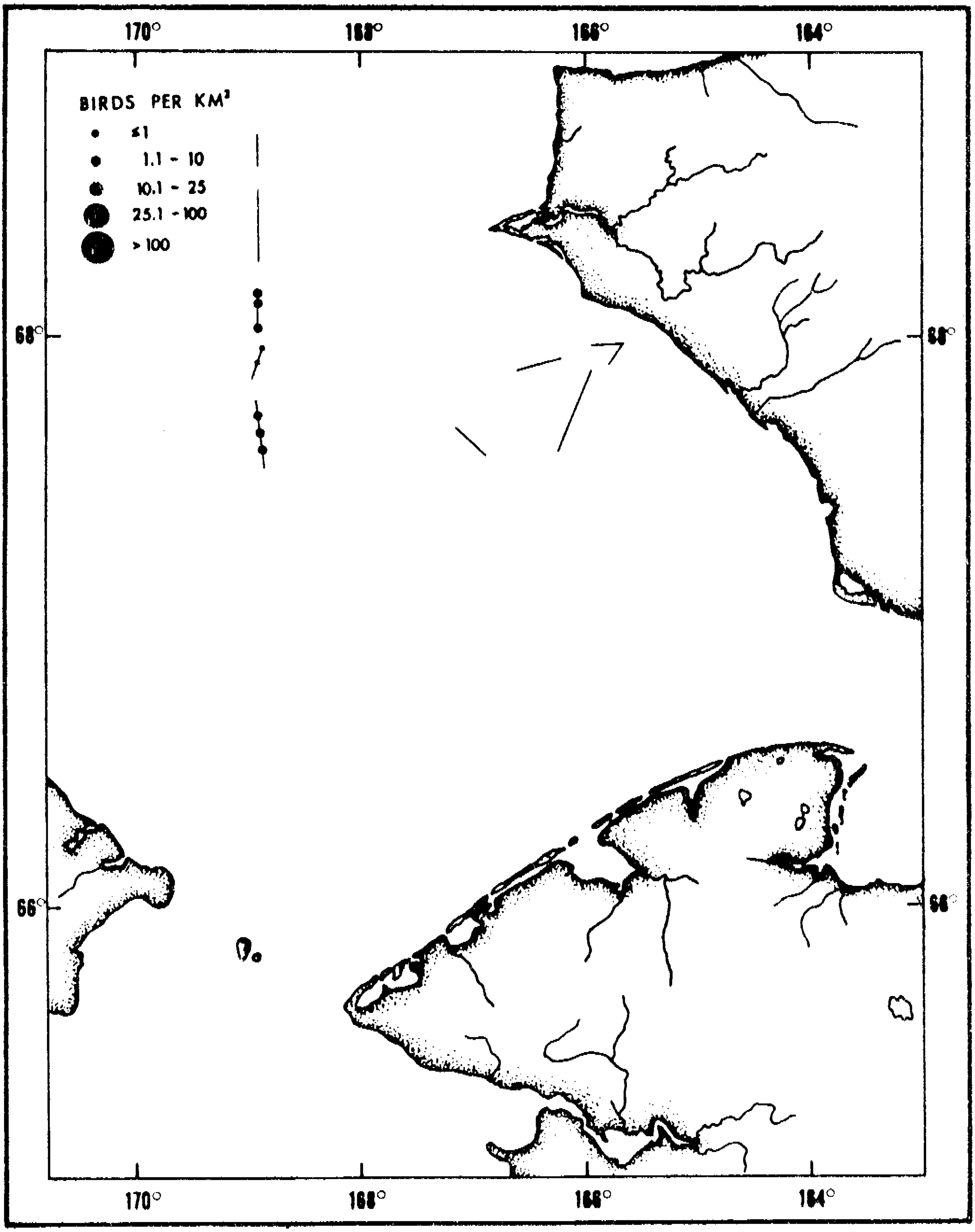


Figure 78. Distribution and abundance of Ross' Gulls in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

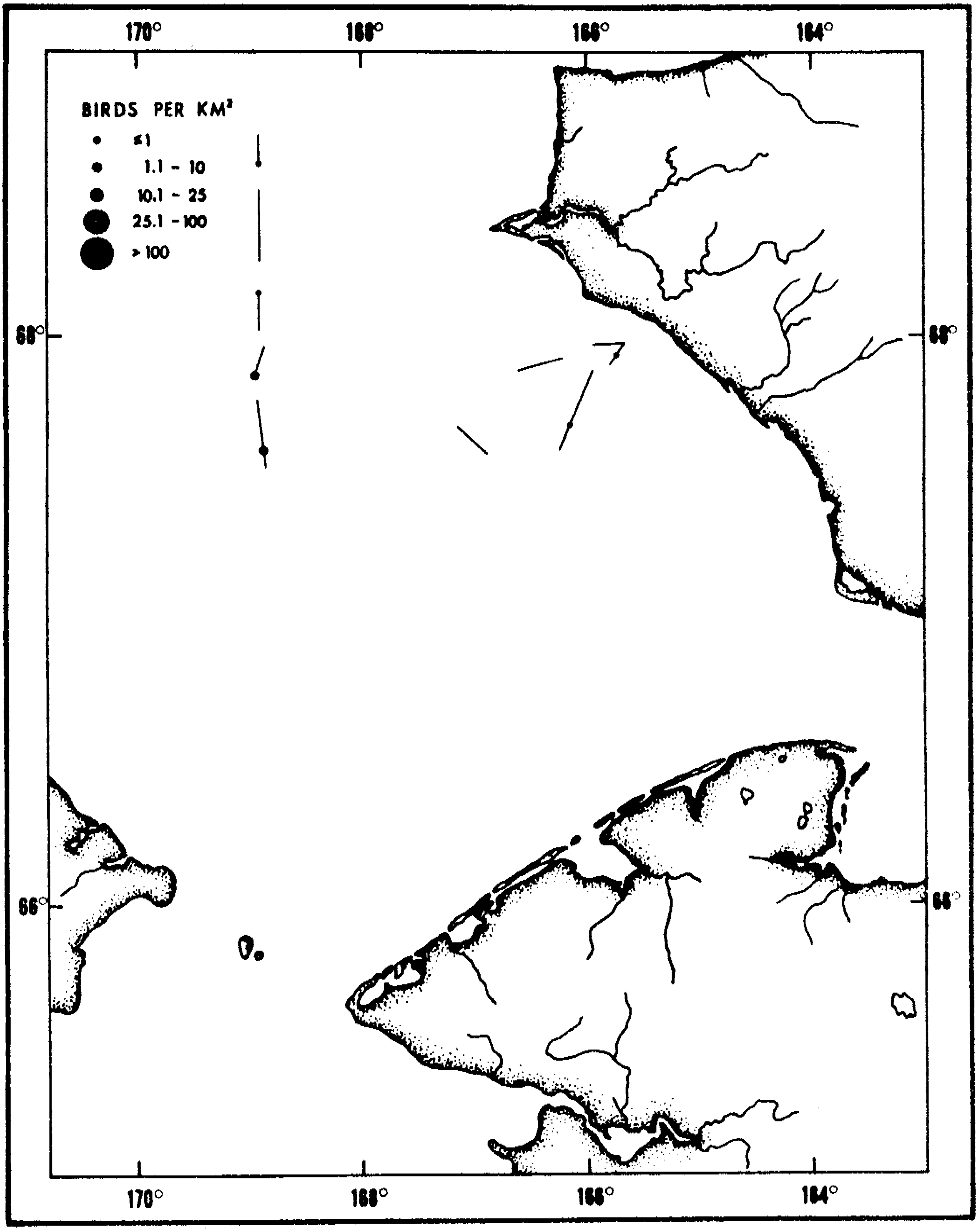


Figure 79. Distribution and abundance of murres in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

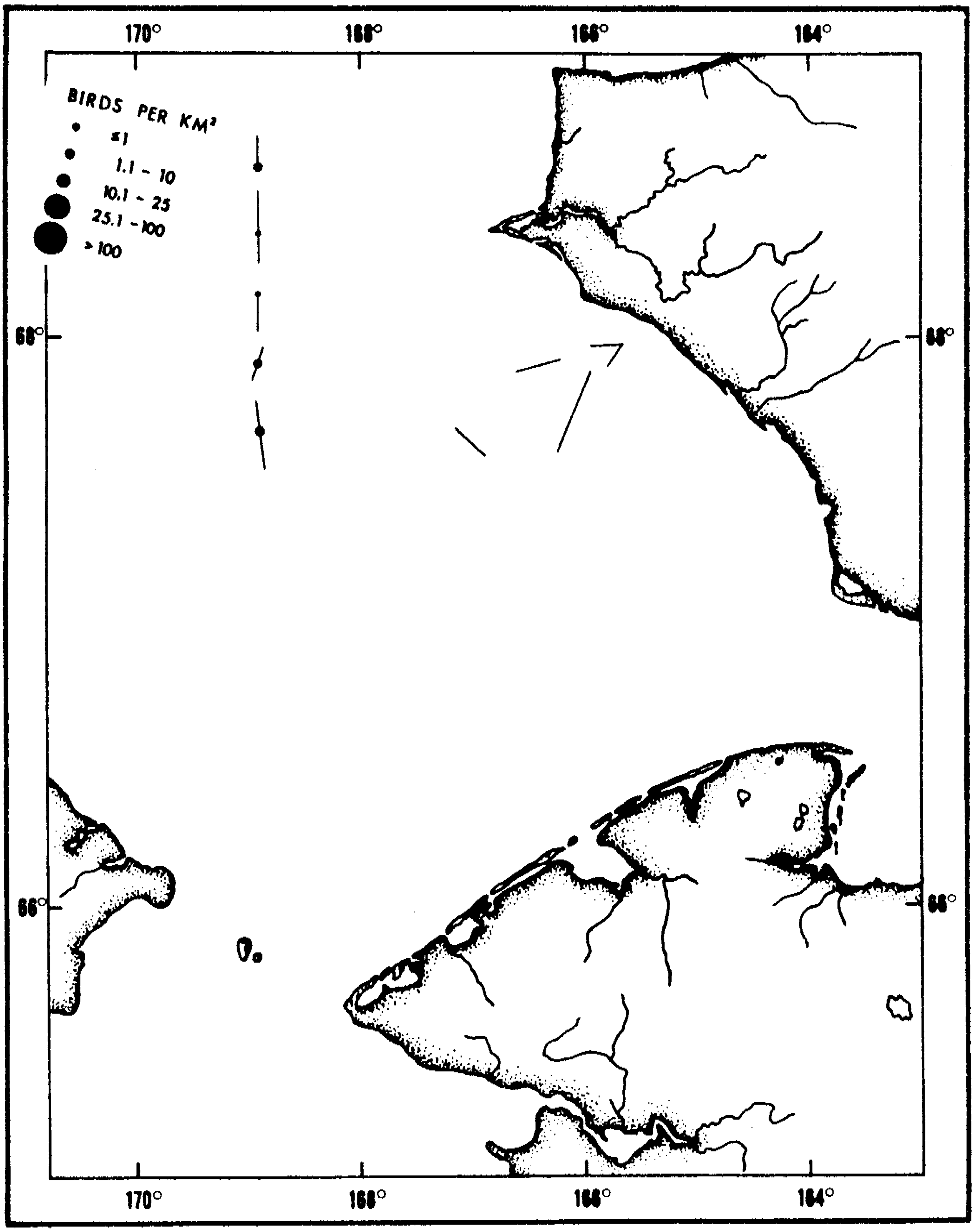


Figure 81. Distribution and abundance of Parakeet Auklets in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

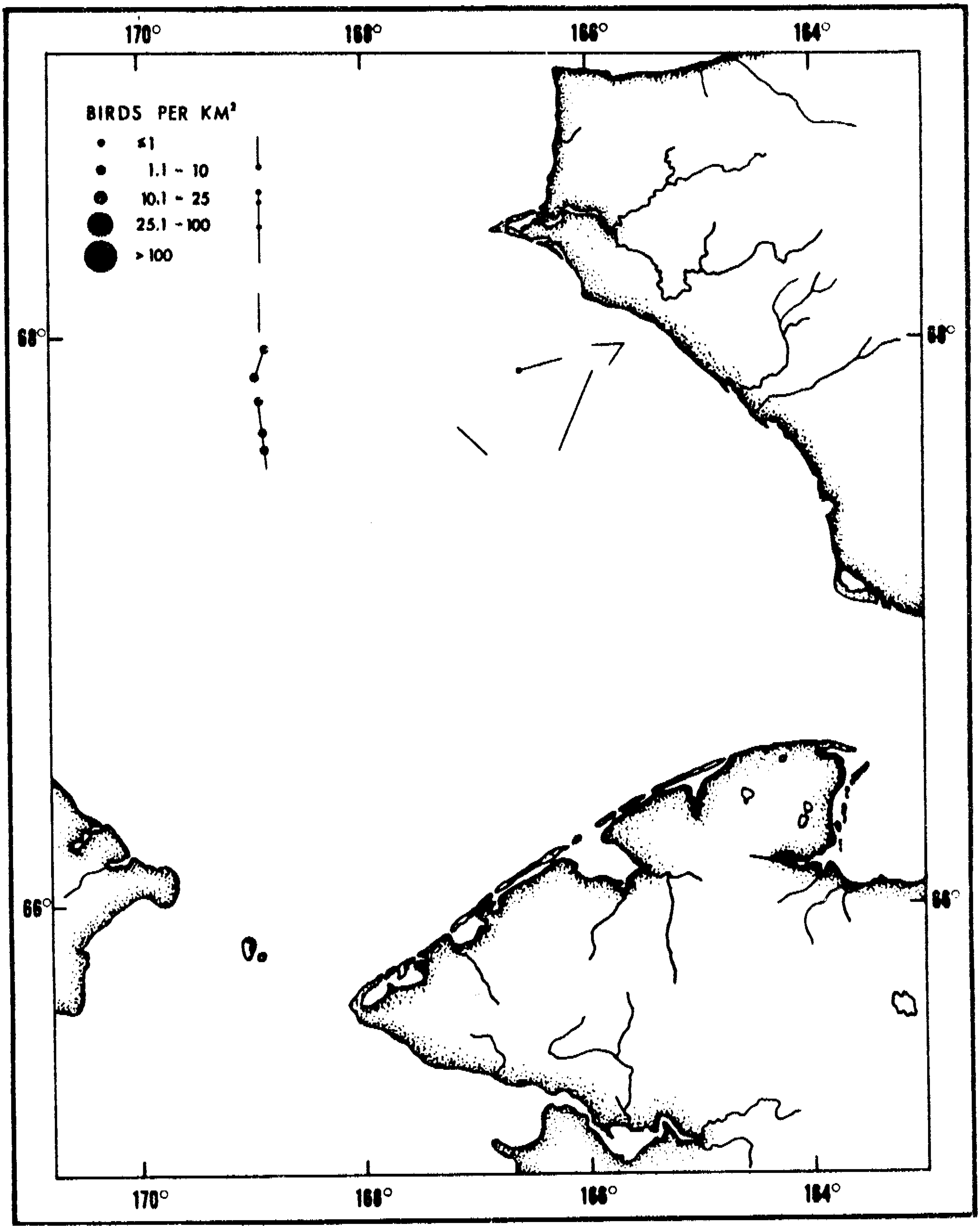


Figure 82. Distribution and abundance of Crested Auklets in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

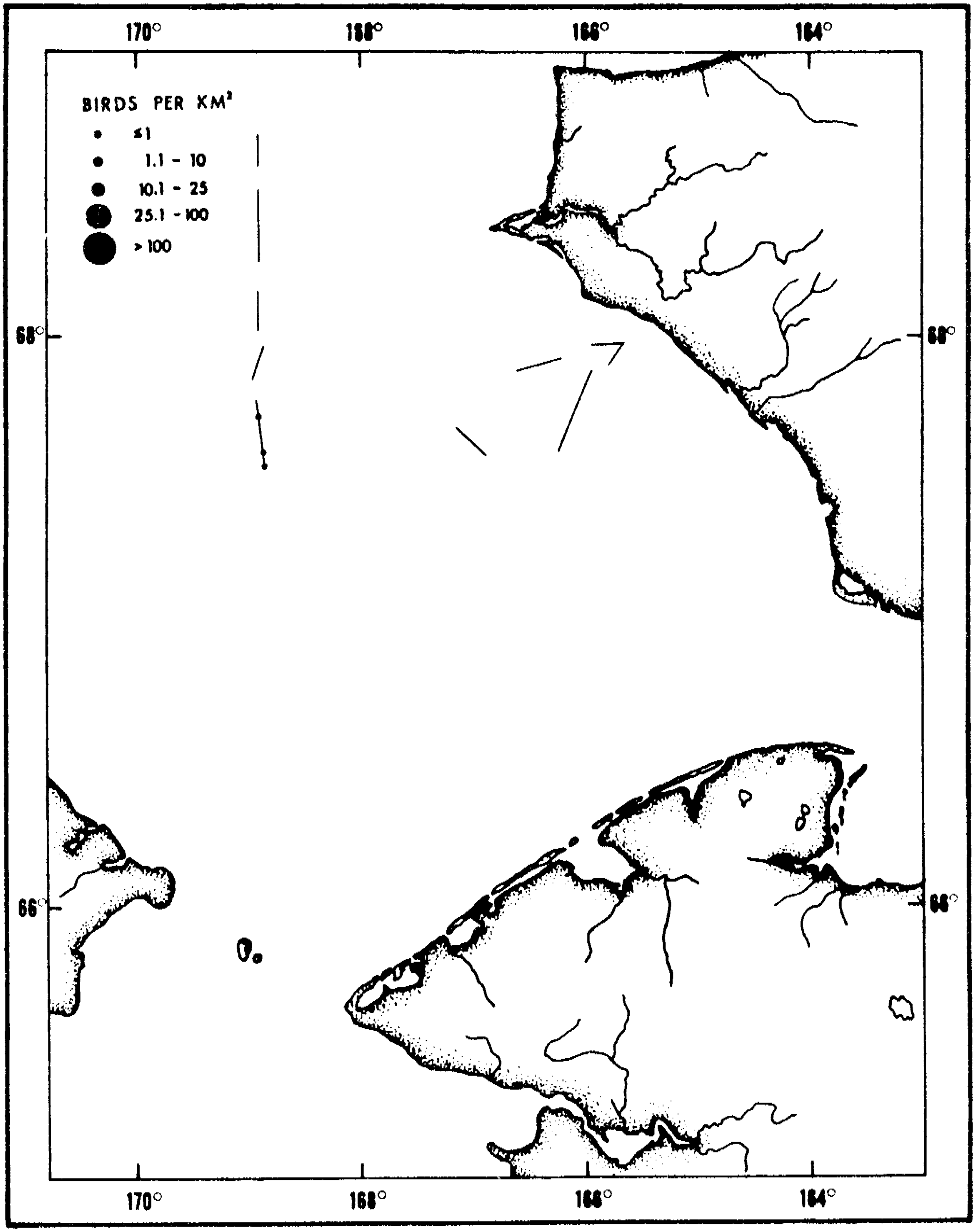


Figure 83. Distribution and abundance of Least Auklets in Bering Strait and southern Chukchi Sea from 28 to 29 September 1976. (2GL976)

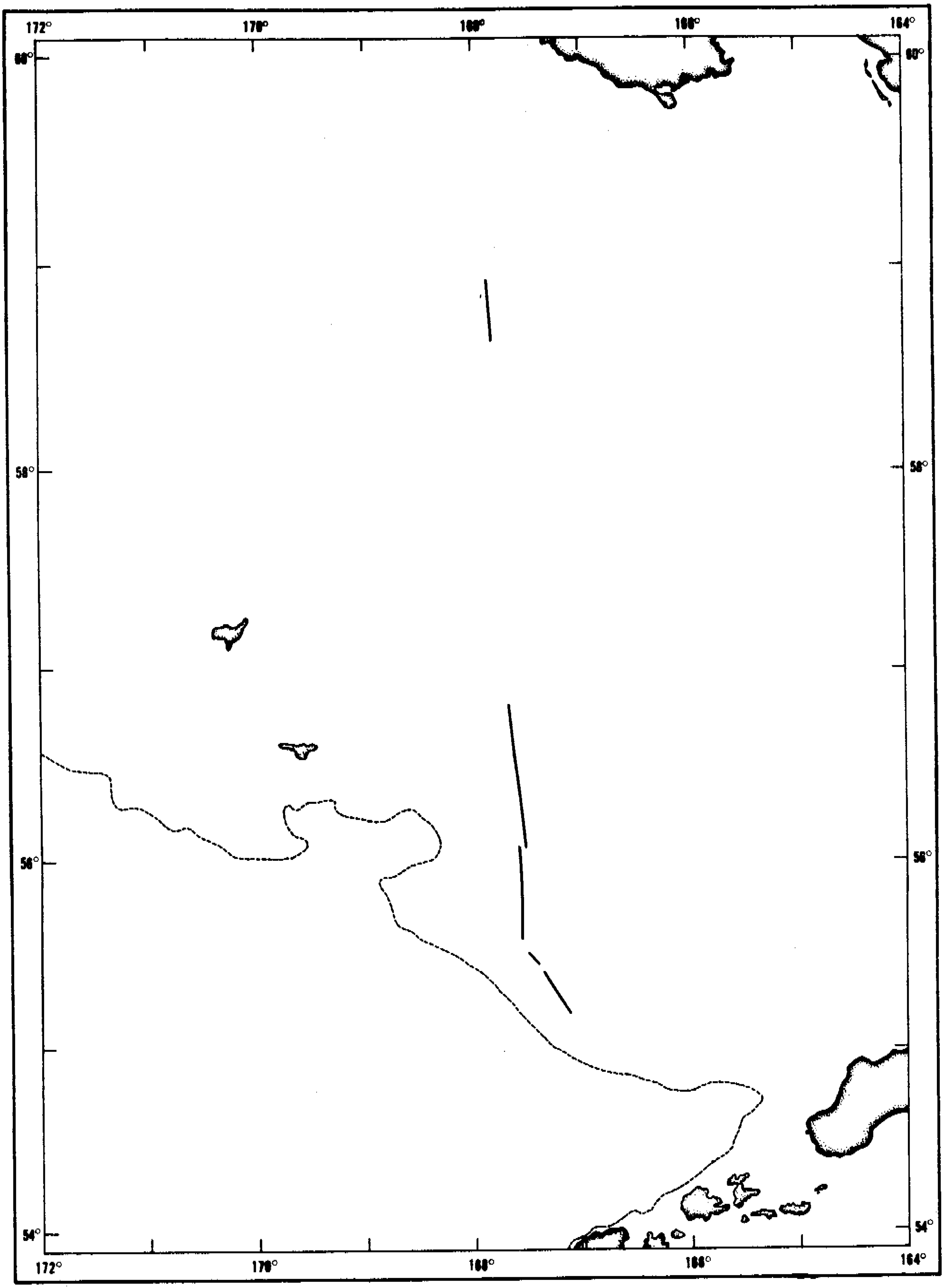


Figure 84. Cruise track during periods of observation in southern Bering Sea from 14 to 15 May 1978. (1SR578)

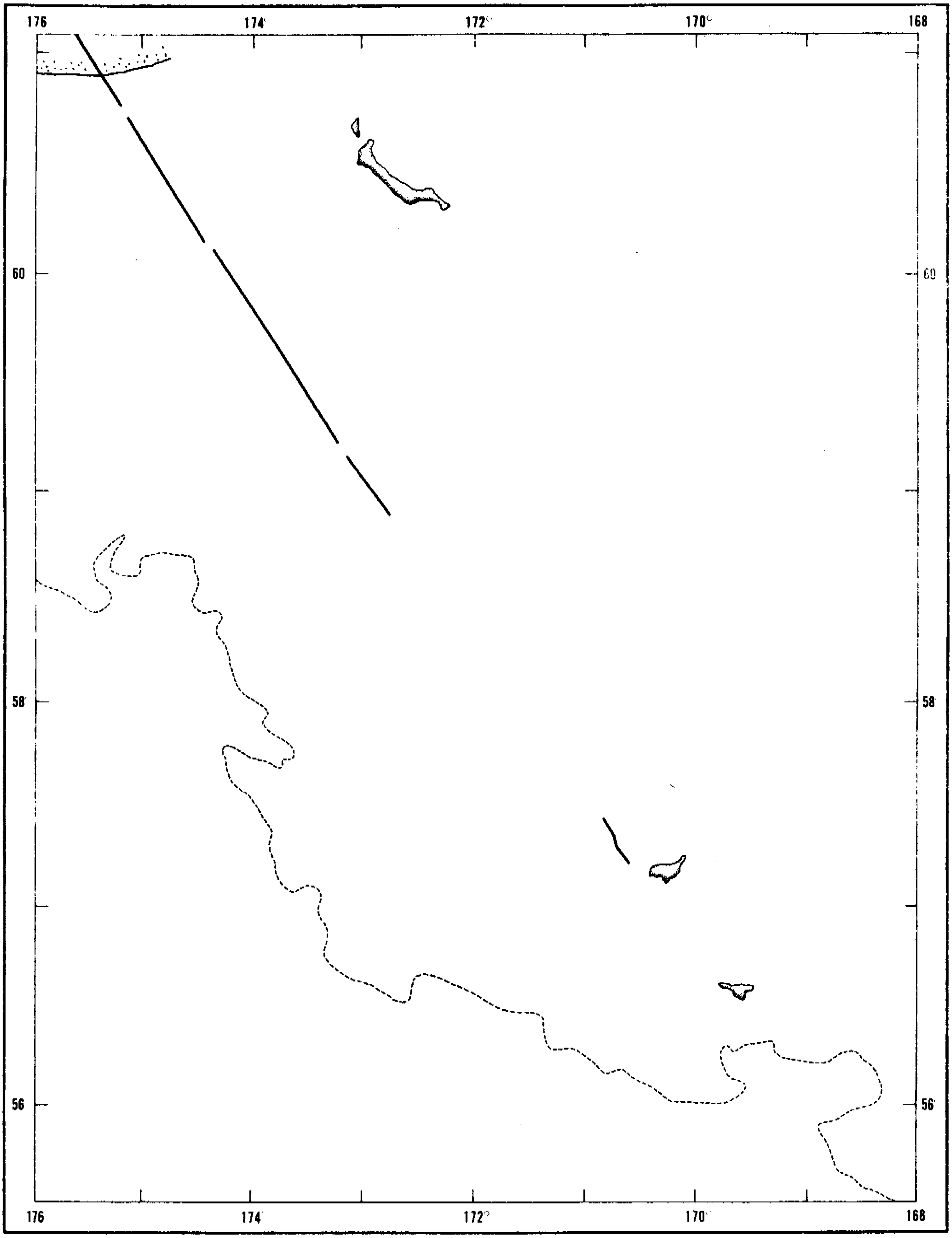


Figure 85. Cruise track during periods of observation in central Bering Sea from 2 to 3 May 1978. (1SR578)

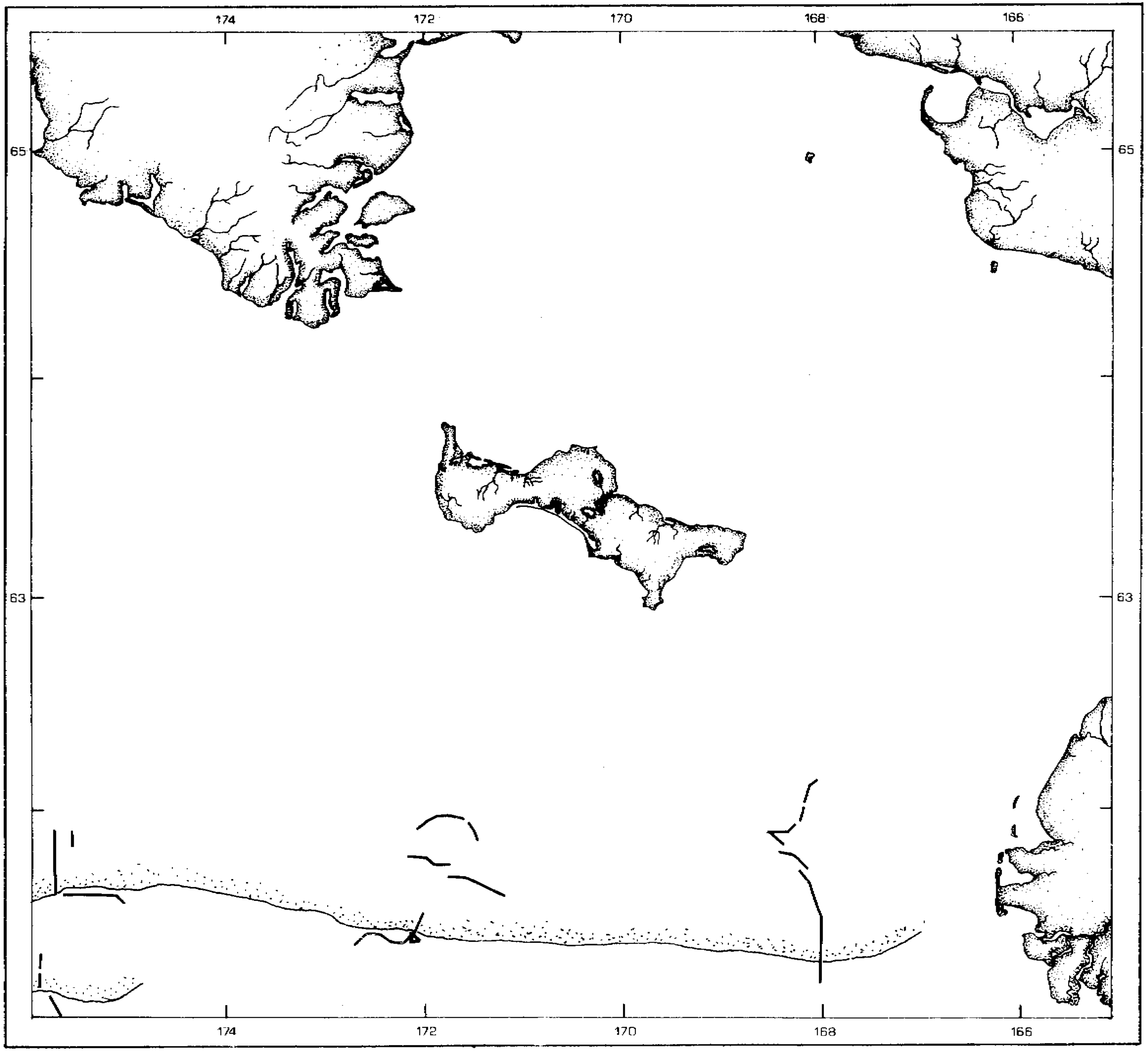


Figure 86. Cruise track during periods of observation in northern Bering Sea from 3 to 13 May 1978. (1SR578)

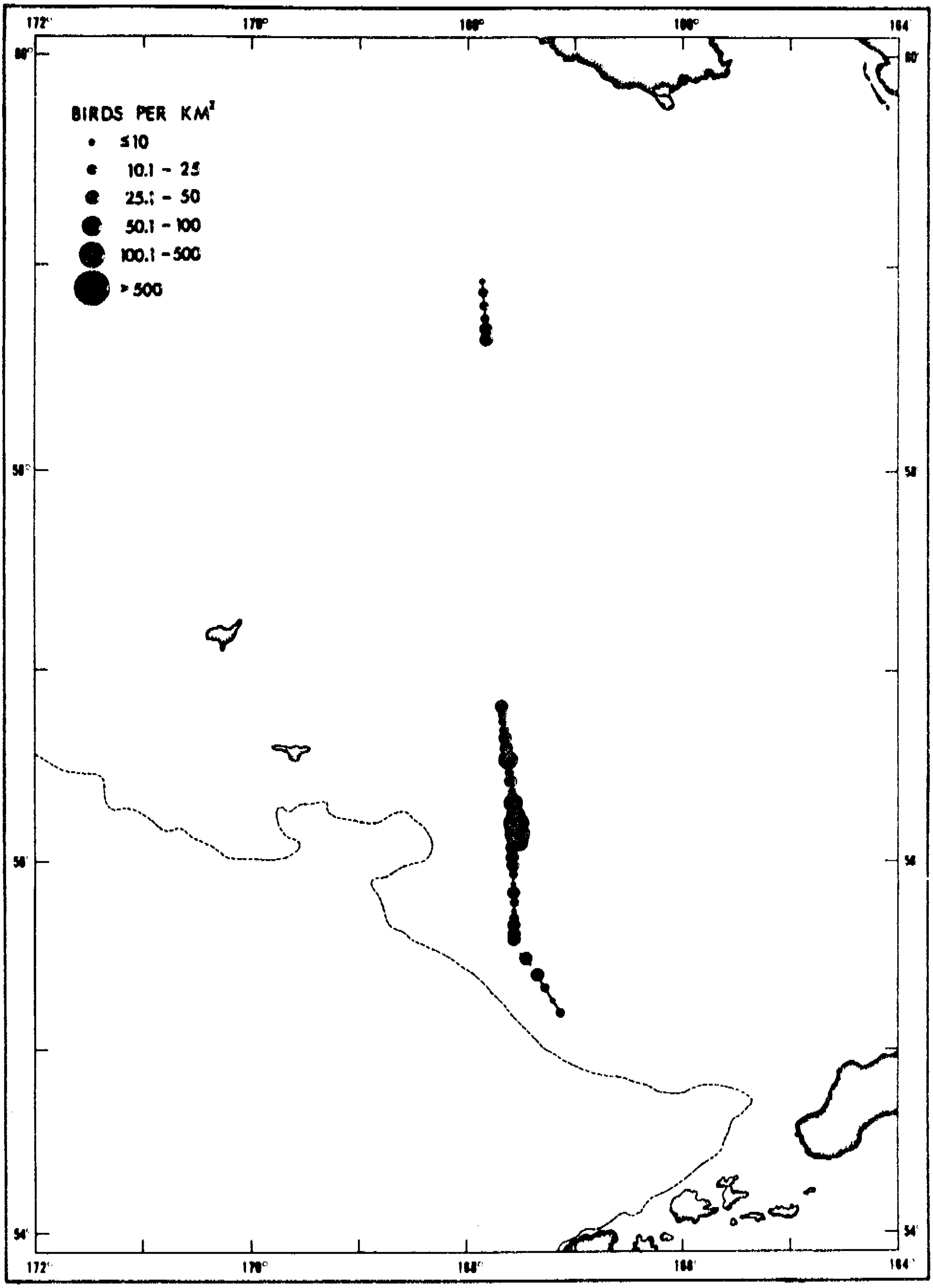


Figure 87. Distribution and abundance of seabirds in southern Bering Sea from 14 to 15 May 1978. (1SR578)

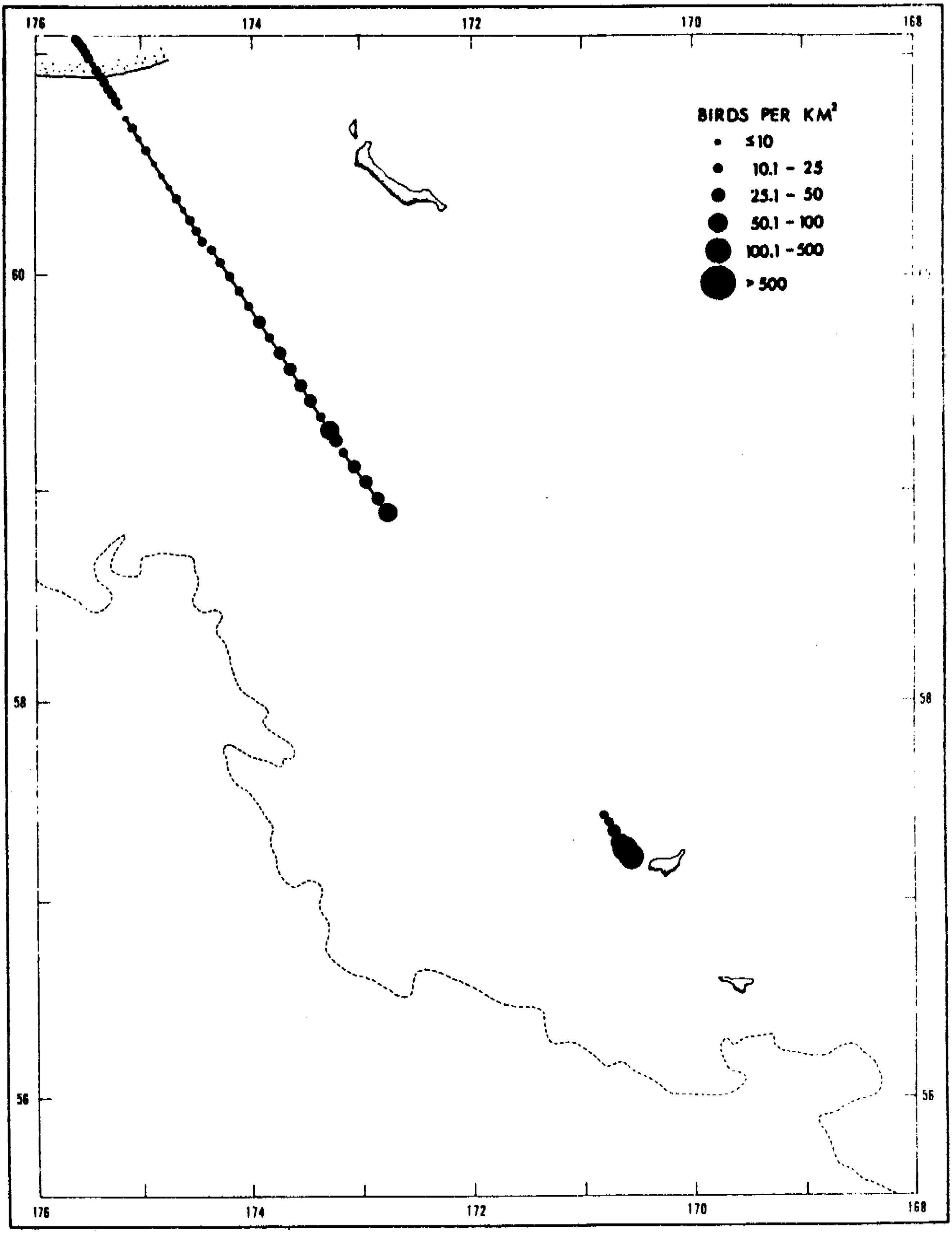


Figure 88. Distribution and abundance of seabirds in central Bering Sea from 2 to 3 May 1978. (1SR578)

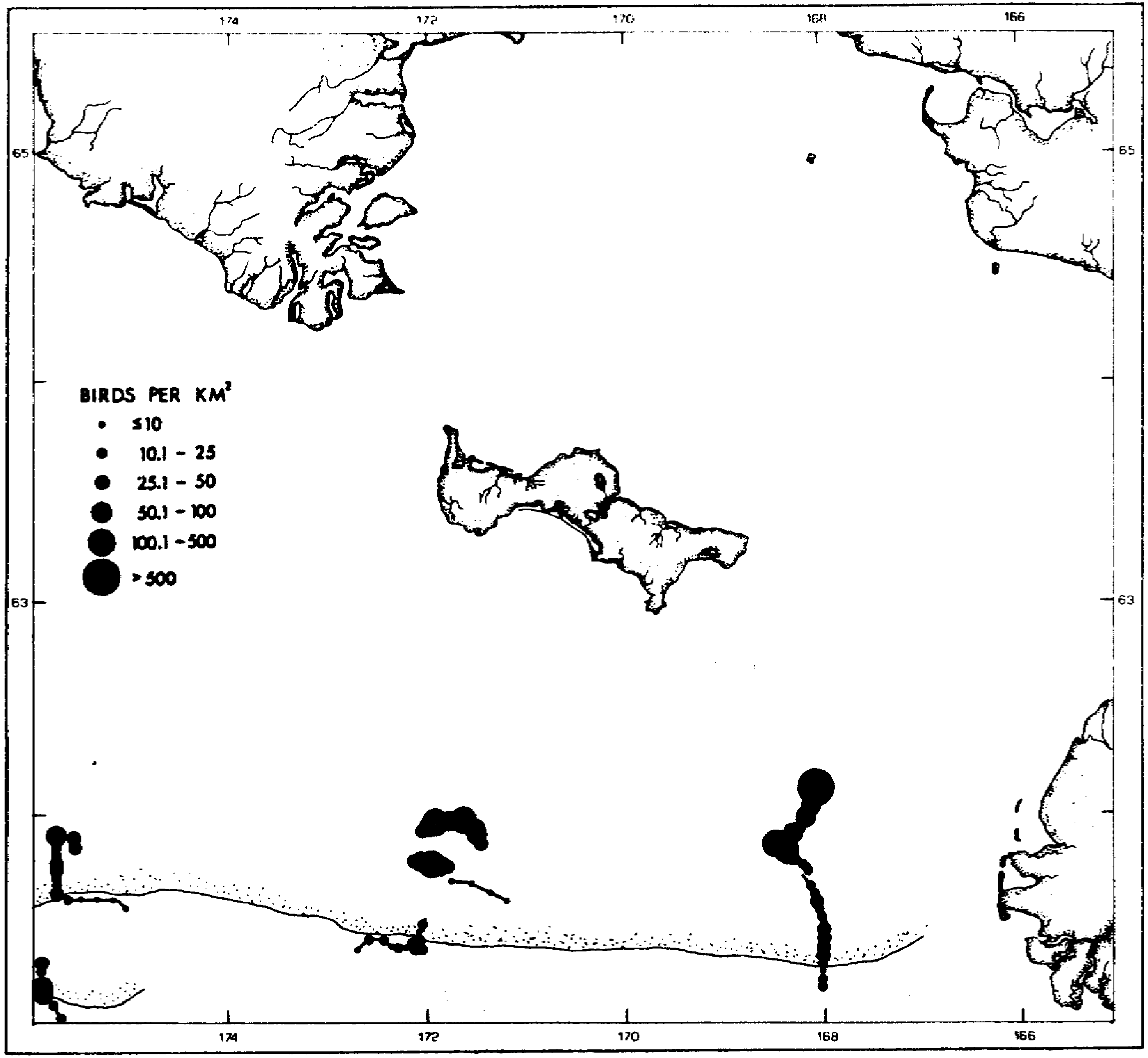


Figure 89. Distribution and abundance of seabirds in northern Bering Sea from 3 to 13 May 1978. (1SR578)

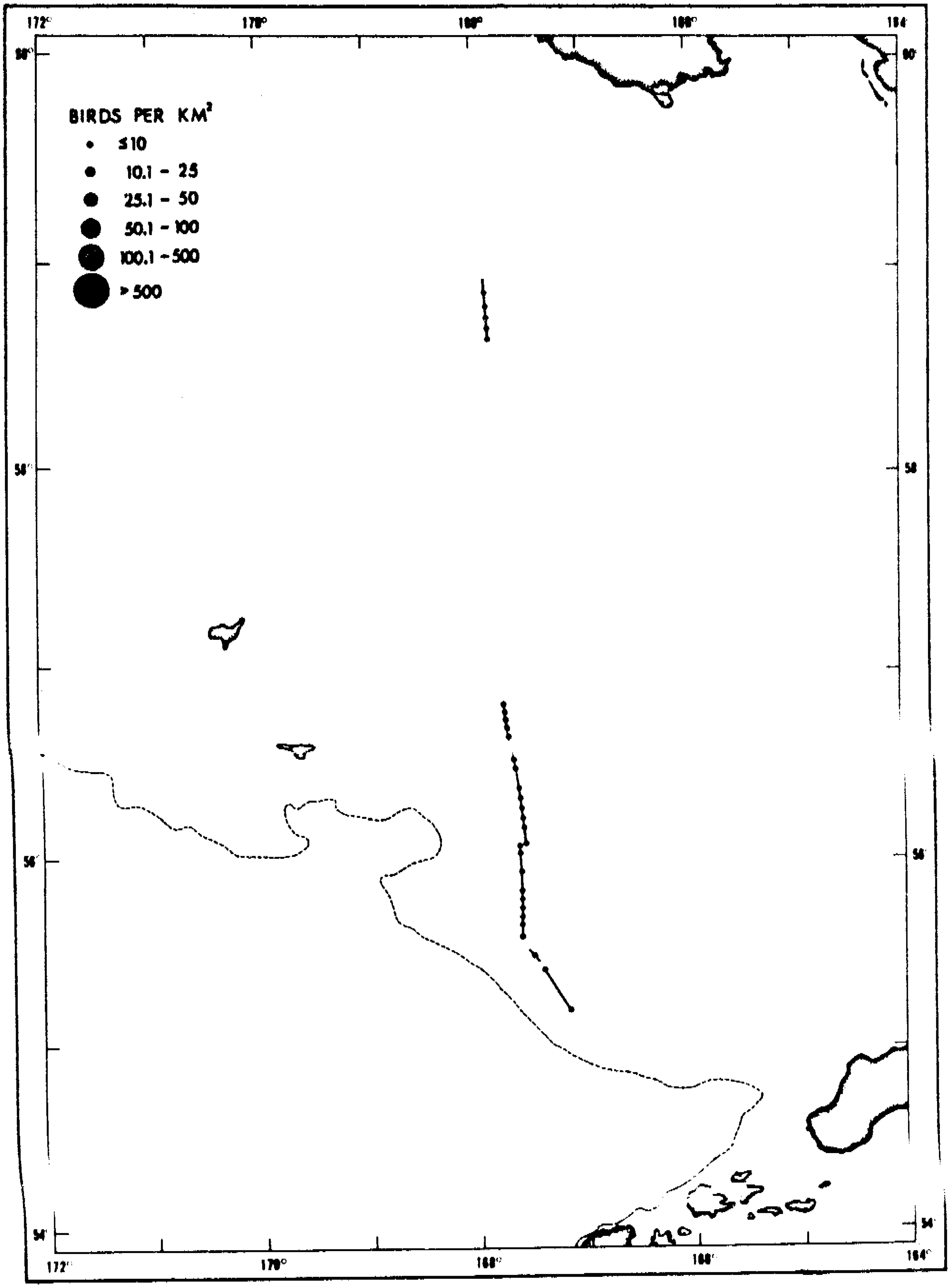


Figure 90. Distribution and abundance of Black-legged Kittiwakes in southern Bering Sea from 14 to 15 May 1978. (1SR578)

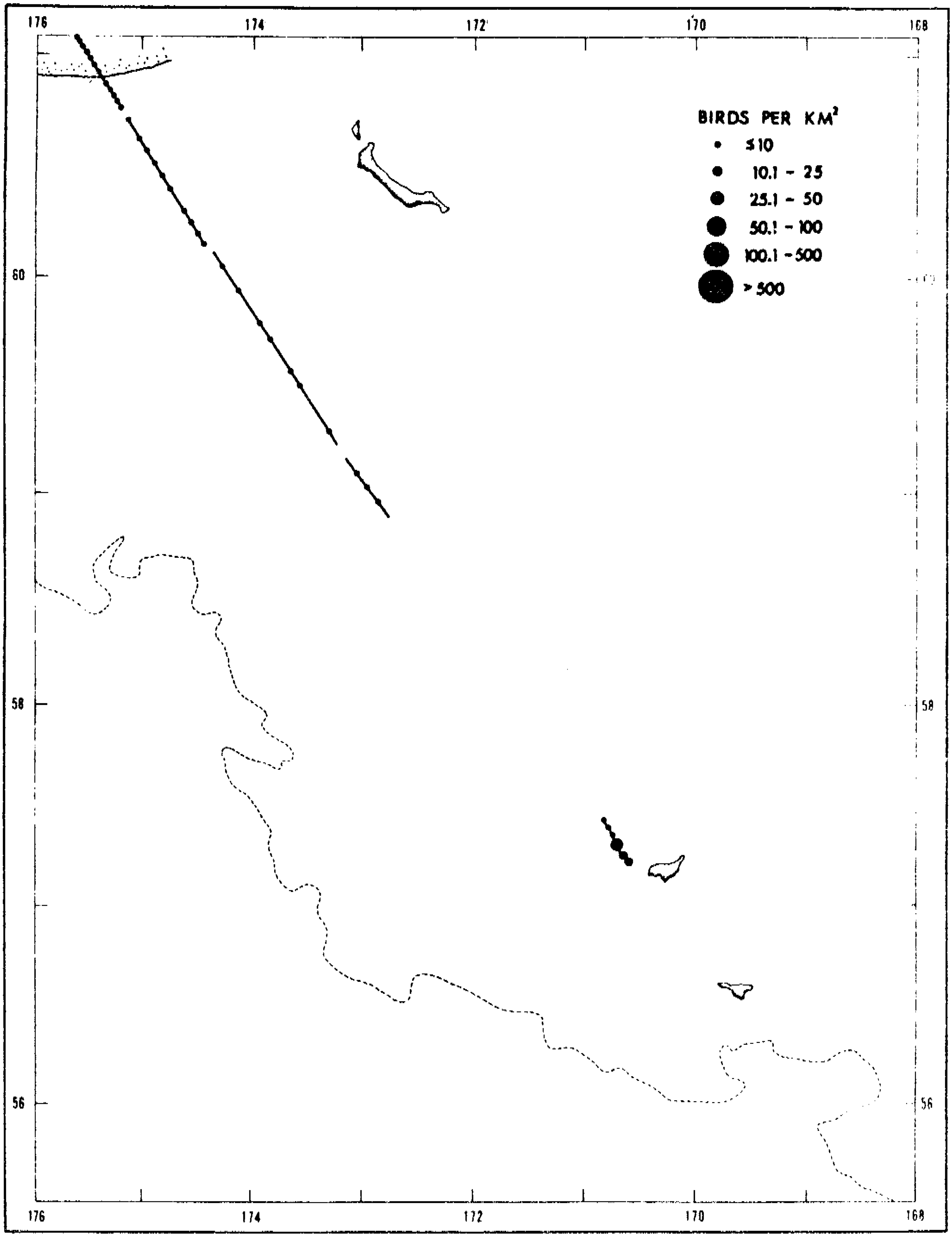


Figure 91. Distribution and abundance of Black-legged Kittiwakes in central Bering Sea from 2 to 3 May 1978. (1SR578)

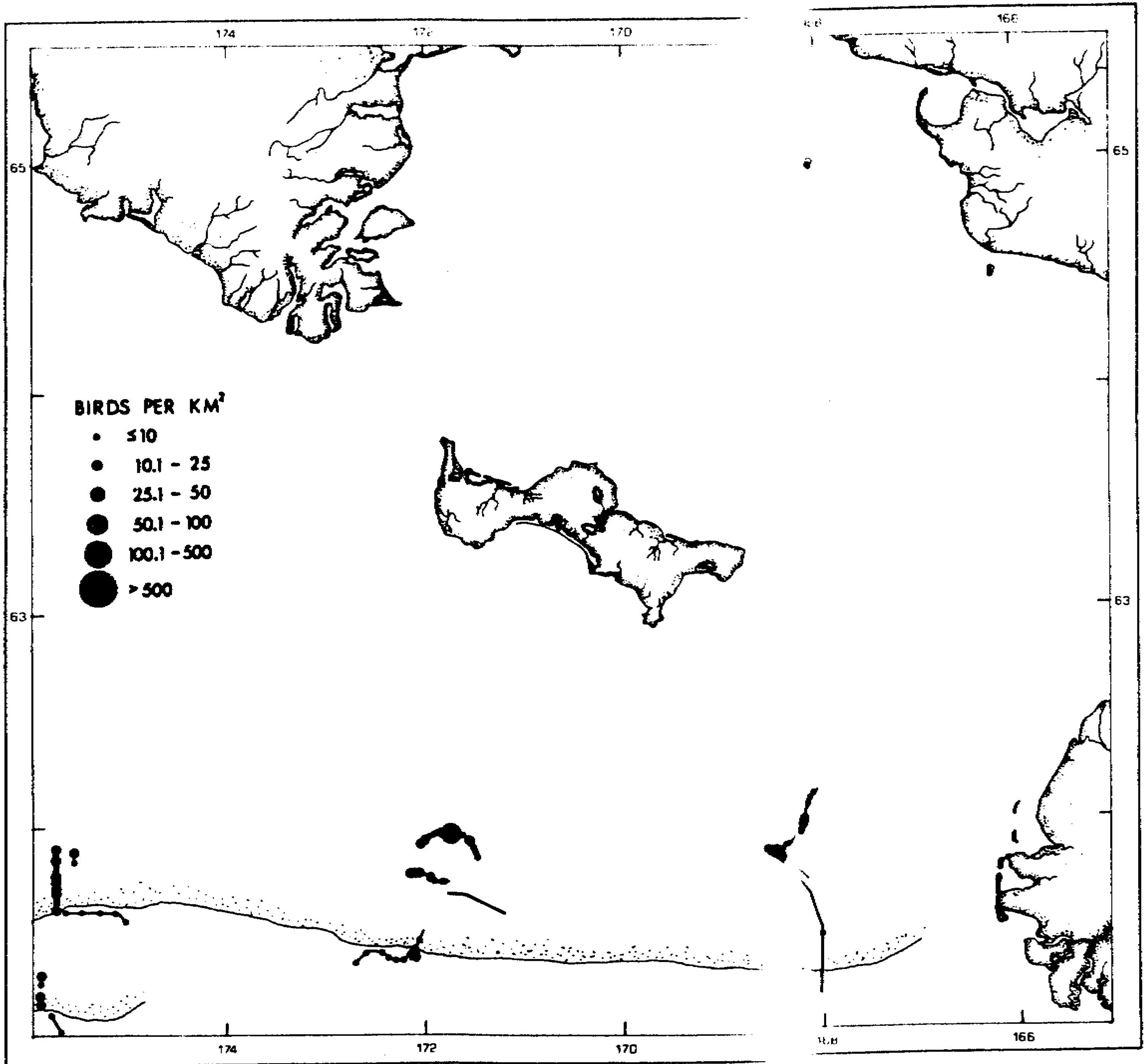


Figure 92. Distribution and abundance of Black-legged Kittiwakes in

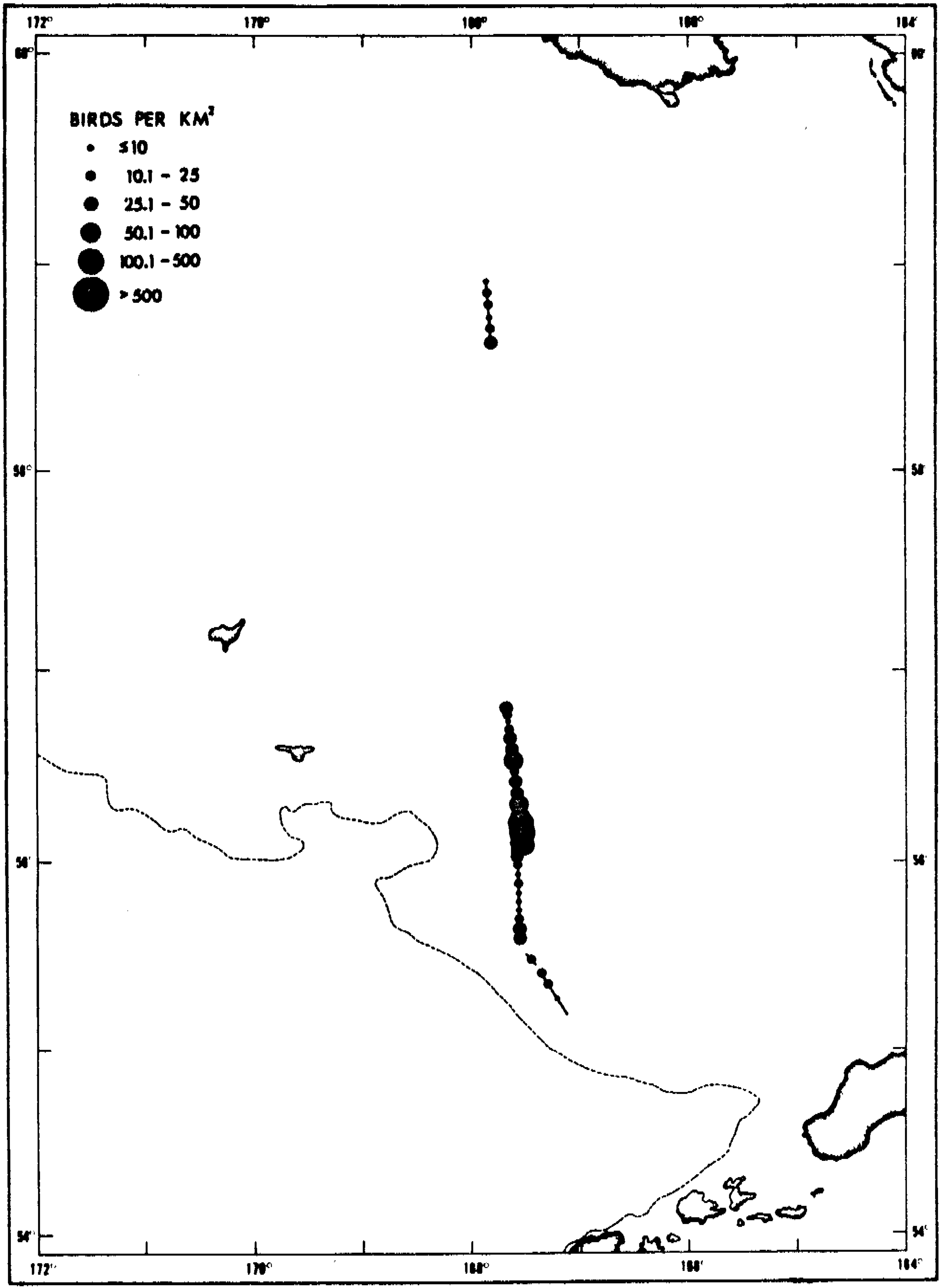


Figure 93. Distribution and abundance of murres in southern Bering Sea from 14 to 15 May 1978. (1SR578)

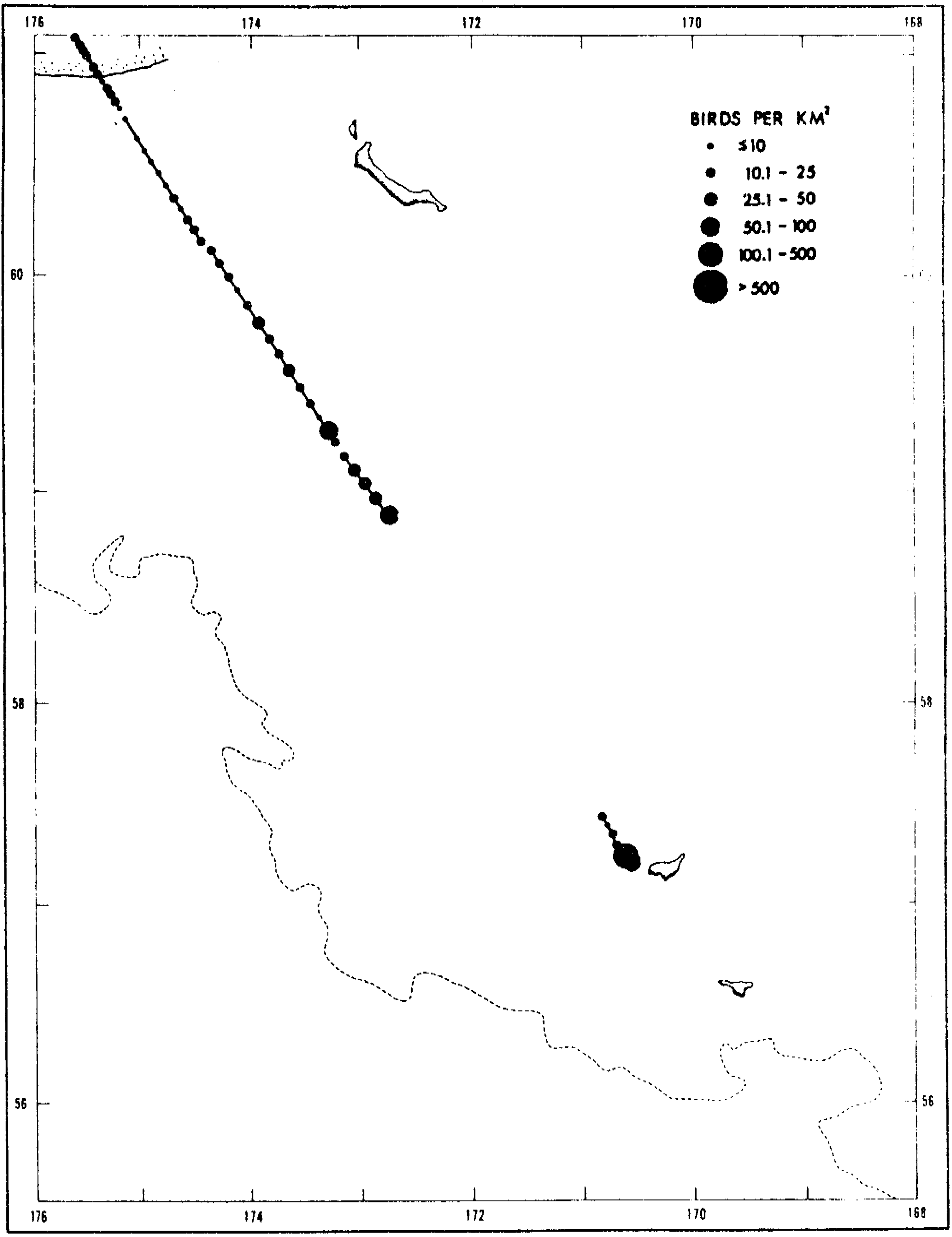


Figure 94. Distribution and abundance of murres in central Bering Sea from 2 to 3 May 1978. (1SR578)

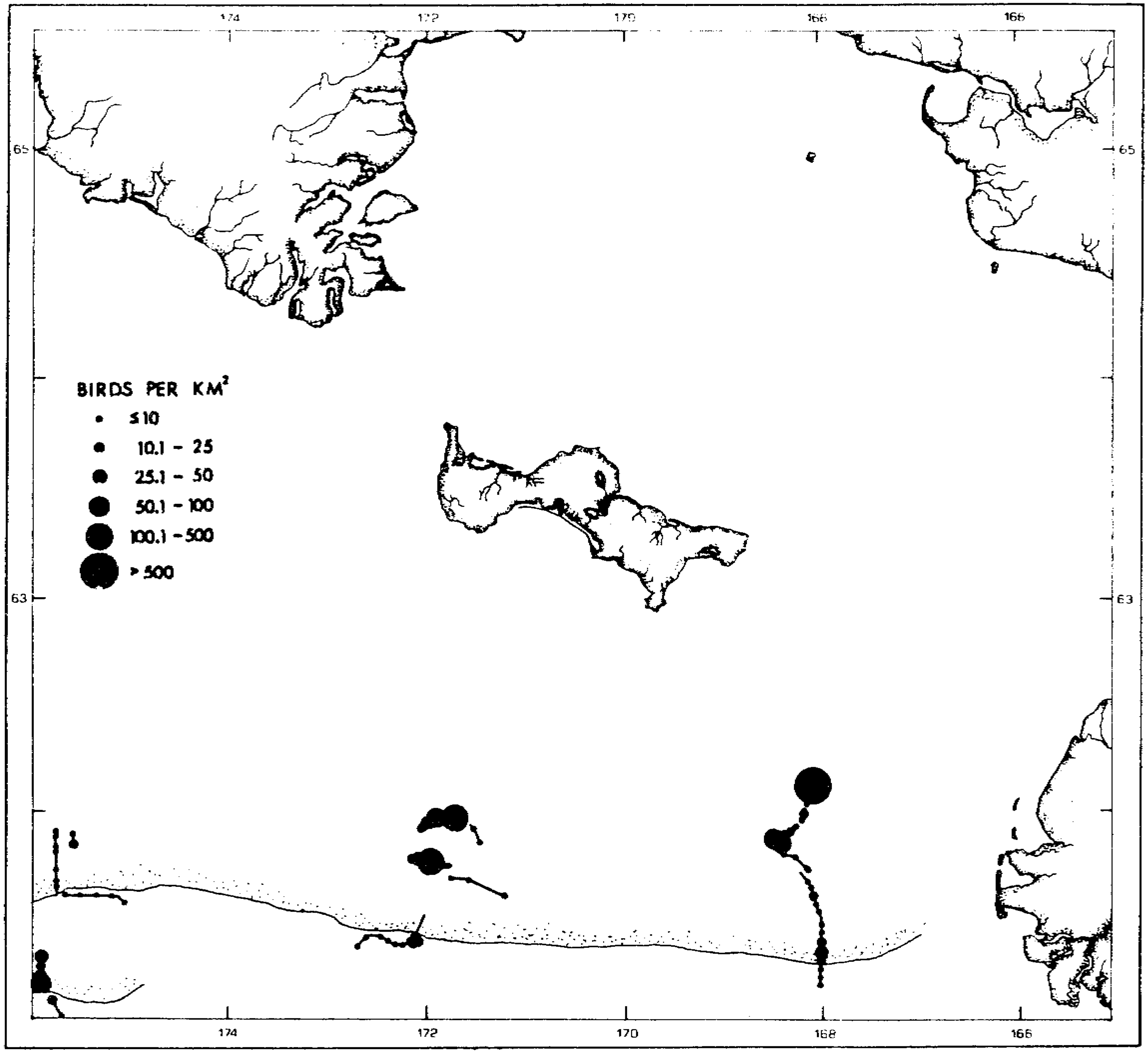


Figure 95. Distribution and abundance of murres in northern Bering Sea from 3 to 13 May 1978. (1SR578)

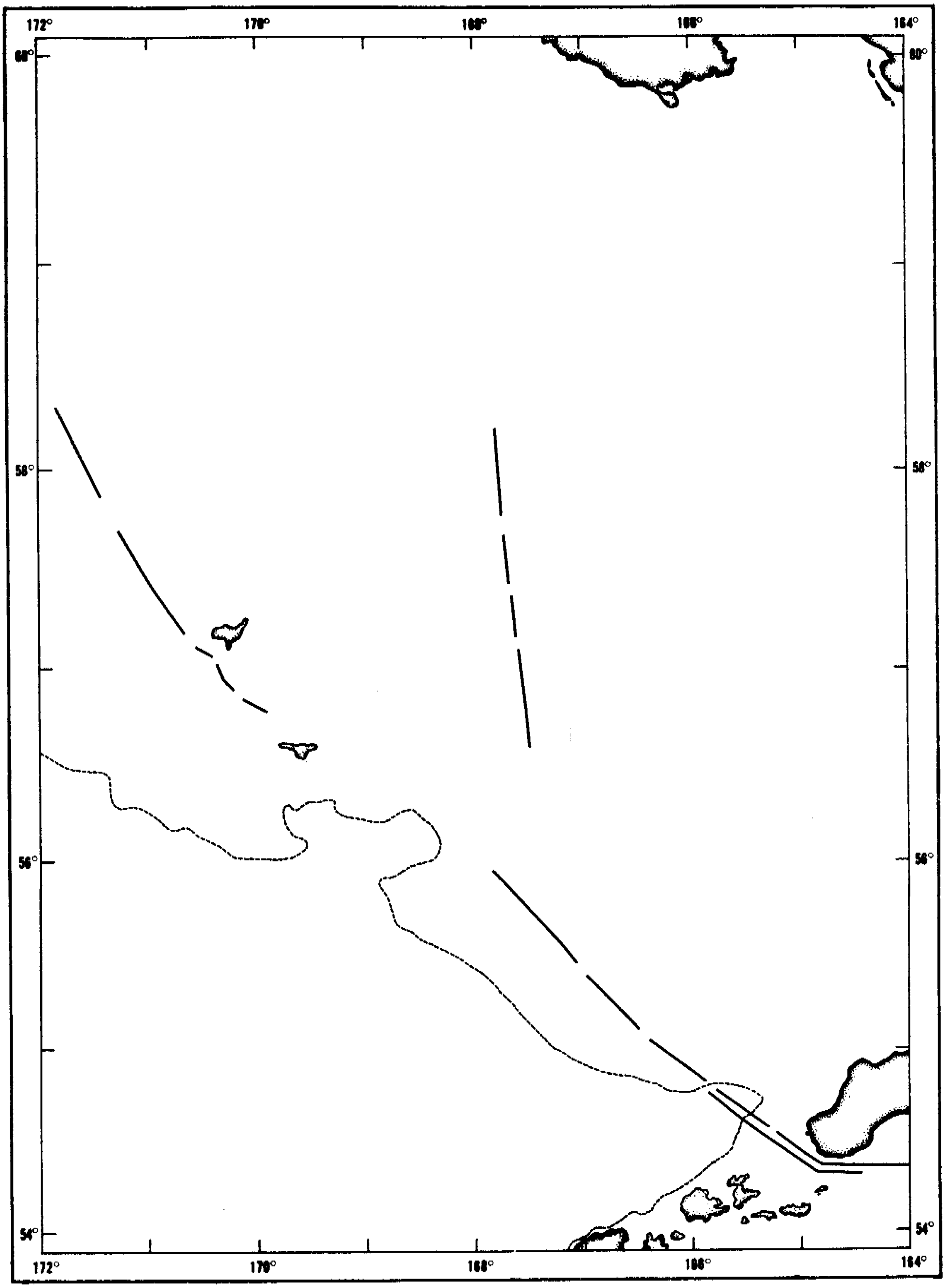


Figure 96. Cruise track during periods of observation in southern Bering Sea on 25 May and from 11 to 13 June 1978. (1SR678)

