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Environmental Assessment of the Alaskan Continental Shelf

Final Reports of Principal Investigators
Volume 18. Biological Studies

US DEPARTMENT OF COMMERCE
National Oceanic & Atmospheric Administration
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US DEPARTMENT OF THE INTERIOR
Minerals Management Service

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The facts, conclusions, and issues appearing in these reports are based on interim results of an Alaskan environmental studies program managed by the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, and primarily funded by the Minerals Management Service (MMS), U.S. Department of the Interior, through interagency agreement.

DISCLAIMER

TABLE OF CONTENTS
Volume 18
Biological Studies

FINAL REPORT

EVOLUTION, PATHOBIOLOGY, AND BREEDING ECOLOGY OF LARGE GULLS (LARUS) IN THE NORTHEAST GULF OF ALASKA

AND

EFFECTS OF PETROLEUM EXPOSURE ON THE BREEDING ECOLOGY OF GULLS AND KITTIWAKES

BY

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Research Unit #96

National Oceanic and Atmospheric Administration
U.S. Department of Commerce
Environmental Research Laboratories
Boulder, Colorado

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

This final report of Research Unit #96 is addressed to the following tasks:

TASK A-4 -- Summarize and evaluate existing literature and unpublished data on the distribution, abundance, behavior, and food dependencies of marine birds.

TASK A-5 -- Determine the seasonal density, distribution, critical habitats, migratory routes, and breeding locales for the principal marine bird species in the study area. Identify critical species particularly in regard to possible effects of oil and gas development.

TASK A-6 -- Describe dynamics and trophic relationships of selected species at offshore and coastal study sites.

TASK A-28 -- Determine by field and laboratory studies the incidence of diseases presently existing in fish, shellfish, birds, and mammals for use in evaluating future impacts of petroleum-related activity.

This report provides information on the evolution, breeding ecology, disease aspects, and effects of petroleum exposure on the breeding ecology of the Gulf of Alaska Herring Gull group (Larus argentatus x Larus glaucescens), with supporting information on the effects of petroleum exposure on the reproductive productivity of Black-legged Kittiwakes (Rissa tridactyla).

There are six known large gull colonies along the northeast Gulf of Alaska between Cordova and Juneau in an area potentially impacted by the development of oil resources. These colonies are located at Egg Island, Copper Sands, Strawberry Reef, Haenke Island, Dry Bay, and North Marble Island. There is little information known about these colonies prior to this investigation. One of the goals of this study has been to assess the reproductive health of these gull populations. Reproductive indices are now available for three of these colonies over a multi-year time span. Additional information of comparative value is available for an interior Herring Gull colony near Glenallen.

This information indicates coastal gull populations have the potential for rapid increase with access to human garbage, sewage and refuse associated with increased oil operations, but their colonies are sensitive to disturbance during the breeding season. Gulls are associated with canneries, fish-processing houses, garbage dumps, sewer outfalls, and municipal water supplies along the coast of Alaska, and are clearly implicated with the spread of human disease in Alaska.

Large gulls are an excellent example of vertebrate "weedy" species, adapted to man-disturbed environments and to utilize artifical food. Future development in coastal Alaska, particularly in fisheries and petrochemical industries, will increase genetic contact between Larus populations and assist in the survival of hybrid forms in disturbed environments. The gene flow between large white-headed gull populations will be increased in future years as a secondary consequence of human activities, and may lead to a new adaptive peak in these commensal forms, with consequences for municipal health and sanitation.

Gulls are opportunistic, efficient predators on other seabird species, and increased gull populations potentially threaten the population stability of other Alaskan seabird species.

Very small amounts (20 microliters) of North Slope Crude Oil exposure to gull eggs in the field, at early stages of incubation, lead to high embryonic mortality. Embryonic resistance to petroleum exposure increases with the duration of incubation.

Gull behavior is altered by continued incubation of eggs killed by petroleum exposure. Adult gulls fail to respond with the normal production of replacement clutches, which usually follow clutch loss to natural causes. The combination of high egg mortality and alteration of adult behavior virtually elminates gull reproduction in experimental areas .

Weathered as well as "raw" North Slope Crude Oil significantly depress gull egg hatchability, but Black-legged Kittiwakes are apparently more resistant than gulls to the effects of oil exposure on egg surfaces.

Thus, while oil spills have a potentially depressing effect on gull reproduction, the net result of increased human development in coastal Alaska will be expanding populations of large gulls, with distinctly negative implications.

(Part I)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

(Part I)

ABSTRACT

Two large white-headed gulls, *Larus argentatus* and *L. glaucescens*, exist in a zone of overlap and hybridization along the southern Alaskan coastline. Mixed pairs, parental phenotypes, and intermediates are found within single colonies. The gulls inhabit geologically dynamic environments, ranging from recently deglaciated fjords, to earthquake-influenced sandbar barrier islands, to river deltas. Nesting habitat selection is flexible, and includes flat gravel bars, sloping grassy hillsides, and nearly vertical cliff faces. Onset of breeding is flexible within an individual colony. A mixed colony at the south of the Alsek River, which connects West Coast marine with boreal interior environments, exhibits most flexibility in timing of breeding.

Analysis of adult morphology and pairing indicates individuals of mixed genetic background survive to breed. The complete range of variability in primary feather pigmentation is expressed by the offspring of hybrid x *glaucescens* backcrosses. Mating patterns, however, are assortative, and include individuals of intermediate phenotype selecting mates of similar phenotypes (Chi-square = 102.64, 36 d.f., $p < .00001$), although exceptions do occur.

Adult gulls are not significantly different in morphological dimensions from population to population with the following exception: males from two Copper River Delta colonies are significantly different ($p < .01$) from all other colonies in bill depth at posterior nares. "Pure" types of *argentatus* and *glaucescens* do not differ significantly in any dimension except wing length, which is significantly greater in *argentatus* ($p < .01$). This may relate to the longer migration pattern

of argentatus, which breeds on boreal lakes and rivers and winters offshore from the Gulf of Alaska to southern California.

Mean wing hybrid indices become progressively darker along a northwest to southeast axis within the study area between Prince William Sound and Glacier Bay. Individual gulls within the study area are highly variable in primary feather pigmentation. The complete range of primary feather pigmentation is found within the colony at the mouth of the Alsek River at Dry Bay. As a general trend, mean wing hybrid indices increase in value from coastal populations most like glaucescens through intermediate populations in fjords and bays to an interior population of argentatus on a freshwater lake. Individual gulls in the Cordova City area show a slightly larger range of body measurements, primaries lighter than the mantle, and light irides, suggesting hyperboreus genes are present in the summer non-breeding Larus population.

There is an uninterrupted continuum of the categories of iris color within the study area, from populations most like glaucescens (dark brown irides) to populations clearly identifiable as phenotypic argentatus (bright yellow irides), with intermediate populations that have irides of light brown to light yellow. Neighboring colonies on the Copper River Delta sandbar barrier islands have strikingly similar distributions of iris hues. The mixed colonies of North Marble Island and Dry Bay share similar, although not identical distributions of iris hues and values. More kinds of iris color were found in the mixed colony at Dry Bay than in any other group examined.

Iris color is highly linked with primary feather pigmentation in gull populations in southern Alaska (Chi-square = 81.4, 36 d.f., $p < .001$). Light-eyed gulls tend to have dark primaries, dark-eyed gulls tend to have light primaries, and gulls with intermediate amounts of melanin in the primaries have irides of intermediate shades.

Gulls in southern Alaskan populations have orbital rings ranging from dark pink to bright yellow, with six intermediate hues connecting the extremes with increasing amounts of yellow pigment. Each population examined had a different composite orbital ring unlike those of other populations (Chi-square = 151.02, 77 d.f., $p < .001$). Some orbital rings in individual gulls were uniformly pigmented, while others were composed of as many as three hues. The mixed colony at Dry Bay had the greatest distribution of uniformly pigmented orbital rings as well as the most even distribution of orbital rings with combination hues.

The composite hybrid index, which unifies characters of primary feather pigmentation, orbital ring and iris color, indicates that gull populations show increasing *argentatus* influence along an axis extending from Prince William Sound southeast towards Glacier Bay. The major source of *argentatus* genes along the North Gulf Coast of Alaska is the mixed colony at Dry Bay, which serves as a partial bridge between coastal and interior populations. Gene flow is more in the direction of *argentatus* into *glaucescens* populations.

Clutch size of "pure" versus mixed pairs is not statistically different (2.89 - 2.93; $p < .05$), although there are significant differences in clutch size between *glaucescens* populations along the southern Alaskan coastline (2.05 - 2.93; $p < .01$). Comparative hatching success is highest (93%) in a mixed colony due to low rates of egg inviability and low rates of egg predation. Hybrid, F_2, and aparent backcross zygotes are not reduced in viability and demonstrate slightly enhanced fledging success (1.47 vs. 1.40 chicks per nest).

The summary comparison of the mean clutch size and the mean number of fledglings produced per nest provides the clearest picture of reproductive success in *Larus* colonies in southern Alaska. The colonies where interbreeding is occuring have a higher mean clutch size (2.9 versus 2.7 - 2.5) and net productivity (1.44 to 1.77) than colonies of either *glaucescens* (1.08) or *argentatus* (0.95) phenotypes. Although clutch size and fledging success of mixed versus "pure" pairs within the individual colony at Dry Bay are not statistically different ($p < .05$), the hybrid pairs are reproducing slightly better than the *glaucescens* phenotypes (1.47 vs. 1.40). In addition, southern Alaskan colonies with mixed populations are reproducing considerably more offspring per pair than colonies of either *argentatus* or *glaucescens* parental types.

L. argentatus and *glaucescens* are proposed as semispecies, since parental phenotypes as well as mixed pairs and intermediates are found within single colonies, and assortative mating is occurring even though hybrids are viable. The Pacific Coast *argentatus* complex, including *hyperboreus*, *glaucescens* and *occidentalis* is not usually included with the rest of the circumpolar *Formenkreis*, but recent information indicates that a chain of interbreeding groups extends up and down the Pacific Coast of North America and that members of this group are members of the Holarctic Herring Gull Formenkreis. The Glaucous-winged Gull is apparently the 'key' species in the Pacific Coast gull complex because it interbreeds with every other large white-headed gull with which it comes into contact.

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This field research could not have been completed without my best aide, companion, illustrator and advisor, my wife, Renee.

DEFINITIONS

allele
An alternative form of a gene at the same locus on the chromosome.

allopatric
Populations distributed in different dimensions of space, occupying mutually exclusive but usually adjacent geographical areas.

allopatric speciation
The separation of a population into two or more evolutionary units as a result of reproductive isolation caused by geographical separation of two subpopulations.

allozyme
A protein with an amino acid substitution but a similar enzymatic function to another such protein.

Artenkreis
A group of closely related species distributed as a partially overlapping mosaic within a given geographic zone. A zoogeographic species.

assortative mating pattern
The choice of individuals of similar phenotype as mating partners.

backcross
An individual of the F_1 or subsequent generations mating to an individual of the parental type.

chick
A young bird from time of hatching until full-grown and flying: technically a 'pullus'.

chroma
The degree of departure of a given hue from a neutral grey of the same value. Chroma scales depend upon the strength (saturation) of the sample evaluated.

circular overlap
The phenomenon in which a chain of contiguous and interbreeding populations curves back until the terminal links overlap with each other and behave as a good species, that is, non-interbreeding. As exemplified by a 'ring' species.

cline
A geographic gradient in a measurable character, or gradient in gene, genotype, or phenotype frequency.

coadapted gene complex

A group of genes in a population, adapted to a particular environment, which interact together, and enhance survival and reproduction in that environment.

conjunction

A connection of two or more subspecies, incipient species, or species to each other along narrow bands or separation by steep clines.

dispersal

The roughly random and nondirectional small-scale movements made by individuals rather than groups, continuously, rather than periodically, as a result of their daily activities.

distal

That portion of a limb or body member or appendage most distant from the main portion of the body.

ecotone

A habitat created by the juxtaposition of distinctly different habitats; an edge habitat; the area of transition between different habitats; an area of overlap in environments of different types.

ethological

Behavioral, particularly with reference to species-specific behavior elements, the phenotype of which is largely determined genetically.

F_1

The first offspring generation of a cross.

F_2

The second offspring generation of a cross.

F-ratio

The statistic appropriate to the analysis of variance.

fitness

The ability of an organism to survive and reproduce; the survival value and reproductive capacity of a given genotype relative to other genotypes in a population.

fledging

The term usually applied to the acquisition by a young bird of its first true feathers; when the process is complete the bird is 'fledged' and may for a short time be described as a 'fledgling.'

<u>Formenkreis</u>

Kleinschmidt's (1900) term for an aggregate of geographically representative (allopatric) species and subspecies.

founder principle

The principle that the founders of a new colony contain only a small fraction of the total genetic variation of the parental population. The differences are enhanced by different evolutionary pressures in the areas occupied by the two populations, acting in different population genetic environments; the result is increased divergence.

gene flow

The exchange of genetic factors between populations; the movement of genetic information between and among populations.

genotype

The totality of genetic factors that make up the genetic constitution of an individual; as contrasted to phenotype.

geographic isolation

The separation by geographical barriers of a population from the main body of the species.

hue

The notation of a color in the Munsell system which indicates its relation to a visually equally-spaced scale of 100 hues. The hue notation in this study is based upon three color-names: Red. Yellow-Red, and Yellow.

hybrid

The offspring of a cross of individuals belonging to two unlike natural populations; those differing in alleles at one or more loci.

hybrid index

A method for analyzing variation in dissimilar yet interbreeding populations of plants and animals, using numerical scores for the characters which differ between the two populations.

hybrid zone

Narrow belts (clines) with greatly increased variability in fitness and morphology compared to that expected from random mixing, separating distinct groups of relatively uniform sets of populations.

incubation period

The time between the onset of incubation of an egg and the date of hatching.

intergradation

Character gradients between groups of populations. Often refers to two or more clines for different characters in the same organism, and going in the same geographic direction.

intergrade

An individual which is the product of a cross between different parental types and which displays characters intermediate between those of the parental types.

introgression

The incorporation of genes of one species into the gene pool of another.

iris

The pigmented main portion of the eye, beneath the orbital ring (eyelid) and surrounding the pupil.

isolating mechanism

A property or properties of individuals that prevent successful interbreeding with individuals belonging to different populations.

Long Call

A series of loud calls given by a gull, associated with a series of postures, combining vocally elements of both sexual display and aggressive defense of territory.

mantle

The back, scapulars, and wing covers of a gull, together presenting an area of distinctive color which extends from the primaries across the rest of the wings and the back.

melanin

A protein forming dark pigments, resulting from the interaction of the enzymes tyrosin and tyrosinase.

migration

The relatively long-distance movements made by large numbers of individuals in approximately the same direction at approximately the same time, and usually followed by a return 'migration.' Compare with gene flow and dispersal.

monotypic

Having only one subspecies or form.

niche

The constellation of environmental factors into which a species (or taxon) fits; the outward projection of the requirements of an organism; its specific way of utilizing its environment. In other words, what the organism does, instead of where it lives (the habitat).

orbital ring

The fleshy portion of the eyelid of a gull visible when the eye is completely open, which forms a circle around the opened eye, and which is variously colored.

parapatric
Two or more subspecies, incipient species, or species which are in contact over a very narrow zone.

phenotype
The totality of characteristics of an individual (the appearance) which results from the interaction of genotype and environment.

philopatry
The tendency, or drive of an individual to return to its home area, especially for breeding. In German, Ortstreue (true to district).

polytypic
Having more than one subspecies or form.

population
Used here in a general sense, any group of organisms of a single species.

primary(ies)
The main flight feathers of a bird, on the distal end of the wing. Usually ten in number, and borne on the manus (carpometacarpus and distal phalanges).

range
The geographic distribution of a species.

Rassenkreis
A group of subspecies connected by clines. Some of its subspecies may be sexually or genetically isolated from each other.

remige
The main flight feathers of a bird (see 'primaries' above).

secondary contact
The rejunction of partially diverged populations derived from a common ancestor.

secondary intergradation
Intergradation between two geographic forms that at one time diverged in isolation.

selection pressure
The environmental resistance leading to differential survival and reproduction of genotypes.

Sewall Wright Effect
The tendency in small isolated populations for greater random variations to become fixed through random drift. The effectiveness of weak selection is low in small populations, which may thus exhibit unusual characteristics.

species group

A group of closely related species, usually with partially overlapping ranges (see '*Artenkreis*' above).

stepped cline

A cline with a very rapid change in gene frequency separating two regions with a relatively small change of gene frequency with distance.

subspecies

An aggregate of local populations of a species, inhabiting a geographical subdivision of the range of the species, and differing taxonomically from other populations of the species.

substrate

The geological formation, usually with vegetation superimposed, upon which a gull colony rests (e.g., sand dunes, rock cliff face, gravel bars, etc.).

subterminal

As applied to gulls, that portion of the main flight feathers (the primaries) prior to the tips.

sympatry

The occurrence of two or more populations in the same area; the existence of a population in breeding condition within the range of another population. As opposed to allopatry.

synchrony

The tendency of a population of colonial birds to reproduce within a short period of time of each other. It is an adaptive anti-predator strategy.

territory

An area defended by an animal against other members of the same species, and occasionally against members of other species.

Throwback

That component of the "Long Call" in certain gulls (e.g., *argentatus*), in which the head is moved rapidly up and to the rear through an arc extending over the back, from a low, nearly horizontal position.

value (Munsell)

The notation of a color indicating the degree of lightness or darkness in relation to a neutral grey scale, extending from absolute black to absolute white.

zygote

A fertilized egg; the cell (individual) that results from the fertilization of an egg cell; a diploid cell formed by the union of male and female gametes.

CHAPTER 1: INTRODUCTION

The evolution and systematics of the Herring Gull group (Larus argentatus and relatives) are complex. A circle of interbreeding races (Formenkreis) extends around the Northern Hemisphere (Stresemann and Timofeeff, 1947). Where the presumed terminal populations on the circle overlap in Western Europe, extreme varient races (L. argentatus and L. fuscus) may act as good species (Paludan, 1951; Goethe, 1955). The critical linking populations occur in areas difficult to visit (e.g., Canadian arctic, east-central Siberia, sub-arctic Alaska), and fundamental questions remain concerning the distribution, intergradation, or isolation among these circumpolar populations. This section of the report concerns the evolutionary dynamics of the western North American portion of the circumpolar Larus complex, more specifically with the large white-headed gulls of the Pacific Northwest, L. hyperboreus, L. glaucescens, L. argentatus, and L. occidentalis.

Spatial isolation, genetic divergence, and subsequent rejunction of populations that may or may not have attained reproductive isolation is regarded as classical speciation theory (Sibley, 1961; Mayr, 1963; Short, 1969). Concurrent with the development of genetic divergence is the evolution of attributes which may, if fully formed, reduce the potential for interbreeding. These attributes have been termed reproductive isolating mechanisms (Dobzhansky, 1937, 1951).

One of the major examples used by Mayr (1963) to support the importance of spatial isolation and the evolution of isolating mechanisms in the speciation process is that of the large white-headed gulls

(Larus) of the Northern Hemisphere. The data on gulls have been interpreted as providing a good example of a dynamic evolutionary system in which gulls may act as distinct species in one region while hybridizing extensively in another (Ingolfsson, 1970). Zones of hybridization can be observed in a breakdown of interspecific isolation in such factors as nest site selection, timing of breeding, and morphological or behavioral characters concerned with or influencing mate selection (Smith, 1966b).

The Larinae (gulls) as a group may have evolved in the North Atlantic or North Pacific regions. Gulls currently have a world-wide distribution of 42 species (Fisher and Lockley, 1954), with 16 species of gulls now found in the North Pacific (Vermeer, 1970). At least 6 species of North Pacific gulls overlap in narrow zones of sympatry along the North Pacific rim (Williamson, 1966) but the question of reproductive isolation in western North American gull populations remains only partially explored. Smith (1966b) focused his study on gull evolution in the eastern Canadian arctic, where he found four sympatric species reproductively isolated by pre-mating mechanisms. Evidence has accumulated since his study suggesting that pre-mating isolating mechanisms are incompletely formed or have broken down in the western North American large white-headed gull populations.

In search of answers to questions of reproductive isolation among these gulls, I have studied gull morphology and breeding biology in Alaska for seven field seasons (1971-1977). Results of this study relate the Alaskan situation to the larger evolutionary history of northern gulls and the connection to the circumpolar Formenkreis.

With the advent of continental ice masses during the Pleistocene, large white-headed gull stock broke up into geographically isolated populations in refugia in Europe, Asia, and North America (Rand, 1947; Macpherson, 1961). Some of these geographically isolated populations, for instance Larus marinus, a large dark-backed predatory species, and L. argentatus, a medium-sized grey-backed scavenger, evolved complete pre-mating isolating mechanisms in species recognition, timing of breeding, and nesting habitat selection. Hybrids between marinus and argentatus are rare except in artificial situations (Grey, 1958; Jehl, 1960; Andrle, 1972). A classic example of populations formerly in geographic isolation is the secondary contact between L. fuscus and L. argentatus, which are now sympatric in Europe at the terminal ends of the circumpolar Formenkreis. These gulls have evolved partial isolating mechanisms; however, these mechanisms were insufficient to prevent occasional hybridization after the post-glacial range expansion of argentatus to Europe from North America. The contact between hyperboreus and argentatus in Iceland since 1925 is an example of lack of pre-mating isolating mechanisms. Prior to 1925, hyperboreus was the only large white-headed gull breeding in Iceland, but a hybrid swarm with argentatus has been formed as argentatus populations colonize Iceland from Britain (Ingolfsson, 1970).

Past workers on northern gulls (e.g., Smith, 1966b; Ingolfsson, 1970) did not directly attempt to relate their results to the concept of the Formenkreis as developed by Stresemann and Timofeeff (1947). Recent studies of gulls in western North America (Strang, 1977; Hoffman et al., 1978) have not linked the Pacific Coast Larus populations to the circumpolar chain of interbreeding races. I have developed the hypothesis during the course of my studies on Pacific Coast gulls which states, in brief, that gull populations other than *argentatus* (already known to be an important link) are part of the *argentatus-fuscus* *Formenkreis*. There is good evidence that a chain of interbreeding groups extends down the Pacific Coast and that members of this chain are part of the circumpolar Herring Gull *Formenkreis* (Fig. 1).

The Pacific Coast *argentatus* complex has not been previously included with the rest of the circumpolar chain of interbreeding races due to the lack of sufficient knowledge of *Larus* populations in the area. Recent investigations, however, have partially clarified the situation. Strang (1977) found a high proportion of intermediates on the Yukon-Kuskokwim Delta, indicating gene flow between *hyperboreus* and *glaucescens* in western Alaska. Williamson and Peyton (1963) and Patten and Weisbrod (1974) found intermediates and mixed pairs between *argentatus* and *glaucescens* in southern Alaska. Scott (1971) and Hoffman et al. (1978) have examined mixed pairs, intermediate adults, and mating behavior between *glaucescens* and *occidentalis* in western Washington.

I focused my investigation most intensively on two members of the genus *Larus* in the Pacific Northwest and the results of this study form the substance of my dissertation. The Glaucous-winged Gull (*L. glaucescens*) which breeds along the coast from Washington state to the Aleutians, is quite closely related to the Herring Gull (*L. argentatus*), a common, widely distributed species. Herring Gulls make up a low proportion of the breeding gulls in the northeast Gulf of Alaska, but occur more frequently in migration, in winter, and offshore. The Herring Gull subspecies *smithsonianus* breeds on boreal lakes in interior Alaska, British Columbia, and the Yukon, while *glaucescens* is confined

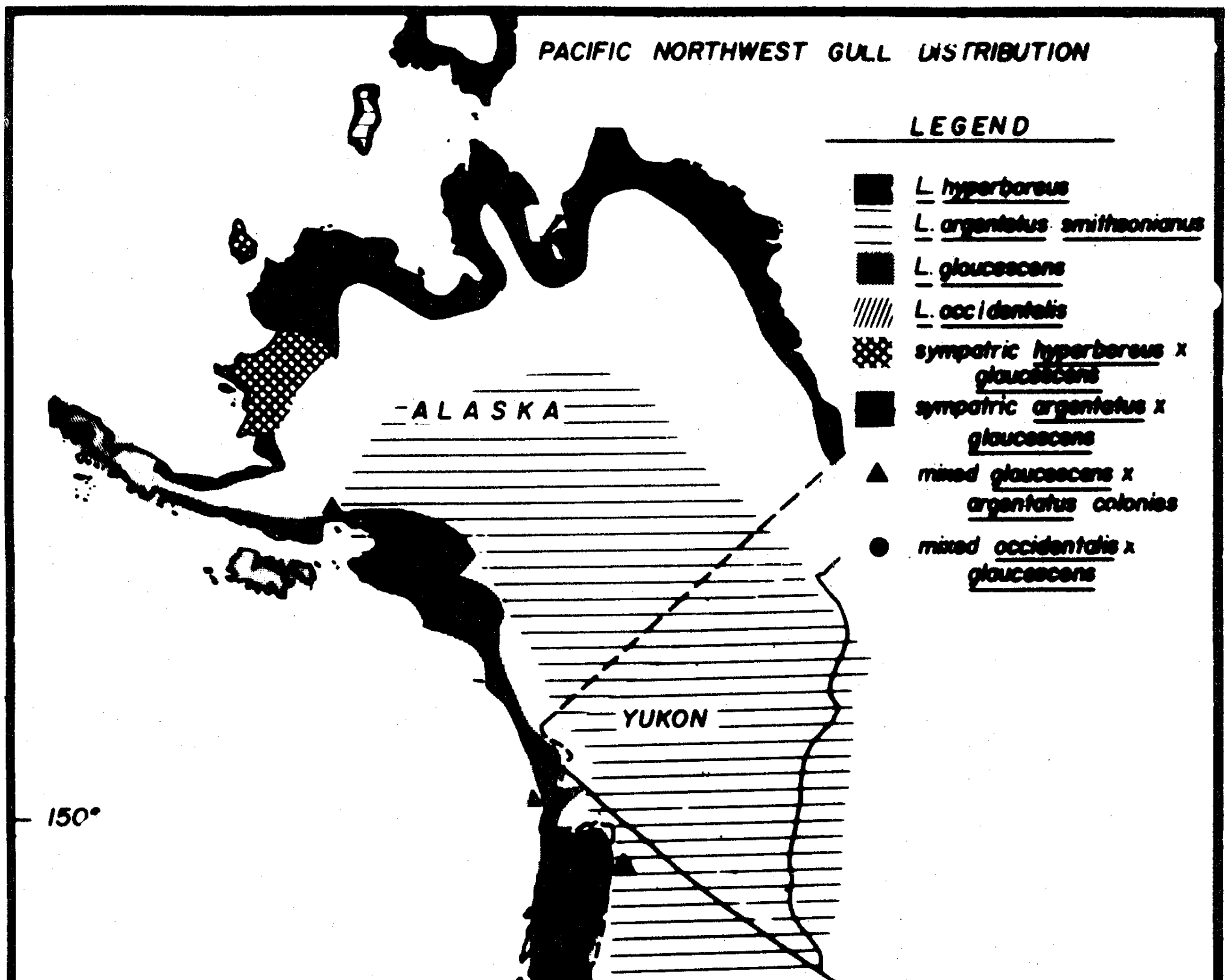

PACIFIC NORTHWEST GULL DISTRIBUTION
LEGEND
L. hyperboreus
L. argentatus smithsonianus
L. glaucescens
L. occidentalis
sympatric hyperboreus x glaucescens
sympatric argentatus x glaucescens
mixed glaucescens x argentatus colonies
mixed occidentalis x glaucescens
ALASKA
YUKON
BRITISH COLUMBIA
WASHINGTON
150°
140°
0 300 KILOMETERS

Figure 1

to coastal areas. *L. glaucescens* resembles *L. a. smithsonianus* in plumage characters, except that the black pigment on the distal ends of the primaries in *smithsonianus* is replaced in *glaucescens* by a light grey matching the rest of the mantle. The iris of *glaucescens* is dark brown while that of *argentatus* is yellow. These two forms are considered separate species in the A.O.U. *Checklist of North American Birds* (1957) but the existence and extent of hybridization between the two were unknown in 1957 and thus their taxonomic and ecological relationships were unclear. In some areas hybrids are common, notably where rivers such as the Susitna and Alsek break through the high range of mountains separating the south coast of Alaska with the interior (Fig. 1).

My previous studies of breeding biology of *glaucescens* and *argentatus* indicated the possibility of tracing gull eggs and chicks of known hybrid or apparent backcross ancestry through the breeding season to the fledging stage (Patten, 1974; Patten and Patten, 1975, 1976, 1977, 1978). In the current studies, I have examined allopatric and sympatric populations of *argentatus* and *glaucescens* in southern Alaska in search of answers to several sets of questions. The first series of questions concerns aspects of breeding biology:

(1) Are there pre-mating or pre-zygotic mechanisms preventing the formation of hybrid zygotes through differences in nesting habitat selection, timing of breeding, or species recognition?

(2) Is mutual attraction between the sexes of *argentatus* and *glaucescens* weak or absent?

(3) Are post-mating or zygotic isolating mechanisms reducing the viability or fertility of hybrid zygotes (e.g., are the eggs fertile)?

(4) Are hybrid zygotes reduced in viability or inviable (indicated by reduced clutch size, reduced hatching or fledging success)?

(5) Are the F_2 or backcross hybrids reduced in viability or fertility?

The second series of questions concerns aspects of morphology:

(1) Are the adult gulls different in morphological dimensions from population to population in southern Alaska?

(2) What is the distribution of primary feather pigmentation and soft part colors (orbital ring, iris, feet and legs) among the different populations?

(3) Are the soft part colors and primary feather pigmentation genetically linked?

(4) What are the mating patterns among these gulls?

My intent in answering these questions is to clarify the taxonomic and ecological relationships between glaucescens and argentatus; relate the southern Alaskan situation to the larger Formenkreis; and aid in further understanding the complex systematics of the Herring Gull group.

Ethological analysis of relationships between gulls in the Pacific Northwest has not been a major focus of this study for the following reasons. Tinbergen (1972) has demonstrated that the complete series of postures associated with the "Long Call" in argentatus involves a motion (the "Throwback") in which the head is moved rapidly up and backwards through an arc, from a low, nearly horizontal position. As the head is lowered from the "Throwback" position, a series of loud calls is given by the gull, combining vocally elements of both sexual display and aggressive defense of territory. *L. occidentalis* and *L. glaucescens* make the "Long Call" but lack the throwback posture. All other displays, such as "Choking," "Mew Call," and "Aggressive Threat," are *identical* in the two species (Tinbergen, 1972; underlining mine).

A study of vocalization in the large gulls of the Pacific Northwest, including *argentatus* and *glaucescens* calls recorded in southern Alaska, is being conducted by J. L. Hand (pers. comm.). Analysis of *glaucescens* and *argentatus* "Long Calls" is incomplete, but sonagrams of "pure" *glaucescens* and *occidentalis* are quite different, yet the gulls interbreed. Clearly different vocalizations are not functioning as pre-mating isolating mechanisms in this case.

The purposes of this research, therefore, are threefold. First, I examined morphology, plumage characters, and breeding biology of large gulls in southern Alaska for the status of characters which may act as isolating mechanisms. Second, I explored theoretical alternative hypotheses for the existence of a narrow hybrid zone between *argentatus* and *glaucescens* in south coastal Alaska. Finally, I related the information gathered during this study to the larger problem of gull relationships within the *Formenkreis*. The nature of this study is thus to examine morphology, reproductive biology, and fledging success in colonies of *glaucescens* and *argentatus* in southern Alaska (Fig. 2). These colonies have been selected for research because of the unknown character of the populations inhabiting the sites, and the potential for sympatry between species.

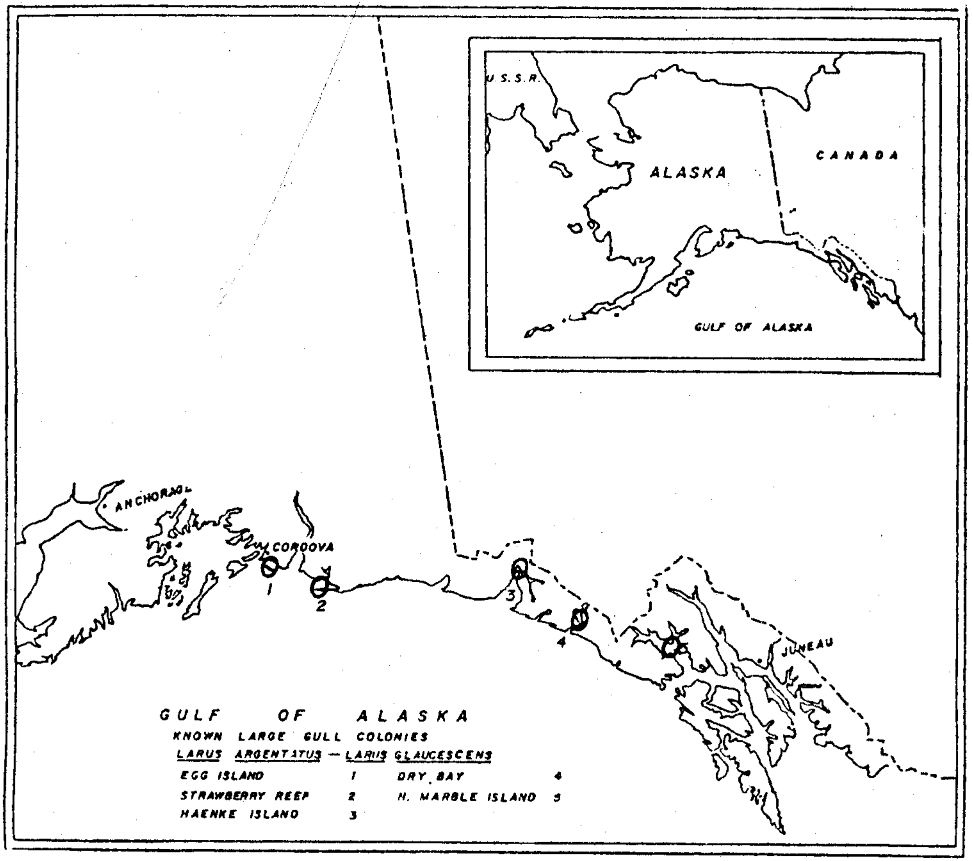


Figure 2. Map of the northeast Gulf of Alaska, showing known large gull colonies of *Larus argentatus* - *Larus glaucescens* (Inset: map of Alaska and northwest Canada showing Gulf of Alaska.)

CHAPTER 2: CURRENT STATE OF KNOWLEDGE

I. Palearctic

The morphology of Eurasian *Larus* has been studied over an extended period of time by various authors. Hartert (1921), Pleske (1928), Stegman (1934), Meinertzhagen (1935, 1950, 1954), Geyr (1938), Stresemann and Timofeeff-Ressovsky (1947), Witherby (1949), Witherby et al., (1958), Voipio (1954), Voous (1959, 1961, 1962, 1963), Portenko (1963), Tinbergen (1960), Goethe (1960, 1961), Bianki (1967), Brown (1967), Barth (1967a,b, 1968, 1975), Harris (1970), and Verbeek (1977) have analyzed aspects of the Palearctic *Larus argentatus* - *Larus fuscus* complex. Conflicting interpretations of morphology and behavior at times have inhibited attempts to resolve dynamic, highly complicated evolutionary problems of variation in foot and mantle coloration and in ecological and ethological segregation.

Geyr (1938), Stresemann (1947), Voipio (1954), Voous (1959), and Kist (1961) have studied the problem of the origin of yellow-footed (*L. argentatus cachinnans* and *L. fuscus* group) and pink-footed (*L. argentatus* group) gulls. These authors agree that during the Pleistocene an ancestral *Larus* population was divided into two refugia by the East Siberian Ice Barrier, with the populations that evolved into the pink-footed *argentatus* grouped on the east side of the barrier, and the populations that evolved into the yellow-footed *cachinnans* on the west side in the Aralo-caspian area. Ancestral *argentatus* dispersed in interglacial times over North America, leading to gradual development of the pink-footed american group, which includes *glaucescens* and *occidentalis* among others (see below). Post-glacially, L. a. smithsonianus emigrated to Europe from eastern North America, coming into contact with the westward-expanding cachinnans-fuscus group, to which argentatus is partially isolated, and forming the classic overlap of a "ring" species. However, after the Pleistocene, L. argentatus also spread into interior Siberia, forming the subspecies vegae and birulai. The pink-footed populations of birulai, moving west, met the populations of the yellow-footed L. a. antelius, moving east. Large-scale hybridization took place in central Siberia, where no geographical barriers exist, thereby forging the connecting link in the Palearctic chain of races of the Formenkreis. Indeed, Jungfer (1956) reported on the occasional arrival of the siberian Herring Gulls (birulai) in the North Sea, indicating that westward movement is still occuring.

The Formenkreis, as developed by European authors, is now best regarded as somewhat of an over-simplification. This is due to previous lack of information concerning the western North American populations. These can also can be linked to the Formenkreis, as demonstrated below.

II. Nearctic

The morphology of large white-headed gulls of the Nearctic argentatus group has been studied since the last century with virtually continuous debate over aspects of species status. Research has focused on two major geographical areas: the high arctic, and more recently, the West Coast. The status of the arctic forms of hyperboreus, thayeri, kumlieni, and argentatus has been examined by Henshaw (1884), Ridgway (1886), Dwight (1906, 1919, 1925), Oberholser (1918), Bishop (1927), Stemann (1934), Portenko (1939), Rand (1942, 1948), Bailey (1948), Salomonsen (1950), Manning et al. (1956), Johansen (1958), Macpherson (1956, 1961), Jehl and Frohling (1965), Smith (1966a,b, 1967), Ingolfsson (1970) and Knudsen (1976). Research interest in Nearctic *Larus* has been in aspects of primary feather, iris, and orbital ring coloration, rather than in foot and mantle pigmentation as in Eurasian large gulls. Studies have demonstrated that *hyperboreus* and *argentatus* are reproductively isolated in the eastern Canadian arctic, but they interbreed in Iceland. The taxonomic positions of *kumlieni* and *thayeri* remain unclear pending results of ongoing research (cf. Knudsen, 1976).

The West Coast forms, *occidentalis*, *glaucescens*, *argentatus* and *hyperboreus*, have been studied by Dawson (1909), Swarth (1934), Shortt (1939), Pearse (1945), Vermeer (1963), Williamson and Peyton (1963), Williamson (1966), Scott (1971), Patten and Weisbrod (1974), Hoffman (1976), Patten (1976), LeValley (1976), Strang (1977) and Hoffman et al. (1978). A literature review of the evolutionary status of these West Coast gulls, together with the North Pacific *vegae* and *schistisagus*, suggests none of these populations are reproductively isolated by premating mechanisms, since they interbreed in narrow zones of sympatry (Williamson, 1966). The contact between these forms clearly bears further study.

III. Narrow Hybrid Zones in Vertebrates

Moore (1977) recently reviewed the literature on vertebrate hybridization and discussed the existence of narrow hybrid zones in vertebrates other than *Larus*. I will briefly describe the four hypotheses presented by Moore as explanations for these zones in order that I may explore the theoretical aspects of interbreeding in the contact zone between *argentatus* and *glaucescens* in southern Alaska.

The ephermeral-zone hypothesis states that hybridization will end either in speciation or fusion of the hybridizing taxa by means of introgression (Dobzhansky, 1940; Sibley, 1957; Wilson, 1965; Remington, 1968). Known examples of stabile hybrid zones, such as the contact between *Corvus corone* and *C. cornix* in central Europe, and the situation between *Colaptes auratus auratus* and *C. a. cafer* on the Great Plains, provide evidence against this hypothesis (Mayr, 1963; Short, 1965, 1969, 1970; Moore, 1977).

The dynamic equilibrium hypothesis allows for stabile hybrid zones. Where hybrids are confined to a small area by steep selection gradients, "crystallization" of antihybridization mechanisms might be prevented by "naive" immigrants from the parental populations even though hybrids are selected against. This hypothesis reconciles the existence of narrow hybrid zones with the concept of co-adapted gene complexes, and states that if two populations have diverged to the point where the hybrids suffer depressed fitness, gene flow through the hybrid zone into the parental populations should be inhibited by selection (Bigelow, 1965). Where selection gradients are steep, intergradation should be restricted to a narrow zone between the parental populations. Although hybrids might be less fit than parental phenotypes, only a few individuals in or near the zone of secondary contact would be exposed to selection against hybridization, while a much larger proportion of the parental phenotypes would never experience this selection pressure. Gene flow from parental populations into the hybrid zone could "swamp" alleles which cause individuals to avoid hybridizing, and thus hinder the evolution of isolating mechanisms. Selection might also be slow, giving the appearance of a stabile zone.

A third hypothesis, which could also account for a stabile hybrid zone, is that hybrids are actually more fit than the parental phenotypes in the narrow zones in which they occur. This hypothesis has been put forward by botanists for some time (Anderson, 1949; Muller, 1953; Grant, 1971) but until recently has not been given serious consideration as an alternative to the ephemeral hybrid zone and the dynamic-equilibrium hypothesis for animals (Moore, 1977). Short (1970) pointed out that ephemeral hybrid zones are the exception rather than the rule in avian hybrids, and concluded that these hybrids are actually more fit than parental phenotypes in stabile hybrid zones, although strong selection may occur in parental populations against immigrant genes (Short, 1972). The hybrid superiority hypothesis states that the range of a hybrid population is determined by the extent of the environmental conditions within which the hybrids are superior. Most vertebrate hybrid zones are, in fact, narrow (Moore, 1977).

The fourth hypothesis explored to account for the narrow contact zone between <u>argentatus</u> and <u>glaucescens</u> is based upon the following logic: hybrids, in some cases, can succeed in environments where competition from parental phenotypes is weak (Anderson, 1949). Ecotones are one such area, and Moore (1977) suggested that stabile hybrid zones are narrow because they tend to occur in ecotones which are themselves narrow.

Exploration of the data collected in the narrow contact zone between argentatus and glaucescens in southern Alaska may provide sufficient insight to allow discrimination among the various hypotheses stated above. I believe they are not mutually exclusive, however, and the "best fit" of the southern Alaskan Larus situation may involve combinations of one or more hypotheses.

IV. The Breeding Biology of Large Gulls

A review of allopatric breeding biology of large gulls aids in understanding selective forces which may operate upon interbreeding forms discussed in the following chapters. The breeding biology of argentatus in Europe and eastern North America has been studied in detail by Goethe (1937), Paynter (1949), Paludan (1951), Tinbergen (1960), Harris (1964), Ludwig (1966), Keith (1966), Brown (1967b), Kadlec and Drury (1968), Drury and Smith (1968), Kadlec et al. (1969), Parsons (1971, 1975), Drury and Nisbet (1972), and Hunt (1972). Nesting habitat selection is flexible (Drury and Nisbet, 1972) and includes marshes (Burger, 1977), sand dunes (Tinbergen, 1960), and cliff faces (Emlen, 1963; Goethe, 1960). Average clutch size in argentatus is nearly always three, and variations are small. Most egg loss is due to predation, and infertility rate is low. Hatching success is usually 60 to 80 percent. Herring Gulls raise an average of one young per pair per year to fledging. Critical factors affecting hatching and fledging rate are egg and chick loss through cannibalism, chick mortality due to aggressive behavior of adults, and weather conditions during the breeding season.

In contrast to the intensive investigations of North Atlantic argentatus, few researchers have studied large gulls along the Pacific Coast of North America. The breeding biology of the Western Gull (L. occidentalis) has been studied by Coulter (1969), Schreiber (1970), Harpur (1971), Coulter et al. (1971), Hunt and Hunt (1973, 1975, 1977), Hunt and McLoon (1975). Most aspects of the breeding biology of occidentalis are similar to East Coast argentatus, or North Pacific glaucescens (see below) but nesting habitat selection differs due to drier conditions on nesting islands (Hoffman et al., 1978). Hunt's (1977) studies have demonstrated the apparent failure of sex recognition in the formation of female-female pairs in occidentalis.

The breeding biology of the Glaucous-winged Gull (L. glaucescens) in the Pacific Northwest has been studied by Schultz (1953), Vermeer (1963), Ward (1973), Patten (1974), Hunt and Hunt (1976), and Patten and Patten (1975, 1976, 1977, 1978). Results of these investigations indicate glaucescens is quite similar to argentatus in nesting habitat flexibility, average clutch size, low infertility rate, moderate to good hatching success, and variable chick mortality and fledging success, often related to availability of food. The Glaucous-winged Gull has the same plumage sequences as the Herring Gull (Schultz, unpub. ms.) and similar adaptability to urban environments (Ward, 1973).

Strang's studies (1972a,b, 1973, 1974, 1977) of the breeding biology of hyperboreus in western Alaska are the only works available on the reproductive productivity of this species. Nesting habitat includes both coastal and marshy sites, clutch size approaches three, infertility rate is very low, hatching success varies around 50%, and mean productivity is slightly over one chick per pair per year.

Philopatry has been documented for several gulls, including argentatus and glaucescens (Gross, 1940; Paynter, 1949; Tinbergen, 1953, 1961; Drost et al., 1961; Ludwig, 1963; Vermeer, 1963). There is a strong tendency for adult gulls to return to natal colonies for breeding. Voous (1961) showed that mantle coloration in L. a. argenteus was related to colony of origin, and that the relationships to neighboring colonies were not gradual in minor details, although apparently gradual on a larger geographical scale. This suggests a degree of isolation between members of adjoining colonies, which in turn leads to rapid evolutionary potential (Sewall Wright Effect).

In summary, studies of the breeding biology of allopatric large gulls indicate that nesting habitat selection is flexible, clutch size approaches three, infertility rate is low, and normal productivity is one chick per pair per year. Adult gulls tend to return to colonies of origin for breeding, suggesting a degree of isolation between neighboring colonies.

CHAPTER 3: DESCRIPTION OF STUDY AREAS

I. The General Milieu

The location of this study is the south coast of Alaska between Juneau and Prince William Sound, including a fresh water lake in the interior, north of Valdez (Fig. 2). The south coast of Alaska is a wild, relatively uninhabitated stretch of North Temperate shoreline, exhibiting dramatic changes in relief, with high mountain ranges in close proximity to marine environments. Fjords, bays, river deltas, and occasional sandy beaches indent the coastline. The basic factors affecting climate are similar at practically all points along the coastal study area (USDC, 1963). The climate is basically maritime, with nearby ocean areas modifying daily and seasonal temperatures at sea level to within rather narrow limits. The area is exposed to frequent low pressure systems moving out of the Gulf of Alaska, providing abundant precipitation. The high, rugged Fairweather, St. Elias, and Chugach Mountain Ranges (to 5800 m) intensify precipitation from onshore movement of moisture-laden air. Glacier Bay Ranger Station receives 225 cm of precipitation annually (Streveler and Paige, 1971), Yakutat 338 cm (Alaska Geographic, 1975), and the Copper River Delta 250 cm (USDC, 1963). Maximum precipitation over the entire area usually occurs from August through November. Average annual snowfall occurs mainly from November through March and ranges from 310 cm to 866 cm, with means at Yakutat of 370 cm and at Cordova of 317 cm (USDC, 1963). Much greater amounts of snowfall in the mountains have caused the formation of glaciers, which may be massive. The Malaspina Glacier northwest of Yakutat is larger than the State of Rhode Island.

The sky is rather persistently cloudy, averaging 80% coverage. Summer days are often characterized by overcast skies, rain, and cool temperatures. The mean annual number of clear days near Cordova is only 52 (USDC, 1963). High temperatures, usually encountered in early July, rarely climb above +27°C, while winter extreme low temperatures, reaching -35°C, are usually of short duration (USDC, 1963). The following is a description of the conditions at the large white-headed gull colonies along the Alaskan coastline between Glacier Bay and Prince William Sound (Fig. 2).

II. North Marble Island in Glacier Bay

The entire Glacier Bay area was covered, until about 200 years ago, by a massive ice sheet that may have been more than 1300 m thick in places (Streveler and Paige, 1971). The ice has retreated rapidly since 1792, uncovering large terrestrial and marine areas. North Marble Island lies in the middle of Glacier Bay and supports the largest (500 pairs) gull colony in the bay (Fig. 3). North Marble is about 600 m long and 300 m wide, and is surrounded by cold, highly oxygenated waters and strong tidal currents. The island emerged from glaciation about 120 years ago (Streveler, pers. comm.). The resistant meadow barley (Hordeum brachyantherum) forms nearly 70 percent of the ground cover in the gull nesting areas on the east, west, and north sides of the island, which are sloping meadows above shallow (5-25 m) cliffs (Fig 4). For a complete description see Patten (1974). Gene flow between previously isolated Larus populations in the area may be as recent as the deglaciation.

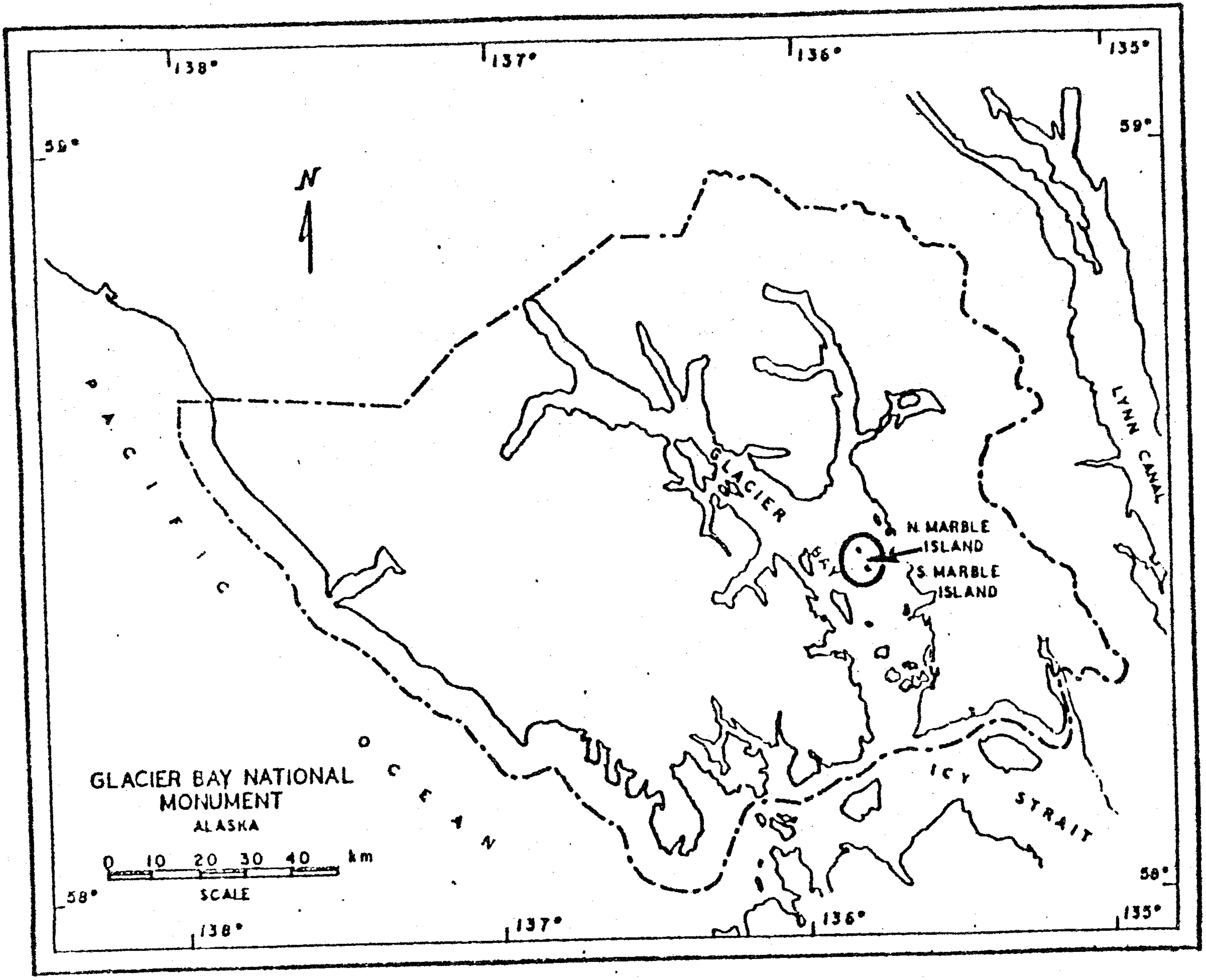


Figure 3. North Marble Island lies in the middle of Glacier Bay and contains large marine bird nesting areas. North and South Marble Islands, 2 km apart, are surrounded by cold, highly oxygenated waters and strong tidal currents.

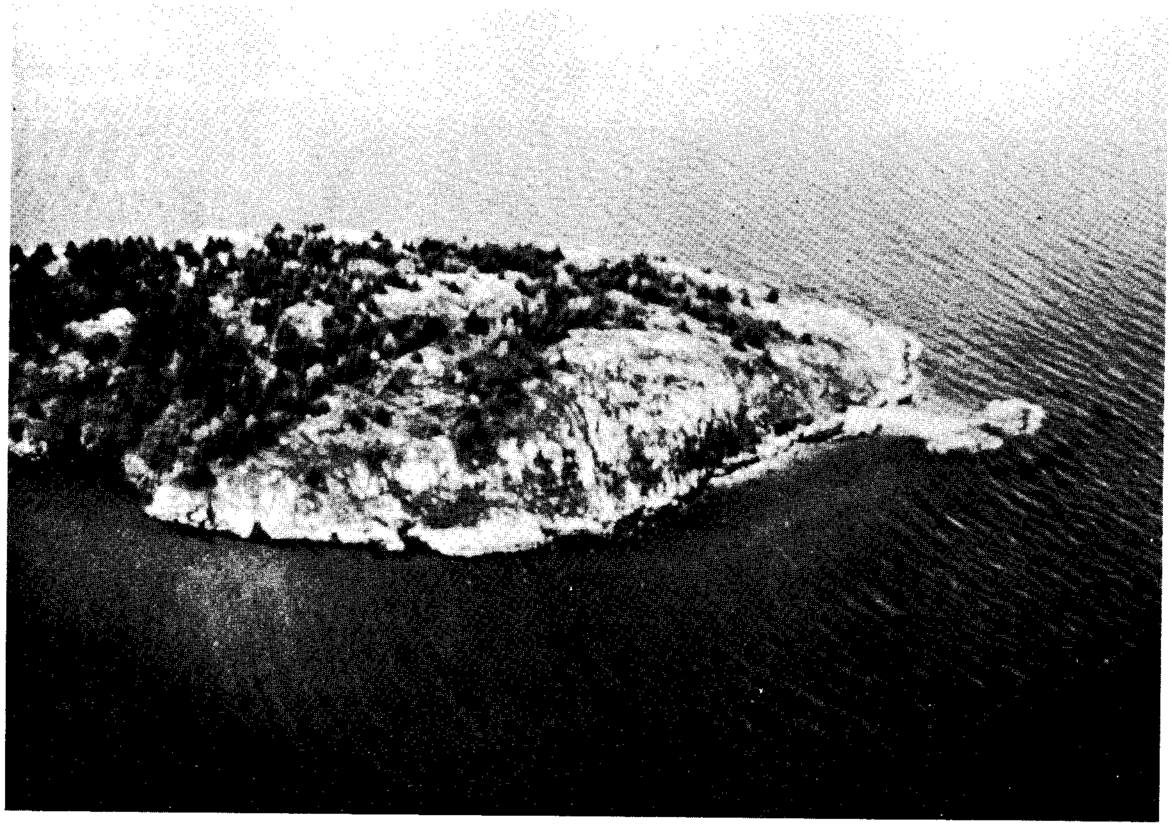


Figure 4. North Marble Island is about 600 m long and 300 m wide. Substrate is Willoughby limestone covered with scrubby Sitka Spruce and Hordeum meadows.

III. Dry Bay

The gull colony (500 pairs) at Dry Bay, 75 km S of Yakutat, is located 4.8 km from the mouth of the Alsek River on flat gravel bars (Fig. 5,6). The Alsek River, rising in the Yukon and partially draining the Fairweather Range, changes in level relative to rainfall and snow melt. Water surrounding the gull colony is fresh although silty, and carries ice floes from the Alsek Glacier, 28 km from the coast. Some years late summer high water stages wash completely over the gravel islands (Mork, pers. comm.). In other seasons, powerful southeast storms cover the delta with heavy rains or snow. Winter winds over 160 kph drive ocean waves over 20 m high onto the outer beaches, occasionally inundating and washing over much of the delta. Japanese glass fishing floats are found on the gravel bars 4 km from the mouth of the river.

Dry Bay has apparently not been glaciated but may have been the location of catastrophic flooding within the last thousand years from glacially dammed lakes in the interior Yukon (Brogle, pers. comm.). Dry Bay is a geologically active, earthquake-prone area. A minor earthquake caused the mouth of the Alsek River to shift 1 km to the west in 1975 (Alaska Geographic, 1975). The gravel islands of the Alsek River Delta at Dry Bay are subject to considerable repositioning due to river action. Vegetation on the gravel bars is a sparse mixture of alluvial and maritime forms. For a complete description of the area see Patten and Patten (1978).

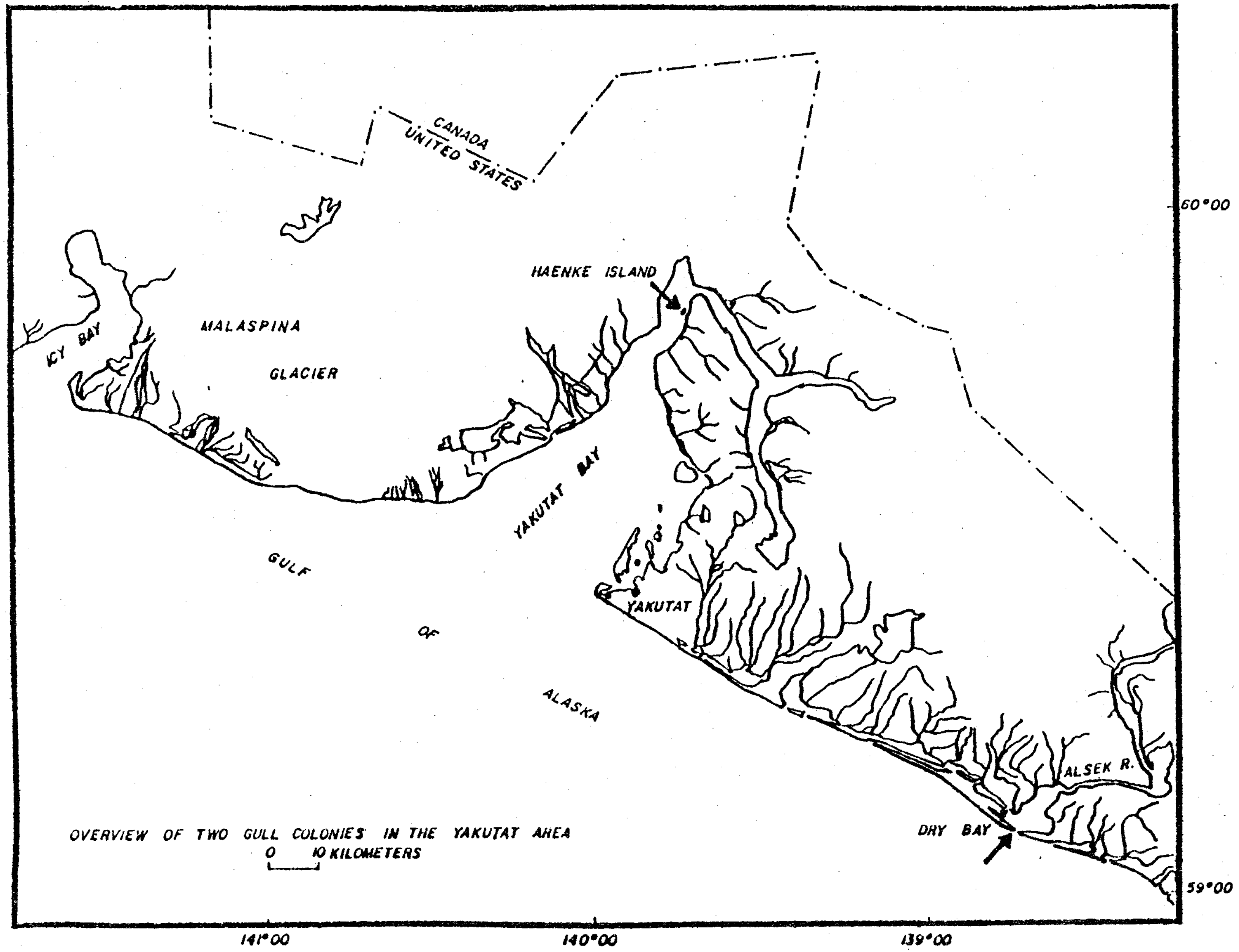

CANADA
UNITED STATES
60°00
HAENKE ISLAND
MALASPINA
GLACIER
ICY BAY
YAKUTAT BAY
GULF
OF
ALASKA
YAKUTAT
ALSEK R.
DRY BAY
59°00
OVERVIEW OF TWO GULL COLONIES IN THE YAKUTAT AREA
0 10 KILOMETERS
141°00
140°00
139°00

Fig. 5.