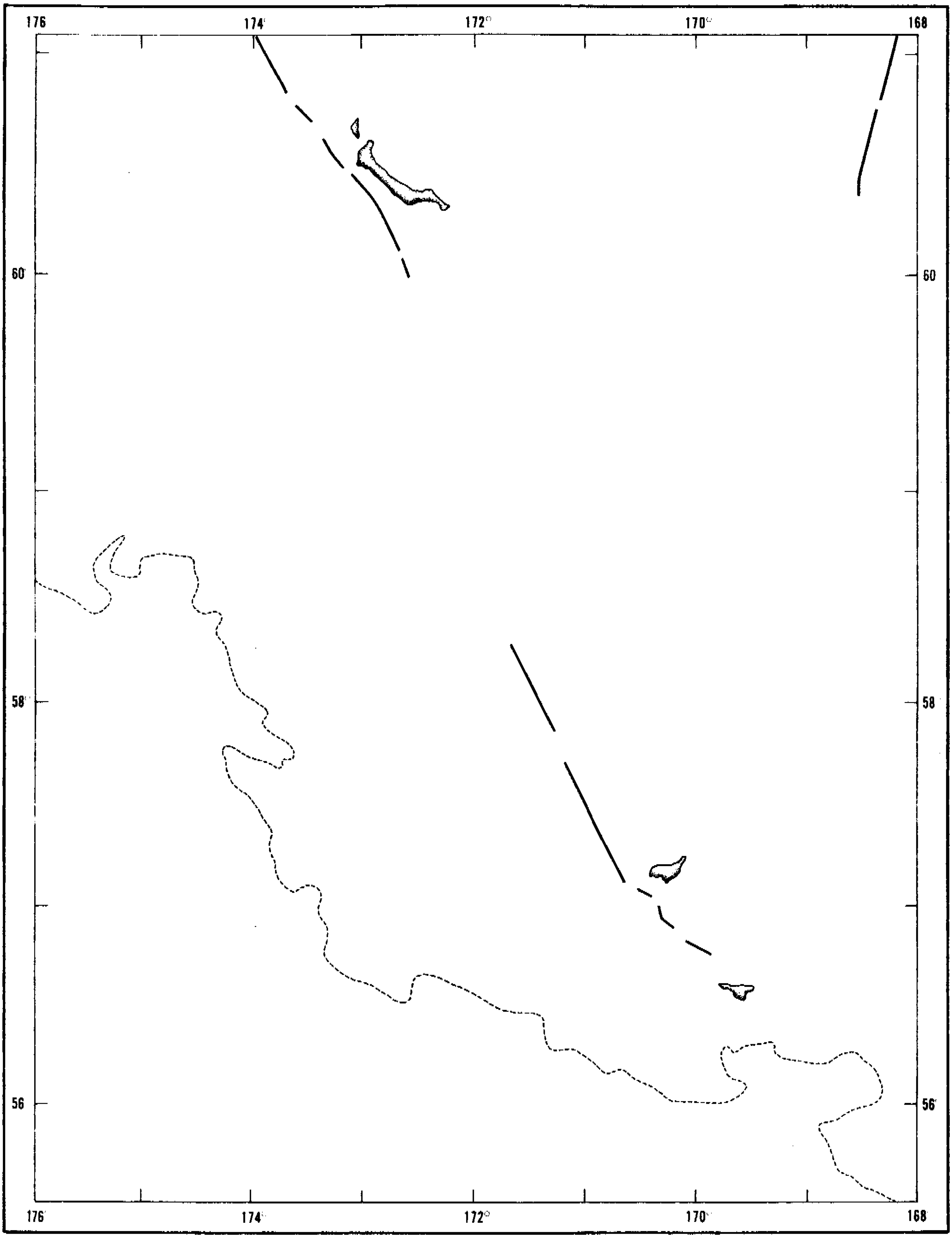


Figure 97. Cruise track during periods of observation in central Bering Sea from 26 to 27 May 1978. (1SR678)

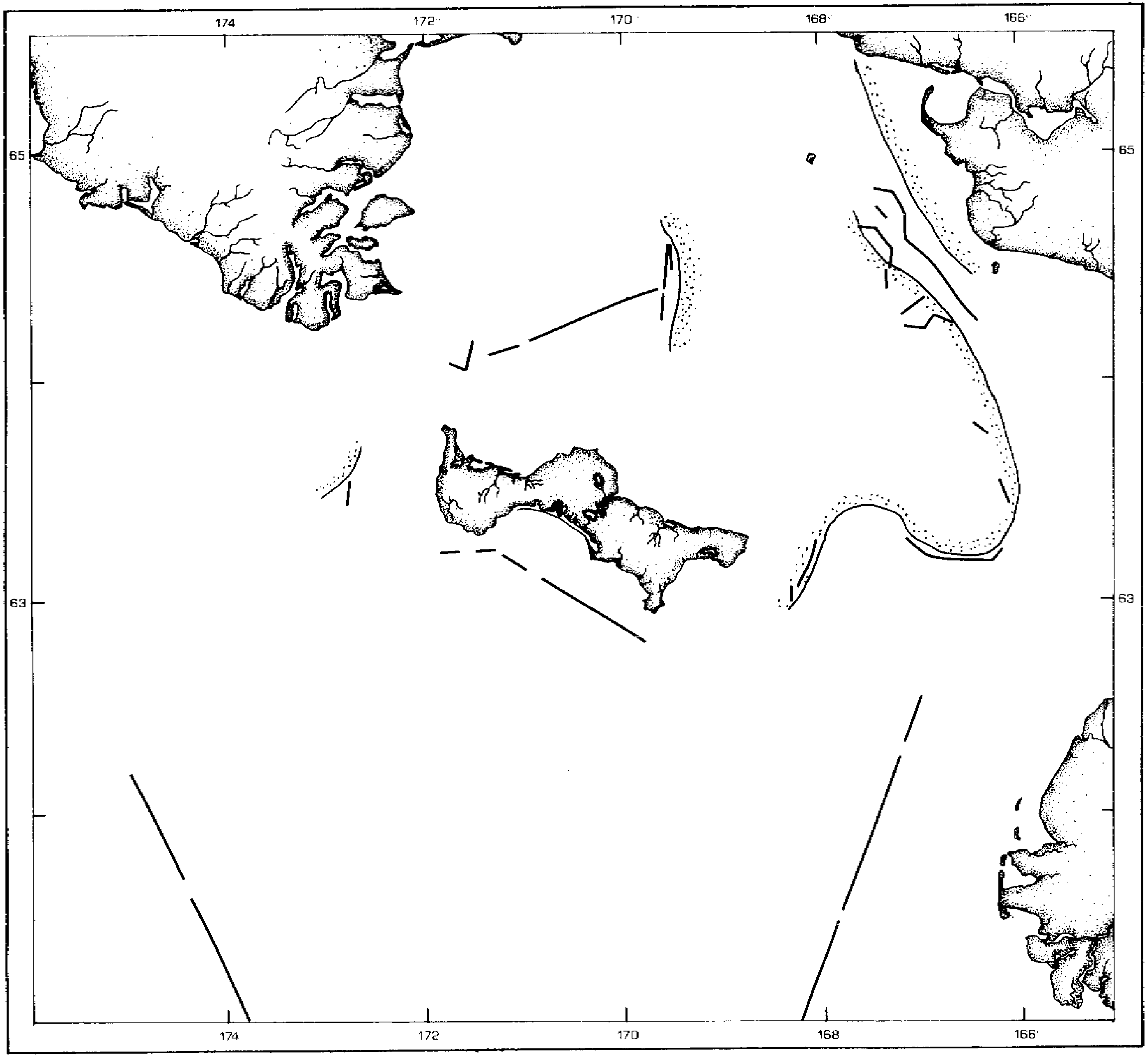


Figure 98. Cruise track during periods of observation in northern Bering Sea from 27 May to 10 June 1978. (1SP678)

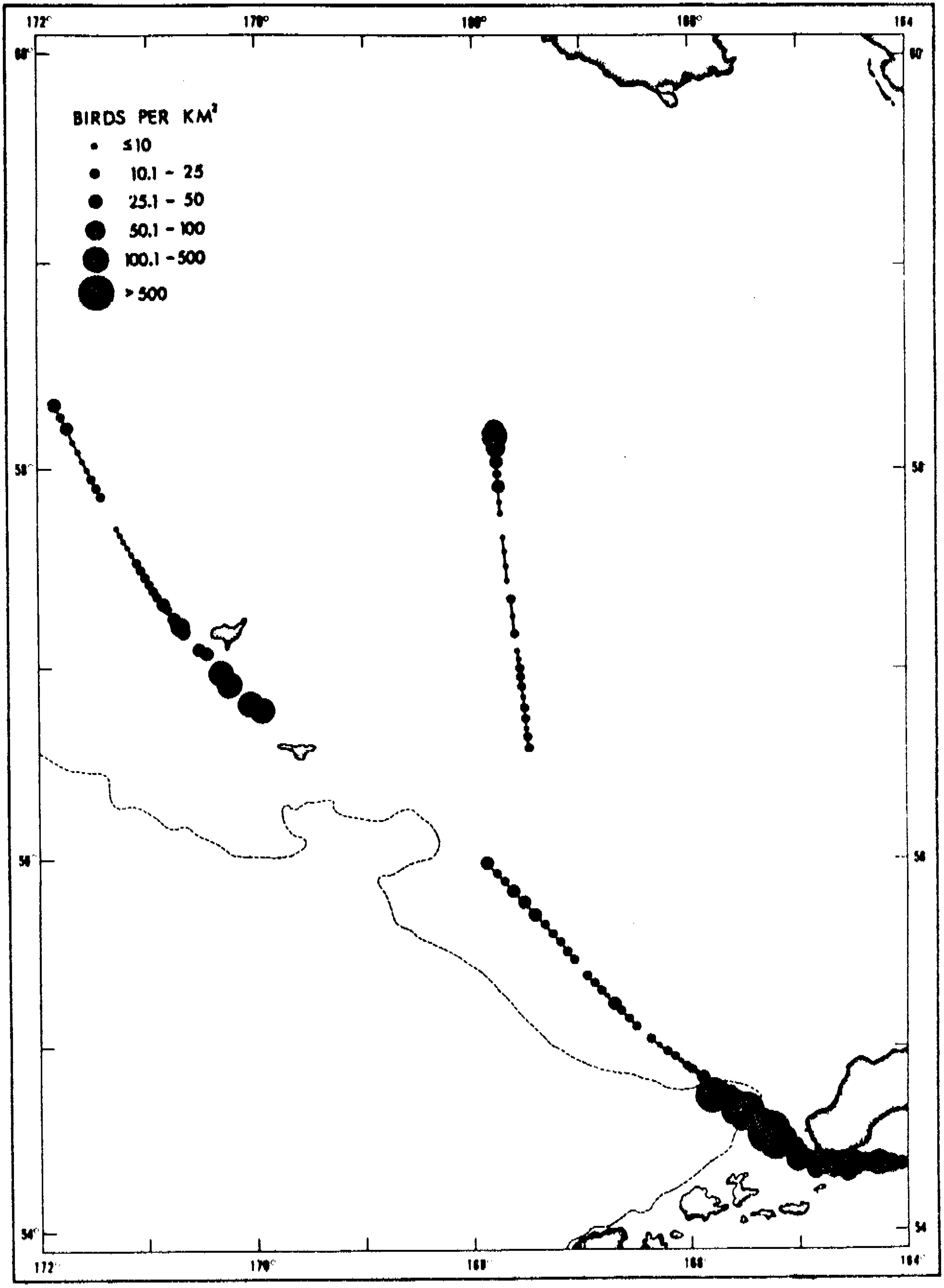


Figure 99. Distribution and abundance of seabirds in southern Bering Sea on 25 May and from 11 to 13 June 1978. (1SR678)

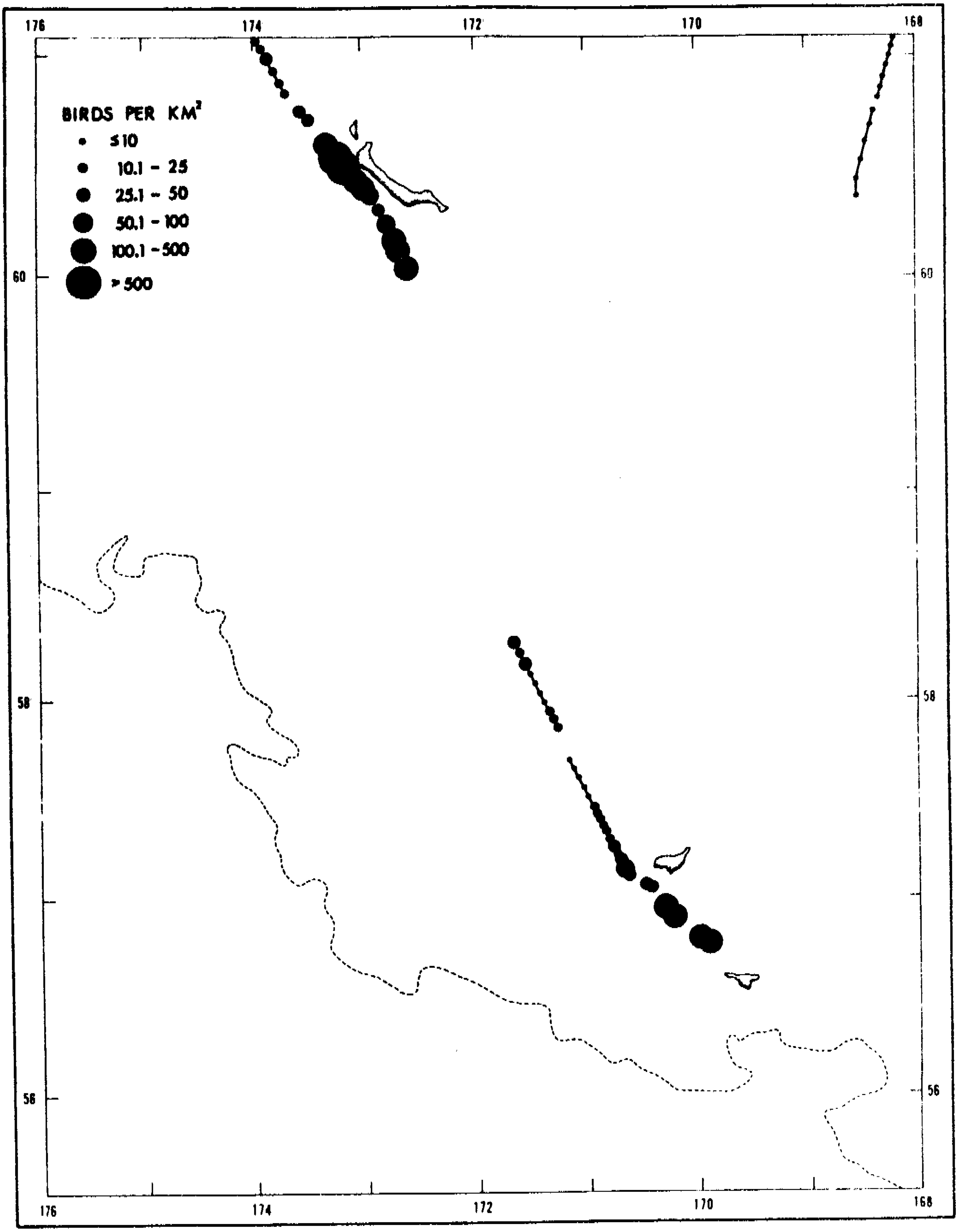


Figure 100. Distribution and abundance of seabirds in central Bering Sea from 26 to 27 May 1978. (1SR678)

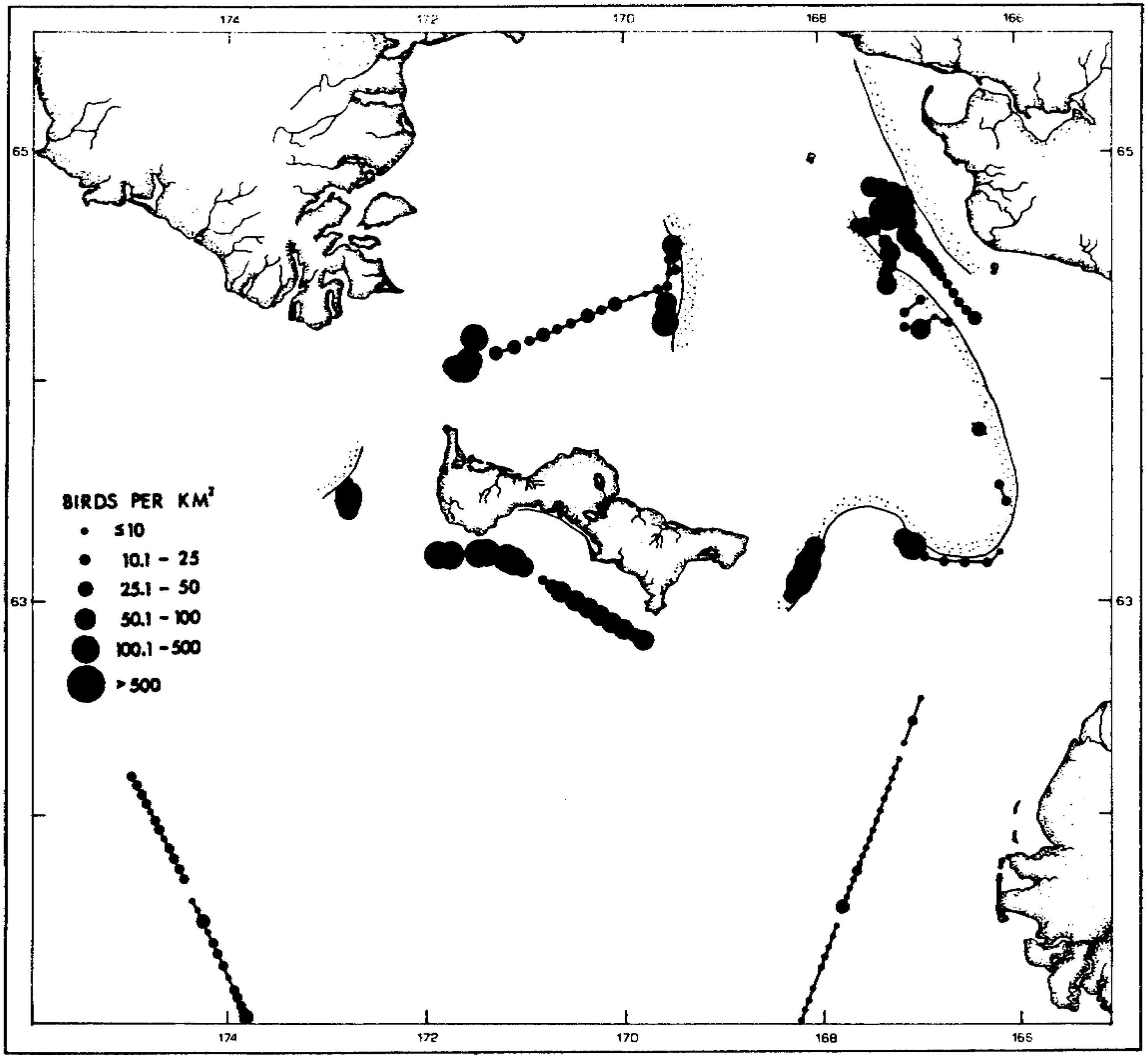


Figure 101. Distribution and abundance of seabirds in northern Bering Sea from 27 May to 10 June 1978. (1SR678)

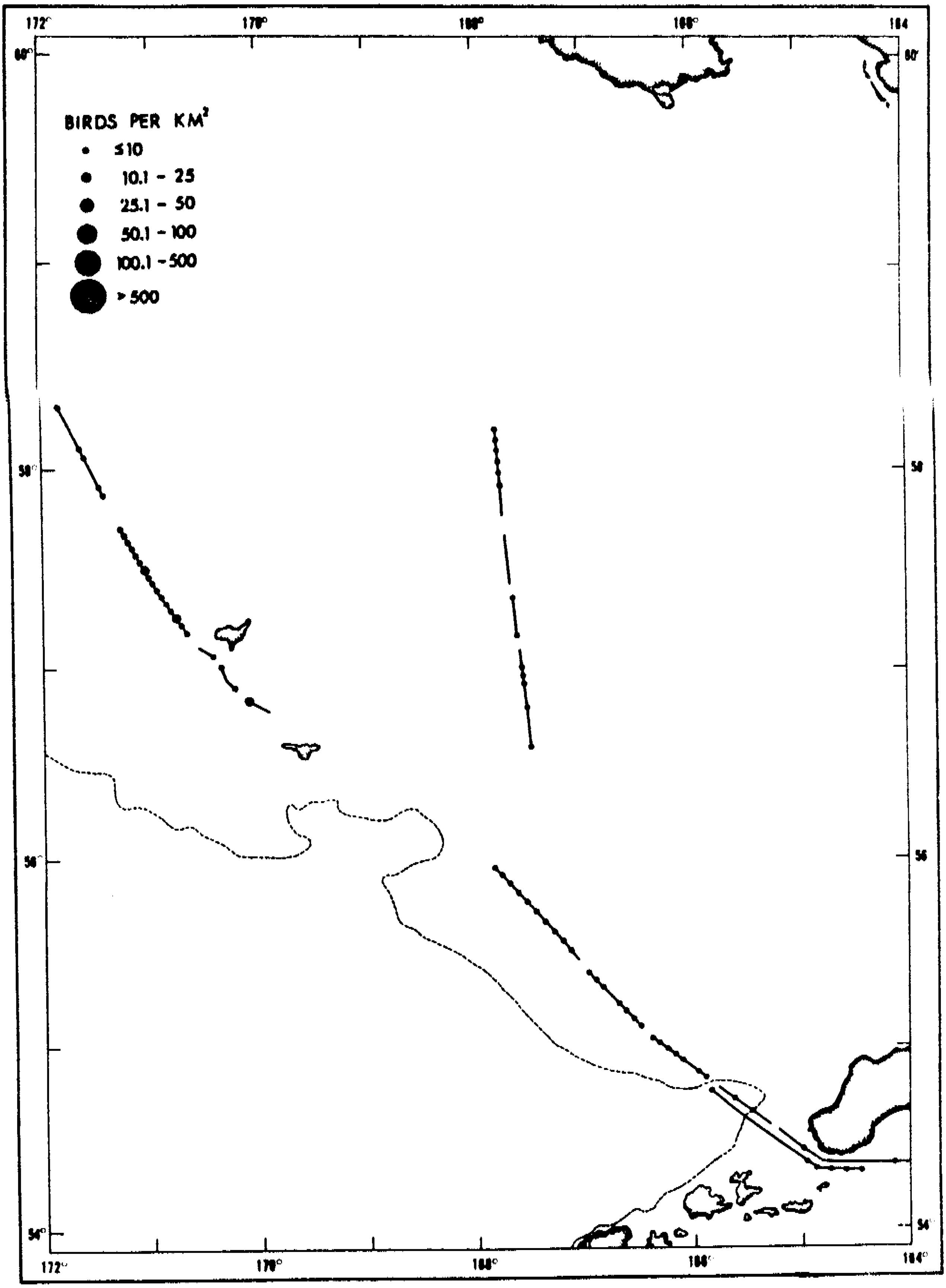


Figure 102. Distribution and abundance of Black-legged Kittiwakes in southern Bering Sea on 25 May and from 11 to 13 June 1978. (1SR678)

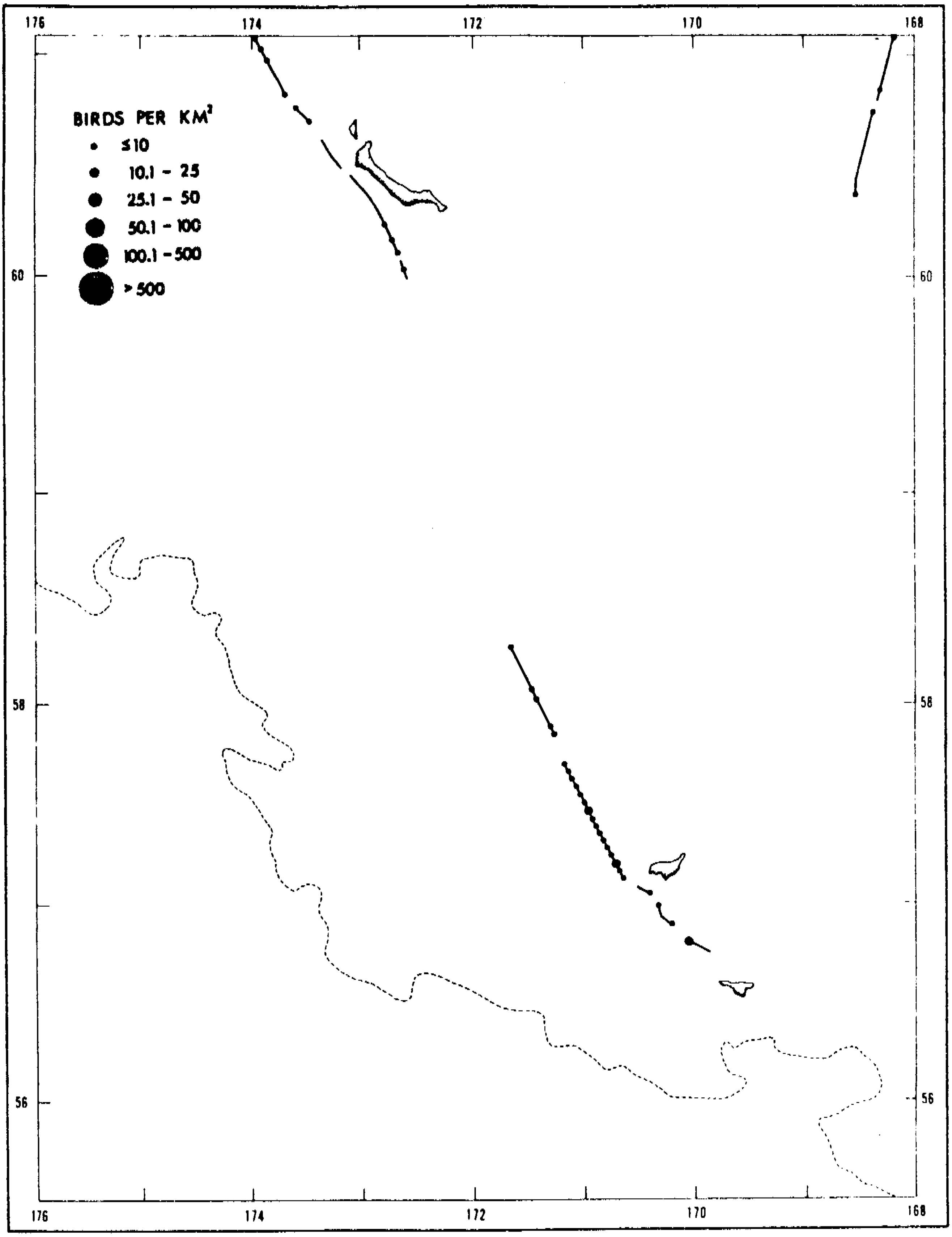


Figure 103. Distirbution and abundance of Black-legged Kittiwakes in central Bering Sea from 26 to 27 May 1978. (1SR678)

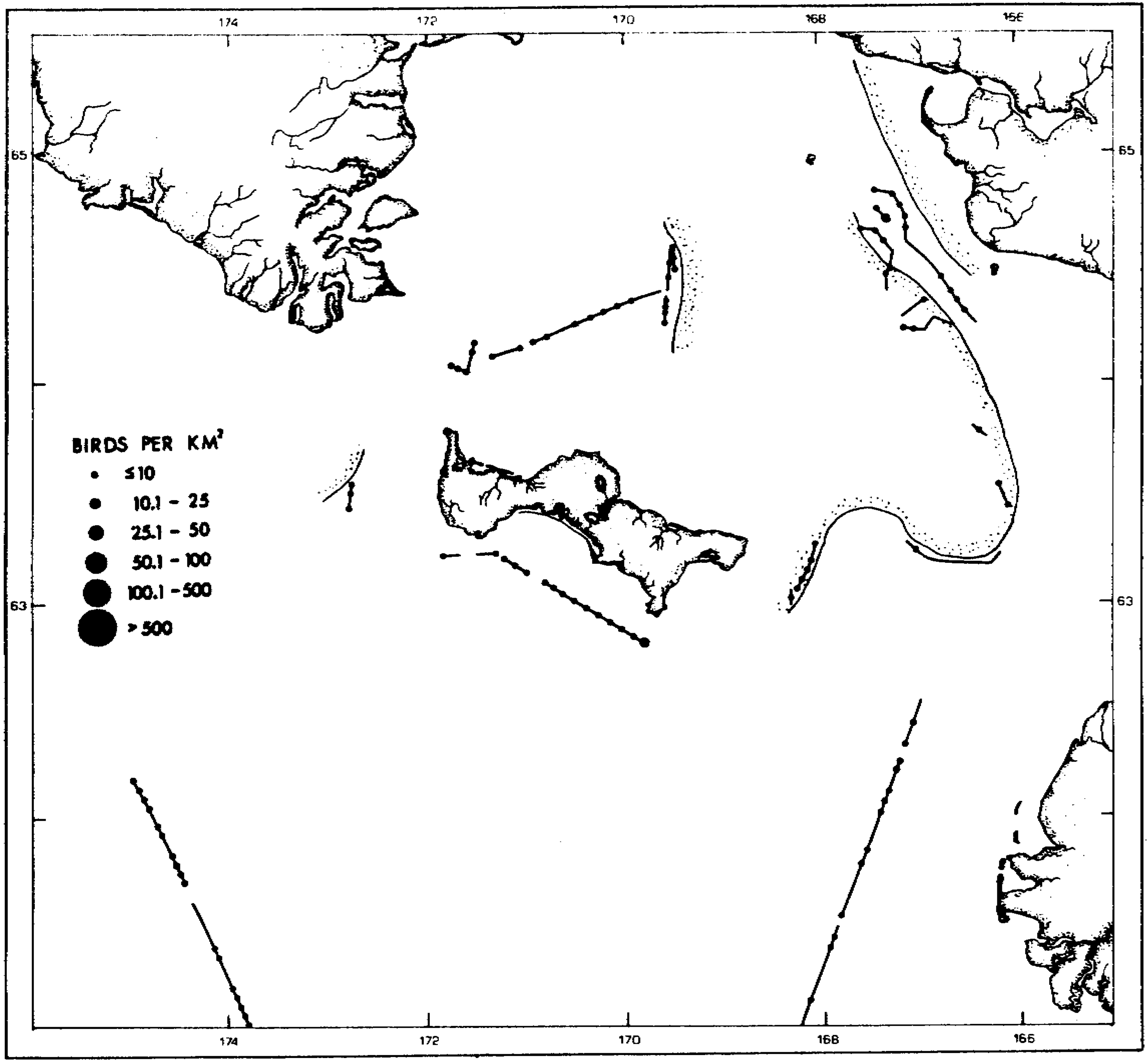


Figure 104. Distribution and abundance of Black-legged Kittiwakes in northern Bering Sea from 27 May to 10 June 1978. (1SP678)

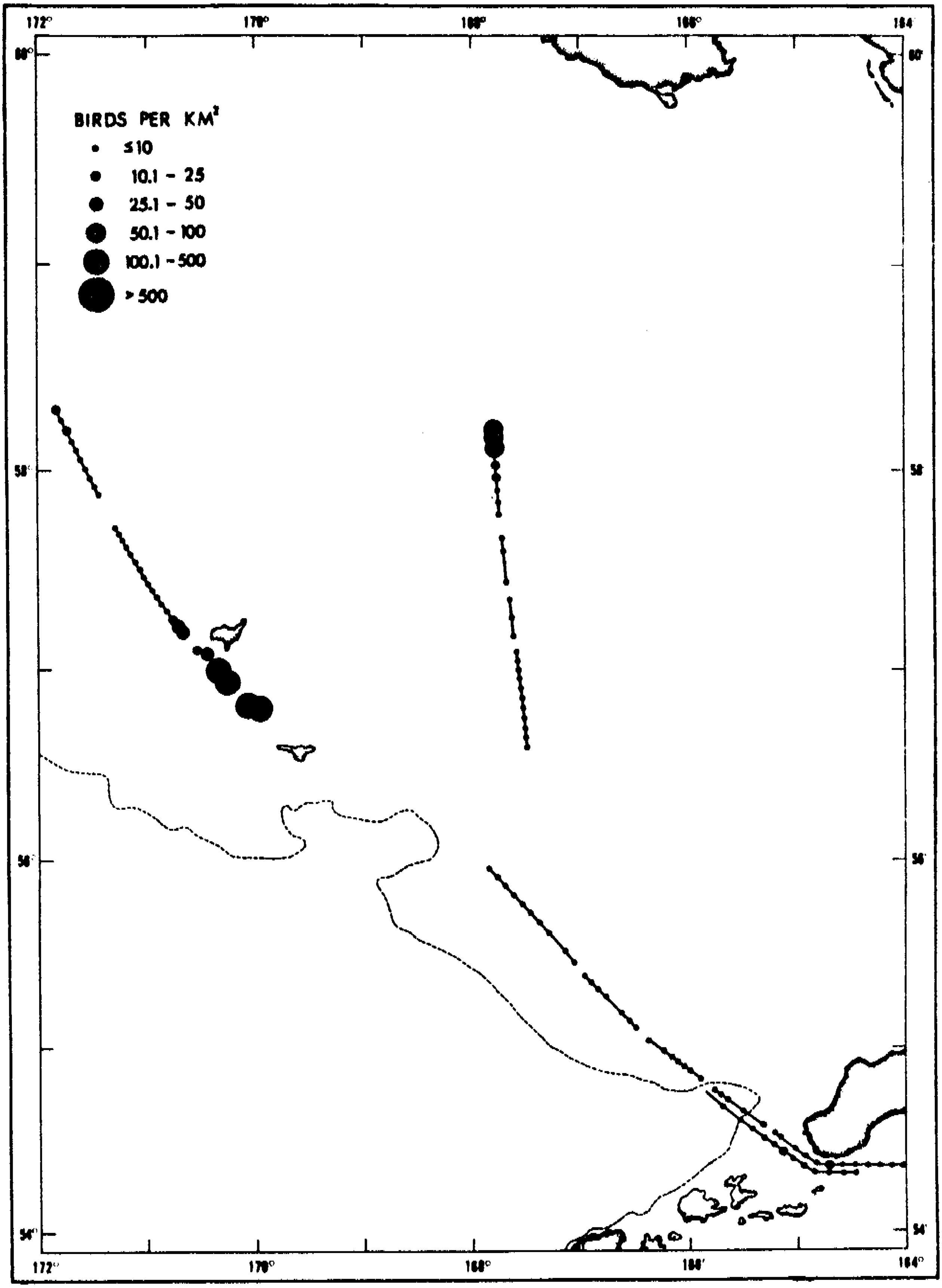


Figure 105. Distribution and abundance of murres in southern Bering Sea on 25 May and from 11 to 13 June 1978. (1SR678)

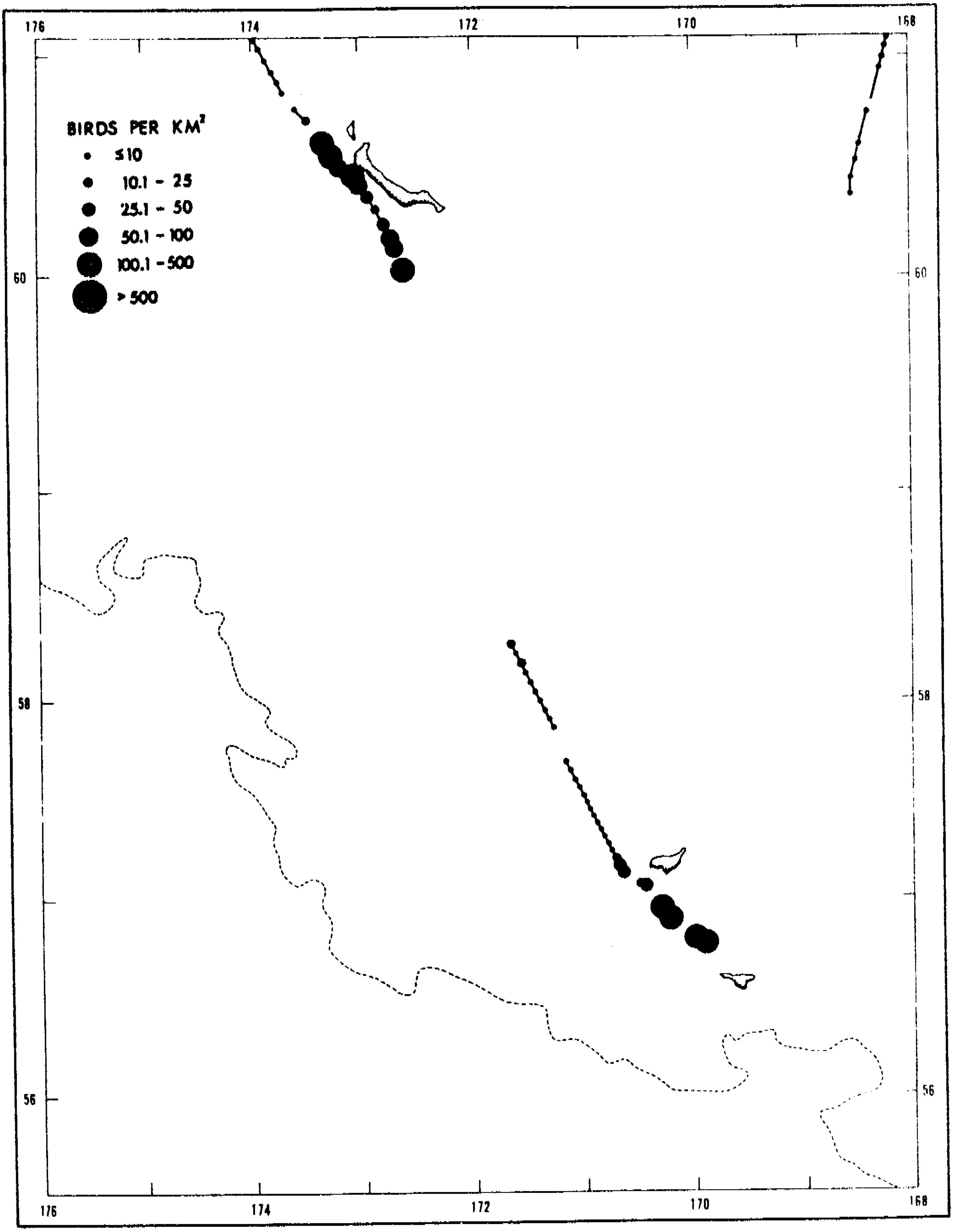


Figure 106. Distribution and abundance of murres in central Bering Sea from 26 to 27 May 1978. (1SR678)

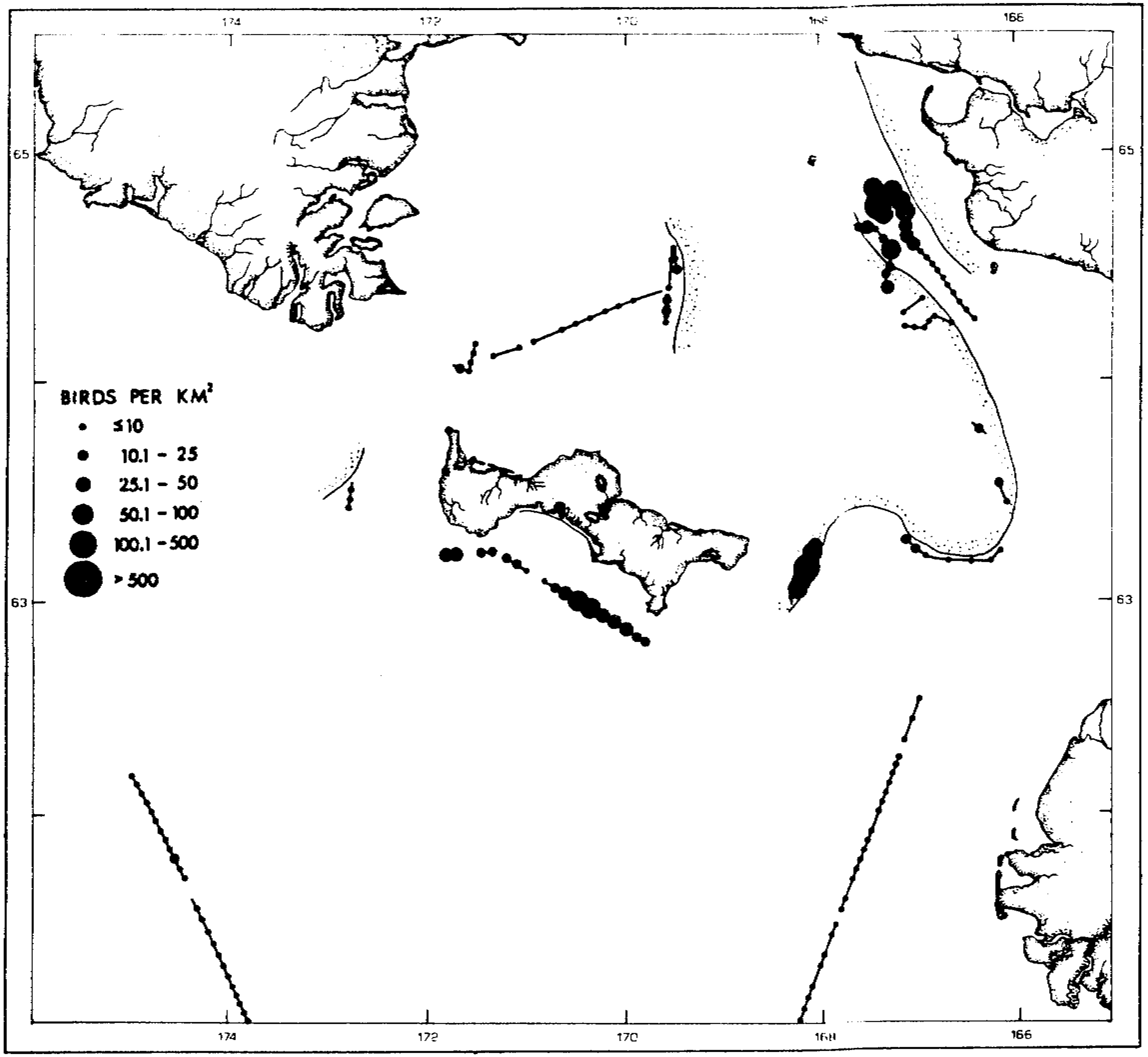


Figure 107. Distribution and abundance of murres in northern Bering Sea from 27 May to 10 June 1978. (1SR678)

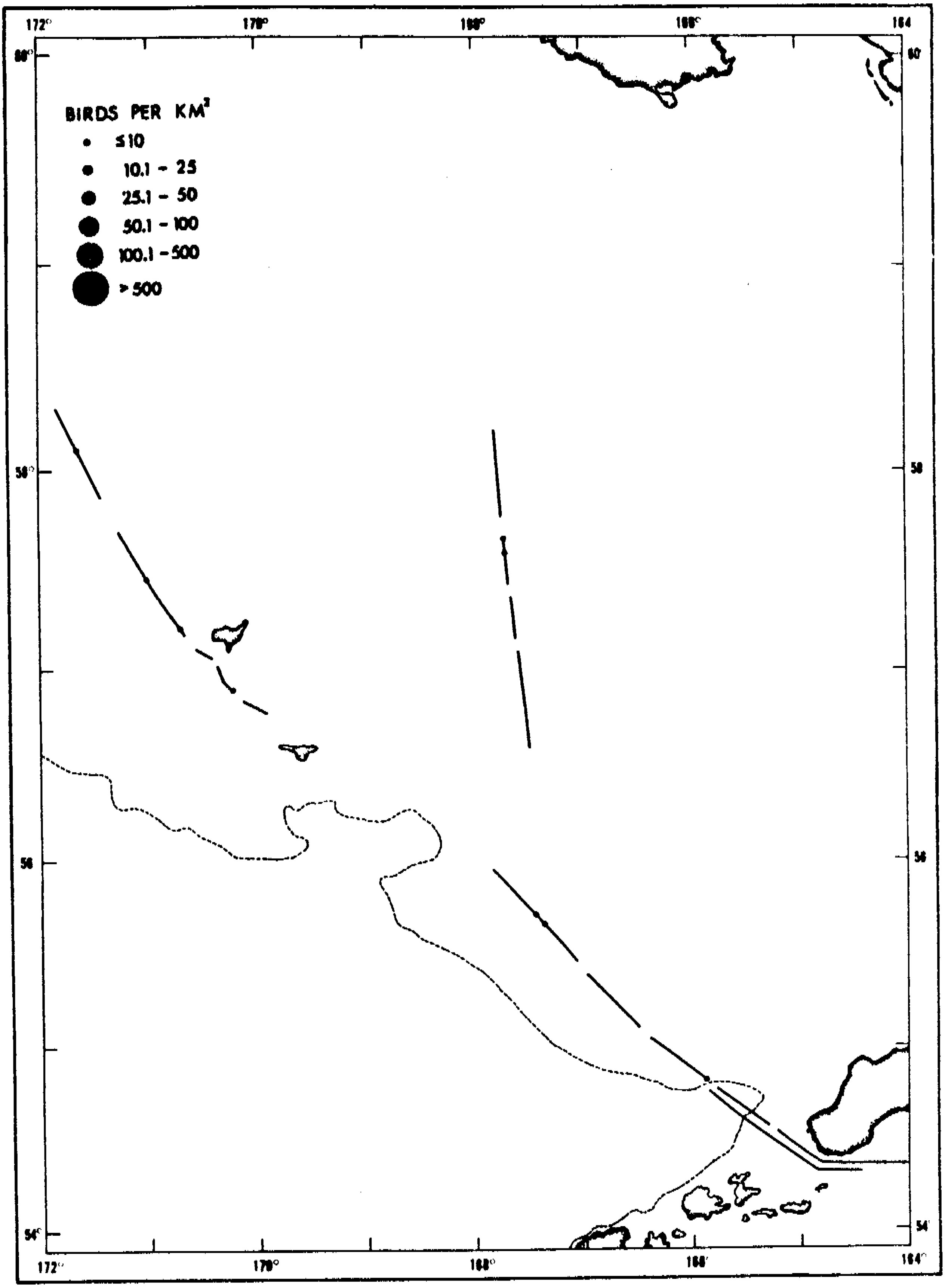


Figure 108. Distribution and abundance of Least Auklets in southern Bering Sea on 25 May and from 11 to 13 June 1978. (1SR678)

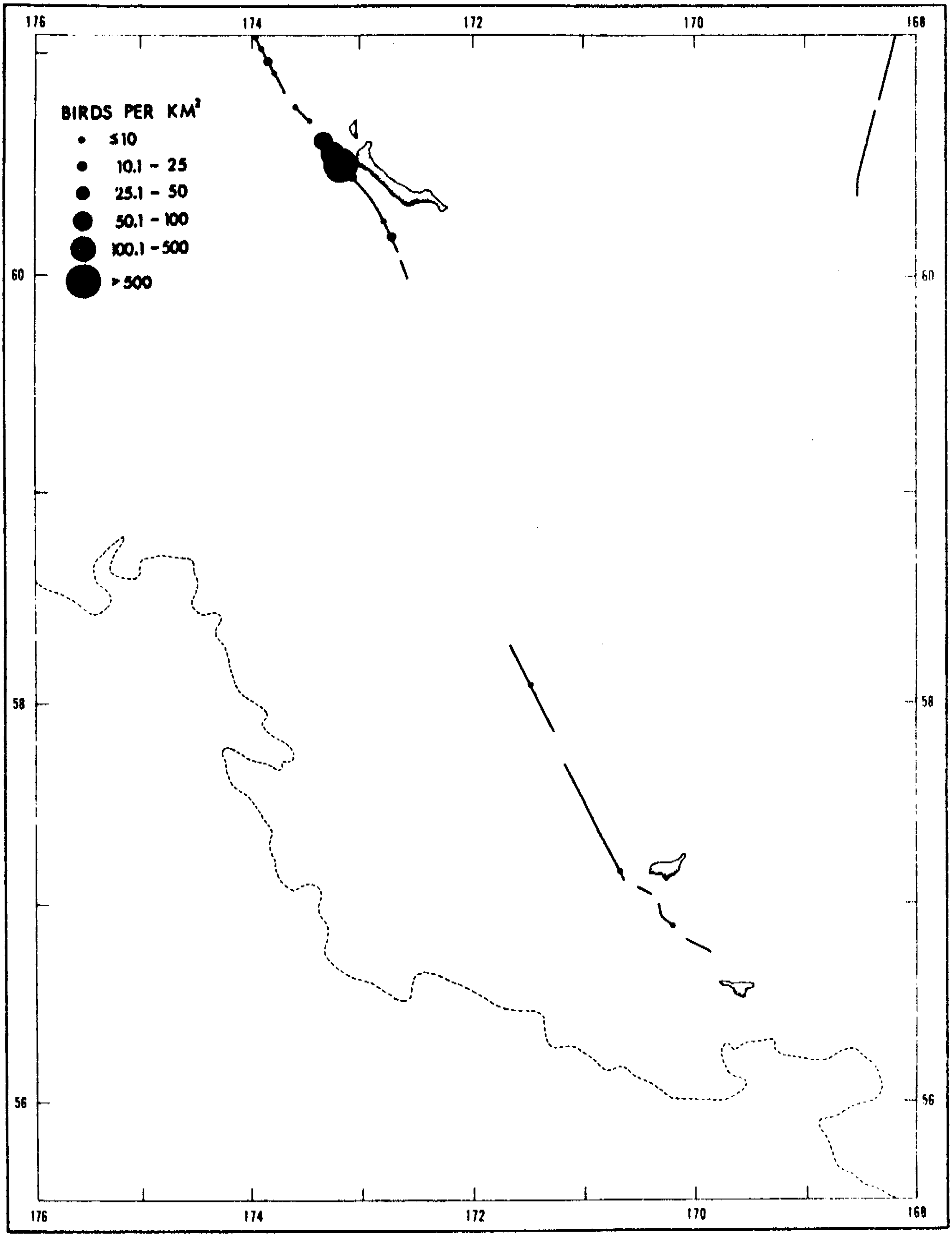


Figure 109. Distribution and abundance of Least Auklets in central Bering Sea from 26 to 27 May 1978. (1SR678)

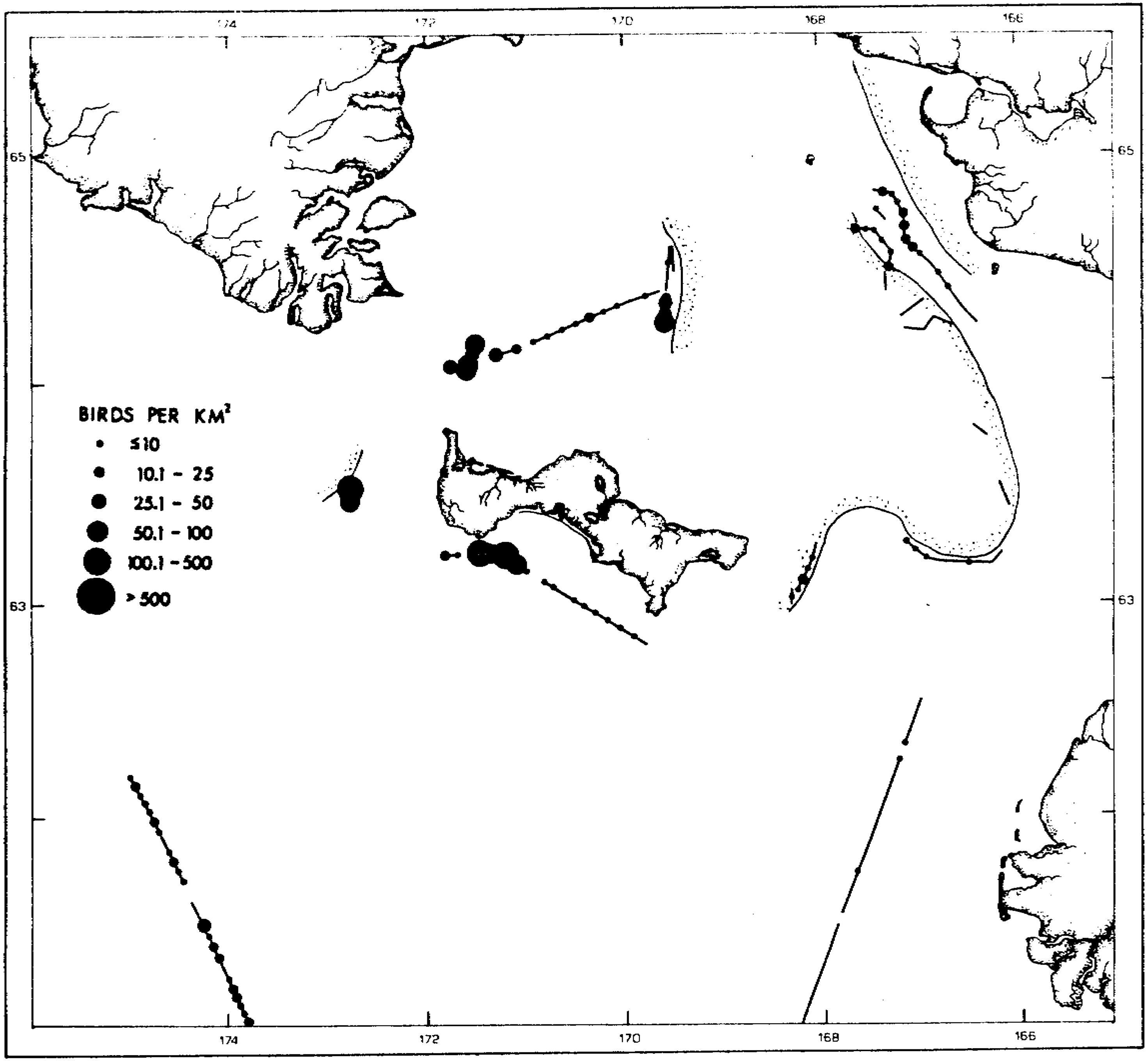


Figure 110. Distribution and abundance of Least Auklets in northern

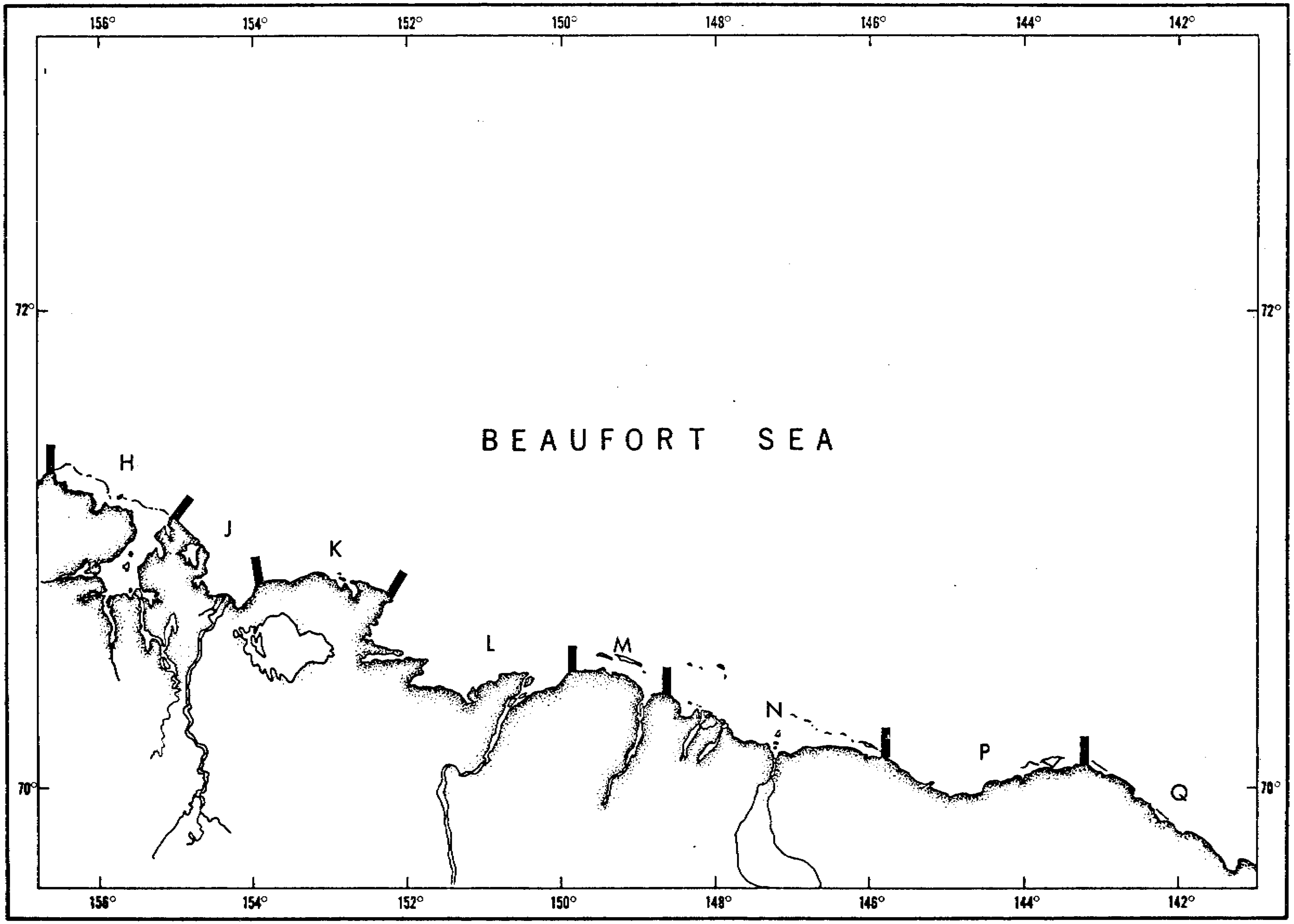


Figure 111b. The Alaskan Beaufort Sea coast showing coastal divisions discussed in text.

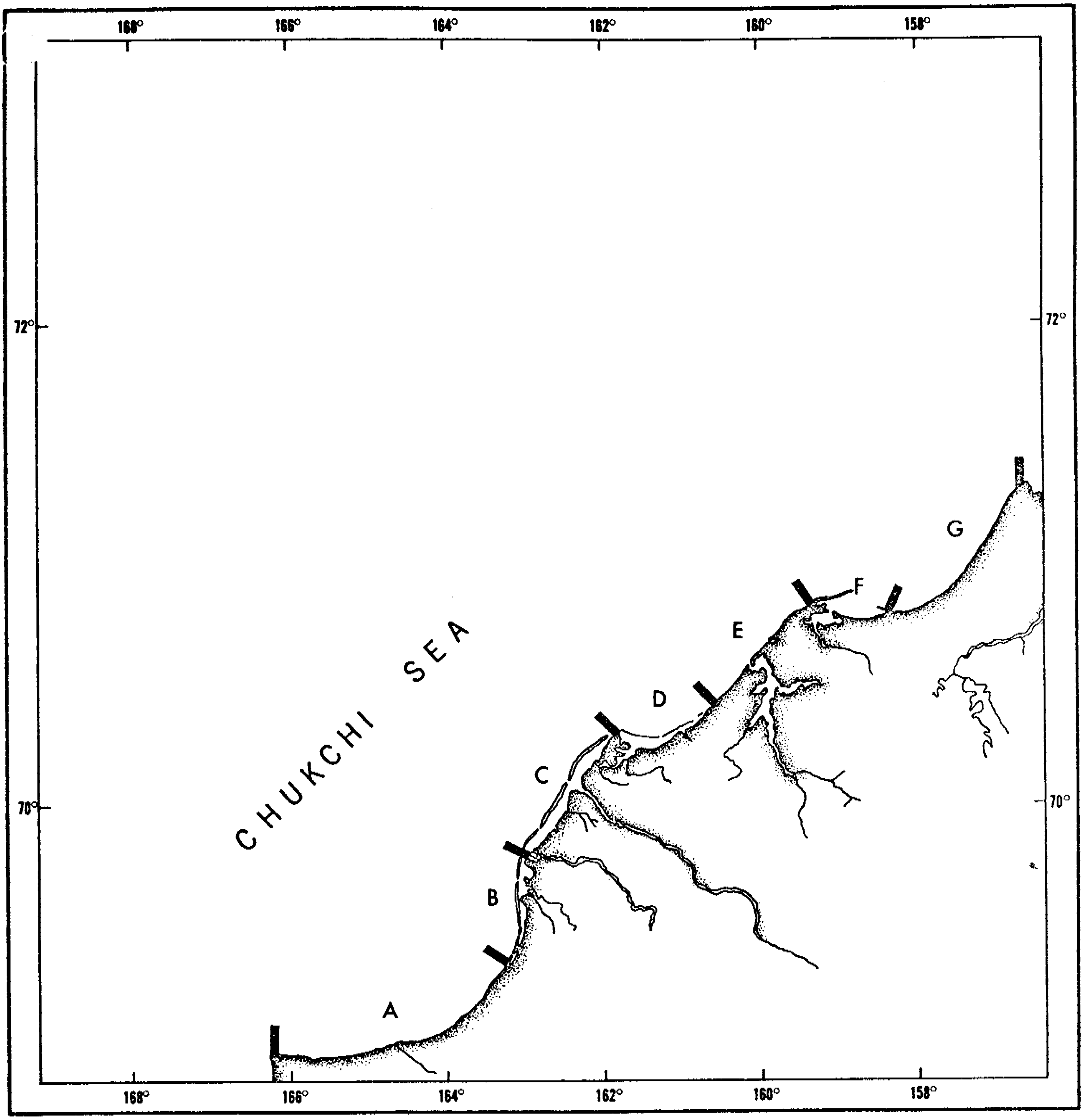


Figure 111a. The northern Chukchi Sea coast showing coastal sections discussed in text.

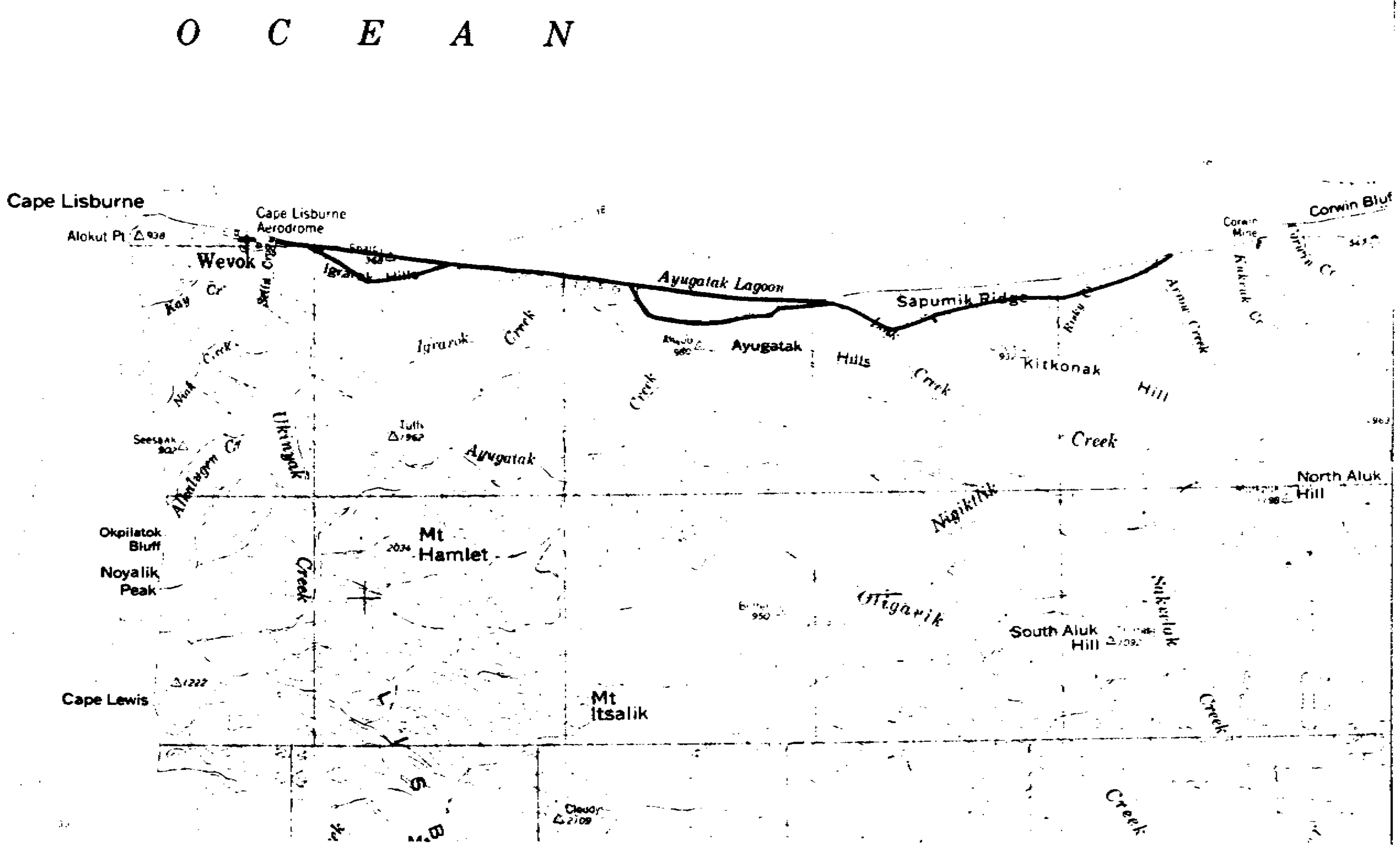


Figure 112. Map showing location of transects (black line) where avian populations were censused (see tables A through B).

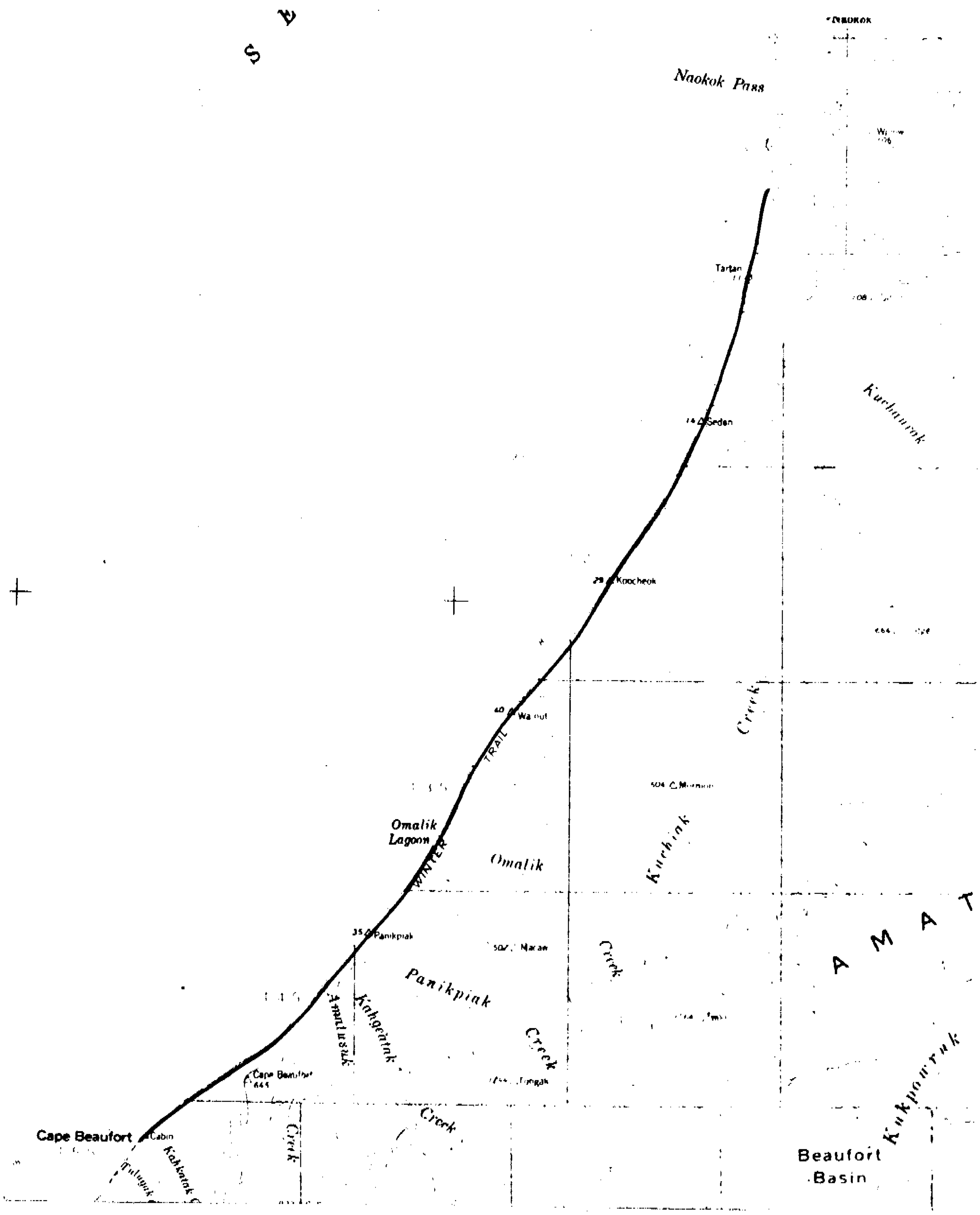


Figure 113. Map showing location of transects (black line) where avian populations were censused (see tables C through D).

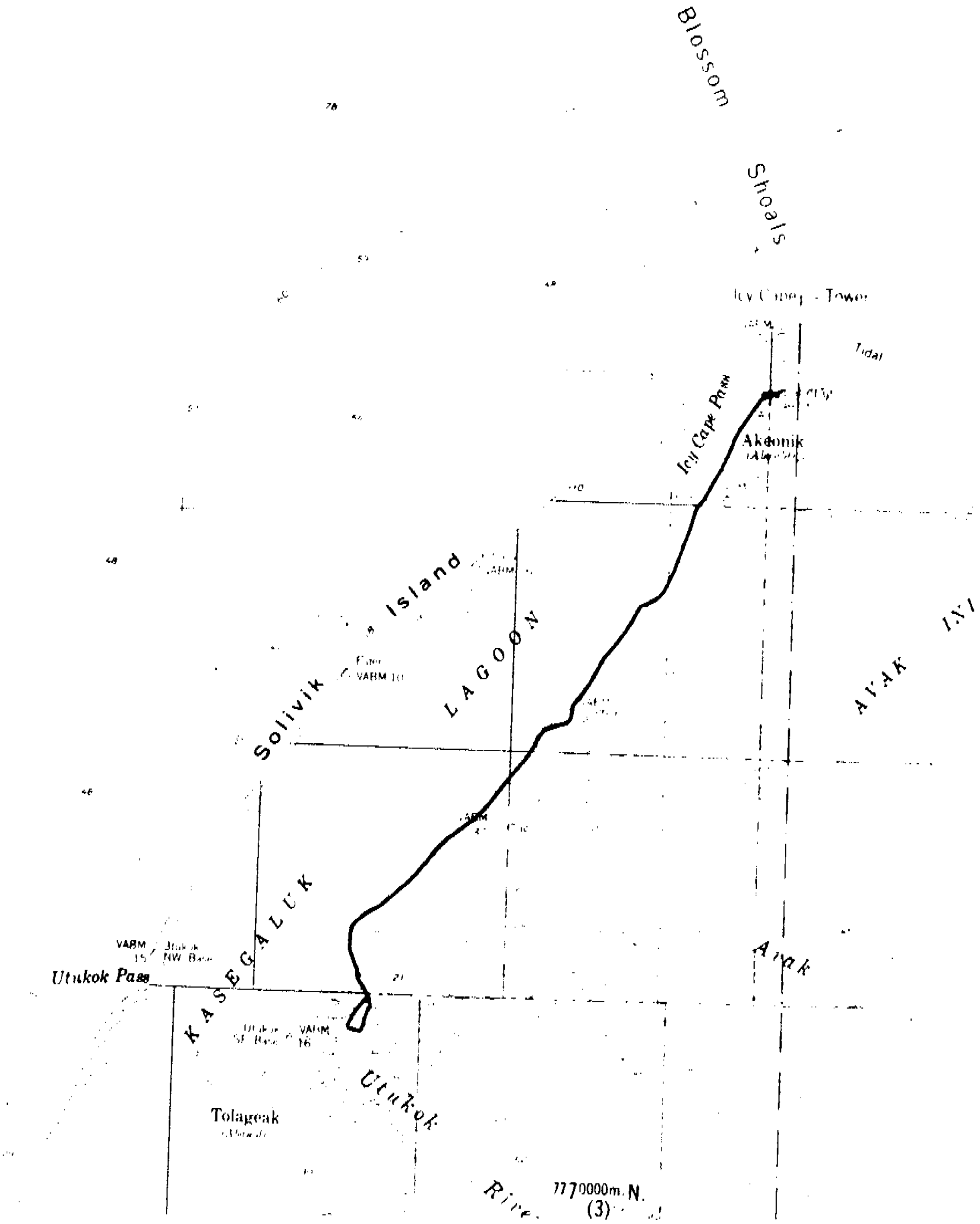


Figure 114. Map showing location of transects (black line) where avian populations were censused (see tables E through G).

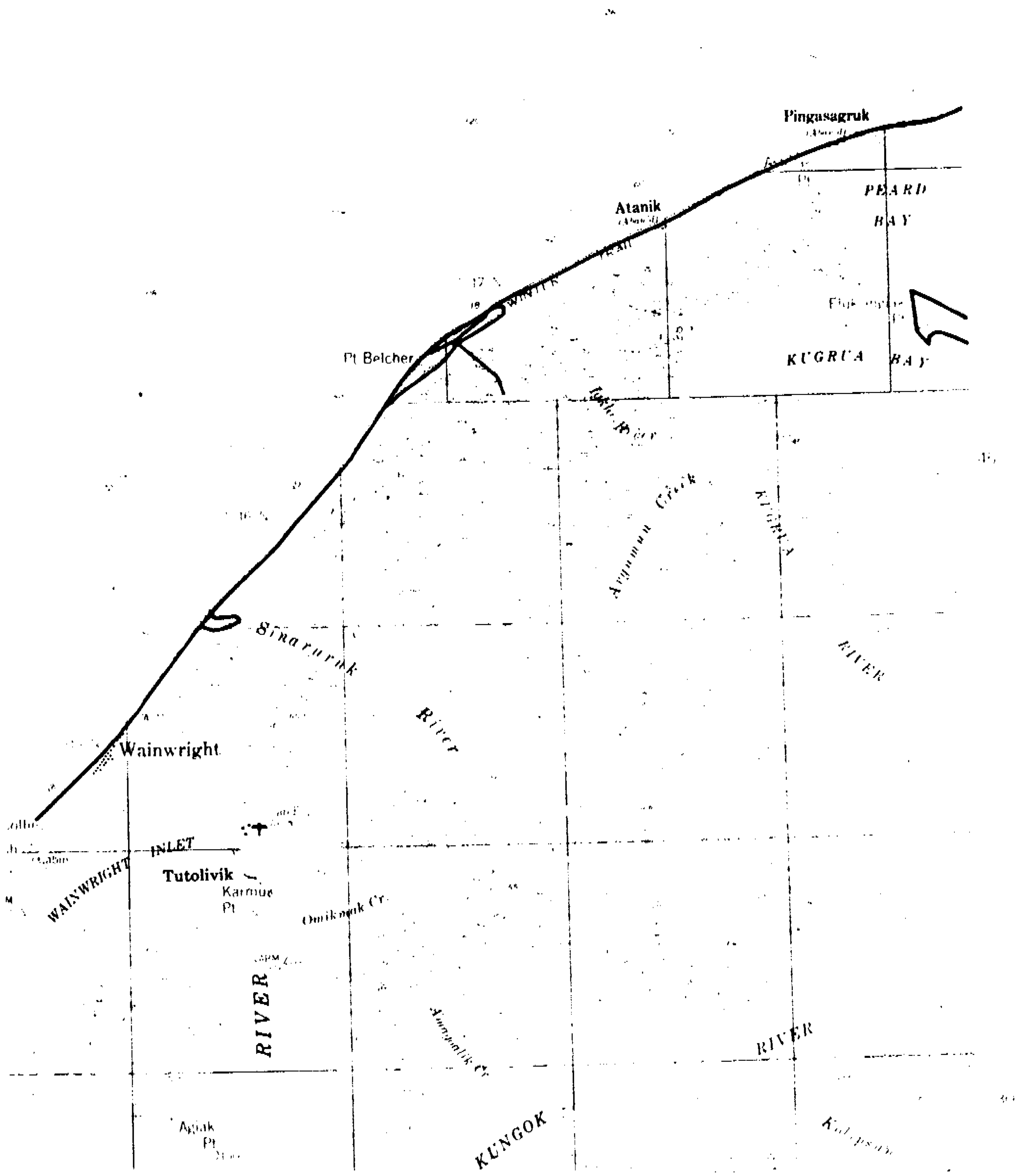


Figure 115. Map showing location of transects (black line) where avian populations were censused (see tables H through J).

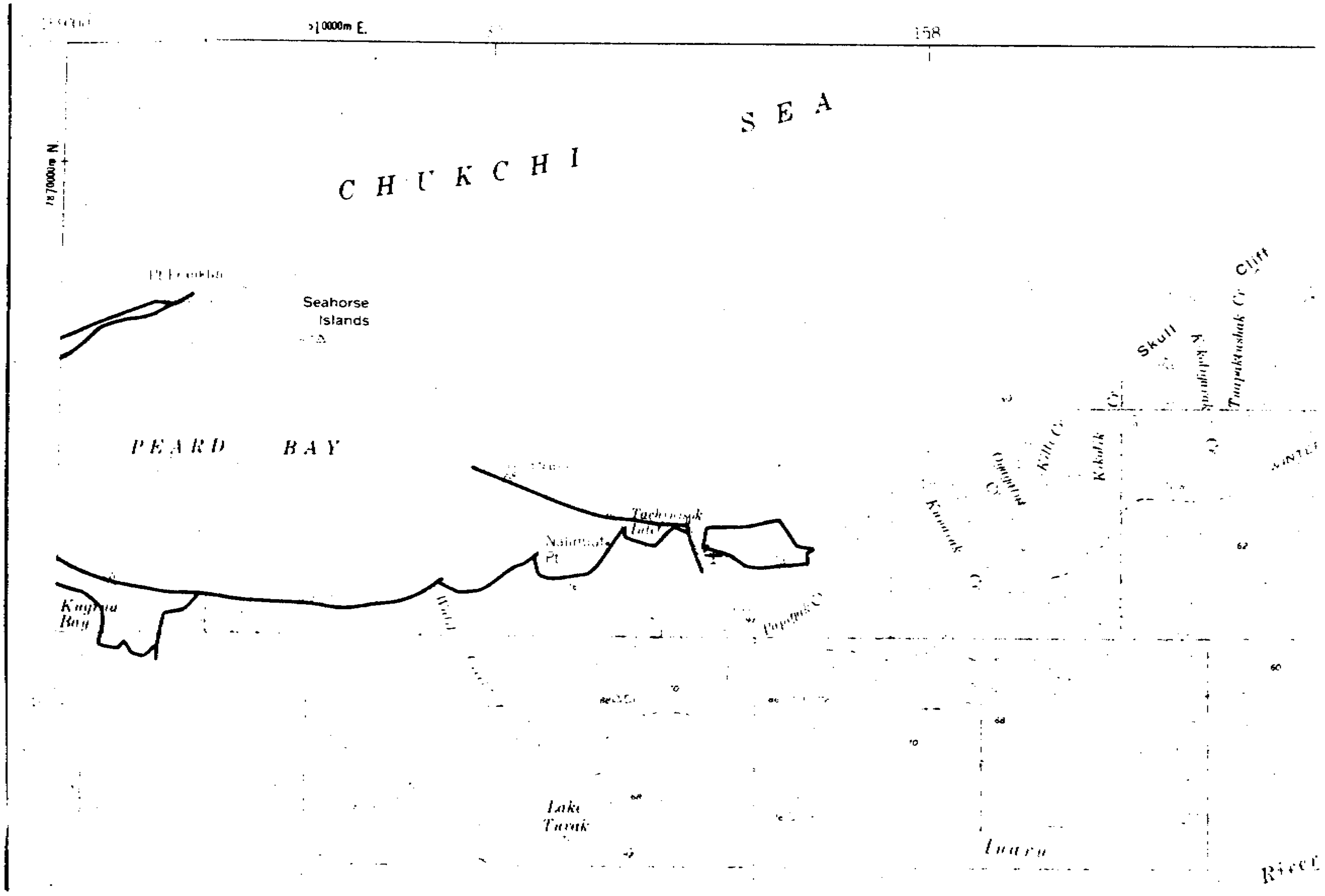


Figure 116. Map showing location of transects (black line) where avian populations were censused (see tables K through M).

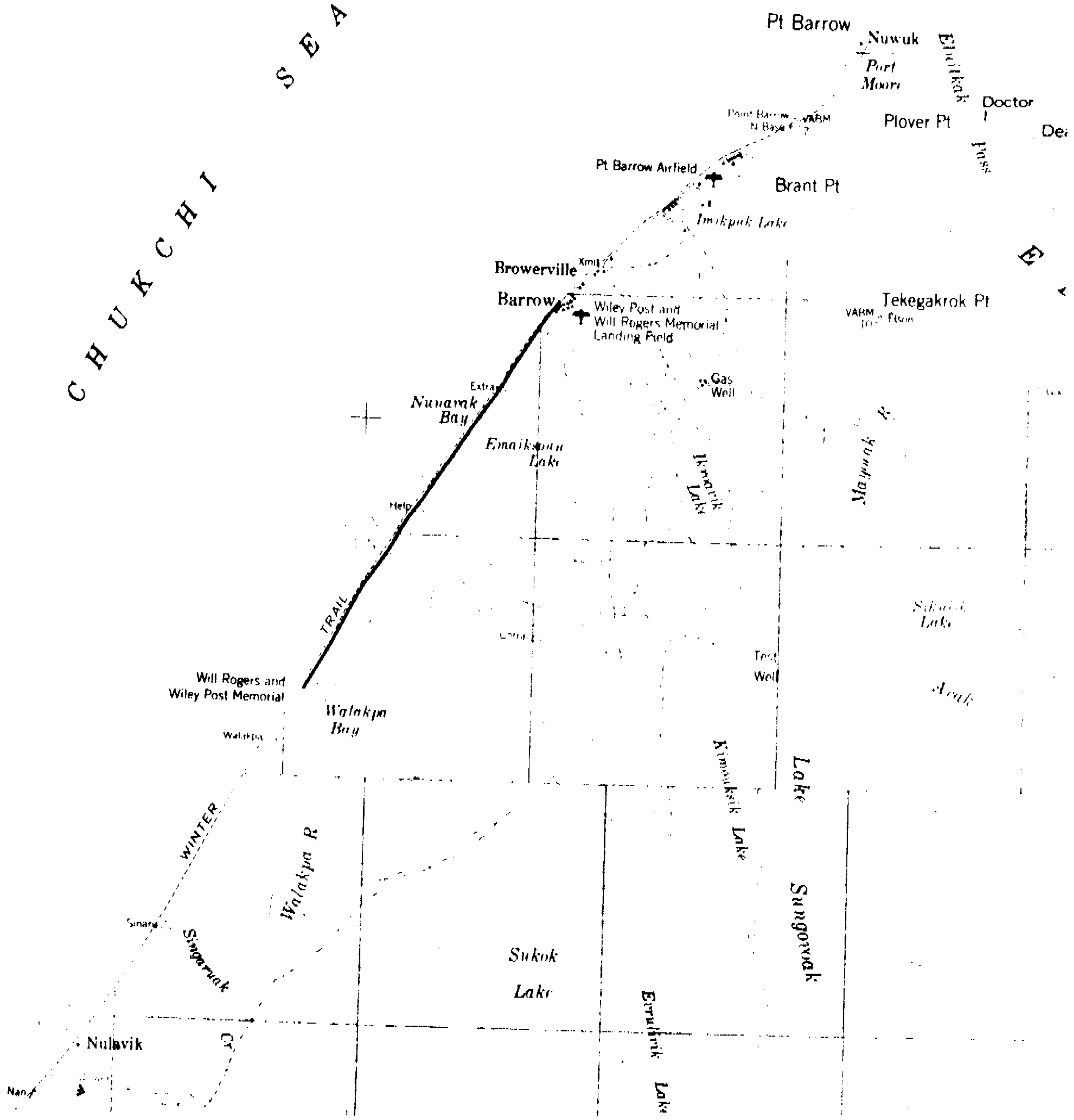


Figure 117. Map showing location of transects (black line) where avian populations where censused (see table N).

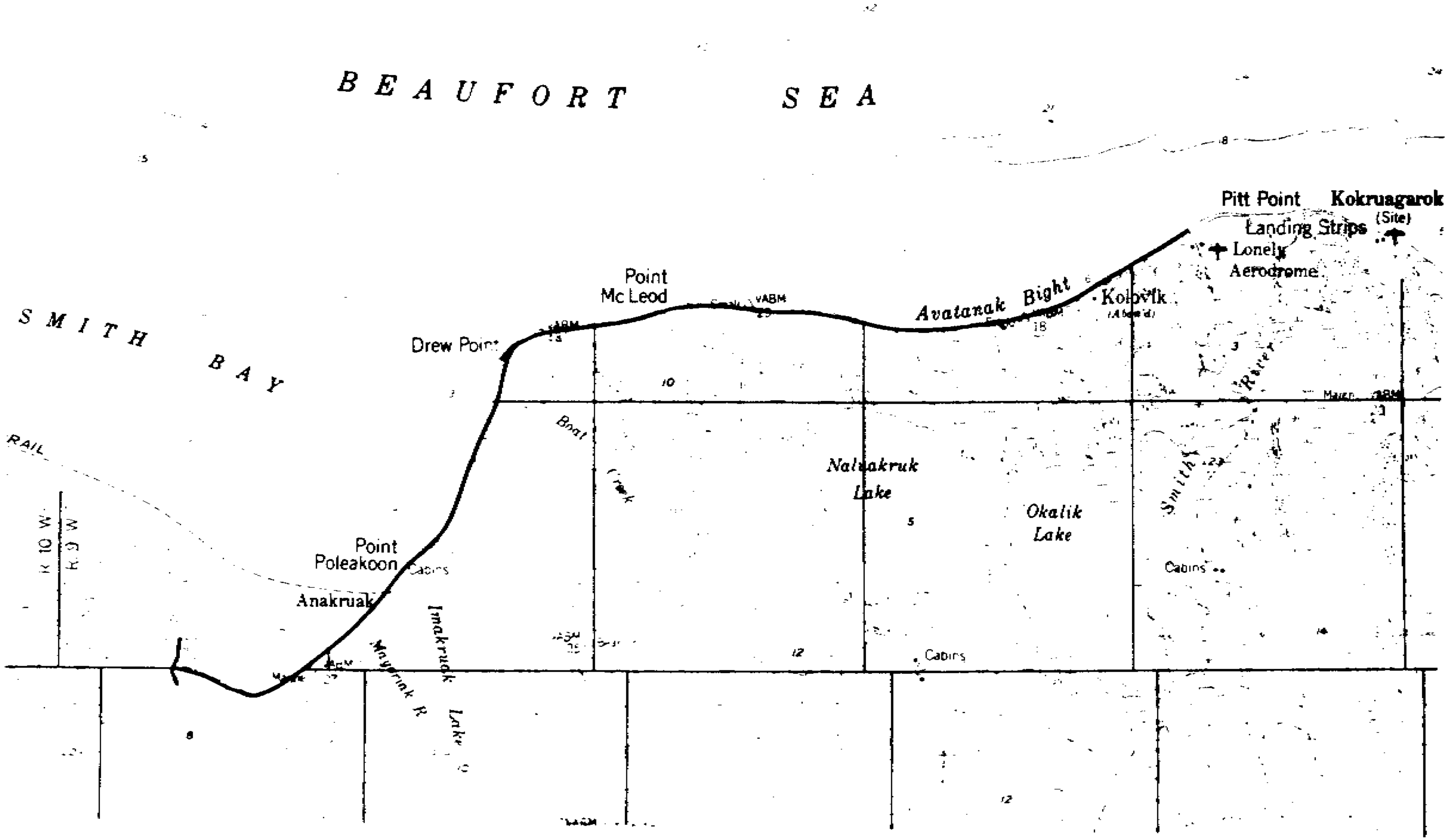


Figure 118. Map showing location of transects (black line) where avian populations were censused (see tables O through P).

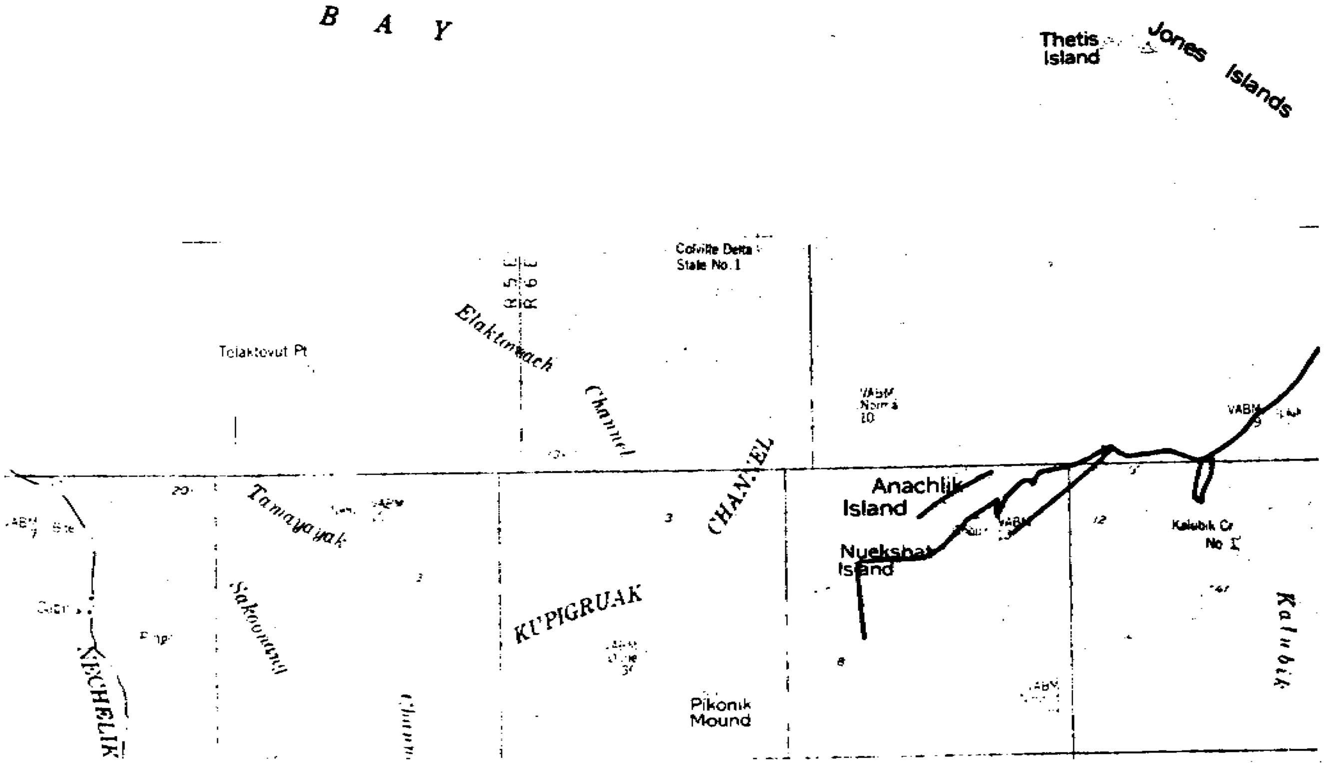


Figure 119. Map showing location of transects (black line) where avian populations were censused (see tables Q through T).

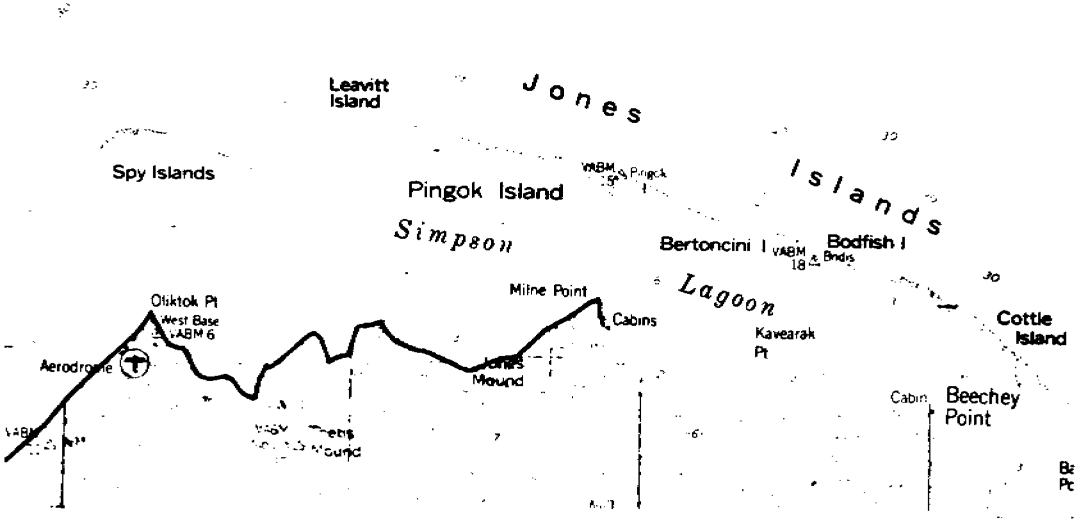


Figure 120. Map showing location of transects (black line) where avian populations were censused (see tables R through T).

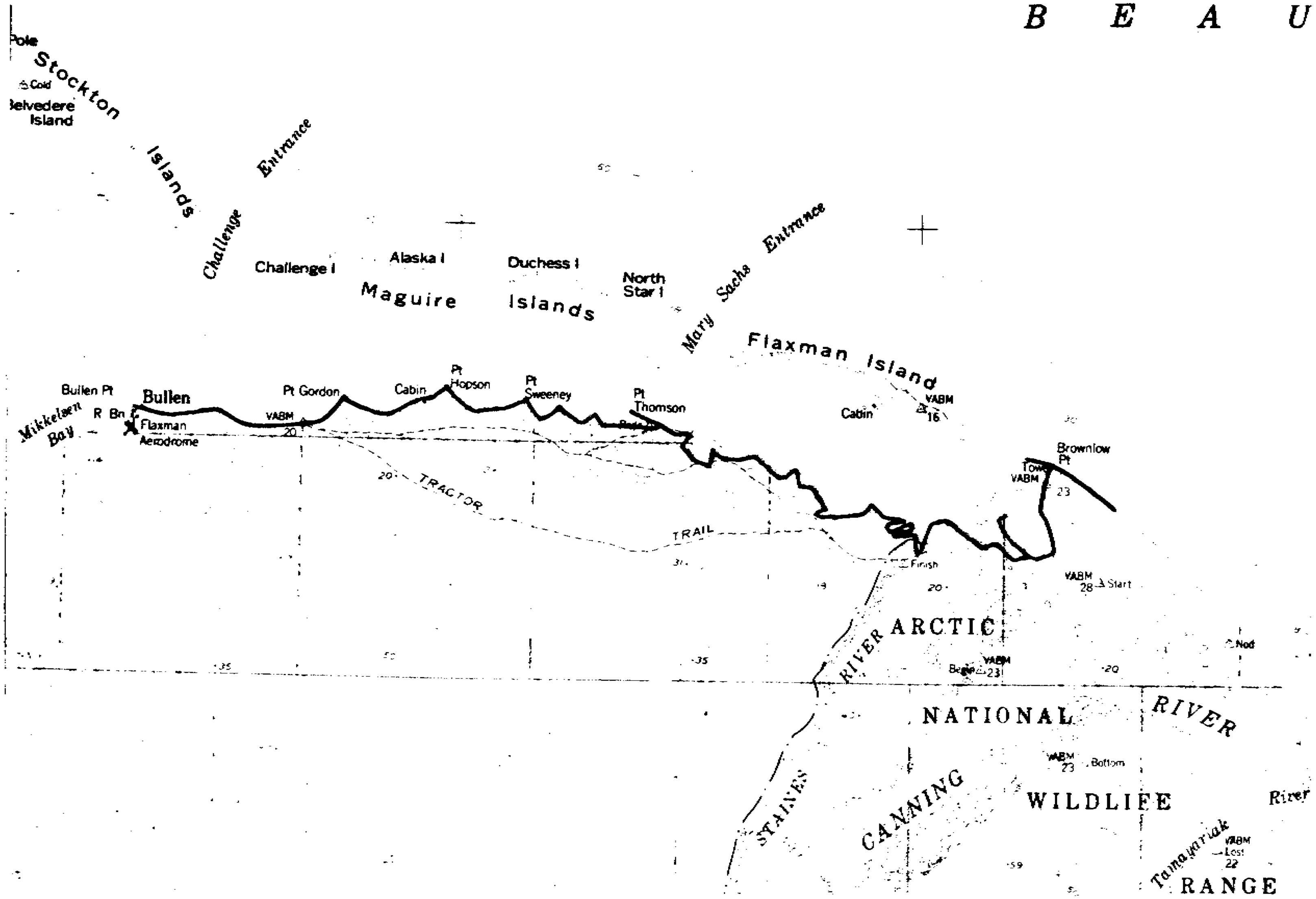


Figure 121. Map showing location of transects (black line) where avian populations were censused (see table W).

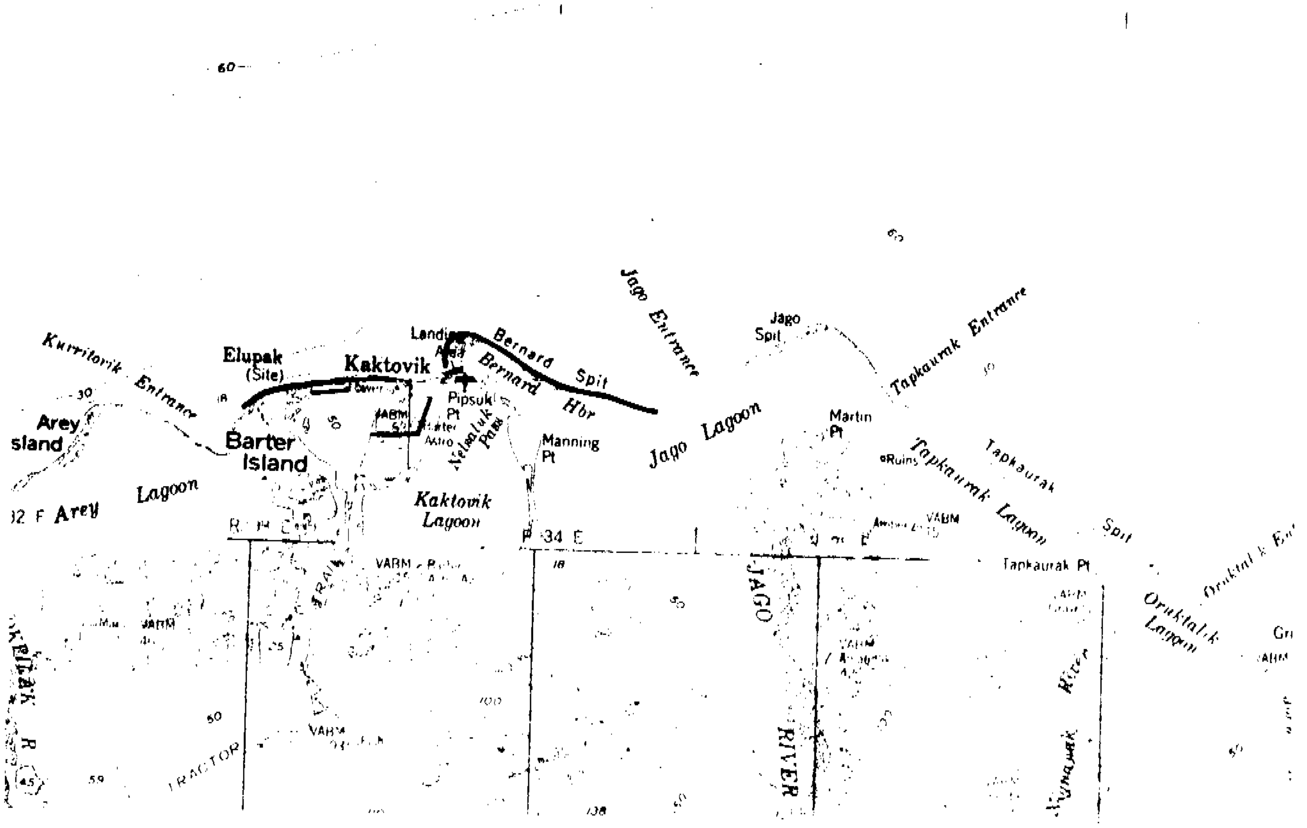


Figure 122. Map showing location of transects (black line) where avian populations were censused (see tables X through Y).

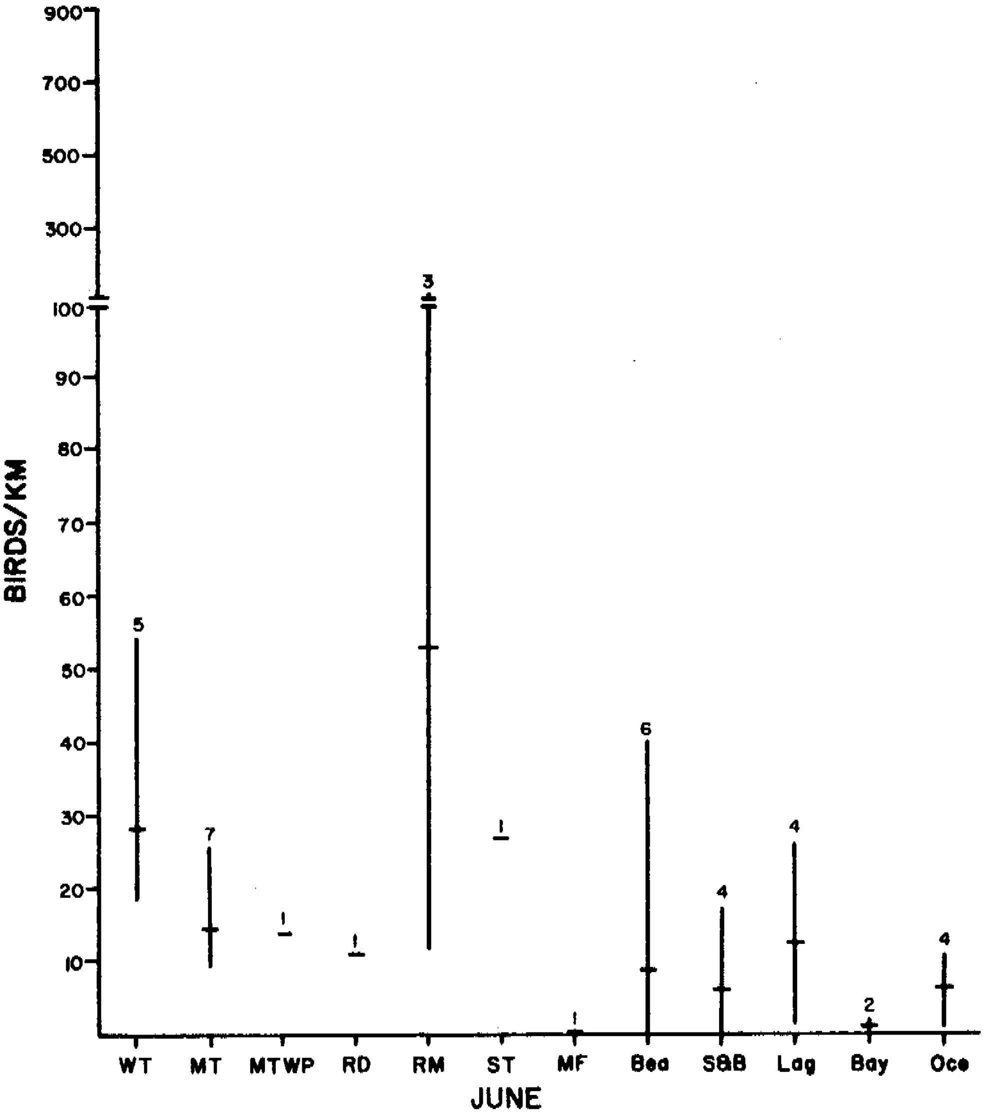


Figure 123. Birds per km per habitat in June.

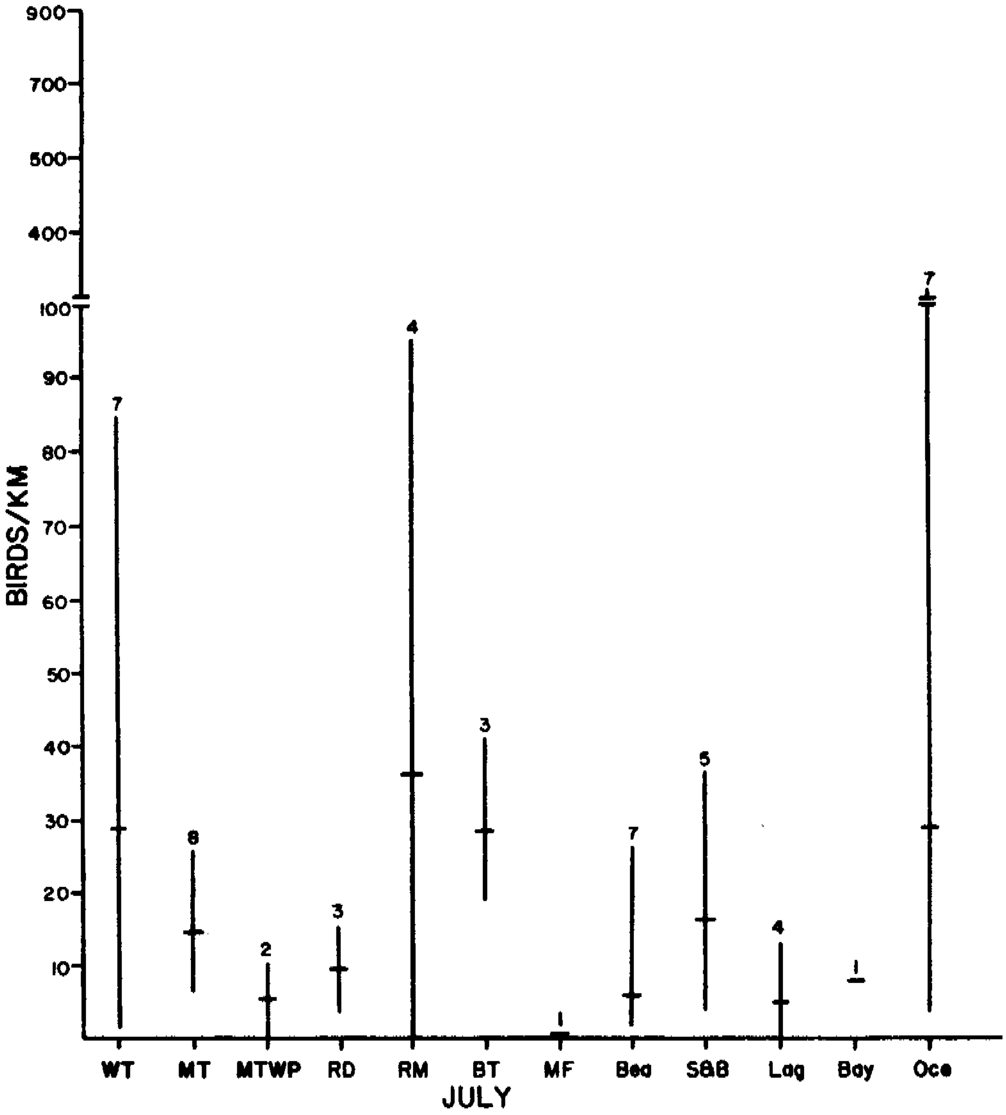


Figure 124. Birds per km per habitat in July.

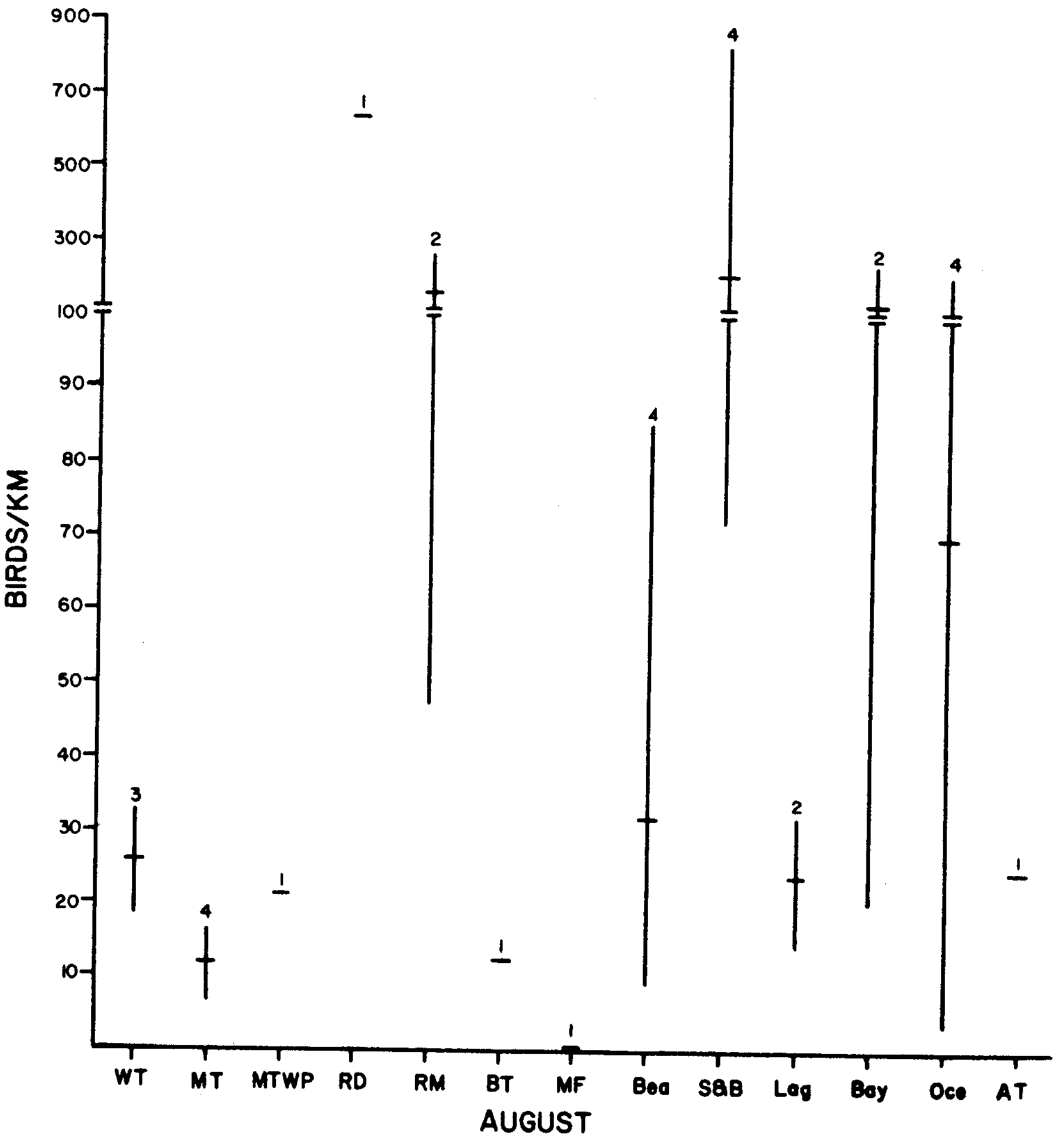


Figure 125. Birds per km per habitat in August.

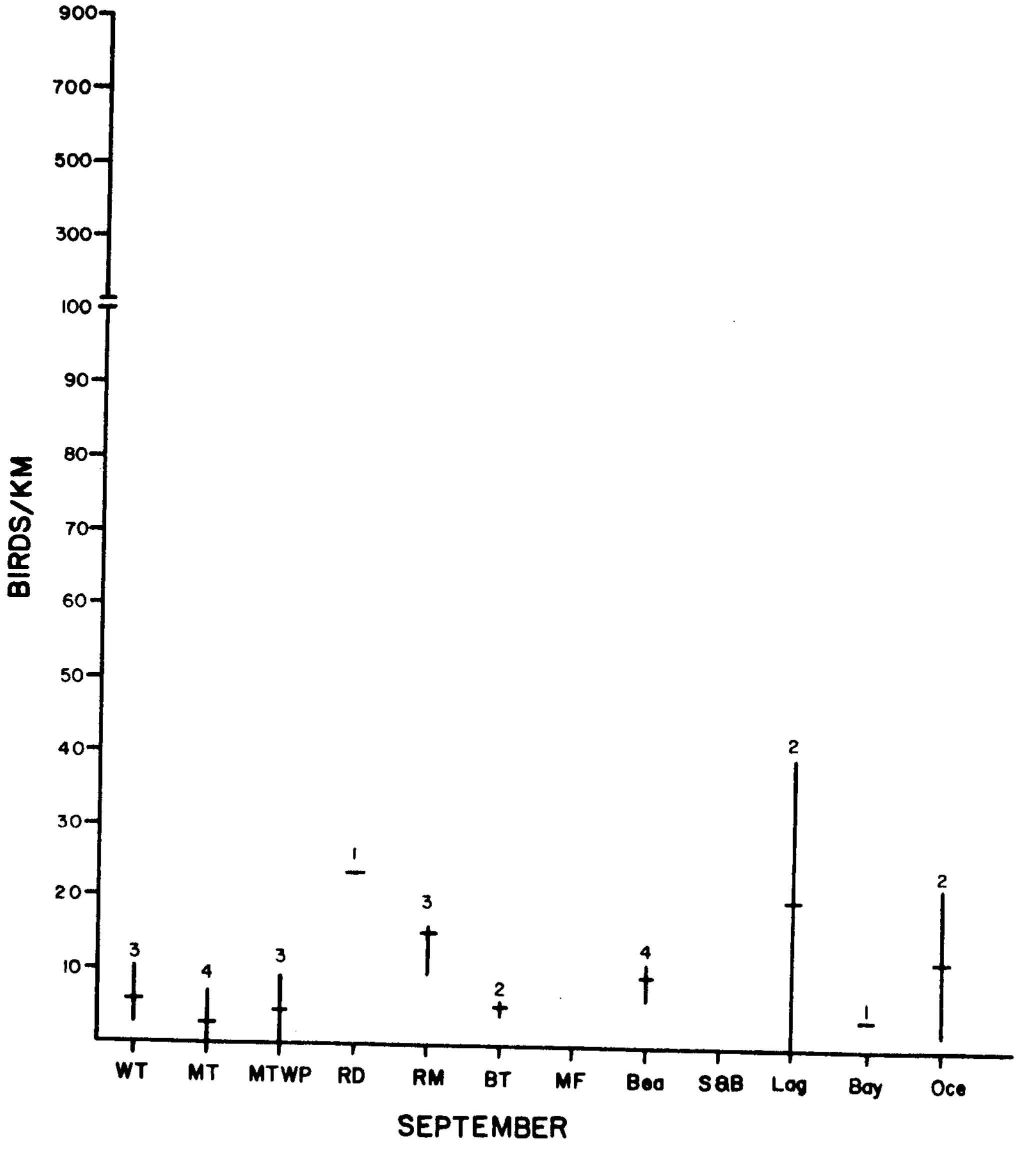


Figure 126. Birds per km per habitat in September.

ANNUAL REPORT

NOAA OCSEAP
Arctic Project Office
Contract No. 03-6-022-35208
Research Unit #237

ECOLOGICAL STUDIES OF BIRDS IN THE NORTHERN BERING SEA:

Seabirds at Bluff
Distribution of Birds at Sea
Movements of Birds in the Bering Strait

PRINCIPAL INVESTIGATOR

William H. Drury
College of the Atlantic
Bar Harbor, Maine 04609

Report by:

Cathy Ramsdell
and
William H. Drury

Appendix by:

Warren L. Flock
and
Joel D. Hubbard

March 1979

TABLE OF CONTENTS

Page

APPENDIX: ENVIRONMENTAL STUDIES AT THE BERING STRAIT:

Radar and Visual Observations of Bird Movements. Warren L. Flock and Joel D. Hubbard, January 1979.

LIST OF FIGURES

LIST OF TABLES

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

The purpose of our work is to identify those aspects of the biology of seabirds and waterfowl which deserve consideration in the planning for development in northwestern Alaska. Our objectives include: locating major concentrations of seabirds, waterfowl and shorebirds and establishing how these change with the seasons; establishing the numbers of birds and the circumstances under which the concentrations are important; investigating the trophic relations of seabirds in the northern Bering Sea. Our studies of the trophic relations of the marine birds are divided into three parts: 1) studies of breeding biology at the cliffs at Bluff; 2) reconnaissance at other seabird nesting cliffs in eastern Norton Sound, at Sledge Island (Ayak), King Island (Ukivok), and Little Diomede Island (Ignalook); 3) observations of the distribution of birds at sea. These studies include measuring reproductive rates and relating these to oceanic ecosystems and to changes in environmental variables such as weather, ice and the marine resources used for food. We believe that human activities which may accompany development will affect wildlife primarily by affecting these interactions.

We believe that our general inventory of the seabirds and waterfowl of Norton Sound, the Chirikov Basin and the Bering Strait, both on shore and feeding at sea provide a good picture of the overall pattern. Much larger commitments will be needed to increase the detail and improve the documentation. Our studies of Pelagic Cormorants, Glaucous Gulls, Black-legged Kittiwakes, Common Murres and Ravens complement other studies of the same or similar species obtained in other parts of Alaska's Outer Continental Shelf and in the North Atlantic. Together these will allow us to interpret spotty observations made where seabird cliffs are inhospitable or remote. They also provide a set of techniques for measuring population size and breeding success of seabirds when only a short time is available.

Our work at Bluff, Square Rock and Sledge Island indicate that both Black-legged Kittiwakes and Common Murres are sensitive to changes in the food supply in Norton Sound. These species are also markedly affected by the intensity and distribution of rain and wind storms, as well as the timing of spring break up of the sea ice. Our four years of studies indicate large differences among the years and suggest correlation with these major environmental variables.

The species we have studied respond quickly to local circumstances, and as a result, the numbers of birds at the cliffs vary with the conditions of the sea. These changes are especially evident in counts of murres; they suggest that counts or studies which do not take into consideration the reasons for the large changes in numbers from hour to hour and day to day may give a false sense of consistency of numbers.

We have found important differences in the proportions of seabirds nesting at the many seabird cliffs in our study area. The proportions of kittiwakes to murres, of Thick-billed Murres to Common Murres, of Horned to Tufted Puffins, and of Least to Crested Auklets vary widely over the region. These variations suggest ecological differences which must have implications in understanding the marine biology of the northern Bering Sea.

We have observed the effects of predation of Glaucous Gulls, Ravens, Arctic Foxes, Red Foxes, and the local people on the bird cliffs. King Island and Little Diomede Island offer opportunities to observe the effects of the presence of people,.of their pets and of native predators. Little Diomede is still occupied and King Island has been abandoned for fifteen years. Little Diomede Islander, John Ayapana, suggested that Crested Auklets and murres have decreased in the last twenty years. King Islanders, Ed Muktoyuk and John Pullock, report that murres and kittiwakes now nest on many ledges which were barren of breeding birds when they were children collecting eggs on the islands. Arctic Foxes come to these islands from the sea ice each spring. Those on King Island are not disturbed, but those on Little Diomede are. We saw Arctic Foxes carrying many dead Parakeet Auklets in our brief time on King Island. Our experiences in the eastern U.S. and those of others elsewhere suggest that foxes, like domestic dogs, have drastic effects on the behavior of breeding seabirds. Foxes apparently cannot survive the summer on Fairway Rock; that island has an unusually large population of Tufted Puffins nesting in turf on the top of the island. The changes associated with release from natural predation should be documented following the removal of foxes.

Our studies indicate that although predation by Glaucous Gulls and Ravens is conspicuous in the number of eggs on the cliff tops, it has a minor effect on the population. The impact of local people collecting eggs or netting birds presently seems to be minor and localized as the people make only symbolic use of the cliffs. Where more purposeful use is made by foxes (and presumably people) there is an important impact, but that impact is limited to birds which nest in vulnerable peripheral areas.

Our studies indicate that Ravens and Glaucous Gulls are benefitting from development in this part of Alaska. These two species use organic wastes supplied by current systems of garbage disposal and the killing of walrus for their ivory. The beaches of northwestern Alaska are scattered with carcasses of headless walrus and each one has a retinue of gulls and is visited occasionally by flocks of Ravens. Experience in other parts of the world suggest that the growth of the populations of aggressive species such as Ravens and gulls will result in competition for nesting sites with sensitive species such as Peregrines, Gyrfalcons, and Rough-legged Buzzards, and will increase the pressures of predation on small species of seabirds and waterfowl.

We have found that seabirds are distributed according to differences in the oceanography of Norton Sound and the Chirikov Basin. The patterns reflect differences in the water masses, movement of the ice, and presumably by response to patterns of the detritus/benthic fauna, the crustacea, the nekton/plankton and the fish. The sea ice persists late along the north shore of Saint Lawrence Island, in the eastern half of the Chirikov Basin and in the Bering Strait. This ice attracts most of the sea mammals and seabirds in the early summer. Late in the summer, Gray Whales and most of the seabirds congregate in the waters west of Saint Lawrence Island and west of King Island. We have been unable to document the western extension of this pattern because we were excluded from flying in Siberian Air Space.

Important observations were made of the movements of birds in the Bering Strait using the radars at Tin City. These records show extensive movements of birds identified as auklets, murres, and kittiwakes from the Diomede Islands to the southeast of Tin City as far as Cape Spencer. They also record heavy movements of Sandhill Cranes, Snow Geese and other waterfowl to the west across the Bering Strait to Siberia in late May and June. These data substantiate the use of the Bering Strait by large numbers of birds and indicate that killing or contamination of birds in this area will have effects that extend far beyond the geographic limits of this region.

We have not yet seen the results of Dr. Barton's studies of the fish resources of this area, but have found the results of Dr. Wolotira's studies of ground fish to be of little help in explaining the distributions of seabirds. Wolotira found minimal stocks of commercial fish where we found maximal concentrations of seabirds.

The contrast in the effects which development will probably have on the murres and kittiwakes as compared to Ravens and Glaucous Gulls suggests that it will be dangerous to suggest, a priori, specific interactions between species and what we consider to be their habitat. Unfortunately the ways in which species are coupled to their "system" remains one of the major puzzles of contemporary ecology. Successful species seem to be able to disassociate themselves from close coupling with any single system or subset of the system. The ability to use several apparently independent systems seems to lead to "success" and seems to depend on the species' perceptions of elements in its habitat, such as prey, whether these are part of one or several systems. For example, the food of murres and kittiwakes in the North Atlantic, North Pacific, Bering and Chukchi Seas varies widely in species composition between geographic regions and between years. Yet the form and habitat of the prey remains consistent: the fish "look" the same and swim in the same part of the water column. This "opportunism" in choice of prey probably reflects how many species of fish look the same rather than any ability of the birds to change their rigid feeding techniques or searching image; detailed studies should document this. Similar variation in foods despite restricted feeding techniques is evident in the large gulls (genus Larus).

We believe that more may be learned by concentrating on the feeding actions of the birds and the consistency and differences in the feeding areas at sea rather than by spending time on details of changes in species of prey. We think that it will be most useful in making predictions as to the effects of development to use seabirds as indicators of water masses and to learn what those masses are and where they are going. Water masses seem to be the fundamental units of the oceanic habit and as such define the areas of sea which must be included in the habitat of the seabird nesting islands in the region. This means that studies of seabirds and sea mammals should be used to guide oceanographic studies.

Finally, our paradigms for the operation of natural systems appear to be fundamentally different from those of scientists who are studying physical systems and productivity. Mathematical models of the structure of ecosystems depend upon the assumptions which their designers make about the interactions among variables. We, therefore, doubt the value of using current models of ecosystems to predict the impact of development, and we believe that our doubts are shared by an important proportion of those who are studying active vertebrates. We believe that this problem is serious, because in essence we doubt the validity of the operations for which data processing has been designed.

II. INTRODUCTION

As the oil fields of northwestern Canada and the North Slope of Alaska are developed, the Bering Strait will become a major avenue of transportation for heavy equipment. Ships waiting to move north will stop in staging areas such as Port Clarence, because ice conditions periodically prevent the passage of ships past Point Barrow. The Seward Peninsula will experience economic expansion as a consequence of developments associated with the exploration and extraction of oil reserves.

The peculiar topography of the Chirikov Basin is associated with a high population of marine mammals, birds and a relatively dense Eskimo population, because the shape of the basin confines and funnels the flow of the water masses moving northward through the Bering Strait.

It is probable that shipment of heavy equipment and products related to development of petroleum resources will have both direct and indirect effects on the region's biological systems, and likewise, that the secondary development will have a major impact on human and wildlife interactions in the area. In order to assess these effects it is important to first know what habitats are present and to what degree they are utilized by wildlife. The surveys reported in this Research Unit were planned to locate the areas of critical importance to wildlife, to assess their value and vulnerability, and to consider how to prevent or mitigate damage. Though there is at present little pressure for decisions and actions concerning developmental effects, lease sales in the northern Bering and Chukchi Seas are imminent, and the movement of heavy equipment through the Bering Strait has started.

A. General Nature and Scope of the Study

1. Geological Setting (Precis of C. H. Nelson, D. M. Hopkins, and D. W. Scholl 1974).

The Bering Strait geographical region is an area of continental shelf across which a set of ridges runs east and west bordered on the north and south by transcurrent faults. These transcurrent faults, by which energy built up as a result of the stresses of plate movements are released, have probably played important roles in the formation and destruction of intercontinental land connections which make this region important biologically.

Transcurrent faults mark the edges of the region and seem to be associated with the major seabird breeding sites. One set of faults runs along the northern border of the Gulf of Anadyr and along Saint Lawrence

Island. Another runs from Golovin north into the center of the Seward Peninsula and westward to the area around King Island. Another parallels the narrow part of the Bering Strait and runs along the north shore of the Chukotka Peninsula. Another runs northwestward from Cape Thompson/Cape Lisburne.

These faults run along a flex in the continental structure which is concave toward the Arctic Ocean. Reverse flexes, concave to the Pacific Ocean, occur on both ends of this flex, one in Siberia and one in Alaska. These seem to result from bending in Siberia relative to North America as a consequence of rifting in the Arctic and Atlantic Oceans. Another consequence of this bending may have been a shift of the subduction zone from the continental margin in the central Bering Sea to the Aleutian Trench. This evidently happened at the beginning of the Cenozoic, when Eastern Siberia and the northwest part of North America began to rub against the Pacific Plate. The Aleutian Basin, south of the Continental Shelf and north of the Aleutian Islands, is a trace of the abyssal sea floor that existed prior to the meeting of the Pacific Plate with the North American/Eastern Siberian Plate.

Mountain glaciers occupied the ridges of the Siberian and Alaskan peninsulas during the Pleistocene, but much of the area was glacier-free. During the Pleistocene, the outlet of Alaska's major river, the Yukon, emptied north of Saint Lawrence Island into the Chirikov Basin. In the most recent Pleistocene, it emptied south of Saint Lawrence Island over the edge of the continental shelf through one of the deepest submarine canyons known. Today it empties into the southeastern corner of Norton Sound.

Metamorphosis and mineralization, combined with glacial and subaerial weathering, erosion and shoreline oscillations, have produced the deposits of heavy metals for which the region is well known. Placer and mother-lode mines for tin, gold, mercury, and platinum occur in the Seward Peninsula. Mercury, chromium and copper are found in beaches on the south shore of the Seward Peninsula in concentrations high enough to be toxic, but are not concentrated enough for present techniques of extraction to be economically worthwhile.

2. Oceanography of the Region

The currents and water masses which pass northward through the Bering Strait have been described in general terms (Hood and Kelley 1974, Coachman, Aagaard and Tripp 1975). Water of deep origins south of the continental shelf moves north of Saint Lawrence Island and mixes with both Continental Shelf

Water and Coastal Water dominated by the outflow of the Yukon and Kuskokwim Rivers. These three water masses sheer against each other and become progressively confined as they approach the Bering Strait. Much of the water passes through the relatively deep channel between Cape Prince of Wales and Little Diomede Island; yet, the effects of mixing and turbulence combine to produce very high levels of productivity in the shallower water west of Big Diomede Island (Hood and Kelley 1974).

While very valuable for painting the picture of events on a grand scale, the studies providing this information have not been done in precise enough detail nor directed toward clarification of the properties of movements, fronts, nutrient concentrations, and productivity which would help clarify the biological oceanography of the region. The data which we have gathered on the distributions of feeding seabirds and sea mammals found in the course of aerial surveys and fixed transects can be related to oceanographic conditions only in very general terms.

3. Biological Resources of Beringia

Because the region is dominated by a northward flow of water during the ice-free seasons, nearly all effects on the ocean will be transported through the heart of an area exceptionally rich biogeographically.

Beringia, a geographic region including the northern part of the Bering Sea, is known for exceptionally high species diversity at high latitudes. This, combined with the tendency of seabirds and shorebirds to increase in diversity at high latitudes, makes the area one of special importance. Immense seabird populations inhabit the region associated with high primary productivity combined with the coincidental presence of suitable cliff and rubble nesting sites. Two major faunas, Palearctic and Nearctic, meet where the two continents do. In addition, many species are limited to or endemic to the Berigian region; Udvardy (1975) listed thirty-four.

Our estimates, together with those of Bédard (1969), indicate that about four and one half million seabirds (4.5×10^6) live in this area which is about the size of the Gulf of Maine and the Bay of Fundy (the area between Cape Cod and Nova Scotia) off the northeast coast of the U.S. This number of birds is larger than and may be twice as many as the number of seabirds breeding between central Labrador and Cape Hatteras. While millions of murres and Dovekies from the Canadian arctic winter off eastern Canada, and millions of Great Shearwaters, Sooty Shearwaters, Wilson's Petrels and Fulmars summer there, large numbers of southern hemisphere Short-tailed Shearwaters enter the northern Bering Sea in late summer.

The Bering Strait Islands, King Island, and Saint Lawrence Island form the northernmost cluster of nesting sites of millions of Least, Crested and Parakeet Auklets. These seabirds have breeding and wintering ranges limited to the western Gulf of Alaska, the Bering Sea and the Sea of Okhotsk. In Norton Sound seabirds are in general relatively scarce and auklets are virtually absent, presumably for reasons of habitat and ecology.

Murres, kittiwakes, and puffins, otherwise widely distributed in all northern seas, have their northern breeding limit at Cape Lisburne. The proportions of kittiwakes to murres and of Common to Thick-billed Murres vary widely among the colonies over the larger Bering Strait region. For example, there are about 60,000 murres (half Common and half Thick-billed) and 35,000 kittiwakes at Little Diomede; 30,000 murres (half Common and half Thick-billed) and 3,500 kittiwakes at King Island; 35-50,000 murres (99% Common) and 4,000 kittiwakes at the Bluff Cliffs.

Black guillemots, an Eastern Arctic species, extend south to Cape Thompson at the northern limit of the range of the Pigeon Guillemot, a closely related member of the Pacific fauna. In addition, Beringia supports a northern element of Kittlitz's Murrelet and Aleutian Tern, major breeding centers for Steller's Eider, Spectacled Eider, Harlequin Duck, Emperor Goose, and one of the few populations of the inland subspecies of Peregrine Falcon (Falco peregrinus anatum) which seems to be reproducing well. Important populations of endemic species, including Bristle-thighed Curlew, Surf Bird, Black Turnstone, and Western Sandpiper, gather on coastal mudflats of the area during migration. All of these species are vulnerable to contamination from pollution or disturbance by secondary effects of development.

In addition to the large numbers of seabirds, the region of the Saint Lawrence Island waters, Chirikov Basin, Bering Strait, and southern Chukchi Sea is also the site of spring gatherings of 120,000 Walrus and summer gatherings of some 15,000 Gray Whales, as well as Finback Whales. According to H. Braham in his report to OCSEAP investigators at Fairbanks in October of 1978, the two species, Walrus and Gray Whale, combine to form biomass in the order of trillions (10^{12}) of kilograms. To the west is the former range of Bowhead, Finback and Minke Whales. In the shallow water of Norton Sound is one of the major Alaskan populations of Belugah Whale. Bearded, Ringed and Spotted Seals are numerous on the winter ice and formed the staples of the Bering Strait Eskimo diet. These concentrations of marine mammals reportedly extend into the southern Chukchi Sea. On the average, the Strait appears to form the southern limit of the Polar Bear's winter distribution. Though the finfish available for commercial exploitation are not important in this area, the benthos upon which the whales, Walrus, and some seals (Bearded) depend, is outstanding (Alton, in Hood and Kelley 1974).

Native settlements in the western part of this area consisted of a number of relatively large (100-125 people) settlements and many small mobile groups of single or several families. The large permanent settlements depended on large marine mammals hunted especially on moving sea ice. Whaling was important at western Saint Lawrence Island and at Point Hope; but according to Ray (1976), whaling was relatively unimportant in the settlements within the more narrow sense of the Bering Strait, that is, King Island, the Diomede Islands, and Wales. The people of King Island reportedly left the island in the summer, dispersing to use resources on the western coast of the Seward Peninsula; the other settlements were more permanent. The main settlement in Grantly Harbor was reportedly at the mouth of the Tuksuk Channel rather than at the present site of Teller, which may have been a result of accomodation between the local people and the depredation of summer travellers from King Island.

Although whaling was pursued by the Eskimos at both limits of this area, Saint Lawrence Island and Point Hope, the language groups of the two are different. The people of Point Hope, Kotzebue Sound, the Diomede Islands, Wales, King Island, and the west coast of the Seward Peninsula as far as Cape Nome, speak Inupiat, the language of the Eskimo of the Arctic Coast of North America. The people of Saint Lawrence Island, however, speak a Siberian form of Yupik. It seems probable that this separation depends on relatively recent tribal movements; i.e., the western end of Saint Lawrence is within sight of Eastern Siberia and is quite remote from the Seward Peninsula and associated islands. It would seem contrived to argue that the separation reflected some important ecological barrier.

If we assume that the traditional Eskimo hunters were subject to the same ecological principles as other opportunistic predators, we can assume that permanent sites were located where the principle prey were most consistently available. Individuals or parties probably made excursions from these centers to collect specific resources. This, therefore, suggests that the most important or critical sites for natives and wildlife are the same.

It does not mean, however, that major feeding grounds of marine mammals and birds are close to those places at which people lived. So although we can draw some straightforward conclusions from the traditional distribution of native settlements and associated hunting sites, there are major features of the distribution of wildlife resources which still need to be clarified, especially in areas beyond the access of hunters using traditional means of travel.

B. Specific Objectives

1. General

The goals of our part of OCSEAP are as follows: to assess the present environmental conditions in the northern Bering Sea and Bering Strait, *vis á vis* the possible impact of oil development; to identify and estimate the social effects, and suggest ways in which development can be compatible with a wide spectrum of social values, including wildlife. Specific objectives of this research unit are as follows:

a) To determine the breeding areas and seasonal changes in density and distribution of the principle seabird species;
   1) To establish species numbers and the schedule of reproduction;
   2) To establish the influence of weather and special oceanographic conditions on the events during the breeding season;
   3) To compare species and numbers at the sixteen major seabird areas: Egg Island, Cape Denbigh, Cape Darby, Rocky Point, Square Rock, Bluff Cliffs, Topkok Head, Sledge Island (Ayak), King Island (Ookvok or Ukivok), Gambel Mountain (Sevuokok), Southwest Capes, Savoonga region, Little Diomede Island (Ignalook), Fairway Rock, Cape Thompson, and Cape Lisburne (Wevok);
   4) To describe the chronology and phenology of events in the breeding season, including changes in population from the beginning of occupation of sites in the spring through departure in the fall;
   5) To establish and describe sampling areas which can be used in subsequent years or by other observers to monitor the status of seabird populations breeding at the main study sites: Square Rock, Bluff Cliffs, Sledge Island, King Island, and Little Diomede Island.

b) To describe the trophic relations of selected species:
   1) To measure reproductive success among Pelagic Cormorants, Glaucous Gulls, Black-legged Kittiwakes, Common and Thick-billed Murres;

2) To determine the amounts and kinds of foods which the seabirds eat themselves and what species they bring to their young;

3) To determine where at sea the nesting birds feed, the regularity of their foraging patterns and, when possible, the relationship of the food selected to the food available. This includes examining whether the relatively even distribution of the fish-eating murres, puffins, cormorants, and kittiwakes, in contrast to the concentrated distribution of auklets in the Saint Lawrence Island waters and Bering Strait, is coincidental or related in a cause-and-effect way to the characteristics of these water masses and their trophic structures.

2. Comparative Studies vs. Experimentation

Our goals include gaining a general understanding of the interactions among the biological and physical ecosystems in the Bering Strait region to a point where we might then pass beyond the stages of description to explanation and prediction, without getting confused with details or fragments of the systems. In the idealized formal scientific method these progressions should include experimental tests to verify our hypotheses. In fact, most scientific topics of investigation are chosen for their accessibility to experimental verification. For this reason many important questions are excluded, especially ones concerned with the relation of parts to a whole.

Our task has been to address questions which have clear social validity, regardless of whether or not they are sympathetic to experimental validation. We are inclined to look for verifiable hypotheses, whether testable by experiment or by comparison, rather than to pursue experimentation as a goal in itself.

The independent habitat variables affecting the living organisms in this area are of such magnitude they are not subject to manipulation; it is, therefore, unrealistic to expect to run meaningful experiments testing cause-and-effect relations.

Our purpose is to learn what we can about such dependent variables as productivity, population levels, and physiological states, and to test our data and hypotheses for validity as best we can given the limitations of time and money. We are therefore using the techniques of comparative studies to help us disentangle the significant elements driving these ecological systems from irrelevant environmental effects.

a) We have extensive information which we can use for comparative purposes. We now have reliable data on the species and proportional differences in species among the sixteen different seabird "cities" in this larger region. We have data from fixed transects which were set up after two years' experience surveying the Norton Basin for the distribution of feeding seabirds. There are data from transects run from on board ships which have travelled through these waters during the last half dozen years. We can best predict the distribution and availability of fish and invertebrate prey populations as far as seabirds are concerned by the distributions of feeding seabirds. We can use what we know about foods, feeding strategies, and distances travelled to feeding areas to sketch out the distribution of preys of i) bird species which are generalists feeding on fish; ii) the bird species which are specialists feeding on larger shrimplike plankton; iii) those species that feed only at the surface; and iv) those species that take food from many depths in the water column.

b) Extensive data exist from work performed on OCSEA projects assessing fisheries resources (Wolotira 1978, Barton 1977) and benthos (Feder 1975). Works by Bédard in the late 1960s supply especially valuable information on the feeding of auklets in the Saint Lawrence Island area, and these data can be compared to data gathered by Sealey on Saint Lawrence Island (1977) and with data collected by Hunt at the Pribilof Islands (1976-1978). Data on fisheries in the southeastern Chukchi Sea from the 1960s are available from Alverson and Wilimovsky in the Cape Thompson studies (Wilimovsky 1966). Data on plankton from the studies of English, on benthic invertebrates from Sparks and Pereyra, and on seacliff birds from Swartz are all available in the Cape Thompson studies (Wilimovski, ed., 1966). Much of this work is not useable for our comparative analyses; in most cases, the sampling methods do not select the organisms which the seabirds are using or do not select proportions relevant to actual densities.

c) Studies in the northern Bering Sea offer excellent opportunities to gather information on the biology of mixtures of panarctic species (murres, kittiwakes, Glaucous Gulls), local species for which there are equivalents in the Atlantic (Pelagic Cormorants, Horned and Tufted Puffins), and local endemics (Crested, Least and Parakeet Auklets). Because different species can be categorized by their differing tactics for obtaining resources, our task can be simplified by making detailed studies of representative species, e.g., those whose feeding grounds are widely diffused, and those whose feeding grounds are concentrated; those which gather in dense numbers at a few cliffs (kittiwakes, murres, auklets), those which scatter in smaller nesting groups along the shore (cormorants, puffins), and those which may nest singly scattered on lowland tundra lakes as well as in sometimes dense aggregations (Glaucous Gulls, Arctic Terns, Aleutian Terns).

Some of the most powerful evidence supporting the effectiveness of comparative studies comes from work conducted at different seabird breeding cliffs, among the four years of our studies, and by comparison of these results with studies in other parts of Alaska, the Barents Sea, and the Atlantic.

There is not the time nor the money available to make detailed studies of many of the species, even those of special significance to humans which are vulnerable to the effects of economic development. Therefore, we are looking for generalizations which grow out of special studies on representative species rather than focusing our efforts in local endemics. We have concentrated our studies on two numerous and widespread species, Common Murres and Black-legged Kittiwakes, because they are convenient to study and offer opportunity to compare our results with those obtained by other students in other parts of these well-studied species' ranges. The Cliffs at Bluff offer convenient circumstances for the study of these species in relation to their resources because of the outstanding abundance of birds there, and the relative simplicity of the cliffs' geography and physical features. The differences observed over the course of four years' study allow us to make judgments on i) the effects of early or late thaw and persistence of sea ice, ii) the effects of absenteeism of adult birds in the early stages of incubation and the probable causes, iii) the effects of rainstorms at several stages in the breeding calendar, and iv) the correlations of changes in feeding movements among the years with the differences in reproductive success. Especially valuable comparisons are available in the data gathered in the course of several years by people working in other parts of Alaska on OCSEA projects and by people such as Belopolskii,Uspenski, Tuck, Coulson, Birkhead, Harris, and others in other parts of the ranges of widely distributed panarctic species.

C. Relevance to Problems of Petroleum Development

The most obvious effects of hydrocarbon exploration and transport on species inhabiting the northern Bering and Chukchi Seas may include:

1. direct disturbance by the presence of and activities associated with heavy equipment; e.g., noise and increased numbers of people;
2. pollution of the waters by hydrocarbons and other industrial chemicals;
3. direct disturbance by increased human activity associated with development: air traffic over wildlife habitat, curiosity about bird cliffs or walrus haul-outs, etc.;

4. secondary effects reflecting increased land development for support facilities and transportation corridors;
5. secondary effects reflecting the recreational demands of additional people travelling off regular transportation corridors, including hunting, fishing, and harassment of wildlife by tourists;
6. effects of increased human activities involving species which are sensitive to disturbance by humans or which attract human hunting or curiosity;
7. effects of human activities that will provide a subsidy for aggressive species able to take advantage of resources, e.g., food from wastes and shelter in human settlements;
8. secondary effects of the impact of aggressive species benefitting from human development, on sensitive species vulnerable to competition from those "kulturfolger."