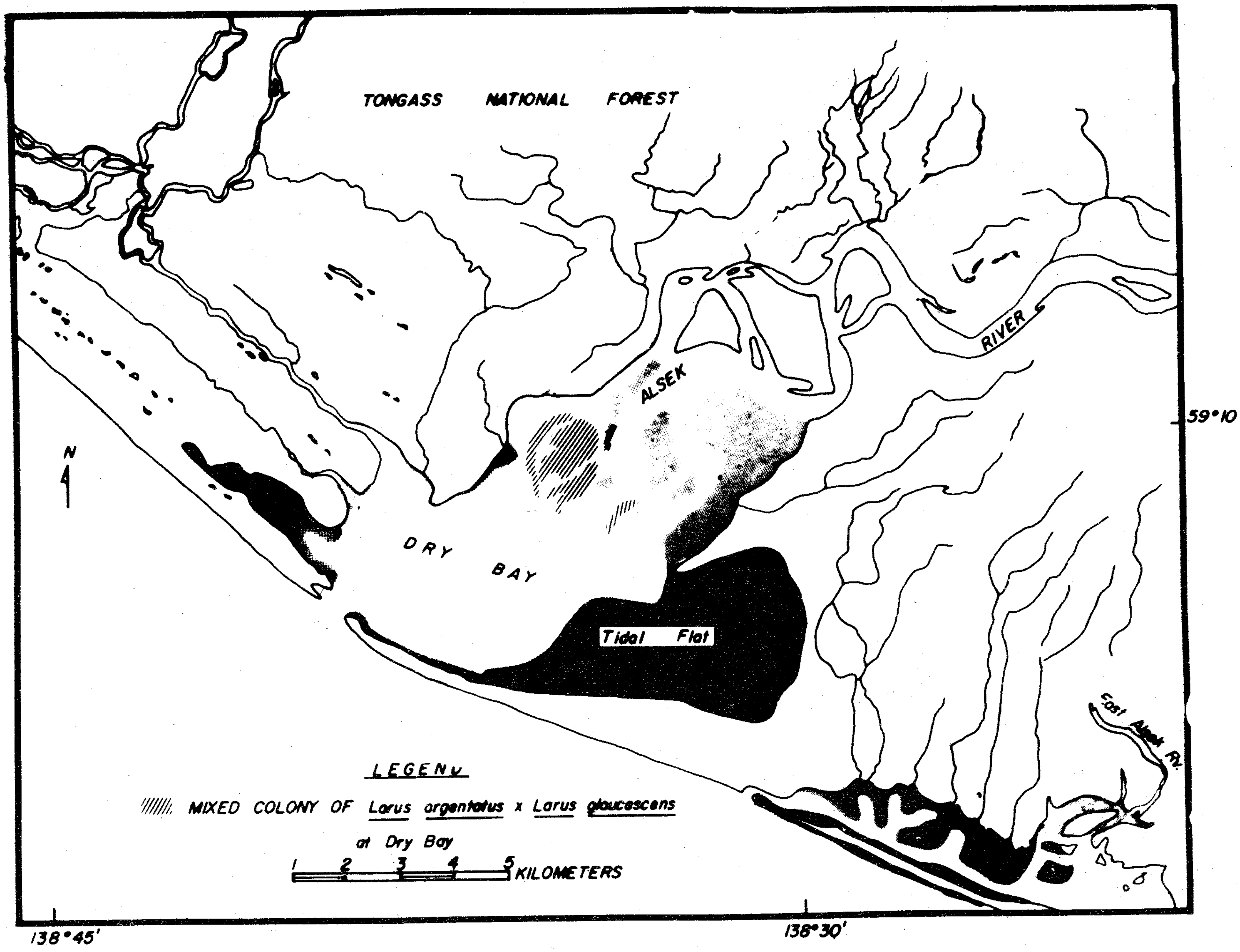

TONGASS NATIONAL FOREST
ALSEK
RIVER
59°10'
N
DRY BAY
Tidal Flat
East Alsek Rv.
LEGEND
MIXED COLONY OF Larus argentatus x Larus glaucescens at Dry Bay
1 2 3 4 5 KILOMETERS
138°45'
138°30'

Fig. 6.

IV. Haenke Island

Haenke Island, located in Disenchantment Bay, 75 km NE of Yakutat, and less than 1 km from the mainland, is often completely surrounded by pack ice from the nearby Hubbard Glacier (Figs. 7, 8). The island, with little level ground, is covered with low brushy vegetation dominated by alders, suggesting relatively recent deglaciation. The east side of the island, facing the Hubbard Glacier, gradually slopes to an elevation of 75 m, and then drops precipitously, forming a large westward-facing cliff, where 500 pairs of glaucescens breed on a series of narrow terraces.

The glacier once filling Yakutat Bay reached its maximum extent sometime in the Middle Ages and began to retreat about 600 years ago (Alaska Geographic, 1975). The retreat went far behind the branches of the Yakutat Bay Glacier, now the tidewater glaciers of Disenchantment Bay (Fig. 7). The ice then readvanced, reaching its largest extent during the 1700's. The Yakutat Bay glacier, best regarded as an expanded Hubbard Glacier, probably extended slightly beyond Latouche Point, 10 km past Haenke Island. The glacier again retreated to the vicinity of Haenke Island by the time of Malaspina and Vancouver, the early white explorers of the 1790's. Haenke Island, similar to North Marble, is thus recently deglaciated, but the exact date is uncertain due to the sporadic advances and retreats of the Hubbard Glacier. The gull colony at Haenke Island probably dates from the most recent deglaciation. For a complete description of conditions at Haenke Island see Patten and Patten (1978). This colony is the most geographically isolated of the sites examined.

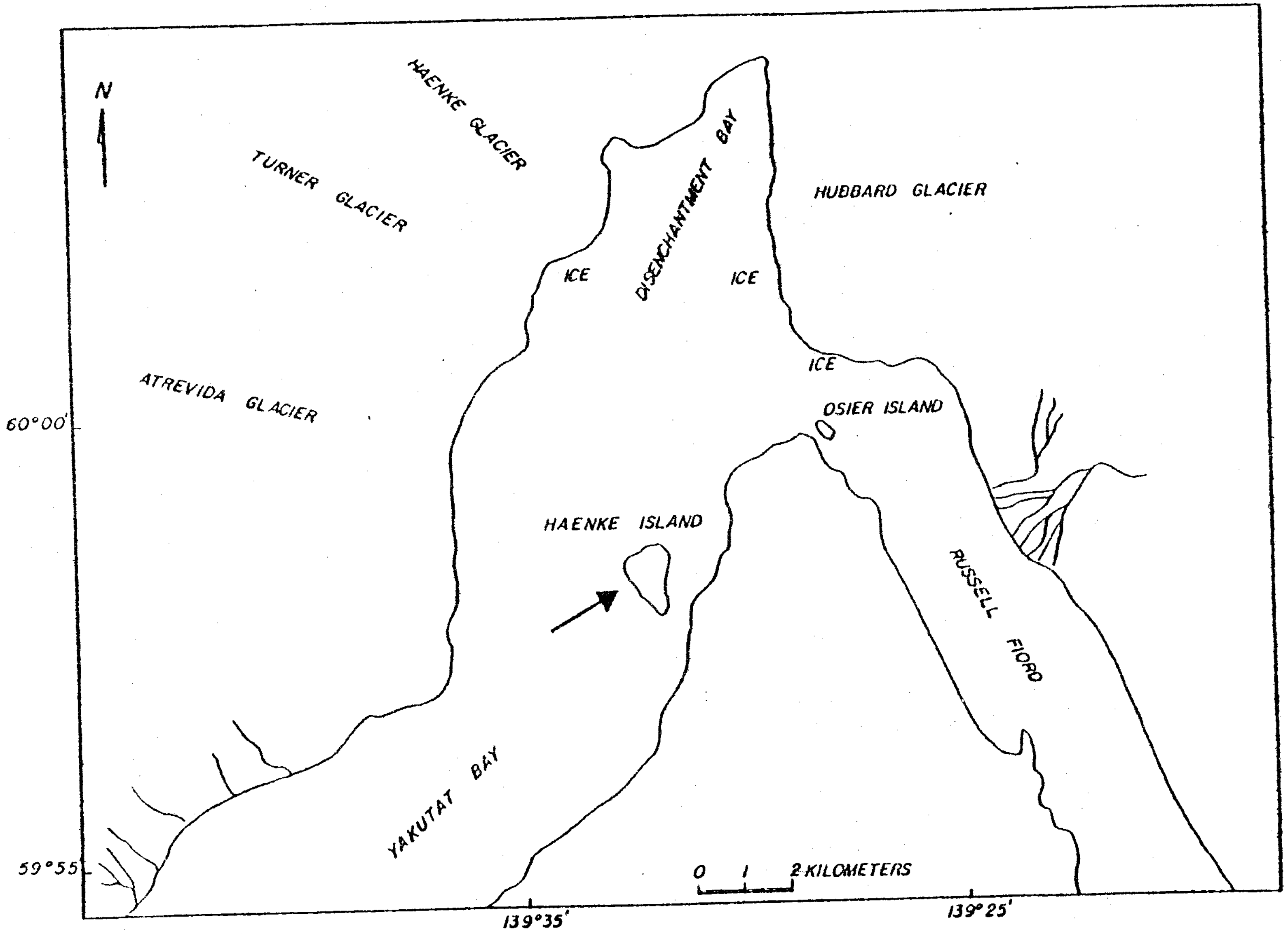


Fig. 7. Map of Haenke Island and surroundings in Disenchantment Bay, near Yakutat Bay, 50 km NE of Yakutat, Alaska. Note the proximity of four major glaciers. The advancing Hubbard Glacier threatens to close Russell Fjord and form a freshwater lake. Haenke Island is located less than 1 km from the mainland.

Fig. 8. HAENKE ISLAND

V. Copper River Delta

The largest gull colonies in the northeast Gulf of Alaska are located on sandbar barrier islands off the Copper River Delta near Cordova, Alaska. South of Cordova the Copper River and the confluent Martin River have deposited sand and mud where they meet the sea, forming a 50 km wide delta. A few kilometers off the mouth of the Copper River a series of low sandbar-dune islands forms a partial barrier to ocean storms. These islands have been formed by the deposition of sand and mud, and have been shaped by the counter-clockwise onshore currents of the Pacific Ocean (Fig. 9).

Constant change is characteristic of the interface between land and sea, especially where rivers enter the ocean. Sandy islands are built up and eroded away in a relatively uninterrupted process. However, the Copper River Delta and surrounding areas have been marked by sudden geological changes that have been extremely important in affecting local biota. Janson (1975) wrote of major earthquakes in the Copper River Delta occurring at the end of the last century. The most severe earthquake recorded on the North American continent during modern times occurred in this area of Alaska in 1964. The entire Copper River Delta including offshore islands was uplifted an average of two meters in a series of severe shock waves (USFS, 1975). The abrupt uplift disrupted the complex delta ecosystem and altered the balance between fresh water and saltwater. Nutrient input from saltwater to the delta appreciably diminished; several species of intertidal invertebrates and nesting populations of ducks declined in numbers. Willows and alders began to replace grass and sedge marshes in areas of the delta. Certain tidal sloughs dried out (Scheierl and Meyer, 1976).

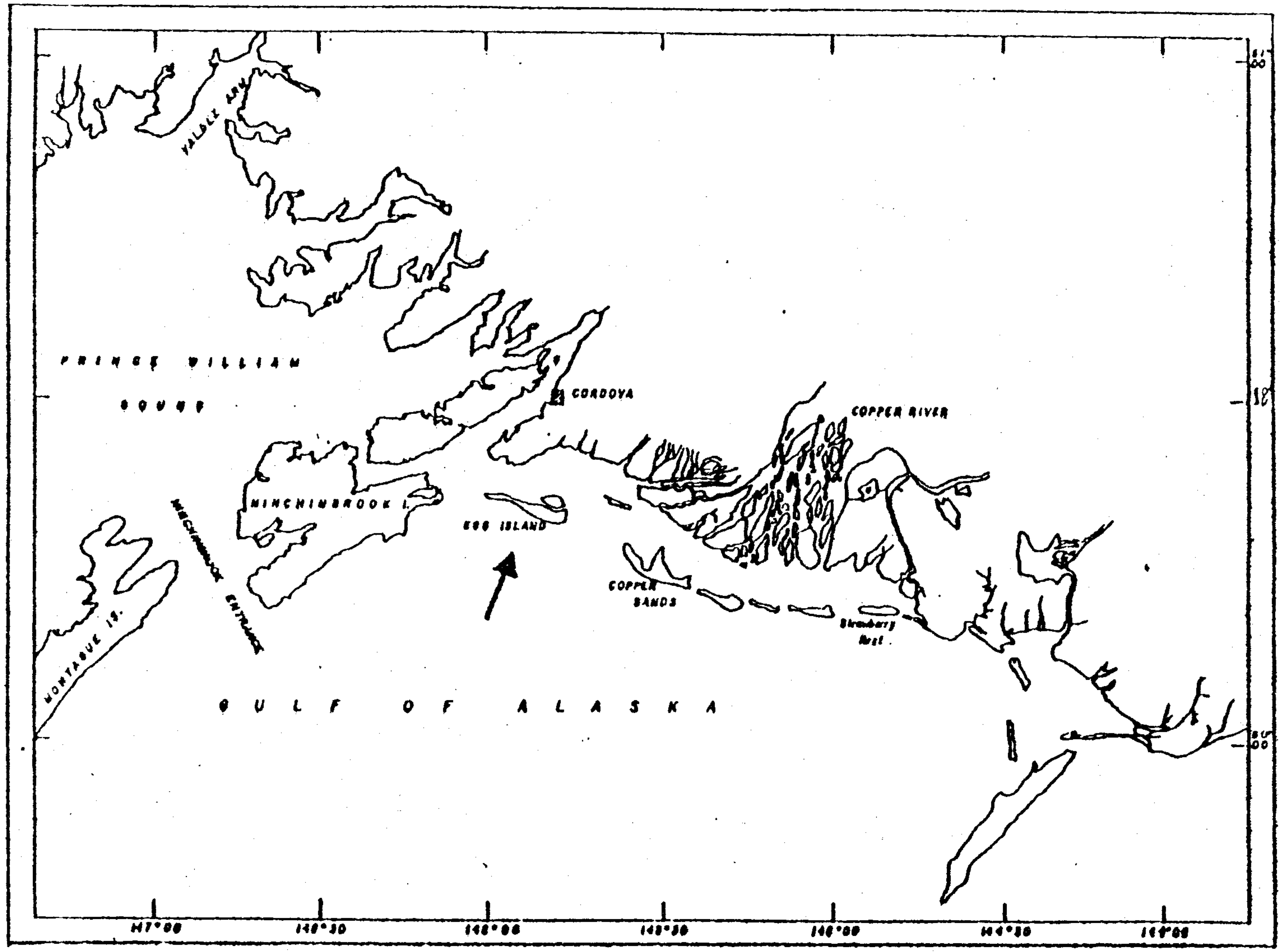


Figure 9. Map of the Copper River Delta region and Prince William Sound, showing location of Cordova, the Copper River, Egg Island (arrow), Copper Sands (S), and Strawberry Reef. Tanker traffic from Valdez will pass through Hinchinbrook Entrance. The area is highly vulnerable to oil spills.

The sandbar barrier islands at the mouth of the Copper River underwent the same sharp geological forces as the delta itself, but due to the nature of the islands and the marine bird species using them, the resulting changes were quite different. Shallow saltwater channels between islets were eliminated, and new ridges of sand dunes formed, joining islets together. The actual land area of the barrier islands increased due to the uplift. Plant succession began on newly formed dunes, with beach rye (<u>Elymus</u> <u>arenarius</u> <u>mollis</u>) forming scattered tufts on the sandy surface. Meadows encroach on dunes as succession continues.

Large colonies of gulls nest on these meadow-covered dunes. The actual area upon which gulls can nest is increasing, and at the moment there are large areas of unoccupied meadows capable of supporting nesting gulls due to the earthquake uplift and subsequent plan succession on newly formed areas (Fig. 10).

Overlying the vegetation and geological changes along the southern Alaskan coastline is the increasing human influence. Since the turn of the century successive tides of human influence have swept over Alaska. The most important developments for gulls have been the rise of intensive fisheries, open garbage dumps, and sewage outfalls. As an example, five seafood packing canneries and fish-processing houses in Cordova provide a major food source to gulls in the form of salmon and crab offal (Fig. 10). Gulls also feed at the open municipal dump at the edge of the harbor.

The potential for discarded human food and industrial waste increases daily in coastal Alaska. Isleib (pers. comm.) sees an increasing gull population in the Cordova area to date. Our NOAA

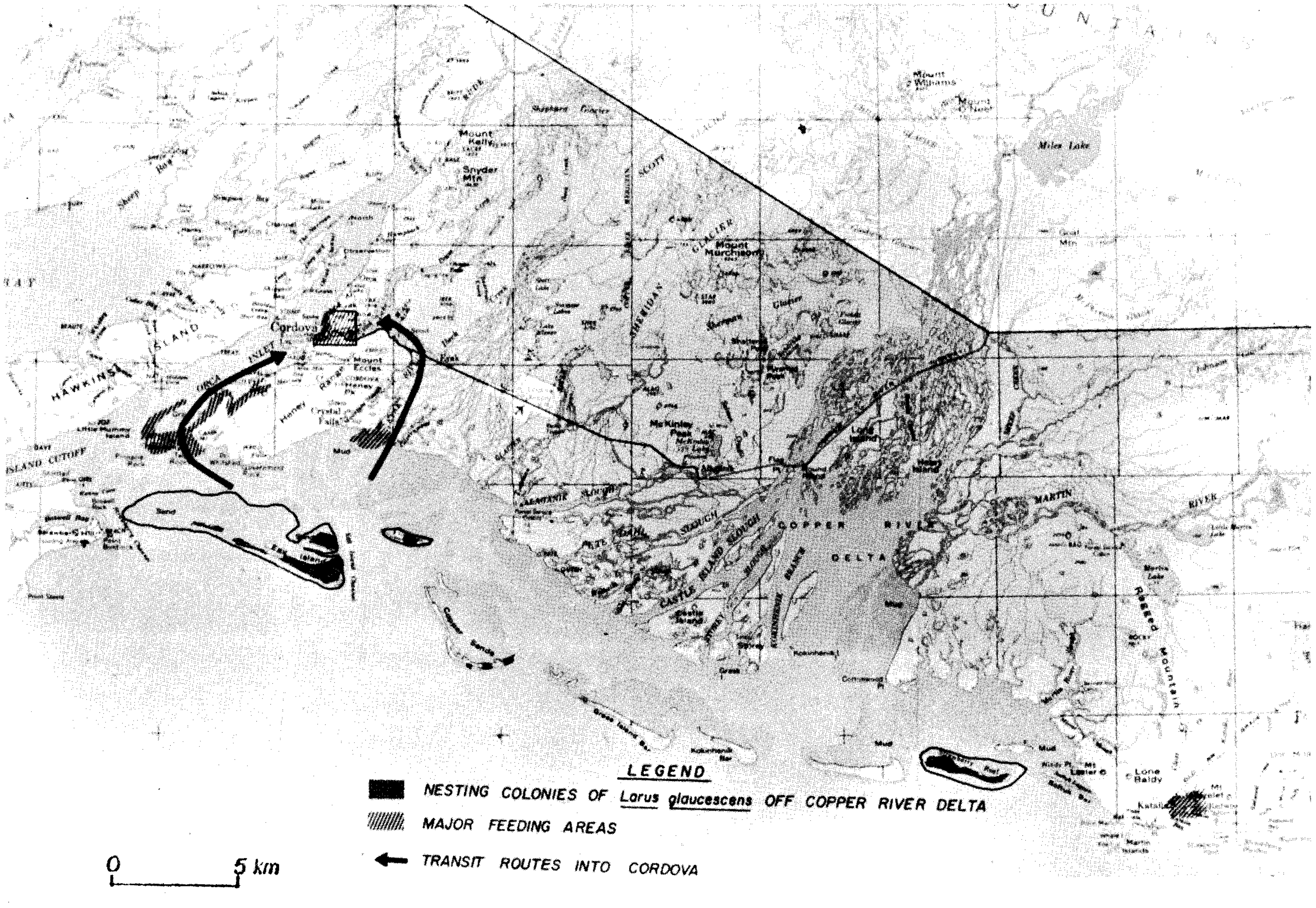

Cordova
ORCA INLET
HAWKINS ISLAND
Mount Eccles
Crystal Falls
Mount Kelly
Snyder Mtn
Sheridan Glacier
Scott Glacier
Mount Murchison
McKinley Peak
Mount Williams
Miles Lake
Goat Mtn
COPPER RIVER DELTA
MARTIN RIVER
CASTLE ISLAND SLOUGH
ALAGANIK SLOUGH
EYAK
Mud
Katalla
Lone Baldy
Ragged Mountain
Martin Islands
Egg Island
Grass Island Bar
Kokenhenik Bar
LEGEND
▆ NESTING COLONIES OF Larus glaucescens OFF COPPER RIVER DELTA
▨ MAJOR FEEDING AREAS
← TRANSIT ROUTES INTO CORDOVA
0 5 km

Fig. 10.

helicopter survey indicated 13,225 gull pairs nested on the sandbar barrier islands off the Copper River Delta in 1976 (Table 1). This number is expected to increase with the development of offshore oil resources, since gull-associated problems of human waste and garbage disposal are not likely to decline.

The discussion of study areas will now focus on four sandbar barrier islands off the Copper River Delta.

VI. Egg Island

Egg Island lies off the south coast of Alaska 20 km S of Cordova. Prior to the 1964 earthquake, Egg Island was a series of sand dunes and bars, but since the earthquake the sandbars and dunes have coalesced and built up one basic island, with a tremendous increase in surface area, which is undergoing colonization by the beach rye Elymus (Fig. 11). Driftwood, remains of fishing vessels, and other debris are scattered along the former storm-tide line, now at least a kilometer from the nearest saltwater (Michelson, 1973). Egg island currently extends for 10 km along a series of dunes arranged on an east-west axis, containing the largest gull colony in the northeast Gulf of Alaska, approximately 10,000 pairs of nesting glaucescens. Changes on this island are nothing less than dramatic over the last dozen years. Quite recent earthquake activity (1964) is important in determining the structure of the island and the plant communities upon which the gulls nest. For complete analysis of the gull colony at Egg Island see Patten and Patten (1975, 1976, 1977, 1978). This is apparently the largest glaucescens colony in the world.

Table 1. Nesting Gull Populations
on Copper River Delta Sandbar Islands
29 June 1976 NOAA Helicopter Survey +

Sandbar Barrier Island	Population Estimate *
Egg Island	10,000 pairs
Copper Sands (N)	200 pairs
Copper Sands (S)	800 pairs
Kokinhenik Bar	a few pairs
Grass Island Bar	200 pairs
Softuk Island	25 pairs among driftwood
Strawberry Reef	2,000 pairs

* estimated by groups of 50 individuals

Other mudflats and islets serve as loafing areas for large populations of immatures and adults which may or may not be breeding.

\+ observers: Pattens

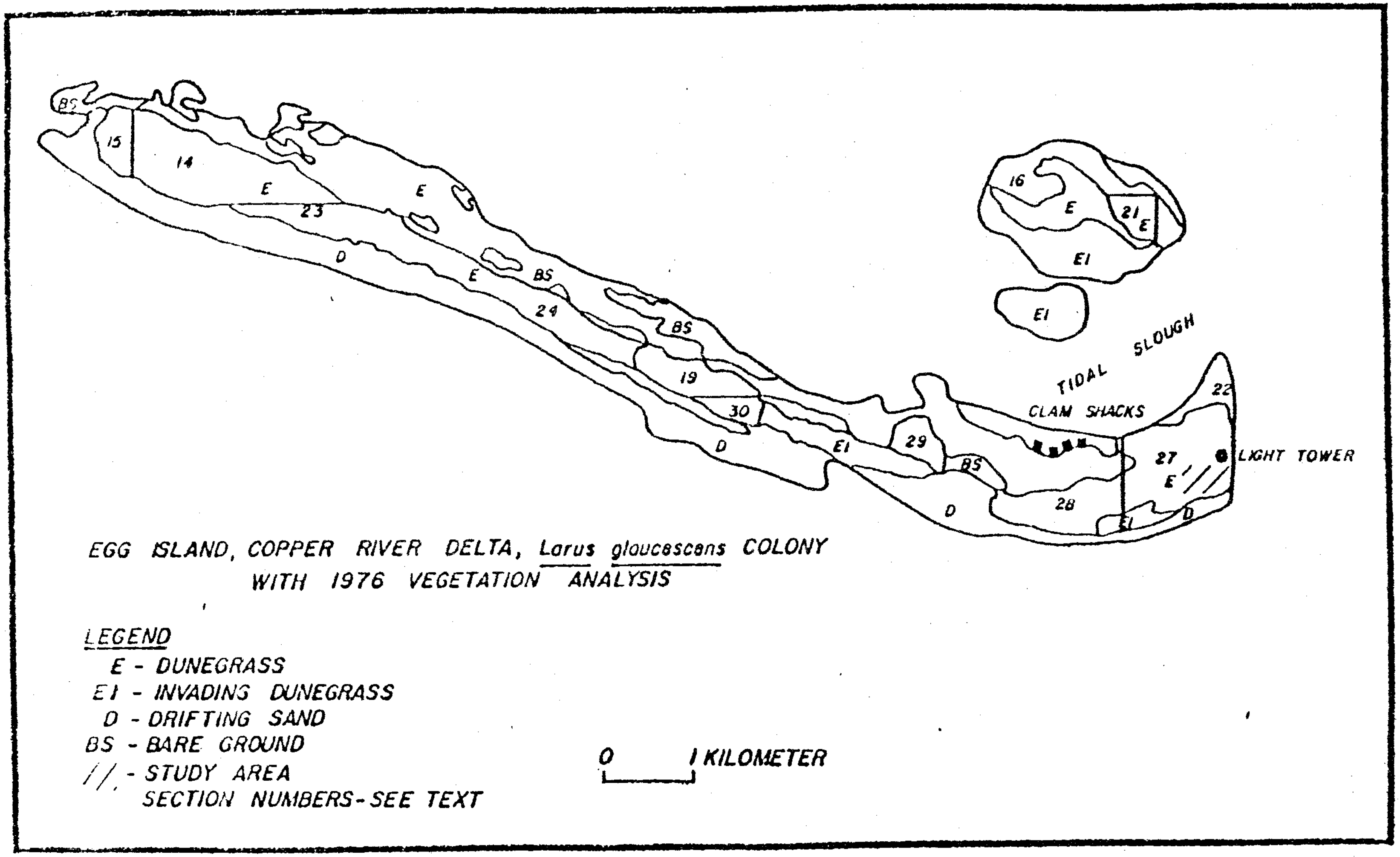

EGG ISLAND, COPPER RIVER DELTA, *Larus glaucescens* COLONY
WITH 1976 VEGETATION ANALYSIS
LEGEND
E - DUNEGRASS
EI - INVADING DUNEGRASS
D - DRIFTING SAND
BS - BARE GROUND
//, - STUDY AREA
SECTION NUMBERS - SEE TEXT
0 1 KILOMETER
BS
15
14
E
E
23
D
E
BS
24
BS
19
30
D
EI
29
BS
D
28
EI
D
27
E
22
LIGHT TOWER
CLAM SHACKS
TIDAL SLOUGH
16
E
21
E
EI
EI

Fig. 11.

VII. Copper Sands and Strawberry Reef

Copper Sands (S.), a bar 12 km long, one of a series of barrier islands at the mouth of the Copper River, lies 5 km ESE of Egg Island and 24 km SE of Cordova (Fig. 10). Copper Sands, consisting of a series of unstabilized dunes extending from southeast to northwest, has risen in elevation since the 1964 earthquake, but shows much less vegetation than Egg Island. The gull colony of 800 pairs is located on three dunes covered with Elymus at the SE tip of Copper Sands (Fig. 10).

Copper Sands (N), a small, newly formed island less than a kilometer long, 2.5 km ENE of Egg Island off the mouth of the Eyak River, did not exist before the 1964 earthquake, but now contains several dunes with 150 pairs of glaucescens nesting in the Elymus (Fig. 10). Other barrier islands between Copper Sands and Strawberry Reef at the east end of the delta support few nesting gulls due to lack of suitable vegetation, a result of intense sand scouring during winter high pressure systems (Michelson, 1975; Isleib and Kessel, 1973). Gulls use unvegetated islands such as Kokinhenik, Softuk, and Grass Island Bar as resting areas (Fig. 10).

Strawberry Reef, 8 km long, the easternmost barrier island at the mouth of the Copper River, contains the second largest glaucescens colony on the delta (Fig. 10). About 2000 gull pairs nest in the Elymus on Strawberry Reef, which is separated from the mainland by shallow tidal channels. The island is undergoing plant succession on recently uplifted areas, becoming more suitable to nesting gulls. Strawberry Reef, as Egg Island, consists of wide ocean beaches, unstabilized dunes, Elymus-covered dunes, and mud flats, but differs by expanding thickets of spruce and alder.

VIII. Lake Louise

Lake Louise, 8 x 12 km, lies 51.2 km NW of Glenallen, in the Copper River Basin on southcentral Alaska. Lake Louise drains through Susitna Lake and the Tyone and Susitna Rivers to Cook Inlet (Figs. 12, 13).

An island gull colony, readily observed due to disturbed vegetation, lies 1 km from the west shore of the lake on a steeply sloping rock known as "Bird Island." Bird Island, radically different in appearance from other spruce-covered islands in Lake Louise, shows evidence of heavy, long-term bird use. Vegetation, composed of lichens, mosses, grasses, resistant forbs, and woody vines, indicates disturbed conditions. Living plants are absent in the peat formation along the island crest, area of heaviest bird use. At least 77 pairs of _L. argentatus smithsonianus_ and 14 pairs of _Phalacrocorax auritus_ nest on the island (100 x 20 x 10 m, 0.36 hectare). Photographs taken by Hayes (pers. comm.) fifteen years ago show little change in island vegetation structure, in contrast to dynamic conditions in gull colonies previously examined. Hayes (pers. comm.) reports gulls and cormorants have inhabited Bird Island for as long as local residents can remember, probably centuries longer. This invites comparison with the biology of gulls on the south coast of Alaska, where change is explosive.

IX. Summary of Study Areas

The study colonies are thus a series of islands in southern Alaska, extending over 4^{0} latitude from Glacier Bay near Juneau, to Lake Louise in southcentral Alaska. Aquatic environments include the coast, tidal bays, river deltas, fjords, and a fresh-water lake.

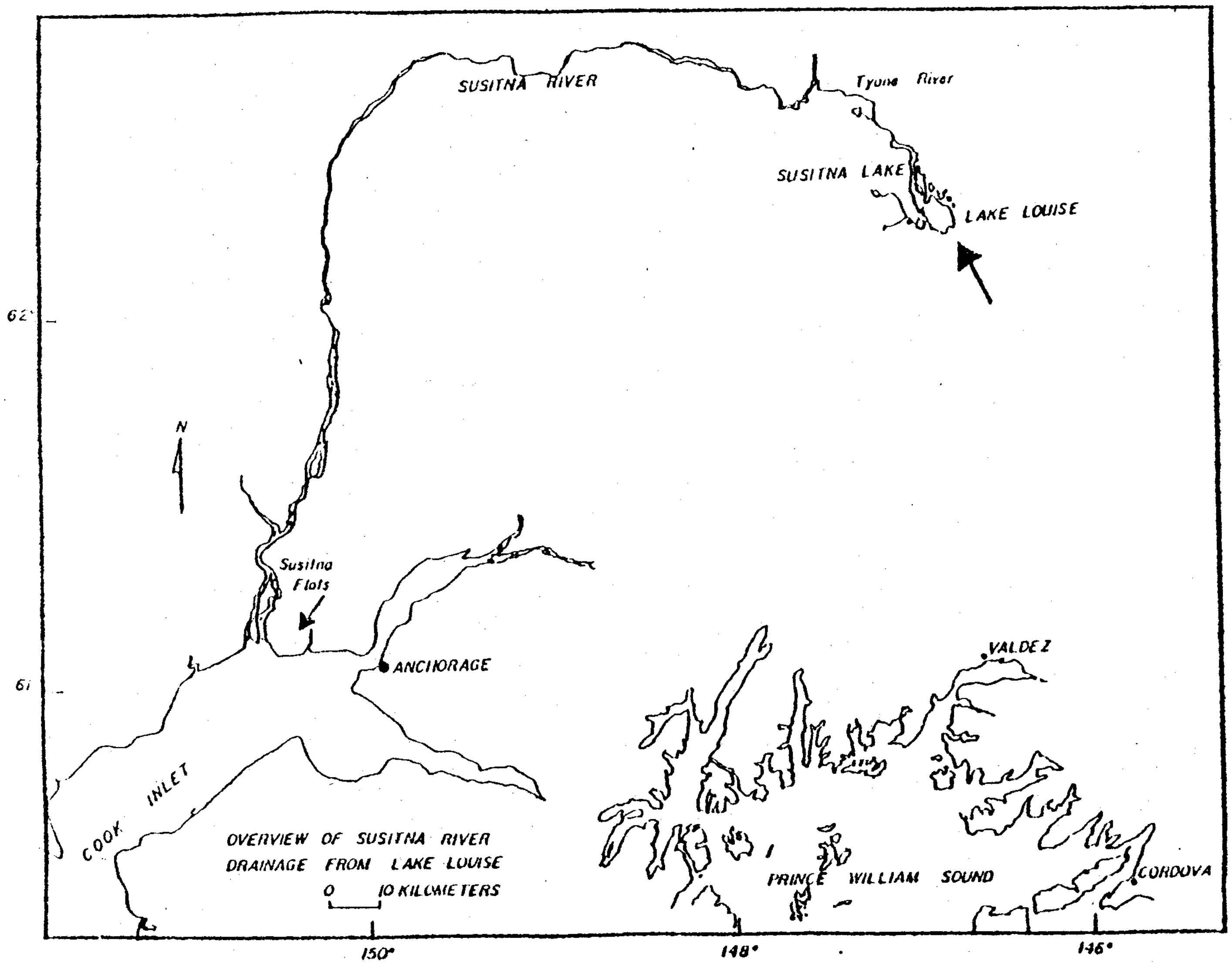


Fig. 12. Overview of Susitna River drainage from Lake Louise to Cook Inlet, showing Prince William Sound, Cordova, Valdez, and Anchorage. Lake Louise and Susitna Flats are indicated by arrows. Williamson and Peyton (1963) investigated hybrid gull populations on the Susitna Flats.

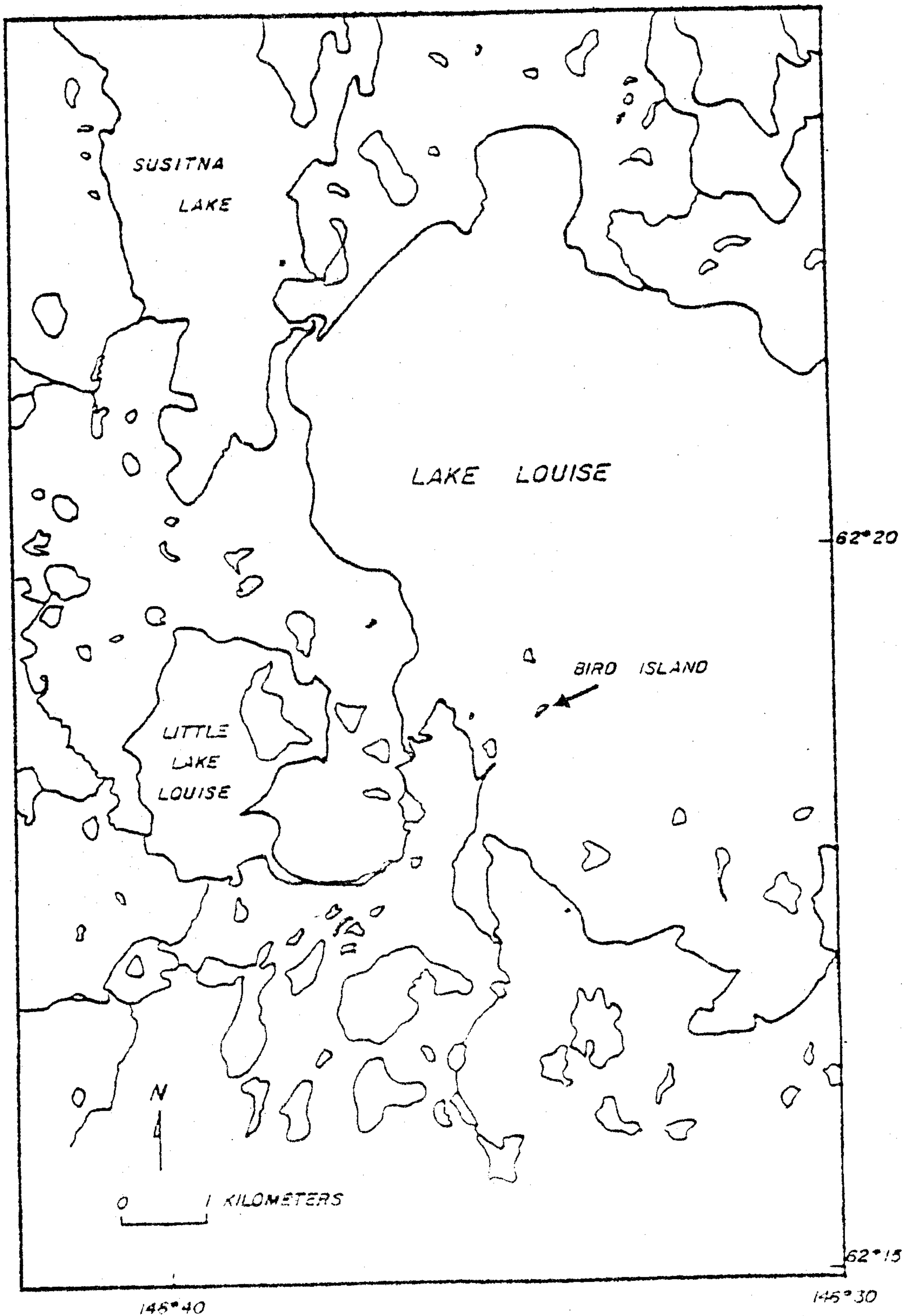


Fig. 13. Overview of the Lake Louise area, showing Susitna Lake and Little Lake Louise. Bird Island (arrow) lies 1 km from the west shore of the lake and contains 77 pairs of Larus argentatus smithsonianus.

The geology of the coastal sites is dynamic due to recent deglaciation, major earthquakes, and floods. Vegetation at the colonies, composed of tolerant, resistant invaders of the early successional stages, reflects both disturbance by gulls and rapid environmental changes. Slope and substrate of the gull colonies vary from horizontal gravel bars to nearly vertical cliff faces (Table 2).

Four coastal colonies, Egg Island, Strawberry Reef, Copper Sands, and Haenke Island, contain allopatric *glaucescens*. Two coastal colonies, North Marble and Dry Bay, support sympatric and interbreeding *argentatus* and *glaucescens*. The interior colony at Lake Louise is composed of allopatric *argentatus*. Cordova, a major feeding area, supports summering populations of *glaucescens*, low numbers of *hyperboreus*, and gulls showing intermediate characters between these two. Table 3 contains the principal periods of study for these *Larus* colonies in southern Alaska.

Table 2.

Study Areas for *Larus* Colonies in Southern Alaska

Colony	Coordinates N	Coordinates W	Species*	Aquatic Environment	Substrate/ Geology/ Slope	Dominant Vegetation
North Marble	58°40'	136°04'	*argentatus*, *glaucescens*	tidal bay	recently deglaciated (120 yrs) sloping island	*Hordeum* meadows
Dry Bay	59°08'	138°25'	*argentatus*, *glaucescens*	river delta/ coastal marine	shifting flat gravel bars	sparse alluvial/ maritime mix
Haenke Island	59°58'	139°32'	*glaucescens*	tidal bay	recently deglaciated island cliff face	*Hordeum*/*Alnus* on cliff terraces
Strawberry Reef	60°13'	144°51'	*glaucescens*	brackish delta/ coastal marine	earthquake influenced low sandbar island	*Elymus*
Copper Sands	60°18'	145°31'	*glaucescens*	brackish delta/ coastal marine	earthquake influenced low sandbar island	*Elymus*
Egg Island	60°23'	145°46'	*glaucescens*	brackish delta/ coastal marine	earthquake influenced low sandbar island	*Elymus*
Cordova **	60°33'	145°45'	*glaucescens*, *hyperboreus*	tidal inlet	artificial urban environment	city dump
Lake Louise	62°20'	146°32'	*argentatus*	freshwater lake	slope lake islet	*Calamagrostris* meadows

* Large white-headed *Larus* populations during breeding season.
** Not a breeding colony but a major feeding area (see text).

Table 3. Principal Periods of Study for *Larus* Colonies in Southern Alaska

Study Area	Year	Periods of Study
Glacier Bay	1971	17 July - 11 August
North Marble Island	1972	15 May - 14 August
North Marble Island	1973	27 April - 9 August
Outer Coast of Glacier Bay National Monument	1974	23 May - 4 August
Haenke Island	1974	14 - 15 June
Dry Bay	1974	17 - 18 June
Dry Bay	1975	28 June - 3 July
Dry Bay	1977	4 May - 23 July
Egg Island	1975	18 June - 18 August
Egg Island	1976	20 May - 15 August
Strawberry Reef	1976	29 - 30 June
Copper Sands (S)	1976	1 July
Lake Louise	1976	24 - 25 August
Lake Louise	1977	9 - 10 June; 8 - 10 July; 1 - 3 August
Cordova City	1975	Intervals: June - August
Cordova City	1976	Intervals: May - August
Cordova City	1977	Intervals: April - August

CHAPTER 4: MATERIALS AND METHODS

I. Colony Selection and Investigation Dates

North Marble, Dry Bay, Egg Island, and Lake Louise were selected as principal locations for reproductive aspects of this study because they supported the largest gull colonies in southern Alaska. Each site has distinguishing features and represents the major colony for a large geographical area. North Marble, only recently deglaciated and thus available for nesting, is being colonized by pioneering populations of both *argentatus* and *glaucescens*. Dry Bay supports a coastal hybrid colony astride a major migration route to the Yukon. Egg Island contains the largest, still expanding, meadow-nesting *glaucescens* population in the northeast Gulf of Alaska. Lake Louise, "Bird Island," has long been inhabited by migratory interior *argentatus*.

II. Reproductive Cycle

All nests under study were marked with forestry survey stakes at the beginning of each colony investigation. Each heavy wire survey stake had a bright vinyl flag attached. Since vegetation growth tended to obscure the flags by mid-season, each survey stake was marked with an additional sequentially-numbered florescent streamer. A fiberglass meter tape was used to find the direct distance from every study nest to the center of the nearest neighboring nest. The nest survey stakes were left in position for two field seasons in order to follow nests for two years where possible. Nest site slope was measured using a Brunton Survey Transit.

As part of each sequential visit through the gull colonies, numbers of eggs and chicks from each nest site inspected were recorded in National Oceanographic Data Center format 035, "Flat Colony Survey".

Visits at North Marble averaged once every three days during incubation, and once every six days during the chick stage. Visits at Egg Island averaged once every three days during incubation, and once every three days during the chick stage. The Dry Bay colony was visited every other day, and the Lake Louise colony at egg-laying, chick hatching, and at fledging time.

The plumage and soft-part colors of both parents at each nest site studied at Dry Bay were examined using a 25x telescope and comparing them to a Munsell color chart. Newly hatched chicks at Dry Bay were web-tagged with fingerling fish tags until large enough for banding with USF&WS rings. Young chicks in other colonies were counted in the nest upon hatching. Older chicks in study areas other than Dry Bay were presumed to have hatched in the nearest nest; such older chicks were marked at Egg Island with 2.5 cm aluminum bands bearing number codes which could be read vertically. The web-tagged chicks at Dry Bay, when nearly fledged, were banded with similar 2.5 cm aluminum bands, and an additional 2.5 cm lynply plastic band with engraved codes in black alphanumeric characters on the opposite leg. The parentage of fledged chicks at Dry Bay could be verified in this manner. At the end of the survey period each summer counts were made of fledged, banded chicks for entire study areas. The productivity of the hybrid colonies at Dry Bay and North Marble has been compared to the allopatric _glaucescens_ at Egg Island and the _argentatus_ at Lake Louise in search of evidence for pre- or post-mating isolating mechanisms.

III. Marking Methods: Banding

We banded 11,212 gulls during this study in order to answer questions of migration routes, wintering areas, and to permit individual recognition of chicks and adults. Outside of the main study areas we banded 1300 flightless chicks in 1975, 2696 in 1976, 1200 in 1977, and 5546 in 1978. These young gulls were banded on their left tarsi with USF&WS butt-end aluminum, monel, or incoloy bands, size 6 (for argentatus) or 7A (glaucescens and hybrids).

All 1975 young glaucescens were captured at Egg Island. In 1976, we banded 2500 glaucescens chicks on Egg Island, 95 chicks at Strawberry Reef, and 101 at Copper Sands (S). In addition, within the 1975 study site (150 m x 150 m) southwest of Egg Island light tower, we captured every glaucescens chick which survived two weeks. These 222 individuals were banded on the left tarsus with 2.5 cm, butt-end aluminum bands, with the reference numbers twice repeated vertically (Sladen et al., 1968). We counted as fledged 157 of the 222 banded chicks in early August. We did not band until chicks were nearly fledged in 1976, in order to reduce disturbance to the study area. We then counted as fledged those 208 glaucescens banded within the study in an intensive effort in late July.

At Dry Bay we banded 25 known hybrid chicks, 1 known argentatus chick, and 403 other chicks assigned to glaucescens. Study area chicks were marked with web-tags, 2.5 cm aluminum bands, and orange lynply 2.5 cm bands with engraved black alphanumeric codes (A001-A000), enabling individual recognition of the chicks.

U.S. Forest Service crews assisted by banding 700 additional glaucescens chicks on Egg Island in 1977. We banded 71 of the 73 argentatus chicks produced at Lake Louise in 1977, and 60 of the 75 produced there in 1978. In 1978 we banded 86 glaucescens chicks on Middleton Island, and with Forest Service assistance, 5400 gull chicks on Egg Island. All other gulls forming the combined total were trapped, banded and released in the municipality of Cordova.

IV. Morphological Measurements

In order to obtain morphological measurements from sympatric and allopatric Larus populations in southern Alaska, adult gull specimens were required. Gulls were collected with a shotgun, and live-trapped, since official permission to use drugs for capture of gulls (cf. Smith, 1966b) was denied. Collecting is less desirable since it invites non-random sampling (see Ingolfsson, 1970). Trapping was a more random method, since I took whatever birds entered the trap.

As soon as an adult gull was trapped or collected, standard measurements were taken (culmen chord length; bill length from the side of the anterior nares to tip; bill depth at posterior nares; diagonal tarsus length; chord of closed (flattened) wing; and weight) and the information was recorded on data sheets These same measurements have been used in previous gull studies and are of comparative value (Smith, 1966b).

The data was sorted into grouping by sex and colony. Only four gulls could be collected from Glacier Bay National Monument, all of which were males, due to permit restrictions. The Lake Louise colony was composed of only 77 pairs; therefore only two males were collected in addition to Williamson's earlier specimens. All birds obtained from Cordova were trapped, since discharge of firearms was not permitted within city limits. Sample size of females in all cases was less than males, suggesting that behavioral differences made them less likely to approach a trap or shotgun range. Both trapped and collected gulls have been included in the analysis of morphology, plumage characters, and soft part colors.

V. Hybrid Index Method

Initial perspective on the morphology and pairing of large gulls in the southern Alaskan contact zone suggested occurrence of second-generation hybrids and backcrosses. An efficient comparison of the interbreeding populations required a method of portraying the variation exhibited by the parental types and intermediate forms.

Anderson's (1936) original techniques for analyzing hybridization, consisting of a list of differences between the hybridizing entities, have been gradually refined to a quantitative approach involving numerical scores for the characters which differ between the two populations (Anderson, 1949; Sibley, 1954). The two principal forms concerned in this dissertation, argentatus and glaucescens, differ in eye and orbital ring color, and in amount and pattern of melanin in the distal primaries. After a gull was captured or collected, I immediately photographed the orbital region of the head, with the primaries in juxtaposition, with a Pentax 35 mm camera and Kodachrome II color film. The iris, orbital ring, tarsi, and feet were verbally described, and then the colors were compared to the standard charts of the Munsell notation by holding the charts directly over the individual parts (Fig. 14; see below).

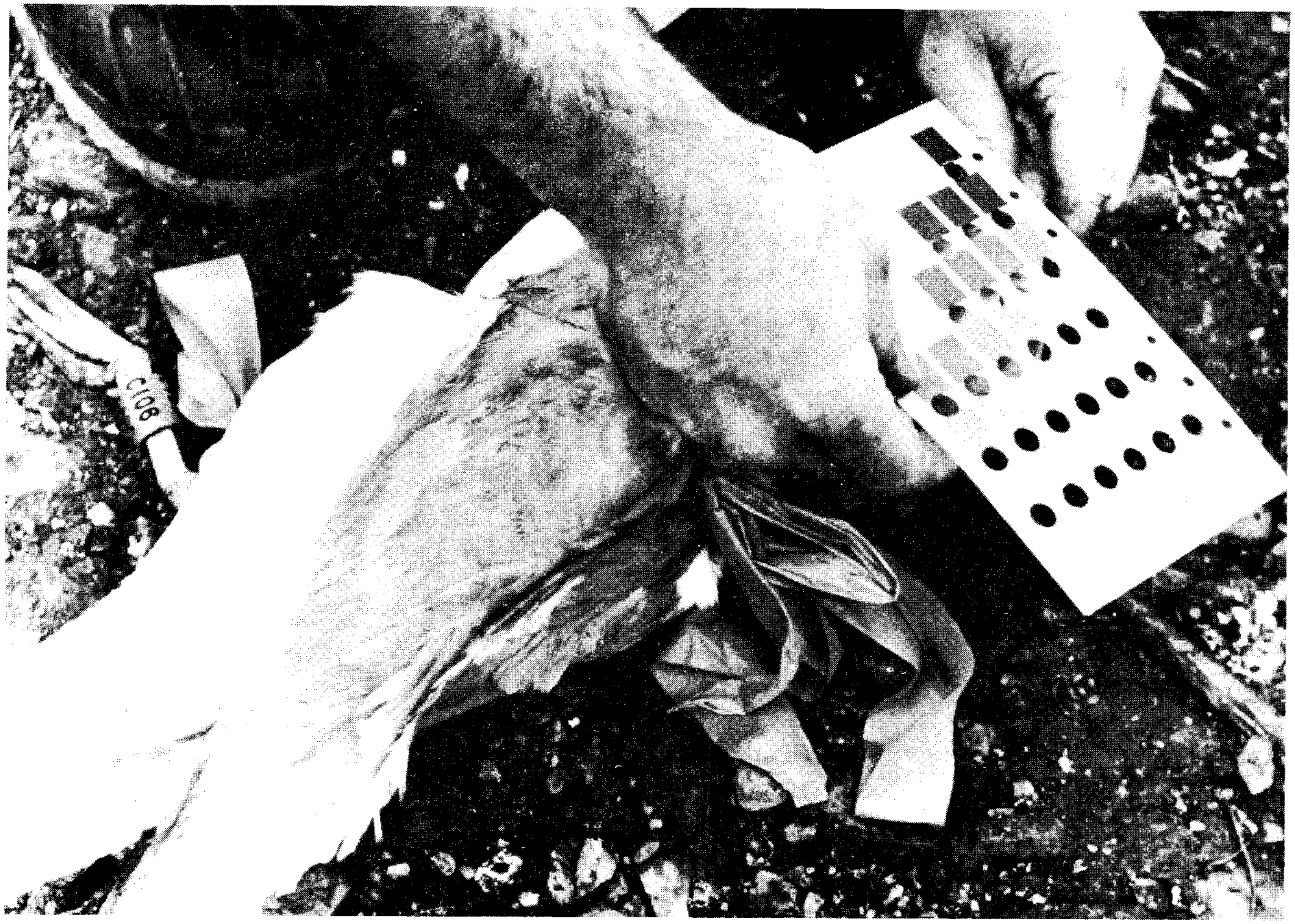
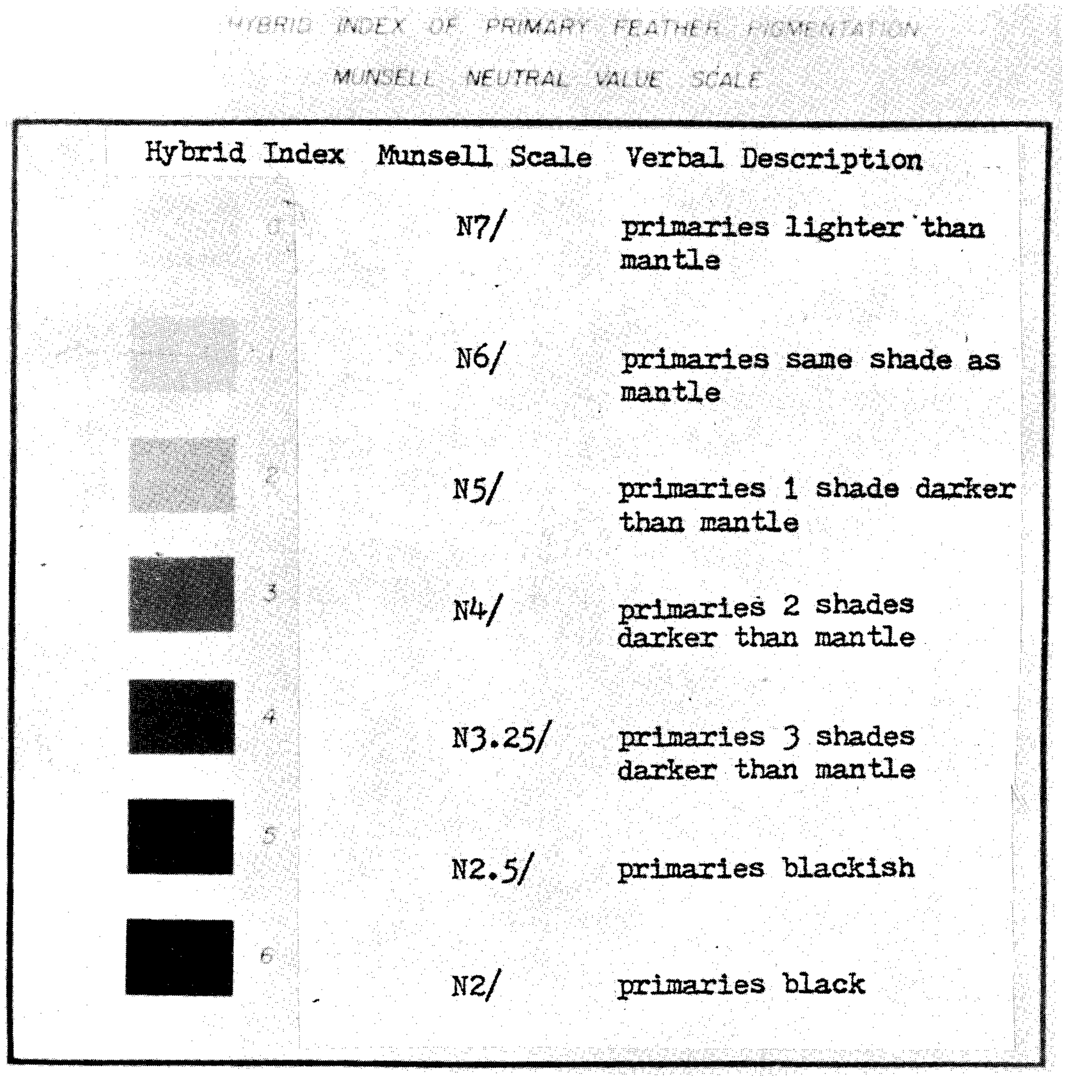


Figure 14. Study of isolating mechanisms. Determination of adult <u>glaucescens</u> orbital ring and iris pigmentation using a Munsell chart of skin, hair and eye colors, based upon the Munsell Soil Color Chart. Note numbered tarsal band. Cordova, 1977.

Mantle and primary pigmentation were also recorded by direct comparison with the Munsell Neutral Value Scale (see below). Mantle, primary color, and a wing hybrid index derived from amount and pattern of melanin on the outer primaries, were included in this analysis. For the wing hybrid index, elements in the series were scored as essentially like one of the two species, or assigned to the spectrum of intermediate forms. The wing hybrid index and the corresponding Munsell notation are presented below (Fig. 15). The combination of amount and pattern of melanin on the distal portions of the five outermost primaries was classified into one of seven categories which were given the numerical notations or scores of 1 (typical glaucescens) to 6 (typical argentatus). The score of 0 was reserved for those atypical Cordova glaucescens in which the primaries were lighter than the mantle. The notation of the primaries in atypically light glaucescens was revised to account for the possibility of genetic interaction with a third species, hyperboreus.

The distribution of iris colors was scored in six grades from 1 (typical glaucescens, hue 2.5 YR) to 6 (typical argentatus, hue 5 Y). The observed range of pigmentation in orbital rings included all nine possible Munsell hues within the major hue names of Red, Yellow-Red, and Yellow (see Munsell System of Color Notation, below). Orbital rings were composed of all three major hues in some cases. The scores within the major hues were added together for the individual gull to form a "composite orbital ring." In similar fashion, the scores for the primaries, irides, and orbital rings were added together for each gull to produce a "composite hybrid index."



HYBRID INDEX OF PRIMARY FEATHER PIGMENTATION

MUNSELL NEUTRAL VALUE SCALE

Hybrid Index	Munsell Scale	Verbal Description
0	N7/	primaries lighter than mantle
▨ 1	N6/	primaries same shade as mantle
▨ 2	N5/	primaries 1 shade darker than mantle
▨ 3	N4/	primaries 2 shades darker than mantle
■ 4	N3.25/	primaries 3 shades darker than mantle
■ 5	N2.5/	primaries blackish
■ 6	N2/	primaries black

Fig. 15.

The scores are set in such a way that resemblance to argentatus is always high in value, and resemblance to glaucescens always low in value. The hybrid index obtained was of course an arbitrary indication of the "hybridness" (i.e., the relative number of argentatus, glaucescens, or in some cases, hyperboreus genes), since the categories were arbitrarily defined. The definitions of the categories used are given in Fig. 15, and typical examples of wing patterns are shown in the Frontispiece. My main concern in defining the categories was to arrive at recognizable stages which could be differentiated from other stages.

Methods used in this study are therefore similar, although not identical, to those used by other authors in analyzing hybrid situations in birds (Sibley, 1954; Ingolfsson, 1970; Strang, 1977; Hoffman et al., 1978). The hybrid index method, simple to apply, has given satisfactory results in previous cases of hybridization, and has proven efficient for exploring complex situations (Anderson, 1949; Sibley, 1954; Ingolfsson, 1970).

VI. Munsell System of Color Notation

The colors discussed in this study, that of gull irides, orbital rings, primary and mantle feathers, required a rapid and precise method of identification and recording. The Munsell System of Color Notation (Munsell Skin, Hair and Eye Color Charts, Matte Finish Edition, Munsell Color Co., Baltimore, Maryland) was used in order to reduce subjective evaluation and because soft part colors quickly fade and may change colors after a specimen is taken. The following introduction is taken from Munsell Color, a privately printed publication of

Macbeth, a division of Kollmorgen Corporation, and is used with permission.

> The Munsell notation system of equally spaced color scales provides a tool for expressing perceived color of an object and the color differences observed among a group of objects. The system of color notation identifies color in terms of three attributes, hue, value, and chroma. This method of color notation arranges the three attributes of color into orderly scales of equal visual steps: the scales are used as parameters for accurate specification and description of color under standard conditions of illumination and viewing.
>
> The hue (H) notation of color indicates its relation to a visually equally-spaced scale of 100 hues.

The hue notation in this study is based upon three major hue names: Red, Yellow-Red, and Yellow, since these cover the range of pigmentation in orbital rings and irides.

> The value (V) notation indicates the degree of lightness or darkness of a color in relation to a neutral grey scale, extending from absolute black to absolute white. The value symbol 0/ is used for absolute black, the symbol 10/ for absolute white.
>
> The chroma (C) notation indicates the degree of departure of a given hue from a neutral grey of the same value. Chroma scales depend upon the strength (saturation) of the sample evaluated.
>
> The complete Munsell notation for a chromatic color is written symbolically: H V/C.

The complete notation for a sample of "vermillion" would be 5 R 6/14, while the notation for a sample of "rose" would be 5 R 5/4.

The notation for a neutral (achromatic) color, such as found in primary feather pigmentation, is written N V/. The notation of black, a very dark neutral, might be N2/; the notation of white, a very light neutral, might be N9/; while the notation for a grey, visually halfway between these two, would be N5/.

VII. Data Analysis

Numbers of eggs and chicks, recorded as part of sequential visits through the gull colonies, with distance to the nearest neighboring nest, were entered on 80-column sheets and key-punched following the NODC Format 035, "Flat Colony Survey." A custom program written by Mr. Mark Miller of the University of Washington and modified by Mr. Galen Smith of the Johns Hopkins Computing Center was used to compute clutch size, egg loss, hatching success, and fledging success for North Marble, Dry Bay, and Egg Island, and to portray these variables graphically using the Cal-Comp system on the Johns Hopkins University DEC-system 10 computer.

VIII. Study Skins

During this study 174 adult gulls were collected from North Marble Island, Dry Bay, Haenke Island, Strawberry Reef, Copper Sands (S), Egg Island, and Lake Louise, for taxonomic verification, food habits, and serology. Representative series of study skins will be presented to the University of Washington, Seattle; National Museum of Natural History, Washington, DC; and the American Museum of Natural History, New York City.

CHAPTER 5: RESULTS

I. Comparison of Measurements

Although there are suggestions in the literature that *argentatus* and *glaucescens* populations are broadly overlapping in body dimensions (Dwight, 1925; Williamson and Peyton, 1963) I did not immediately dismiss the possibility that certain morphological features might be useful to discriminate between populations of gulls in southern Alaska. I formulated two null hypotheses, and examined the standard measurements of 174 gulls in search of evidence to accept or reject these null hypotheses:

(1) There are no significant differences in mensural characters between sympatric and allopatric populations of *glaucescens* and *argentatus* in southern Alaska;

(2) There are no significant differences in measurements between so-called "pure types," e.g., those exhibiting plumage and soft part colors characteristic of strictly parental types. (For descriptions of the parental types please see the Introduction.)

The morphological measurements of gulls in populations in southern Alaska are presented in Tables 4 and 5. Means, standard deviations, and ranges have been included in an exploratory univariate analysis of the body measurements. Since gulls are sexually dimorphic in body size and mensural characters, males were not compared against females. Inspection of the means, ranges, and standard deviations reveals that the magnitude of difference between colonies is not absolutely great (Tables 4 and 5).

Table 4. Comparison of the Measurements (in Millimeters) of Sympatric and Allopatric *Larus* Gulls in Southern Alaska -- Males

Measurement	Colony	Composition	Mean	Range	S.D.
Culmen	North Marble	*arg.* x *glauc.*	59.8	57-62	2.06
	Dry Bay	*arg.* x *glauc.*	59.7	56-64	2.36
	Haenke Island	*glauc.*	60.6	59-63	1.81
	Strawberry Reef	*glauc.*	59.2	55-64	2.31
	Copper Sands	*glauc.*	60.5	58-61	1.46
	Egg Island	*glauc.*	59.1	55-64	2.57
	Cordova	*glauc.*/*hyperbor.*	59.9	57-63	1.97
	Lake Louise	*arg.*	60.5	58-63	2.50
Bill: Anterior Nares to Tip	North Marble		27.8	27.5-28.5	0.50
	Dry Bay		28.0	24.5-31	1.58
	Haenke Island		28.4	26-30	1.46
	Strawberry Reef		28.8	27-31	1.09
	Copper Sands		30.2	28.5-33	1.99
	Egg Island		28.2	25-31	1.56
	Cordova		29.3	27-32	1.39
	Lake Louise		28.5	28-29	0.50
Bill: Depth at Posterior Nares	North Marble		19.7	18.7-20	0.65
	Dry Bay		19.9	18-22	1.04
	Haenke Island		19.8	19-21	0.75
	Strawberry Reef		21.4	27-31	1.13
	Copper Sands		21.6	21-22.5	0.73
	Egg Island		20.3	18-23	1.24
	Cordova		20.1	19-25	1.45
	Lake Louise		20.5	20-21	0.50

Table 4, cont'd.