Decisions aimed toward mitigating the possible effects of petroleum development should be made on the basis of answers to questions such as the following:

1. If oil spills occur in the Norton Basin-Hope Basin, where will the oil move and collect? How damaging will it be as it is spilled? How fast and under what circumstances will it congeal or change its chemical and physical properties, thus changing its impact on seafowl?
2. What species of waterfowl and seafowl are especially vulnerable to oil spills? Where and under what conditions are they vulnerable? What are the age structures and reproductive potential of vulnerable species, i.e., what is their potential for recovery?
3. Where are major waterfowl and seafowl resources concentrated at several seasons of the year: on arrival in spring, when breeding and feeding young, when gathering on migration, when wintering? Are these in areas where spilled oil will collect? Do feeding birds gather at "fronts" between water masses or at lenses of water masses and do they find the "fronts" or lenses by surface "slicks"?
4. What levels of coexistence of waterfowl and seafowl with development are possible? What constraints or what standards of performance might be set to ensure survival of waterfowl and seafowl resources during development? What impact will the activities associated with oil development and its secondary activities (such as onshore and at sea construction and transportation, increased population and recreational

pressures, new corridors of transportation, new facilities and transshipment sites) likely to have on waterfowl and seafowl, their habitats and food? What species are most vulnerable to these effects, i.e., the indirect effects of human presence? Where and under what circumstances are they vulnerable? Will any be disturbed from successful reproduction by hunting, harassment on breeding grounds, or human presence, as has been suggested for Barren Ground Caribou, Bowhead Whales, Ivory-billed Woodpeckers, and Black Ducks? What effects do exploitive uses by certain groups, e.g., hunting or egg-taking, have on the nonexploitive uses made by other groups, e.g., tourists?

5. What species are perceived as having significant social importance to humans? To what degree are endemic species (auklets, Aleutian Tern, Kittlitz's Murrelet) or those populations which gather occasionally in a few large concentrations, or endangered species (Peregrine Falcon, Steller's Eider, Spectacled Eider, Surf Scoter) of such social importance that their presence justifies specific stipulations or changes in plans for economic or industrial development?

In the past, the Eskimos' access to wildlife resources was restricted by transportation. The mobility of the Eskimos has increased substantially in recent years and they now enjoy virtually unlimited access to game under the name of subsistence hunting. The effects of generous Federal and State programs for schools, housing, medical assistance, transportation, even clothing and firearms, have contributed to the westernization of their economy. Until recently, the whites also enjoyed the *laissez-faire* attitude of law enforcement, but now officials are applying pressure to make local Caucasians conform to wildlife laws in effect in the rest of the United States. The white Americans who have come to live in the country feel they are discriminated against, while the Eskimo Americans seem to reap the benefits of both worlds. One can predict that friction will grow or that pressures will increase for all local citizens to be treated equally.

IV. STUDY AREA

Intensive studies were concentrated at Bluff Cliffs and Square Rock (approx. 64°33'N, 163°40'-45'W). Short-term surveys were made of Rocky Point (approx. 64°20'N, 163°00'W), Topkok Head (approx. 64°40'N, 164°00'W), and Sledge Island (approx. 64°28'N, 166°12'-13'W). Aerial transects of birds along the shore or at sea were flown from Tolstoi Point (south of Unalakleet, approx.63°30'N, 161°00'W), to southwest of Saint Lawrence Island (approx. 62°30'N, 172°00'W), and north to Wainwright (approx. 62°30'N, 170°00'W). Figure 1 is a map of the northern Bering Sea showing these locations.

V. METHODS

A. Seabirds at Breeding Colonies

1. Bluff (Figures 2, 3, 4, and 5)

During the field season of 1978, two people visited Bluff from 27 May to 2 June. Counts of murres and kittiwakes on the water and on the cliff were made by walking the top perimeter of the cliff. A field party of two to four, with an occasional maximum of up to seven people were at Bluff from 13 June to 18 August. Three observers returned on 20 August to conduct a chick census and to close up the living quarters at the east end of the cliffs.

Research activities included colony censuses, sample counts, twenty-four hour counts, and studies of reproductive success at the stakes; these are defined and described below.

Colony censuses were made from a small boat moving at 1-2 mph, within 300 yards of the cliff. The cliff was divided into geographic sections, A through J, shown in Figure 6 ; each section was counted separately during censuses.

Table 1 presents the dates and times of the censuses, the number of observers, and the species counted. We chose to census at the time of day when birds seemed most abundant. We often made more than one pass in front of the cliff. Because of wind direction, we started the 26 June and 14 August censuses from the west end of the cliff; this meant we initially had to motor the length of the cliff at some distance out to sea so as to avoid disturbing the birds on the cliff.

If two people counted the same species, e.g., murres on the cliff, the highest number for each section was used because previous experience indicated that the higher number was more accurate. These counts were used in diagrams

Figure 1

Map of the Bering Strait Region

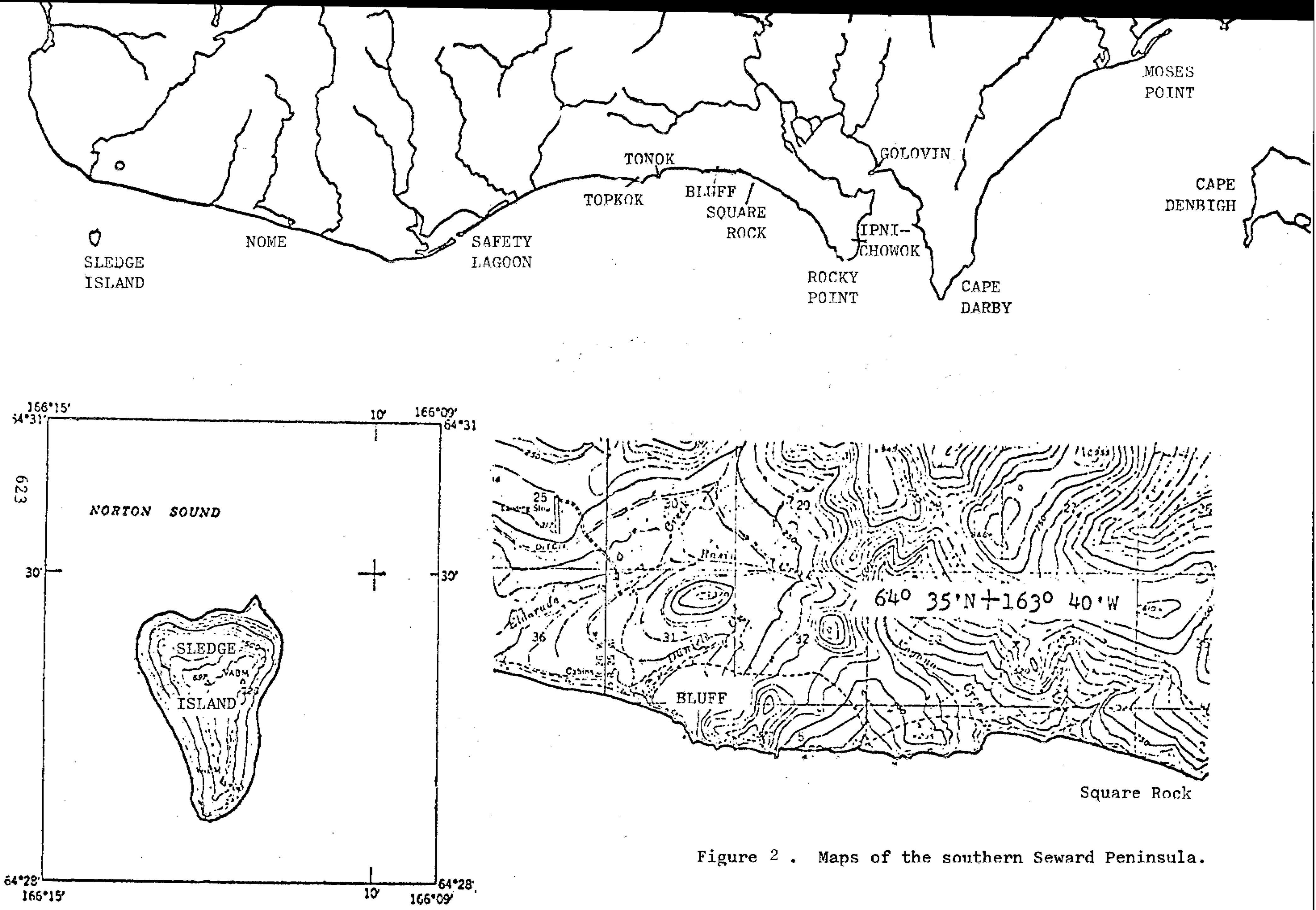


Figure 2 . Maps of the southern Seward Peninsula.

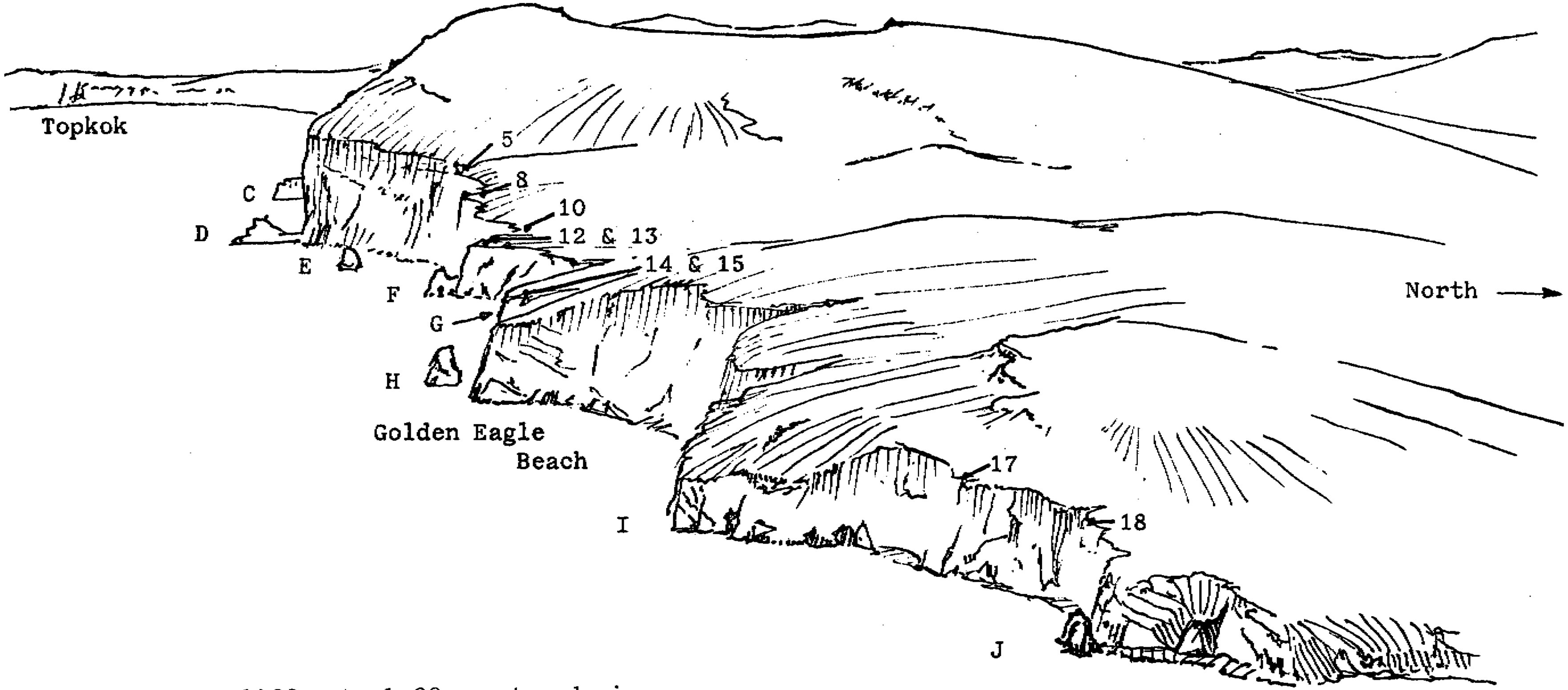


Figure 3. Cliffs at Bluff, westward view.

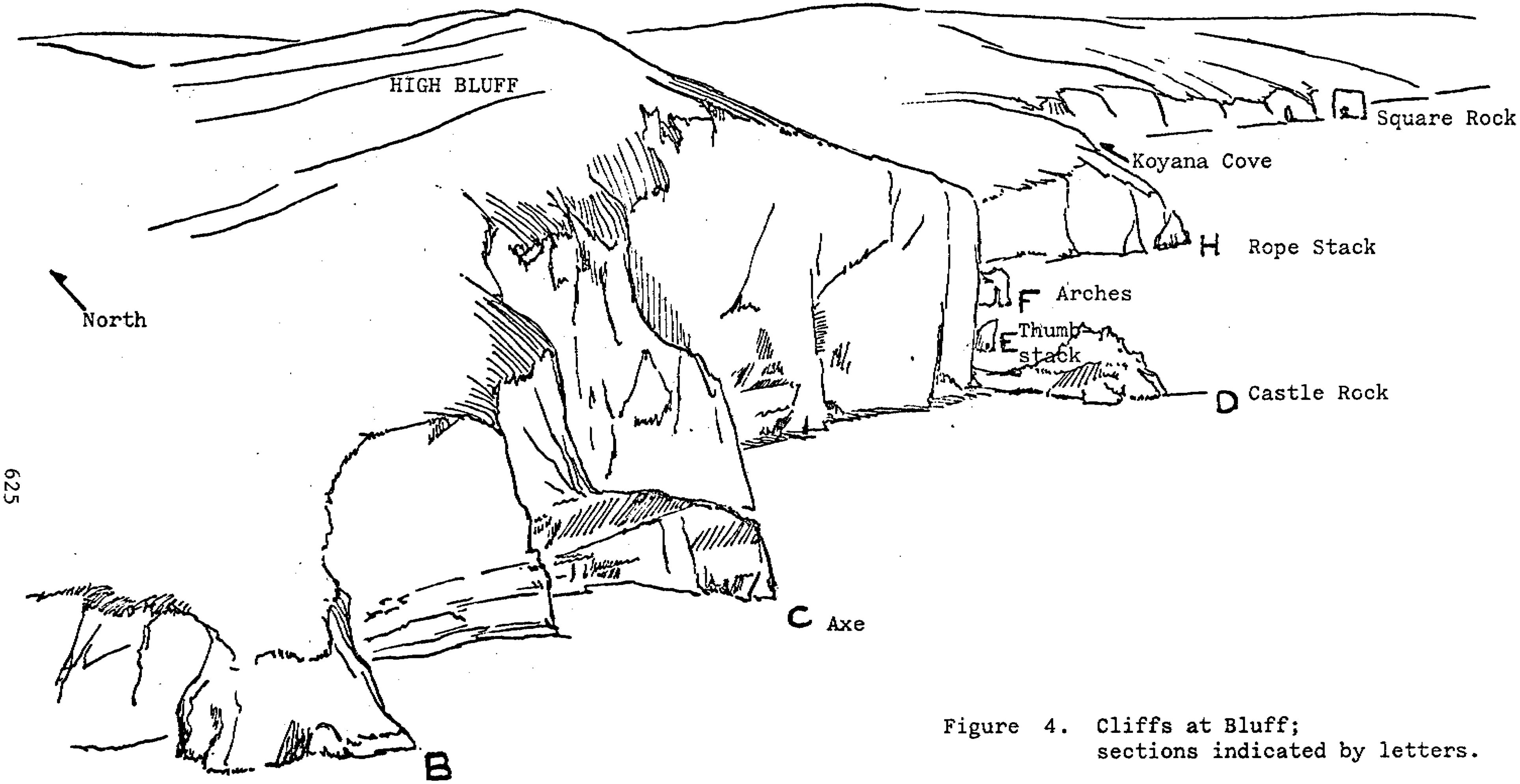
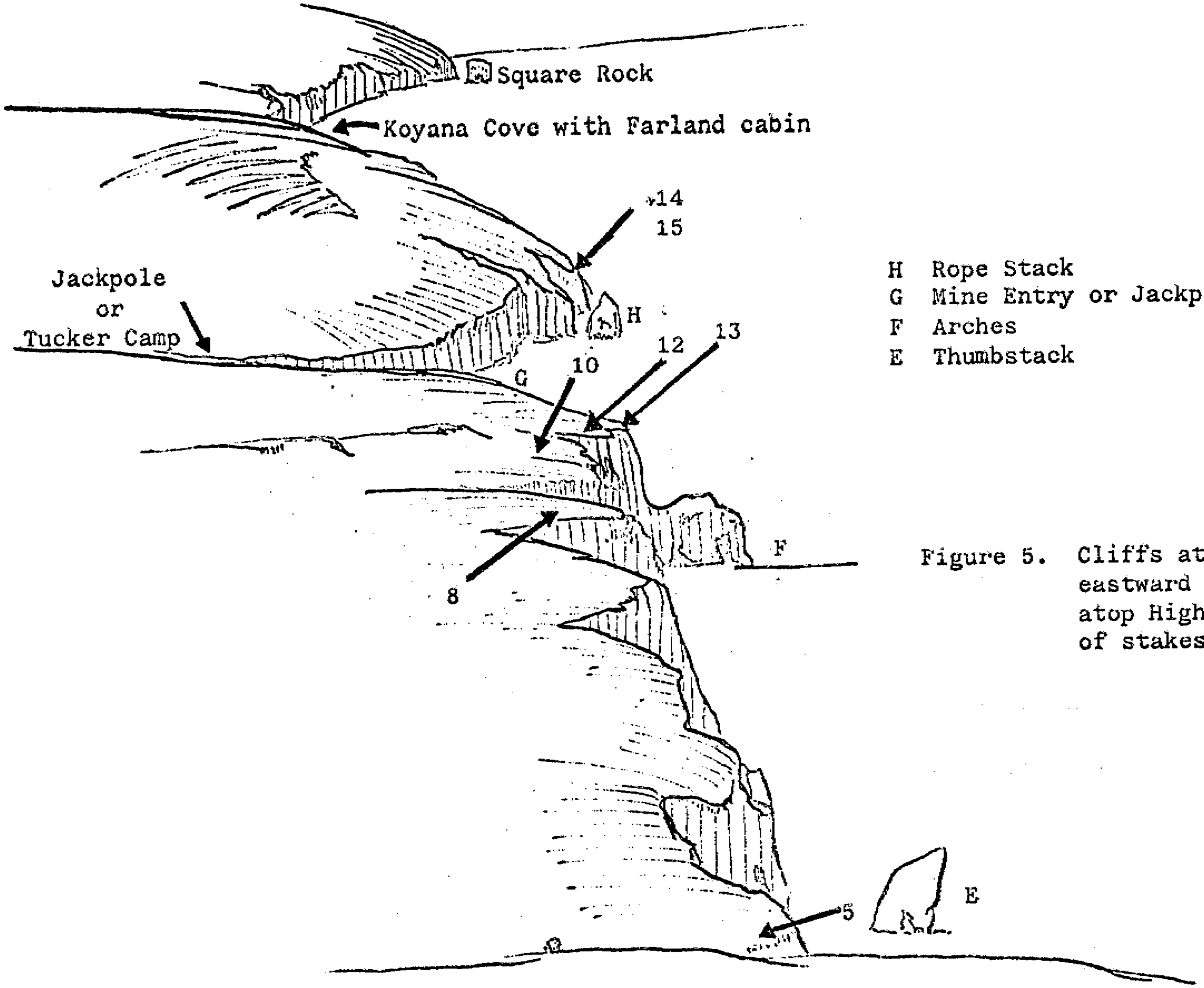


Figure 4. Cliffs at Bluff; sections indicated by letters.



H	Rope Stack
G	Mine Entry or Jackpole
F	Arches
E	Thumbstack

Figure 5. Cliffs at Bluff, eastward view from atop High Bluff; numbers of stakes shown.

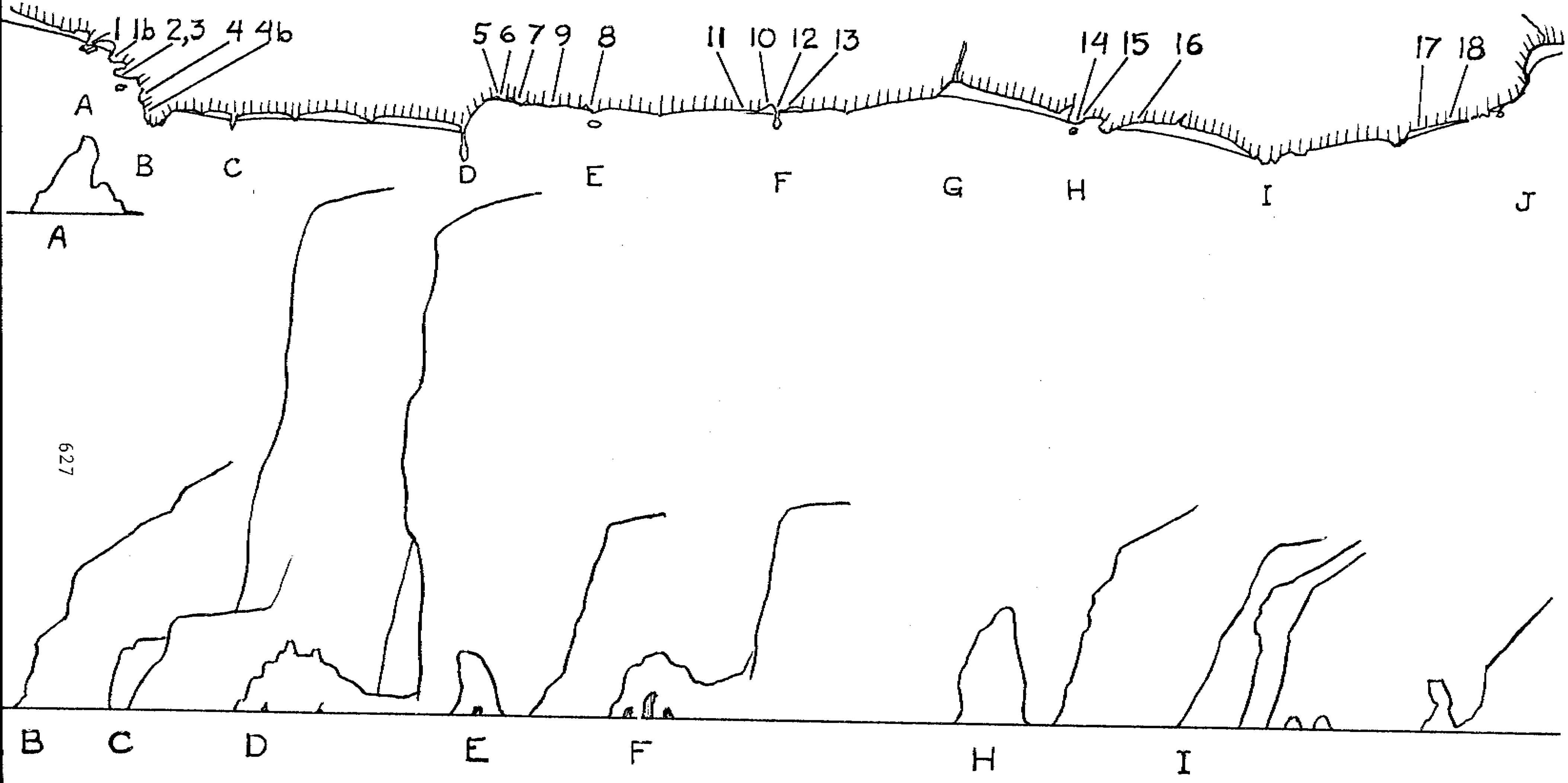


Figure 6. Map of Cliffs at Bluff showing sections A to J.

Table 1 . Dates of colony censuses made by boat at Bluff Cliffs in 1978; also shown, time censuses were started, direction cliff passes, and species counted by observers.

Date	Time	Direction	Observer:	Species Counted
26 June	1115	West to East	a:	murres on cliff
			b:	murres on cliff murre flyers (alternated with c)
			c:	murre flyers (alternated with b)
			d:	kittiwakes
18 July	1330	East to West	a:	murres on cliff
			b:	kittiwakes
			c:	gulls puffins
9 Aug	0900	East to West	a:	murres on cliff
			b:	murres on cliff murre flyers
			c:	kittiwakes
			d:	gulls puffins
14 Aug	0900	West to East	1st pass:	
			a:	murres on cliff
			b:	murre flyers
			c:	kittiwakes
			d:	puffins cormorants
		West to East	2nd pass:	
			a:	cormorant nests and chicks
			b:	gull nests and chicks

of population fluctuations through the 1978 season, and in estimates of reproductive effort and success for the entire colony.

Stakes were study sites located where especially good views of the cliff face were available. These places were marked by a wooden stake driven into the ground. It is important to note that a stake marked the spot at the edge of the cliff where observers consistently sat and used telescopes, binoculars and notebooks, to make counts and record observations. (Table 2) Sample and twenty-four hour counts were made from stakes, as well as studies of kittiwake and murre reproductive success. In the case of kittiwakes, areas of cliff visible from the stake were mapped, and individual spots where kittiwakes were perched within the map area were numbered. Each murre stake involved a mapped area divided into subsections defined by the details of topography of the cliff.

Sample counts. Birds on four large sections of the cliff were counted from the clifftop several times through the summer. The sections were chosen for clear natural rock boundaries allowing easy identification of the area counted, and for their being more or less regularly spaced along the cliff. The sample count areas were at Stakes 1, 3, 5, and 15. Four of the ten counts at Stake 15 were made within 22-26 hours of when a colony census was made. We did this so as to compare the seasonal changes in numbers of the whole colony to changes in subsections of the colony.

Twenty-four hour counts were made of the cliff face at Stake 15. These counts were made approximately every four hours for twenty-four hour periods on five days: 29 May, 19 June, 6 July, 21 July, and 3 August. The four-hour intervals between counts were timed so that counts fell before and after the lengthening period of darkness.

Reproductive schedule and success at kittiwake stakes. Black-legged Kittiwake map areas were established with the aid of photographs of sections of the cliff. Studies were made at Stakes 8, 10, 13, 14, and 17. Individual sites within the mapped area were assigned a number for the season. Three types of attended sites were distinguished: 1) rock roost, where a bird was frequently seen and a guano flag was evident; 2) active non-nest, where a pair was seen during at least half of the visits to the stake, where new nest material was deposited but never became a nest; and 3) nest, a substantial mud platform showing evidence of activity this season. (Notes on Kittiwake Workshops, Pacific Seabird Group, January 1978.) During each stake visit, the status of the site and the numbers of adults, eggs, and chicks at each occupied site were recorded.

Table 2. List of data collected at Stakes at Bluff Cliffs in 1978.

	Kittiwakes		Common Murres		Puffin	
Stake	count	map	count	map	count	map
1			X			
3	X		X			
4	X					
4b	X					
5	X					
8		X		X		
10		X		X		
12 "inside"				X		
12 "crack"				X		
14		X		X		
15	X	X	X	X		
17		X				
18					X	X
Square Rock		X				
19				X		

We have described the reproductive schedule based on our records of the appearance of eggs and chicks in nests in the five kittiwake map areas. Reproductive success was determined by comparing the number of chicks produced with the number of nests built in the five map areas of the stakes. A census of chicks along the entire cliff was undertaken on 21 August during the advanced stages of the brooding period when chicks in nests were large enough to be seen relatively easily. Counts were made of the numbers of nests, broods, and chicks in forty-two sections of cliff visible from above. A ratio of chicks per nest was calculated from these data and compared to reproductive success as recorded at the stakes.

Reproductive schedule and success at Common Murre stakes. Common Murre study areas were established with the aid of photographs of cliff sections visible from Stakes 8, 10, 12 "inside," 12 "crack," 13, 14 and 17. Each map area was divided into subsections separated by obvious geographic features so as to include, on the average, six to eight birds. Intensive studies of Murres were begun on 5 July; visits to the stakes were made every two to three days, except at Stake 10, which was visited almost daily once hatching began. The last visits were made on 14, 15 and 18 August.

During each visit, the following data were collected for each subsection:
a) The total number of adults in each subsection was counted and recorded.
b) A count was made of the number of "sitters"; these were adult murres assuming either incubating or brooding postures, described below. Assessment of whether or not a bird was a "sitter" was made only during the time it took to look briefly at each bird (five seconds or less). It should be noted that even though a bird might be assuming a "sitting" posture, it might not have an egg under it; likewise, not all eggs are covered by "sitters." We tried not to allow our knowledge of the presence or absence of an egg under a bird influence our decision of whether or not the bird was in the "sitter" posture when the sample was taken.

Among the "sitters" we recognized an "incubator" in those murres exhibiting any combination of the following characteristics:

- sitting on the cliff with "wrists" lowered close to the ledge
- edges of last secondary feathers partly spread and covering rump, but "wrists" not down or out
- breast pushed down, or belly flattened against the rock, breast feathers expanded, back stooped, sometimes with the neck bent back so that the bill raised vertically and the throat out, i.e., against cliff face

- guano on the back of a sitting bird
- body looks fat or inflated, but does not present characteristics associated with a "brooder" (described below)

As the breeding season progressed we defined "brooders" as separate from "incubators" as those with the following characteristics:

- assymetrical position of wings; one wrist up, one down, and the body rotated (about a horizontal axis through the spinal column)
- primaries on the ground and "wrist" held out away from body; a posture similar to this may be used by murres on hot days, and there may be a bias when the sun is strong (the posture of "sunning" murres has the two wings spread symmetrically)

Birds with straight spines, ventral surfaces that extend straight down to the feet, or that face the ocean were not considered to be in a posture of reproductive significance.

c) Maps of each subsection in the map areas were drawn during each visit to a stake. Individual murres were represented by circles; each circle was given an "E" for the association of an egg with the bird, a "C" for chick, an "X" for nothing, or was left blank if we could not see under the bird. At Stake 10, each chick was identified by a letter on the map. Individual chicks were monitored by one observer nearly daily. In this study we concentrated on determining the number of chicks hatched, lost or fledged in each subsection, and spent little time on locating eggs. We had found in previous years that we spent a lot of time for few data in trying to locate eggs during incubation.

The number of chicks produced in each subsection at other stakes was calculated by the length of time each "C" appeared at one spot on the maps of the subsection. We assumed the average time a chick spends on the ledge to be eighteen days. As chicks may have been two to four days old before they were first seen, we calculated chick loss on the disappearance of chicks believed to be less than two weeks old. Chicks disappearing after having been seen on a ledge over a period of fourteen days or more were considered to have successfully fledged.

The number of breeding pairs of murres was estimated by relating the average number of "sitters" to the average total number of adults at the stakes during the hatching period (a time of minimal fluctuations in the total number present). The number of chicks produced at each stake was then related to the estimated number of breeding pairs, resulting in a ratio of reproductive success, or the number of chicks produced per breeding pair.

No specific Thick-billed Murre areas were studied in 1978; therefore, estimates of reproductive success were for Common Murres only.

Trophic studies: murres and kittiwakes. As in 1975, 1976, and 1977, we entered remarks in field notebooks on feeding aggregations seen from land, and on fish brought to the cliffs. Edward Murphy, of Research Units #460 and #461, collected stomach contents of murres and kittiwakes in August, 1978.

Section IIB discusses the methods and results of aerial transects conducted to determine the distributions of birds feeding at sea away from colonies.

Other species at Bluff.

Horned Puffin

We made counts of puffins regularly at Study Site 18 to determine seasonal and daily variations in attendance at the cliff. Unfortunately, these counts were not conducted regularly or frequently enough to draw conclusions. We have a little information on puffin reproduction gathered by peering into eighteen burrows visible from the top of the cliff.

Pelagic Cormorant and Glaucous Gull

Colony censuses were made of Glaucous Gulls on 26 June, 18 July and 9 August; of Pelagic Cormorants on 18 July and 13 August. We monitored three nests of Glaucous Gulls and six nests of Pelagic Cormorants.

Predators

An extensive study of predators was conducted in 1977. No special studies were made in 1978 but notes on occurrence and reproductive success are summarized.

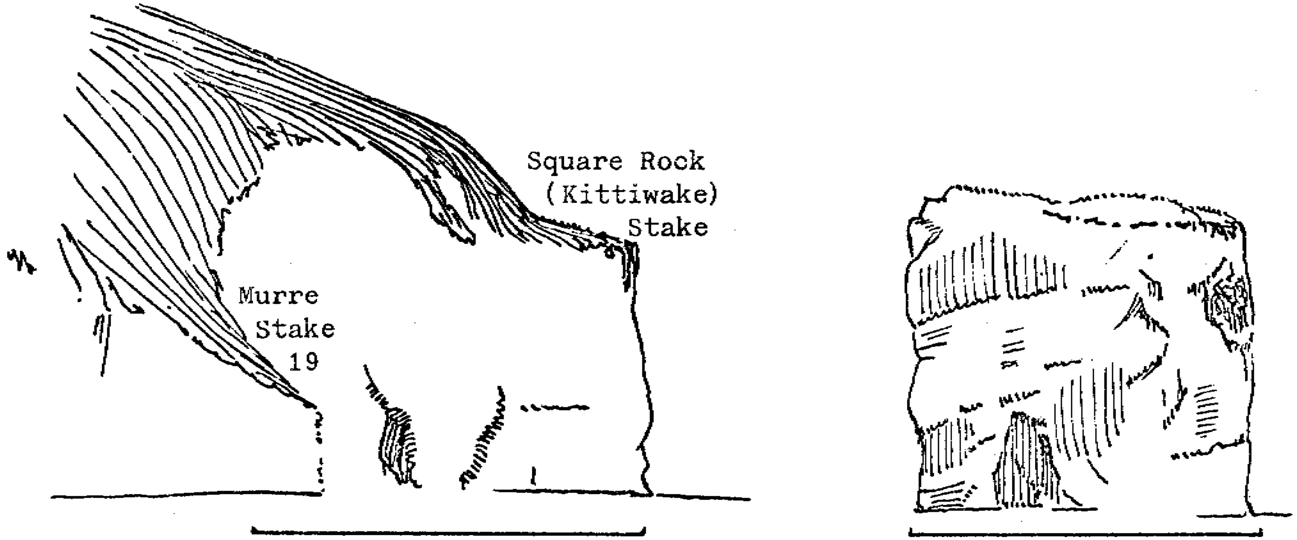
2. Square Rock (Figure 7)

Counts of birds at Square Rock were made on 28 May (murres on the water), 30 May (Glaucous Gulls), 15 and 18 July, and 6 August. Studies of reproduction were made as at Bluff. One murre and one kittiwake study area each were established; data were collected about every three days.

3. Topkok Head and Rocky Point were visited on 2 July and 4 August, respectively. Counts were made of all seabirds on these trips, and sample counts were made of nests and contents to allow us to estimate the reproductive success of Pelagic Cormorants and Glaucous Gulls.

4. Sledge Island (Figure 8)

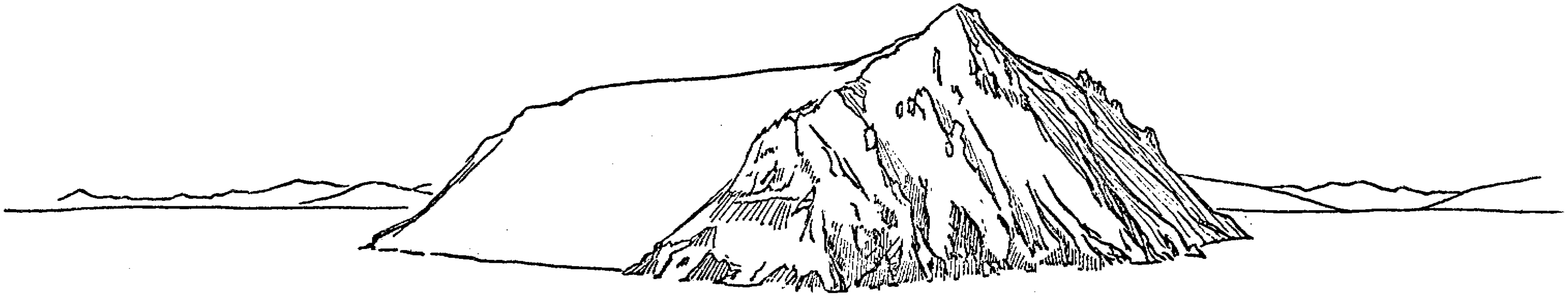
On 11 July, two people went by boat to Sledge Island. Over the next six days, they conducted censuses of the seabirds, visited two study sites to sample reproductive success of Pelagic Cormorants and Black-legged Kittiwakes, and collected samples of the flora on the island. On 11 August, a return



mainland bird cliffs

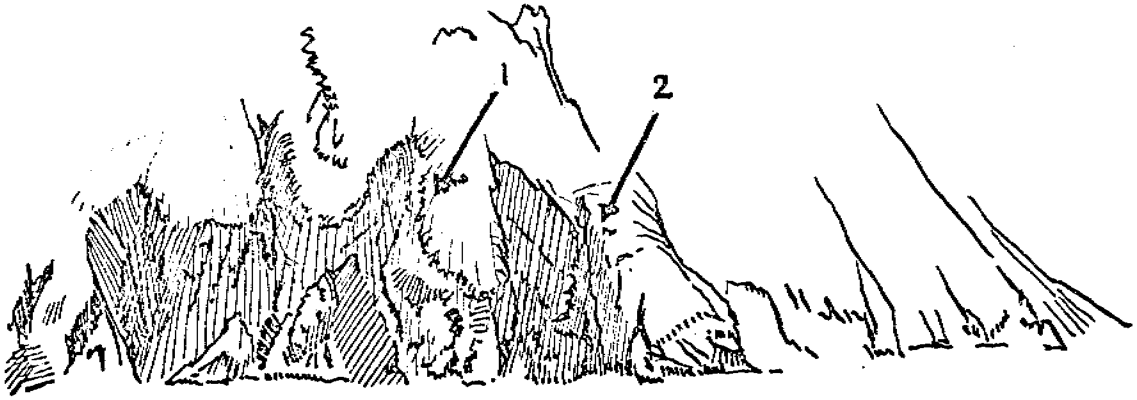
Square Rock

Figure 7 . Square Rock and adjacent mainland bird cliffs. The kittiwake stake on the mainland is for study of kittiwakes on Square Rock; Stake 19 is oriented toward murres on ledges below the kittiwake stake itself.



SLEDGE ISLAND

Figure 8. The seabird colony at Sledge Island. The locations of the two study areas marked by stakes are shown in the lower drawing,



trip was made to obtain an unhatched Peregrine Falcon egg, but the egg was no longer there.

B. Seabirds at Sea

1. General Remarks

The first priority was to cover a large area of ocean rapidly in order to find where birds occur and the patterns in which they occur, i.e., whether dispersed or clumped. Until we know where the birds gather we cannot ask questions which might be answered by detailed work such as from shipboard.

The obvious vehicles for surveying the northern Bering Sea looking for seabirds are ship and aircraft. Each has its advantages, but aircraft seems to be clearly preferable for the work which we were doing.

We were supplied some time on NOAA vessel Surveyor during 1976, and made transects south from King Island and across the southern half of Norton Sound. The vessel was not available to us in other years, which is just as well because she is much too large for our needs and is, therefore, grossly expensive. Moreover, compared to an airplane, any ship will be very slow, and thus is less suitable for locating the birds at sea. Ships are well suited for close observations of behavior of birds on the surface, such as feeding behavior, and are the best platforms for shooting birds to collect stomachs and to see what the birds are eating. Work aboard ship complements the work that can be done from aircraft.

2. Types of Aircraft

a) For prolonged flights over the ocean it is necessary to have a twin-engine plane; for making transects it is important to have clear visibility from the passenger seats as well as copilot seat. With two observers, duplicate information can be obtained from the observers on each side of the aircraft. In 1976 we used a deHaviland "Islander" operated by Munz Northern Airlines out of Nome. This plane provided excellent visibility from the copilot's seat, but poor visibility from the passenger seats.

We tried the Cessna 336 in 1976, using a plane flown by Nome Flying Service, and it proved to be very satisfactory. Though we had made arrangements to use this aircraft in 1977, we learned the plane had been sold when we arrived in Nome. We then made arrangements through Donald Olson of Golovin to charter a 336 from Arctic Aviation of Kenai during June and August of 1977. The plane was based in Kenai and we had to pay for ten hours of "deadhead time" for each set of survey tracklines. Although we were given an excellent price, the lost time and the inconvenience led us to make special arrangements in 1978, by which Donald Olson had his own Cessna 336 in Golovin. This arrangement proved to be excellent.

b) Limitations of survey by aircraft

The most serious limitations set on aircraft surveys are 1) that U.S. aircrafts are excluded from the western half of the area which we would like to study; and 2) that navigation in aircraft is much less precise than on shipboard. Additional limitations include 3) that it is difficult to maintain consistency of transect width as the plane's altitude changes; and 4) that identification of some species is often difficult. Some of these limitations are only apparent, or can be overcome. One must judge how fine-grained is the distribution of birds at sea before one judges whether the navigation of the aircraft must be precise. The precision of detail one is trying to distinguish should dictate how precisely the width of the transect and the altitude of the aircraft must be maintained. We are convinced that by using aircraft we collected much more data than we could have from shipboard and that the data are precise and rigorous enough to fill the needs of our objectives. Moreover, expense would increase several fold in order to improve standards of rigor. Thus, it makes neither scientific nor economic sense to collect data of any greater precision.

In order to locate our tracklines as precisely as possible, we set our grid so that each line was "anchored" on an identifiable "point of departure" for our "ded" reckoning. We used Sledge Island, King Island, Gambel, Savoonga, the Northeast Cape, Cape Prince of Wales, Little Diomede, and so on. We planned our grid so that as few lines as possible depended on extrapolated positions. Actual tracks over the water could be deduced from points of departure and arrival, elapsed times, and calculated rate of progress.

Inconsistency results from the effects of wind drift and anomalies of the compass headings of our plane. Not only are the magnetic courses in this part of the world evidently approximate, the deviation or declination of the plane's compass was different on different headings. We anticipated most of this difficulty by setting a gyro compass at departure. We are confident that by plotting out our courses we have removed errors to the level of "significant figures."

3. Techniques

a) Instructions for shipboard transects have been provided 1) for use by the Royal British Navy, 2) by Germaine and Brown for use in PIROP in western

Atlantic water, 3) for use in the "Pacific Ocean Survey", and for use in Antarctic studies (Cline et al 1969), and 4) for use on "ships of opportunity" during OCSEAP by Coulter, Heineman, and Wiens, and by Lensink's group of the U.S. Fish and Wildlife Service. Many people have discussed the advantages and disadvantages of these systems. All of these use standard periods of watch, areas surveyed, and distances to which birds are counted.

For our shipboard watch we used ten-minute periods, an arc of 90° from directly ahead of the ship, and tried to identify in our counts those birds which were within 200 meters of the ship. We reviewed our technique with Juan Guzman of the University of Calgary who was on Surveyor when we did our transect work from shipboard. It is important to recognize that visual acuity varies greatly. The acuity of one of our observers was much less than that of the other observer. Attention span also varied.

b) On aerial transects we used techniques described by Craig Harrison of the Coastal Ecosystems group of U.S. Fish and Wildlife Service. We counted the birds seen within a swath from approximately under the aircraft out to 30° from vertical; we marked this point on the strut of the "336". We kept records for five-minute periods (Harrison and others used two-minute periods), determined by a standard kitchen timer which rang a bell. This timing mechanism was accurate within ten to twenty seconds.

In some place we also recorded birds seen "outside" the survey line, but we did not emphasize this effort because our attention was distracted from the important area by looking "outside." I believe that lapses in attention are the most serious cause of failures of precision and consistency. Note, the Fish and Wildlife Service group had a "spare" observer to spell the other two. Rested observers probably have a better attention span. Changes in consistency should be no larger then differences between two observers on opposite sides of the plane.

We planned our flights to be at 100 feet altitude and at 120 knots, but doing so was difficult. Our altitude varied on average between 90 feet and 140 feet, seldom went below 60 feet or above 160 feet. These failures of consistency have their toll, but again we do not think that they affect the conclusions which we are trying to draw.

Indefiniteness in altitude affects size of the transect sample and our identifications. They affect comparing four murres with six murres, but not comparing two with ten, twenty, or fifty. Birds dive ahead of the aircraft if it flies too low, Crested Auklets begin to resemble Least Auklets if the aircraft is too high. Parakeet Auklets can be confused with murres when too high. Several observers did not try to separate species of auklets for that reason. The categories which we considered important were: murres, auklets, ducks, puffins, Glaucous Gulls, kittiwakes, jaegers. There is no confusion among these in our data.

Of more serious concern is the affect of glare from the sun on one side of the airplane which may seriously effect those counts. It is also important that birds become highly visible when the sea is glassy calm in contrast to when the surface is ruffled, marked with white caps, or boiling in current rips. In our experience, however, our observations made in the most unfavorable conditions conform to the pattern of those made when the situation is ideal, with the sea flat and sky overcast.

VI. RESULTS

A. Seabirds at the Breeding Colonies

1. Norton Sound: Censuses

In 1978, breeding censuses were made of seven species of seabirds at five nesting localities in northern Norton Sound. The maximum and minimum numbers are shown in Table 3.

Table 4 presents numbers of murres counted at Bluff Cliffs, Square Rock, and Sledge Island from 1975 to 1978.

2. Bluff: Black-legged Kittiwakes

a) Year to year variations in numbers

Similar numbers of kittiwakes were counted at Bluff Cliffs in 1978, a year of high reproductive success, as in 1976 and 1977, both years of poor reproductive performance. Unlike previous years, we did not record a period of desertion of the cliffs in 1978.

b) Seasonal variation in attendance

The results of four censuses of kittiwakes at Bluff are shown in Table 5. The number of kittiwakes counted on the cliffs reached a peak in mid-July, as seen in Figure 9.

c) Daily activity patterns

Figure 10 shows the results of five 24-hour counts made at Stake 15. At the end of May, before the beginning of nest building, the numbers of birds at the cliffs was highest in the early morning (06:00), and dropped dramatically through the day. More pairs were present in mid-late June, as egg-laying began,

Table 3. Seabird populations at five colonies in Norton Sound, 1978. Maximum and minimum counts shown.

	(7/13) Sledge Island	(7/2) Topkok Head	Bluff Cliffs	Square Rock	(8/4) Rocky Point
Pelagic Cormorant	472 121 nests	386 134 nests	87-461		507 164 nests
Glaucous Gull	42 adults 41 subadults	304 adults 5 subadults	89-138 adults	12-40 adults	386 + 1550 loafers (one group)
Black-legged Kittiwake	2455	298 (in lagoon)	6040-7760	1118-1520	148 loafers
Murre	4290		17,415-48,460	2118-3820	
Pigeon Guillemot	10	4	2		3
Horned Puffin	74	71	190-775	8-70	179
Tufted Puffin	13	20	10		6

Table 4. Variations in numbers of murres at Bluff Cliffs, Square Rock, and Sledge Island, 1975-1978. (Date of count is in parentheses.)

	1975	1976	1977	1978
BLUFF				
[a]pre-breeding season count	—	40,000 (5/30)	61,000 (5/21)	89,000 (5/29)
breeding season high count	[b]90,000 (7/4)	55,390 (8/12)	[c]45,250 (7/29)	48,460 (8/9)
estimated number of breeding pairs	25,000	20,000	20,000	23,500
SQUARE ROCK	6,100 (7/3)	4,000 (7/11)	7,600 (8/19)	4,070 (7/15)
SLEDGE ISLAND	2,200-3,000 (7/23)	2,900 (8/7)	2,800 (8/23)	4,300 (7/13)

[a] These pre-breeding season counts are of murres on the water in front of the cliffs.

[b] This is the total number of murres on the water in front of the cliffs as well as on the cliffs.

[c] In the Annual Report for 1977 (March 1978), this count was "corrected" to the nearest twenty-four hour count; the number appearing here is the original number counted.

Table 5. Estimates of total numbers of Black-legged Kittiwakes, Bluff, 1978. (Counts made from a boat passing in front of the cliffs.)

Section of Cliff	26 June	18 July	9 August	14 August
A	250	290	510	
A to B	430			600
A to C	(1010)	1340	960	(1250)
B to C	580			650
C to D	1420	1690	1540	1215
D to E	640	1130	740	880
E to F	1050	1250	950	780
F to G	660	820	600	530
G to H	210	300	220	270
H to I	640	640	710	750
I to J	160	300	130	150
TOTAL (A to J)	6040	7760	6360	5825

Figure 9. Maximum numbers of Black-legged Kittiwakes counted during colony censuses at Bluff in 1978.

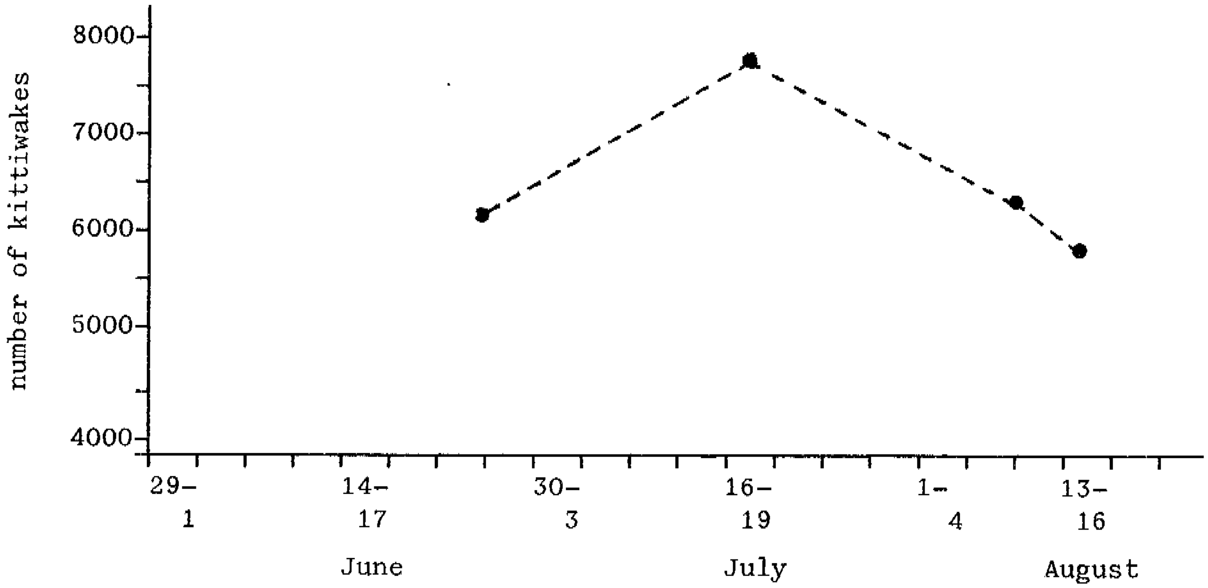
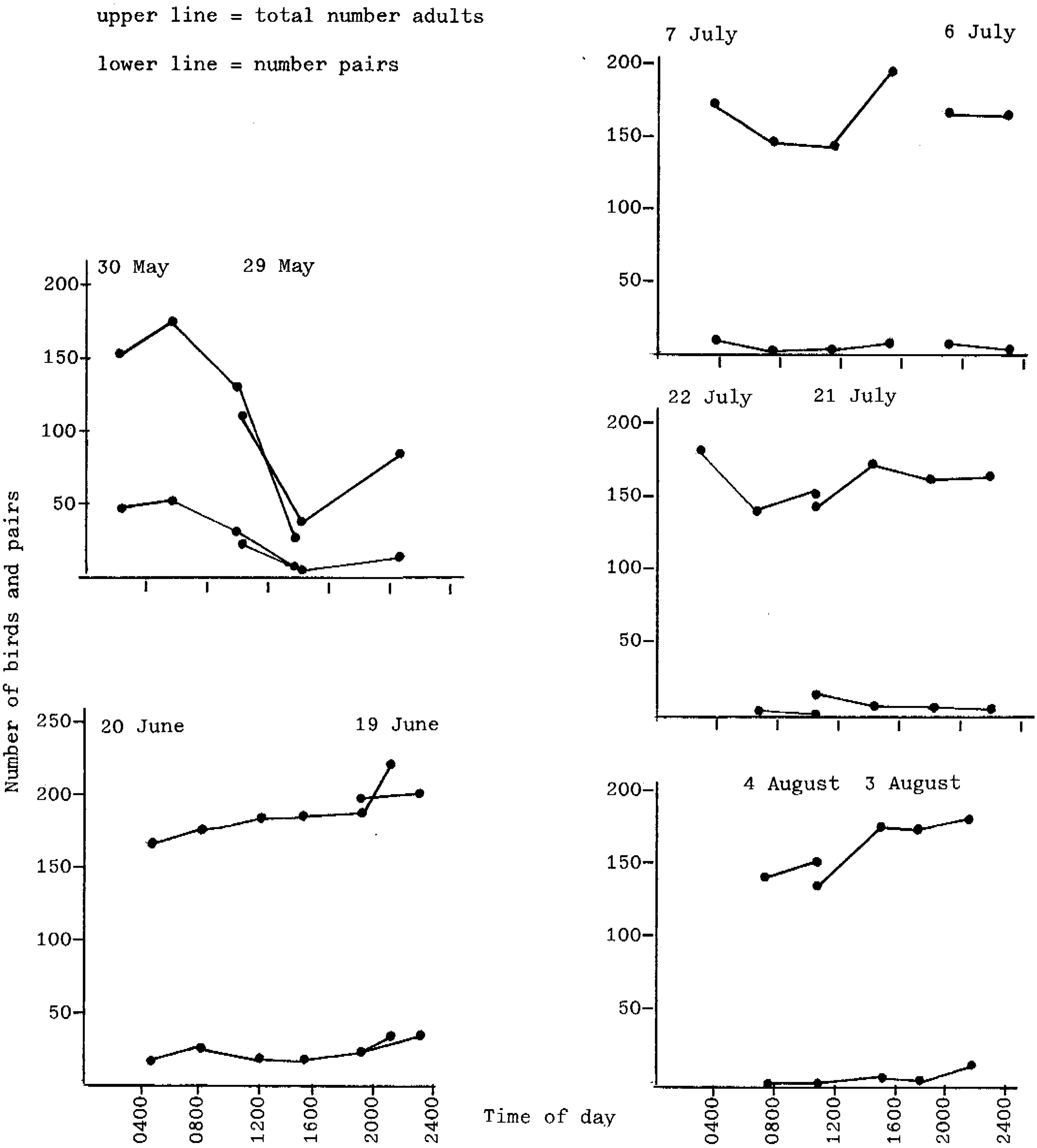


Figure 10. Five twenty-four hour counts of kittiwakes at Stake 15, Bluff, 1978. Each point represents the number counted at the corresponding time. Line segments were drawn between points to accent variation.



than later in the season. The numbers of adults on the cliff face were higher in the early morning and late afternoon during incubation and hatching (July and August).

The numbers of birds at the cliff varied little during incubation and feeding young, varying about 25% (see Figure 11). This steady level of attendance contrasts with high variation in numbers during 1977. For example, we recorded 90% variation in the numbers of kittiwakes on 29-30 July 1977 (see pp. 14-15 of Annual Report for 1977).

d) Reproductive schedule

The ice broke up in Norton Sound between the 7th and 10th of May, 1978. On 25 May, kittiwakes were present in numbers at Bluff and had not yet begun to build nests. A few seemed to be paired. We saw several copulations. On the 28th and 30th of May we saw flocks of as many as 270 kittiwakes on the water, in bunches and lines oriented to the wind. These birds were calling, begging, and choking. Non-territorial birds were sleeping both on the water and on the stacks near to the cliffs.

<u>Nest building</u>. The Nome Weather Service reported June 1978 as the wettest month on record for the Seward Peninsula. This factor, coupled with the relatively early departure of the ice, was associated with early and intense nest building by the kittiwakes at Bluff and Square Rock.

When we returned to Bluff on 13 June, occupation of the cliffs and building nests had already begun. Building occurred in flurries all through the season, i.e., it was neither continuous nor limited only to a specific period. These flurries were associated with periods of rain (Figure 12). The most conspicuous gathering of material and activity at nest sites was recorded from 18-24 June.

Our observations indicated that gathering of nest material is a social phenomenon. Flocks of kittiwakes would "attack" a patch of grass associated with a standing pool of water. Flying kittiwakes would join those gathering material on the water or at the tideline.

Table 6 shows the status of 278 sites studied at five kittiwake map areas in 1978. Eighty-six percent (240 of 278) were occupied throughout the season. Of the 240 occupied sites, 84% (201) had nests built on them at some point in the season. As we said in Methods, we define a nest as a substantial mud platform with evidence of activity in the present season. Seven percent (17 sites) were "rock roosts," sites at which no material was

Figure 11. Variation in kittiwake attendance through the day, from five twenty-four hour counts made in 1978 at Stake 15, Bluff.

Percentages are based on the difference between highest count and lowest count relative to the highest count:

$$\frac{\text{high count} - \text{low count}}{\text{high count}} \times 100.$$

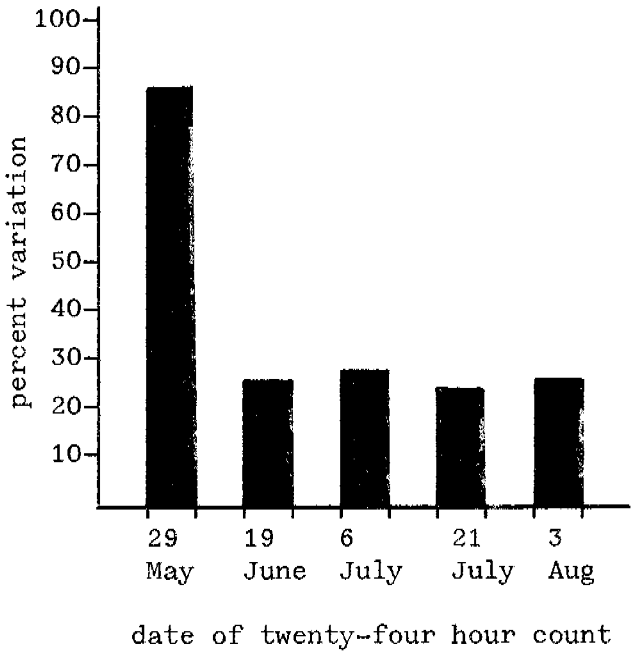


Figure 12. Days of rain at Bluff Cliffs in relation to days on which nest-building activities of kittiwakes were noted; 1978.

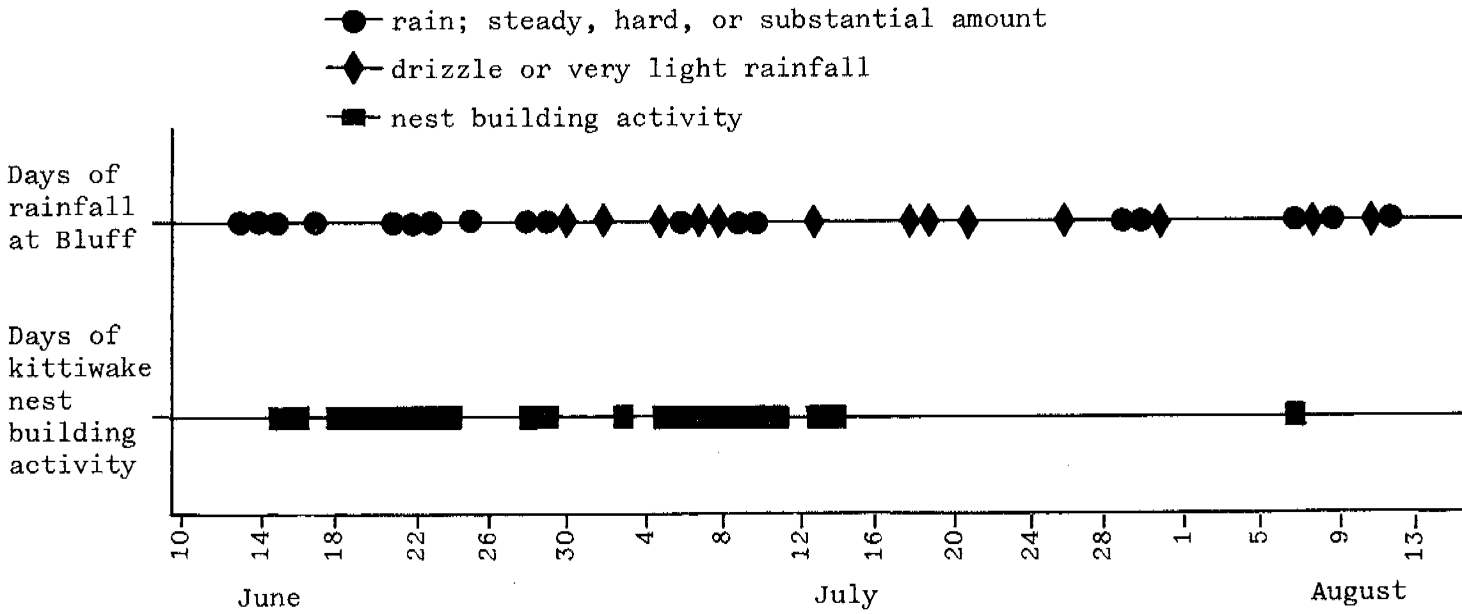


Table 6. Status of Black-legged Kittiwake sites monitored at five stakes at Bluff, 1978.

Stake	Total sites monitored	Rock-roosts	Active non-nests	Nests	Total occupied sites
8	50	2	6	37	45
10	75	5	3	53	61
13	63	0	5	47	52
14	38	3	5	29	37
17	52	7	3	35	45
Total	278	17	22	201	240
% of sites occupied		7%	9%	84%	

seen to be added, yet single adults were seen at the site during at least half the visits to the stake; 9% (22 sites) were active non-nests, where pairs were seen or material was brought to the site, but never became a nest.

The nests of 1978 were built early and persisted through the season. In 1976 and 1977, most nests were temporary. The material soon fell off, leaving pads built in previous years or a rock roost as the site was abandoned from time to time. In 1978, large amounts of material were used as material was available when the birds were highly motivated. Also, attendance at nests was steady throughout the season and nests did not deteriorate except in the few cases in which murres took over kittiwake nest sites.

Laying. Egg-laying began earlier and more abruptly in 1978 than in past years (Figure 13). The first kittiwake egg was seen on 18 June, on the top of the cliff near a raven nest. Eggs were seen at study areas on 20 June. The observed peak of laying was 22-25 June, over a week earlier than that in 1976 or 1977, Figure 14. The laying period extended over twenty-five days into mid-July, and overlapped with the period of hatching by a week.

Hatching. The first chicks were seen at Stake 14 and Square Rock colony on 10 July. After that, the number of chicks seen increased with each visit until the first week in August. Hatching began about ten days earlier than in 1978 in both 1976 and 1977, Figure 14, but ended in all three years at about the same time. Hatching occurred over a thirty-four day period, from 10 July to 12 August. The peak of hatching was 20-23 July (Figure 14).

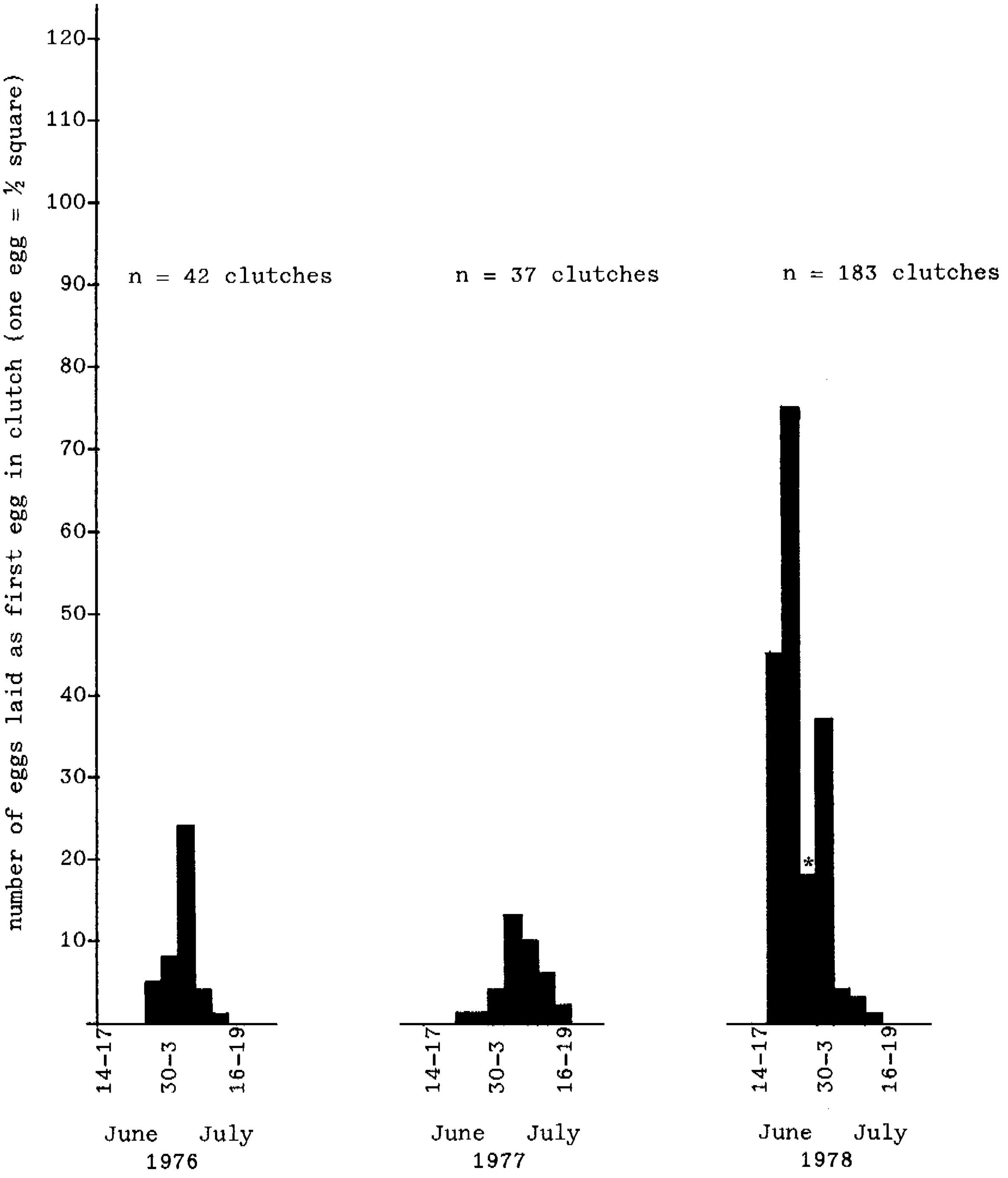
Fledging. The first fledged kittiwake chick was seen on 21 August, forty-two days after the first young were seen; this is similar to the average fledging period obtained by Coulson and White (1958) as 42.7 ± 4.4 days. The calculated peak of fledging, based on a forty-three day interval from the peak of hatching (20-23 July), was 29 August-1 September, after we had left the cliffs.

e) Stages of chick development and growth rates

We have identified several stages in the development of kittiwake chicks (Table 7).

Thirty kittiwake chicks were banded at three places along the cliffs at Bluff. Table 8 presents the weight in grams of each. Figures 15a, b, and c present the weight increases of chicks from one-chick broods in three areas sampled. Figure 16 compares these single chicks with heavier and lighter chicks from two-chick broods. The weight gained during the first two to three weeks of growth was dramatic. After that increase in weight tapered off (as indicated in Figure 17). The average daily increase in weight of twenty-one chicks over an eighteen-day period

Figure 13. Date of first appearance of first eggs in all clutches at five kittiwake stakes at Bluff in 1976, 1977, and 1978.



*Stakes were visited only once during this four-day period.

Figure 14. Laying and hatching (cross=hatched sections of bars) of Black-legged Kittiwake eggs at five stakes in 1976, 1977, and 1978.

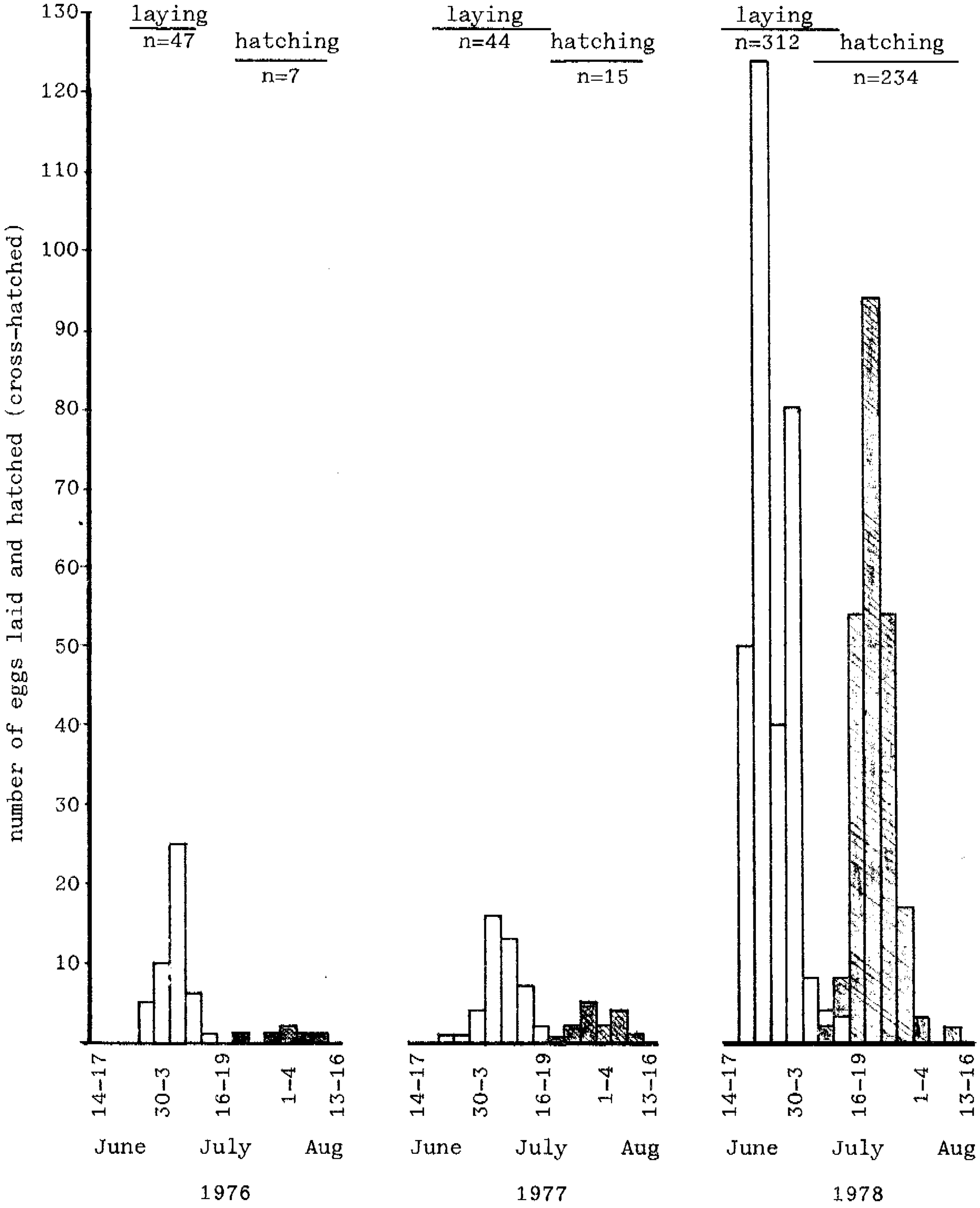


Table 7. Identifiable stages of kittiwake chick growth.

1a	1-4 days. Chick downy with buff brown to red tint; small; lies or crouches in nest; egg tooth on bill; head and body of similar size.
1b	4-7 days. Defecates over edge of nest.
2	7-14 days. Downy, but increasingly gray; active- stands, walks in nest; loses egg tooth but bill tip is pale; body large relative to head.
3a	14-21 days. Downy, becoming feathered; black feathers erupting on elbows; silver back feathers emerge; dark pinfeathers visible on forearm and hand.
3b	17-26 days. Mixed down and feathers; can first clearly see black on tail feathers; pinfeathers have erupted into feathers on wing; down on collar; black ear patch and black smudge between eye and bill.
4a	21-30 days. As the birds perches on nest the tips of primaries extend to the tips of tail feathers; mostly feathered out; down still on back of head, flanks, rump; white at base of tail feathers.
4b	30-37 days; no down.
	37-45 days; flying.

Table 8. Kittiwake chicks weights at Eagle Beach, Thumbstack, and Castle Rock, 1978. Weights are in grams. Chicks were banded on 10 August. In two chick broods, heavier chicks at banding were assigned the heavier weights obtained prior to banding. Brackets ([ ) indicate chicks in same nest.

Band Number	19 July	27 July	2 August	10 August	14 August
Eagle Beach					
101		117	257	395	440
102		69	155	290	340
103		142	277	405	460
104	59		320	390	430
[105		135	237	385	450
[106		107	173	295	385
107	39	66	274	400	430
[108	43	162	252	360	370
[109		121	233	350	415
110	51	182	320	380	390
[111				345	355
[112				360	370
Thumbstack	(18 July)				
113	95	255	375	425	435
114	65	241	380	420	440
115	50	211	280	400	405
116	39	150	330	450	465
117		83	210	355	390
118				260	290
Castle Rock	(18 July)				
119		51	138	268	310
121		58	160	305	340
122	59		282	290	gone
123			134	300	340
124				248	360
[126		35	184	320	350
[127		140	264	375	385
[128	77	258	330	440	470
[129	46		239	350	385

Figure 15a. Weights in grams of six Black-legged Kittiwake chicks in one-chick broods at Eagle Beach, Bluff, 1978.

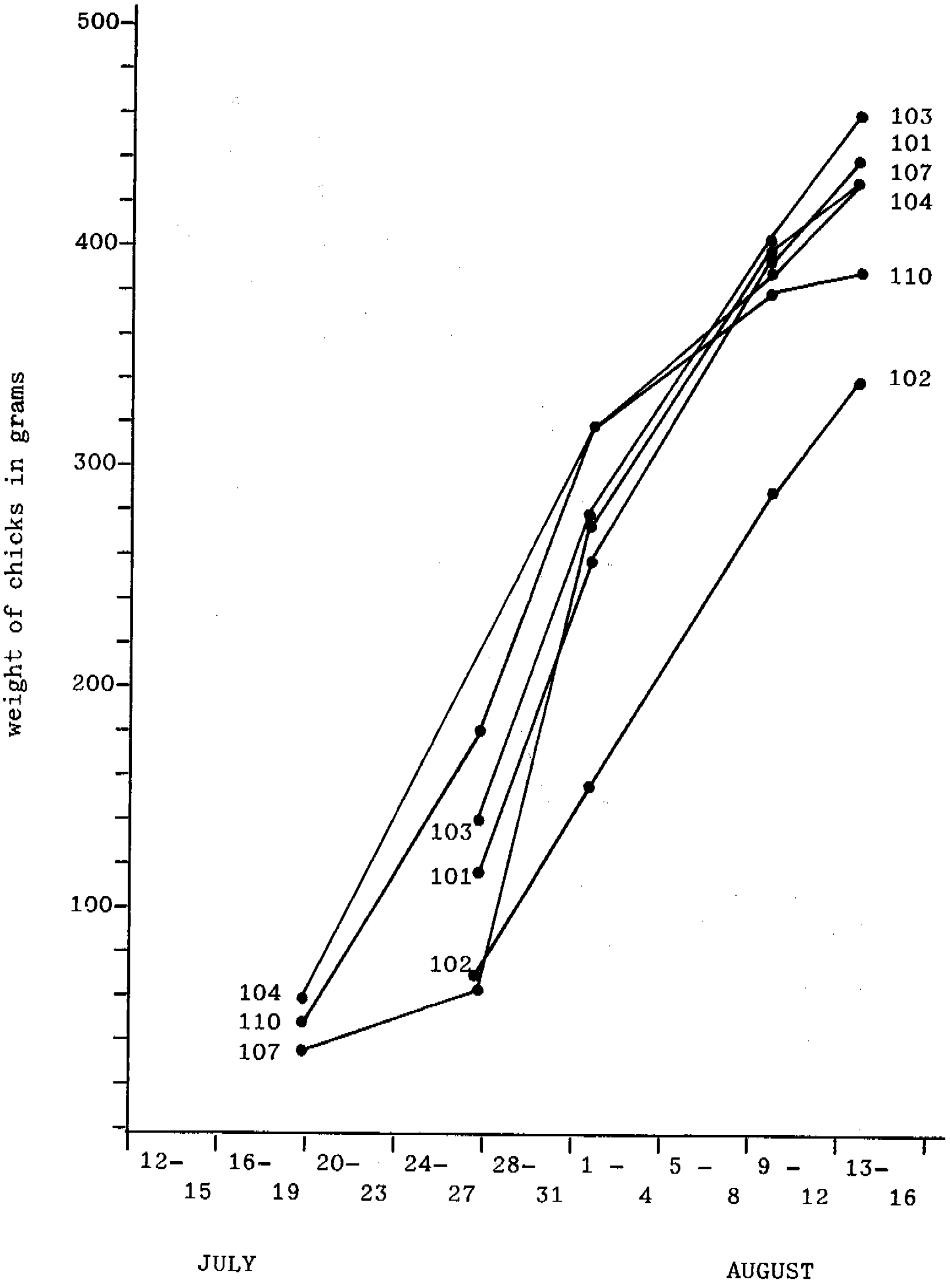


Figure 15b. Weights in grams of six Black-legged Kittiwake chicks in one-chick broods at the Thumbstack, Bluff, 1978.

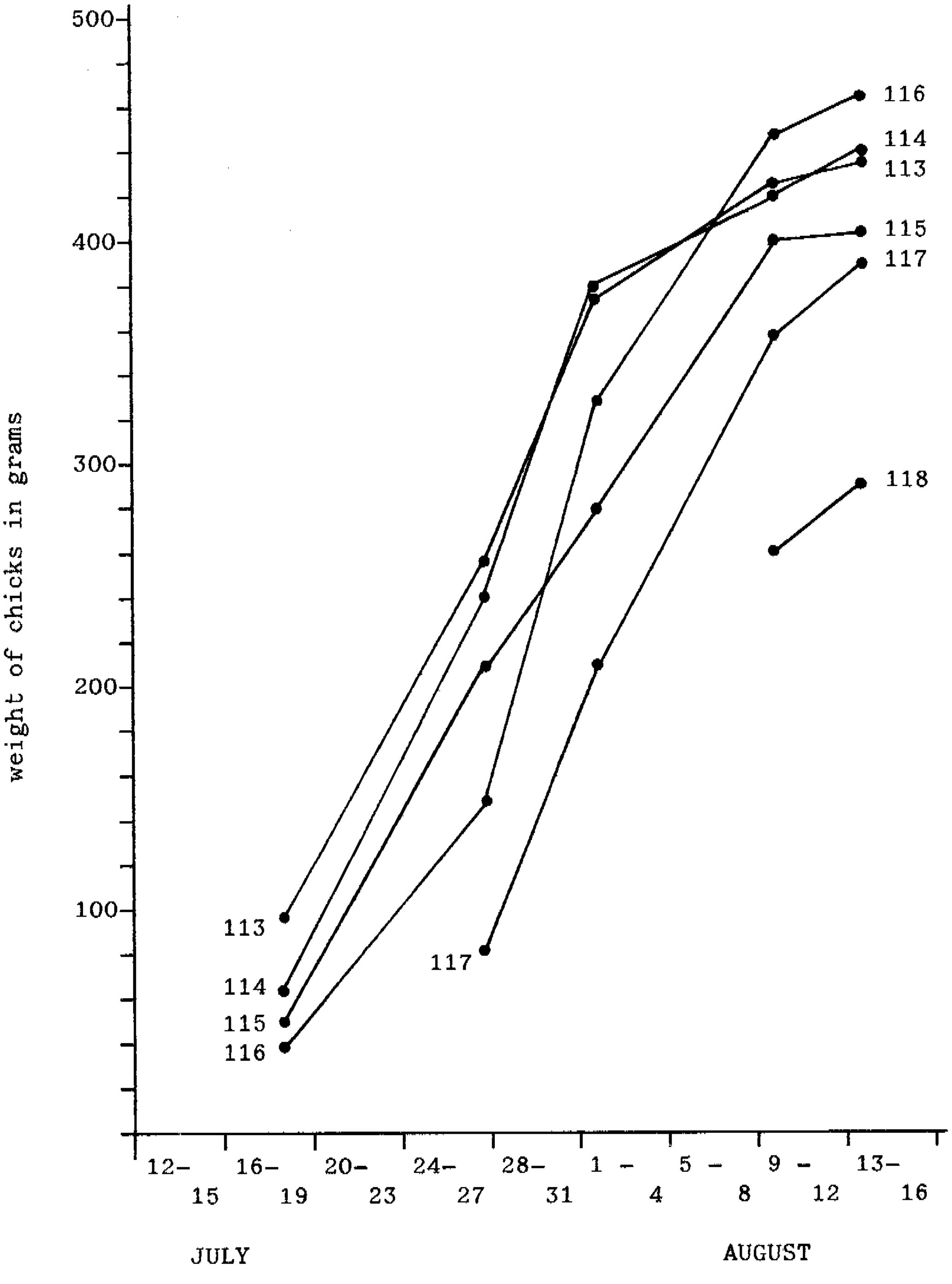


Figure 15c. Weights in grams of six Black-legged Kittiwake chicks in one-chick broods at Castle Rock, Bluff, 1978.

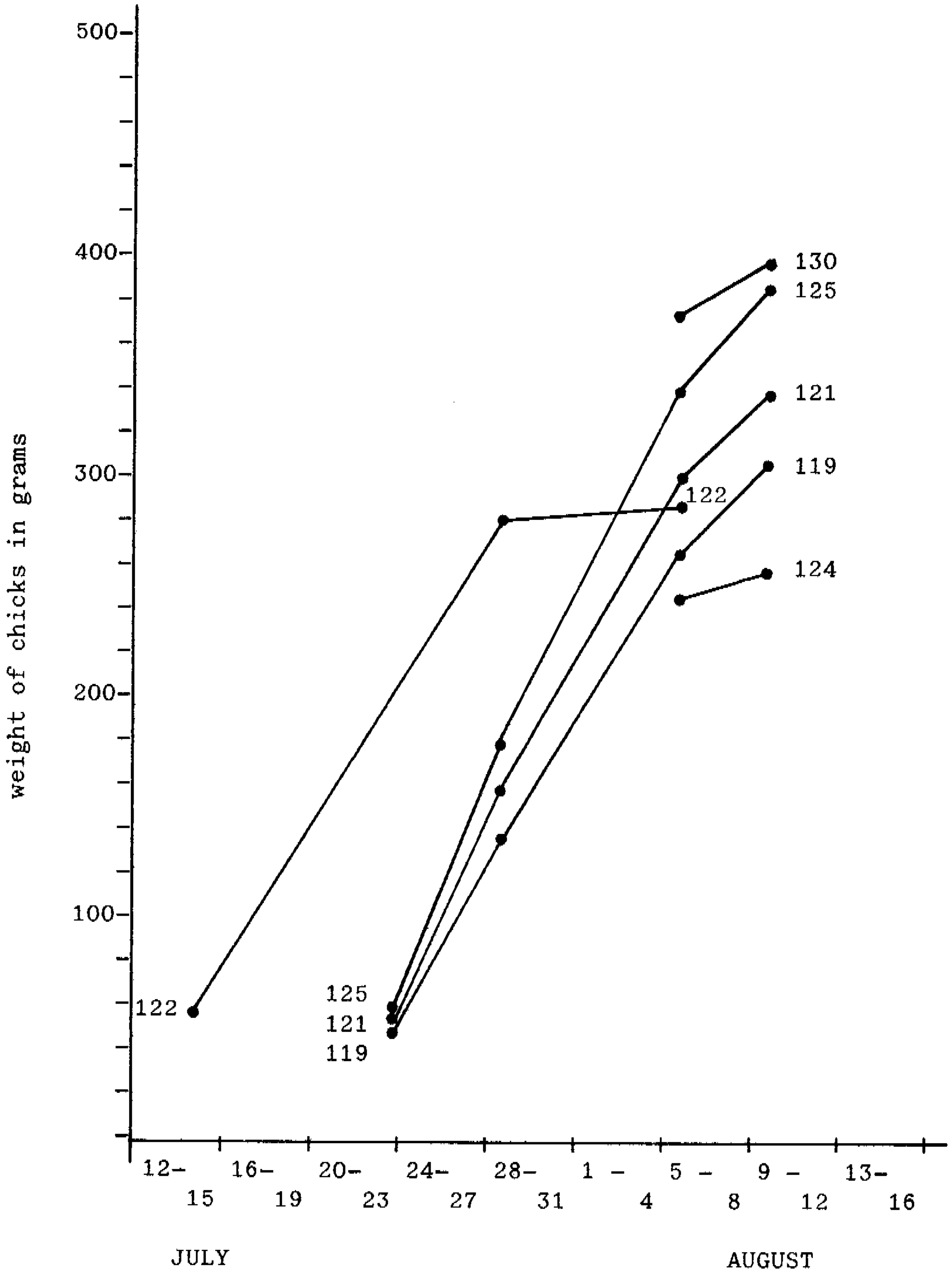


Figure 16. Increases in average weight of chicks in one-chick broods (●), larger chicks in two-chick broods (■), and smaller chicks in two chick broods (▲). Points on graph are average weights for chicks at Eagle Beach, Thumbstack, and Castle Rock.

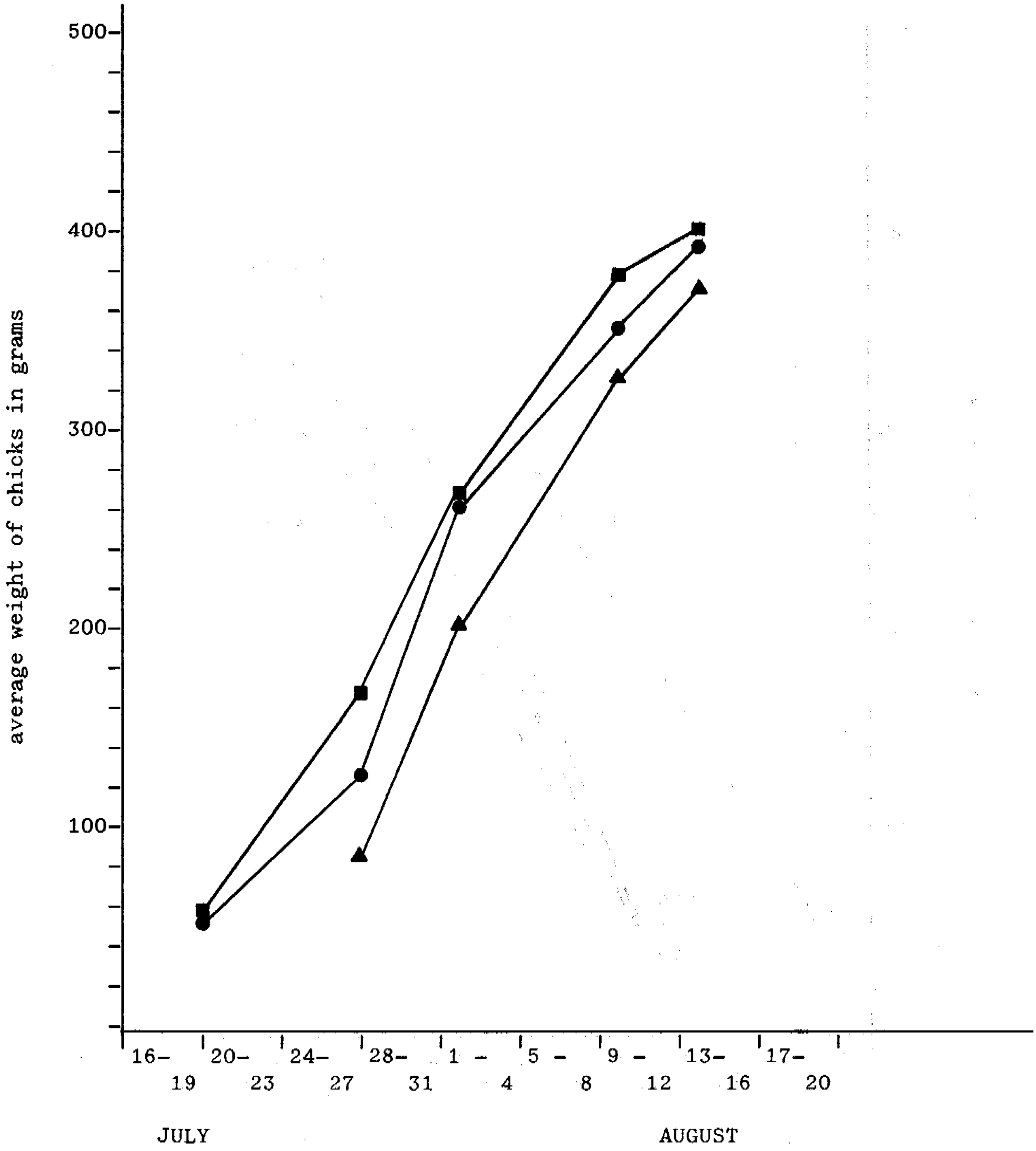
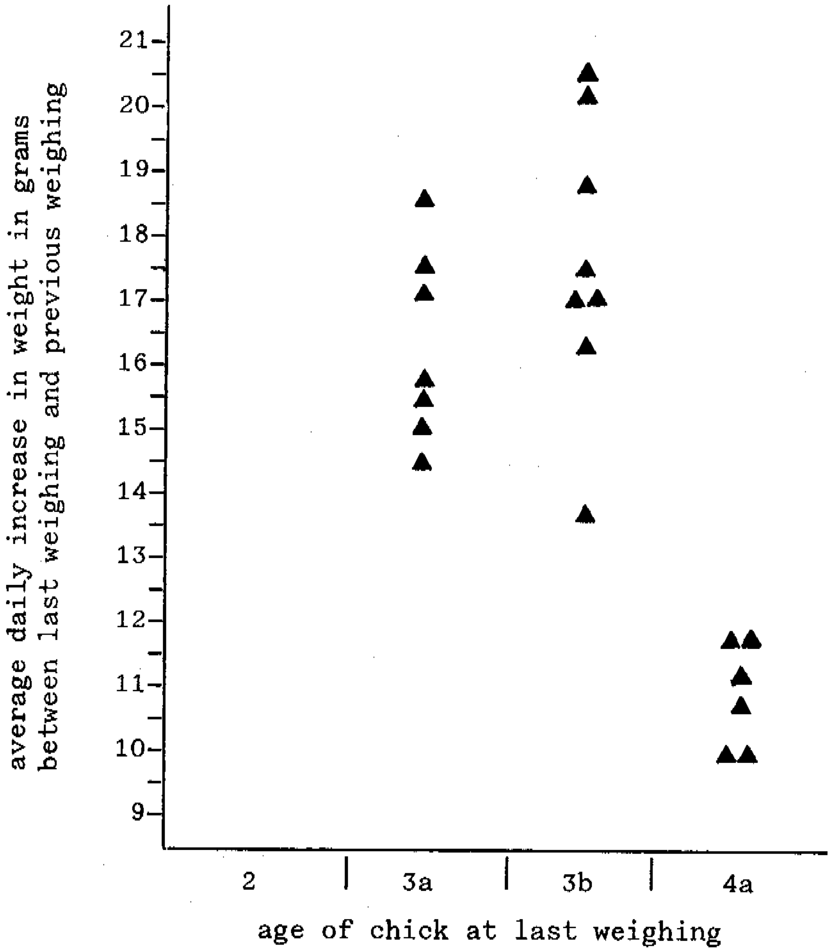


Figure 17 . Weight gain in grams per day in relation to ages of 21 kittiwake chicks at Bluff, 1978.



(27 July to 14 August), was computed for each chick. The average increase in weight (at the 95% level of confidence using t test) was:

Eagle Beach	15.5 ± 1.9 grams per day
Thumbstack	15.8 ± 3.0 grams per day
Castle Rock	15.5 ± 2.2 grams per day

The average for all chicks over the eighteen-day period was 15.6 grams per day. This is similar to an average daily increase of 16 grams in the weight of chicks between 100-300 grams at Northumberland, U.K., obtained by Coulson and White (1958).

f) Reproductive Success

Laying, hatching and fledging. Of the 201 nests that were built during the season within the map areas at the five kittiwake stakes, 183 (91% of all nests built), received eggs, as shown in Table 9 . Most contained two-egg clutches; of the 183 clutches computed, 54 were one-egg, and 129 (about 70%) were two-egg; total 312 eggs laid. Average clutch size for 1978 was 1.7 eggs per clutch.

We observed eggs to be lost when an egg was damaged or crowded out of the nest by the parent or chick, when a parent was distracted from its incubating by fighting, or by a raven or Glaucous Gull.

A total of 234 eggs hatched (see Table 9). Of these 234 chicks, 164 are believed to have fledged (see Table 9). We left as fledging began, so this number represents the number of chicks present on our last visit to the stakes. At that point 4% of the chicks were still downy (younger than age 3b).

Table 10 shows that 75% of the eggs that were laid hatched, representing 83% of the completed clutches; 53% of the eggs laid produced chicks; 70% of the eggs that hatched fledged.

Table 11 shows the hatching success and chick survival (the number of chicks fledged as a percentage of the number of eggs hatched) for 1976, 1977, and 1978. The outstanding success of the 1978 season is clearly shown in this table. It is also evident that kittiwake reproductive success at Bluff is controlled by loss of eggs, not loss of chicks after hatching. Chick mortality was about 30% each year. The percentage of eggs lost varied widely from 75% in 1976, to 15% in 1978.

Fate of two-egg clutches. One hundred twenty-nine two-egg clutches were laid at the five map areas. While twelve hatched nothing, thirty-five hatched one egg, and eighty-two (almost two-thirds of the two-egg clutches) hatched two eggs.

Table 9. Success of One Egg Clutches, Two Egg Clutches, and All Clutches completed at five kittiwake stakes, Bluff, 1978.

Stake	One Egg Clutches	Number Hatched	Number Fledged
8	9	7	6
10	15	11	10
13	14	8	8
14	7	5	5
17	9	4	5*
Total	54	35	34

Stake	Two Egg Clutches	One Egg Hatched	One Chick Fledged	Two Eggs Hatched	One Chick Fledged	Two Chicks Fledged
8	26	6	6	19	18	0
10	32	13	13	16	11	4
13	31	6	6	24	18	6
14	18	4	5*	11	11	0
17	22	6	6	12	10	3*
Total	129	35	36*	82	68	13

Stake	Total Eggs Laid	Total Clutches Completed	Clutch Size: Eggs/Clutch	Total Eggs Hatched	Total Chicks Fledged
8	61	35	1.74	51	30
10	79	47	1.68	56	42
13	76	45	1.69	62	44
14	43	25	1.72	31	21
17	53	31	1.71	34	27
Total	312	183	1.70	234	164

*Number of chicks fledged is higher than number hatched in some instances because of chick migration-foster parenting phenomenon described in text.

Table 10. Kittiwake reproductive effort measured at five stakes, Bluff, 1978.

CLUTCH SIZE: 312 eggs laid/183 clutches completed = 1.70 eggs per clutch starte

312 eggs laid/201 nests built = 1.55 eggs laid per nest built

HATCHING SUCCESS: 234 eggs hatched/312 eggs laid = 0.75 eggs hatched per egg la

BROOD SIZE: At Hatching: 234 chicks/152 broods = 1.54 chicks per brood

At Fledging: 164 chicks/151 broods = 1.09 chicks per brood

CHICK SURVIVAL: One Egg Clutches: 34 chicks fledged/54 eggs laid =
0.63 chicks fledged per egg laid

Two Egg Clutches: 130 chicks fledged/258 eggs laid =
0.50 chicks fledged per egg laid

All Clutches: 164 chicks fledged/312 eggs laid =
0.53 chicks fledged per egg laid

Chicks hatched and died:
One Egg Clutches: 2 chicks lost/ 35 hatched =
0.06 chicks lost per egg hatched

Two Egg Clutches: 69 chicks lost/199 hatched =
0.35 chicks lost per egg hatched

All Clutches: 71 chicks lost/234 chicks hatched =
0.30 chicks lost per egg hatched

Success: 164 chicks fledged/234 eggs hatched =
0.70 chicks fledged per egg hatched

164 chicks fledged/201 nests built =
0.82 chicks fledged per nest built

All thirty-five two-egg clutches that hatched only one egg, successfully fledged one chick. Sixty-eight (about 85%) of the eighty-two two-egg clutches that hatched two eggs fledged only one chick.

Of thirty nests in which both eggs hatched within a day of one another, ten successfully fledged two chicks each (33%), eighteen fledged one chick (60%), and two failed entirely (6%). In fifty-one two-egg clutches, the eggs hatched on different days; three broods (6%) successfully fledged two chicks each, while forty-eight broods (94%) flegded only one.

Asynchronous hatching of two eggs obviously decreased the chances of survival of one chick. Larger chicks were aggressive toward smaller chicks and pecked them to death or crowded them out of the nest. Figure 18 illustrates that the survival of two chicks is relatively rare, that and the shorter the time span between the hatching of two eggs in a nest, the greater the probability of both chicks surviving.

Competition between siblings may have caused some of the chicks to move between nests. In five instances, one at each stake, we saw foster parents accept a chick from a neighboring nest. Parents accepted a chick in four situations:

1) The eggs in the foster parents' nest hatched, but the young are smaller than the adopted chick (one nest; only one chick fledged).
2) The eggs in the foster parent nest had not hatched (two nests; one chick fledged from each).
3) No eggs had been laid, but the nest had been maintained (one nest; one chick fledged).
4) Two chicks had hatched, a third chick of similar size migrated to the nest, and for over three days the three chicks were brooded alternately, two at a time (two chicks fledged from the nest).

Estimate of reproductive success. Our estimate of reproductive success is the number of chicks fledged per nest built. We defined a nest earlier. The values for 1978 were based on two sets of data, shown in Table 12; those from the stakes, and those from a census on 21 August, made by walking the perimeter of the cliff counting nests and chicks wherever at least twenty-five nests were visible below.

Reproductive success at the stakes was 0.82 chicks per nest. The census of 21 August gave data indicating 0.94 chicks per nest (shown in Table 13) (.94-.821/.82), a figure 15% higher than that for the stakes. If one compares the number of nests at the stakes on the last stake visit to the total number of nests built through the season $(\frac{210-170}{210})$, there is a 15% loss of nests.

Table 11. Chick survival at five kittiwake map areas at Bluff: 1976, 1977, 1978.

Year	Total Eggs Laid	Total Hatched	Hatching Success: number hatched as % of number laid	Chicks Fledged	Chick Survival: number fledged as % of number hatche
1976	47	7	15%	5	71%
1977	44	15	34%	11	73%
1978	312	234	75%	165	71%

Figure 18. Probability of two kittiwake chicks surviving out of all nests that hatched two eggs against the number of days between hatching. Based on the following data:

13 of 81 two chick broods fledged two chick each;
10 nests hatched both eggs within one day of each other;
2 nests hatched both eggs with 2 days, and 1 nest within 5 days.

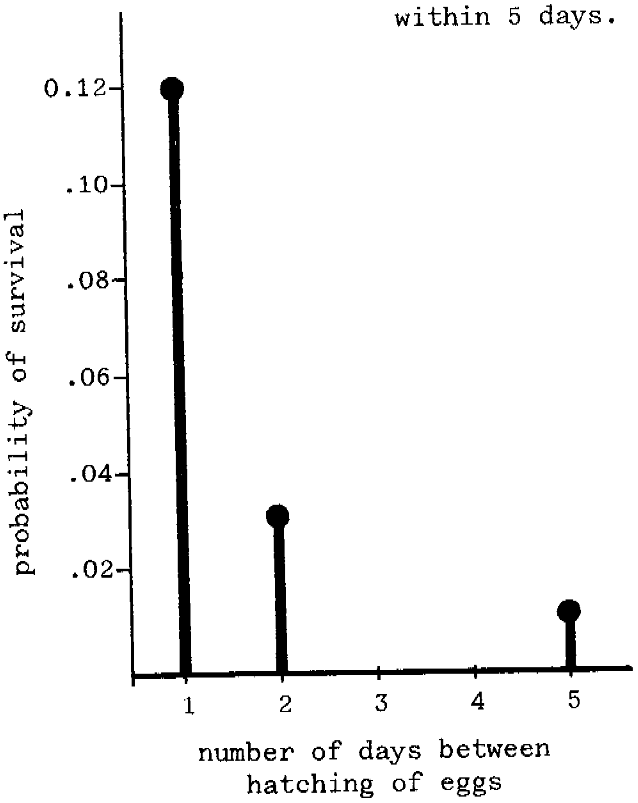


Table 12. Nests and chicks counted at Bluff at stakes through the season and during census on 21 August 1978.

	Total Nests	Total Chicks	Total Broods	one chick broods	two chick broods	three chick broods
Stakes through season	201	165	146	127	19	0
Chick Census 21 August	2462	2304	2049	1798	247	4

Table 13. Estimates of reproductive success: stake and chick census data from Table , Bluff 1978.

	% empty nests	% one chick broods	% two chick broods	% three chick broods	Reproductive Success Ratio: Chicks per Nest
Stakes through season	27%	63%	10%	0%	0.82 chicks per nest
Chick Census 21 August	17%	73%	10%	0.2%	0.94 chicks per nest

Table 14. Reproductive success at five kittiwake map areas at Bluff: 1976, 1977, 1978.

Year	Total Nests Built	Chicks Fledged	Reproductive Success: number of chicks fledged per nest built
1976	131	5	0.04 chicks per nest
1977	98	11	0.11 chicks per nest
1978	197	165	0.82 chicks per nest

The census taken 21 August obviously omitted nests built and lost earlier in the season. Thus, we believe the 15% difference in reproductive success reflects omission of nests which had been lost earlier in the season.

Table 14 presents data on reproductive success taken at five kittiwake stakes in 1976, 1977, and 1978. The number of nests built in 1977 as indicated, is low relative to 1976 and 1978, because "nest" was narrowly defined (depending on depth of cup and the observer's assessment of whether it might hold an egg). These differences in definition of nest are evidently trivial. 1978 stands out as a success in northwestern Alaska, though such a reproductive performance would be average in the north Pacific part of Alaska and poor in northeast England.

3. Bluff: Common Murres

a) Year to year variations in numbers

Data from censuses of murres at Bluff during the breeding seasons of 1975-1978 are presented in Table 15. The number of flyers (murres flying off the cliff during the counts) is given in Table 16 as percentages of the total number counted during the census.

The censuses of 26 June 1976 and 28 June 1977 were made before laying had begun and the percentage of flyers was high. Laying was well underway by this time in 1978 and the murres' attachment to the cliff was higher as indicated by the lower percentage of flyers. The percentage of flyers was consistently low in 1978, in contrast to the consistently high percentages of flyers in 1976.

b) Seasonal variation in attendance

Figure 19 shows counts of murres on the water in front of the cliffs at Bluff in late May, 1978. By 30 May 1978, 80% of the murres were on the cliffs, and some birds were bringing fish in for courtship. On 31 May and 1 June, numbers dwindled to a few dozen birds on, and about 700 in front of the cliffs; the murres had gone to sea, ending what Tuck (1960) referred to as "the prospecting stage." Birkhead (1978) showed that Common Murres make several prospecting visits before settling in when eggs are laid.

The number of murres counted on each section of the Bluff Cliffs (A to J) during four colony censuses during the breeding season are shown in Table 17. The fluctuations of numbers through the summer are illustrated by the plot of maximum counts in Figure 20.

These counts indicate that the number of murres increased through the laying and incubation periods, until early August. Figure 20 indicates that

Table 15. Maximum total numbers of murres, both flyers and non-flyers, counted during colony censuses at Bluff, 1975-1978.

1975		1976		1977		1978	
Date	Total	Date	Total	Date	Total	Date	Total
		26 June	41,780	28 June	42,000	26 June	23,595
[a]4 July	90,000	11 July	20,779	7 July	42,600	[b]18 July	33,520
1 Aug	69,900	26 July	45,175	29 July	45,250	9 Aug	48,460
8 Sept	6,545	12 Aug	55,390	19 Aug	36,100	14 Aug	32,080

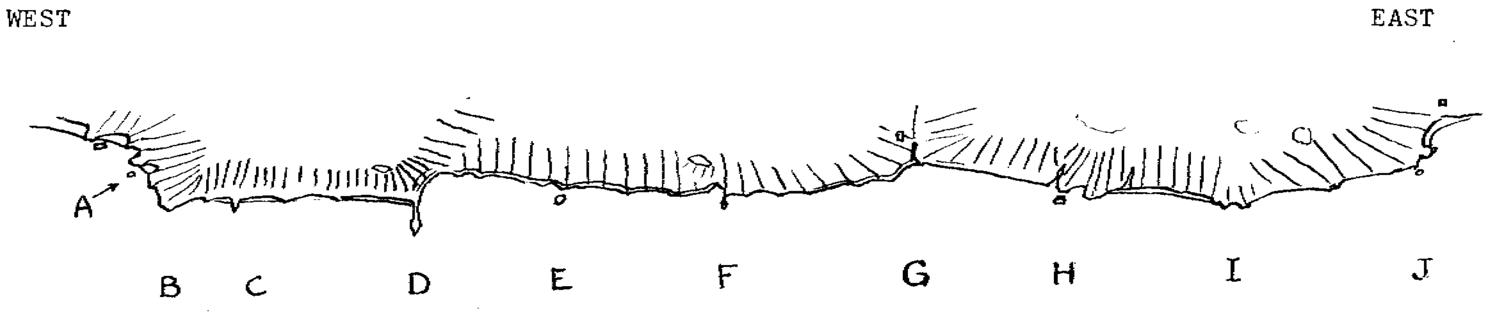
[a] Number includes birds on the water as well as on the cliff.

[b] Flyers not included in this census; number is only non-flyers (i.e., birds on the cliff).

Table 16. Number of murre flyers as percentage of total number of murres counted during colony censuses of Bluff Cliffs, 1976-1978. In 1975, flyers were counted with non-flyers for a lumped total, so percentages are not available.

1976		1977		1978	
Date	% Flyers	Date	% Flyers	Date	% Flyers
26 June	55%	28 June	34%	26 June	5%
11 July	49%	7 July	7%		
26 July	41%	29 July	4%	9 Aug	7%
12 Aug	32%	19 Aug	14%	14 Aug	7%

Figure 19. Three pre-breeding season counts of murres on the water in front of Bluff Cliffs on 27, 28, and 31 May, and four colony censuses on 26 June, 18 July, 9 and 14 August, 1978. The early counts on the water extend one-half to three-quarters of a mile east and west of the cliffs. Numbers shown are maximum counts.



Date	Max. Total										
27 May	33,930	5030				9300		8900		10700	
28 May	89,000	29000		15000			20000		14000		11000
31 May	800	700						10^+ on each section of cliff			
26 June	23,595	450	640	3760	7550	2405	3550	1290	1580	2100	270
18 July	33,520	1160	5110		9470	3600	5710	2440	2030	3350	650
9 Aug	48,460	2040	8240		17000	4540	7150	2560	2170	4190	570
14 Aug	32,080	2910		5790	8450	3170	4190	1800	1600	3720	180

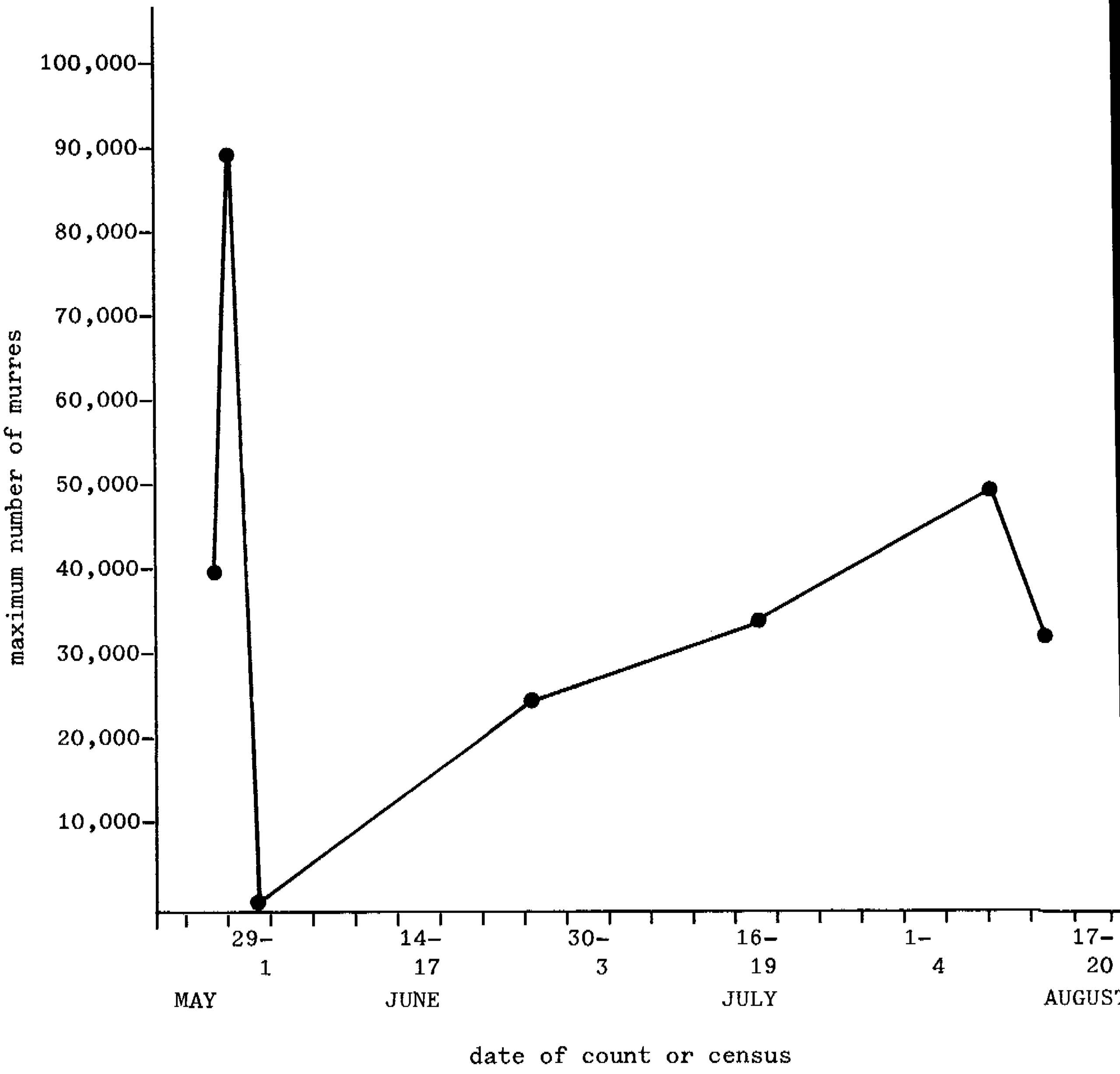
Table 17. Estimates of total number of murres at Bluff in 1978. Counts were made from a boat passing in front of the cliff and include flyers.

Section of Cliff	26 June		[a]18 July	9 August		14 August
	max.	min.		max.	min.	
west of A	450	440	1160	2040	1970	
A to B	640	550				[b]2910
A to C	(4400)	(2980)	5110	8240	6610	(8880)
B to C	3760	2430				5970
C to D	7550	5590	9470	17000	15550	8540
D to E	2405	1875	3600	4540	4530	3170
E to F	3550	2740	5710	7150	6890	4190
F to G	1290	1070	2440	2560	2380	1800
G to H	1580	1000	2030	2170	2140	1600
H to I	2100	1500	3350	4190	4040	3720
I to J	270	220	650	570	550	180
TOTAL (A to J)	23,595	17,415	33,520	48,460	44,660	32,080
Non-flyers (murres remaining on cliff)	22,400	16,220	33,520	44,840	41,040	29,740
% of total	95%	93%	--	93%	92%	93%

[a] Flyers were not included in the 18 July census; i.e., numbers are birds on the cliff only.

[b] This counts includes birds west of A to B.

Figure 20. Results of three early counts and four colony censuses of murres at Bluff Cliffs, 1978.



a second peak in numbers occurred around 9 August. This corresponds to the peak of jumping of murre chicks, 9-12 August (Figure 25 , see section on Reproductive Schedule). The additional birds may indicate the presence of both parents, the return of some of the murres who departed before the breeding season began, or the appearance of young birds prospecting for breeding sites.

The variations in numbers of murres counted in each section of the cliff section during the four colony censuses are plotted in Figure 21 . The increase in numbers of birds at the cliff to 9 August is obvious, except in area I to J, the eastern end of the cliff. The numbers of murres vary widely in this area (0 to 650 birds). The cliffs are made of poorly consolidated rocks in some places; a pair of Golden Eagles has nested in this section each year.

The seasonal variation in numbers of murres is reflected in sample counts, as well as cliff counts. The plot of ten sample counts at Stake 15, in Figure 22 , is similar to Figure 20 of the 1978 colony censuses. A decrease in the number of murres on the cliff occurred from 29 May to 1 June, followed by a rise through the laying and incubating periods, a peak on 21 July and 9 August, and a decrease as adults and chicks left.

c) Daily activity patterns

Five twenty-four hour counts were made through the season at "the far cliff" at Stake 15. These counts (Figure 23) show daily fluctuations in numbers of murres and changes with the season.

In 1978 counts were made at four-hour intervals, whereas in 1977 counts were made every hour. A comparison of Figure 23 of the 1978 counts with the 1977 counts (Figure 13 of the Annual Report for 1977) indicates that counts every four hours give the same patterns, as the more laborious counts made every hour.

Figure 24 shows the percentage variation in the number of murres during each 1978 twenty-four hour count. In the count made before laying, an early morning peak was followed by a complete desertion at mid-day. As egg-laying and incubating progressed, the variation decreased to 30% and 15%, on 19 June and 6 July, respectively. The number of birds present at mid-day was higher and the numbers decreased to a minimum at night. During late July and August, variation increased to about 25%, and numbers reached a peak in late afternoon.

d) Reproductive schedule: laying, hatching, fledging

Laying. The first murre egg was seen on 12 June in 1978; it was washed up by the tide. We did not try to find all eggs laid at our study sites in

Figure 21. Variation in the maximum number of murres counted in each section of cliff (A to J) during colony censuses at Bluff, 1978.

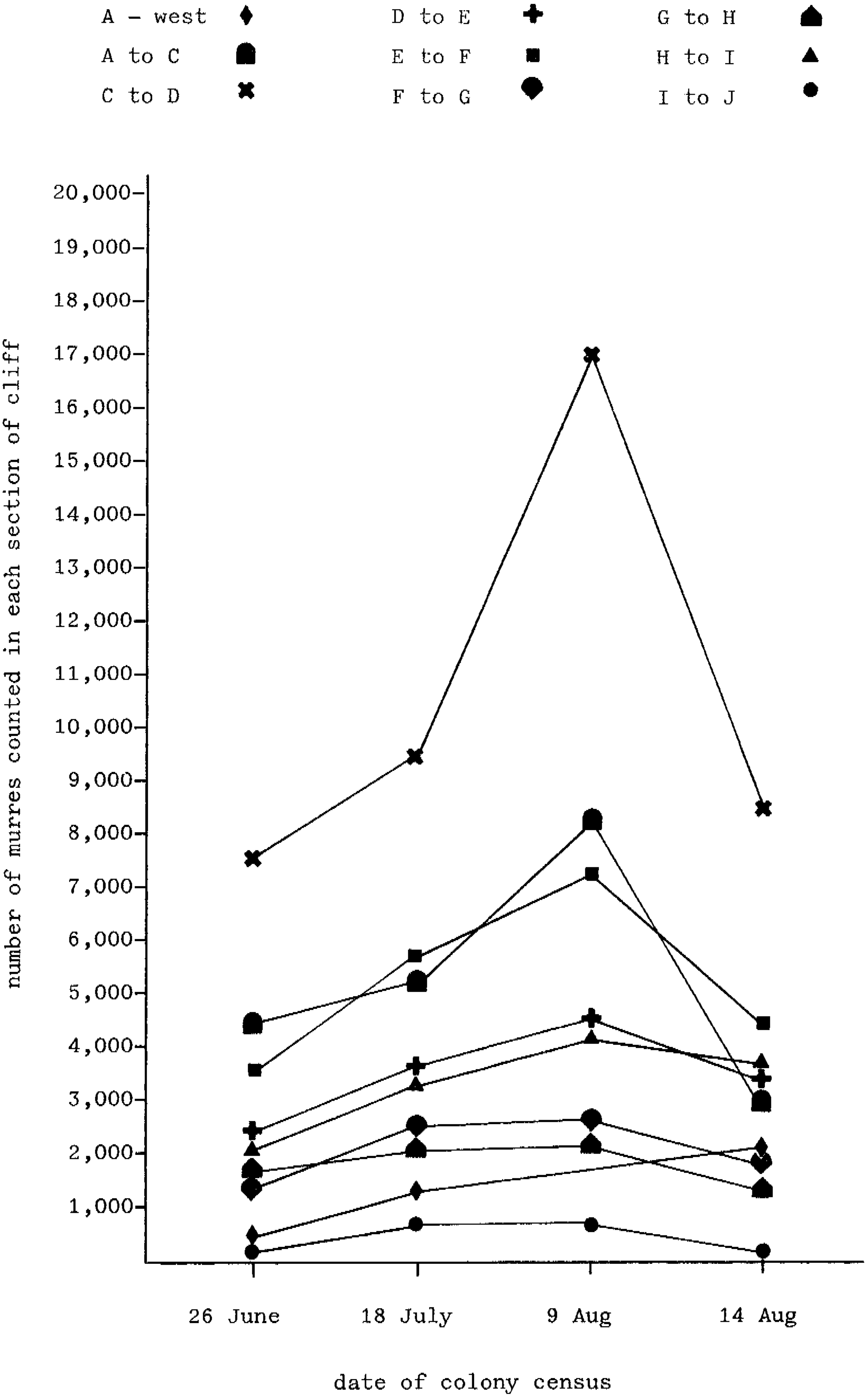


Figure 22. Murre sample counts at stakes 1, 3, 5, and 15; Bluff 1978.

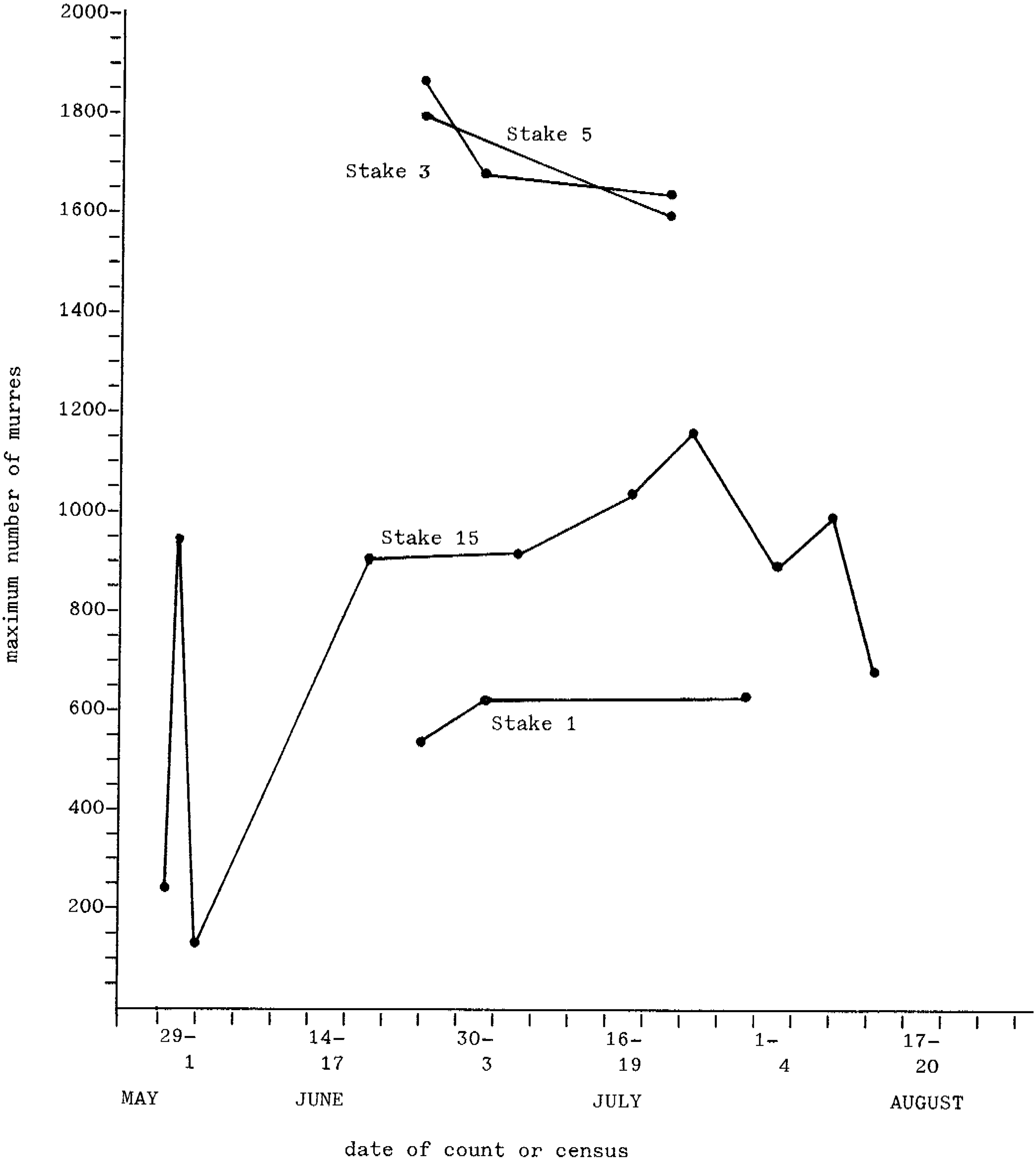


Figure 23. Twenty-four hour counts of murres; Stake 15, Bluff 1978.

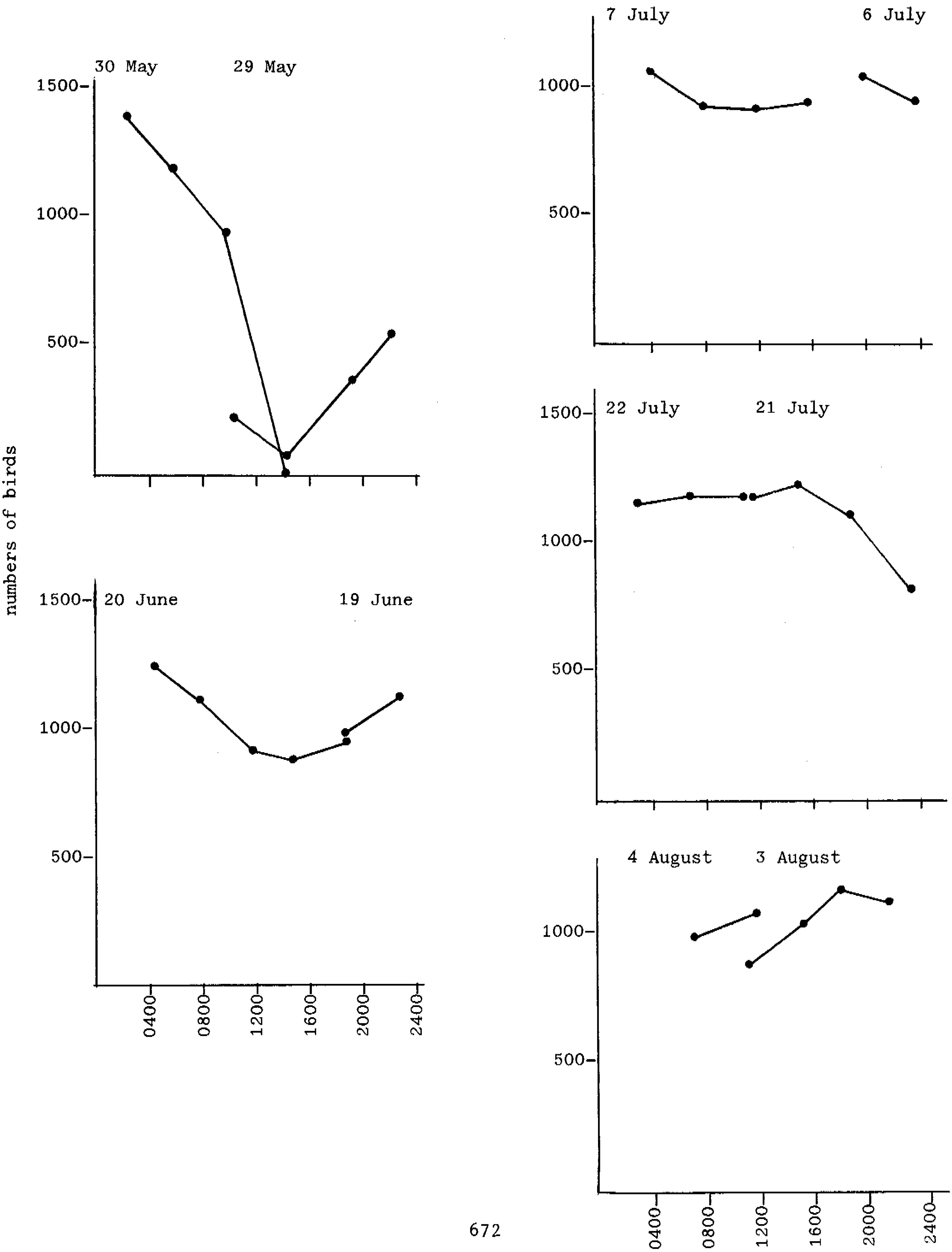
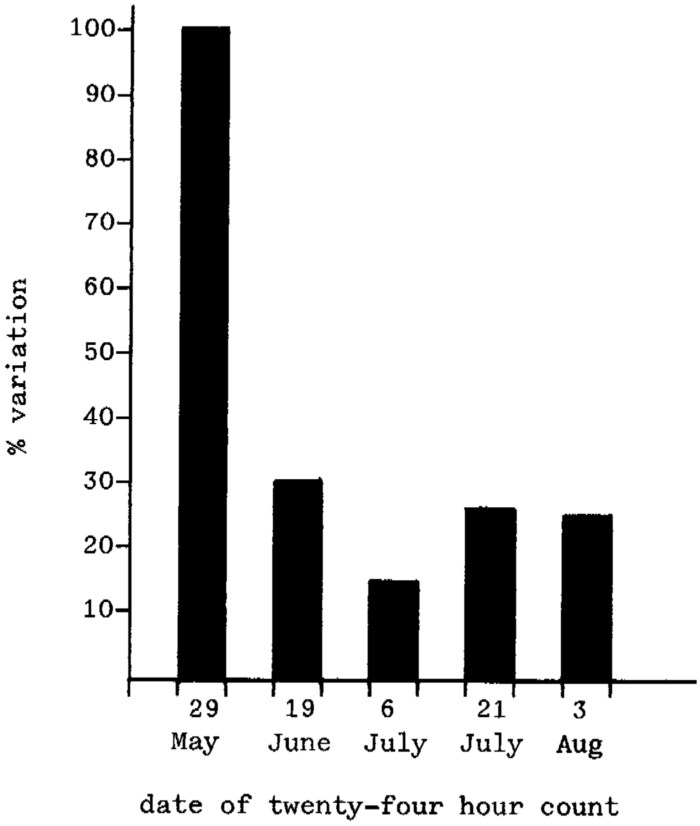


Figure 24. Variation in murre counts through the day, from five twenty-four hour counts made through the breeding season at Stake 15, Bluff, 1978. Percentages are based on the differences between the highest and lowest counts relative to the highest count:

$$\frac{\text{high count - low count}}{\text{high count}} \times 100.$$



1978 because we had found our data on egg-laying to be shaky in the past. Intensive studies of Common Murres at seven study sites were begun on 5 July, after many eggs had been laid. The peak of egg-laying was calculated to be 18-21 June, by subtracting thirty-three days (average incubation time, Tuck 1960) from the peak of hatching which we recorded.

Hatching. Murre chicks remain hard to see after they first hatch. As they grow they begin to move around on the ledges, and thus become more visible with age. Our hatching dates are based on our first sightings of chicks. The chicks, when first seen, were often already one to four days old. The first recorded appearances of chicks at the seven stakes are shown in Table 18. Murre stakes were visited on 14 July, but no chicks were seen; on 16 July, chicks were conspicuous, and several were thought to be more than a day old.

The peak of hatching at Stake 10, our most intensively studied stake, occurred 20-23 July. The span of the hatching period was from 16 July to 10 August, about twenty-six days (Figure 25). We believe the peak and span of hatching occurred at about the same time at most other stakes. Stake 14 seems to have deviated from this schedule as a result of "egging" by Eskimos on 25 June. A high percentage of chicks (66%) was still on the cliff at Stake 14 during our last visit on 17 August.

Fledging. The first jumping of Common Murre chicks from Stake 10 was after 31 July (Figure 25). The peak of jumping was the night of 10 August, when 30% of the chicks believed to have fledged from Stake 10 disappeared. We defined success as disappearance after fourteen days. The average jumping age of the chicks produced at Stake 10 was nineteen days, while some chicks stayed on the ledges twenty-five days.

Study areas at Stake 10 were last mapped on 18 August; by then 90% of the chicks considered successful had already jumped.

Table 19 compares the 1978 breeding schedule of Common Murres at Bluff to that of 1977. The 1978 season was, on the average, two and one half weeks earlier than the 1977 season. This may reflect in part, early break up of the sea ice (around 7 May), and may be associated with the high reproductive success in 1978.

e) Identifiable stages of chick development

Stages of development of murre chicks are described on page 25 of the Annual Report for 1977 for this Research Unit.

Figure 25. Periods of hatching (first dates chicks seen) and fledging of Common Murre chicks at Stake 10, 1978.

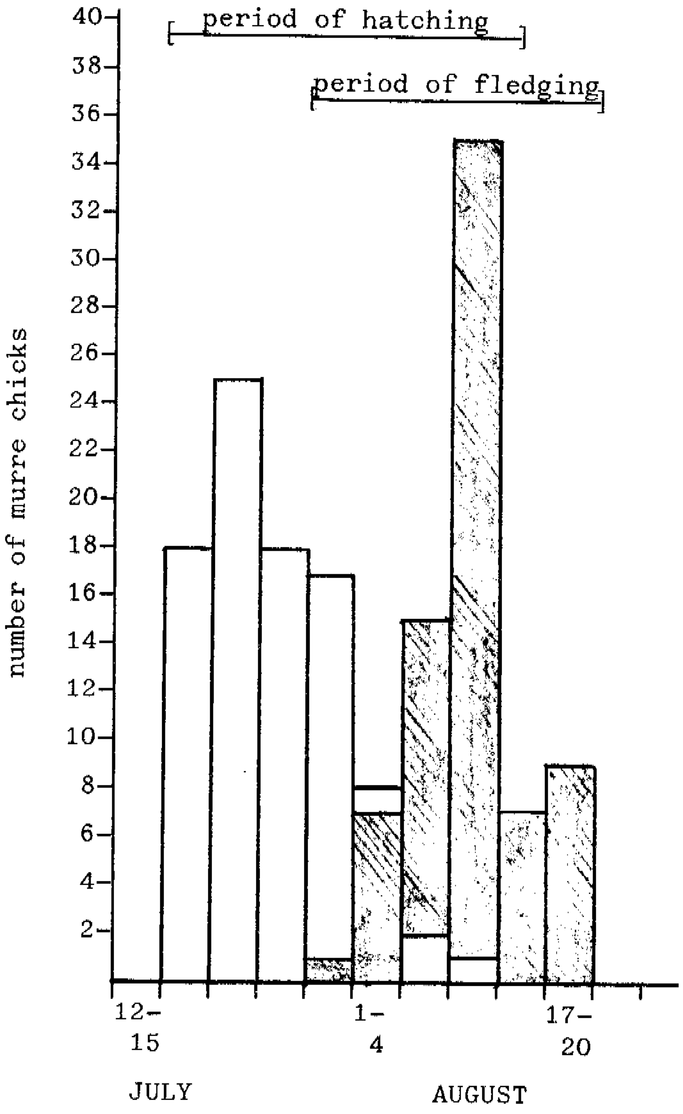


Table 18. First appearance of Common Murre chicks at seven stakes, Bluff, 1978.

Stake	date of first appearance of chicks at stakes	number of chicks seen
8	16 July	6
10	16 July	10
12 "inside"	18 July	1
12 "crack"	18 July	3
13	16 July	1
14	18 July	2
15	16 July	3

Table 19. 1978 vs. 1977 phenology of Common Murres at Bluff.

	1977	1978	number of days difference
first egg seen	21 June	12 June	9
peak of laying	7-10 July	18-21 June	19
first chicks seen	3 Aug	16 July	18
peak of hatching	8-12 Aug	20-23 July	19
first chick jump	20 Aug	31 July	20
peak of jumping	1-5 Sept	9-12 Aug	23

Average number of days difference = 18

f) Reproductive success

All calculations of murre reproductive success for 1978 are based on our Common Murre map areas at the stakes.

Success is represented as the number of chicks fledged relative to the number of murres motivated to assume "sitter" postures. We believe that these postures indicate readiness to respond to the presence of an egg or chick (see Discussion). Clearly, egg-laying represents an important step beyond "readiness to respond," but we believe our data give reliable data, again to the level of "significant figures."

The total numbers of murres and the number of "sitters" (birds in an incubating or brooding posture), counted at stakes, are graphed in Figure 26. We began these counts on 5 July, and continued until 18 August; most counts were made between 1200 and 1700. The numbers varied little through the hatching period.

An average of the totals of murres and an average of the counts of "sitters" between 16 July and 6 August were derived for each stake (Table 20).

The ratio of "sitters" to total was 0.56, which has been rounded to 0.6 (because one year of our data does not allow the higher level of precision). This means that roughly sixty out of every one-hundred murres on the cliff during an afternoon in the hatching period were assuming an incubating or a brooding posture.

We define the number of breeding pairs as the number of pairs defending a territory and laying an egg (Dyck and Meltofte 1975, Birkhead 1978). We can estimate the number of breeding pairs by calculating the number of eggs laid, as in Table 21. In 1977, we determined egg mortality at six Common Murres stakes to be at 15% level. If we assume the same for 1978, that is, a hatching success of 85%, we can then estimate the number of eggs laid, and hence, the number of breeding pairs at our seven stakes:

$$\text{eggs laid} = \frac{\text{319 eggs hatched}}{\text{0.85 eggs hatched/eggs laid}} = \text{375 breeding pairs}$$

The ratio of the estimated number of breeding pairs to total present was 0.6 (Table 22). We estimate that 350-375 breeding pairs occupied sites at the seven Common Murre stakes.

Table 23 shows the number of chicks hatched, fledged, and believed lost, at the seven stakes. Because six chicks seen at Stake during the last visit to that stake were less than fourteen days old, they

Figure 26. Sumtotals of the number of murres present and the number in incubating and brooding postures ("sitters", shaded portion of bars) at seven stakes at Bluff, 1978.

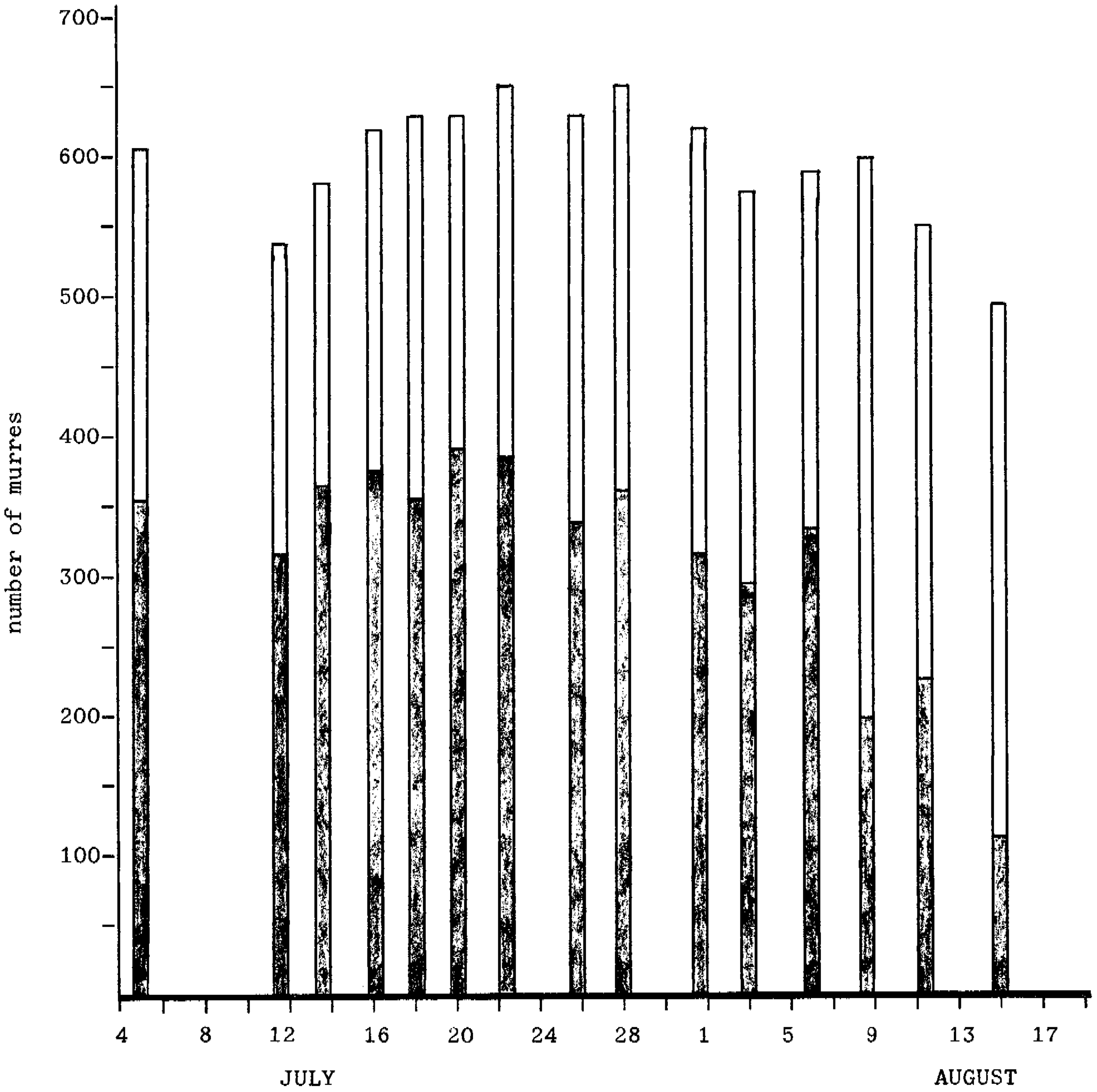


Table 20. The average total number of Common Murres seen at seven stakes at Bluff in 1978, compared to the average number of "sitters" (murres assuming incubating or brooding postures) during the count; numbers derived from stake counts 16 July - 6 August.

Stake	Average Total Number of Murres	Average Number of Sitters	Ratio of Sitters to Total
8	71	34	0.48
10	166	90	0.54
12 "inside"	52	29	0.56
12 "crack"	49	24	0.49
13	81	50	0.62
14	131	79	0.60
15	71	42	0.59
total	621	348	0.56

Table 21. Estimated number of eggs laid at seven murre stakes, based on the number hatched and 85% hatching success; Bluff, 1978.

Stake	Chicks Hatched	Estimated Number of Eggs Laid (number hatched/0.85 hatch per lay)
8	26	31
10	89	105
12 "inside"	28	33
12 "crack"	29	34
13	44	52
14	73	86
15	30	35
total	319	376

Table 22. Estimates of "breeding pairs" from seven Common Murre stakes at Bluff, 1978.

Average Total Number of Murres	Average Number of "Sitters"	Estimated Number of Eggs Laid	Estimated Number of Pairs as Total x 0.6
621	348	376	375

["Sitters" / Total = 350/620 = 0.56]

[Eggs Laid (or Breeding Pairs / Total = 375/620 = 0.6]

Table 23. Numbers of chicks hatched, fledged, and lost at each of seven Common Murre stakes at Bluff, 1978.

Stake	Number Hatched	Number Fledged	Number Lost	Percentage Lost
8	26	21	5	19%
10	89	74	15	17%
12 inside	28	25	3	11%
12 crack	29	24	5	17%
13	44	36	8	18%
14	73	65	2*	3%
15	30	27	3	10%
Total	319	272	41	13%

*Six of the chicks at Stake 14 were less than 14 days old on 14 August, the date of the last stake visit; they were ommitted from estimates of chick loss at Stake 14.

have been eliminated from estimates of the number of chicks fledged or lost. This accounts for the difference of six chicks between the total number hatched and the number fledged plus lost in Table 23, and the 2% difference between total hatched and percentage fledged plus lost below. Of 319 chicks hatched, 272 or 85% were believed to have fledged.