Measurement	Colony	Composition	Mean	Range	S.D.
Tarsus	North Marble	*arg.* x *glauc.*	69.1	67-72	2.19
	Dry Bay	*arg.* x *glauc.*	68.0	61-73	2.58
	Haenke Island	*glauc.*	65.6	61-69	2.88
	Strawberry Reef	*glauc.*	67.9	63-72	2.61
	Copper Sands	*glauc.*	68.9	64-73.5	3.38
	Egg Island	*glauc.*	67.2	63-72	2.41
	Cordova	*glauc.*/*hyperbor.*	68.2	62-72	3.37
	Lake Louise	*arg.*	70.3	66.5-74	5.30
Wing	North Marble		434.8	420-451	12.79
	Dry Bay		433.5	414-463	13.80
	Haenke Island		432.4	430-435	2.30
	Strawberry Reef		437.4	418-463	13.95
	Copper Sands		433.0	422-445	8.78
	Egg Island		435.4	419-455	9.25
	Cordova		434.1	417-450	9.49
	Lake Louise		455.0	450-460	7.07

Table 5. Comparison of the Measurements (in Millimeters) of Sympatric and Allopatric *Larus* Gulls in Southern Alaska -- Females

Measurement	Colony	Composition	Mean	Range	S.D.
Culmen	Dry Bay	*arg*. x *glauc*.	53.6	50-57.5	2.09
	Haenke Island	*glauc*.	53.2	50-57	2.78
	Strawberry Reef	*glauc*.	52.8	50-55	1.80
	Copper Sands	*glauc*.	53.1	52-53.5	1.24
	Egg Island	*glauc*.	54.2	51-60	2.33
	Cordova	*glauc./hyperbor*.	54.6	50-58	2.65
Bill: Anterior Nares to Tip	Dry Bay		26.6	24-31	1.83
	Haenke Island		26.5	22-29	2.42
	Strawberry Reef		24.9	22-27	1.64
	Copper Sands		26.7	26-28	0.83
	Egg Island		25.8	23-29	1.48
	Cordova		26.8	24-29	2.32
Bill: Depth at Posterior Nares	Dry Bay		18.5	17-22	1.30
	Haenke Island		18.1	17-20.5	1.28
	Strawberry Reef		19.5	18.5-21	0.76
	Copper Sands		19.1	18-20	0.89
	Egg Island		18.2	17-20	1.08
	Cordova		19.0	17-23	2.19
Tarsus	Dry Bay		65.6	62-70	2.24
	Haenke Island		62.9	60-66	1.12
	Strawberry Reef		61.4	57-67	1.37
	Copper Sands		62.9	61-64.5	1.44
	Egg Island		62.3	56-69	3.29
	Cordova		62.0	58-64	2.83

Table 5, cont'd.

Measurement	Colony	Composition	Mean	Range	S.D.
Wing	Dry Bay	*arg.* x *glauc.*	418.7	400-450	12.38
	Haenke Island	*glauc.*	412.2	403-424	9.44
	Strawberry Reef	*glauc.*	421.3	410-435	9.81
	Copper Sands	*glauc.*	414.8	412-418	2.50
	Egg Island	*glauc.*	416.9	400-445	11.91
	Cordova	*glauc.*/*hyperbor.*	410.5	400-425	10.85

F-ratios (the statistic appropriate to the Analysis of Variance), were then computed, using the SPSS-10 ONEWAY program. This program is an Analysis of Variance that takes into account differences in sample size and changes in degrees of freedom by groups. The F-test may require some qualification if the means are skewed. However, since gull body measurements (within sexes) are approximately normally distributed, the F-test should give a good approximation of the real differences between population means.

The F-ratios for the measurements of the female adult gulls indicated no significant differences between any of the populations examined at either level: $P < .01$ or $p < .05$ (Table 6). However, for male gulls, the comparison of body measurements first yielded a significant F-ratio at the 5 percent level for two measurements: bill depth at posterior nares; and bill length, anterior nares to tip (Table 7). Further exploration of the data revealed that the males in two colonies, Copper Sands (S) and Strawberry Reef (neighboring colonies on the Copper River Delta) were the source of the significant variation. If the males from Copper Sands and Strawberry Reef were eliminated from the analysis, then the F-ratio indicated no significant differences between the remaining populations (Table 8). Males from Copper Sands and Strawberry Reef, compared to each other, showed no significant difference (Table 9). Further, the difference between population means in the measurement of bill length (anterior nares to tip) was of marginal significance ($p < .04$).

Since the F-ratio was at least marginally significant for these two dimensions, further comparisons were necessary. Analysis now required a rank-ordering approach. Duncan's New Multiple Range Test

Table 6. Analysis of Variance (SPSS-10 ONEWAY) of Morphological Measurements For Adult Gulls (Female)

Captured/Collected at: Dry Bay, Haenke Island, Strawberry Reef, Copper Sands (S), Egg Island, Cordova.

Body Part	Degrees of Freedom Between Groups	Degrees of Freedom Within Groups	F-ratio	Significance
Wing	5	41	0.741	n.s.*
Tarsus	5	41	2.515	n.s.
Culmen	5	41	0.483	n.s.
Bill: Anterior Nares to Tip	5	42	1.015	n.s.
Bill: Depth at Posterior Nares	5	42	1.079	n.s.

* n.s. = not significant at $p < .01$ or $p < .05$

Table 7. Analysis of Variance (SPSS-10 ONEWAY) of Morphological Measurements For Adult Gulls (Male)

Captured/Collected at: North Marble, Dry Bay, Haenke Island, Strawberry Reef, Copper Sands (S), Egg Island, Cordova, Lake Louise.

Body Part	Degrees of Freedom Between Groups	Degrees of Freedom Within Groups	F-ratio	Significance
Wing	7	94	1.143	n.s.*
Tarsus	7	94	1.197	n.s.
Culmen	7	94	0.593	n.s.
Bill: Anterior Nares to Tip	7	94	2.320	significant at $p < .05$ n.s. at $p < .01$
Bill: Depth at Posterior Nares	7	94	3.526	significant at $p < .01$

* n.s. = not significant at $p < .01$ or $p < .05$

(Since analysis of variance has given a significant F-ratio at two variables, further analysis is needed.)

Table 8. Analysis of Variance (SPSS-10 ONEWAY) of Morphological Measurements For Adult Gulls (Male)

Captured/Collected at: North Marble, Dry Bay, Haenke Island, Egg Island, Cordova, Lake Louise; WITHOUT Copper Sands, Strawberry Reef.

Body Part	Degrees of Freedom Between Groups	Degrees of Freedom Within Groups	F-ratio	Significance
Wing	5	76	1.554	n.s.*
Tarsus	5	76	1.503	n.s.
Culmen	5	76	0.565	n.s.
Bill: Anterior Nares to Tip	5	76	1.593	n.s.
Bill: Depth at Posterior Nares	5	76	0.456	n.s.

* n.s. = not significant at $p < .01$ or $p < .05$

Table 9. Analysis of Variance (SPSS-10 ONEWAY) of Morphological Measurements For Adult Gulls (Male)

Captured/Collected at: Strawberry Reef, Copper Sands.

Body Part	Degrees of Freedom Between Groups	 Within Groups	F-ratio	Significance
Wing	1	18	0.431	n.s.*
Tarsus	1	18	0.510	n.s.
Culmen	1	18	1.431	n.s.
Bill: Anterior Nares to Tip	1	18	3.442	n.s.
Bill: Depth at Posterior Nares	1	18	0.130	n.s.

* n.s. = not significant at p <.01 or p <.05

(Steele and Torrie, 1960) is well suited to this sort of analysis. This test, and the t-test used below, are both robust (i.e., they assume a normal distribution of means, not samples, and therefore can be used without qualification).

The results of Duncan's Multiple Range Test confirmed that the differences between male populations in bill length (anterior nares to tip) were of marginal significance (not significant at $p < .01$). However, the next test showed that males from the two neighboring Copper River Delta colonies, Copper Sands (S) and Strawberry Reef, were significantly different ($p < .01$) in bill depth (at posterior nares) from all other colonies examined (Table 8). The two colonies were not significantly different from each other (Table 9).

After testing the significance of differences in measurements between various populations, "pure types" were selected from the data base, and the means of the body measurements of the "pure types" were compared by t-test, appropriate for the small sample size (n=15). The "pure types" did not differ except for wing measurement, which was significantly longer in _argentatus_ types ($t=3.20$, $p < .01$). The observed statistical difference in bill depth between the two Copper River Delta populations and the other colonies examined cannot, therefore, be used in taxonomic discrimination, since the "pure types" of _glaucescens_ and _argentatus_ do not differ statistically in this dimension. However, this difference may have other genetic and evolutionary implications (see discussion below).

Since no significant differences were found in measurements between female gull populations examined, the first null hypothesis was accepted. This hypothesis was rejected for males, however, since there is a significant difference in bill depth between two Copper River Delta colonies and other populations examined. However, male gull populations examined do not differ significantly in any other dimension.

The "pure types" of _argentatus_ and _glaucescens_ do not differ significantly in any dimension except wing length, which is significantly longer in _argentatus_. However, the non-significant F-ratio for allopatric and sympatric populations indicates broad overlap in wing length (Table 7).

The conclusion was therefore drawn that a minor sex-linked difference in bill measurement exists among various populations of gulls in southern Alaska, but there is broad overlap in all other mensural characters. As a result, the examination of morphology was extended to include an analysis of colorimetric characters, including primary feather pigmentation, iris and orbital ring coloration.

II. _Primary Feather Pigmentation_

The most obvious character which differed between individuals and populations of gulls in southern Alaska was the amount and pattern of melanin in the distal ends of the primaries. As the amount of melanin in the primaries intensified, the pattern of deposition expanded from the subterminal area to include progressively more of the distal portions of the outermost remiges. The melanin extended up the feather shafts of the three outermost primaries in very dark-primaried gulls. Initial field observations suggested that gulls could be sorted into groups by their primary feather pigmentation. As I inspected the primaries at close range in collected or captured specimens, I began to classify the patterns into categories.

This combination of amount and pattern of melanin deposition was used to construct a wing hybrid index (HI). The index ranged from 1 to 6. The range of the index included typical glaucescens, with primary tips the same shade of grey as the mantle (Munsell N6; a score of 1 on the hybrid index) and typical argentatus, with primaries of extensive black pigment (Munsell N2; an HI of 6) (Fig. 15).

When unusual gulls were trapped in the Cordova dump, this classification was revised. These birds had primaries one shade lighter than the mantle, as well as light-colored irides, and often had slightly, although not statistically larger body measurements than other populations (Tables 4, 5). The wing hybrid index was modified to account for this variation, with the unusually light-primaried gulls given a score of 0 on the index. The revised wing hybrid index for 174 gulls from populations between Glacier Bay and Lake Louise is presented in Table 10.

The mean hybrid index of the Cordova population was the lightest of the groups sampled, due to the presence of three light-primaried gulls (Table 10). Another gull with primaries lighter than the mantle was collected from Egg Island, and the range of the index for Egg Island includes this individual. Egg Island has the greatest upward range (to 4) of colonies where "pure" argentatus is absent. The means of the hybrid indices constructed for Cordova, Egg Island, Haenke Island, Copper Sands (S), and Strawberry Reef are grouped around the score of 2, i.e., the populations showed slight but noticeable darkening of the distal portions of the primaries. The hybrid indices for these colonies are within one standard deviation of each other. No colonies studied on this section of the Alaskan coastline exhibited a monomorphic, typically glaucescens characteristic of primaries the same shade as the mantle. Such colonies are found in the Aleutians (Williamson, pers. comm.; Strang, 1977).

The complete range of primary feather pigmentation, including forms most like glaucescens and argentatus, along with four intermediate types, is found in the gull colony at Dry Bay (Table 10). The means of the hybrid indices constructed for Dry Bay and North Marble are close to the middle of the range, with large standard deviations, reflecting the presence of many intermediate types. Gulls scoring 6 on the index, with black primaries, and melanin extending up the shafts of the three outer primaries, are present in the Dry Bay, North Marble, and Lake Louise populations. The means of the hybrid indices for Dry Bay and North Marble are beyond the standard deviations of all other colonies except Lake Louise, but are within one standard deviation of each other. Gulls at Lake Louise, the darkest population examined, all scored 6 on the index.

Inspection of Table 10 indicates that a very highly significant ($p < .001$) distribution exists for wing hybrid indices in Larus colonies in southern Alaska, including the complete spectrum of variation between the parental types of argentatus and glaucescens. The observed distribution of primary feather pigmentation includes

Table 10. Hybrid Index of Primary Feather Pigmentation for *Larus* Colonies in Southern Alaska

Colony	Mean	Range	Standard Deviation
Cordova	1.58	0.0-3.0	0.87
Egg Island	1.91	0.0-4.0	0.69
Haenke Island	1.95	1.0-3.5	0.83
Copper Sands (S)	2.03	1.0-3.0	0.67
Strawberry Reef	2.20	1.0-3.0	0.54
Dry Bay	3.10	1.0-6.0	1.56
North Marble	4.12	3.0-6.0	1.32
Lake Louise	6.00	6.0-6.0	0.00

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F-ratio
Between Groups	7	88.0957	12.5851	13.130 *
Within Groups	166	159.1055	0.9585	
Total	173	247.2011		

* very highly significant ($p < .001$)

primaries lighter than the mantle, primaries the same shade as the mantle, primaries of various shades of grey, and primaries of extensive black pigment. Since the F-ratio for the wing hybrid indices was very highly significant, the data were explored further using Duncan's Multiple Range Test. The results of this test are presented in Tables 11 and 12. The Cordova, Egg Island, Haenke Island, Copper Sands (S), and Strawberry Reef populations are coastal groups most like _glaucescens_. However, the mean wing hybrid index becomes progressively darker (HI 1.59 - 2.20) along a northwest to southeast axis. These populations are included in a homogeneous subset in this test, with no significant differences at either $p < .05$ or $p < .01$ level of significance (Tables 11, 12). The wing hybrid indices constructed for Dry Bay, North Marble, and Lake Louise are significantly different from each other and from the remaining colonies at the $p < .05$ level. However, at the $p < .01$ level, the colonies of Dry Bay and North Marble form a hybrid subset, while North Marble and Lake Louise are grouped in an _argentatus_-like subset. A genetic bridge can therefore be postulated, connecting coastal _glaucescens_ with interior _argentatus_ through hybrid colonies at the heads of fjords and bays (e.g., North Marble and Dry Bay) in southern Alaska.

In summary, the primary feather pigmentation of 174 gulls in southern Alaska was analyzed using a wing hybrid index. Individual gulls within the study area are highly variable, and the variation includes primaries lighter than the mantle with no observable pattern of melanin deposition, to a distinctly delimited and extensive

Table 11.

Ranked Means for the Wing Hybrid Index for *Larus* Colonies in Southern Alaska

(Duncan's New Multiple Range Test: $p < .05$ level)

Homogeneous subsets (subsets of groups, whose highest and lowest means do not differ by more than the shortest significant range for a subset of that size). Underlined numbers indicate there is no significant difference between the means.

Subset 1 (subterminal primaries slightly darker than mantle)

Group	Cordova	Egg Island	Haenke Island	Copper Sands (S)	Strawberry Reef
Mean	1.5870	1.9107	1.9500	2.0313	2.2000

Subset 2 (primaries 2 shades darker than mantle; extensive melanin)

Group	Dry Bay
Mean	3.1053

Subset 3 (primaries 3 shades darker than mantle; extensive melanin)

Group	North Marble
Mean	4.1250

Subset 4 (primaries black; distinctly delimited and extensive black pattern)

Group	Lake Louise
Mean	6.000

Table 12. Ranked Means for Wing Hybrid Indices for *Larus* Colonies in Southern Alaska

(Duncan's New Multiple Range Test: $p < .01$ level)

Homogeneous subsets (subsets of groups, whose highest and lowest means do not differ by more than the shortest significant range for a subset of that size). Underlined numbers indicate there is no significant difference between the means.

Subset 1 (subterminal primaries slightly darker than mantle)

Group	Cordova	Egg Island	Haenke Island	Copper Sands (S)	Strawberry Reef
Mean	1.5870	1.9107	1.9500	2.0313	2.2000

Subset 2 (primaries 2 - 3 shades darker than mantle; extensive melanin)

Group	Dry Bay	North Marble
Mean	3.1053	4.1250

Subset 3 (primaries 3 shades darker than mantle to black; extensive and distinctly delimited pattern)

Group	North Marble	Lake Louise
Mean	4.1250	6.000

black pattern including much of the outermost primaries. The complete range of variation in primary feather pigmentation between glaucescens and argentatus types is found in the colony at Dry Bay. Some gulls in the Cordova area show primaries lighter than the mantle. Mean wing hybrid indices gradually increase from coastal populations most like glaucescens (HI 1.59), through intermediate populations (HI 3.1 - 4.1) in fjords and bays, to an interior population of argentatus (HI 6) on a freshwater lake.

The next most obvious character which differed between individual gulls and by populations in southern Alaska was eye color. Since iris pigmentation may serve as an isolating mechanism between gull populations in other areas, the following analysis of iris pigmentation seeks to demonstrate whether eye color could serve as an isolating mechanism in southern Alaska.

III. Iris Pigmentation

Iris color has been suggested as an important morphological character which exerts its effect during pair formation and copulation in gulls (Smith, 1966b). Differences in contrast afforded by eye color against the white head may function as an isolating mechanism in mate selection, e.g., in species recognition. I sought to determine, with this background in mind, whether the variation and distribution of iris color would function as a factor in species recognition between the light-eyed argentatus and the dark-eyed glaucescens in the southern Alaskan study area.

Iris color was analyzed by four main methods. First, the distribution of colors was determined by computation of a hybrid index based upon broad categories equivalent to the mid-values of Munsell hues. Second, an analysis of variance was conducted on the iris color data to test for the significance of the observed distribution. Since the resulting F-ratio was very highly significant, the data were further analyzed using Duncan's Multiple Range Test. Third, iris color was examined by qualitative comparison of the percentages of the individual Munsell categories of hue, value, and chroma. Fourth, the Munsell parameters of iris hue, value, and chroma were combined and the resulting detailed frequencies of the complete notation were analyzed qualitatively. Finally, the possible linkage of iris color with primary feather pigmentation was tested by an analysis of variance, crosstabulation, and Chi-square value.

A. Index of the Broad Categories of Iris Color

The results of the index constructed for the broad categories of iris color are presented in Table 13. The range of iris coloration within the southern Alaskan study area includes very dark brown (HI 4), dark brown (HI 5), brown (HI 6), light brown (HI 7), light yellow (HI 8), and bright yellow (HI 9). The Haenke Island population had the darkest index (6.30), the least range (6 - 7), and the smallest standard deviation (other than the monomorphic Lake Louise population), reflecting a relatively uniform population of coastal glaucescens-like types. Egg Island had the greatest range, extending from very dark brown (HI 4) to light yellow (HI 8). North Marble had the greatest standard deviation, reflecting a mixture of iris colors in the population. All gulls observed at Lake Louise had yellow irides (HI 9). Light brown (HI 7) was the most frequent mean eye color, and occurred in coastal populations.

Table 13. Hybrid Index of Broad Categories of Iris Color for *Larus* Colonies in Southern Alaska

Colony	Mean	Color	Range	Standard Deviation
Haenke Island	6.30	brown	6 - 7	0.48
Egg Island	6.86	light brown	4 - 8	0.98
Strawberry Reef	7.08	light brown	6 - 8	0.95
Copper Sands (S)	7.12	light brown	6 - 8	0.96
North Marble	7.25	light brown	6 - 9	1.50
Cordova	7.26	light brown	6 - 9	0.81
Dry Bay	7.79	light yellow	6 - 9	0.81
Lake Louise	9.00	yellow	9 - 9	0.00

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F-ratio
Between Groups	7	34.7799	4.9698	6.062 *
Within Groups	166	136.0477	0.8196	
Total	173	170.8276	0.8196	

* very highly significant ($p < .001$)

B. Ranked Means of Eye Color Categories

Since the F-ratio for the observed distribution of iris color was very highly significant (F = 6.062, 173 d.f., $p < .001$), the data were further analyzed using Duncan's Multiple Range Test for subsets of ranked means. Results of this test are presented in Table 14. Inspection of this Table reveals an uninterrupted continuum of the categories of iris color, from populations most like glaucescens to populations clearly identifiable as argentatus. The mean of the coastal Haenke Island colony (brown irides) is connected to the mean of the interior Lake Louise colony (clear yellow irides) by a "bridge" of intermediate colonies at North Marble (light brown) and Dry Bay (light yellow) (see Subset 3, Table 14). The Cordova population falls into this same subset, suggesting a mixture of dark and light-eyed genes is present in this population. Interestingly, the mean wing hybrid index for Cordova was the lightest of any population examined. This finding has implications of a genetic contact between glaucescens and hyperboreus (see Discussion).

C. Munsell Parameters of Iris Color

(1) Hue - the notation of a color indicating its relation to a visually equally-spaced scale. The hue notation in this study is based upon three color names: Red (R), Yellow-Red (YR), and Yellow (Y).

Qualitative analysis of the frequencies of iris hue demonstrates that Haenke Island, a geographically rather isolated colony, is most different from other populations, with the highest frequency of 7.5 YR (a brown hue) (Table 14; Fig. 16). Strawberry Reef, Copper Sands (S), and Egg Island, neighboring colonies on the Copper River Delta, have

Table 14. Ranked Means for the Broad Categories of Eye Color for *Larus* Colonies in Southern Alaska

(Duncan's New Multiple Range Test: $p < .05$ level)

Homogeneous subsets (subsets of groups, whose highest and lowest means do not differ by more than the shortest significant range for a subset of that size). Underlined numbers indicate there is no significant difference between the means.

Subset 1 (brown - light brown)

Group	Haenke Island	Egg Island	Strawberry Reef	Copper Sands (S)	North Marble
Mean	6.30	6.86	7.08	7.12	7.25

Subset 2 (light brown)

Group	Egg Island	Strawberry Reef	Copper Sands (S)	North Marble	Cordova
Mean	6.86	7.08	7.12	7.25	7.26

Subset 3 (light brown - light yellow)

Group	North Marble	Cordova	Dry Bay
Mean	7.25	7.26	7.79

Subset 4 (light yellow - bright yellow)

Group	Dry Bay	Lake Louise
Mean	7.79	9.00

strikingly similar frequencies, with distributions of 7.5 YR (brown), 10 YR (light brown), and 2.5 Y (light yellow). The means of iris colors for these three colonies are also closely grouped around 7 (light brown) on the index (Table 14). The distribution of iris hues in the Cordova population, with high percentages of 10 YR and 2.5 Y, is quite different from that of the Copper River Delta populations, although the means of the color indices are statistically similar (Fig. 16; Table 14). The North Marble and Dry Bay populations both exhibit strong yellow hues (5 Y), which are absent in other groups except Lake Louise (Fig. 16). North Marble, compared to Dry Bay, has a higher percentage of 7.5 YR, although the means of the broad categories of eye color are statistically similar. Dry Bay, compared to all other colonies, has the highest percentage of 2.5 Y, and the lowest percentage of 7.5 YR. Lake Louise has the highest percentage of 5 Y (Fig. 16). The means of the iris color indices for Dry Bay and Lake Louise were not statistically different (Table 14).

(2) Value - the notation of a color indicating the degree of lightness or darkness in relation to a neutral grey scale.

Comparison of the percentages of iris values again demonstrates that the Haenke Island population possesses particular characteristics, here with a high concentration (80%) of the moderately dark value 4. The value 8 on the Munsell System (quite light, indicating decreased melanin pigments) is present in the irides of the North Marble and Dry Bay populations in the southern portion of the study area, and in the Egg Island and Cordova populations in the north. The value 8 is not found in the populations of Haenke Island, Strawberry Reef, and Copper Sands (S) in the central part of the study area.

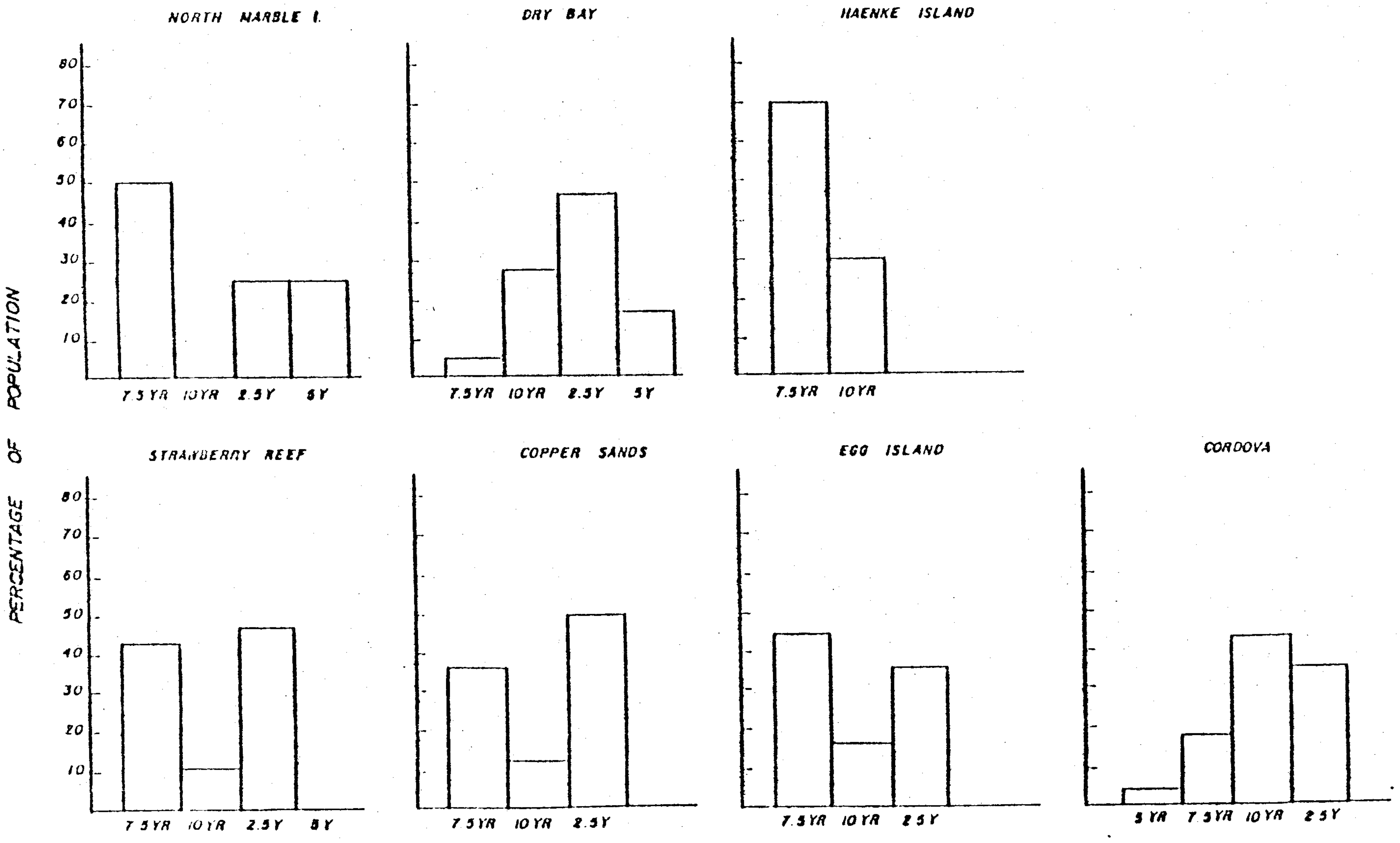

PERCENTAGE OF POPULATION
NORTH MARBLE I.
DRY BAY
HAENKE ISLAND
STRAWBERRY REEF
COPPER SANDS
EGG ISLAND
CORDOVA
80
70
60
50
40
30
20
10
7.5YR
10YR
2.5Y
5Y
5YR
IRIS HUE

Fig. 16.

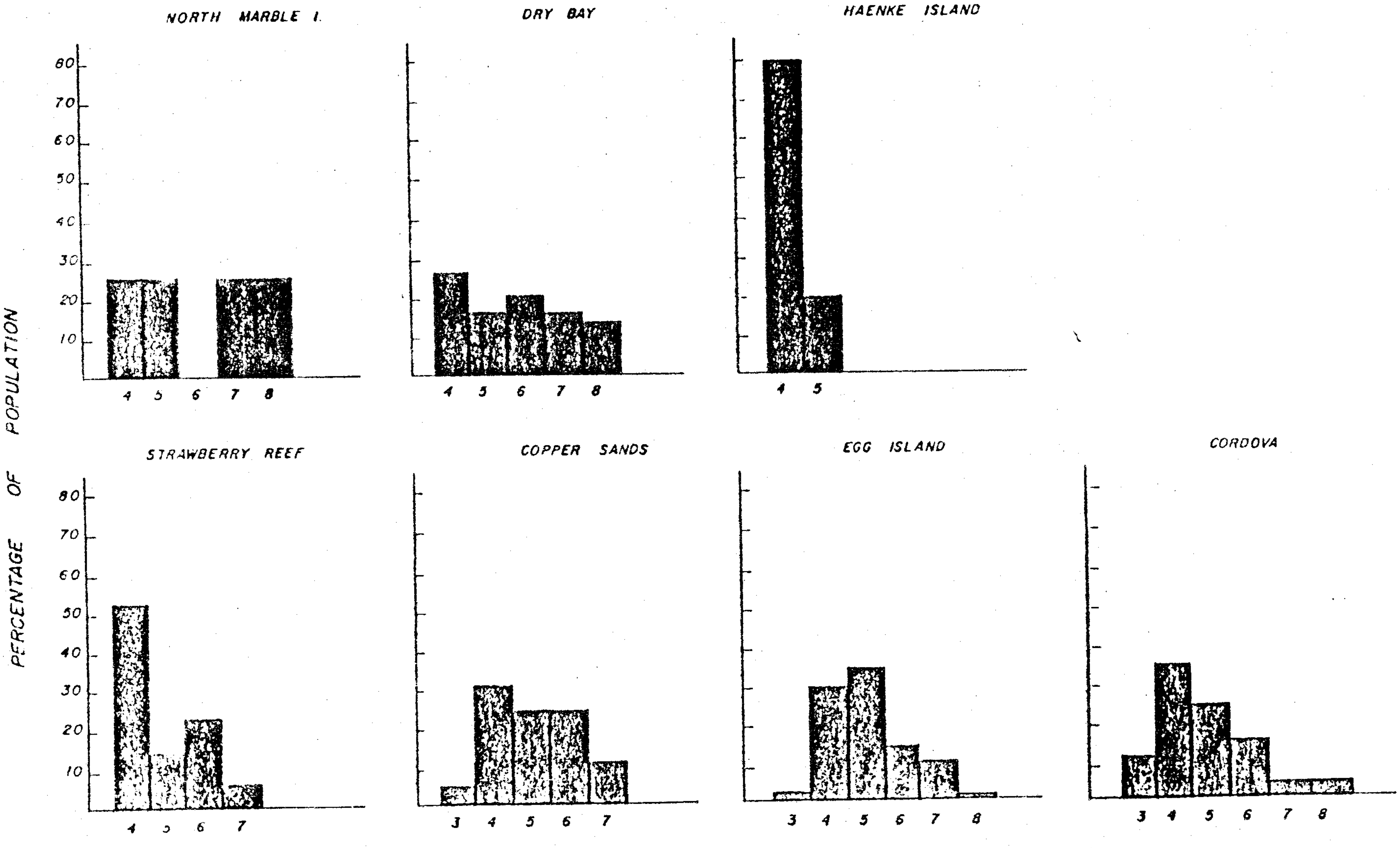

NORTH MARBLE I.
DRY BAY
HAENKE ISLAND
STRAWBERRY REEF
COPPER SANDS
EGG ISLAND
CORDOVA
PERCENTAGE OF POPULATION
80
70
60
50
40
30
20
10
4 5 6 7 8
4 5 6 7 8
4 5
4 5 6 7
3 4 5 6 7
3 4 5 6 7 8
3 4 5 6 7 8
IRIS VALUE

Fig. 17.