Chick loss was 13% in 1978. Though we recorded the same percentage mortality in 1977, we suspect that actual loss may have been higher. We believe this because, first, we recorded a 17% loss at Stake 10 (Table 23) which was studied more closely than the other stakes. Second, 40% of the chicks lost at Stake 10 were lost within five days of when they were first seen. We may have never seen some chicks because chicks are so difficult to see during these earliest days. The major causes of chick loss at Bluff are 1) predation, primarily by Glaucous Gulls and ravens, 2) exposure, and 3) falling off ledges.

Table 24 shows the 1978 estimates of reproductive success of Common Murres at each of the stakes. The average of the totals is 0.78 chicks fledged per "sitter," and 0.73 chicks fledged per estimated egg laid.

In comparison, the figure for murre reproductive success in 1976 was 0.06-0.09 chicks per egg, and in 1977 from 0.14 to 0.53, with an average of 0.37 chicks per egg. It is obvious, despite some differences in methods, that 1978 was much more productive for murres at Bluff than either 1976 or 1977.

To estimate reproductive success for the entire Common Murre population at Bluff, we first calculated the average number of murres on the cliff during censuses in the hatching period (39,180). This number was multiplied by 0.6 (the ratio of breeding pairs to total present), yielding an estimate of about 23,500 breeding pairs. This is comparable to the 1977 estimate of 20,000 breeding pairs. Assuming that the seventy-five chicks produced per one-hundred breeding pairs of murres at the study sites was typical of the cliffs as a whole, we get an estimate of 17,400 chicks produced at Bluff in 1978.

g) Late-season territorial activity

As more murres arrived at the cliffs later in the season, there was an increase in aggressive behavior seen at the stakes. As chicks left, bickering, presumably among birds prospecting for breeding sites or between them and resident birds defending their territory, increased.

In 1977, we noted that many birds assumed "sitting" postures late in the season. Figure 27 illustrates the temporary resurgence of this motivation seen at Stake 10 in 1978. About one-third of the chicks believed to have

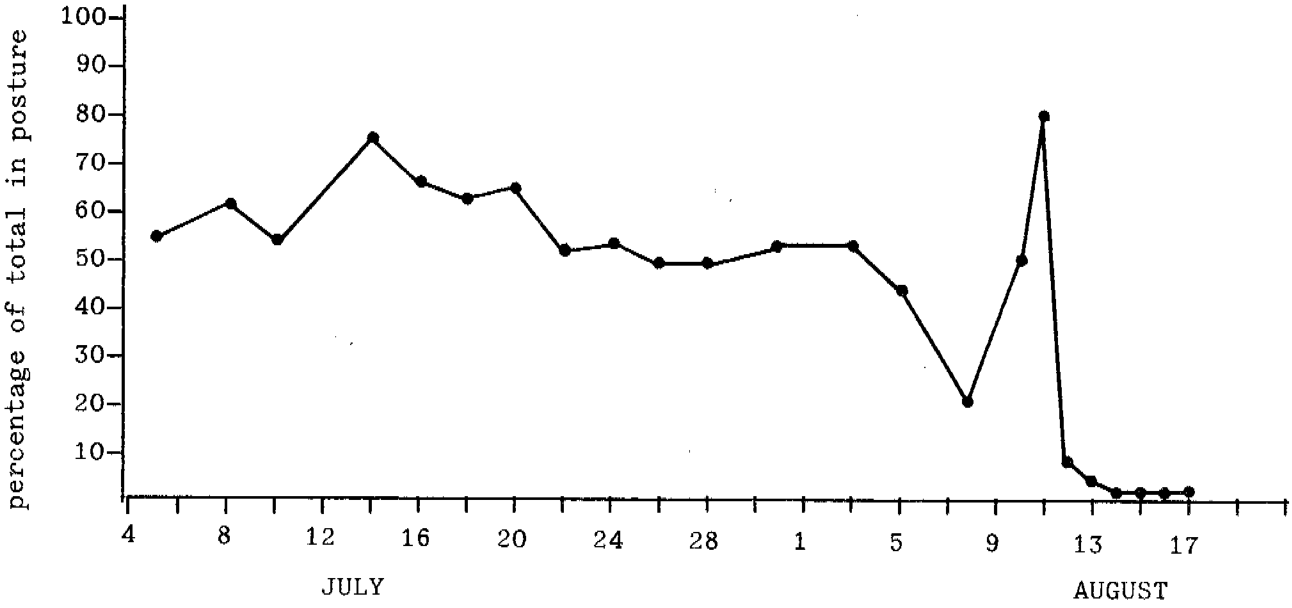
Table 24. Estimates of reproductive success at seven Common Murre stakes at Bluff, 1978.

Stake	Chicks Fledged / Average Number of Sitters[a]	Chicks Fledged / Estimated Number of Eggs Laid[b]
8	0.62	0.68
10	0.82	0.71
12 inside	0.86	0.76
12 crack	1.00	0.71
13	0.72	0.69
14	0.82	0.76
15	0.64	0.77
Total	0.78	0.73

[a] From Table 20.

[b] From Table 21.

Figure 27. Number of "sitters" (murres in incubating or brooding postures) as a percentage of total counted, Stake 10, 1978.



fledged from Stake 10, jumped on the night of 10 August. The lowest percentages of "sitters" at Stake 10 were recorded on 8 and 10 August, presumably because adults were standing beside independent young before the jump. On 11 August we saw a drastic increase in the number of "sitters" (from 20% to 80%). As parents and chicks depart, there seems to be an immediate reoccupation of the sites by both single parents and new prospectors. This peak is a reflection of the peak of jumping.

4. Food Resources at Bluff

Kittiwake feeding melees were most obvious during July and early August. Observations are summarized in Table 25, and indicate the daily frequency of feeding melees and the species involved. These gatherings were seen as close as one and one-half miles and as far off shore as we could see. They were usually seen between Bluff and Square Rock.

From 9-12 August, Edward Murphy collected murres and kittiwakes for their stomach contents. Although the data are not yet analyzed, it was obvious that over 90% of the kittiwakes' diet consisted of 1 1/2-2 inch long Sand Launce (Ammodytes). This is consistent with what we have found over four years, in the regurgitations of chicks. Sand Launce appear to play a critical role in the reproductive success of Black-legged Kittiwakes at Bluff.

Murres, while eating Sand Launce themselves, apparently concentrated on Prickleback (Lumpenus) as the food they brought to their mate or young.

5. Other Species at Bluff

We have little information on the breeding of Pelagic Cormorants, Glaucous Gulls, and Horned Puffins in 1978. Table 26 shows the colony censuses of these three species for 1978.

a) Pelagic Cormorant

Of six nests observed, five hatched a total of fourteen chicks. Of these, nine chicks are believed to have fledged. Hatching occurred during the last week of June, about a week earlier than in 1977. On a survey of nests conducted on 18 July, the middle of the brooding period, fifty chicks were counted in twenty-eight broods of forty-one nests sampled (see Table 27). Fledging began during the first week of August.

b) Glaucous Gull

Of three incidentally monitored nests, two each hatched three chicks; one fledged one chick, while the other fledged two. Hatching coincided with peak of laying of murre and kittiwake eggs in the last week of June. The first fledged chick was seen on 1 August. A census on 9 August showed thirty-four fledged chicks.

Table 25. Feeding frenzies or mélées seen in the Bluff Cliffs - Square Rock area, 1978.

	FIRST WEEK	SECOND WEEK	THIRD WEEK	FOURTH WEEK
MAY				30 May: kittiwakes take no notice of 6-8" fish in cove below Stk 15.
JUNE		12 June: at night, several groups, not mélées, feeding close to shore in breakers east of Square Rock.		
JULY	One to two mélées seen almost daily, west of Bluff and southeast of Square Rock; up to 150 kittiwakes.	Many small mélées off Taylor Lagoon. 8 July: 1-5 groups scattered periodically.	15 July: 1 mélée off Bluff. 17 July: 4 mélées between Bluff and Square Rock.	22 July: mélée of 100 kittiwakes near east end of Bluff; one at Tonok; another at Tonok of 100 kittiwakes, 25 cormorants, 20 puffins, 30 murres, 15 gulls; 2 mélées off Tonok beach of more than 75 kittiwakes each; one off Koyana Cove of 75-100 kittiwakes. 23 July: one of 200 kittiwakes, 30 gulls, 5 horned puffins, 5 murres, 5 cormorants.
AUGUST	Frequency of mélées on the increase; kittiwake chicks regurgitating sand launce during weighing.	8 Aug: one mélée off Koyana Cove early a.m.; another 150 yards off Farland Point at Bluff of 40 kittiwakes, 5 Horned Puffins. 14 Aug: late a.m. off Koyana Cove - one of 150 kittiwakes 12-25 murres; one of 50 kittiwakes, some murres; one two miles east of Square Rock of 150-200 kittiwakes. 13 Aug: 3 mélées Bluff area.		

Table 26. Pelagic Cormorants, Glaucous Gulls, and Horned Puffins at Bluff, 1978.

	26 June	18 July	9 August	13 August
Pelagic Cormorant		adults: 82 nests: 41 chicks: 50		adults: 87
Glaucous Gull	adults: 98	adults: 89 chicks: 6	adults: 138 chicks: 34	
Horned Puffin		on cliff: 190	on cliff: 610 flyers: 66 water: 24	461

Table 27. Results of Pelagic Cormorant nest survey at Bluff on 18 July 1978.

Brood Size	Number of Nests on 18 July
0	13
1	10
2	14
3	4

Number of nests sampled	41
Number of broods	28
Total number of chicks	50
Chicks per Brood	1.79
Chicks per Nest	1.22

c) Horned Puffin

The number of puffins at the cliffs varies enormously both through the day and from day to day. We conducted a series of counts at Stake 18, to look for a pattern, but the results were inconclusive.

On 8, 11, 18 July and 3 August, puffins were seen carrying straw. Presumably, these birds were prospecting for burrows.

We found eighteen occupied burrows along the eastern section of Bluff Cliffs, and observed them through the summer. The first egg was seen on 19 June, and eggs were laid in fourteen of the burrows. The first hatching occurred on 28 July. A total of twelve chicks hatched in the eighteen burrows and were last seen on 14 August.

One immature Horned Puffin was seen perched on the cliff at Stake 18 on 26 July.

d) Tufted Puffin

A high count of ten Tufted Puffins was obtained during the 9 August colony census. On 18 and 24 July, immature Tufted Puffins were seen on the cliff.

e) Parakeet Auklet, Crested Auklet, Pigeon Guillemot

We counted twenty to thirty Parakeet Auklets on the water off Stake 18 during the morning most days. On 22 July, there were fifty-one. These birds landed on the cliff infrequently. One or two were seen sitting about 6 feet from what appeared to be a dug burrow twenty feet down the cliff; they were never seen to enter or leave.

On 11 August we saw one Crested Auklet on the water off Stake 18.

Two Pigeon Guillemots were seen east of Stake 13 during the colony censuses at Bluff this year.

6. Predators at Bluff

We made no special studies of predation at Bluff in 1978.

a) Raven

There were three raven nests this year; one at Square Rock, one on the easternmost point of Bluff Cliffs near the Farland cabin, and one near the center of Bluff Cliffs at Stake 8.

On 27 May, five chicks were seen in the Stake 8 nest, and the adults were molting primaries. By 13 June, four of the chicks had fledged; no further evidence of the fifth chick was seen, and murres had taken over the nest.

At the Farland nest, four young had hatched by 30 May, but only three were in the nest on 17 June; one dead chick was on the rocks below the nest.

One chick fledged on 30 June, and by the next day, all three were flying short distances and hopping about on the tundra above the nest.

Two raven chicks were visible in the Square Rock nest on 16 June, but the fate of these birds is not known.

Eggshells along the edge of the cliff were evidence of predation by ravens. Ninety-four percent were murre eggs; kittiwake and puffin eggs comprised about 3% each. We repeatedly saw ravens carrying eggs inland, northwest from Stake 1, north from Stake 8 and northeast from Square Rock. This suggests there may have been a group of ravens nesting inland.

Through July and into August, ravens were continually cruising the cliffs, flushing murres off ledges and kittiwakes off nests. Family groups were still recognizable in late July; after the first week of August, flocks of ten to thirteen were seen.

b) Golden Eagle

A pair of Golden Eagles nested at Bluff again this year. Their nest was built at a different site than in 1975, 1976 or 1977, although on the same 200m section of cliff. Two eaglets covered with white down were seen in the nest on 30 May. On 25 July, one had climbed from the nest to the top of the cliff where it sat for most of the day. The next day, neither eaglet was seen in the nest or above on the cliff edge. On 27 July, both were seen sitting on the rocky beach below the nest. A storm on 29 July washed a dead eaglet onto the beach in front of the Farland cabin. The other eaglet was seen flying over the cliffs on 31 July, and again on 5 August.

c) Falcons, buzzards, harriers, and humans

There were no Gyrfalcons nesting at Bluff this year, though we saw three in July. The following sightings were recorded: one on 6 July at Koyana Cove; three on 31 July, headed from sea toward Tucker Camp; one flew eastward past Tucker Camp on 3 August; one on 8 August soared over the High Bluffs.

One pair of Rough-legged Buzzards nested at the western end of the cliffs, and one pair nested at Square Rock. The western nest contained four eggs on 29 May when the adults were molting first primaries; two chicks are believed to have fledged. The nest at Square Rock fledged two of three chicks hatched.

We saw one male harrier hunting in the Koyana Creek Valley on 29 May.

On 25 June, the Olsons from Golovin came to Bluff to gather murre and kittiwake eggs. They took about one hundred murre eggs and a half-dozen kittiwake eggs from Rope Stack (area H), and another one hundred murre eggs and a dozen kittiwake eggs from Castle Rock (area D).

7. Square Rock

The 1978 Square Rock colony censuses are shown in Table 28.

a) Black-legged Kittiwakes

We counted between 1100 and 1500 kittiwakes at Square Rock in 1978, about the same number as in 1977. A map area at a stake was established and fifty-two sites were monitored. Table 29 presents the data and calculations of success. Seventy-five percent of the sites became nests; 82% of these nests received eggs. Seventy-five percent of the clutches were two-egg. Seventy-three percent of the eggs hatched, and 68% of the chicks were believed to have fledged successfully. Chick mortality was 32% in the map area. Twenty-eight chicks fledged from thirty-nine nests; success was 0.72 chicks per nest.

b) Common Murres

Murre Stake 19 (20 subsections) was at Square Rock. Table 30 presents the data. "Sitters" comprised about 54% of the birds at the stake; the number of breeding pairs was estimated to be forty to forty-five. Reproductive success was 0.89-1.0 chicks fledged per breeding pair.

8. Topkok Head

We travelled by boat to Topkok Head on 2 July, censusing the shoreline west of Bluff, as well as the cliffs at Topkok. The counts are presented in Table 31.

Gulls were scattered along the beach singly and in groups as large as thirty-five. Nests of Glaucous Gulls and Pelagic Cormorants were seen on Little Topkok and Topkok Head; brood sizes are presented in Table 31. Horned Puffins dotted the cliffs, and Pigeon Guillemots were seen on the water or perched on shore rocks.

In the estuary just east of Topkok were forty bathing kittiwakes, five adult Glaucous Gulls, and a high density of Chum Salmon. One Golden Eagle was perched on a rock outcrop inland this year as in previous years. A raven family of two adults and three birds of the year were seen near the lagoon.

9. Rocky Point

On 4 August, we went east from Bluff around Rocky Point by boat, counting Glaucous Gulls and chicks, Pelagic Cormorants and chicks, and puffins.

The cormorant chicks were at an optimal stage for counting as they were ready to fledge and stood conspicuously in the nests. We estimated that five to

Table 28. Censuses of Square Rock Colony, 1978.

	28 May	30 May	15 July	18 July	6 August
Common Murre	[a]2600-6000 on water		cliff: 3020 flyers: 800 total: 3820	cliff: 2832	cliff: 2040 flyers: 78 total: 2118
Black-legged Kittiwake			1118		cliff: 1130 flyers: 390 total: 1520
Glaucous Gull		[b]adults: 21 (11 incubating)	adults: 38 subadults: 2 chicks: 5	adults: 12 chicks: 3	
Horned Puffins			cliff: 8		water: 70

[a] Counts were made from top of cliff on mainland next to Square Rock.

[b] Census was not completed due to swelly seas, so numbers are low.

Table 29. Reproductive effort and success of Black-legged Kittiwakes at Square Rock in 1978.

sites monitored	rock roosts	active non-nests	nests built
52	4	5	39

eggs laid	clutches completed
56	32

one egg	number hatched	number fledged
6	3	3

two egg	one hatched	one fledged	two hatched	one fledged	two fledged
25	10	8	14	11	3

CLUTCH SIZE: 56 eggs laid/32 clutches = 1.75 eggs per clutch

HATCHING SUCCESS: 41 hatched/56 laid = 0.73 eggs hatched per egg laid

BROOD SIZE (at hatching): 41 hatched/27 broods = 1.52 chicks per brood

CHICK SURVIVAL: One Egg Clutches: 3 chicks fledged/6 eggs laid =
0.5 chicks fledged per egg laid

Two Egg Clutches: 25 chicks fledged/50 eggs laid =
0.5 chicks fledged per egg laid

Chicks Hatched and Lost:
One Egg Clutches: 0 chicks lost/3 chicks hatched =
0 chicks lost per egg hatched

Two Egg Clutches: 13 chicks lost/38 chicks hatched =
0.34 chicks lost per egg hatched

All Clutches: 28 chicks fledged/56 eggs laid =
0.5 chicks fledged per egg laid

13 chicks lost/41 hatched =
0.32 chicks lost per egg hatched

Success: 28 chicks fledged/41 eggs hatched =
0.68 chicks fledged per egg hatched

28 chicks fleged/ 39 nests built =
0.72 chicks fledged per nest built

Table 30. Reproductive success of Common Murres at Square Rock, 1978.

average number of adults: total	average number of adults in postures	chicks hatched	chicks fledged
74	40	45	40

Estimated Number of Breeding Pairs:

74 total adults x 0.6 ratio of breeding pairs to total =
44 breeding pairs

Chicks Fledged per Postured Murre:

40 chicks fledged/40 postured adults=
1 chick fledged per postured murre

Chick Survival: 40 chicks fledged/45 chick hatched=
0.89 chicks fledged per hatch

Success: 40 chicks fledged/45 breeding pairs =
0.89 chicks per breeding pair

Table 31. Reproductive effort in Pelagic Cormorants and Glaucous Gulls at Topkok Head on 2 July and at Rocky Point on 4 August, 1978.

TOPKOK HEAD

Brood Size	Pelagic Cormorant	Glaucous Gull
0	83	1
1	10	1
2	29	7
3	12	2
	nests: 134	broods: 10
	broods: 51	chicks: 21
	chicks: 104	brood size: 2.10
	brood size: 2.01	
	chicks per nest: 0.78	

ROCKY POINT

Brood Size	Pelagic Cormorant	Glaucous Gull
0	5+	
1	44	3
2	64	3
3	50	1
	1	
	broods sampled: 159	broods sampled: 7
	chicks: 326	chicks: 12
	brood size: 2.05	brood size: 1.71

ten had fledged, although we found it difficult to separate birds of the year from adults on the water.

Table 31 presents the number of chicks in the 159 broods sampled.

Puffins were nesting at the same cliffs as the cormorants. Three adult ravens and nine birds of the year were seen. An outcrop of rock divides the beach at Ipnichowok; Glaucous Gulls gathered on either side in flocks of 900-1000 and 500-550. We saw a pair of Peregrine Falcons on the cliffs on the west side of Ipnichowok. A pair of Gyrfalcons soared over the gull and cormorant colony on the east coast of Ipnichowok. Note that Peregrines were seen at Topkok, Bluff and Cape Darby in 1975 and 1976, and Gyrfalcons nested at Square Rock in 1977.

10. Sledge Island

A party of two went to Sledge Island by boat on 11 July, and censused the island on 13 July. Counts at map areas at two stakes were made on 12 and 14 July. The counts of Black-legged Kittiwakes and Cormorants are shown in Table 32. No murre chicks were seen during the visit.

Two Tufted Puffins were seen coming out of a burrow in the southeast corner of the island. Pigeon Guillemots and Parakeet Auklets were seen on the water around the island, but were not seen on the cliffs.

A Snowy Owl, a raven family of two adults and four birds of the year, and a Peregrine Falcon family of two adults, two nestlings and one unhatched egg were also seen. We returned to Sledge on 11 August in hopes of obtaining the unhatched egg for analysis, but the nest was empty.

Table 32. Reproductive information on Black-legged Kittiwakes and Pelagic Cormorants on Sledge Island, 12-16 July 1978.

Black-legged Kittiwakes

56 nests sampled	
51 contained 89 eggs	1.56 eggs per nest
Clutches: 13 one-egg, 38 two-egg.	1.75 eggs per clutch
No chicks seen on 12 July, one seen on 16 July	

Pelagic Cormorants

40 nests sampled	
39 contained 106 chicks	2.65 chicks per nest
Broods: 3 one-chick, 11 two-chick, 19 three-chick, 6 four-chick.	2.72 chicks per brood

B. Seabirds. Distributions at Sea

1. General

At 120 knots the plane has moved about 10 nautical miles (10 minutes of latitude) in a five-minute period. Using the 30° angle of observation, the observers on the two sides of the plane have surveyed about one square kilometer of water surface. These averages are affected by head winds or tail winds.

In our data each survey line (a course run for several five-minute periods) is represented on a separate sheet with associated data on visibility, clouds, sea state, wind direction, speed, etc. Each five-minute period is represented by a row or line on that sheet and each species by a column. The observers' recordings, from each side of the aircraft, are reported separately. The total number of birds observed is represented on charts of the sightings of murres, total auklets, and kittiwakes.

We reported our main conclusions in 1977. The most conspicuous are: 1) many more birds are seen west of a line from the eastern end of Saint Lawrence Island to Cape Spencer than are seen to the east; 2) birds tend to be aggregated in areas near drift ice when ice is present; 3) feeding birds are clumped and occur on consistent "feeding grounds," usually at great distances from nesting areas; 4) auklets tend to feed in flocks, murres are more dispersed than we expected; 5) kittiwakes feed in the debris brought to the surface by feeding Grey Whales, as do, to a lesser extent, puffins, murres, and Glaucous Gulls.

Each species has a characteristic pattern of distribution which, one presumes, reflects the "foraging tactics" of that species.

2. Species Distributions

Pelagic Cormorants are seldom seen more than 5 nautical miles from a nesting or loafing rock. When occasionally they have been seen further off, they were associated with or perched on ice pans.

Glaucous Gulls are found scattered along the sand beaches. They also occur in flocks or on breeding territories at bird cliffs, tundra lakes, or the mouths of rivers. They are seldom seen over the open sea, and if so, they are associated with the smudges made by Grey Whales or with seals and walrus on ice pans. Glaucous Gulls are closely associated with carcasses of Walrus, floating, where butchered on ice pans, or stranded on the beaches.

Black-legged Kittiwakes are seen close (within 20 miles) of nesting areas and beyond that are very sparce and highly clumped. They occur consistently over debris brought up by Grey Whales. We have seen them in feeding melees east and southeast of King Island, between Cape Spencer and York Mountains, east of Little Diomede Island, and between Sledge Island and the mouth of Golovin Bay. When the pack ice is drifting northward east of King Island, kittiwakes occur in groups in the same areas as murres, that is, along the edges of the ice or clumped here and there where pans of ice are widely scattered. Kittiwakes also occur in large and dense flocks on freshwater near the coast: lakes, and at the mouths of rivers.

Pomarine Jaegers are seen far at sea in small numbers. They are usually seen near drifting ice and especially near pods of marine mammals. They occur with Glaucous Gulls where walrus have been butchered.

Thick-billed Murres and Common Murres occur in a half-moon shaped pattern extending east to south about half way between Sledge Island and King Island. They occur scattered all the way between King Island and Savoonga or Gambel, but in loose aggregations rather than evenly distributed. Murres tend to be less numerous to the southwest of King Island where Grey Whales are most numerous. They are numerous to the northwest of King Island. Murres occasionally occur in moderately dense groups between King Island and Wales, and they gather in certain water masses east of Little Diomede. Murres are scattered out to about 25 miles south of the cliffs at Bluff and gather near the mouth of Golovin Bay, and to a lesser extent between Topkok and Safety Lagoon. They aggregate along the edges of windrows of ice pans in June and occur with the ice further east at that time than they do later in the year.

When the light was good, we tried to separate those murres which appeared to be brown (presumed to be Common Murres) from those which appeared to be black (reportedly Thick-billed Murres). These observations suggest that Thick-billed Murres occur further offshore than do Common Murres, but we need many more observations. We are not convinced that this distinction is dependable because some Thick-billed Murres appear to have brown heads and because in the diffuse light, most murres look lead color intermediate between black and brown.

Pigeon Guillemots have been seen close to the rubble slopes where they nest and have occasionally been reported tens of miles at sea. It is hard to assess the possibility of mididentification of those seen at sea because they have been reported by relatively inexperienced observers. Some plumages of Steller's Eiders resemble a Pigeon Guillemot in flight, and these small eiders are occasionally seen far at sea.

Kittlitz's Murrelet deserves special attention because the species is so rare and widely scattered. Individuals have been seen from about 10 miles south of Sledge Island through an arc to the southwest and west to a point 10-15 miles west of Cape Woolley.

Auklets are readily recognized as such, but distinguishing among the species is often difficult. Usually separating Crested Auklets and Least Auklets is straightforward unless the altitude of the aircraft is varying. Least Auklets are recognized by small size, pale belly, and buzzy flight. Crested Auklets have a somewhat clearer separation of the wingbeats, are larger and have dark bellies. Parakeet Auklets are clearly distinguishable when one gets a good look, which is seldom. Parakeet Auklets have longer wings than the other auklets and show a lot of white flank feathers as they take off. They appear blacker than the other auklets and have a white belly.

Although auklets occur further east during June when ice pans are drifting north, their primary feeding grounds are west of Savoonga and King Island, where restriction by the International Dateline becomes significant. In June, auklets have been seen in moderate numbers half way between King Island and Cape Rodney on the Seward Peninsula in calm water surrounded by ice pans. They were also seen between Savoonga and Sledge Island in June when the ice had recently moved through. They are often seen in June, two-thirds of the way from Sledge to King Island together with feeding murres. The largest numbers of auklets unquestionably occur southwest, west, and northwest of Saint Lawrence Island, except for the extraordinary concentrations in the Bering Strait. In July and August the auklets are found along the west edge of the Alaska DEWIZ (Distant Early Warning Identification Zone). Our experience is that they continue to be numerous when one drifts too far west and crosses the International Line.

Our data suggest little as to segregation of the feeding waters of the three species of auklets. Our impression is that Crested Auklets may forage more to the east and southeast than Least Auklets, whose numbers are conspicuously high near Saint Lawrence Island and in the Bering Strait. According to our results, Parakeet Auklets occur mostly south, and perhaps to the southeast, of King Island. However, Parakeet Auklets are sparce and occur with the other auklets; so the problem of attention arises, i.e., "not looking for" Parakeet Auklets and "looking for" Parakeet Auklets once one has been noticed. Both of these human weaknesses will bias reports of distribution of Parakeet Auklets.

Horned Puffin may be the one species for which one can refer to "feeding radii." Moderate numbers are observed within 10 miles of nesting areas. Then there is usually a ring of sparse distribution, beyond which they are seen again in small numbers out to 35 nautical miles. The small numbers seen at longer distances from nests may erroneously suggest "over dispersal" simply because of the larger area of water at greater distance. They rush to gather at kittiwake feeding mélées, and are seen at smudges raised by Grey Whales. Tufted Puffins' distribution resembles that of Horned Puffins. A gap between those feeding near and far is evident, and Tufted Puffins occur at greater distances from breeding grounds than do Horned Puffins. We have seen unexpectedly large numbers of Tufted Puffins in comparison to their actual numbers among nesting birds. Tufted Puffins occur more than we would have expected southwest of Sledge Island and southeast of King Island toward Saint Lawrence Island.

3. Changes in the distribution of birds at sea through the Summer season

In June, most of the seabirds occur further east than they do later in the season. This may be related to the concentration of drifting ice. When the ice is moving through, auklets occur southeast of King Island, northeast of Savoonga and east of King Island. There were proportionately fewer auklets west of King Island and in the Saint Lawrence Island area where there was little drift ice.

We saw more murres in June than we saw later; many of these were in a crescent pattern from south and southeast to east of King Island. Murres were reported in more areas in June, while later on they gathered in a few seemingly preferred fishing grounds. This may be related to feeding early in the season on crustacea or Arctic Cod associated with the ice, and later, a concentration on fish. It would be desirable to make counts of "black" and "brown" murres at the different times of year.

In July, there are virtually no birds feeding between Sledge Island and the Northeast Capes of Saint Lawrence Island. Some murres and a few auklets feed in the area which lies half to two-thirds of the way between Sledge Island and King Island. Though our data are not enough to do more than suggest a segregation, murres seem to feed in an area to the southeast of King Island and again to the northwest, while Grey Whales occupy the southwest quadrant. Murres also feed in large numbers north and west of Gambel, and in an area from 20 miles south of Fairway Rock to 10 miles north of Little Diomede. In this northern area we have found the clearest evidence of murres feeding in some bodies of water to the exclusion of others. When we pass over a "front" marked by a slick and sometimes spindrift into a water mass of different color, we may pass from many murres to none or vice versa.

In July, auklets are found in large numbers from Gambel to southwest of King Island, then in lesser numbers west and northwest of King Island, and in very large numbers between Fairway Rock and the Diomedes and a short distance to the north. At this season we have seen few auklets between King Island and Savoonga.

In July, the "balls" of Sand Launce arrive; feeding melées of kittiwakes, puffins and a few murres, associated with these dense schools, occur west of Cape Woolley, off Sledge Island and Safety Lagoon, and southeast of the Cliffs at Bluff.

In August, murres persist in the feeding grounds southeast of King Island and occur all along the way from King Island to Gambel and beyond into the Anadyr Strait. Murres also occur north of King Island and in the "front" waters near the Bering Strait. Moderate numbers of auklets occur from north of King Island all the way to the southeast toward Gambel, the numbers becoming heavy within 40 miles of Saint Lawrence Island and near the Diomede Islands. Both murres and auklets are numerous in the Anadyr Strait west of Gambel and to the southwest of the Bunnel Cape on Saint Lawrence Island.

Large, dense flocks of auklets flying southwest are seen from Gambel on Saint Lawrence Island during all summer months. This suggests that birds from the nesting grounds near Gambel or near Savoonga may be commuting to feeding grounds in the Anadyr Strait, or that auklets from Owalit Mountain and Bunnel Capes commute to feeding grounds north of Gambel.

We have noticed that when fog patches lie close to the nesting areas, large numbers of all species are found close, within 5 nautical miles, of the cliffs and many fewer beyond.

The waters of Norton Sound are virtually empty of birds in August beyond 20 miles from the Cliffs at Bluff, although there are small feeding aggregations off the mouth of Golovin Bay.

Shearwaters move into the Chirikov Basin in mid-August and concentrate between King Island and the western part of Saint Lawrence Island. Flocks have also been seen south of Sledge Island and north of King Island.

VII. AND VIII. DISCUSSION AND CONCLUSIONS

A. Seabirds at Bluff: Kittiwakes and Murres

The short growing season in the arctic and the sudden arrival of spring provide strong selection pressure on birds to return to their nesting cliffs promptly. The sooner the ice is broken or gone, the earlier the birds can return. In the spring of 1978, the ice left Norton Sound a month earlier than in the previous three years. We believe that the outstanding breeding success of murres and kittiwakes at Bluff in 1978 was due in part to this early start.

1. Kittiwakes

We have noticed an interaction between kittiwakes and the places where they gather nest material. Snow melt and early summer rains may affect nest building. Either may soak and soften the tundra making the collection of nest building materials that much easier. We watched kittiwakes in frenzied mélées rooting out plants on the softened tundra, creating bare patches where they gathered mud. We found pools of water in several of these places although pools were rare elsewhere on the clifftop. We think these pools may have been the site of a gathering frenzy in a past year. Rain storms in June also provided nest-building material, as storm waves tore seaweeds from the bottom and formed windrows of debris along the high water line. The stickiness of these damp materials -- grasses, mud, seaweeds -- made them useful for construction of well-shaped and solid nests.

The coincidence of availability of good material and high level of motivation resulted in the building of many substantial, durable, (in some cases extravagant), nests which persisted through the season.

We believe that closeness of attendance at their breeding site is a measure of motivation. This includes attendance at active non-nest sites and rock roosts as well as at nests. Neighbors pilfer nest material from unattended nest sites; hence the large proportion of nests which persisted on the cliff throughout the season indicate continual nest attendance and high motivation.

We noted that some of the rock roosts and some sites with small amounts of nesting material were occupied as early in the season in both 1977 and 1978 as some successful nests. Some were occupied every year of our study while several sites of successful nests were unoccupied one or more years. We assume that occupation early in the season all season and every year indicate high motivation. Were these birds foolish or simply unfortunate in becoming attached to an unsuitable site?

Table 19 shows that the difference between the timing of breeding in 1977 and 1978 increased as the season progressed. The average date of breeding was made even later in 1977 because virtually all nests failed, so a broad spectrum of nests was included in establishing the mean date. In 1978, birds were able to lay early and in general the early birds are more successful than the late ones. As the birds which laid later in 1978 failed, the number of days increased between the dates of the successful birds and the average date of all nests laid in 1977.

2. Murres

a) Comings and goings

We counted high numbers of murres at the colony before the breeding season in 1975 and 1978. We believe these counts represent most of the birds associated with the colony, both breeders and non-breeders. We also believe that the numbers of adults at the colony reflects conditions at sea which influence reproductive success. 1975 and 1978 were both years of higher counts and greater success than both 1976 and 1977.

The numbers of murres counted during colony censuses increased through the season. This increase may reflect not only the presence of both of a breeding pair, but also the return of less highly motivated adults who visited and left again before the breeding season began as well as young birds prospecting for the first time (this work; Annual Report for 1977; Tuck, 1960). It might be that as incubation advanced and eggs were lost, more murres stood with their white breasts to the sea and black backs to the cliffs. This effect would be more conspicuous during a disturbance such as a colony census. The greater visibility of the birds may have contributed to the increase in numbers counted late in the season. We think that these non-breeders, being loosely attached to the cliff, comprise the flyers counted during colony censuses. In 1978, the percentage of flyers was consistently low after laying. This suggests that the birds present were highly motivated.

After the peak of laying, counts of murres were high at midday and low at night. This may reflect the arrival of non-breeding birds in the morning and their departure in the evening (Birkhead 1978; pp. 21-22, Annual Report for 1977). After eggs hatched the high counts were made in late afternoon, presumably reflecting the return of adults (probably males, Bruemmer 1979) with food for chicks.

b) Measuring reproductive success

It has been very difficult to measure reproductive success in murres. They crowd together on narrow ledges, and do not build nests. They seem to shuffle about while incubating, so that individuals or pairs are virtually impossible to identify over time. Egg loss is high early in the laying period, and as a consequence, it is difficult to determine which murres have laid, lost or relaid eggs. Thus we have little confidence in our data on laying. In contrast, chicks become more conspicuous with age. Though we may overlook some chicks which are lost within a few days of hatching, we believe the error to be small. Because we use the number of chicks produced in relation to the total number of adults present (corrected to an estimate of breeding pairs) to represent breeding performance, we discontinued the inefficient process of "looking for eggs" and concentrated our efforts on monitoring chicks and studying adult postures.

c) Counts of successful birds

As eggs hatched, we noticed a new posture among "sitters." The posture was more exaggerated and assymmetrical. We concluded that we were witnessing the shift from incubation to brooding. We began to look carefully for chicks and we further refined the definition of "sitters" to include two categories: "incubating" and "brooding." As chicks grew larger, parents had bigger items to cover, hence took on the more exaggerated "brooding" posture. Highly motivated non-parent murres also began to assume the "brooding" postures, while some birds (both parents and non-parents) retained the more subtle "sitting" or "incubating" posture. Our records of "brooding" murres appeared late because we did not record the "brooding" posture until the difference "sank in."

Even after the first chicks jumped, some murres continued to bring fish to the cliff or to assume "sitting" postures. Nettleship (in Bruemmer 1979) reports that the male Thick-billed Murre is usually guarding the chick at night. Hence the male accompanies the chick when it jumps, and they swim off to sea together. The next morning "when the foraging female murre returns, she finds her mate and chick gone. Seemingly bewildered, she sits on the nest site, holding the limp fish, bobbing and bowing to no one in particular. Eventually she eats the fish. She usually remains at the nest site for another two weeks, defending the small, reddish, excrement-smeared patch of ledge against any would-be usurpers, thus probably fortifying her attachment and claim to this vital bit of rock space." The action is probably what Lorenz would call Leerlauf reaktion or vacuum activity. The bird is all programmed for special adaptive activities, but when it returns to find the "purpose" of its actions gone, it has to "go through the motions" anyway.

d) Counts of breeding pairs

We tested a number of ideas in our search for an efficient way to count the number of breeding pairs on the nesting ledges.

We fully realize that the number of "sitters" on the cliff at any one time is not an accurate indication of the number of eggs or chicks present. These postures indicate birds whose motivation to reproduce is raised; i.e., these postures are analagous to nest-building in kittiwakes.

Dyck and Meltofte (1978) estimated the ratio of breeding pairs to total birds in a colony of murres at the Faroe Islands to lie between 0.51 and 0.67. Southern, Carrick and Potter (1965) and Tuck (1960) used the figure 0.6. In 1978, we arrived at a ratio of 0.56 "sitters" to total; we will use 0.6 as the proportion of breeders to the total count at Bluff.

3. Relation of Breeding Success to Consistency of Counts of Adults

Seasonal variation in the number of birds at the cliff apparently reflects the breeding success for the year. In 1978, numbers of both murres and kittiwakes varied little. We found no decrease in mid-season as we had in 1976 and 1977. The number of well-attended and maintained kittiwakes' nests stayed constant; the number of adult murres stayed up and the number of murre flyers stayed down throughout the season. Perhaps this means that birds were not driven to leave the cliff in search for food. This good record of attendance was matched by a good record of reproduction. Attendance and reproduction were both poor in 1976 and 1977. Our data for 1975 are not good enough to be sure, but they suggest that attendance was up and constant while reproduction was moderate.

B. Seabirds at Sea

1. Interpretation: Distribution of Birds at Sea

The distribution patterns of these birds fall into two groups, even and clumped, and these groups probably correspond to the types of food taken. Our first interpretation of the data is that fish-eating species (Pelagic Cormorant, Glaucous Gull, Black-legged Kittiwake, Common Murre, Horned Puffin, Tufted Puffin) are more evenly distributed over the region than are the plankton feeders (Thick-billed Murre, Crested Auklet, Least Auklet). Black-legged Kittiwakes and Thick-billed Murres feed on both fish and plankton.

Parakeet Auklets, which feed on a wide variety of crustacea, occur in Norton Sound in small numbers, as do Thick-billed Murres. The auklets and Thick-billed Murres occur in much larger numbers in the Chirikov Basin; the auklet numbers apparently increase on western Saint Lawrence Island waters and in the Bering Strait.

This segregation by feeding types corresponds to differences in the depth and temperature of the sea water. West of King Island the bottom is deeper, 20-25 fathoms or 40-50 meters, in contrast to about 10 fathoms in Norton Sound.

The preliminary studies of the physical and chemical oceanography that are available indicate that there are three major masses of water: coastal water to the east, Alaska shelf water around Saint Lawrence Island, and Anadyr Strait water to the west. The water in Norton Sound is coastal water contributed by outflow of the Yukon and Kuskokwim Rivers. It is relatively warm, of low salinity, and contains a heavy load of sediments. A moderately well-developed gyre dominates the water of Norton Sound, and dead waters occupy the eastern portion. The water in the western Chirikov Basin is colder, more highly saline, and comes out of the deeper water of the Anadyr Basin. According to Aagaard et al (1975) this is upwelling water coming over the shelf break southwest of Saint Lawrence and Saint Matthew Islands. The auklets and Thick-billed Murres evidently congregate in the western waters.

The three major water masses meet and mix along two lines. One is a line from King Island to Savoonga where we have noticed that bird numbers are relatively high. The higher numbers extend to the West as compared to numbers to the east. The other mixing zone is along a line from the Northeast Capes of Saint Lawrence Island to east of King Island. In the spring murres and auklets occur along this line while the drifting ice is moving north. Later, murres occur in the "mixing" zone in a half moon shaped area from southeast to some distance east of King Island. Although students of currents have not made any comments on this subject, it may be that drifting ice moves north and concentrates along the convergence of the coastal water with the shelf water. The persistence of unbroken drifting sea ice north of Saint Lawrence Island after most of the Chirikov Basin has thawed seems to be related to the relative stability of shelf water there in the lee of the island. Seabirds and sea mammals gather at the edge of that "fast" ice.

As these waters flow northward during the summer months, the nozzle-like geography of the region confines the flow. Both the Siberian and Alaskan coasts converge on the mid-point in the Bering Strait. This convergence and the confinement of the water as it moves through the strait is presumably responsible for the high productivity in the Bering Strait and the phenomenal numbers of Least and Crested Auklets there.

The relation of the observed distribution of seabirds to the findings of fisheries biologists is obscure. In fact, the most complete report available, that by Wolotira et al 1978, shows that the few commercially valuable bottom fish available are concentrated in the warmer, shallower water in Norton Sound, and are relatively less abundant in the deeper, colder western waters. Among the seabirds, the fish-eating species are evenly distributed and the plankton feeders are more abundant to the west. Thus, the available fisheries findings do not correlate with any of ours. We may be able to use data collected by Barton et al, on mid-water and surface fish, when that report is available.

In the available fisheries reports it is clear that while fisheries sampling may find large numbers of some abundant fish, such as Sand Launce, the samples may miss fish such as Prickle-backs, which are of major importance to the major seabird element of Norton Sound. We do not know how to interpret the non-overlap of the two sets of "highly selective" samples.

2. Discussion

a) Surveys and fixed transects

We have given first priority to finding where birds occur and describing the patterns in which they occur. We have used aircraft to cover as much of the area we are allowed to visit as cheaply as possible, but we are uneasy about literal interpretation of our results. Survey lines provide a common sense way of surveying an area which is too large to visit in detail. Unfortunately statistical methods which allow "more sophisticated" analysis contain some weakening assumptions about regularity of distribution of the organisms surveyed. The central assumptions include that distributions will be homogeneous and that clumping will be consistent, or that they will be random, not something in between. We know enough to set up systems of sampling that would be adequate, but we believe that they would be unjustifiably expensive. We believe that we will still need to use the option of "looking for birds" in a non-statistically-useful manner. After we know where the birds are, we can set up some "fixed transects" that are designed to yield comparable sets of information for use in the future. At that stage we should also plan a program of surface watches and sub-surface samples to try to explain the patterns. The problem is to "focus" the grid with respect to space and time to see the patterns of change through the season. One problem we have not addressed is whether or not the daily variation in distribution is greater than the seasonal or monthly changes we see.

b) The relation between breeding sites and feeding grounds

Feeding areas are crucial to the survival of nesting areas; viz. there are no auklets in Norton Sound where there are suitable nesting sites, probably because these sites are too far from feeding areas. The feeding areas do not form patterns of feeding radii around colonies, but seem to depend on the under water topography and oceanography of the area.

Seabird concentrations at sea are lowest in the coastal water, moderate in the shelf water, and largest in the deeper water west of Saint Lawrence Island, King Island, and in the Bering Strait.

The areas where seabirds congregate have been consistent during the short period of our surveys and can be identified on charts as critical areas for the survival of the seabirds and thus extensions of the seabird nesting areas. The areas where the birds congregate are, however, highly responsive to local water conditions; therefore, it is important that survey tracklines be continued in order to confirm the location and consistency of feeding grounds from year to year.

There are not separate feeding areas for each colony; all must feed together somewhat. This raises questions about the biological significance of each colony and colony contributions to each feeding area. Do the locations of colonies merely reflect the distribution of good nesting sites within a certain radius of a feeding site? Can this interaction between nesting and feeding areas be regarded as "nesting radii"?

c) Foraging strategies of seabirds

In this section, we discuss the ways in which seabirds divide up the resources in the northern Bering Sea. There are good reasons for concluding that the seabirds do not use even an important percentage of the food actually present, though many individuals have difficulty finding food. The birds have certain tools, such as perceptions (search image) and muscle coordinations, which they use to find, catch, handle, and eat the species that are vulnerable to the techniques. But there are many food resources which the birds do not recognize or for which their rigid techniques are not adequate.

Our observations are consistent with the classical work done by L. Tinbergen (1943) on the interactions between European Sparrow Hawks and several species of songbird prey. Some species of prey are "suited" to the adaptations held by seabirds and these are preyed upon in preference to others which the seabirds do not notice or whose living space the seabirds do not visit. It is important to realize that natural selection does not respond to a need. Natural selection chooses among alternatives available within each species and among the species. Thus, natural selection is effective in modifying species so that several do not compete with each other for a limited food supply. But selection is poor at stimulating a species to cross a selective "valley" to a higher adaptive peak beyond, such as experimenting with new foods. While biologists are on firm ground when they discuss ways in which seabirds use different prey species, they are on shaky ground when they talk about efficiency of utilization of available energy provided by the lower trophic levels in the local ecosystems.

Storer (1952) and Bedard (1969) discussed the anatomical adaptations of species which specialize on feeding fish or crustacea -- longer, thinner bills with sharp margins for fish catchers, and broad flat bills with rough edges and special pads for catching small crustacea. Such finely tuned modifications are expressed in the subtle differences between Thick-billed and Common Murres (Spring 1971).

A general principle was drawn by Grinnel (1909) and Gausse (1924), that closely related species tend to avoid using the same food resource because one will have techniques which allow it to use the resource better, and individuals of the other species will benefit by developing talents to use other resources -- or, those individuals will be selected which do so. This trend is called "character displacement" (Brown and Wilson 1956).

Ashmole (1971) described categories of ways in which seabirds seek and catch their food: skimming, dipping, plunge diving, diving below the surface. Some species feed on only what is available at or near the surface (kittiwakes, Glaucous Gulls, jaegers). Others dive as far as midwater but feed on surface fish (puffins and shearwaters). Others feed throughout the water column (murres and cormorants). Lack (1966) described coadapted complexes of characteristics of seabirds: those terns and gulls that feed close to their nests and live dispersed along the sea beaches; those puffins and cormorants that nest on islands or cliffs but do not commute more than a few miles; those kittiwakes and murres that nest in large, dense groups on remote islands which commute many tens of miles for their food. The adaptations include how well hidden nests and young are, how fast the young grow and therefore how often they must be fed, and how "conservative" the birds are, i.e., how readily they become colonists at new sites and abandon old ones.

Pearson (1968), and later Cody (1973), described situations in which seabirds seem to apportion the feeding areas of the sea according to how far the species flies from a central place (e.g., colony), before it begins to feed. This may apply in some cases, but as Bedard (1976) pointed out, it is a dangerous generalization. This model using fixed feeding radii suggests that there are fixed ways in which seabirds' foods are distributed. The seabirds in the Northern Bering Sea illustrate the dangers of that sort of "model", because several species commute as far as 100 nautical miles, and several species may clump together at resources tens of miles away from their nests.

Our surveys indicate that some of the feeding grounds change with the season in response to whether drifting ice is present. It is reasonable to think that birds will be freer to commute long distances to preferred feeding areas before they have laid eggs and so are relatively free from their nesting ledge (provided they do not have to protect their ledge against usurpation). The presence of birds at great distances from colonies in June support this suggestion. During incubation one of the pair can travel long distances, but not go so far that its absence stresses the incubating partner. When their young are being fed, the parents have to compensate for two additional difficulties: first, they must return relatively frequently with food for the young one, and second, the food must be large enough to make the commuting trip energetically efficient. Royama (1970) discussed the implications of feeding efficiency in the choice of prey by some songbirds. It may well be that the primary selecting force which makes the young murres "jump" from the nesting ledge at a young age (relative to other seabird fledglings), is the importance of shortening the distance to which the parents have to carry food.

One of the least understood parts of the study of feeding ecology is that related to the availability of food and why some species may fail to breed or may starve while the sea is full of food.

As examples: MacKay (1873) and Brewster (1896) reported there to be about 100,000 pairs of Common Terns breeding in Nantucket Sound, south of

Cape Cod, Massachusetts, in the last decades before devastation by the plumage trade. At the end of the 19th century, they and Herring Gulls were so scarce in southern New England that Edward Sturtevant (who wrote The Birds of Rhode Island with H. Howe, 1899) spent four years on the shore of Aquidneck Island on Narragansett Bay without seeing a Herring Gull. Since the release from predation, terns, Laughing Gulls, Herring Gulls, and Great Black-backed Gulls increased apace. Common Terns reached about 40,000 pairs in the early 1920's, Laughing Gulls reached 40,000 pairs in the late 1940's, and Herring Gulls reached about 36,000 pairs in the mid-1960's. Great Black-backed Gulls are still increasing. Common Terns have now decreased to about 6,000 pairs and still have difficulty finding food for their young, although the population consists of only 15% of its former numbers. Laughing Gulls have decreased to about 2,000 pairs chiefly as a result of being driven from their breeding grounds by Herring Gulls. The point is that the effects of these spectacular changes in numbers of the species at the top of the trophics pyramid have had no detectable effect on the numbers of their food species. Their primary foods, Sand Launce and Silversides, have increased and decreased during the decades, regardless of whether or not Common Terns were present.

I conclude that while the presence and availability of certain food types (equivalent to growth forms of plants) set limits to the presence or general abundance of species in an area, individuals are selected to use what food items of suitable types are present without regard for details. Those species occur which can use several species as prey in the same form-type, and, in fact, species must be able to extemporize with secondary food types if they are to persist in environments which are subject to wide oscillations in species numbers and environmental conditions as are arctic regions. As an illustration, plant species have the "problem" that many seasons in the arctic never "produce" suitable summer conditions for reproduction by flowers. Because they cannot "count on" having seeds germinate in any given year, most plants are perennials and can survive many years without reproducing. Similarly, many insects remain in immature stages for several years, a most unusual life history at lower latitudes. Seabirds are long-lived, and our observations at Bluff show that kittiwakes may go several years without producing enough young to replace "average mortality."

The work of Belopol'skii (1961) and Uspenski (1956) in the Kara Sea and Barent's Sea show marked variation of food species, with form-types, used by Thick-billed Murres, Atlantic Puffins and Black-legged Kittiwakes. Foods used by murres and kittiwakes on the Alaskan Outer Continental Shelf show parallel variations of species "chosen" from a number of species of similar form in different parts of the shelf between Cape Lisburne and Middleton Island. The foods used by Herring Gulls, Glaucous-winged Gulls, and Glaucous Gulls have been studied in great detail in many parts of the Northern Hemisphere; the reports illustrate similar generalizations. The birds are "sampling" the water column for what prey items they can notice and catch.

In the same way, fisheries biologists are sampling for what they can catch. The sampling techniques of the two, the birds and the biologists, are each excellent for certain vulnerable prey, but the sampling techniques may be poor for other species. The seabirds and the fisheries biologists are often not adept at catching the same prey. Therefore, there are sometimes differences of opinion as to the content of the water column.

For the reasons we have tried to illustrate above, we conclude that it will be useful to proceed with general exploration of the physical, chemical and biological characteristics of the water masses where seabirds congregate, and to compare these characteristics with those water masses where seabirds gather or the masses which seabirds tend to avoid. However, we conclude that it is not valuable yet to embark on closely coordinated studies of feeding until more is known about the technical characteristics of feeding behavior of the species. We believe that there are dangers of gathering data which can be "built into" trophics models so as to reinforce preconceived ideas, until we know to what degree the ecosystems operating in the real world are mimicked by systems whether deterministic or stochastic (May 1975).

IX. NEEDS FOR FURTHER STUDY

Although scattered measurements of primary productivity have been made and some sample of benthic animals reported (Hughes in Hood and Kelley, 1973), little is known of the biology of key fish or invertebrate species used as food by seabirds (Ammodytes, Lumpenus, etc.)
The distribution of productivity and feeding areas in the northern Bering Sea is not yet clear, especially those areas west of the International Date Line.

Feeding areas are presumably indispensable parts of the habitat of the larger vertebrates, but until they are mapped we do not know the extent or distribution of critical parts of the system. It is important to continue survey tracklines in order to confirm the location and consistency of feeding grounds from year to year. The level of knowledge now available for seabirds is probably equal to that required for NOAA/OCSEAP purposes. It will be very expensive to increase understanding to the next higher useful level.

We know to the 85% level what the birds eat, how food types and feeding grounds vary with season and geography. We know that the birds' relation to this resource fails in some years and that the resource may be good at times or in places where the food no longer does any good, i.e., the Sand Launce may appear in numbers off Bluff after the kittiwakes have lost most of their eggs. We should ask what is the most useful data we can gather to address these problems.

1. It will be useful to use a small fast boat, such as an Aquasport 22.5 or Boston Whaler 23, to visit feeding grounds in fair weather to watch feeding techniques, time dives, watch how birds shift among areas, shoot birds to collect stomach contents, and sample the water for temperature and salinity to identify water masses. With this support one can collect data comparable to that available for some marine mammals from the work of Kathy Frost and Lloyd Lowry.

2. It will be useful to use a moderate sized fishing vessel, 65-85 ft., to investigate the relations between feeding areas and water masses, lenses, turbulent areas, productivity of algae, spawning grounds of fish and crustacea. A decision on going ahead with this kind of work should wait for and grow out of the study of reports being prepared by Lou Barton of ADF&G and an assessment of the usefulness of fisheries studies in clarifying and explaining seabird distributions and trophic relations. This sort of general natural history information is still badly needed for the northern Bering Sea, and will require a crew that combines disciplines, cooperation, a lot of coordination and extemporization.

The most important question relates to whether NOAA/BLM's OCSEAP will put effort into studies in the Norton Basin-Bering Strait-Chukchi Sea area of a magnitude to match the effort put into the Beaufort Sea, the Saint George Basin-Bristol Bay, Cook Inlet, and the northeast Gulf of Alaska. The next useful steps are expensive in money and human effort.

It seems profitable therefore to examine the levels of rigor and degree of verification which are required to support decisions necessary in order to proceed with sale of leases and with the supervision of development of oil resources. A priori, it seems highly desirable to insist upon a high level of rigor and verification; in some cases where regulations will be legally tested in court this may be necessary. However, for most decisions, we are convinced that a much lower level of peer approval is needed and thus justified in the competition for funds. We think that we should proceed to that level at which additional rigor requires rapidly increasing costs for relatively little increase in reliability, even though that level may not meet the usual expectations of our peers.

We believe that we are now at a stage at which we have satisfactory understanding of major parts of the environment in the area which was assigned to us. We believe that a rapid increase in marginal costs is required to expand that understanding. Thus we are convinced that reassessment of our goals vis a vis the needs of NOAA and BLM are appropriate.

Appendix

Research Unit No. 237

Environmental Studies at the Bering Strait

Warren L. Flock
Department of Electrical Engineering

and

Joel D. Hubbard
Department of Environmental, Population,
and Organismic Biology

March, 1979

University of Colorado
Boulder, Colorado 80309

TABLE OF CONTENTS

1. INTRODUCTION

The environmental studies reported here have a dual nature. On the one hand they are concerned with the use of radar and visual means for obtaining information about the environment. On the other hand they involve the effects of the environment on the operation of radar systems used for surveillance of aircraft. In a broader sense one approach puts emphasis on the environment itself and utilizes whatever tools are available for the purpose. The second approach is concerned with the environment also but puts emphasis on the effects of the environment on systems used for communication and surveillance. Looking at the environment from the two different viewpoints (which might be described as pure and applied) tends to provide a more nearly complete picture and minimizes the possibility of overlooking potentially useful information. Actually, although the motivations for the two approaches are different, much the same information is needed in both cases. Thus it is felt appropriate to look on the program as having a dual nature even though the Outer Continental Shelf Environmental Assessment Program (OCSEAP) is concerned primarily with the environment itself and not with radar systems as such. Also the expressed interest of the Electronic Systems Division (ESD), U.S. Air Force and the Mitre Corporation facilitated making arrangements to use the Tin City Air Force Station and, for this reason among others, it was desired to give attention to Air Force as well as OCSEAP interests. On the way from Boulder to Tin City, Professor Flock stopped at Elmendorf Air Force Base and conferred with Colonel Robert T. Cassell, Commander 531st Aircraft Control and Warning Group, Colonel James Sey (Logistics), Mr. R. Schenker (radar), and other personnel of the Alaskan Air Command (AAC). This discussion helped to pave the way for a productive visit to the Tin City radar site.

This report emphasizes the radar and visual observations of birds made in 1978 with support from OCSEAP, arranged as part of the College of the Atlantic program directed by Dr. William H. Drury. The principal investigator in charge of this particular portion of the research was Professor Warren L. Flock of the Department of Electrical Engineering, University of Colorado, Boulder. Dr. Flock conducted radar observations at Tin City, Alaska, and Dr. Joel D. Hubbard made visual observations of bird migration at Wales, Alaska (about 8.5 km from Tin City). To present a more nearly complete picture of bird migration at the Bering Strait, results from previous years (1969, 1970, and 1975) are also utilized to some extent. The use of radar for studying bird movements has certain advantages and limitations, and the same can be said for visual observations; both radar and visual observations were therefore included in this program. Echoes from sea ice are often the dominant radar echoes in May when the sea ice breaks up, and considerable attention was given to sea ice and sea waves as well as birds. Although not supported by OCSEAP, Dr. JoAnn W. Flock made a collection of lichens and mosses at Wales in June 1978, and her work is mentioned briefly.

A number of studies of the birds of Alaskan coastal waters have been carried out in recent years (Bartonek and Lensink, 1978; Schamel, 1978). Much of the research has been sponsored by OCSEAP and is described in Annual Reports, Final Reports, Interim Synthesis Reports, and Work Statements of OCSEAP. Many of the recent studies deal with the breeding biology of birds; the work reported here emphasizes the migration of birds, in particular the migration of birds through the crucial area of the Bering Strait. This program is one of apparently only two in OCSEAP to use radar as a tool for studying bird movements. A report on the other program, carried out by LGL at Oliktok near Prudhoe Bay, is scheduled to be completed in fall, 1979 (Richardson, W.J., personal communication).

Spectacular migrations by several species take place along the coast of western Alaska. [King Eider and Sandhill Crane in the early spring (Brandt, 1943; Bailey, 1943, 1948; Gabrielson and Lincoln 1959; Flock 1972 and Sec. 2) and Black Brant in the fall (Einarsen, 1965; Hubbard and Flock, 1974).] Almost equally impressive is the nearly continuous passage of flocks of many species (Common Eider, Black Brant, Oldsquaw, Black-legged Kittiwake, murres, etc.) in late spring. This migration was observed in 1978 at the Bering Strait where the marine migratory corridor is relatively restricted by the proximity of land masses and pack ice and the concentration of migrant seabirds and waterfowl is high.

Vast numbers of birds utilize the marine and coastal ecosystems of the Bering Strait and Seward Peninsula, both in migration and during the breeding season. This suggests that, as the level of human activity increases, problems involving bird-human interactions may arise. Disruption of avian activities and destruction of habitat utilized during critical periods of the annual cycle may result from human activities associated with oil exploration and development, transportation, settlement, and recreation. Any effort to minimize disruption of bird populations will require greater knowledge of their seasonal distribution and movements than is now available. Relatively little information is available that deals specifically and quantitatively with the migratory or postbreeding periods when populations of many species are concentrated, making them especially vulnerable to environmental perturbations.

Major goals of the studies reported here were to contribute to the available information about bird migration in the area and to obtain experience that would be useful in devising improved techniques for future investigations. We sought to determine if observations made with ACW radars accurately reflect fluctuations in the passage of migrant birds as determined in the field, and, secondarily, to ascertain whether such fluctuations exhibit a predictable pattern of occurrence.

2. THE ENVIRONMENT

2.1 Bird Movements: Visual Observations

2.1.1 Background

The Bering Strait is a unique location from many points of view (Hopkins, 1967). It connects and forms the channel for shipping between the Bering Sea and the Arctic Ocean. The Asian and North American continents are separated here by as little as 52 statute miles (84 km). Birds migrate in all directions through and across the strait (Bailey, 1948; Flock, 1972), and large numbers of sea birds breed in the area (Drury, 1977a, 1977b, 1978). Cape Prince of Wales and the village of Wales (population about 130) are at the very edge of the Bering Strait, and Tin City (primarily an Air Force radar site) is about 8.5 km from Wales on the other side of Cape Mountain. Figure 1 shows the Cape Prince of Wales area but is a reproduction made from topographic maps that were drawn before the construction of the Tin City radar site by the U. S. Air Force. The powerful Tin City L-band radar transmitter is at the top of Cape Mountain, and the main facility of the 710th ACW Squadron is located where "Mill Sites" are shown in Fig. 1 (between Cape Mountain and Tin City). Figure 2 shows shore fast ice and the steep slope of Cape Mountain along the coastline between Tin City and Cape Prince of Wales, as seen looking to the northwest from a viewpoint west of Paulina Creek near Tin City.

In previous studies at Tin City by Flock (1972, 1975), visual observations were made as well as possible, but the programs were strictly one-man operations which gave considerable attention to radar observations. Furthermore, conditions for visual observations are not as good at Tin City as at Wales in certain respects. In 1978 Flock arrived at Tin City on 17 May and, in recognition of the need to remedy the previous deficiencies, visual observations were made at Wales by Hubbard while Flock was at Tin City from 20 May to 3 June 1978. Both Flock and Hubbard were subsequently at Wales together until 12 June, and Hubbard stayed on alone until 3 July. Records of migration were maintained during the entire period, but Hubbard gave principal attention after the first week in June to a study of breeding Lapland Longspurs and Snow Buntings. Hubbard's technique until 3 June had been to walk out to the edge of the shore fast ice to make observations, but this ice broke up on 3 June and observations had to be made from shore after that date.

The early spring eider migration of 1978 was described by a number of people who were in the area at the time as being extremely impressive and spectacular. Certain observations were reported by Bob Huntsman, an RCA employee who is an active traveler and observer in the immediate area. He reported that the first eiders, approximately 1000, flew past Wales on 19 April. Tin City weather records show that most of April before then had been cold with near or below 0° F temperatures except for 4-6 April when a temperature of 20° F was reached on 5 April and 13-15 April when 33° F was reached on 14 April. The temperature dropped to -3° F on 17 April but reached 30° F on 18 April and was 30-33° F on 19 April. The 13-15 and 18-19 April warm spells occurred when the wind switched from the north to the south. Following the initial movement of eiders on 19 April, the major movement took place on about 21 April. (Other observers confirmed the above dates approximately. Dick Lee reported the major movement as taking place before 24 April.) It was reported that masses or clouds of eiders extended over a length of miles with a major grouping taking about 15 minutes to pass. The temperature had dropped to 24-25° F by 21 April. The wind had reverted to the north by then but was moderate (8-16 knots).

Glaucous Gulls were reported by Bob Huntsman as first being observed on 22 April. Sandhill Cranes were still passing through upon arrival by Flock on 17 May, but the Nome weekly newspaper, The Bering Straights, reported the first cranes near Nome on May 5, and comments by site personnel appeared to indicate that the major movement had taken place at Tin City by 14 or 15 May.

2.1.2 The Spring Migration at Cape Prince of Wales, Alaska, 1978.

Methods

Sea watch observations were made three times per day (usually at 0800, 1300, and 2000 hours) from the edge of shore fast ice, approximately one mile off the village of Wales, unless prevented by extremely high winds, fog, or other conditions. Observation sites were occupied for one-hour intervals during which species, numbers, sex if obviously dimorphic, estimated altitude, flight direction, and flock configuration (line, vee, group; compact, loose, straggling) were recorded for all sightings. Prevailing weather conditions and estimates of ice floe presence also were recorded. Most observation points were about ten feet above sea level. The field of view varied from about 150 to 180°.

Most birds initially were sighted with 8x32 binoculars; confirmation of species, sex, and numbers were made with a 15-40x spotting scope. Only those individuals or flocks apparently in migratory flight, namely those progressing with deliberate speed directly across the field of observation, were counted. The wandering flights of Glaucous Gulls over the shore ice and flights of Pelagic Cormorants and auklets without consistent direction, for example, were assumed to be local movements. Nearly all the birds counted were flying from south to north.

Species

Of those individuals passing Wales in apparent migration, 30 species were identified and counted during the 15 day period that regular sea watches were maintained. Most (24) occurred in fewer than 10 observation periods, while those species most frequently sighted (Black Brant, Pintail, Oldsquaw, murre, Common Eider, and Black-legged Kittiwake) appeared in 13-21 of the 26 counts made during this investigation (Table 1). With one exception (Pintail) these also were the most abundant species; Pintails, though frequently observed, traveled in smaller flocks (usually 2-6 individuals) than the other five species.

TABLE 1. Number of observation periods during which each species was sighted[a].

No. of Observation Periods	Species
1	Arctic Loon, Spectacled Eider, Golden Plover, Ruddy Turnstone
2	Whistling Swan, Emperor Goose, White-fronted Goose, Black Scoter, Pectoral Sandpiper, Parasitic Jaeger, Arctic Tern, Black Guillemot
3	Harlequin Duck, King Eider
4	Parakeet Auklet[b], Sandhill Crane
5	Red-throated Loon, Snow Goose, Red-breasted Merganser
6	Glaucous Gull
7	Pomerine Jaeger
8	Pelagic Cormorant, Steller's Eider
9	Yellow-billed Loon
13	Black Brant
15	Pintail
17	Oldsquaw, murre
20	Common Eider
21	Black-legged Kittiwake

[a] Total of 26 observation periods.

[b] Most auklets close enough to identify were swimming near the edge of shore fast ice and thus not migrating. Least and probably Crested Auklets were also in flocks but could not be counted accurately.

Some species, including loons, Whistling Swan, Steller's Eider, Red-breasted Merganser, jaegers, and Arctic Tern, were not observed until several days to more than a week after sea watches commenced. Yellow-billed and Red-throated Loons were not sighted until 25 and 26 May respectively. Other dates of first observations were 28 May for Whistling Swan, 22 May for Steller's Eider, 22 May for mergansers and then not until 27 May, 31 May for Parasitic Jaeger, 22 May for Pomarine Jaeger, and 31 May for Arctic Tern. Other species, such as Emperor Goose, White-fronted Goose, and Spectacled Eider, were observed so infrequently that little can be said of their arrival times. Pelagic Cormorants were present from the time of our arrival, but not obviously migrating until later in the month. First sighting dates of all species may be found in the annotated list of species, included as an addendum.

Abundance

Murres (those identified positively were Common Murre) were by far the most abundant of the 30 species, followed by Black-legged Kittiwake, Black Brant, Common Eider, and Oldsquaw. Numbers of murres counted during observation periods ranged from 5.2 to 4565.0 individuals/hour with a mean value of 847.2 for the 15-day field period (Table 2), exceeding by a factor of two the combined total of the other four species. Forty seven percent of the values ranged from 355.4 to 1051.0, averaging 705.6 birds/hr. Numbers of Black-legged Kittiwakes averaged 171.1 individuals/hr (range, 24.5 to 829.9); mean values (range) for Black Brant, Common Eider, and Oldsquaw were 98.2 (4.4 to 370.2), 86.4 (2.6 to 366.9) and 83.8 (5.4 to 575.7) birds/hr respectively (Table 2). Fifty seven percent of the kittiwake values ranged from 64.5 to 189.9 averaging 116.2 individuals/hr, and comparable values for the other three species were: Black Brant, 75.0 to 201.4 (54% of values); Common Eider, 22.6 to 94.3 (55%); and Oldsquaw, 24.2 to 92.5 (47%).

In addition to the five most abundant species two others, Snow Goose and Sandhill Crane, were observed in substantial numbers over a short interval early in the investigation (Table 2). The remaining species were observed in comparatively smaller numbers (Table 2). Auklets, though abundant, were not included in the counts principally because it was not clear whether their movements in various directions were migratory or strictly local in the vicinity of large breeding colonies on Fairway Rock and the Diomede Islands. Accurate counts and identification were difficult since their flights characteristically took place some distance from the shore and just above the sea surface. Several estimates made when large numbers of auklets (probably Least although Parakeet and Crested Auklets certainly could have been present as well) were in flight averaged 150 individuals/min. Such flights were not continuous, but flocks of several thousand individuals were not uncommon during periods of heightened auklet activity.

Although sightings of the five abundant species as well as several other species were made on most days if not during most observation periods, their temporal patterns of abundance were not uniform. Most species displayed periods of peak movement separated by intervals when relatively few individuals or flocks were observed (Figs. 3- 9). Flock (Sec. 2.2) describes a broad-fronted movement observed on the Tin City radar 27-30 May. Visual observations made at Wales confirm this as a period of extensive bird movement. Greatest numbers were provided by the five most abundant species (Figs. 3-7) but several other species, including Pelagic Cormorant, Pintail & Steller's Eider (Fig. 9), Pomerine Jaeger, and Glaucous Gull appeared in numbers well above those of the preceding days (Table 2). Also during this period Yellow-billed and Red-Throated Loons (Fig. 8) and Red-breasted Merganser made their first consistent appearances. Large numbers of Parakeet and/or Least Auklets (probably Crested as well) were observed on 27 and 28 May, and especially on 29 and 30 May while both investigators were at Tin City (information based on informal counts by another researcher at Wales).

While not involving as many species, other peak periods are also evident from both radar and visual observations (Table 2). Coinciding with our arrival, large numbers of murres and Common Eider, as well as substantial numbers of Black-legged Kittiwake and Black Brant, were observed passing Wales on 20 and 21 May (Figs. 3-6). Supplementing their numbers were flocks of Snow Goose and Sandhill Crane (Table 2). Flocks of brant continued to pass until early on 24 May while on 22-23 May kittiwakes achieved their greatest abundance since observations commenced. Black-legged Kittiwake did not exhibit a peak as pronounced as the other abundant species during either of the first two peak periods, but fluctuated within a relatively small range until the end of May when it culminated in a large peak over the period 31 May to 3 June (Fig. 4, Table 2). A third peak in murre abundance coincided with the latter stage of the kittiwake peak on 2-3 June, and these two species were accompanied by the largest numbers of Yellow-billed and Red-throated Loons (Fig. 8), Pelagic Cormorant, Red-breasted Merganser, and Glaucous Gull (Table 2) sighted during this study, as well as by many flocks of Black Brant. Smaller numbers of Pintail, Common and Steller's Eider, Oldsquaw,and Pomerine Jaeger continued to pass at this time (Table 2).