North Marble resembles Dry Bay in the distribution of iris values, as in many other parameters, except for a lack of the value 6, perhaps due to smaller sample size (Fig. 17). The frequency of iris values in the Strawberry Reef population, which has slightly darker primaries and longer wings than other Copper River Delta colonies, resembles that of Dry Bay, with two differences. There is a greater percentage of the dark value 4, and a complete lack of the light value 8 at Strawberry Reef.

The iris value 3 (quite dark, indicating abundant melanin pigments) is present in the Copper Sands (S), Egg Island, and Cordova populations. Interestingly, quite light values of 8 are also present at Egg Island and Cordova (see above). This somewhat paradoxical result can be explained by postulating a mixture of both light-eyed and dark-eyed genes in these populations.

(3) Chroma - the degree of departure of a given hue from a neutral grey of the same value. Chroma scales depend upon the strength (saturation) of the sample evaluated.

All populations except Cordova show a concentration of the chroma 4 (Fig. 18). The Cordova population is quite different, with chroma rather evenly distributed among the classifications of 2, 3, and 4, with a smaller amount of chroma 6. Haenke Island shows relationship to other colonies with a high frequency of chroma 4 (but not through frequencies of hues and values). The distribution of iris chroma at North Marble is bimodal, with strong concentrations at the classifications of 4 and 8. The Dry Bay distribution is qualitatively different from that of North Marble, in comparison to the rather similar distributions of iris hues and values. (These two colonies are also related in the broad index of

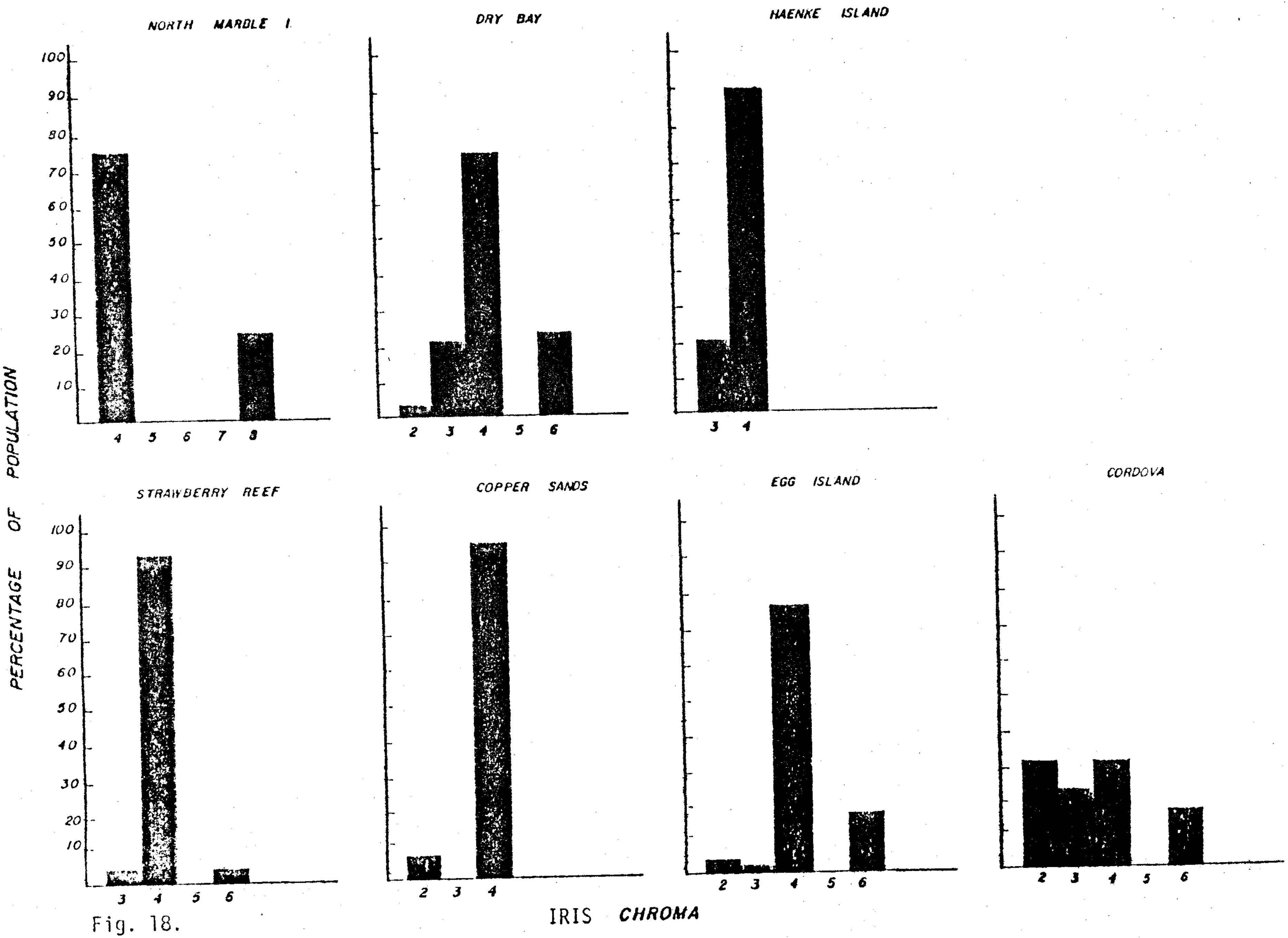

NORTH MARBLE I.
DRY BAY
HAENKE ISLAND
STRAWBERRY REEF
COPPER SANDS
EGG ISLAND
CORDOVA
PERCENTAGE OF POPULATION
100
90
80
70
60
50
40
30
20
10
4 5 6 7 8
2 3 4 5 6
3 4
3 4 5 6
2 3 4
2 3 4 5 6
2 3 4 5 6
IRIS CHROMA

Fig. 18.

eye color, and the wing hybrid index.) Less intensely saturated chroma (2, 3) are present in the Dry Bay population, as well as an intermediate chroma of 6.

IV. Iris Hue, Value, and Chroma Combined

Hue, value, and chroma are the parameters which make up a complete color in the Munsell system. The iris colors of similar base hues are graphed in proximity to each other in Figs. 19, 20, 21, 22.

The combination of iris parameters extends well into the realm of individual variation. For instance, each of four gulls collected at North Marble had different colored eyes. The distribution of the combined iris parameters for North Marble is thus related to sample size. Dry Bay has the widest distribution of the combined iris parameters; there are more kinds of eye color in this colony at the mouth of the Alsek River than in any other group examined. The breeding population at Dry Bay is highly mixed in other characters such as primary feather pigmentation and orbital ring coloration. The Cordova and Egg Island populations also show a wide distribution of combined iris parameters.

Copper Sands (S) and Strawberry Reef, neighboring colonies on the Copper River Delta, have the most similar distribution of combined iris parameters. These colonies also share similar indices of primary feather pigmentation, similar distributions of the individual Munsell parameters of hue and chroma, and significant enlargement of bill depth.

In summary, qualitative comparisons of the iris frequencies of the individual Munsell categories of hue, value, and chroma, and the combinations thereof, reveal subtle aspects of relationships not apparent

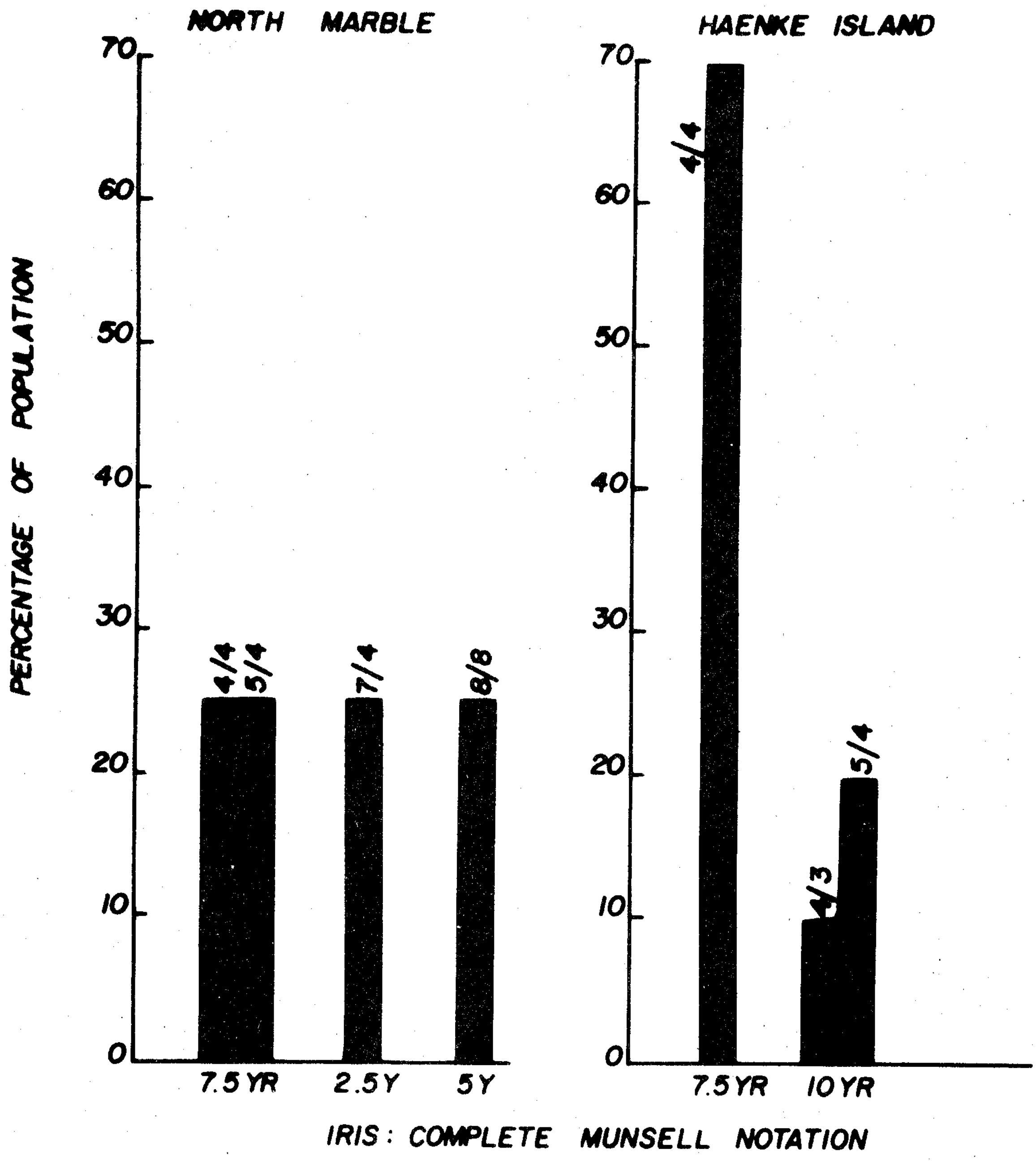

NORTH MARBLE
HAENKE ISLAND
PERCENTAGE OF POPULATION
70
60
50
40
30
20
10
0
4/4
5/4
7/4
8/8
7.5 YR
2.5 Y
5 Y
4/4
4/3
5/4
7.5 YR
10 YR
IRIS: COMPLETE MUNSELL NOTATION

Fig. 19.

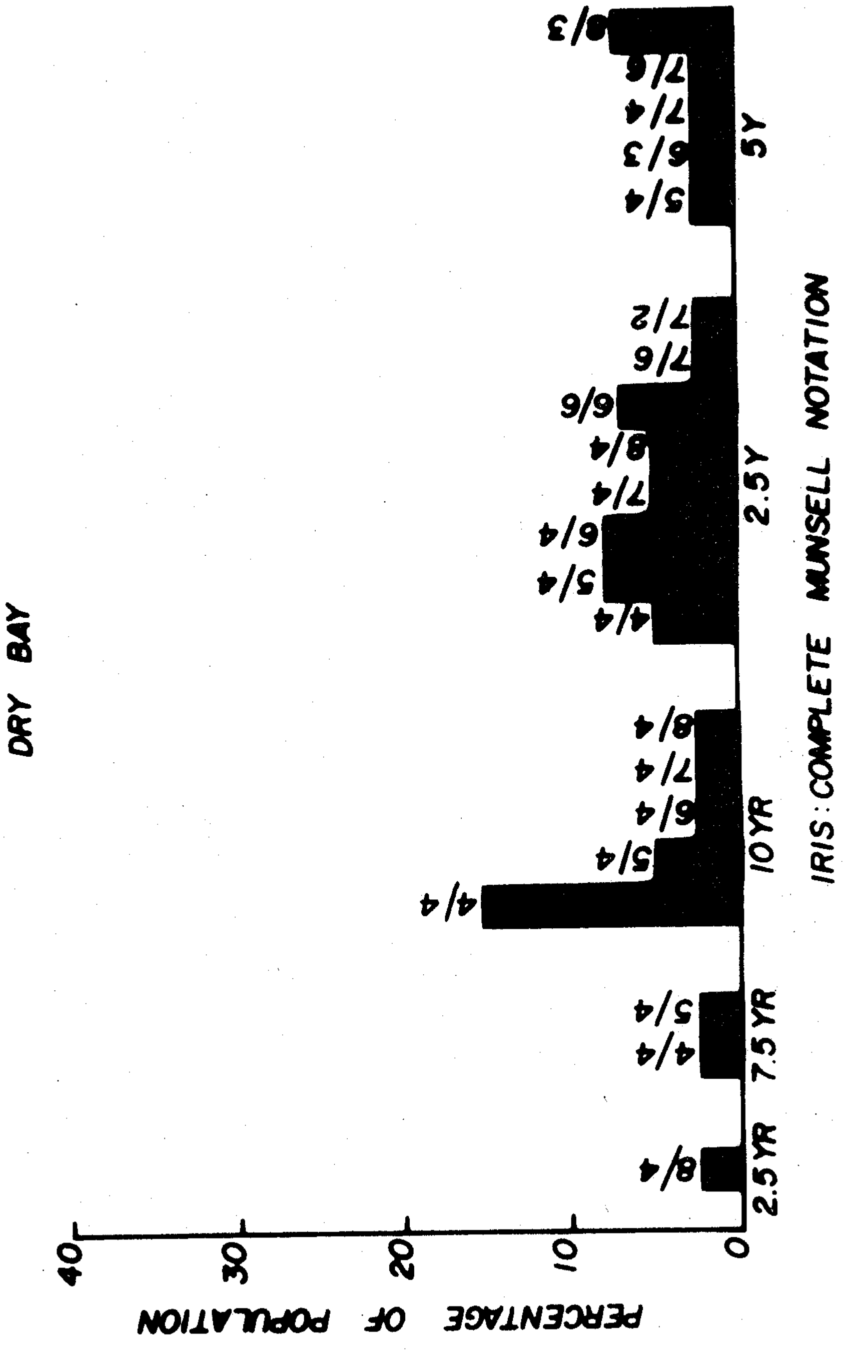

DRY BAY
PERCENTAGE OF POPULATION
0
10
20
30
40
8/4
2.5YR
4/4
5/4
7.5YR
4/4
5/4
6/4
7/4
8/4
10YR
4/4
5/4
6/4
7/4
8/4
6/6
7/6
7/2
2.5Y
5/4
6/3
7/4
7/6
8/3
5Y
IRIS: COMPLETE MUNSELL NOTATION

Fig. 20.

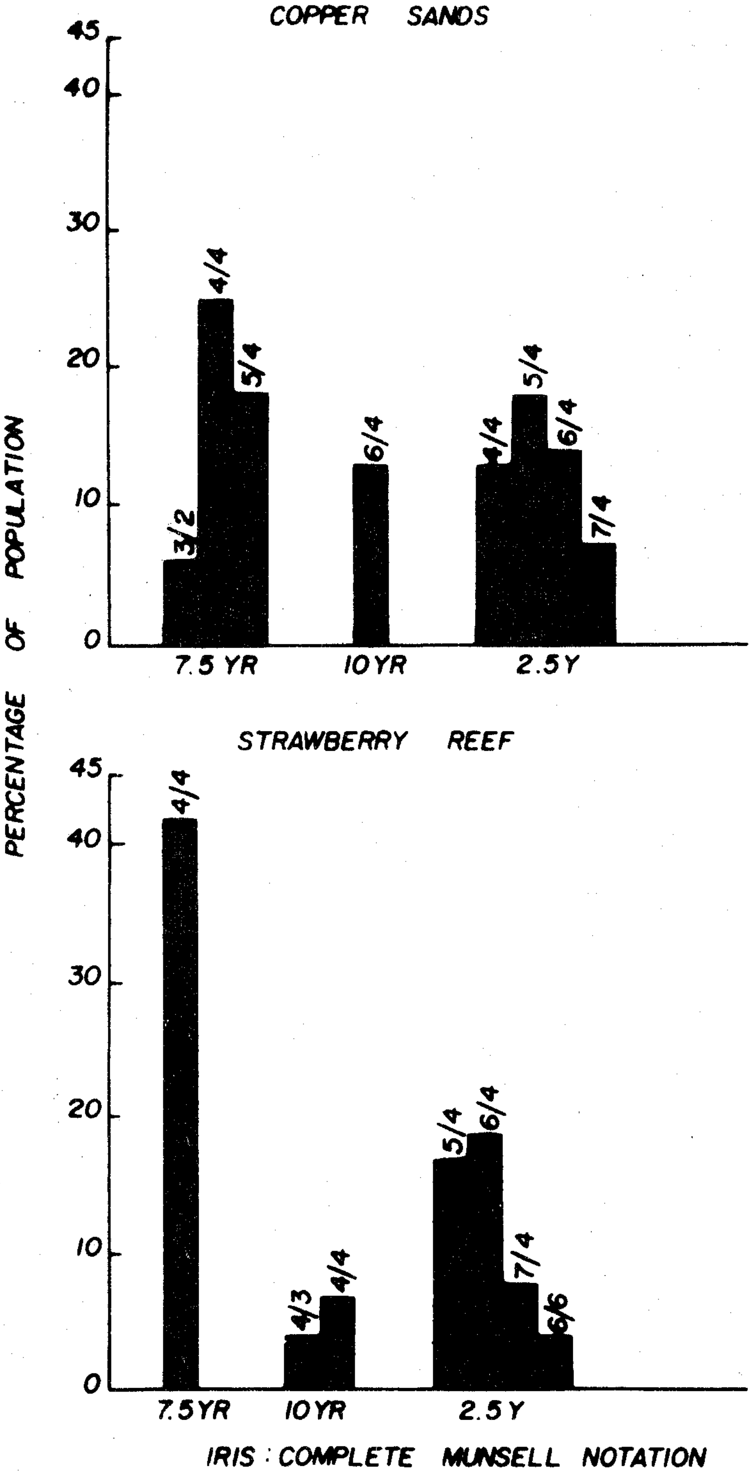

COPPER SANDS
PERCENTAGE OF POPULATION
45
40
30
20
10
0
3/2
4/4
5/4
6/4
4/4
5/4
6/4
7/4
7.5 YR
10YR
2.5Y
STRAWBERRY REEF
45
40
30
20
10
0
4/4
4/3
4/4
5/4
6/4
7/4
6/6
7.5YR
10YR
2.5Y
IRIS : COMPLETE MUNSELL NOTATION

Fig. 21.

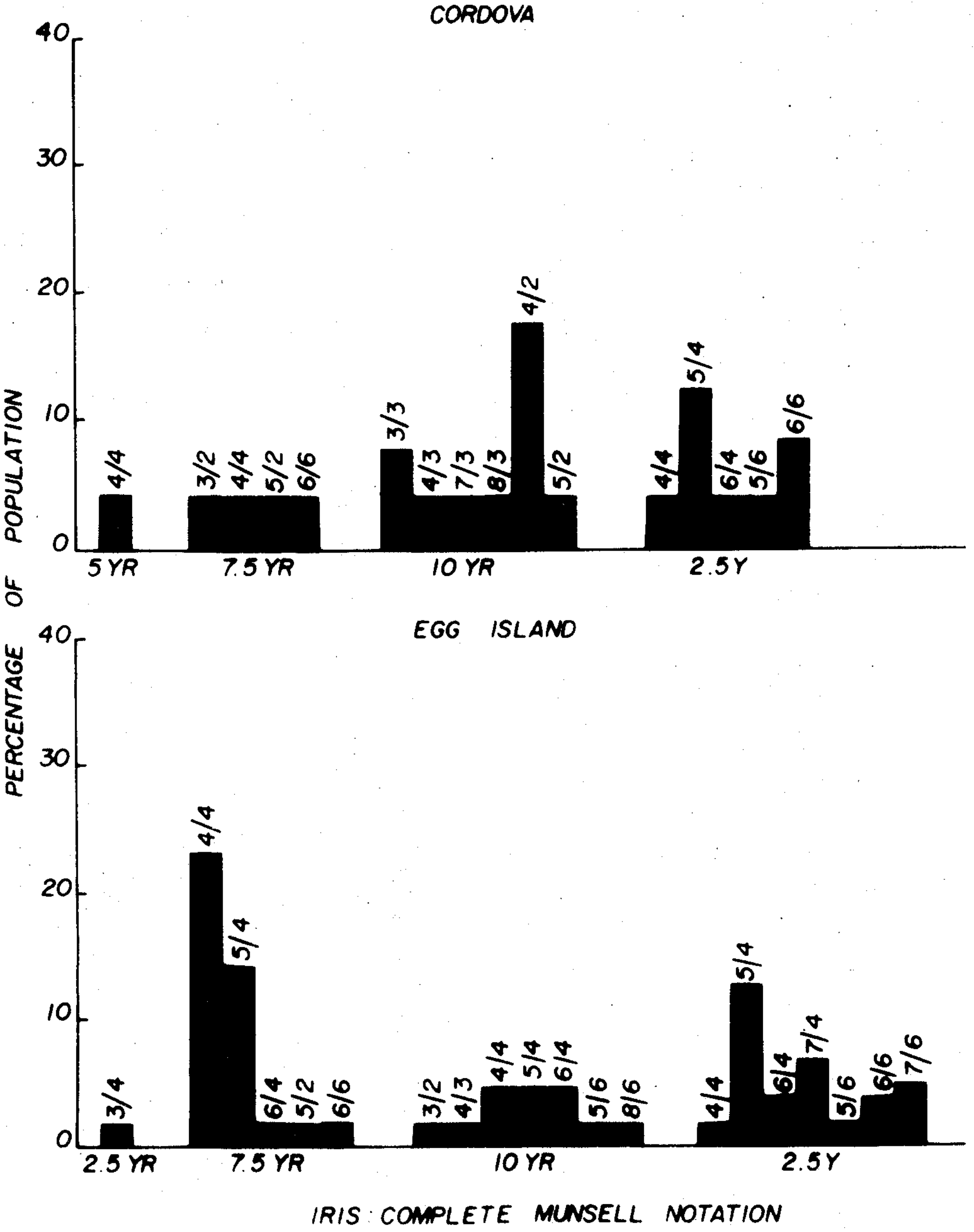

CORDOVA
40
30
20
10
0
4/4
3/2 4/4 5/2 6/6
3/3 4/3 7/3 8/3 4/2 5/2
4/4 5/4 6/4 5/6 6/6
5 YR
7.5 YR
10 YR
2.5 Y
PERCENTAGE OF POPULATION
EGG ISLAND
40
30
20
10
0
3/4
4/4 5/4 6/4 5/2 6/6
3/2 4/3 4/4 5/4 6/4 5/6 8/6
4/4 5/4 6/4 7/4 5/6 6/6 7/6
2.5 YR
7.5 YR
10 YR
2.5 Y
IRIS COMPLETE MUNSELL NOTATION

Fig. 22.

in the comparison of means of the broad categories of eye color. Neighboring colonies on the Copper River Delta have strikingly similar distributions of iris hues. The Cordova gull population is qualitatively different in distribution of iris hues from the Copper River Delta populations. North Marble and Dry Bay share similar, although not identical distributions of iris hues and values. Haenke Island has a particular pattern of both hues and values, but shares a concentration of chroma with other populations. Strawberry Reef resembles Dry Bay in the distribution of iris values. (Strawberry Reef gulls also have slightly, although not statistically, longer and darker wings than other Copper River Delta populations.)

All populations except Cordova show a concentration of the chroma 4. (Cordova gulls also have the lightest mean wing index, and slightly, although not statistically larger body measurements.) Cordova, Egg Island, and Dry Bay populations have a wide distribution of the combined iris parameters, indicating that gulls of different eye colors are present in these populations. Copper Sands (S) and Strawberry Reef are related in many morphological parameters, including iris color, although Strawberry Reef shows an additional affinity to a population like that inhabiting Dry Bay to the southeast.

V. Linkage of Iris Color to Primary Feather Pigmentation

To test whether iris color could be linked to primary feather pigmentation, I formulated a null hypothesis that there was no linkage between these characters. I then conducted an analysis of variance on the observed distribution of wing hybrid indices (0.0 - 6.0) as compared to the distribution of six categories of iris hue, using

Table 15. Analysis of Variance of Wing Hybrid Index by Iris Hue

Source of Variation	Sum of Squares	d.f.	Mean Square	F-ratio
Main Effects	38.605	4	9.651	7.819 *
Iris Hue	38.605	4	9.651	7.819 *
Explained	38.605	4	9.651	7.819 *
Residual	208.597	169	1.234	
Total	247.201	173	1.429	

(n = 174) * very highly significant (p <.001)

Crosstabulation of Iris hue by Wing Hybrid Index: Chi-square = 81.4322 with 36 degrees of freedom: very highly significant association of Wing Hybrid Index by Iris Hue.

data from 174 gulls. The results of this test are presented in Table 15. Inspection of this table reveals a very highly significant F-ratio. A further crosstabulation of iris hue by wing hybrid index produced a value of Chi-square (81.4322, 36 d.f., $p < .001$), indicating a very highly significant association of wing hybrid index with iris hue. I therefore rejected the null hypothesis.

Iris color is highly linked with primary feather pigmentation in gull populations between Lake Louise and Glacier Bay in southern Alaska. Light-eyed gulls tend to have dark primaries, dark-eyed gulls tend to have light primaries, and gulls with intermediate amounts of melanin deposition in the primaries have irides in various intermediate shades. There are some exceptions to this rule, notably around Cordova, where gulls may have both light eyes and primaries distinctly lighter than those found elsewhere (see Discussion).

The variation and distribution of iris color, although apparently linked with primary feather pigmentation, seems unlikely to function in species recognition between the light-eyed argentatus and the dark-eyed glaucescens in southern Alaska, since the two forms are linked by a complete range of intermediates.

VI. Orbital Ring Pigmentation

The orbital ring of a gull is that fleshy portion of the eyelid which is visible when the eye is completely open. The orbital ring forms a circle around the opened eye, and is variously colored in different species of gulls. The orbital ring, along with the iris, contrasts against the white head of the gull, and may function as an isolating mechanism between certain species.

Larus argentatus "pure types" in southern Alaska have yellow orbital rings of the hues 2.5 Y - 5 Y. In contrast, other argentatus populations may have orange eye-rings (Smith, 1966b). Larus glaucescens "pure types" have dark pink or vinaceous orbital rings of hue 5 R. This section of the study examines the variation, distribution, and possible function of orbital ring pigmentation in southern Alaskan gulls.

Orbital ring pigmentation was analyzed by similar methods to those used in the analysis of eye color. A hybrid index was computed, based on the orbital ring hues of 174 gulls. The orbital rings in some cases were made up of two to three hues. In such cases, the indices for the individual hues were summed, giving a composite index for the orbital ring. An analysis of variance was conducted for the significance of the observed variation. An analysis was then conducted for subsets of ranked means, using Duncan's Multiple Range Test. The qualitative frequencies of the orbital ring hues were compared by colony. Finally, a crosstabulation of orbital ring hues by colony identification number resulted in a Chi-square value of the significance of the distribution.

A. Hybrid Index of Orbital Ring Pigmentation

(1) Broad Index

The results of the hybrid index of orbital ring pigmentation for gull colonies in southern Alaska are presented in Table 16. Note that the extreme pigments are dark pink and bright yellow, but six intermediate hues exist, and more than one hue may occur in an

Table 16.

Hybrid Index of Orbital Ring Pigmentation for *Larus* Colonies in Southern Alaska (Hue 1 + Hue 2 + Hue 3)

Colony	Mean	Munsell Hue	Color
Haenke Island	1.30	5 R	dark pink
Cordova	1.83	7.5 R	pink
North Marble	2.75	10 R	light pink
Egg Island	3.66	2.5 YR	yellowish pink
Copper Sands	4.00	2.5 YR	yellowish pink
Dry Bay	4.36	2.5 YR	yellowish pink
Strawberry Reef	4.60	5 YR	pinkish yellow
Lake Louise	8.50	2.5 Y	light yellow
		5 Y	bright yellow

Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F-ratio
Between Groups	7	226.1396	32.3057	4.875 *
Within Groups	166	1100.0500	6.6268	
Total	173	1326.1897		

* very highly significant ($p < .001$). Crosstabulation of the Index of Orbital Ring Pigmentation by colony: Chi-square = 151.021 with 77 degrees of freedom; very highly significant association of index of Orbital Ring Pigmentation by colony.

individual eye-ring. Each colony examined had a different mean composite orbital ring, but the extremes are connected through increasing amounts of yellow pigment.

Haenke Island again represents a coastal population most like parental glaucescens, with orbital rings of 5 R, dark pink (Table 16). North Marble scored relatively light on the index, with a mean of 10 R, light pink, in contrast to other characters showing hybrid influence. The Cordova population mean was 1.83, closest to moderate pink values. Egg Island. Copper Sands (S), and Dry Bay were grouped around 4.00 on the index, with intermediate yellowish pink orbital rings. The Strawberry Reef population had slightly more yellow present in the orbital rings than other Copper River Delta populations, with an index of 4.60. The index jumped sharply between Strawberry Reef and Lake Louise (4.60 - 8.50). Lake Louise represents the population most like parental argentatus, with orbital rings of hues 2.5 Y - 5 Y.

Inspection of Table 16 shows that a very highly significant F-value is produced by the Analysis of Variance of the hybrid indices of orbital ring pigmentation. An additional crosstabulation of these indices by colony results in a Chi-square value of 151.021, 77 d.f., $p < .001$; a very highly significant association. Each population, therefore, had orbital rings unlike those of other populations. Since the F-ratio for the distribution of orbital ring pigmentation was very highly significant, the means were ranked using Duncan's Multiple Range Test. Three subsets of ranked means were produced at the $p < .05$ level (Table 17). Most populations (five) fall into the intermediate subset 2, with orbital rings ranging from light pink to yellowish pink. Populations from Copper Sands, Dry Bay, and Strawberry Reef are most

Table 17. Ranked Means for Orbital Ring Indices for *Larus* Colonies in Southern Alaska

(Duncan's New Multiple Range Test: p < .05 level)

Homogeneous subsets (subsets of groups, whose highest and lowest means do not differ by more than the shortest significant range for a subset of that size). Underlined numbers indicate there is no significant difference between the means.