Flock Size and Frequency

Flock size and frequency determine the absolute numbers of birds passing a given point per unit time, and thereby provide the basis for describing migratory patterns. Peaks in counts of a particular species may result from increased flock frequency or flock size or both. For example, murre flock size (Table 3) ranged from 20.0 to 500.0 ($\overline{X} = 110.4$) individuals/flock on 20-21 May, the largest recorded for this species during the entire study, and combined with the largest flock frequencies recorded for any species during this period (3.4 to 35.0 flocks/hr, $\overline{X} = 20.5$; Table 3) resulted in the extremely large numbers of this species observed (Table 2, Fig. 3). During the subsequent peak period on 27-30 May, although flock frequency increased somewhat (range 11.1-32.0, $\overline{X} = 22.3$ flocks/hr), individuals/flock were lower ($\overline{X} = 28.0$) resulting in a much lower peak. The third peak, on 2-3 June, was somewhat lower, a result of decreased flock size ($\overline{X} = 20.2$ individuals/flock) offsetting a slight increase in flock frequency ($\overline{X} = 26.2$ flocks/hr).

Considering this type of information, the primary source of the single large third period peak for the Black-legged Kittiwake is seen to be a large increase in mean flock frequency, from 4.4 to 25.7 flocks/hr, which more than compensated for the decline in flock size from 22.7

TABLE 2. Summary of seawatch counts (individuals/hr) during three peak periods of migration and overall means for species observed at Wales, Alaska.

	Peak Period[a]			
	1	2	3	Grand
Species	Mean (Range)	Mean (Range)	Mean (Range)	Mean (Range)
Murre	2356.4 (134.5-4565.0)	638.8 (355.4-1051.0)	552.4 (32.5-916.4)	847.2 (5.2-4565.0)
Black-legged Kittiwake	104.3 (24.5-189.9)	80.2 (45.4-159.5)[b]	434.3 (152.0-829.9)[b]	171.1 (24.5-829.9)
Black Brant[c]	104.1 (31.0-201.4)	128.8 (4.4-370.2)	64.7 (17.4-112.0)	98.2 (4.4-370.2)
Common Eider	182.0 (14.4-366.9)	133.2 (34.4-362.6)	no peak	86.4 (2.6-366.9)
Oldsquaw	no peak	286.9 (92.5-575.7)	no peak	83.8 (5.4-575.7)
Yellow-billed Loon	------[d]	1.6 (0.9-2.2)	4.0 (2.1-6.9)	2.7 (0.9-6.9)
Red-throated Loon	------	0.9 (0.8-1.0)	2.8 (1.0-4.5)	1.6 (0.8-4.5)
Pelagic Cormorant	------	4.4 (1.6-17.5)	27.2 (27.2)	7.3 (1.6-27.2)
Snow Goose	53.8 (7.9-77.6)	no peak	------	37.0 (5.1-77.6)
Pintail[e]	10.3 (3.7-16.9)	7.8 (3.6-11.7)	7.5 (0.9-13.4)	7.4 (0.9-16.9)
Steller's Eider[e]	7.1 (4.1-10.1)	12.0 (8.1-16.0)	8.1 (7.9-8.3)	8.9 (3.6-16.0)
Red-breasted Merganser	no peak	2.9 (1.5-4.3)	11.7 (1.8-21.6)	6.5 (1.5-21.6)
Sandhill Crane	135.5 (120.0-151.0)	no peak	no peak	68.8 (1.8-151.0)
Pomerine Jaeger	no peak	21.6 (21.6)	7.1 (2.7-11.6)	8.2 (2.7-21.6)
Glaucous Gull	no peak	4.2 (3.4-5.6)	10.9 (2.1-19.7)	6.9 (2.1-19.7)

a. Peak periods: 1 = 20-22 May (probably included 18-19 May as well);
2 = 27-30 May (31 May for Murre); 3 = 31 May-3 June (possibly longer).

b. Essentially a single peak encompassing periods 2 and 3.

c. Peaks for Black Brant occurred outside peak periods defined by abundance of other species (See Fig. 5).

d. Lines indicate species not present or individuals observed were not migrating.

e. First peak for Pintail and Steller's Eider occurred on 24 May.

TABLE 3. Summary of flock frequency (flocks/hr) and flock size (individuals/flock) during three peak periods of migration at Wales, Alaska.[a]

	Peak Period[b]		
	1	2	3
Species	Mean (Range)	Mean (Range)	Mean (Range)
Murre	20.5 (3.4-35.0) 110.4 (20-500)	22.3 (11.1-32.0) 28.0 (2-150)	26.6 (4.3-44.2) 20.2 (1-60)
Black-legged Kittiwake	4.4 (1.2-7.4) 22.7 (5-75)	6.0 (4.3-9.0)[c] 12.8 (4-40)[c]	25.7 (17.6-40.2)[c] 16.9 (2-100)[c]
Black Brant[d]	2.2 (0.8-4.3) 45.3 (8-100)	2.3 (0.7-5.1) 54.8 (2-175)	3.0 (1.0-5.1) 21.3 (2-50)
Common Eider	4.2 (1.2-7.0) 41.8 (6-100)	5.3 (2.4-10.7) 24.6 (2-100)	no peak
Oldsquaw	no peak	8.5 (2.6-13.9) 34.0 (5-200)	no peak
Yellow-billed Loon	------[e]	1.6 (0.9-2-2) 1.1 (1-2)	3.0 (2.1-3.6) 1.3 (1-4)
Red-throated Loon	------	0.9 (0.8-1.0) 1.0 (1.0)	2.8 (1.0-4.5) 1.0 (1.0)
Pelagic Cormorant	------	1.8 (0.8-3.9) 2.4 (1-12)	16.3 (16.3) 1.7 (1-2)
Snow Goose	1.6 (1.0-2.4) 38.4 (3-75)	no peak	------
Pintail[f]	2.4 (1.2-3.6) 4.7 (1-8)	1.1 (0.8-1.5) 7.5 (4-11)	2.1 (0.9-2.7) 3.8 (1-7)
Steller's Eider[f]	0.9 (0.9-1.0) 8.0 (4-12)	1.4 (0.8-2.6) 8.6 (3-20)	1.0 (1.0) 8.0 (8.0)
Red-breasted Merganser	no peak	0.8 (0.7-0.9) 3.5 (2-5)	2.4 (0.9-3.9) 4.8 (2-7)
Sandhill Crane	2.0 (1.2-2.8) 63.8 (34-100)	no peak	no peak
Pomerine Jaeger	no peak	3.2 (3.2) 6.8 (4-13)	1.6 (1.0-2.7) 5.4 (1-10)
Glaucous Gull	no peak	0.9 (0.8-0.9) 5.0 (4-7)	4.8 (1.0-8.5) 2.3 (1-4)

a. Upper figures for each species refer to flock frequency; lower figures refer to flock size.

b. Peak periods: 1 = 20-22 May (probably included 18-19 May as well);
2 = 27-30 May; 3 = 31 May-3 June.

c. Essentially a single peak encompassing periods 2 and 3.

d. Peaks for Black Brant occurred outside peak periods defined by abundance of other species (see Fig. 5).

e. Lines indicate species not present during this period or individuals observed were not migrating.

f. First peak for Pintail and Steller's Eider occurred on 24 May.

birds/flock in peak period 1 to 16.9 in period 3 (Table 3). Substantial numbers of kittiwakes continued to move along the coast until at least the end of June.

Average Black Brant flock frequency and size remained similar during the first two peak periods resulting in peaks of similar magnitude (Fig. 5, Table 3), while early in the third period somewhat greater numbers of much smaller flocks were observed, but none were observed on 2-3 June, as a result of which no sharply defined peak was evident (Fig. 5). Larger flocks of brant continued to pass sporadically well offshore until at least 26 June.

Like the brant, Common Eider exhibited peaks during just the first two periods (Fig. 6), but without any evidence of a third peak at all. In spite of an increase in flock frequency of from 4.2 to 5.3 flocks/hr the mean number of eiders passing Wales declined from period 1 to period 2, mainly as a result of a substantial decrease (41.8 to 24.6) in mean flock size (Table 3). On Figure 6, peak 2 is larger than peak 1, seemingly in contradiction to the values given above; however, the magnitude of peak 2 is due primarily to a single very high count on 28 May. No unusual flights of Common Eider were noted after the cessation of regular seawatches.

Like the kittiwake, the Oldsquaw exhibited just one peak (Fig. 7), but in period 2 rather than in period 3 (Table 3); this peak was preceded by a slight increase in numbers passing but neither before nor after was there indication of another major peak.

Yellow-billed and Red-throated Loons arrived in numbers after 30 May (Fig. 8), although the latter never were common. Yellow-billed Loons typically were observed singly or in pairs with one group of four sighted; Red-throated Loons invariably occurred singly. Yellow-billed Loons were increasing in abundance as the period of regular observation was terminated when the shore fast ice broke up (Fig. 8).

Likewise, Pelagic Cormorant and Glaucous Gull flock frequency was increasing sharply at the close of observations (Table 3). Both species had been present before our arrival, but lacked consistent directionality in their flights earlier in the study. Flock also noted that numbers of cormorants were increasing at this time near Tin City where a small colony exists west of the radar site.

Direction of Movement

Throughout the study flocks of all species moved predominantly in a northerly direction. Of 862 flocks counted (excludes auklet flocks) 810 (94.0%) were traveling north and 52 (6.0%) were moving south (Table 4). Most of the latter (12.4% of flocks observed) were sighted after 27 May, while only 1.4% of flocks observed on or before this date were headed south.

Flocks of most species appeared to continue along the coast while still in view; however, several flocks of Sandhill Cranes eventually disappeared in the west, and some Red-throated Loons, Pintails, and jaegers turned inland at this point.

TABLE 4. Percent of flocks (all species) moving north or south on or before 27 May, and following this date.

Direction	Before	After	Entire Period
North	98.6	87.6	94.0
South	1.4	12.4	6.0

If the apparently local movements of auklets are excluded, 44.2% (23 of 52) of the southward flocks were murres. Next most abundant were Pelagic Cormorant (6), Pintail (4), Oldsquaw (7), and Black-legged Kittiwake (7), followed by Harlequin Duck (1), King Eider (1), Steller's Eider (1), and Pomerine Jaeger (2).

Total Numbers

Over the entire study period 24593 individuals of 30 species were counted, or approximately 1000 birds/hr during periods of observation. Considered on a daily basis, total numbers reflect the three periods of peak migratory movement (Fig. 10) that many of the individual species exhibit (Figs. 3-9). In particular, because of the large numbers of individuals involved, the overall pattern of abundance is most strongly influenced by the abundance of murres. Since data are not available for the entire period 2 peak it is conjuctural, yet probable on the basis of informal counts by other observers at Wales, that this peak should exhibit greater magnitude than is shown on Fig. 10.

2.1.3 Observations at Tin City

Visual observations as well as radar observations have been conducted during all previous visits to Tin City. The importance of Wales as an observation post has been recognized and Flock has walked to Wales (about 8.5 km crosscountry from Tin City) and back at least once during each visit to Tin City, but visual observations have been largely restricted to the area of Tin City itself in the past.

The main site at Tin City provides a view of the water to the south but is too far from the edge of the shore fast ice, and even the shoreline itself, to be suitable for monitoring migration. Some of the large, rather high-flying birds that are not restricted to overwater migration, such as the Sandhill Crane and Snow Goose, can be seen readily from the site itself and major overwater movements can also be seen but distances tend to be too great for efficient identification in general. Some birds such as kittiwakes are conspicuous and have a distinctive flight and can be readily recognized over water at a distance.

Walking to the west to beyond Paulina Creek (Fig. 1) takes one to a beautiful viewpoint which is protected from the persistent north wind (Fig. 2). This site is a considerable improvement over the main site itself for visual observations, but the height above the water (about 300 feet) and the distance to the edge of the shore fast ice are not ideal. A lagoon along the shore to the east of the main site is visited by many birds after it thaws, but thawing usually does not occur until 3-5 June. The slope and lower flat area below the main site is a good location for early passerines and sandpipers and is visited by interesting species such as the Bluethroat, Red-throated Pipit, White Wagtail, Varied Thrush, Robin, etc. Certain species appear to be more regular and/or abundant at Tin City than at Wales. The Semipalmated Plover, Rock Sandpiper, and Baird Sandpiper fall into this category.

Only limited visual observations were carried out at Tin City in 1978. On 21 May 1978 between 1200 and 1300 ADT 1266 birds were estimated to have passed the Paulina Creek viewpoint. Of these 586 were eiders (mostly Common Eiders), 440 were murres, 54 were cranes, and 30 were Black Brant. By 31 May Black-legged Kittiwakes were the most obvious migrant but during a particular observation period from 0730 to 0830 ADT they were flying by in small groups and only 184 passed by. A small colony of Pelagic Cormorants (124 birds observed on 31 May) utilizes the area and at least 4 Harlequin Ducks were there regularly. Site personnel report that a few puffins breed there but arrive rather late. On 3 June many auklets were observed to be flying to the southeast, opposite to the normal spring-migration direction. They were too far away to identify except that they appeared to be of three sizes.

It presumably would be possible to walk to the edge of the shore fast ice at Tin City to observe migration, but it is farther to the edge at Tin City than at Wales. Also at Wales the villagers go out on the ice, and one can learn from them what is safe and what is not and one can stop going out when the villagers stop. Many of the same birds fly past both Tin City and Wales, but some migrating birds fly past Tin City and not Wales and vice versa. It would thus be advantageous to have persons concentrating on visual observations at both Tin City and Wales.

2.2 Bird Movements: Radar Observations

2.2.1 Background

Observations made in 1969 and 1970 (Flock, 1972) demonstrated the utility of the Tin City radar for monitoring bird migration in the Bering Strait area, including the migration of the Sandhill Crane (Fig. 11) across the strait to Siberia and that of the Snow Goose (Fig. 12) to Wrangel Island, located north of Siberia. Arranged near the start of OCSEAP, a 1975 visit had the principal purposes of monitoring the Snow Goose migration in cooperation with Dr. Vladimir Jacobi of the U.S.S.R. and investigating the utility of the Tin City radar for sea-ice studies (Flock, 1977). The 1978 effort was arranged to supplement the program of Dr. William H. Drury who has been engaged in studies of breeding colonies of seabirds in the general area (Drury, 1977a, 1977b, 1978). One goal was to conduct both radar and visual observations, which had not been possible in a satisfactory manner earlier because only one person was involved in the studies. It was desired also to investigate procedures for obtaining quantitative data on bird echoes, including radar cross sections, and to actually obtain such data if possible. One approach to this problem is to record data on video tape for later analysis, and it was hoped to use the video recorder which is permanently located at the site. It was learned, however, that this recorder is designed to show only the presence of signals and is highly nonlinear and unsuitable for recording signal amplitude. Another possibility considered was to observe the radar signals on an A scope and to record signal amplitude by visual inspection. In either case it would be necessary to calibrate signal amplitude. The procedure planned for this purpose was to feed signals of known amplitude into the system through a directional coupler.

The data taken in 1975 showed the capability of the Tin City radar for recording echoes from sea ice and the fact that echoes from sea ice and birds are often closely associated. In 1978 it was desired if possible to obtain quantitative data on sea-ice echoes as well as bird echoes. Sea-ice studies, however, had a lower priority than study of bird migration.

The 1978 radar record of bird movements at Tin City is described in the following Sec. 2.2.2. A brief running narrative account of project activities is included along with the listing of radar observations in order to make the latter more comprehensible. Some gaps in the radar record are due to the radar system being unavailable because of maintenance or training operations by Air Force personnel.

2.2.2 The Radar Record

The radar record for 1978 at Tin City consists of photographs of PPI (plan-positions-indicator) displays taken by use of a Model 180 Polaroid camera and Type 107 Polaroid film. This particular model is no longer manufactured but other cameras using Polaroid film are available. The use of Polaroid film has the important advantage that results can be seen immediately. Corrections can then be made to exposure, scope settings, etc., if necessary. The technique utilized is to take time exposure photographs, usually of 5-minute duration. Visual inspection or one-rotation photographs of PPI screens may sometimes be sufficient to provide recognition of bird echoes, but usually time-exposure photographs are necessary. Birds proceeding with a consistent direction show as streaks on time-exposure photographs. Recognition is more difficult when flight directions do not remain essentially constant. Eighteen packs of Polaroid film, each providing eight prints, were utilized at Tin City in 1978.

Upon arrival at Tin City on 17 May, north winds were strong and little evidence of bird migration could be seen visually or on the radar PPI displays. A walk to the viewpoint west of Paulina Creek from the main site on 18 May provided no sign of migration. Sea-ice echoes, however, were intense and interesting and considerable attention was given to them during the first days at Tin City (Sec. 2.3 and Figs. 13-15). By the evening of 20 May evidence of bird echoes appeared on PPI photographs. On the morning of 21 May, sea-ice echoes were widespread and intense and interfered with attempts to detect bird echoes but it was concluded that echoes near the edge of the shore fast ice were due to migrating birds. On this date a watch from the Paulina Creek viewpoint between 1200 and 1300 ADT disclosed a movement of about 1270 birds in an hour. When the Tin City PPI was again available at 2000 on that date, sea-ice clutter was somewhat diminished and clear bird echoes were evident, as shown in Fig. 16. The bright area on the left-hand side of the photograph is due to a peculiarity of the particular PPI that was available, namely the fact that the electron beam produced considerable light when it had passed beyond the face of the PPI.

Movement continued on the morning of 22 May. On that date Flock took the aerial tramway to the transmitter site on the top of Cape Mountain (Top Camp) to investigate signal calibration procedures. On the next morning of 23 May, three flocks of Snow Geese were seen flying over the water some 2000 feet below. Later the north wind began a gradual buildup to near 60 knots by evening. Mr. Jones, in charge of the Top Camp, reported that during the night the wind held steady at 95 knots, with gusts to 110 knots, before the wind gauge failed due to being encrusted with rime ice. The strong north wind, which continued but with lower speeds on 24 May, blew the loose ice floes away from the area and echoes from sea waves rather than sea ice dominated the radar record (Figs. 17 and 18). Birds were not obvious visually or on the radar screen during the period of high wind.

Upon return to the main camp on 25 May, after staying at Top Camp for one day longer than planned because the wind was too high for the tramway to operate, bird movement was noted in varying degree on 26-30 May. Attention was given during this period to the effect of polarization on the radar signals and clutter. Horizontal polarization is normally used at the site, but circular polarization is sometimes used when clutter is severe. It is well known that circular polarization decreases echoes, or clutter, from precipitation and it appears to be rather effective against sea-ice clutter also. Comparison of Fig. 20 (right-circular polarization) and Fig. 21 (horizontal polarization) shows a strong contrast, but Fig. 24 shows a rather considerable clutter even with circular polarization. By 27 May, broad-frontal movement of birds from the southwest was evident on the radar record. Figures 22-24 show this movement, with movement near the radar also and considerable bird activity along the south shore of the Seward Peninsula in Fig. 23 as well. On 28 May Flock walked to Wales and back to confer with Hubbard. It was planned to leave Tin City for Wales by air on 2 June, but poor visibility prevented air travel until 3 June.

2.3 Sea Ice, Sea Waves

The 1975 visit established the capability of the Tin City ACW (Aircraft Control and Warning) radar for monitoring sea ice in the area (Flock, 1977). The L-band ACW radar, however, uses long pulse lengths and provides poor spatial resolution. Kovacs and Weeks (1977) have installed an X-band marine radar in the same radome as the L-band radar on the top of Cape Mountain and have used the radar to obtain information on ice movement through the Bering Strait. The X-band radar has considerably better resolution and shows more detail than the L-band radar. In the spring of 1978, however, the X-band radar was not functioning, and the photographs taken of the L-band display constitute the only radar record of sea-ice echoes for that period (Figs. 13-15, 19). These photographs are of MTI (moving-target-identification) video signals. The short-time-constant video utilized in 1975, in addition to the MTI video, was not available in 1977.

Figure 13 is of an 80-nmi display in which MTI signals appear out to about 65 nmi with normal-video signals beyond. It is included primarily because it appears to show sea-ice returns in the normal-video range beyond 65 nmi to the south. The returns apparently come from ice which has little velocity and therefore does not appear within 65 nmi or within the range for which MTI techniques are employed. The other large signals beyond 65 nmi are from mountains, on the Seward Peninsula to the east and on Siberia to the west. The display of Fig. 14 shows the area out to 50 nmi more satisfactorily than in Fig. 13. The bright areas are believed to be polnyas or areas of water in which there is a considerable amount of loose pack ice that bobs about under the influence of wind and waves. The boundaries of the bright areas are believed to represent boundaries between water (containing pack ice) and areas of more or less continuous, relatively immobile ice (shore fast ice to the east adjacent to the Seward Peninsula). MTI circuitry tends to eliminate echoes from stationary objects or objects having very low radial velocity, but some of the loose pack ice moves about with sufficient velocity to appear on MTI displays. Figure 15, taken the day following Fig. 14, shows a different pattern, with water extending farther to the north.

Figures 17 and 18 are of photographs taken from the Top Camp on 23 and 25 May and show echoes from open water with little in the way of ice floes, the strong north wind having driven the floes to the south. It can be recognized that the appearance of the echoes is different, and examination of the signals on an A scope showed the signal amplitudes to be close to 60 dB lower than the echoes from the bright areas of Figs. 14 and 15. (The appearance of brightness or lack of brightness on a PPI display does not give a good indication of signal intensity as the appearance is a function of video gain and scope intensity settings.)

After the strong north wind of 23-25 May, the wind switched to the south and blew some of the pack ice back toward the Seward Peninsula. Fig. 19, taken on 26 May, shows a different pattern of water and ice than previously and appears to indicate the presence of pack ice in the area of the Bering Strait.

2.4 Vegetation

From 3 June to 16 June, Dr. JoAnn W. Flock studied the vegatation of the area near Wales and made a collection of the cryptogams (lichens, liverworts, and mosses) which grow luxuriantly there. Dunlins, Semipalmated Sandpipers, Western Sandpipers, and Lapland Longspurs are among the birds that breed in some of the areas where collecting was conducted, and these birds make use of the vegetation, including the lichens and mosses, for their nests. Identification of the cryptogams is proceeding; it is estimated that about 100 species of lichens and 100 species of bryophytes (mosses and liverworts) occur in the area. Dr. J. W. Flock plans to spend the month of July 1979 at Wales to collect vascular plants and to study the cryptogams further. It seems surprising that essentially no botanical investigation at all has been conducted previously in such a unique and fascinating area.

3. RADAR CLUTTER

3.1 Birds

What is the desired signal to one party may be merely clutter to another and vice versa. Radar can provide useful information about birds, sea ice, and sea waves, but echoes from these objects may be clutter for a radar system designed to detect aircraft. This investigator is a proponent of multiple use, rather than single use, of radar systems, but in this section echoes from birds and sea ice are looked on as sources of clutter. Furthermore, if one is interested only in birds, echoes from sea ice may be regarded as clutter, whereas a person studying sea ice may look on bird echoes as clutter.

The human eye can do a rather good job of picking signals of interest out of clutter, but the clutter problem becomes more severe when automatic data processing is employed, as will be the case for the modern radar systems which will be deployed in the future. To deal with the clutter problem it then becomes essential to have more nearly complete data concerning clutter than in the past. Two types of data are needed, the phenomenological and the quantitative. The phenomenological data on birds involve the topics of what birds are found where and at what times and what is the qualitative appearance and effect of bird echoes on radar displays. The quantitative data needed are statistical in nature and involve radar cross sections, the spectra of amplitude fluctuations and Doppler frequencies, and spatial densities of targets. Techniques for obtaining the needed quantitative data are discussed in Sec. 4. This material is presented in a separate section because it is pertinent to the use of radar to obtain information on bird migration as well as to the subject of clutter.

3.2 Sea Ice, Sea Waves

Radar is useful for obtaining data on sea ice, but sea ice has an effect on radar system performance and may be viewed by the radar system designer (or the radar ornithologist) as merely a troublesome form of clutter. As mentioned in Sec. 2.2.2, the use of circularly-polarized transmissions may help diminish sea-ice clutter as it does for the case of echoes from precipitation. This fact is known to ACW radar operators, and, whereas horizontal polarization is normally used, a switch may be made to circular polarization when sea-ice clutter becomes severe. Little information is available about sea-ice clutter, however, and quantitative, statistical data are needed concerning the amplitude and Doppler frequency of sea-ice echoes for circular and linear polarizations.

4. TECHNIQUES FOR OBTAINING QUANTITATIVE DATA

The needed quantitative data on radar echoes or clutter involve amplitude and Doppler frequency magnitudes and spectra and spatial densities. In order to obtain data on target fluctuation characteristics alone and to avoid modification by antenna rotation, it is desirable to utilize a fixed antenna beam rather than a rotating antenna. The operational surveillance radars in the Arctic, however, rotate continuously and special arrangements must be made if it is desired to make measurements with a fixed antenna beam. If the purpose of the measurements is to better interpret and utilize data from the present radars, rotation may not be much of a handicap, but, if the purpose is to obtain data to be used in the design of new systems, rotation is a more serious limitation. For obtaining spatial densities as a function of azimuth, however, rotation is desirable. In any case no arrangements were made for fixed-antenna operation at Tin City in 1978.

It had been hoped to use the tape recorder permanently located at the site to record signal amplitudes for processing at a later time, but it developed that the recorder was highly nonlinear and unsuitable for the purpose. Apparently all magnetic tape recorders are more limited in dynamic range than radar systems, and this characteristic will always be a problem. Another approach considered was to use an A scope and record signal levels by visual inspection or photographs of the A scope. In either case it is necessary to calibrate the signal levels. Recording signal levels by visual inspection or by photographic means is highly inefficient at best, but attempting to do so on a limited basis should be helpful in determining what features an automatic recording system should have.

A-scope photographs were obtained by use of a Tektronix 453 oscilloscope, and an example is shown in Fig. 25. The obvious, amplitude-limited signals on the right are from stationary targets beyond the range for which MTI circuitry is applied. The closer echoes are sea-ice-clutter echoes. It is of interest that the clutter amplitudes recorded in this way are sometimes as high as the limiting level, but caution is needed in interpretation because, among other reasons, the signals appear to limit at different levels depending on their duration. Photographs like that of Fig. 5 are of some interest, but it proved to be impractical to record bird echoes in this way because at the time the bird echoes tended to be lost in sea-ice clutter. Also, it is extremely difficult to accuate the scope sweep at the proper instant to capture a particular echo. Under some circumstances, when little clutter except that due to birds is present as at the Pt. Barrow DEW site, for example, this technique might work but it was not successful at Tin City.

A procedure for calibrating signal amplitudes was investigated while at Top Camp on 23 and 24 May. The procedure is a standard one, except that it is commonly used only to determine the minimum detectable signal (MDS). A signal of known amplitude was fed into the system through a directional coupler using a TS 419/U Test Set as the signal source. The results of the calibration were as shown in Table 5.

The test signal level is given in dB below one milliwatt (dBm). The MDS was estimated as 113.8 dBm.

Scope Deflection -cm	Test Signal -dBm
3.6	41.8
3.0	96.8
2.0	106.8
1.0	111.8
0	113.8

TABLE 5. Calibration of A-Scope Display

The experience with recording and calibrating signals on an A scope was informative. For obtaining and processing any very large amount of data, however, operation with a fixed antenna position is desirable as stated earlier. Furthermore the radar should supply Doppler frequency as well as amplitude information and the receiver should be linear and not have MTI or STC (sensitivity-time-control). The signals to be recorded can be selected by using one or more range gates and boxcar integrator circuits. Considerable advantage would accrue from using a research radar designed for the purpose rather than one of the present operational radars. Obtaining and operating such a radar may pose some practical problems, but the radar would not need to have high power, extremely high antenna gain, or the capability for continuous rotation. Thus it could be relatively simple and low in cost.

5. DISCUSSION

5.1 Bird Migration

General

Two of the most spectacular migrations past Cape Prince of Wales are the spring migrations of King Eider and Sandhill Cranes. The migration of the King Eiders was extremely early in 1978. Neither Flock nor Hubbard were able to arrive as early as desired in 1978 because of University commitments, but even if arrangements had been made to come to Wales as early as thought necessary it probably would not have been planned to arrive before the last week of April. It appears now, however, that observers should be in the area by mid April. Most University personnel would need support for the entire spring semester if they were to be free from classes in order to be able to travel to the Bering Strait in April. In 1970 Flock did arrive on 10 May in time to record the migration of Sandhill Cranes (Fig. 11). The early eider and crane migrations are not only impressive but come generally at a time when the sea ice has not yet broken up extensively into floes which cause serious sea-ice clutter for the Tin City radar. An impressive migration of mixed species also occurs in the last two weeks of May and early June as described in Sec. 2.1.2. Birds migrating in numbers at this time include the Black Brant, Oldsquaw, Common Eider, Black-legged Kittiwake, murres, and auklets.

Yet another migration of major interest past Cape Prince of Wales in late May-early June is that of the Snow Goose which breeds on Wrangel Island north of the Siberian mainland (Fig. 12). Migrating Snow Geese have been seen during all visits to Tin City. In 1970 and 1975 significant movements recorded by radar were assumed to be those of Snow Geese. In 1978 more individual flocks of geese were seen visually than previously but they were scattered and no single pronounced movement was observed either by visual means or on the radar.

Further data during the last two weeks of May are highly desirable, especially if improvements can be made in observational techniques, and data are needed from earlier and later periods as well. As noted the most spectacular King Eider migration occurs before mid May. Also, interesting broad-frontal, high-altitude migrations take place during the first two weeks of June. Finally the return migration of various species begins in July and continues into August and September and later. Brief samples of radar data for June and July were obtained in 1969 (Flock, 1972). While very incomplete, these data provide a basis for the statement that wide-spread migrations of interest occur during these periods. Also Slender-billed Shearwaters are reported to migrate through the Bering Strait in the late summer (Lockley, 1974, where this species is referred to as the Short-tailed Shearwater or mutton bird; Divoky, 1977).

Arrival Dates

Determination of actual arrival dates, as well as numbers of individuals present, is difficult in any area unless one can effect adequate coverage. At Wales even though our field observations were made from the edge of shore fast ice about a mile offshore, our counts still encompass only those migrants which stayed within a few miles of the coast since we did not have access to regular marine transportation. However, the location of Wales, at the tip of the Seward Peninsula, probably enhances the ability of land-based investigators to observe maximum numbers of birds since there must be a funneling effect of the Bering Strait, particularly for species which characteristically utilize marine routes, and the cape itself presents a natural landmark and obstacle that must be passed before migrants can turn north or northeast to their breeding grounds.

Nevertheless, for species whose migratory route lies more than a few miles offshore at this point, or are scattered in migration, or perhaps choose an overland route across the peninsula, early arrival dates and accurate estimates of numbers passing are difficult to obtain. At the time of our arrival in the third week of May, or shortly thereafter, the strait was open essentially to the Siberian shoreline with relatively little pack ice remaining, in contrast to the restricted leads described by Bailey (1943) in years of later ice break-up. Thus, at this time little else than habit would have prevented migrants from traveling well offshore out of telescope range, and in fact substantial numbers of flocks were seen against the sky on the horizon, too far out to permit positive identification or counts. However, many hundreds of flocks were within positive identification range, and only a few species were rare or absent as expected migrants.

Also, we are fairly confident that the appearance of Yellow-billed and Red-throated Loons, Red-breasted Mergansers, Parasitic and Pomerine Jaegers, and Arctic Tern after our arrival represents their approximate first arrival. Of several others, such as Whistling Swan, Emperor Goose, White-fronted Goose, and Spectacled Eider, we cannot be certain in view of their rarity in our observations. Likewise, it was difficult to estimate whether particular species were just beginning their migration, nearing its completion by the bulk of the population, or somewhere in between. Species, such as Yellow-billed and Red-throated Loons, jaegers, and perhaps Steller's Eider, appeared after observations were begun and continued to pass throughout the field period, suggesting that their migration was beginning with our first sightings. Species such as King Eider and Sandhill Crane, present in small numbers during peak period 1 and rarely thereafter, were undoubtedly stragglers or remnants of their major migrations which occurred in April and early May respectively. Likewise, the majority of Common Eider appeared to have passed by the end of our observations while the Snow Geese observed in peak period 1 may have been the last of this species' migration or simply the only individuals to pass within viewing distance.

Relation of Bird Movement to Wind

Periods of peak bird movement appear most closely associated with the occurrence of wind shifts to the south. In May and early June these shifts were invariably accompanied by increasing temperature and pressure, but it is assumed that the wind with its direct effect upon flight speed and migratory energy requirement is the important factor. For example, winds from the south on 19-20 May were accompanied by the largest flux of migrants, principally murres, Common Eider, and Black Brant, observed during this study. Flock noted substantial numbers of radar echoes on 22-23 May after the wind had shifted back to the north; these probably were flocks of brant, which were present in numbers until 24 May, and perhaps Black-legged Kittiwakes and Common Eider. Murres and Common Eider appeared to respond more quickly to south winds than brant or kittiwakes; abundance of the former reached peak values during or shortly after intervals of southerly winds (when winds often were calm), whereas flights of the latter often preceded southerly shifts or continued well after a return to winds from the north.

It is evident, however, that southerly winds were not necessary to initiate a large migratory movement since flocks of at least ten species were abundant on 27 May, the first day of peak period 2, even though no wind shift to the south occurred until about 0900 on 28 May. With this wind shift numbers of the five most abundant species (murre, Oldsquaw, Black-legged Kittiwake, Common Eider, and Black Brant) increased markedly. Similarly, although the wind shift in peak period 3 did not occur until about 0930 on 2 June, several species including Yellow-billed and Red-throated Loons, Black Brant, Pintail, Glaucous Gulls, and kittiwakes were present in much larger numbers on 31 May and 1 June than on preceding days. As before, maximum numbers were recorded on the day of the wind shift to the south, or the day following. Although visual observations at Wales are not available prior to 20 May, we might predict a similar sequence to have occurred during peak period 1. The wind shift to the south/southwest occurred on 19 May and continued through 20 May. It is evident that the trend of bird numbers on 20 and 21 May represents the declining portion of an extremely large peak (Fig.10) which probably reached its maximum value either on 19 or 20 May and might have been increasing by late on 18 May prior to the wind shift.

Migration of two other species also appears related to wind direction changes. Prior to our arrival the major migration of King Eider (about 19-24 April) and Sandhill Crane (about 5-15 May), as noted by interested observers in the area, coincided approximately with periods of south winds on 17-19 and 21-22 April and 3-5 and 12 May.

It is interesting to note that not only did large movements start before the favorable wind shift in each peak period, but that all of these preceding intervals were periods of very strong northerly winds, usually exceeding 20 knots. Energetically this seems an inefficient strategy for migrating birds to adopt. On the other hand, if spring migrants were to move north only on a following wind they might waste much valuable time reaching their breeding grounds in this area of prevailing northerly winds (winds were from the north 66.9% of days from mid-April to mid-June). Any such delay could be critical for these species breeding in the short arctic summer. Migrants certainly gain energetically with a tailwind but it would seem that the delay in awaiting a south wind must be balanced against their ability to accumulate tissue reserves for proceeding rapidly with breeding activities, especially egg production.

The cue(s) which allow migrants to anticipate a period of favorable weather are problematical at the present time. This topic has received attention from many investigators (e.g., Bagg et al, 1950; Lack, 1960; Hassler et al, 1963; Nisbet and Drury, 1968; Williamson, 1969; Berthold, 1975) and it generally has been observed that the movements of migrant birds is closely correlated with certain weather conditions which are produced by barometric pressure patterns, temperature, and wind direction (Pettingill, 1970). Since the majority of migrants observed during this study anticipated intervals of favorable wind, and temperatures invariably were cool and relatively stable prior to a shift to southerly winds, changes in barometric pressure would seem to be the most likely cue of the three. That some species are specifically responsive to changes in barometric pressure has been demonstrated by Stolt (1969). However, no experimental proof of the actual role of specific weather conditions in migration is available at present.

At this point we should note that although the fluctuating pattern of migrants past Wales could be a result of individuals which initiate a particular migratory flight from a southern locale providing an attractive stimulus along the migratory route for those not yet in the air (a "cascade" effect), we still must determine the initiating stimulus. The role of physiological condition of migrants as they approach the breeding areas also requires investigation. As with most natural phenomena, it is unlikely that only a single stimulus factor is involved.

Near the termination of regular seawatches in early June, and thereafter, Black-legged Kittiwakes (as well as several other species) appeared to alter their response to southerly winds. Whereas prior to 31 May nearly all flocks were flying north, especially during periods of south wind, from this date on substantial numbers of flocks flew south when the wind was from that direction, and after 2 June nearly all kittiwakes observed exhibited this tendency. When south winds were especially strong many individuals flew overland from the general direction of Lopp Lagoon (Fig. 1) southwest to the cape before joining others following the shoreline. Kittiwakes continued to fly north when the wind was from that direction and thus exhibited a striking tendency to reverse their direction of travel as the wind direction reversed, flying into the wind whether from the north or south. The explanation for this phenomenon is unknown; we might surmise that it is related in in some manner to the origin of the migrants, availability of nest sites at various colonies, size of non-breeding population, movement to foraging areas and food availability, or other undetermined factors. Nearly all individuals observed were in adult plumage.

The occurrence of northward migration through the Bering Strait before the change to a south wind was known to Bailey (1948) on the basis of his experience at Wales in 1922. He reported that the natives knew that a south wind was coming when great strings of birds started flying north over the leads. The Bering Strait area provides a relatively unobstructed pathway for the southward flow of air from the polar cap of high pressure or cold air dome over the Arctic and the prevailing wind at the strait is from the north. As discussed, temporary periods of south wind do occur, however, and birds migrating to the north in the spring take advantage of them to the extent possible. When the wind was from the north in May-June 1978 the air pressure at Tin City itself was relatively low, whereas the pressure was relatively high when a south wind was blowing. The change from a north wind to a south wind was thus accompanied by an increase of air pressure at Tin City, and the increase began before the wind actually changed direction. For the first migration peak the pressure changed from 29.310 in. of Hg on 15 May when the wind was from the north to 30.030 on 20 May when the wind was from the south and had increased to 29.880 on 19 May before the rather abrupt change to a south wind. For the second peak the pressure changed from 29.485 on 26 May (wind from north) to 29.915 on 30 May (wind from south) and reached 29.635 on 28 May before the change to a south wind. Finally for the third peak the pressure rose from 29.575 on 1 June (wind from north) to 29.700 on 2 June (wind from south) and reached 29.660 before the change to a south wind. The preceding figures are from the Tin City weather station, where values of the standard weather parameters are recorded hourly.

Migration Patterns

A majority of species with more than one peak of abundance exhibited declines in flock size through the study period and, with the exception of Pomerine Jaegers, these invariably were accompanied by at least modest increases in flock frequency (Table 3). In species such as murres, brant, and Pintail, later peaks were smaller than earlier ones, suggesting that a majority of nearshore migrants had passed by early June, although substantial flocks of brant continued to pass sporadically until at least the end of June. It may be that as numbers in southern areas dwindle during spring migration those remaining tend to form smaller flocks, perhaps simply as a result of fewer individuals dispersed over a large area as the major concentrations move north. Also, as the number of individuals moving north declines, those remaining receive a lower level of stimulation perhaps resulting in their joining flocks less readily.

Despite the tendency of many species to migrate in greatest numbers with a southerly wind, a common migratory pattern is not evident in our data. However, we should not find this surprising in view of the many factors, including physiological (hormonal and energetic) condition, sexual maturity, flocking habit, response to seasonal and short-term environmental changes, influence of molt condition, and probably numerous other stimuli and conditions, which have been shown to influence or are thought to affect the migration of birds. In addition, even if response to these factors by various species was similar, their different breeding habits and habitats probably would dictate a variety of migratory patterns.

Migration Routes Other Than Through the Bering Strait

Migration through the Bering Strait is very impressive, but the Strait appears to be used largely by seabirds and waterfowl with marine affinities. Certain other waterfowl largely bypass the Strait in their northward migration. In particular, some waterfowl that breed commonly near the north coast of the Seward Peninsula (Department of the Interior, 1975) are seen in only rather small numbers at the Strait (*e.g.*, Whistling Swan, Canada Goose, Emperor Goose, White-fronted Goose, Mallard, American Wigeon, Greater Scaup). Also Bailey (1948) does not believe that all the Black Brant migrate through the Strait, and the same must be said about Snow Geese. Bellrose (1976) shows four different routes by which Lesser Snow Geese migrate to Wrangel Island (via the Bering Strait, St. Lawrence Island, Kotzebue Sound, and the arctic coast of Alaska). Many of the birds mentioned above must migrate overland over the Seward Peninsula or farther east or north. It is of interest also that flocks of migrating shorebirds are seldom seen in the Bering Strait or elsewhere in Arctic Alaska in the spring. Bailey (1948) commented that the shorebirds appear suddenly without other visible evidence of migration. Very likely many of these shorebirds migrate at high altitudes.

Practical Considerations Concerning Visual Observations

Observing bird migration from the edge of the shorefast ice involves an element of adventure and requires caution and judgment, especially as the time for breakup of the ice nears. Warm clothing is needed for protection against low temperatures and strong winds. The prevailing wind at Wales is from the north, and the average wind velocity for the entire year is about 25 knots. Waterproof boots having removable felt liners are recommended. The use of a collapsible stool and/or insulating cushion is advantageous, and improvising a shelter of some type is helpful. Having a boat or raft of some type at the water's edge could provide some element of safety and could allow moving a distance from the ice edge in good weather in order to obtain better information about the migration that takes place at a distance from the edge of the shore fast ice. Hiring a local resident to take one out in a boat is another possibility, but this may not be easy to arrange, as hunting activities tend to have a high priority. Chartering an aircraft could allow one to follow migrations that take place in good weather.

5.2. Comparison of Radar and Visual Observations

The purpose of having both radar and visual observations is not primarily to compare or correlate the two types of data but to take advantage of both to obtain as complete a picture of bird migration as possible. On the other hand, it is obviously desirable to know to what degree the radar detects the birds that are observed visually and vice versa. Generally the radar and visual observations at the Bering Strait are correlated to the extent that when the visual observer sees many birds, the radar record also shows significant movement. Conversely, when movement is very slight because of severe weather or other reasons, neither the radar or visual record is very interesting.

The radar recorded only the latter part of the first peak movement that was observed visually in 1978. Some indication of bird movement showed on the radar screen on 20 May and considerable movement was evident on the radar on the evening of 21 May, but the radar did not indicate the peak murre movement recorded visually on May 20 (Fig. 3) and provided no information on when that movement began. The reasons for this discrepancy deserve discussion. Most obviously, sea-ice clutter was severe on 20 and 21 May and tended to obscure bird echoes. Secondly, continuous recording of PPI data was not carried out and considerable attention was given on these days instead to attempts to obtain single-sweep A-scope data. Furthermore, migration was not obvious visually from the site at Tin City at this time, and the observer was not alert to the occurrence (Sec. 5.1) of major movement before a shift from the north wind to a south wind. Finally, the radar location is not ideal for recording low-level movements near the edge of the shore fast ice in the immediate vicinity of Cape Prince of Wales. The degree to which the Tin City radar has the capability for monitoring the murre migration is not clear at this time. The later portion of the first migration peak that the radar recorded clearly apparently involved the movement of Black Brant and Common Eiders. These birds might be expected to provide better radar targets (for the Tin City radar) than murres.

The radar recorded a broad-frontal movement during 27-30 May, the time of the second peak of migration as observed visually. The radar has a clear advantage with respect to detecting high-altitude, broad-frontal movements a large distance away. Radar does not generally have capability for identifying the species involved, but even so it is desirable to know that the movements take place. The visual sightings during 27-30 May provide clues as to the identity of the radar targets, but the correlation between the radar and visual observations is somewhat tenuous and general in nature, as it is difficult to correlate particular radar echoes and particular visual sightings. Because of unavailability of the radar part of the time, the third peak migration period was not very well documented by radar.

Radar has the advantages that it can theoretically operate continuously for 24 hours a day and can operate in fog and darkness, whereas a single human observer can only function for a certain number of hours per day. As discussed in Sec. 5.4, however, a second radar located elsewhere and having different characteristics is needed to provide the best coverage of low-level movements near the edge of the shore fast ice at Cape Prince of Wales.

5.3. Sea Ice

Radar and sea ice are related in the dual manner mentioned in the introduction to this report. Radar can be used as a tool to study sea ice, and sea ice can be an important source of radar clutter. Both aspects appear to be in their infancy, but the subject of sea ice as radar clutter seems to have received the least attention. Clutter due to sea ice is evidently most severe in the Bering Strait in the spring when there is much loose pack ice. The strong winds of the area exacerbate the problem. There is a need for quantitative data on the characteristics of clutter due to sea ice. The coherent radar considered in the following section could provide these data.

When visibility conditions and orbital scheduling permit, the Landsat satellites provide excellent imagery showing the distribution of sea ice in the Bering Strait area. For the spring of 1978, images were obtained for 12 April and 26 May. Even in April there was some open water south of the Seward Peninsula and south of a line extending from Wales to the Diomedes and beyond. A very narrow lead extended north from Wales. The 26 May image showed a time when the area south of the Seward Peninsula had been swept free of pack ice by strong winds, with only a narrow strip of shore fast ice remaining (Fig. 26).

5.4 Recommendation for the Installation of a Research Radar at Wales

The Tin City ACW radar provides good wide-area coverage of bird migration in the Bering Strait and vicinity. It shows well broad-frontal, high-altitude migrations of the type mentioned in Sec. 5.2, but it suffers from certain limitations. The present system does not provide Doppler frequencies. It does have MTI, which allows the separation of targets with near zero Doppler from those with higher Doppler frequencies, but the MTI of the present system tends to be somewhat unstable and difficult to adjust precisely for research purposes. Even when functioning in an optimum manner, furthermore, MTI does not separate returns from birds and sea ice when the two occur simultaneously and the latter is in the form of loose pack ice that is churned by strong winds. The problem is not so severe as to preclude monitoring migration along the coastline, but it does seriously limit the quality of the record obtained. The long pulse length of the present radar, furthermore, provides only low-resolution coverage of the area. The limitations of no Doppler frequency capability and low spatial resolution may not apply to any new radar system that may be installed, but the location at the top of Cape Mountain does not allow coverage of the edge of the shore fast ice near Wales and the tip of the Cape.

This condition has been commented on previously, and the installation of an additional radar, close to the tip of Cape Prince of Wales on the ridge south of Wales, has been considered (Flock, 1975). The logistics of such an installation at the tip of the Cape would be a serious problem, however, and the present thought is that a fixed-beam or sector-scan radar system should be installed in Wales itself. Such a system has the practical advantages of relative simplicity and low cost, as it does not involve a continuously rotating antenna or a PPI. An ordinary oscilloscope can be used for displaying the echoes. Data analysis is also simplified when using a fixed antenna beam, as contrasted to a continuously rotating antenna. The approach for processing the data would be to employ a certain number of range gates and to record separately the signals appearing in each gate. For each range gate the number of targets, the target amplitude and amplitude spectra, and the Doppler frequencies and spectra can then be obtained. Amplitude data for up to 4 range gates could be displayed on a paper-chart recorder, and data should also be recorded by a tape recorder for later detailed analysis. The beam would be directed outward from the village and everything that crossed the beam would be recorded out to a distance of 5 km or more.

The Cape Prince of Wales Field Station, operated for the Naval Ocean Systems Center of San Diego, California, at the north end of town is the preferable location for such a radar in many respects, but one of the houses at the south end of town may also be suitable. (A number of families in Wales have rather new homes but retain their serviceable older homes and sometimes rent them to summer visitors.) Operating from either end of town has the advantage of a minimum of human traffic in front of the radar. Elevation above the sea surface is available at the south end of town. The flat roof of a garage or storage building noted at the Field Station would be a suitable location for the radar antenna if space was also available inside the building. The use of a radome or the location of the radar antenna on the south side of a building would provide protection from strong north winds.

6. CONCLUSIONS

6.1 Visual observations from the edge of the shore fast ice at Wales after 20 May 1978 showed three periods of peak bird migration, roughly 20-24 May, 27-30 May, and 31 May-3 June. Peak periods of bird movement were associated with wind shifts to the south; however, even though the greatest numbers of individuals passed Wales on south winds, many anticipated the shift as indicated by substantial increases during the preceding days. Movement of some species, such as Black-legged Kittiwake and Pintail, less rigorously reflected wind shifts to the south, and Black Brant appeared to avoid such periods, or at least did not utilize them.

6.2 The great majority of flocks of all species were observed to fly north, especially prior to 31 May. In the final days of regular observation (terminated 3 June), however, an increase in flocks traveling south, principally auklets, murres and kittiwakes, was observed. Also, after 31 May kittiwakes exhibited a striking tendency to fly against the wind, whether blowing from north or south, reversing their flight direction with each shift in the wind.

6.3 The majority of individuals counted during this study belonged to five species: murre (the most abundant), Black-legged Kittiwake, Black Brant, Common Eider, and Oldsquaw. Altogether, 30 species were identified from the edge of the shore fast ice.

6.4 The present Tin City radar provides good coverage of relatively high-altitude, broad-frontal bird migration and shows the large-scale features of the sea ice of the area. Sea ice echoes in late May and early June tend to obscure echoes from birds migrating close to the water surface near the edge of the shore fast ice.

6.5 Coverage of the early-spring migration of King Eiders past Cape Prince of Wales would be very interesting ornithologically and would provide data concerning a potential source of extremely serious radar clutter. Data are needed concerning the late summer and early fall migrations through the Bering Strait.

6.6 A high-resolution fixed-beam or sector-scan coherent (pulse-Doppler) radar located at the village of Wales and directed outward across the water could provide a high-resolution record of bird and sea ice movements and echo characteristics, including amplitude and Doppler frequency magnitudes and spectra. The deployment of such a radar in combination with a program of visual observation is recommended, in order to obtain a more nearly complete, quantitative description of bird migration and radar clutter due to birds and sea ice at the Bering Strait.

REFERENCES

Bagg, A.M., W.W.H. Gunn, D.S. Miller, J.T. Nichols, W. Smith, and F.P. Wolfarth, Barometric pressure-patterns and spring bird migration, *Wilson Bull.*, 62:5-19, 1950.

Bailey, A.M., *The Birds of Cape Prince of Wales, Alaska*. Denver: Colorado (Denver) Museum of Natural History, 1943.

Bailey, A.M., *Birds of Arctic Alaska*. Denver: Colorado (Denver) Museum of Natural History, 1948.

Bartonek, J.C., and C.J. Lensink, A review of the literature and a selected bibliography of published and unpublished literature on marine birds of Alaska, in *Environmental Assessment of the Alaskan Continental Shelf, Final Reports*, Vol. 1: 108-204, OCSEAP, Boulder, CO, 1978.

Berthold, P., Migration: control and metabolic physiology. In D.S. Farner and J.R. King (eds.), *Avian Biology*, Vol. V: 77-128. New York: Academic Press, 1975.

Brandt, H., *Alaska Bird Trails.* Cleveland, OH: Bird Research Foundation, 194

Department of the Interior, Chukchi Imuruk National Reserve. Alaska Planning Group, U.S. Dept. of the Interior, 1975.

Divoky, G.J., The distribution, abundance, and feeding ecology of birds associated with pack ice, in *Environmental Assessment of the Alaskan Continental Shelf, Annual Reports*, Vol. II: 525-573, OCSEAP, Boulder, CO, 1977.

Drury, W., Birds of coastal habitats on the south shore of the Seward Peninsula, Alaska, in *Environmental Assessment of the Alaskan Continental Shelf, Annual Reports*, Vol. III: 1-178, OCSEAP, Boulder, CO, 1977.

Drury, W., Studies of populations, community structure and ecology of marine birds at King Island, Bering Strait region, Alaska, in *Environmental Assessment of the Alaskan Continental Shelf, Annual* Reports, Vol. V: 75-149, OCSEAP, Boulder, CO, 1977.

Drury, W., Site-intensive studies of marine birds at selected localities in the northern Bering Sea and Bering Strait, Alaska, in *Environmental Assessment of the Alaskan Continental Shelf, Program Work Statements*, Vol. II: 177-2-4, 1978.

Einarsen, A.S., *Black Brant*. Seattle: University of Washington Press, 1965.

Flock, W.L., Radar observations of bird migration at Cape Prince of Wales. *Arctic,* 25: 83-98, June, 1972.

Flock, W.L., Bird migration at Cape Prince of Wales: radar and visual observations, in *Environmental Assessment of the Alaskan Continental Shelf*, Vol. 4: 276-319, OCSEAP, Boulder, CO, 1975.

Flock, W.L., Monitoring open water and sea ice in the Bering Strait by radar. Trans. IEEE on Geoscience Electronics, GE-15: 196-202, Oct. 1977.

Gabrielson, I.N. and F.C. Lincoln, The Birds of Alaska. Harrisburg, PA: Stackpole, 1959.

Hassler, S.S., R.R. Graber, and F.C. Bellrose, Fall migration and weather, a radar study. Wilson Bull., 75: 56-77, 1963.

Hopkins, D.M. (ed.), The Bering Land Bridge. Stanford, CA: Stanford University Press, 1967.

Hubbard, J.D. and Flock, W.L., Radar Observation of Migratory Waterfowl at Cold Bay, Alaska. Air Force Weapons Lab. Tech. Note AFWL-DE-TN-74-008, Kirtland AFB, NM, 1974.

Kovacs, A. and W.F. Weeks, Dynamics and near-shore ice, in Environmental Assessment of the Alaskan Continental Shelf, Annual Reports, Vol. XVI: 151-163, OCSEAP, Boulder, CO, 1977.

Lack, D., The influence of weather on passerine migration. Auk, 77: 171-209, 1960.

Lack, D., Weather factors initiating migration. XIIIth Inter. Ornithol. Congr. 412-414, 1963.

Lockley, R.M., Ocean Wanderers. Harrisburg, PA: Stackpole, 1974.

Nisbet, I.C.T. and W.H. Drury, Short-term effects of weather on bird migration: a field study using multivariate statistics. Anim. Behav. 16: 496-530, 1968.

Pettingill, O.S., Jr., Ornithology in Laboratory and Field, 4th Ed., Minneapolis, MN: Burgess, 1970.

Schamel, D. (ed.), Birds, in Environmental Assessment of the Alaskan Continental Shelf, Interim Synthesis: Beaufort/Chukchi, 152-173, OCSEAP, Boulder, CO, 1978.

Stolt, B.O., Temperature and air pressure experiments on activity in passerine birds with notes on seasonal and circadian rhythms, Zool. Bidr. Uppsala, 38: 175-231, 1969.

Williamson, K., Weather systems and bird movements. Quart. J. Roy. Meteorol. Soc., 95: 414-423, 1969.

ACKNOWLEDGMENTS

We would like to express our appreciation to Dr. William H. Drury for supporting this program under his auspices; to Colonel Robert T. Cassell, Commander 531st Aircraft Control and Warning Group, Colonel James Sey, and other personnel of the Alaskan Air Command for their cooperation; and to Colonel Raymond V. McMillan, Electronic Systems Division, Hanscom Air Force Base, and Dr. Thomas Kabaservice of the Mitre Corporation for their support. We also wish to thank Major Raymond McLeod, Commander of Tin City Air Force Station; Mr. Nils S. Wedin, Station Supervisor for RCA at Tin City; and the other Air Force and RCA personnel at Tin City for their most helpful cooperation. We thank the Bering Strait School District of Nome for making available the facilities of the Wales school.

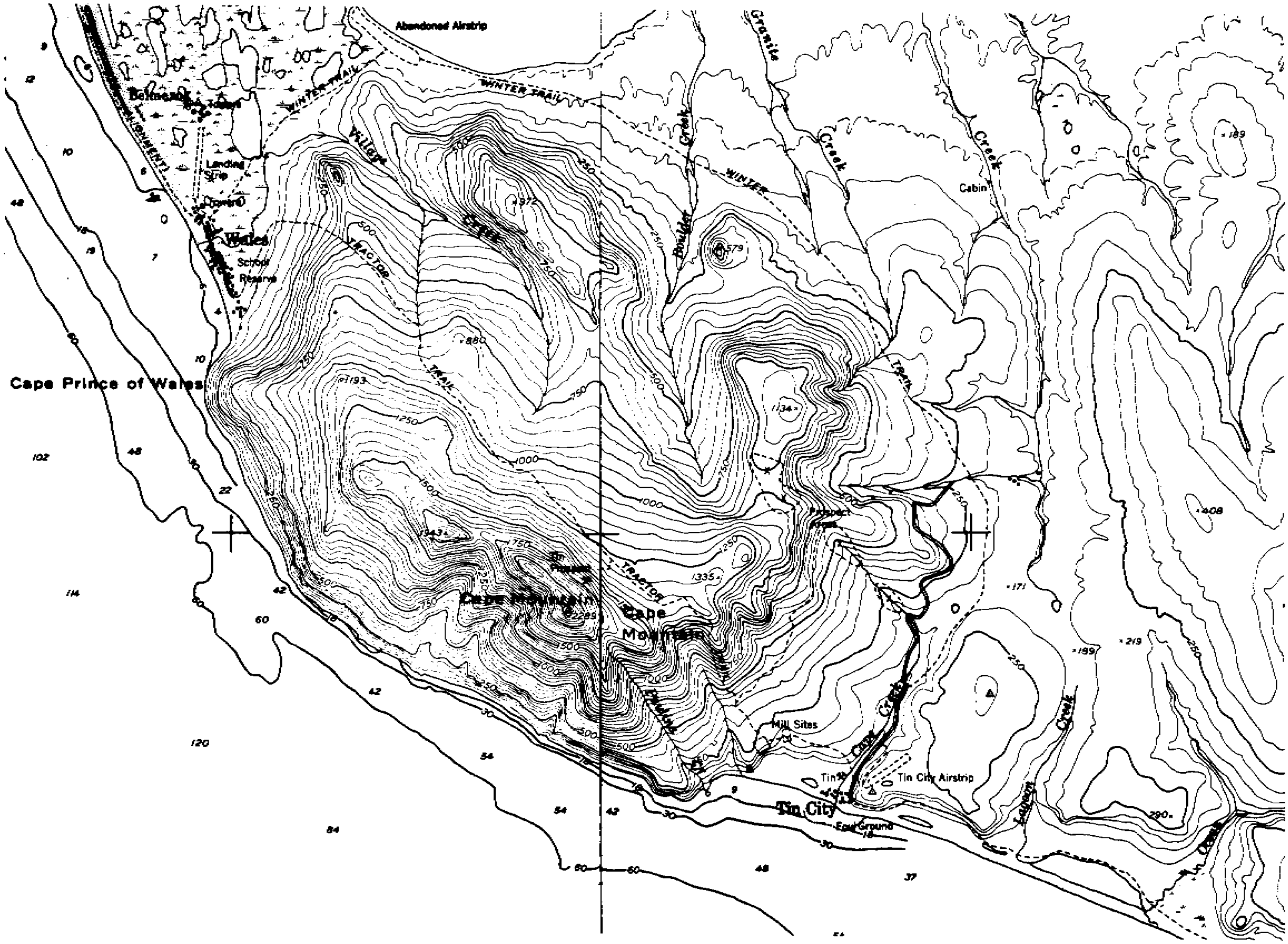


Fig. 1. Map of Cape Prince of Wales area, with elevations in feet. To obtain elevations in meters multiply by 0.3048.

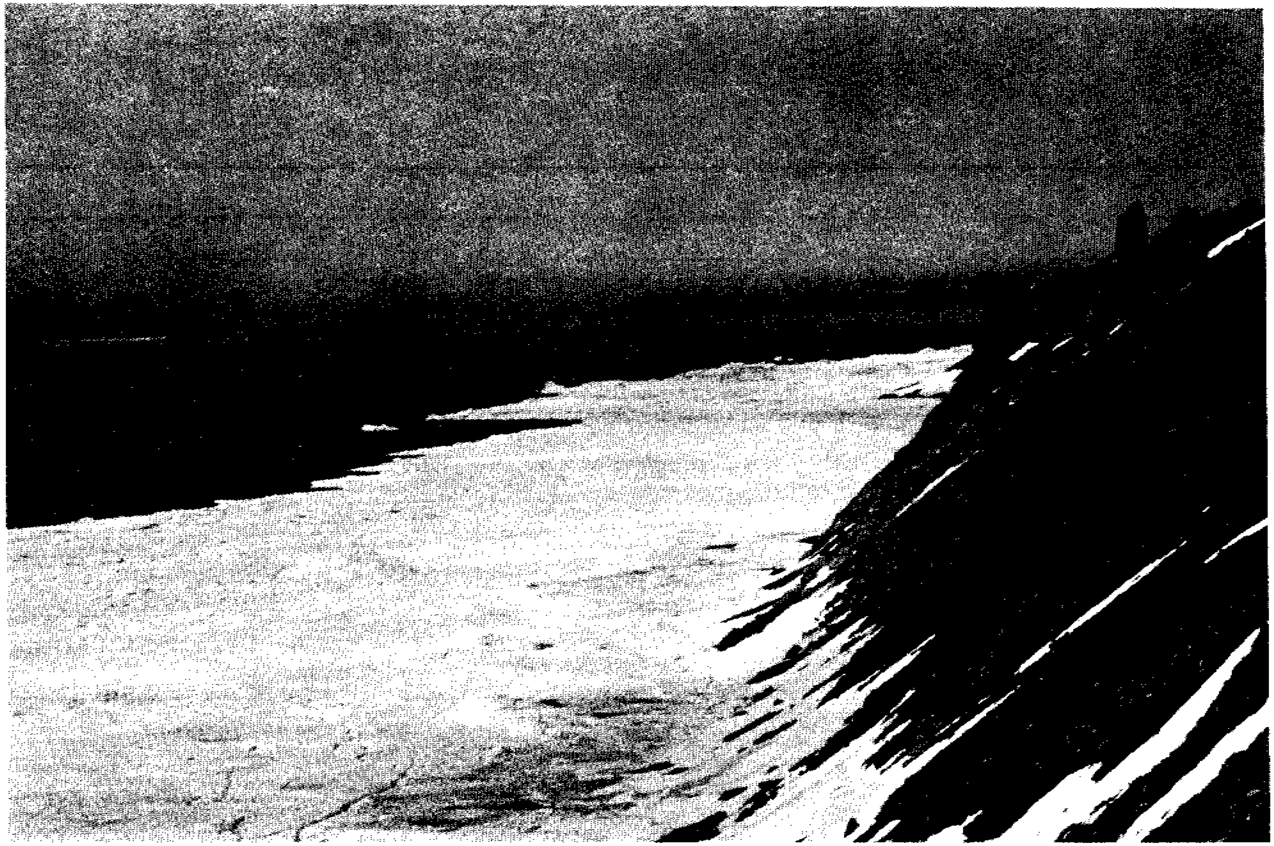


Fig. 2. View looking northwest from observation point west of Paulina Creek towards Cape Prince of Wales, 19 May 1978.

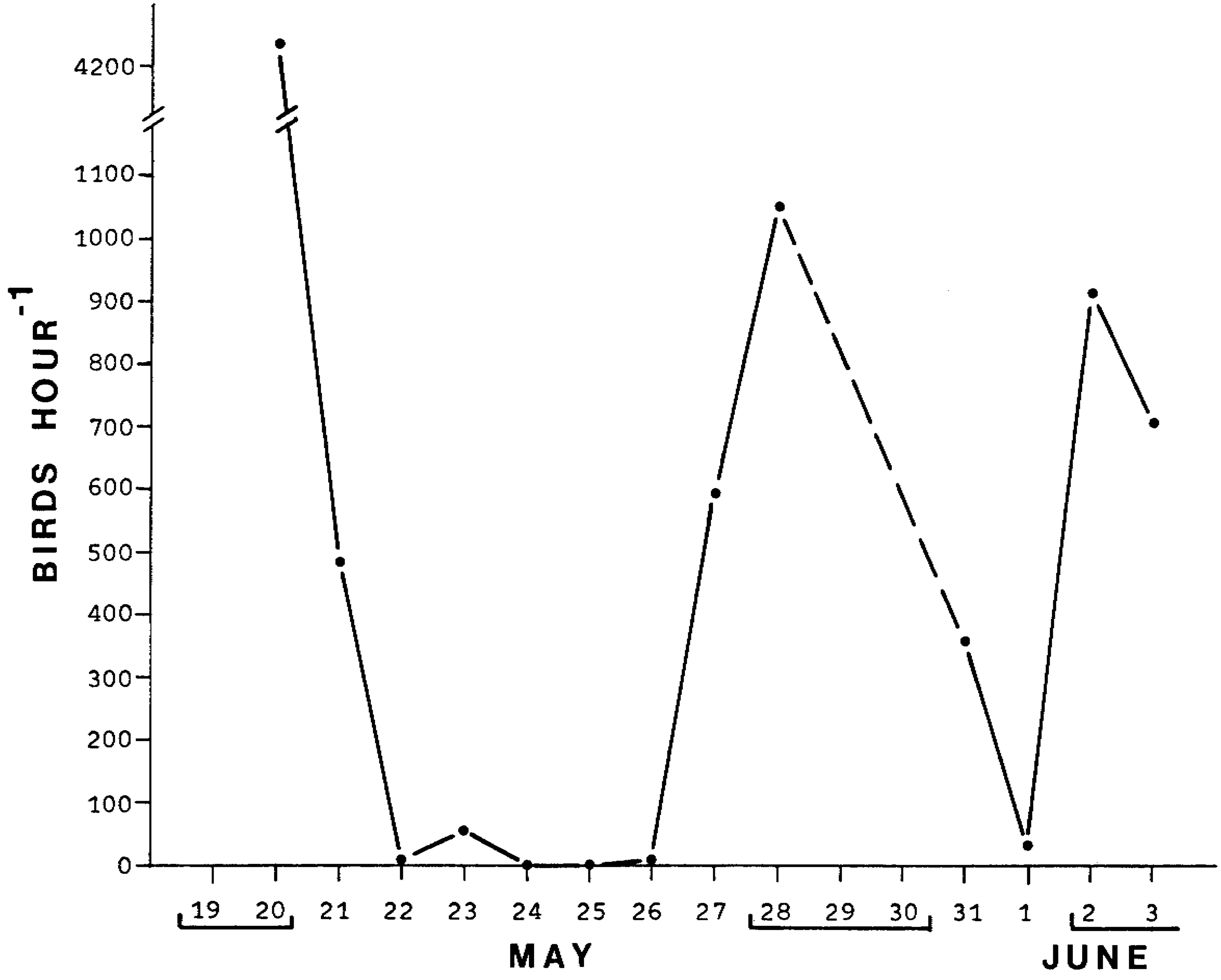


Figure 3. Daily average number of murres passing Wales, Alaska in May and early June (in this and all other figures brackets beneath dates indicate periods of southerly winds, dashed portions of graphs indicate where data were not obtained.

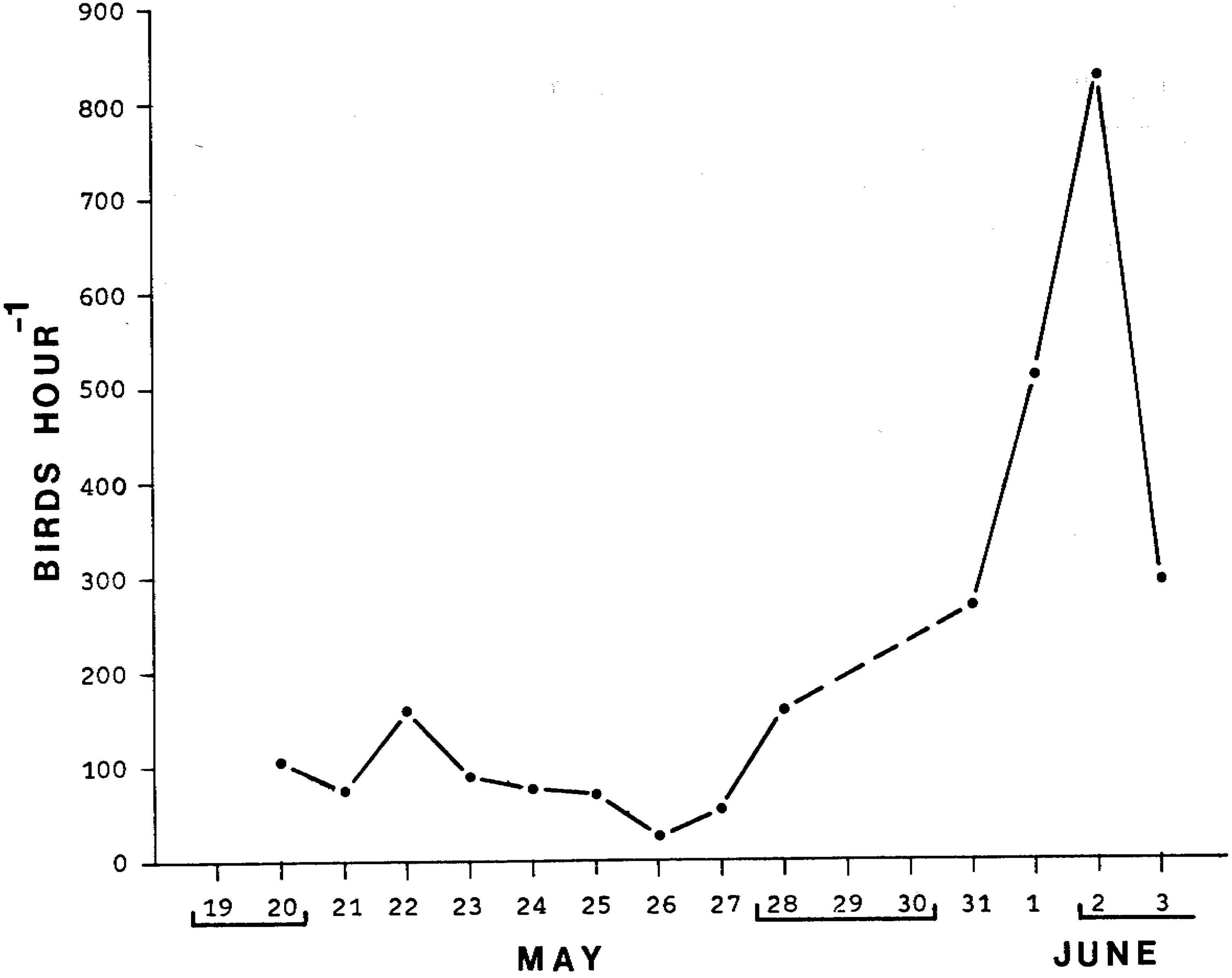


Figure 4. Daily average number of Black-legged Kittiwakes passing Wales, Alaska, in May and early June.