Subset 1 (dark pink - light pink)

Group	Haenke Island	Cordova	North Marble
Mean	1.30	1.83	2.75

Subset 2 (light pink - yellowish pink)

Group	North Marble	Egg Island	Copper Sands	Dry Bay	Strawberry Reef
Mean	2.75	3.66	4.00	4.36	4.60

Subset 3 (light yellow - bright yellow)

Group	Lake Louise
Mean	8.50

---

* The only difference in this test between the p <.05 and p <.01 levels of significance, is at the p <.01 level, Lake Louise joins Subset 2.

nearly intermediate between the extremes of dark pink and bright yellow orbital rings. At the $p < .01$ level, Dry Bay joins Subset 2, thereby forming a statistical continuum of orbital ring pigmentation.

(2) Solo Hues

Some orbital rings were uniformly pigmented, with the color evenly distributed on all portions of the eyelid. These will be referred to as "solo hues." Orbital rings with solo hues occurred in the North Marble, Dry Bay, Haenke Island, and Cordova populations (Figs. 23, 24, 25). Orbital rings with solo hues only were found in North Marble and Haenke Island populations.

Dark pink (5 R) was the dominant solo hue in the North Marble, Haenke Island, Dry Bay, Egg Island, and Cordova populations (Fig. 23). Yellowish pink (2.5 YR) was the second most important solo hue (after 5 R) occurring in the Dry Bay, Haenke Island, and Egg Island populations. The hue 5 R (without 2.5 YR as the second most important hue) was found at North Marble and Cordova. The North Marble population showed the maximum number of solo hues, ranging from 5 R (dark pink) to 2.5 Y (light yellow). The Dry Bay population contained every possible orbital ring hue between these two extremes (Fig. 23). Gulls with black primaries at Dry Bay had orbital ring hues including 2.5 YR (yellowish pink), 5 YR (pinkish yellow), and 10 YR (light pinkish yellow). Gulls with similar indices of primary feather pigmentation (HI 6) at Lake Louise had orbital ring hues of 2.5 Y (light yellow) to 5 Y (bright yellow).

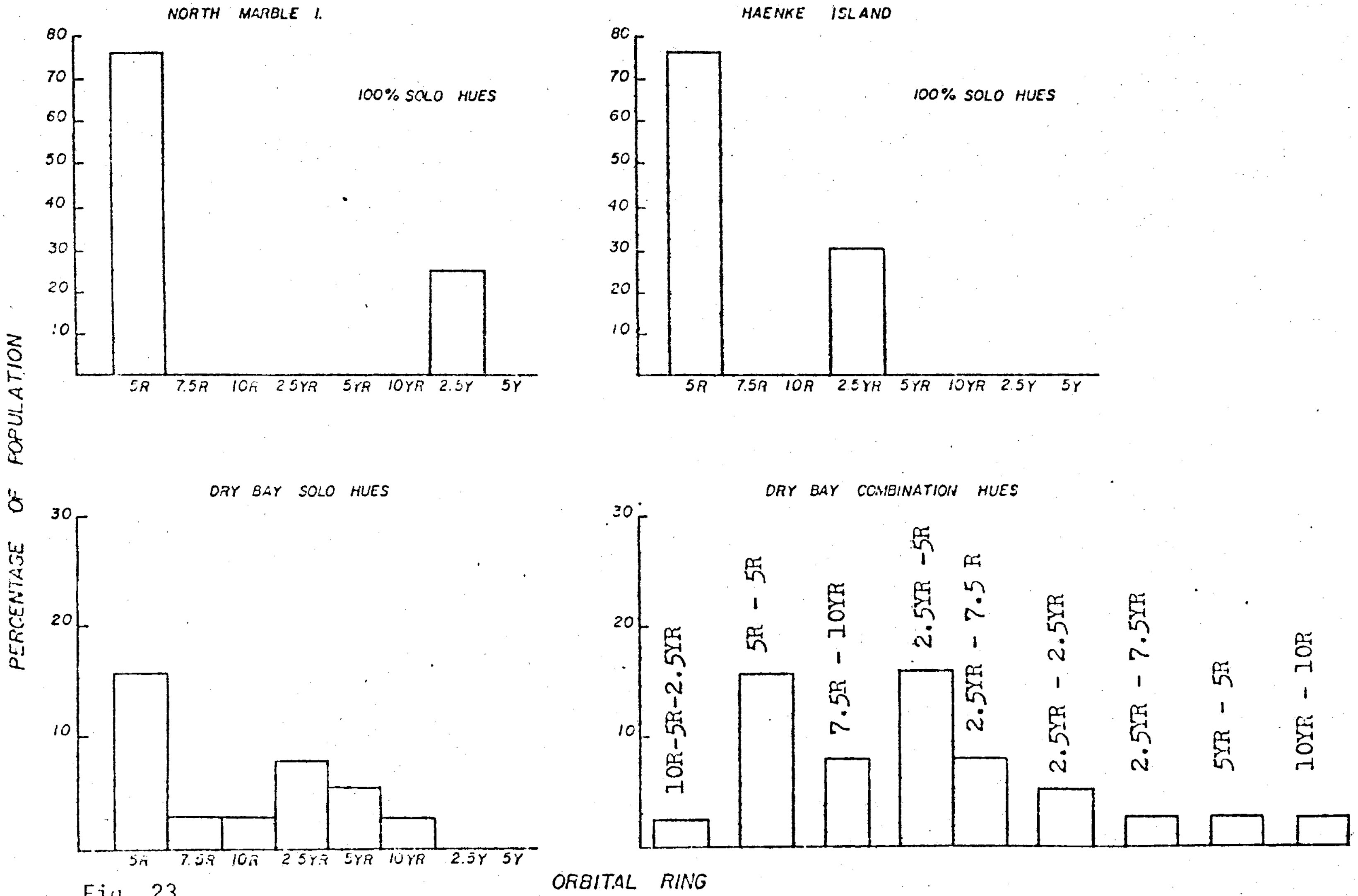

NORTH MARBLE I.
100% SOLO HUES
HAENKE ISLAND
100% SOLO HUES
80
70
60
50
40
30
20
10
5R
7.5R
10R
2.5YR
5YR
10YR
2.5Y
5Y
PERCENTAGE OF POPULATION
DRY BAY SOLO HUES
DRY BAY COMBINATION HUES
30
20
10
10R-5R-2.5YR
5R - 5R
7.5R - 10YR
2.5YR -5R
2.5YR - 7.5 R
2.5YR - 2.5YR
2.5YR - 7.5YR
5YR - 5R
10YR - 10R
ORBITAL RING

Fig. 23.

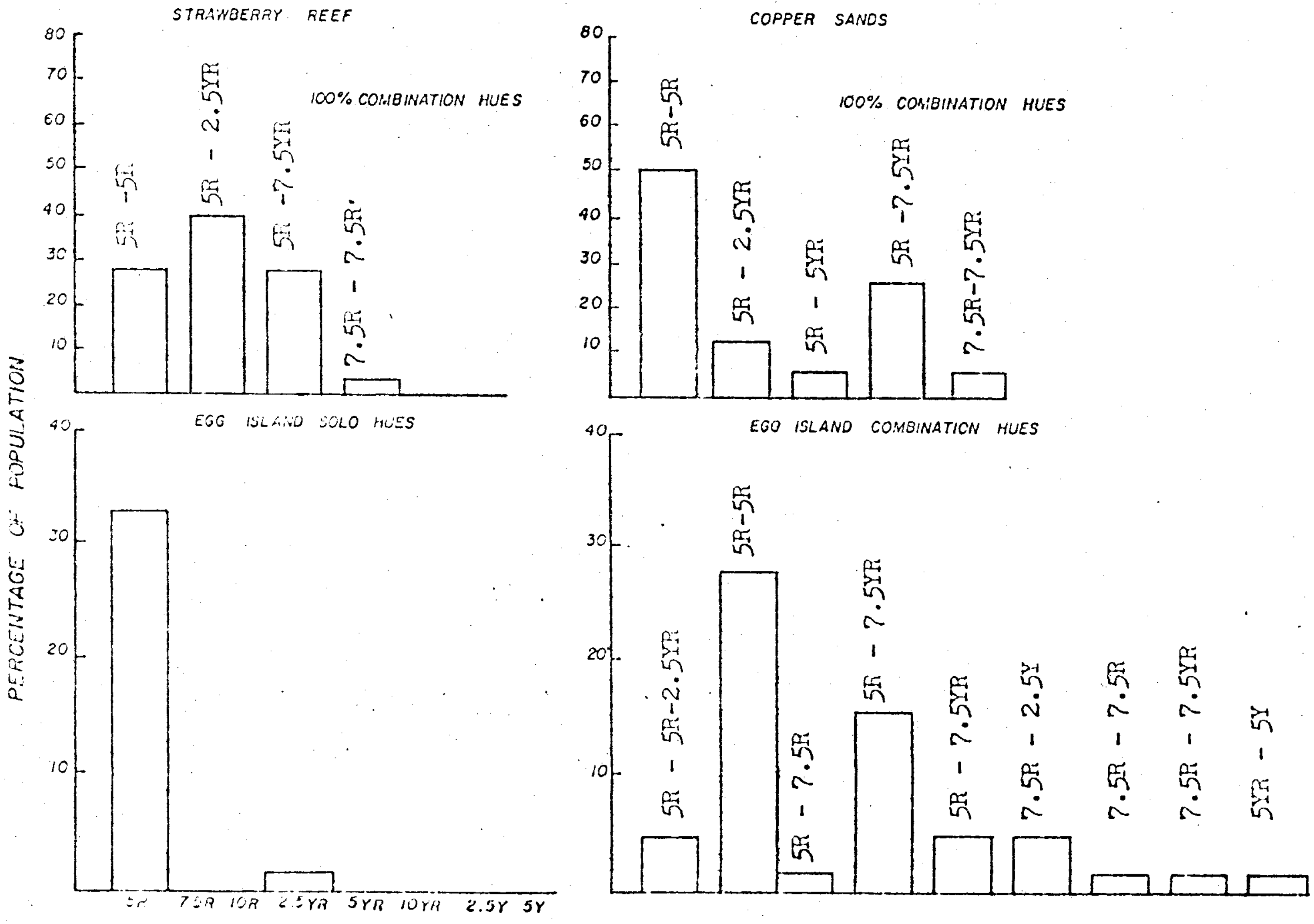

STRAWBERRY REEF
100% COMBINATION HUES
80
70
60
50
40
30
20
10
5R -5R
5R - 2.5YR
5R -7.5YR
7.5R - 7.5R
COPPER SANDS
100% COMBINATION HUES
80
70
60
50
40
30
20
10
5R-5R
5R - 2.5YR
5R - 5YR
5R -7.5YR
7.5R-7.5YR
PERCENTAGE OF POPULATION
EGG ISLAND SOLO HUES
40
30
20
10
5R
7.5R
10R
2.5YR
5YR
10YR
2.5Y
5Y
EGG ISLAND COMBINATION HUES
40
30
20
10
5R - 5R-2.5YR
5R-5R
5R - 7.5R
5R - 7.5YR
5R - 7.5YR
7.5R - 2.5Y
7.5R - 7.5R
7.5R - 7.5YR
5YR - 5Y
ORBITAL RING

Fig. 24.

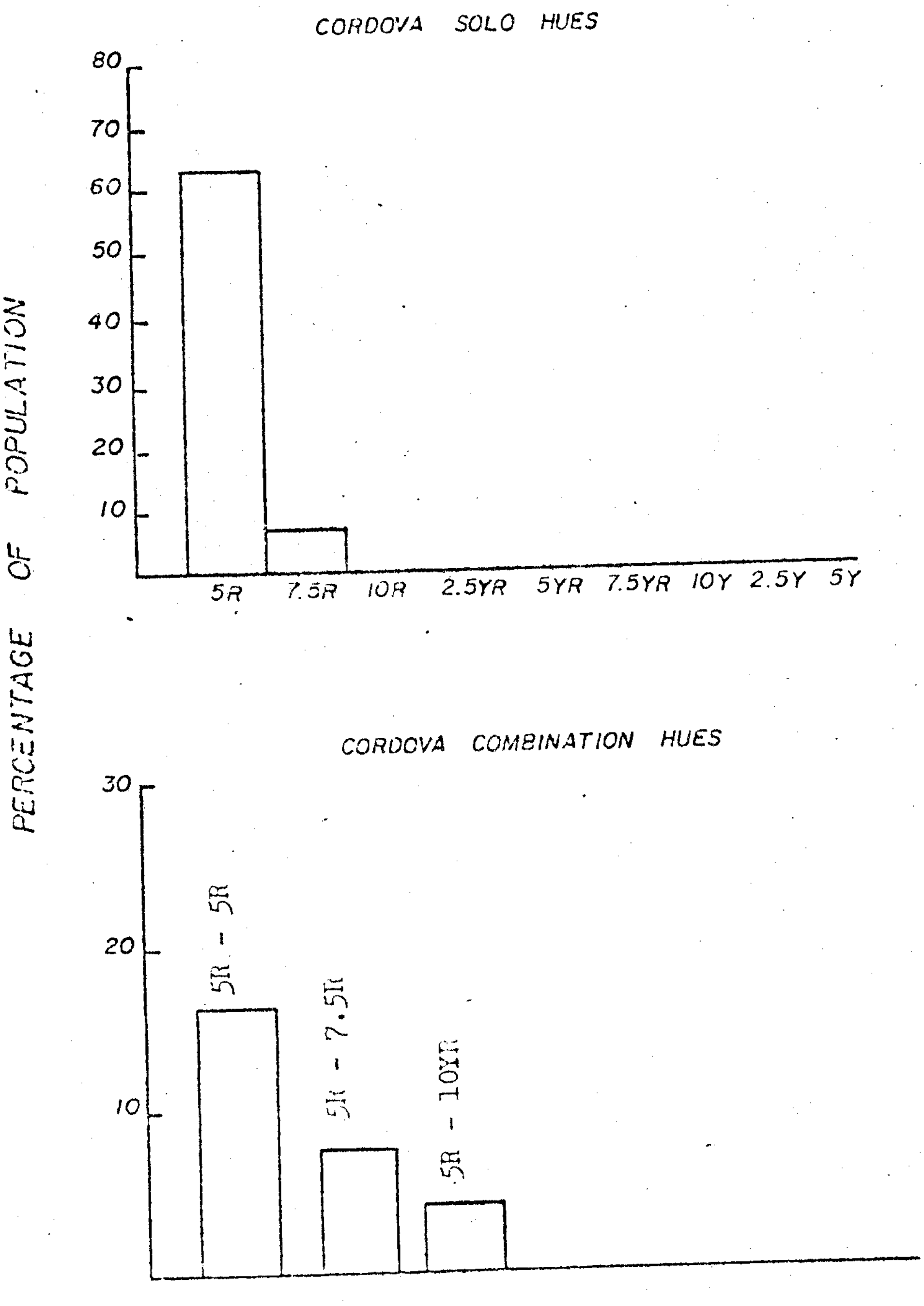

CORDOVA SOLO HUES
80
70
60
50
40
30
20
10
5R
7.5R
10R
2.5YR
5YR
7.5YR
10Y
2.5Y
5Y
PERCENTAGE OF POPULATION
CORDOVA COMBINATION HUES
30
20
10
5R - 5R
5R - 7.5R
5R - 10YR
ORBITAL RING

Fig. 25.

(3) Combination Hues

Orbital rings with a composite index were made up of two to three hues, or "combination hues." Orbital rings with combination hues may have similar base hues (5 Y - 5 Y), each having different value and chroma. For example, a pink eye-ring with areas of more intense reddish pigmentation occurs with a relatively high frequency in the Dry Bay, Egg Island, and Cordova gull populations (Figs. 23, 24, 25).

Only combinations of two hues occurred in the orbital rings of the Copper Sands (S) and Strawberry Reef populations, further demonstrating the close similarity of these populations (Fig. 24). An orbital ring with a pinkish hue on the upper rear portion of the eyelid, and a yellowish hue on the lower front portion, is a typical pattern in these populations. Other populations have 5 R - 2.5 YR combinations (pink with yellowish pink); or 5 R - 7.5 YR combinations (pink with light pinkish yellow).

The gull populations at Egg Island and Dry Bay had individuals with a combination of three hues within a single orbital ring. An example from Dry Bay is an orbital ring of the pigmentation 10 R - 5 R - 2.5 YR (light pink, dark pink, yellowish pink). An example from Egg Island is 5 R - 5 R - 2.5 YR; this eye-ring was pink with darker pink areas on the upper rear, and yellowish pink on the lower front portion.

Egg Island had the greatest distribution of combination hues, ranging from 5 R - 5 R (pink with darker pink areas); to 5 YR - 5 Y (pinkish yellow with yellow). The 5 YR - 5 Y combination did not appear in the gull population at Dry Bay. The distribution of combination hues at Dry Bay ranged from 5 YR - 5 R (pinkish yellow to pink); to 5 R - 7.5 YR (pink to light pinkish yellow). Dry Bay had the greatest distribution of solo hues in addition to the most even distribution of combination hues.

B. Summary of Orbital Ring Pigmentation

Gulls in southern Alaska have orbital rings ranging from dark pink to bright yellow, with six intermediate hues connecting the extremes with increasing amounts of yellow pigment. Each population examined had a different composite mean orbital ring unlike those of other populations. Some orbital rings in individual gulls were uniformly pigmented, while others were composed of as many as three hues. The colony at Dry Bay had the greatest distribution of uniformly pigmented orbital rings, as well as the most even distribution of orbital rings with combination hues. The function of orbital ring pigmentation as a species-specific recognition character in southern Alaska is unlikely, due to the spectrum of variation. However, the variability may function as a character for individual or population recognition.

VII. Composite Hybrid Index

Primary feather pigmentation, iris and orbital ring coloration, have been analyzed individually to discern relationships between gull populations in southern Alaska. These colorimetric characters will now be unified in a composite hybrid index in order to offer the most complete exploration of relationships between gull populations in southern Alaska.

Since the F-ratios for these individual analyses of variance were all very highly significant, it is logical that the F-ratio for the composite hybrid index by colony is also very highly significant ($F = 20.614$, 172 d.f., $p < .001$). The composite hybrid index data were therefore further analyzed using Duncan's Multiple Range Test. The results of this test at the $p < .05$ level of significance are contained in Table 18.

The population with the lowest composite index, and therefore most like *glaucescens*, is from Haenke Island. The population with the highest index, and therefore most like *argentatus*, is from Lake Louise. Between the two extremes are four homogeneous subsets. Subset 1 contains coastal populations most like *glaucescens*. Subset 2 contains as a unit the colonies of the Copper River Delta. Subset 3 contains the hybrid colonies in bays and fjords, with individual phenotypic *argentatus* present in the populations as well as intermediates and *glaucescens*. Subset 4 contains the interior Lake Louise *argentatus* population.

The subsets of ranked means are reduced to three if the Duncan's Multiple Range Test is conducted at the $p < .01$ level of significance (Table 19). The Copper River Delta populations become unified with other populations most like *glaucescens* in Subset 1. Note that in Subset 2, the Strawberry Reef population at the east end of the Copper River Delta is included with the hybrid colonies of Dry Bay and North Marble. Subset 3 contains only the interior *argentatus* at Lake Louise. Individual gulls scoring high on the composite hybrid index, e.g., identifiable as phenotypic *argentatus*, were found at Dry Bay and

Table 18. Ranked Means for the Composite Hybrid Index for *Larus* Colonies in Southern Alaska
(Primary Feather Pigmentation + Iris + Orbital Ring)

(Duncan's New Multiple Range Test: $p < .05$ level)

Homogeneous subsets (subsets of groups, whose highest and lowest means do not differ by more than the shortest significant range for a subset of that size). Underlined numbers indicate there is no significant difference between the means.

Subset 1 (most like *glaucescens*)

Group	Haenke Island	Cordova	Egg Island	Copper Sands
Mean	9.55	10.02	10.39	10.41

Subset 2 (Copper River Delta colonies)

Group	Egg Island	Copper Sands (S)	Strawberry Reef
Mean	10.39	10.41	11.40

Subset 3 (hybrid colonies with individual *argentatus*-types present)

Group	Dry Bay	North Marble
Mean	13.54	14.12

Subset 4 (interior *argentatus*)

Group	Lake Louise
Mean	23.5

Table 19. Ranked Means for the Composite Hybrid Index for *Larus* Colonies in Southern Alaska (Primary Feather + Iris + Orbital Ring Pigmentation)

(Duncan's New Multiple Range Test: $p < .01$ level)

Homogeneous subsets (subsets of groups, whose highest and lowest means do not differ by more than the shortest significant range for a subset of that size). Underlined numbers indicate there is no significant difference between the means.

Subset 1 (most like *glaucescens*)

Group	Haenke Island	Cordova	Egg Island	Copper Sands (S)	Strawberry Reef
Mean	9.55	10.02	10.39	10.41	11.40

Subset 2 (hybrid colonies with and without individual *argentatus*-types present)

Group	Strawberry Reef	Dry Bay	North Marble
Mean	11.40	13.54	14.12

Subset 3 (interior *argentatus*)

Group	Lake Louise
Mean	23.5

North Marble, but none were found at Strawberry Reef. However, in population parameters of primary feather pigmentation, iris and orbital ring coloration, Strawberry Reef shows argentatus influence, and is assigned at the $p < .01$ level to the category of a hybrid colony.

A geographical tendency or cline is evident with the exception of the extreme indices of Haenke Island and Lake Louise. Gull populations show increasing argentatus influence along an axis extending from the northwest to the southeast within the study areas. Primary feathers become darker and yellow pigments increase in the irides and orbital rings of gull populations between Cordova and North Marble. North Marble is quite recently deglaciated (within the last 120 years) and was colonized thereafter. This suggests that the major source of argentatus-like genes along the North Gulf Coast of Alaska is the hybrid colony at Dry Bay, which serves as a bridge between coastal and interior Larus populations.

VIII. Analysis of Mating Patterns

L. argentatus, L. glaucescens, and adult gulls of highly variable primary feather pigmentation were observed nesting together in different habitats in Glacier Bay in 1971 (Patten and Weisbrod, 1974). These observations led to a subsequent study of mating patterns in the mixed colonies of North Marble and Dry Bay. The null hypothesis was that mating was random.

At North Marble, 162 gull pairs nesting on sloping grassy meadows were examined in 1972. The study of the pairs revealed the following: 157 apparently phenotypic glaucescens pairs, 1 "typical" argentatus paired with a "typical" glaucescens, and 3 "intermediates" paired with glaucescens. An intermediate is defined here as a gull not identifiable in the field as either glaucescens or argentatus, but having characteristics of both, i.e., in primary feather pigmentation and iris color. Permission was granted by Park Service officials to collect only four adult gulls at the close of the 1972 nesting season. The birds collected were the same three intermediates and the argentatus analyzed above.

Gull pairs at 290 nest sites were examined on North Marble in 1973. The following pairs were recorded: 276 apparent glaucescens pairs; 1 pair of argentatus; 3 argentatus paired with glaucescens; and 10 pairs of "intermediate" gulls paired with glaucescens. The differences between the two years were not significant ($p < .05$). The presence of species-specific pairs within the study area led to a tentative conclusion that a form of mate selection was occurring.

Mating patterns within the gull colony on flat gravel bars at Dry Bay were studied in detail during May, 1977. The plumage and soft part colors of both parents at 112 nests were examined using a 25 x telescope and comparing them to a Munsell color chart, or in the case of primaries, a Munsell neutral value scale. The orbital ring colors, however, were beyond effective resolution of the telescope. The analysis was hence restricted to primary feather pigmentation and iris color indices (Tables 20, 21, 22).

Three statistical tests were conducted on the mating patterns of the gulls at Dry Bay, using the SPSS-10 CROSSTABS subroutine on the Johns Hopkins University DEC-system 10 computer. First, the index of primary feather pigmentation for each male was compared against

Table 20.

Hybrid Indices of Primary Feather Pigmentation of Males Against Females in 112 Pairs of *Larus* Gulls at Dry Bay, Alaska

	Same As Mantle	1 Shade Darker Than Mantle	2 Shades Darker Than Mantle	Black Primaries	Row Total
Same As Mantle	51 * 77.3 70.8 45.5	7 10.6 38.9 6.3	5 7.6 35.7 4.5	3 4.5 37.5 2.7	66 58.9
1 Shade Darker Than Mantle	11 45.8 15.3 9.8	8 33.3 44.4 7.1	4 16.7 28.6 3.6	1 4.2 12.5 0.9	24 21.4
2 Shades Darker Than Mantle	5 45.5 6.9 4.5	1 9.1 5.6 0.9	4 36.4 28.6 3.6	1 9.1 12.5 0.9	11 9.8
Black Primaries	5 45.5 6.9 4.5	2 18.2 11.1 1.8	1 9.1 7.1 0.9	3 27.3 37.5 2.7	11 9.8
Column Total	72 64.3	18 16.1	14 12.5	8 7.1	112 100.0

* Each section contains:
Count
Row %
Column %
Total %

(Raw Chi Square = 24.20370, 9 d.f., significance = $p < 0.0040$.)

Table 21. Hybrid Indices of Eye Color (Equivalent to Munsell Hues) of Males Against Females in 112 Pairs of *Larus* Gulls at Dry Bay, Alaska

	7.5 YR	10 YR	2.5 Y	5 Y	Row Total
7.5 YR	100 95.2 96.2 89.3	2 1.9 100.0 1.8	1 1.0 100.0 0.9	2 1.9 40.0 1.8	105 93.8
10 YR	1 33.3 1.0 0.9	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 66.7 40.0 1.8	3 2.7
2.5 Y	1 100.0 1.0 0.9	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.9
5 Y	2 66.7 1.9 1.8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 33.3 20.0 0.9	3 2.7
Column Total	104 92.9	2 1.8	1 0.9	5 4.5	112 100.0

* Each section contains: Count
Row %
Column %
Total %

(Raw Chi Square = 34.82256, 9 d.f., significance = $p < 0.0001$.)

Table 22. Combined Indices of Primary Feather Pigmentation and Eye Color of Males Against Females in 112 Pairs of *Larus* Gulls at Dry Bay, Alaska

		Glaucescens Phenotypes	Female Intermediates					Argentatus Phenotypes	Row Total
"Pure"		51 *	6	3	2	2	0	0	64
Glaucescens		79.7	9.4	4.7	3.1	3.1	0.0	0.0	57.1
Primaries As		71.8	33.3	27.3	66.7	40.0	0.0	0.0	
Mantle		45.5	5.4	2.7	1.8	1.8	0.0	0.0	
Iris 7.5 YR									
Male Intermediates	8	10	7	4	1	1	1	0	24
		41.7	29.2	16.7	4.2	4.2	4.2	0.0	21.4
		14.1	38.9	36.4	33.3	20.0	100.0	0.0	
		8.9	6.3	3.6	0.9	0.9	0.9	0.0	
	9	5	1	3	0	1	0	0	10
		50.0	10.0	30.0	0.0	10.0	0.0	0.0	8.9
		7.0	5.6	27.3	0.0	20.0	0.0	0.0	
		4.5	0.9	2.7	0.0	0.9	0.0	0.0	
	10	0	2	0	0	0	0	1	3
		0.0	66.7	0.0	0.0	0.0	0.0	33.3	2.7
		0.0	11.1	0.0	0.0	0.0	0.0	33.3	
		0.0	1.8	0.0	0.0	0.0	0.0	0.9	

* Each section contains: Count
Row %
Column %
Total &

. Table 22, cont'd.

	Glaucescens Phenotypes	Female Intermediates					Argentatus Phenotypes	Row Total
Male Intermediates 12	5 62.5 7.0 4.5	2 25.0 11.1 1.8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 12.5 20.0 0.9	0 0.0 0.0 0.0	0 0.0 0.0 0.0	8 7.1
Male Intermediates 13	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 0.0 0.0 0.0	1 100.0 33.3 0.9	1 0.9
"Pure" Argentatus Primaries Black Yellow Eyes	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 50.0 9.1 0.9	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 50.0 33.3 0.9	2 1.8
Column Total	71 63.4	18 16.1	11 9.8	3 2.7	5 4.5	1 0.9	3 2.7	112 100.0

* Each section contains: Count (Raw Chi Square = 102.63608, 36 d.f., significance = $p < 0.00001$.)
Row %
Column %
Total %

each of the females in 112 pairs (Table 20). The crosstabulation produced a Chi-square of 24.204, 9 d.f., p <.004. The iris colors of the males were then crosstabulated against the iris colors of the females in each pair, resulting in a Chi-square of 34.823, 9 d.f., p <.0001 (Table 21). The indices of primary feather pigmentation and iris color were then combined for each individual gull, and the sums of the males in the 112 pairs were crosstabulated against the sums of the females. This produced a Chi-square value of 102.636, 36 d.f., p <.00001 (Table 22).

The mating patterns of the gulls were therefore very highly significantly assortative; the null hypothesis was rejected. Gulls tend to choose mates similar to themselves, but in some cases select mates of widely different phenotypes, forming mixed pairs and apparent backcrosses. Although primary feather pigmentation and iris color are both significant in mate selection, iris color is considerably more significant than primary feather pigmentation, and the combination of the two characters is much more significant than either as a single factor in mate selection.

IX. Nest Site Selection: Slope, Substrate, and Cover

Southern Alaskan argentatus and glaucescens nest on a variety of substrates ranging from bare cliff ledges in Glacier Bay, to sloping grassy meadows at Egg Island, North Marble, and Lake Louise, and to flat gravel bars at Dry Bay. Glacier Bay is recently deglaciated; while not in the arctic, it approximates high latitude conditions in some areas. In Glacier Bay *argentatus* is most often found in fjords close to glacier fronts; *glaucescens* concentrates in more marine regions, but not exclusively. *L. argentatus* and *glaucescens* were first observed nesting together with gulls of variable primary feather pigmentation in July, 1971, on sea cliffs at William Field Cairn #3. This colony is located 4 km from the active front of the Johns Hopkins Glacier, on the north side of Johns Hopkins Inlet. The cliff was deglaciated within the last 20 years; therefore, the colony could not have been occupied for long. In subsequent field seasons *argentatus*, *glaucescens*, and mixed pairs were found nesting together on low rocky islets, flat gravelly islands, and sloping grassy hillsides in Glacier Bay (Table 23).

Dry Bay, at the mouth of the Alsek River, northwest of Glacier Bay, supports 500 pairs of mixed *argentatus* and *glaucescens* nesting on flat gravel bars. The low alluvial islands, washed by high waters in late summer and during winter storms, are of unstabilized substrate. Vegetation is sparse and indicates a combined maritime and fresh-water influence. Vegetative cover is important in nest site selection, since nests are clumped near drift logs, willow bushes, and grass patches.

Thousands of *glaucescens* at Egg Island, off the Copper River Delta, nest on dunes covered with *Elymus* meadows. The nest sites are usually in proximity to old drift logs or *Sambucus* bushes. Slope of the dunes is shallow, with a mean less than 3 %. The highest dunes on Egg Island are only 10 m above sea level.

North Marble, as Egg Island, has highest nesting densities on grassy meadows; the dominant vegetation is *Hordeum*. Some sites

Table 23.