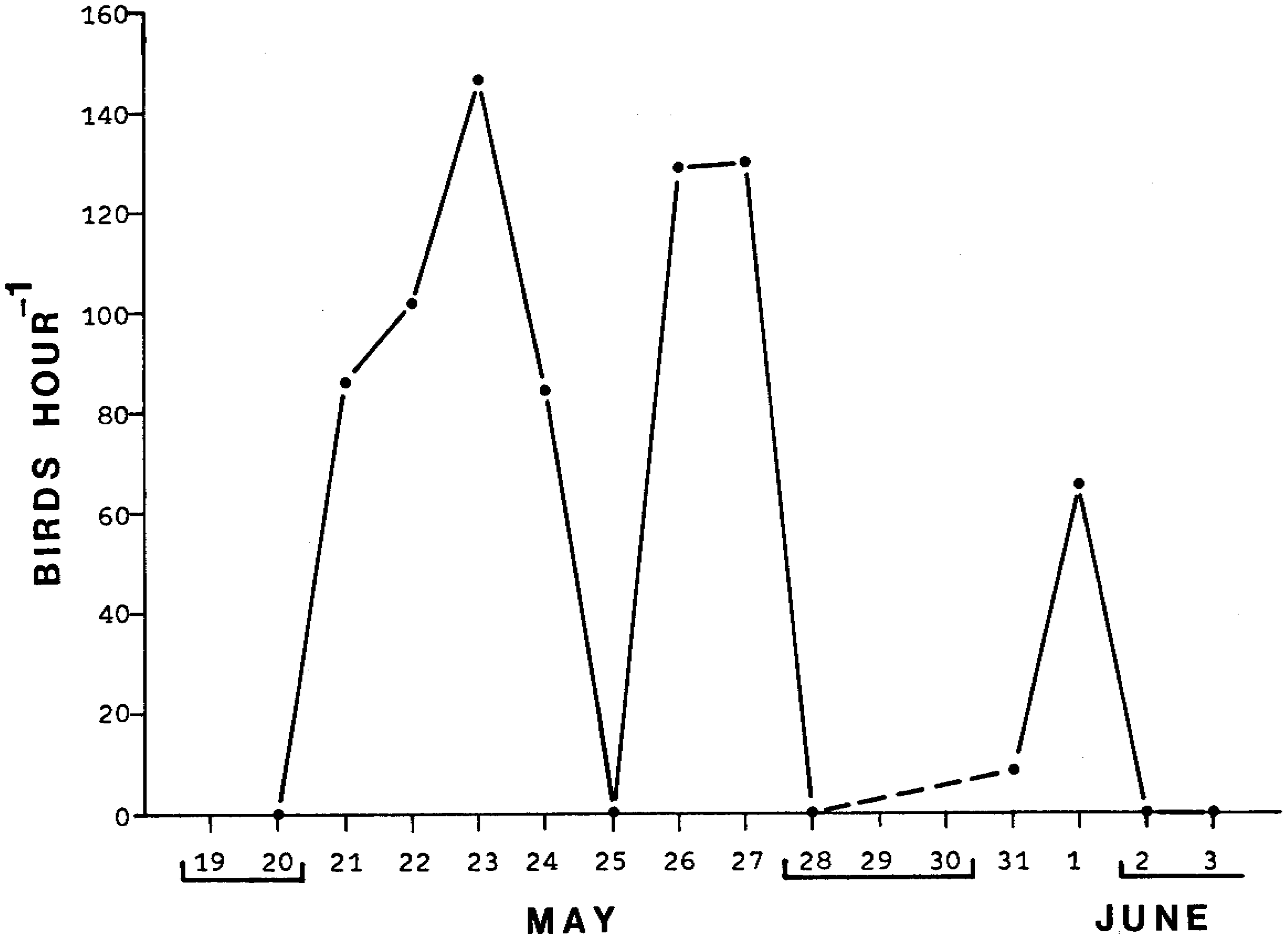


Figure 5. Daily average number of Black Brant passing Wales, Alaska, in May and early June.

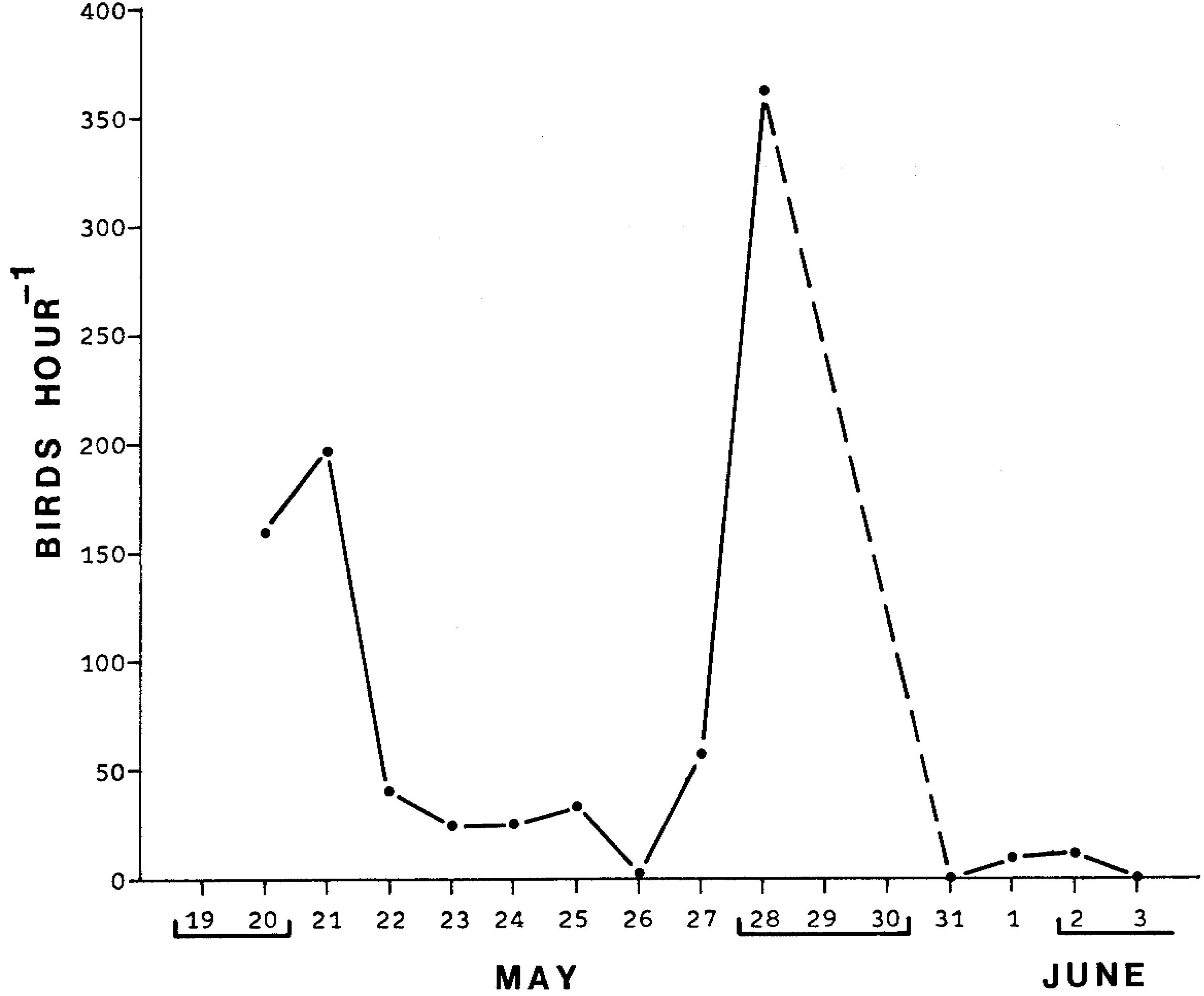


Figure 6. Daily average number of Common Eider passing Wales, Alaska, in May and early June.

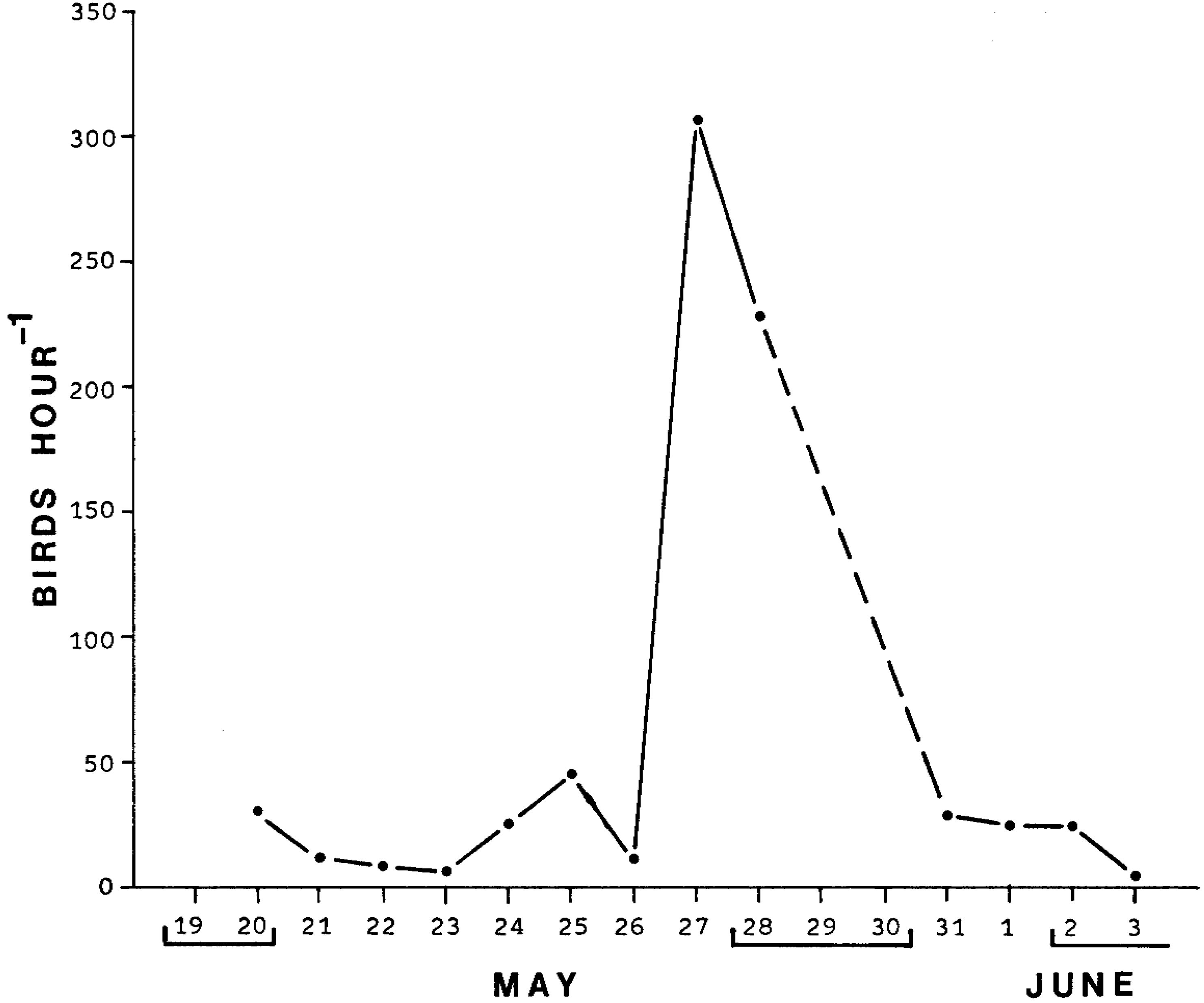


Figure 7. Daily average number of Oldsquaw passing Wales, Alaska, in May and early June.

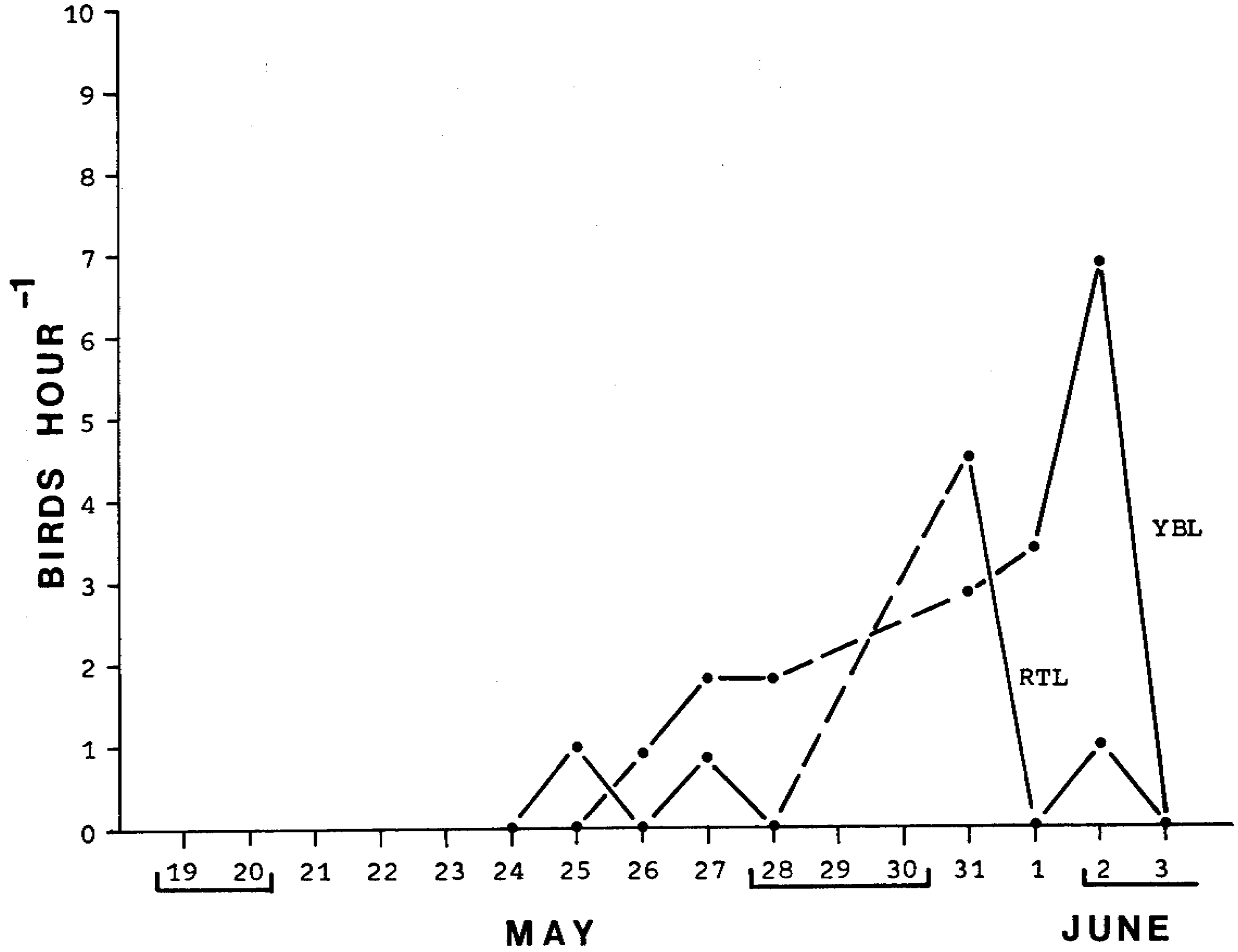


Figure 8. Daily average numbers of Yellow-billed and Red-throated Loons passing Wales, Alaska, in May and early June.

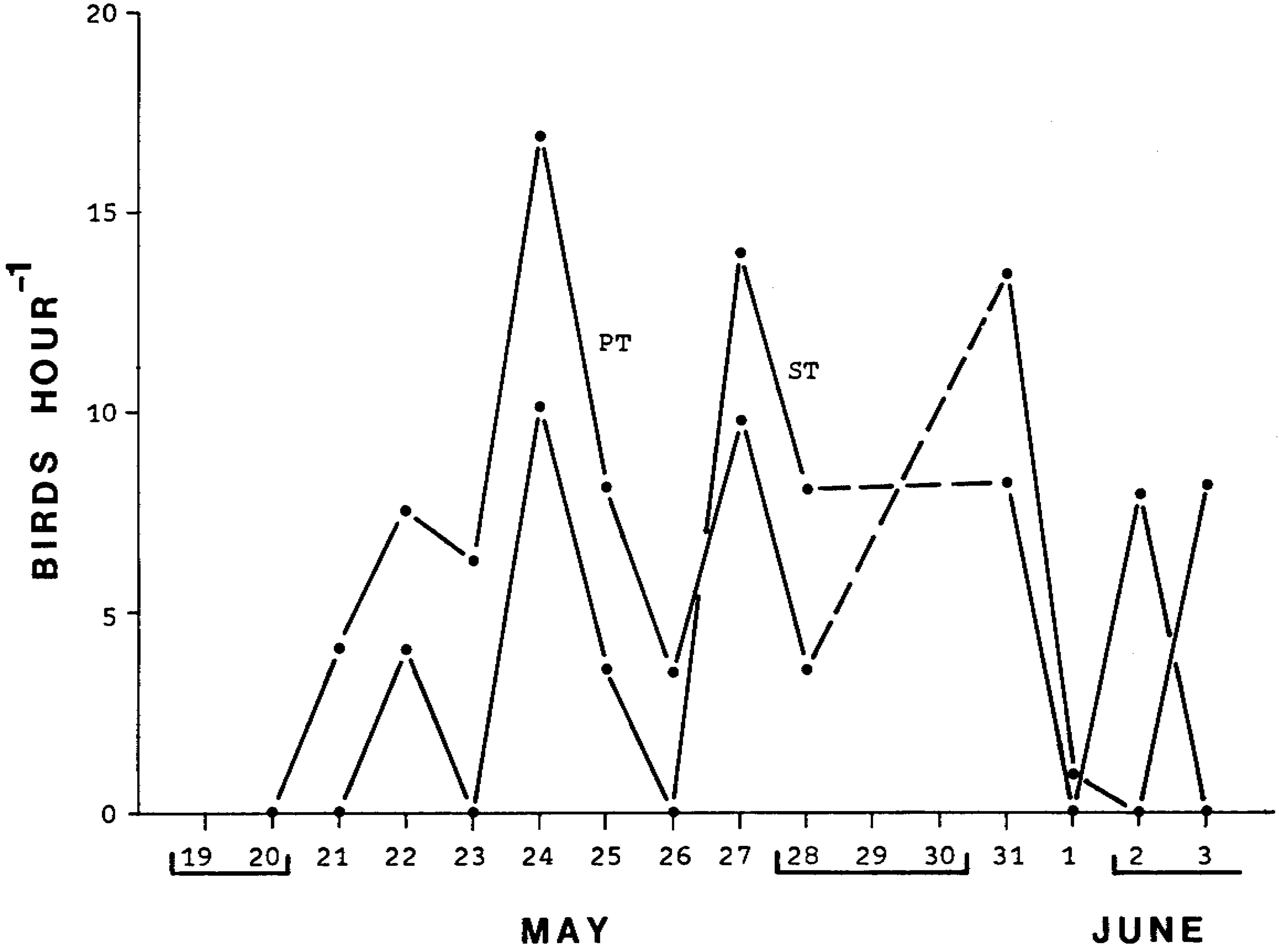


Figure 9. Daily average numbers of Pintail (PT) and Steller's Eider (ST) passing Wales, Alaska, in May and early June.

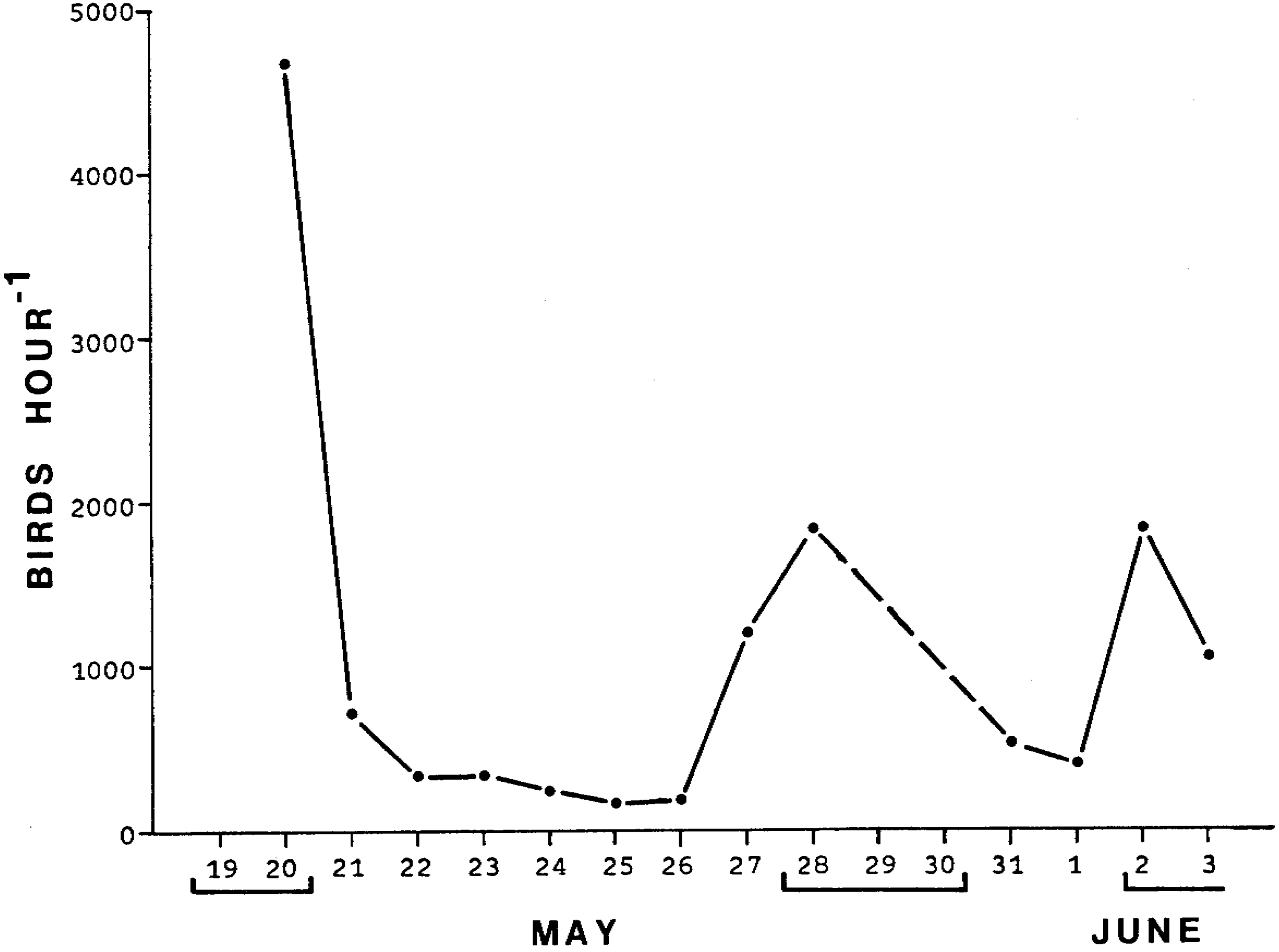


Figure 10. Total numbers of birds counted per hour.

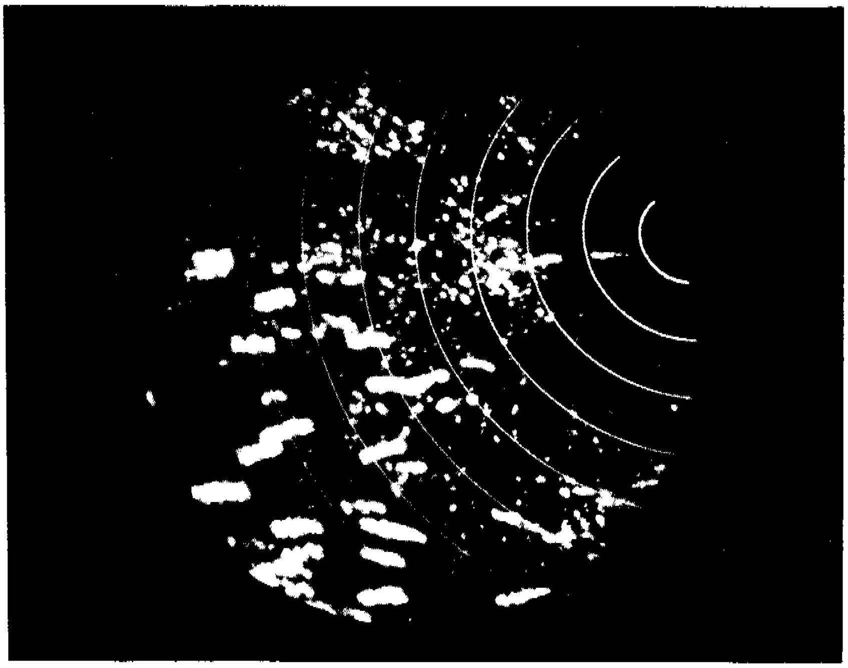


Fig. 11. Migration of Sandhill Cranes across the area south of the Bering Strait, 11 May 1970, 2050 ADT, 5-nmi range marks, 5-min exposure.

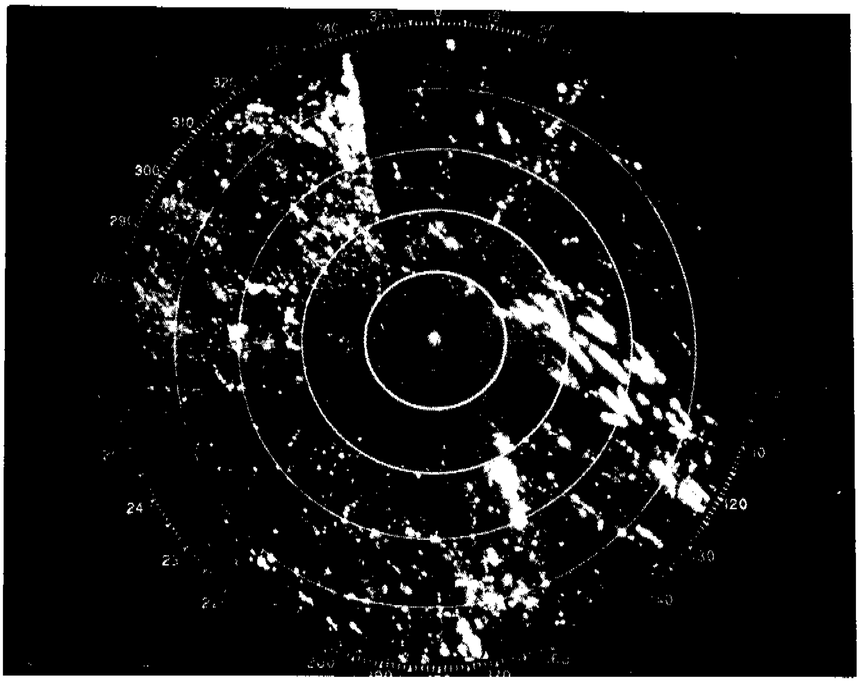


Fig. 12. The streaks on the right-hand side are believed to be caused by Snow Geese migrating towards Wrangel Island, 19 May 1970, 0640 ADT, 10-nmi range marks, 5-min exposure.

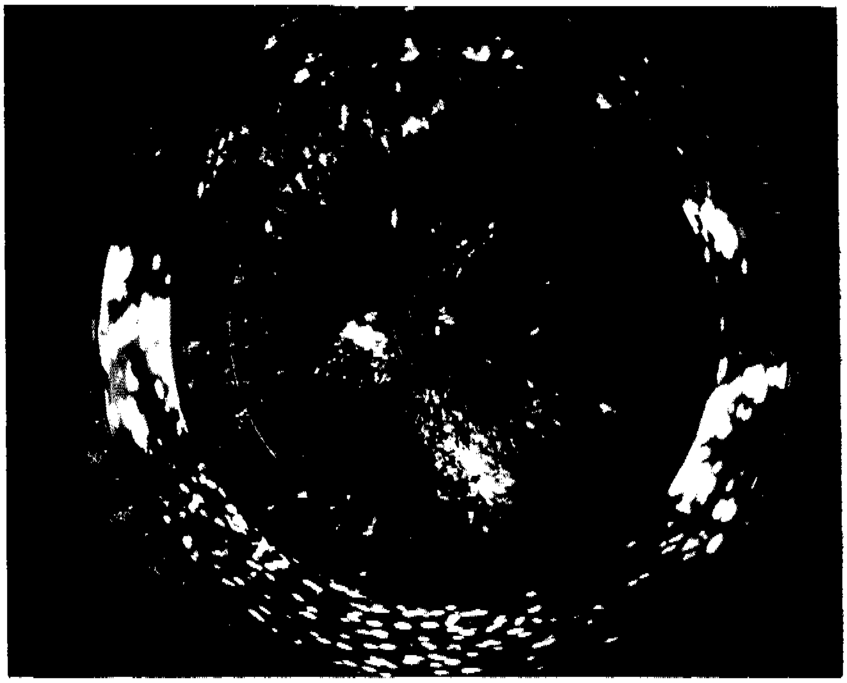


Fig. 13. Tin City PPI screen, 19 May 1978, 1000 ADT. All 1978 PPI photographs were 5-min exposures and show 10-nmi range marks. Sea-ice returns appear here in the far south.

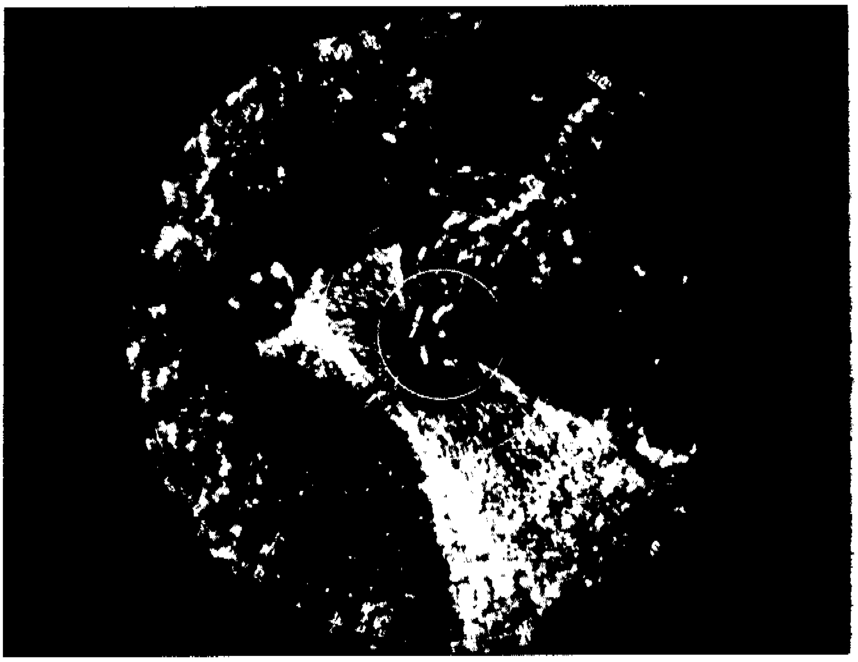


Fig. 14. Tin City PPI screen, 19 May 1978, 1840 ADT, showing prominent pack-ice echoes.

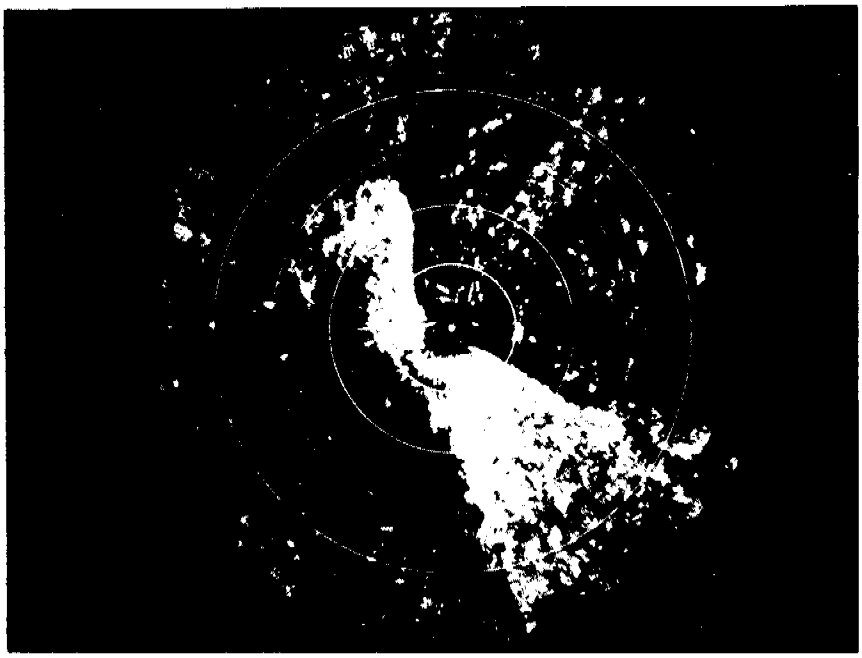


Fig. 15. Tin City PPI screen, 20 May 1978, 1445 ADT, showing prominent pack-ice echoes.

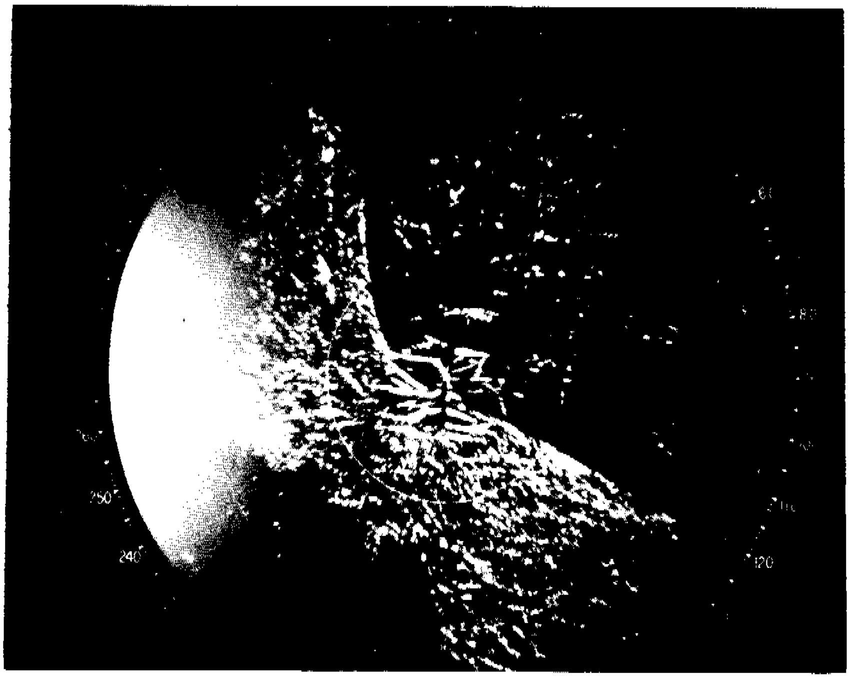


Fig. 16. Tin City PPI screen, 21 May 1978, 2145 ADT. Moderate bird movement, horizontal polarization.

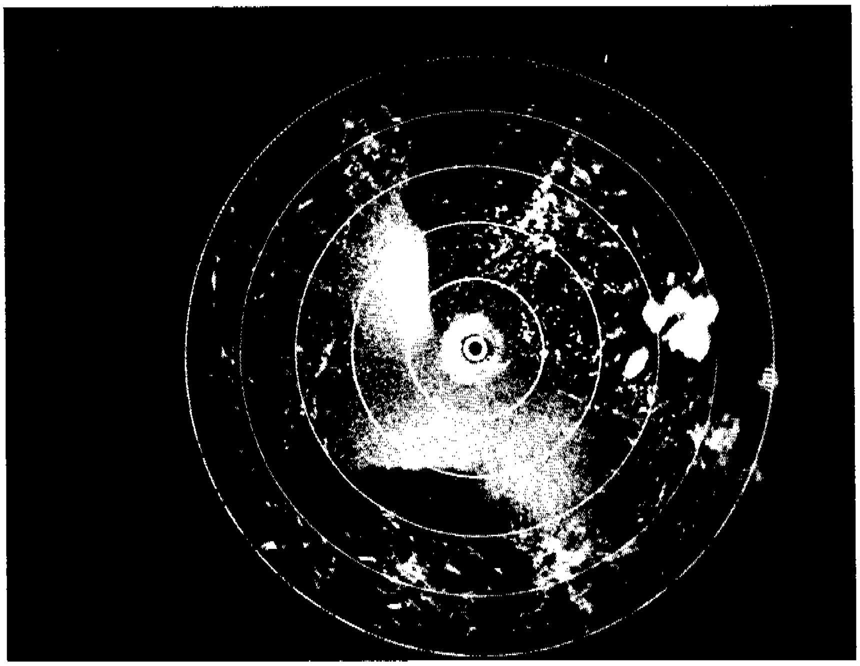


Fig. 17. Tin City PPI screen (at Top Camp, wind velocity near 50 knots), 23 May 1978, 1640 ADT, showing sea-wave echoes.

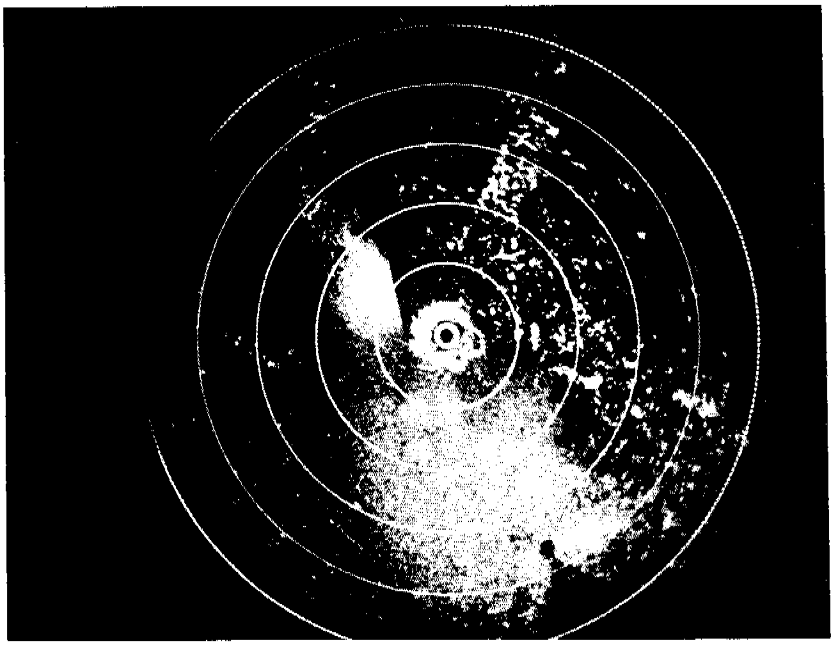


Fig. 18. Tin City PPI screen (at Top Camp), 25 May 1978, 0728 ADT, showing sea-wave echoes.

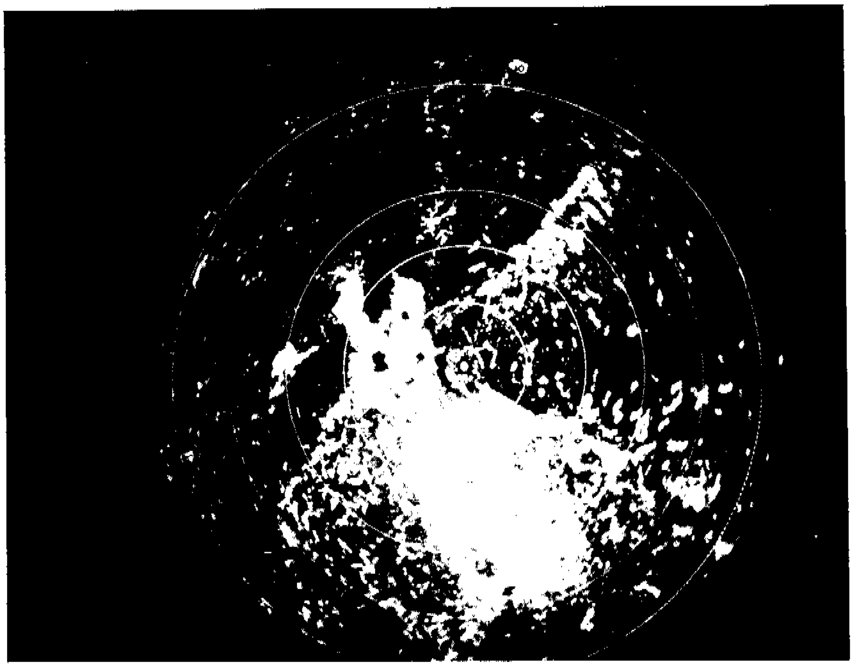


Fig. 19. Tin City PPI screen, 26 May 1978, 1830 ADT, showing sea-ice and sea-wave echoes.

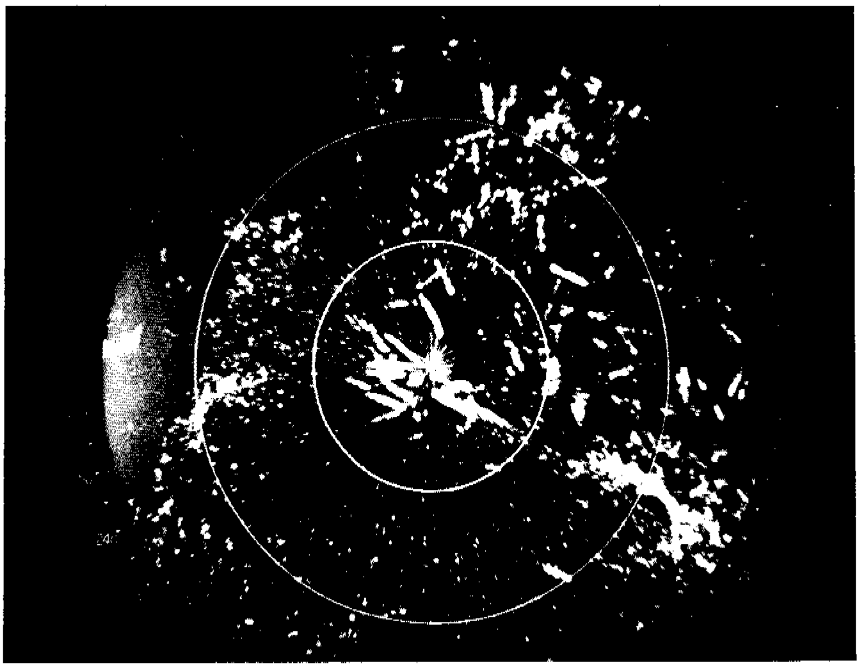


Fig. 20. Tin City PPI screen, 27 May 1978, 0755 ADT. Clear bird echoes, right-circular polarization.

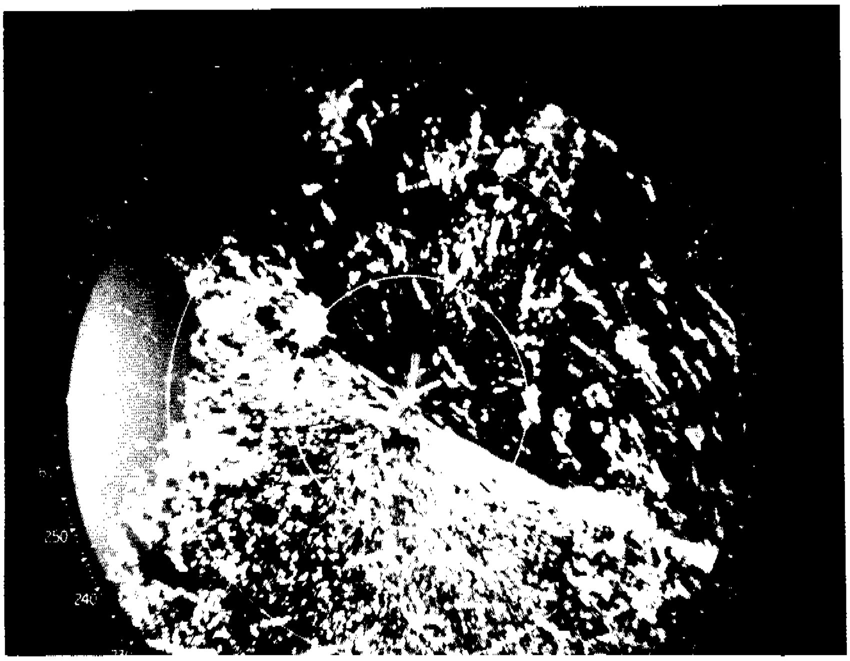


Fig. 21. Tin City PPI screen, 27 May 1978, 0952 ADT. Bird movement but considerable sea-ice clutter, horizontal polarization.

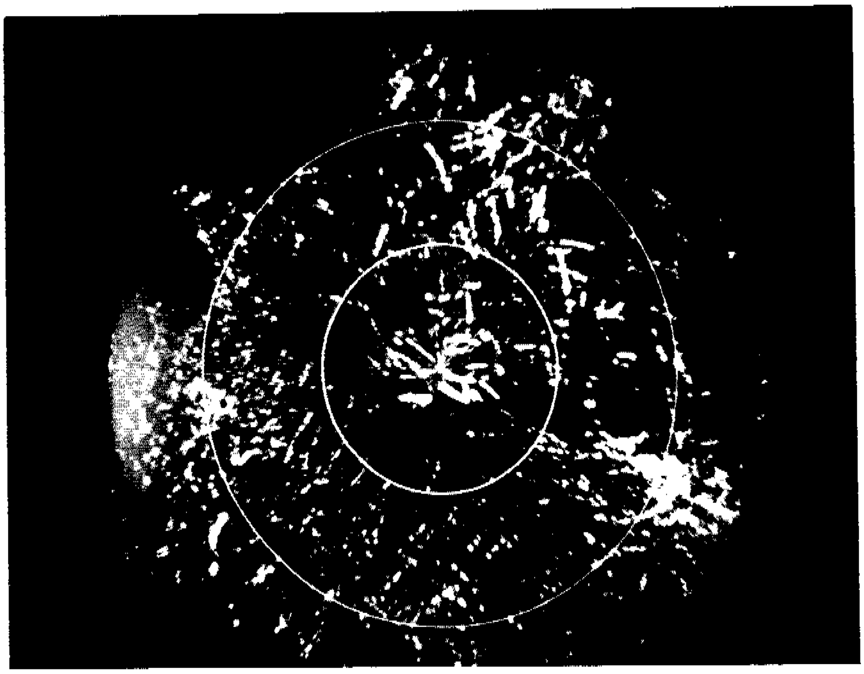


Fig. 22. Tin City PPI screen, 27 May 1978, 2139 ADT. Right-circular polarization.

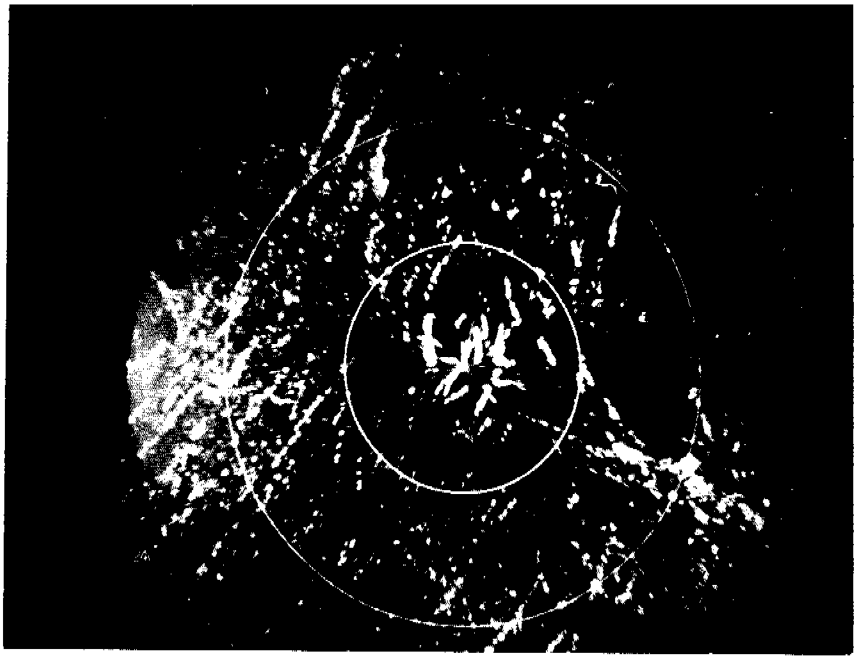


Fig. 23. Tin City PPI screen, 28 May 1978, 2131 ADT. Broad-frontal movement from southwest, right-circular polarization.

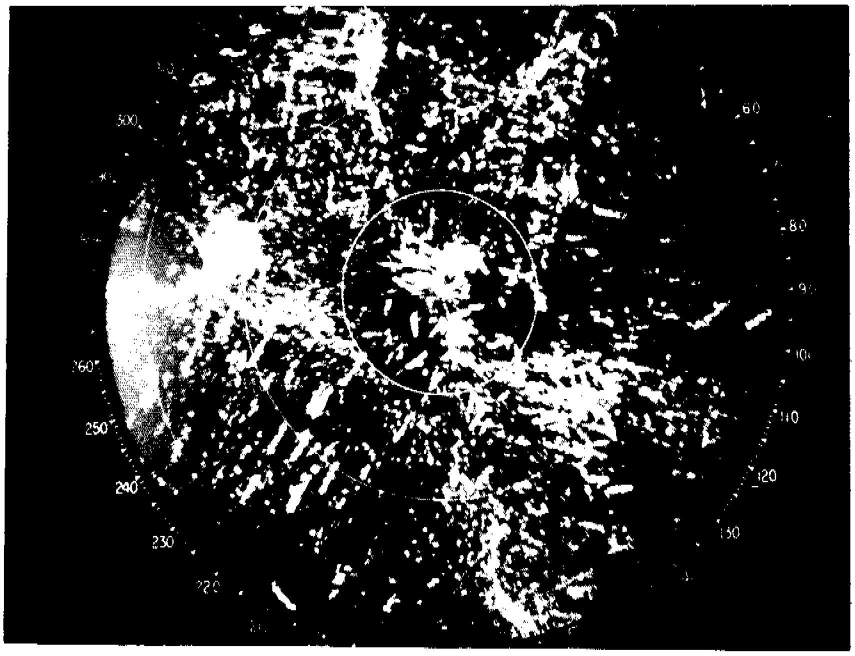


Fig. 24. Tin City PPI screen, 30 May 1978, 0824 ADT. Right-circular polarization.

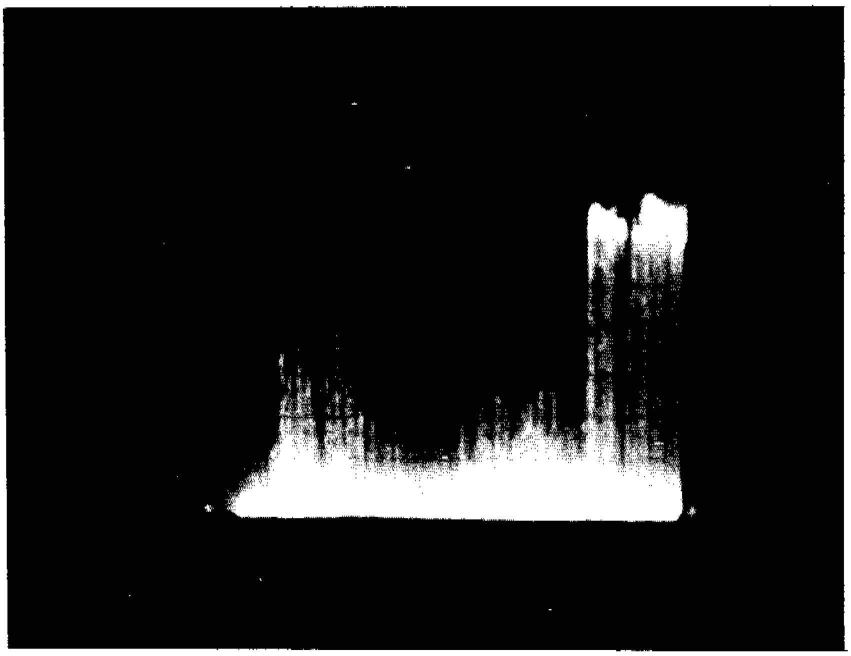


Fig. 25. Tin City A screen, single-sweep photograph showing sea-ice echoes, 19 May 1978, 1900 ADT.

Fig. 26. Landsat image of western tip of Seward Peninsula, 26 May 1978. Only a narrow strip of shore fast ice shows near Cape Prince of Wales but a rather broad expanse remains to the north.

ANNOTATED SPECIES LIST - Flock and Hubbard

The following annotated species list gives emphasis to observations by Joel Hubbard at Wales, Alaska from 20 May to 3 July 1978 but is also partially based on observations by Warren Flock at Tin City and includes some species seen only by him at Tin City or Wales in 1969 (17 May to 3 June), 1970 (9 May to 19 May), 1975 (14 May to 1 June), or 1978 (17 May to 12 June). Dates are for 1978 unless stated otherwise and are dates of first arrival unless indicated otherwise. Observations by Flock were at Tin City unless stated otherwise. The status indicated for several species (e.g. Rock Sandpiper, Baird's Sandpiper, Gray-cheeked Thrush, Red-throated Pipit, Yellow Wagtail, Golden-crowned Sparrow) may be conservative as a result of spending relatively little time in the habitats where they most commonly occur.

1. Yellow-billed Loon: fairly common in nearshore migration; first observed on 26 May, 7 on 27 May, 3 off ice edge on 28 May, 6 on 31 May, 4 on 1 June, 7 on 2 June (all flying north).

2. Arctic Loon: rare to uncommon in migration; 1 on water near ice edge on 28 May, 1 flying north along ice edge on 31 May, 1 on water near ice on 2 June, 1 near beach at south end of village on 4 June, observed 2 June 1969 by Flock.

3. Red-throated Loon: fairly common in migration; 1 flying inland along north slope of Cape Mt. on 25 May, 3 flying over ice edge on 27 May, 5 on 31 May (all flying north); migrants observed frequently to turn inland in vicinity of Wales, fairly common on tundra lakes near Wales (based on calls primarily).

4. Red-necked Grebe: rare; 1 observed about 100 m off ice edge on 22 May.

5. Pelagic Cormorant: fairly common in vicinity of Wales; early in period: always a few present on ice floes, on pressure ridges at edge of ice, or swimming or flying off the edge, many of earlier individuals flying south, perhaps to cliffs near Tin City; later in period: many moving north. Flock noted 40 and 65 on two ice floes on 3 June, near cliffs at Tin City where there is a colony. Also observed 25 May 1969 and 30 May 1975 by Flock.

6. Whistling Swan: rare to uncommon in migration; 3 flying north over Wales on 28 May, 1 flying north on 31 May, 2 on 5 June, 10 flying to southwest over Wales on 12 June, observed 2 June 1969 by Flock.

7. Canada Goose: lone bird observed on 15 May 1970 by Flock.

8. Black Brant: common to abundant in migration; flocks of 20-200 observed frequently during sea watch starting 21 May, all flying north; flocks of 20 and 75 on 21 May, 100 on 8 June, 200 on 19 June, 100 and 150 on 26 June, large flocks passing to north throughout last half of June.

9. Emperor Goose: rare in nearshore migration; 2 flying north along ice edge on 20 May, 3 flying northwest on 23 May, 6 flying north near shore on 15 June, observed 25 May 1969 and 30 May 1975 by Flock.

10. White-fronted Goose: rare in nearshore migration; 3 flying north off ice edge on evening of 27 May, 3 on 28 May.

11. Snow Goose: fairly common in migration; 50 in irregular vee flying WNW, flock of 60, and two groups of 3 and 4 at evening, all flying north on 21 May, 16 on 23 May, observed 5 and 9 June, observed 17 May 1969, 18 May 1970, 27 May 1975, and 22 May 1978 by Flock.

12. Pintail: the common puddle duck; 4 flying to north low at ice edge on 21 May, 4 flying inland on 21 May, 26 at edge of lake behind village on 23 May (mostly males); during sea watch most observations were of small groups of males flying generally north or inland through 4 June; observed 17 May 1969 and 18 May 1970 by Flock.

13. American Wigeon: one observed at Tin City on 18 May 1978 by Flock.

14. Shoveler: observed at Wales by Flock on 21 May 1969.

15. Green-winged Teal: fairly common; pair on pond behind village on 26 May, second pair present 27 May, at least 19 observed on lake behind village on 28 May, 3 pairs behind village on 9 June, fairly commonly foraging on lower slopes of ridges surrounding village, observed 31 May 1969 and 18 May 1970 by Flock.

16. Greater Scaup: uncommon; pair flying over ponds by road to airstrip on 6 June, observed 1 June 1969 by Flock.

17. Harlequin Duck: uncommon at Wales, pair flying north near ice edge on 20 May, other pairs flying north on 21 May, southeast on 22 May, and north on 27 May; observed 27 May 1978 at Tin City by Flock, 2 pairs there on 31 May 1978.

18. Common Eider: abundant in migration; flocks of 6-100 flying north parallel to ice edge 20 May; observed throughout study period, particularly numerous 20-21 May, 28 May; occasionally small groups stopped to forage along ice edge.

19. King Eider: uncommon during sea watch but abundant earlier in April (Sec. 2.1); flock of 100 flying southeast along ice edge on 21 May (both sexes); small groups, pairs, or singles foraging along ice edge during most observation periods; Erckmann reported seeing 70-100 from ice edge on 28-29 May, 3 immature males and 3 females in front of village on 7 June.

20. Spectacled Eider: rare; 2 flying north along ice edge on 27 May.

21. Steller's Eider: fairly common in migration; several groups of 4-8 each off ice edge on 20 May (more females than males), occasional small groups off ice edge on succeeding days (up to 15 birds), most numerous on 27-31 May.

22. Oldsquaw: abundant in migration; some pairs on tundra lakes, occasional flocks of about 12 foraging along ice edge, many males not in full summer plumage; flocks of 6-100 frequently in view during sea watch, most abundant 25-31 May.

23. Black Scoter: uncommon in migration; 1 on 31 May, 2 with flock of murres on 2 June, flock of 6 near south end of village among broken ice floes on 4 June, observed 1 June 1969 by Flock.

24. Red-breasted Merganser: fairly common; pair with 1 male following flying along ice edge to northwest on 22 May, pair in water on 27 May, 1 off ice edge on 31 May, 3 pairs at base of cliffs at Tin City on 29 May, females near south end of village on 4 June, most numerous 27 May to 2 June.

25. Rough-legged Hawk: rare; one flying below Tin City headquarters on 29 May (harassed by Raven), one over razorback behind Wales on 8 June.

26. Rock Ptarmigan: uncommon near Wales; pair plus another male calling along road from Tin City to trail to Wales on 30 May, 45 observed on snow field near Tin City on 17 May 1975.

27. Sandhill Crane: common during third week in May, then fairly common to uncommon to mid-June; several flocks (100, 100,34,50,100,35,11) on 21 May over near side of strait, first two in from the west, others from the southeast along the coast, 24 north of village near airstrip on 23 May, 17 foraging behind village on 8 June, 4 flocks of 5-6 each near airstrip on 9 June, observed 17 May 1969, 10 May 1970, 25 May 1975, and 19 May 1978 by Flock. The main migration had passed by arrival time in 1978 but was observed on 10 May 1970 by Flock (see Sec. 2.1).

28. Golden Plover: fairly common, 1 over school on 27 May, 5 behind village on 28 May, 5-10 pairs in immediate vicinity of village, observed on 28 May 1969 and 25 May 1975 by Flock.

29. Semipalmated Plover: rather rare at Wales; one foraging on wet tundra behind school on 23 May, 1 still there on 26 May, 1 on beach at south end of village on 3 June, 1 on beach on 22 June, observed on 17 May 1969, 13 May 1970, 25 May 1975, and 19 May 1978 by Flock, occurs regularly near headquarters at Tin City.

30. Wandering Tattler: rare; one observed behind the north end of the village on 31 May.

31. Long-billed Dowitcher: fairly common breeder in vicinity of village; 1 on wet tundra behind village on 26 May, 2 in from strait on 27 May.

32. Ruddy Turnstone: uncommon in migration; 2 on village beach on 26 May, 2 in from strait on 27 May, 1 behind village and 2 on beach on 27 May,2 at Tin City on 29 May, 4 on village beach on 28 May, 2 pairs on wet tundra behind village on 30 May, 4 on 1 and 2 June.

33. Black Turnstone: observed on 21 May 1969 at Wales by Flock.

34. Rock Sandpiper: rare to uncommon at Wales; 1 behind village on 5 June, 1 on saddle south of razorback on 8 June, observed on 25 May 1969, 25 May 1975, and 18 May 1978 by Flock, rather common near Tin City.

35. Pectoral Sandpiper: uncommon in migration and breeding, 6 on wet tundra behind village on 22 May, 4 in from strait north of village on 27 May, 2 on beach behind village on 2 June, 1 flight display near road to airstrip on 23 June, observed on 25 May 1969 by Flock.

36. Knot: rare, 1 observed along road to Tin City airstrip on 29 May, observed on 2 June 1969 and 27 May 1975 by Flock.

37. Dunlin: common on wet tundra, present in smaller numbers on drier slopes; present in numbers upon arrival on 20 May, observed 27 May 1969, 18 May 1970, and 18 May 1978 by Flock.

38. Baird's Sandpiper: rare near Wales; pair on saddle south of razorback on 8 June, observed on 28 May 1969, 12 May 1970, 26 May 1975, and 18 May 1978 by Flock, rather common near Tin City.

39. Semipalmated Sandpiper: common on lower areas; present on arrival on 20 May, observed 31 May 1969, 12 May 1970, and 18 May 1978 by Flock.

40. Western Sandpiper: abundant on lower areas, smaller numbers on wetter slopes; present on arrival on 20 May, observed 25 May 1969, 13 May 1970, 24 May 1975, and 17 May 1978 by Flock.

41. Red Phalarope: common; 1 foraging at ice edge at village on 27 May, 3 on tundra on 1 June, 75 on "Iceberg Lake" on 2 June, at least 110 on lake on 4 June, observed on 31 May 1969 and 1 June 1975 by Flock, abundant when ice went out at Tin City on 31 May 1969.

42. Northern Phalarope: uncommon; 2 behind village on 27 May, at least 10 with Red Phalaropes on Iceberg Lake on 2 June, 6 behind village on 4 June, observed 31 May 1969 by Flock.

43. Common Snipe: rather uncommon; 1 flew up briefly and winnowed at low altitude near large mound behind village on 26 May, 3-4 pairs may be in vicinity of village with at least 3 areas of winnowing on 9 June, observed 2 June 1969, 18 May 1970, and 25 May 1975 by Flock.

44. Parasitic Jaeger: uncommon; several over tundra on 28-31 May, 1 flying north along ice edge and then inland on 31 May, 3 observed from ice edge flying north on 2 June, observed 2 June 1969 by Flock.

45. Pomarine Jaeger: common; groups of 4 and 6 observed flying northwest from ice edge on 22 May, 2 along road to Tin City airstrip on 29 May, most abundant during sea watch from 27 May to 3 June, observed 27 May 1969 by Flock.

46. Long-tailed Jaeger: uncommon; 2 along road north from Tin City on 28 May, 3 along road to Tin City airstrip on 29 May, 3 over slope behind Wales on 30 May, pair breeding in lower Village Creek valley, observed 30 May 1969 and 25 May 1975 by Flock.

47. Glaucous Gull: common; most directional movement observed 26 May-1 June during sea watch.

48. Mew Gull: rare; 2 along beach at south end of village on 4 June, observed on 30 May 1969 by Flock.

49. Black-legged Kittiwake: abundant in migration, flying along ice edge more or less continually in loose flocks or scattered irregular lines of 10-75 birds, generally traveling north although many flying south when wind was from that direction, often observed flying from inland towards the cape, perhaps from Lopp Lagoon, especially in bad weather, *e.g.*, on 5-6 June moving south into a south wind.

50. Sabine's Gull: observed 31 May 1969 by Flock.

51. Arctic Tern: rare to uncommon; 2 observed over lake behind village on 28 May, 1 flying north along ice edge on 31 May and 1 June, at least 6 over tundra between village and airstrip on 3 June, pair consistently northeast of village a few 100 yards through June and early July, observed 31 May 1969 by Flock.

52. Common Murre: abundant in migration (not differentiated from Thickbilled, all those observed at close range were Common); most abundant during sea watch on 20-21 May, 27-31 May, and 2-3 June.

53. Black Guillemot: rare to uncommon in migration; 1 foraging next to ice edge on 22 May, also on 23 and 27 May.

54. Pigeon Guillemot: rare; several observed on water in front of village on 4 June.

55. Horned Puffin: rare close to shore; small flock flying north well out from shore on 10 June.

56. Tufted Puffin: rare close to shore; 1 observed on water out from village on 4 June, another about 1/3 of distance to Fairway Rock on water on 19 June.

57. Crested Auklet: probably abundant, few near enough to identify except possibly by size (obviously auklets and larger than Least), large numbers of auklets flying close to water surface on 28 May.

58. Least Auklet: probably abundant, large numbers flying over water surface.

59. Parakeet Auklet: probably common to abundant; 10 feeding along ice edge, probably others in flight farther out on 21 May, numerous on water and flying in small groups, mostly to the south, on 28-31 May.

60. Short-eared Owl: rare; 1 flying over ice toward village on 24 May, 1 flying over ice north of village on 27 May, observed 13 May 1970 and 25 May 1975 by Flock.

61. Snowy Owl: rare to uncommon; 1 on 29 May near Wales airstrip, 1 in lower part of Village Creek valley on 8 June, 1 south of village on 9 June, 1 on bench behind village on 16 June.

62. Horned Lark: rare; observed on 25 May 1975 by Flock.

63. Cliff Swallow: rare; observed on 21 May 1969 at Wales by Flock.

64. Tree Swallow: rare; 1 observed over village beach on 27 May.

65. Raven: pair on razorback behind village, regular in small numbers at Tin City.

66. Robin: observed 15 May 1970 by Flock.

67. Varied Thrush: rare to uncommon; 3 along bluff below Tin City headquarters on 29 May, 1 flying east over Wales school on 10 June, observed on 15 May 1970 and 19 May 1975 by Flock.

68. Bluethroat: observed on 26 May 1975 below headquarters building at Tin City by Flock.

69. Wheatear: rare to uncommon; 1 on wet tundra behind village on 22 May, 20-30 in from west across strait north of village on 27 May, 2 on slope at south end of razorback on 8 June, observed on 27 May 1969, 22 May 1975, and 18 May 1978 by Flock, apparently more common near Tin City than Wales.

70. Gray-cheeked Thrush: uncommon; 1 foraging in vegetation among boulders on west slope of razorback on 3 June, at least 8 near razorback on 8 June, observed on 26 May 1975 by Flock.

71. Water Pipit: fairly common breeder; 2 on north slope of Capt Mt. on 20 May, 1 on south exposure of cape giving flight song, plus 2 others on 20 May, pairs scattered along most upper rocky slopes by June, with estimated 6 to 10 pairs along slopes behind village, 2 undertaking song flights at base of razorback on 3 June, observed 15 May 1970 by Flock.

72. Red-throated Pipit: rare; 1 foraging at edge of rank vegetation below Tin City headquarters building on 29 May (throat and upper breast light rosy color, sides and flanks more heavily streaked than Water Pipit, otherwise rather similar), 1 in vegetation of lower bluffs at south end of village on 4 June, 2 there and 1 at Wales school on 5 June.

73. White Wagtail: uncommon but regular in occurrence: 1 on beach among refuse on 27 May, 2 on school roof on 28 May, 2 near navy field station and 1 at school on 31 May, probably 3-4 pairs breeding in village (navy field station, school, south end of village, one pair nesting in small building south of school), observed on 30 May 1969, 1 June 1975, and 28 May 1978 by Flock.

74. Yellow Wagtail: rare to uncommon; 6 in from strait and continuing inland at north end of village on 27 May, pair near bridge across Village Creek and probably nesting, 1 near navy field station on 6 June, observed on 29 May 1975 by Flock.

75. Yellow-rumped (Myrtle) Warbler: rare or accidental; 1 foraging in beach grass in front of school on 31 May (all field characteristics except that yellow crown patch was not obvious).

76. Wilson Warbler: rare; observed 27 May 1969 and 31 May 1978 at Tin City by Flock.

77. Brown-headed Cowbird: accidental; male observed at north end of village on 17 June.

78. Gray-crowned Rosy Finch: rare; observed on 26 May 1975 by Flock.

79. Redpoll (Hoary, Common): common in vicinity of Wales and Tin City, usually indistinguishable, especially common in taller vegetation, most appeared to have light rump, suggesting that the Hoary is the more common, perhaps outnumbering the Common by 2 to 1.

80. Savannah Sparrow: rare; 1 singing in vicinity of large mound behind village on 9 June, observed 28 May 1969 and 24 May 1975 by Flock.

81. Dark-eyed (Slate-colored) Junco: rare; observed 18 May 1975 by Flock.

82. Tree Sparrow: rare; 1 in rank vegetation below Tin City headquarters on 29 May, observed on 18 May 1970 and 19 May 1975 by Flock.

83. White-crowned Sparrow: rare to uncommon, all checked were Gambell's; 3 in rank vegetation below Tin City headquarters on 29 May, 1 in rank vegetation at south end of village on 4 June, observed 28 May 1969 and 17 May 1975 by Flock.

84. Golden-crowned Sparrow: rare to uncommon; song heard near village on 27 May, 1 observed near school on 28 May (small white patch at posterior edge of gold crown), observed 30 May 1969 and 26 May 1975 by Flock.

85. Fox Sparrow: rare; 1 frequenting area behind north end of village on 8 June and possibly on the week preceding, observed on 15 May 1970 and 18 May 1975 by Flock.

86. Lapland Longspur: abundant; most nest on small elevated sites on otherwise wet areas, areas surrounding nests on upper slopes usually drier, present on arrival by Flock at Tin City on 17 May and by Hubbard at Wales on 20 May, also observed upon arrival on 17 May 1969 and 3 days after arrival dates on 12 May and 17 May in 1970 and 1975, respectively, by Flock.

87. Snow Bunting: fairly common; probably at least 6 pairs nesting in the village, 2-3 pairs on razorback (1 female incubating and 1 carrying nest material), several in boulder fields near south end of razorback, a few pairs in various rocky slope areas, observed on arrival by Flock in all years (17 May 1969, 9 May 1970, 14 May 1975, and 17 May 1978).

☆ GPO 1979—667-096/1215