Nest Site Substrates
in *Larus* Colonies
in Southern Alaska, British Columbia, and Yukon Territory

Colony	Species Composition	Substrate
Glacier Bay colonies:		
Johns Hopkins Inlet	mixed *argentatus* - *glaucescens*	bare cliff face
Sealer's Island	mixed *argentatus* - *glaucescens*	low rocky islet
Tlingit Point	mixed *argentatus* - *glaucescens*	flat gravelly islet
North Marble	mixed *argentatus* - *glaucescens*	sloping grassy hillsides
Dry Bay	mixed *argentatus* - *glaucescens*	flat alluvial gravel bars
Haenke Island	*glaucescens*	grassy cliff terraces
Strawberry Reef	*glaucescens*	*Elymus*-covered dunes
Copper Sands	*glaucescens*	*Elymus*-covered dunes
Egg Island	*glaucescens*	*Elymus*-covered dunes
Lake Louise	*argentatus*	sloping grassy islet
Dezadeash Lake Y.T.	*argentatus*	boreal lake, forested islet shores
Atlin Lake, B.C.	*argentatus*	low rocky islet

Table 24. Nest Site Slope in *Larus* Colonies in Southern Alaska

Colony	Species Composition	Mean	Range	S.D.	n
North Marble	mixed	16.2	1 - 48	15.7	9
Dry Bay	mixed	0	0	0	112
Egg Island	*glaucescens*	2.8	0 - 8	2.4	186
Lake Louise	*argentatus*	15.9	1 - 50	14.9	50

at North Marble, however, are precipitous, approaching 50 % slope. Sympatric and interbreeding glaucescens and argentatus are found on the grassy slopes of North Marble. Allopatric argentatus at Lake Louise nest on a grassy (Calamagrostris) islet, with slope and substrate similar to North Marble (Tables 23, 24). Study of other colonies at Dezadeash Lake, Yukon Territory, and Atlin Lake, British Colombia, revealed that argentatus also nest on low rocky islets and on the edges of forested islands in boreal lakes (Table 23).

In summary, both allopatric and sympatric argentatus and glaucescens are flexible in nesting habitat selection in coastal southern Alaska and the adjoining interior lakes. Nest site substrate ranges from gravel bars to cliff faces and includes from 0 % to over 50 % slope. Favored sites for both forms are grassy slopes.

X. Clutch Size

Clutch size, hatching success, and fledging success of Larus gulls in southern Alaska were examined for evidence of post-zygotic isolating mechanisms. Populations of argentatus were compared against glaucescens and mixed populations, and "pure" pairs were compared against mixed pairs. Analysis of variance, and if F-ratios were significant, Duncan's Multiple Range Test, were used.

There is spatial and temporal variation in clutch size in gull populations in southern Alaska. The range of clutch size in argentatus, glaucescens, and mixed populations between 1972 to 1977 includes means of 2.05 to 3.0 eggs per nest. Notably, the extremes both occur in glaucescens populations (Table 25). The 1975 Egg Island population was at the low end of the range. Clutch size increased significantly

Table 25. Clutch Size, and Number of Fledglings Per Nest in *Larus* Colonies in Southern Alaska

Colony	Year	Species	Number of Nest Examined	Mean Clutch Size	Mean Number of Fledglings
North Marble	1972	mixed			
East			94	2.8	1.8
West			36	2.9	2.2
North			20	2.8	1.5
Top			12	2.1	0.4
Total			162	2.8 *	1.75 *
North Marble	1973	mixed			
East			104	3.0	1.6
West			60	2.9	2.2
North			15	3.0	1.7
Top			12	2.9	1.6
Total			191	2.96 *	1.80 *
Dry Bay	1977	"pure"	76	2.93	1.40
		mixed	36	2.89	1.47
Total			112	2.92 *	1.44 *
Egg Island	1975	*glaucescens*	153	2.05	1.03
Egg Island	1976	*glaucescens*	186	2.56	1.12
Lake Louise	1977	*argentatus*	77	2.74	0.95

* weighted means

between 1975 and 1976 (Table 27). Analysis of population parameters at Egg Island suggests an expanding population with a high proportion of young females, which tend to lay smaller clutches than older adults (Patten and Patten, 1975, 1976, 1977, 1978). The interior Lake Louise argentatus population had an intermediate clutch size of 2.74. The upper extreme in clutch size was the mean for "pure" glaucescens pairs at Dry Bay in 1977 (2.93).

The weighted means for the mixed North Marble Island population were quite high (2.80 in 1972; 2.96 in 1973; combined 2.90). Only the North Marble "Top Colony," composed of 12 glaucescens pairs, had a significantly smaller clutch size compared to other sites in 1972 (2.1; $F = 6.066$; $p < .01$). Differences were not significant in 1973.

Phenotypes of both parents were determined for 112 nests in two study plots at Dry Bay in 1977. The categories containing pairs with at least one hybrid parent were combined for analysis. Only one argentatus x argentatus pair was found at these sites. The analysis of clutch size of "pure" pairs at Dry Bay was therefore confined to glaucescens. However, "pure" pairs of argentatus at Lake Louise have been compared against coastal glaucescens and mixed pairs.

The analysis of variance for clutch size in southern Alaskan Larus colonies produced a highly significant F-ratio of 35.574 (7 d.f., $p < .001$) (Table 26). The data were therefore further analyzed using Duncan's Multiple Range Test. The differences between 1972 and 1973 for the colonies on North Marble were not significant, with the exception of the Top Colony. The Top Colony, however, due to its small size, did not significantly depress the population mean. The North Marble data were thus included as a single mean.

Table 26. Analysis of Variance of Clutch Size

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F-ratio
Between Groups	8	88.7920	12.6846	35.574 *
Within Groups	796	283.8299	0.3566	
Total	173	372.6219		

* very highly significant (p < .001)

Table 27 contains the results of Duncan's Multiple Range Test at the $p < .05$ level of significance. Note that the Dry Bay colony is broken down into two groups: "pure" *glaucescens*, and mixed pairs; but that North Marble data are combined as one mean.

In the Duncan's Multiple Range Test (at the $p < .05$ level), there are four homogeneous subsets of clutch sizes for *argentatus*, *glaucescens*, and mixed populations, between the two extreme clutch sizes (both *glaucescens*) (Table 27). Subset 1 contains the 1975 Egg Island population. Subset 2 contains populations of *glaucescens*, *argentatus*, and mixed pairs, not significantly different in clutch size. In Subset 3, clutch size of *argentatus* is not significantly different from two mixed populations. In Subset 4, the mixed pairs at Dry Bay are not significantly different from the "pure" pairs, or from the mixed colony at North Marble.

At the $p < .01$ level of significance, homogeneous subsets of ranked means for clutch size are reduced to three. The 1976 clutch size for *glaucescens* at Egg Island is not significantly different from that of *argentatus* at Lake Louise, nor from that of mixed pairs at Dry Bay. In Subset 3, *argentatus* clutch size is not significantly different from that of *glaucescens*, mixed pairs, or the mean of the combined colonies at North Marble (Table 28).

In summary, while there are significant temporal and spatial differences in clutch size between *Larus* colonies in southern Alaska, populations of *argentatus* are not significantly different from mixed or *glaucescens* populations. Within the colony at Dry Bay, "pure" pairs of *glaucescens* are not significantly different from mixed pairs in mean clutch size.

Table 27.

Ranked Means for Clutch Size for Larus Colonies in Southern Alaska

(Duncan's New Multiple Range Test: $p < .05$ level)

Homogeneous subsets (subsets of groups, whose highest and lowest means do not differ by more than the shortest significant range for a subset of that size). Underlined numbers indicate there is no significant difference between the means.

Subset 1	glaucescens		
Group	Egg Island - 1975		
Mean	2.05		
Subset 2	glaucescens	argentatus	hybrid *
Group	Egg Island - 1976	Lake Louise	Dry Bay
Mean	2.56	2.74	2.89
Subset 3	argentatus	hybrid	combined **
Group	Lake Louise	Dry Bay	North Marble
Mean	2.74	2.89	2.90
Subset 4	hybrid	combined	glaucescens
Group	Dry Bay	North Marble	Dry Bay
Mean	2.89	2.90	2.93

* hybrid = pairs containing at least one intergrade gull

** combined = arg. x glau.; arg. x arg.; intergrade x glau.; glau. x glau.

Table 28.

Ranked Means for Clutch Size for *Larus* Colonies in Southern Alaska (Duncan's New Multiple Range Test: $p < .01$ level)

Homogeneous subsets (subsets of groups, whose highest and lowest means do not differ by more than the shortest significant range for a subset of that size). Underlined numbers indicate there is no significant difference between the means.

Subset 1	*glaucescens*			
Group	Egg Island - 1975			
Mean	2.05			
Subset 2	*glaucescens*	*argentatus*	hybrid *	
Group	Egg Island - 1976	Lake Louise	Dry Bay	
Mean	2.56	2.74	2.89	
Subset 3	*argentatus*	hybrid	combined **	*glaucescens*
Group	Lake Louise	Dry Bay	North Marble	Dry Bay
Mean	2.74	2.89	2.90	2.93

* hybrid = pairs containing at least one intergrade

** combined = *arg*. x *arg*.; *arg*. x *glau*.; intergrade x *glau*.; *glau*. x *glau*.

XI. Hatching and Fledging Success

Factors influencing hatching and fledging success in southern Alaskan Larus colonies have been analyzed in detail in a previous series of publications (Patten, 1974; Patten and Patten, 1975, 1976, 1977, 1978). The purpose of this concluding section on results is to present highly condensed data on reproductive success of glaucescens, argentatus, and mixed populations, and to compare fledging success of "pure" glaucescens versus "hybrid" pairs within the colony at Dry Bay. "Hybrid" pairs are here considered to be those containing at least one intergrade, and thus include F_1 and F_2 backcrosses.

Hatching success in southern Alaskan Larus colonies is influenced by three principal factors: eggs diappearing from the nest, due to predation, which are considered "lost"; eggs which are inviable, i.e., those which remain in the nest but fail to hatch; and eggs which pip but the embryo fails to emerge and dies (Table 29). The most important factor influencing hatching success is egg loss to predation, ranging from 4 % to nearly 30 % of eggs laid. In most cases, egg predation is due to Larus gulls. The glaucescens colony at Egg Island (1975-76) and the mixed colony at North Marble (1972-73) do not differ significantly from each other in egg loss due to predation, but both have significantly ($p <.05$) higher rates from the mixed colony at Dry Bay (Table 29). Data on egg loss to predation and hatching success is not available for the argentatus colony at Lake Louise. Inviable eggs range from 1.9 % in the Egg Island glaucescens population, to 6.2 % in the argentatus population at Lake Louise. Inviable eggs in the mixed colonies of North Marble

Table 29. "Lost," Inviable, and Pipped Eggs Failing to Hatch in *Larus* Colonies in Southern Alaska (1972 - 1977)

Colony	Year	Species	Total Eggs	Lost Eggs	Inviable Eggs	Pipped/Failed to Hatch
North Marble	1972	mixed	455	125 (27.5%)	22 (4.8%)	1 (< 1%)
North Marble	1973	mixed	566	150 (26.5%)	26 (4.6%)	1 (< 1%)
Egg Island	1975	*glaucescens*	313	92 (29.5%)	8 (2.6%)	1 (< 1%)
Egg Island	1976	*glaucescens*	476	104 (21.8%)	9 (1.9%)	1 (< 1%)
Dry Bay 'A'	1977	mixed	265	10 (3.7%)	8 (3.0%)	2 (< 1%)
Dry Bay 'B'	1977	mixed	63	7 (11.1%)	0	0
Lake Louise	1977	*argentatus*	211	n.a.	13 (6.2%)	2 (< 1%)

and Dry Bay have similar low frequencies ranging from 0 % to 4.8 %. Differences between the populations in frequencies of inviable eggs are not significant ($p < .05$). The last cause of failure to hatch is eggs which pip, without emergence of the embryo. In all cases, this is well below 1 % at any colony.

Hatching success in southern Alaskan Larus colonies ranged from 67 % to 93 % (Table 30). The colony with the highest hatching success was the mixed population at Dry Bay in 1977. This colony also had the lowest egg loss to predation; hatching success was thus inversely related to predation. The Egg Island glaucescens population was not significantly different in hatching success or observed chick mortality from the mixed colony at North Marble, but chick disappearance was significantly higher ($p < .05$) at Egg Island than North Marble (Table 30). This was most likely related to the much greater meadow area on Egg Island. Dry Bay, due to intense eagle predation, had the highest rate of chick disppearance. An active eagle nest was located within 1 km of the colony. Gull chicks found dead within the colony usually showed peck wounds to the head, presumably from territorial defense by other adult gulls. North Marble had the highest percentage of chicks fledged of those hatching, and Dry Bay the lowest percentage. However, the final fledging success as measured in chicks produced per nest depends additionally upon the clutch size and the hatching success.

The summary comparison of the mean clutch size and the mean number of fledglings produced per nest provides the clearest picture of reproductive success in Larus colonies in southern Alaska. The

Table 30. Hatching Success, Chick Mortality, and Fledging Success in *Larus* Colonies in Southern Alaska (1972 - 1977)

Colony	Year	Species	Nests Examined	Chicks Hatching	Observed Mortality	Disappeared	Fledged (% of hatched)
North Marble	1972	mixed	162	304 (67%)	16 (5%)	5 (2%)	283 (93%)
North Marble	1973	mixed	191	390 (69%)	31 (8%)	16 (4%)	343 (88%)
Egg Island	1975	*glaucescens*	153	254 (69%)	30 (12%)	75 (26%)	157 (62%)
Egg Island	1976	*glaucescens*	186	343 (77%)	27 (8%)	108 (31%)	208 (61%)
Dry Bay 'A'	1977	mixed	90	245 (92%)	16 (6%)	95 (39%) *	134 (54%)
Dry Bay 'B'	1977	mixed	22	59 (93%)	2 (3%)	29 (49%) *	28 (48%)
Lake Louise	1977	*argentatus*	77	n.a.	--	--	73 --

* Most chick disappearance was due to sustained eagle predation.

Table 31. Comparison of Mean Clutch Size and Fledging Success in *Larus* Colonies in Southern Alaska

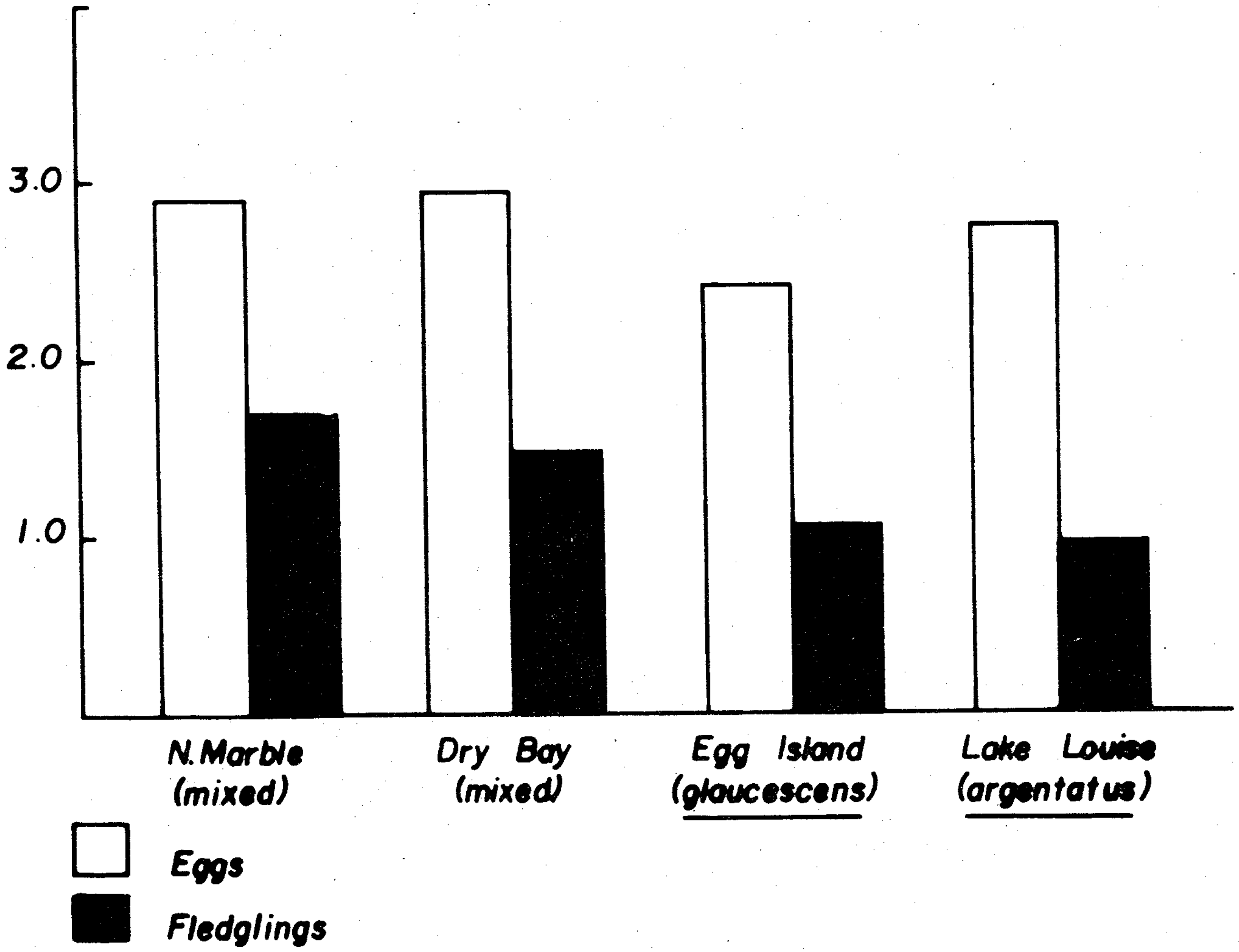
Colony/ Species Composition	Mean Clutch Size	Mean Number of Fledgings Per Nest	Mean Territory Size (m^2)*	Number of Nests Examined
North Marble (1972-1973) (mixed)	2.90	1.77	18 m^2	162-191
Dry Bay (1977) (mixed)	2.92	1.44	32.2 m^2	112
Egg Island (1975-1976) (*glaucescens*)	2.40	1.08	29.6 m^2	153-186
Lake Louise (1977) (*argentatus*)	2.74	.95	13.5 m^2	77

* Substrates:
North Marble: Willoughby limestone with *Hordeum* meadows.
Dry Bay: alluvial sand and gravel with sparse vegetation.
Egg Island: sand dunes with *Elymus* meadows.
Lake Louise: rocky islet with *Calamagrostris* meadows.

colonies where interbreeding is occurring, e.g., North Marble and Dry Bay, have higher mean clutch sizes and net productivity than colonies of either *glaucescens* or *argentatus* "pure" parental types (Table 31). Within the mixed colony at Dry Bay, however, the "hybrid" pairs had a reproductive success of 1.47 chicks fledged per nest, while in comparison, the phenotypically "pure" *glaucescens* produced 1.40 chicks per nest. The differences between the two groups in fledging success were not significant, nor were the differences in mean clutch size (2.89 vs. 2.93).

In summary, although clutch size and fledging success of "hybrid" versus "pure" pairs within the individual colony at Dry Bay are not significantly different, the hybrid pairs are reproducing *slightly* better than the *glaucescens* phenotypes, and southern Alaskan colonies with mixed populations are producing considerably more offspring per pair than colonies of either *argentatus* or *glaucescens* parental types (Fig. 26).

Fig. 26. **MEAN CLUTCH SIZE AND FLEDGING SUCCESS**



CHAPTER 6: DISCUSSION

I. Ancestral Populations

The ancestral Larus populations most likely emerged from eastern Siberia during the early Pleistocene, spreading in both easterly and westerly directions across the Eurasian land mass, and crossing the Bering Strait Land Bridge into the North American continent (Hopkins, 1962; Haag, 1962). Expanding ice masses subsequently separated the ancestral gull populations, forcing them into refugia in Europe, Asia, and North America during successive glaciations. With an increasingly severe climate, and with small populations, the opportunities for differentiation would have been considerable.

North American gull populations resembling argentatus stock were pushed back by continental glaciation to an interior refugium along the Yukon-Kuskokwim - Bering Strait Land Bridge. Other populations were forced to retreat southward along the Pacific Coastline to the Puget Sound region, where they evolved in proximity to glacier fronts. The relatively uniform mantle and primary feather pigmentation of glaucescens resembles that of high latitude arctic species such as glaucoides, which breeds on exposed cliffs in similar glacier environments (Hoffman et al., 1978).

As the ice sheets retreated, Larus populations which had continued to evolve in separate pathways rejoined, and in some cases interbred, and on other cases did not. While these gulls shared a common gene pool at one time, enough evolution occurred to account for certain colorimetric differences between argentatus and glaucescens, for instance in the amount and pattern of melanin deposition in the primary feathers, and in orbital ring and iris coloration, and to account for certain habitat preferences.

L. argentatus is a wide-ranging species currently found along the Eastern Seaboard, the Great Lakes, and on boreal lakes of North America, exhibiting tolerance for both freshwater and marine conditions. L. glaucescens is a coastal Pacific Northwest species, generally confined to marine environments. The more flexible argentatus, breeding on boreal lakes, and wintering offshore in the Pacific, appears to possess the capacity to colonize the southern Alaskan coastline, while glaucescens is not found in the interior. The area where these two gull forms come into contact is the region of the Pacific Northwest coastline between southeastern Alaska and the Alaska Peninsula.

II. Larus Populations in Southern Alaska

Williamson and Peyton (1963) collected a series of specimens which were intermediate between argentatus and glaucescens from the Cook Inlet region, near Anchorage, Alaska. The authors suggested that sympatry between breeding argentatus and glaucescens occurs in southeastern Alaska. The preceeding chapter has demonstrated that additional sympatry and interbreeding of glaucescens and argentatus occurs in southcentral and southeastern Alaska. Mixed populations exhibit a higher reproductive rate than colonies of parental phenotypes.

These Larus gulls inhabit geologically dynamic nesting habitats along the southern Alaskan coastline, ranging from recently deglaciated fjords to earthquake-influenced sandbar barrier islands and delta gravel bars. Nesting habitat selection is flexible, and ranges from flat gravel bars to sloping grassy hillsides and nearly vertical cliff faces. Onset of breeding is flexible within an individual colony, and is related to weather conditions and snow cover. The mixed colony at Dry Bay at the mouth of the Alsek River exhibits the most flexibility in timing of breeding of seven colonies examined, although over fifty percent of the eggs are laid in just over a one-week time span.

Clutch size of "pure" versus mixed pairs within the colony at Dry Bay is not significantly different. Hatching success in the entire colony was quite high, due to low rates of egg inviability and egg predation. Hybrid, F_2 and apparent backcross zygotes, with a slightly enhanced fledging success, are clearly not reduced in viability to fledging stage. Analysis of morphology and pairing indicates that individuals of mixed genetic background survive to adulthood and may interbreed with parently types, usually glaucescens. The complete range of variability is expressed by the offspring of the backcrosses. Mating patterns, however, are strongly assortative, with individuals of intermediate phenotypes tending to select mates of similar phenotypes, although exceptions occur regularly.

This outline of the two forms and the environment in which they meet presents fundamentals of the argentatus - glaucescens interaction in southern Alaska: the two colorimetrically different but interfertile forms, largely kept apart by dissimilar natural environments, are interbreeding in a zone of contact in ecologically dynamic coastal Alaska. In addition to the rapid geological and successional changes in coastal southern Alaska, certain aspects of the environment are becoming progressively more altered by human influence, notably with the development of intensive fisheries, with increasing amounts of fish offal and similar garbage.

Four theoretical alternative hypotheses for the existance of a narrow hybrid zone between argentatus and glaucescens in south coastal Alaska will be explored in search of the best explanation for the data collected. These four hypotheses are not mutually exclusive, and the "best fit" for the southern Alaska Larus situation may involve combinations of segments of several hypotheses.

The ephermal-zone hypothesis, e.g., that hybridization will end in either speciation or fusion of the hybridizing taxa by means of introgression (Dobzhansky, 1940, 1951; Sibley, 1957, 1959, 1961; Wilson, 1965; Remington, 1969; Moore, 1977) is inappropriate to the southern Alaskan argentatus - glaucescens contact zone for several reasons. Speciation requires selective pressure against those individuals which enter into mixed pairs, and is to be expected if the populations have diverged to the extent that the hybrids would serve as a bridge for introgressive hybridization. While historical data on the duration and extent of the contact are not available, other than from Williamson and Peyton (1963), natural selection is apparently not acting against hybrid zygotes in the coastal environment, at least until fledging stage. Further, analysis of adult morphology indicates intermediate adults are common and reproduce as well as "pure" types within the contact zone. The viable and fertile hybrids could serve as a bridge for introgressive hybridization, yet evidence suggests that glaucescens genes are not penetrating interior argentatus to the degree that the converse is occurring. Therefore, rapid speciation or fusion of these two forms is not occurring, although the glaucescens population is increasing in variability.

The dynamic equilibrium hypothesis, as postulated by Bigelow (1965) and discussed by Moore (1977), requires influxes of genes from both parental populations. This hypothesis has aspects which apply to the southern Alaskan *Larus* contact zone. The migration pattern of *argentatus* from offshore wintering areas, which extend from the Gulf of Alaska to southern California (Harrington, 1973; Sanger, 1975) towards breeding localities in interior Alaska and the Yukon, includes major river valleys such as the Alsek and the Susitna. These rivers pass through major mountain formations, such as the Alaska and St. Elias ranges. Local *glaucescens* populations at colonies near mouths of rivers may receive substantial influxes of *argentatus* genes, as well as *glaucescens* genes from other colonies. Continued immigration of "naive" individuals could swamp evolution of isolating mechanisms. Hoffman et al. (1978), using computer simulation techniques, suggested that immigration of parental types is assisting in maintenance of the apparently stabile *glaucescens* - *occidentalis* contact zone in western Washington state. Bigelow (1965) proposed that stabile hybrid zones might result from a dynamic balance between gene flow and selection against hybrids. He suggested that steep selection gradients on either side of the contact zone might inhibit introgression. The evolution of an antihybridization mechanism in the restricted zone of contact might be disrupted by migrants moving into the restricted zone from more extensive areas of allopatry. However, hybrids are apparently not selected against in the southern Alaskan contact zone, and theoretically, mating should be random in a stabile hybrid zone. There is strong evidence that assortative mating is occurring, possibly counter to evolution of an equilibrium.

There is also the additional evidence that more argentatus genes are entering coastal populations than the reverse, e.g., not an equilibrium state.

The hybrid superiority hypothesis suggests that hybrids are actually more fit than the parental phenotypes in the restricted regions in which they occur (Anderson, 1949; Muller, 1952; Hagen, 1967; Short, 1969, 1970, 1972; Littlejohn and Watson, 1973; Moore, 1977). Data from the southern Alaskan Larus contact zone indicates that this possibility certainly exists. There is evidence of hybrid fertility, backcrossing, morphological intermediacy, and hybrid viability. At first, the assortative mating pattern seems to counter the hybrid superiority hypothesis, but intermediates which select like types as mates within the contact zone should increase their reproductive fitness by the production of offspring adapted to the intermediate environment.

Zones of contact (c.f., Mayr, 1963) usually involve only small portions of the complete ranges of the participating populations. The vast majority of both glaucescens and argentatus populations breed outside this particular contact zone, although glaucescens is in genetic contact with two other forms, hyperboreus (Strang, 1977), and occidentalis (Hoffman et al., 1978), to the north and south. The continuation of hybridization in the southern Alaskan contact zone may result from the very sharp boundary between the two environments in which argentatus and glaucescens usually occur, in this case the radical division of interior from coastal Alaska by very high mountain ranges. The abrupt division allows such a small fraction of each form to be sympatric with the other, at river mouths, bays, and recently deglaciated fjordlands, that gene flow to these ecotones may swamp development of complete ethological pre-mating isolating mechanisms (Jackson, 1973).

The concept that ecological factors are most important in determining the fitness of these hybrids is central to the development of the hybrid superiority hypothesis (Moore, 1977). The extent of a contact zone is determined by the geographical range of ecological conditions to which the intermediates are adapted, or to which the parental phenotypes are less well adapted. Most hybrid zones are narrow and occur at the juxtaposition of the ranges of the parental populations (Moore, 1977). The _argentatus_ x _glaucescens_ contact zone is clearly narrow and at the interface between the two parental populations (Short, 1969; Fig. 1).

The fourth explanation to be considered to account for the _argentatus_ x _glaucescens_ contact zone is based upon the following logic: most stabile hybrid zones appear to occur in ecological conditions that are ecotones, disclimax, marginal habitats, or perpetually disturbed habitats (Moore, 1977). This explanation, along with aspects of the hybrid-superiority hypothesis discussed immediately above, provides the best possible explanation for what has been observed in _Larus_ populations in southern Alaska. The mixed populations of gulls are found when _argentatus_ of the boreal lakes meets the marine _glaucescens_ at the mouths of rivers and in recently deglaciated fjords. The occurrence of the zone of overlap and hybridization appears to correlate with a change in climatic conditions from West Coast Marine to Boreal Interior, or in the case of the recently deglaciated fjords, from West Coast Marine to circumstances which mimic arctic conditions. These ecotones probably provide marginal habitats for the forms which represent ecological communities on either side of the ecotone.

L. argentatus and L. glaucescens are forms which have diverged in response to particular external conditions exerted by the respective communities in which they evolved. The argentatus x glaucescens hybrid may be physiologically homeostatic and no less adapted to the transitional habitat than are the parental phenotypes. The selection gradients exerted by the distinctly integrated West Coast Marine and Boreal Interior communities on either side of the ecotone prevent expansion of the hybrid zone. However, complete reproductive isolation is not evolving because, when the opportunity to hybridize occurs, there is no selection against the mixed forms. The hybrids are able to survive in the dynamic southern Alaskan contact zone because they do not have to compete in stabile communities with species that are well adapted to those communities. Since the hybridization is occurring in zones of marginal habitat for both parental phenotypes, the hybrids would not have to overcome rigorous competition from either argentatus or glaucescens phenotypes and therefore persist in the dynamic ecotones.

River valleys are among the most variable of environments (Anderson, 1949). Extant conditions may be drastically altered within a short period of time by river action. The connection between disturbed environments and the results of hybridization is typical of many cases of hybridization (Anderson, 1949; Grant, 1971; Moore, 1977). The greater the number of gene differences between the parental types, the greater will be the number of special new habitats necessary for the segregants. Presumably, the genetic differences between argentatus and glaucescens are not especially great. Theoretically, if F_2 and subsequent generations are to survive and reproduce, there must be environments not only with intermediate habitats, but that present all possible recombinations of the contrasting differences of the parental environments (Anderson, 1949). The theoretical expected intermediate habitat for these two gull forms would be a fresh-water / salt-water mosaic within a mixed West Coast Marine - Boreal Forest environment. This is precisely the environment near the mouths of the Alsek and Susitna Rivers in southern Alaska. These sites are apparently the center of gull interbreeding along this section of Pacific Coastline, since argentatus gene frequencies (as analyzed by colorimetric hybrid indices) diminish with distance away from these areas.

Pioneering gull populations in recently deglaciated fjordlands are within a partially different selective framework, even though the environment is a dynamic ecotone. Whenever retreat of ice masses is rapid, as within the last 200 years in Glacier Bay, large areas are open for colonization. Tinbergen (1960) noted that hybridization is characteristic of pioneering populations. When the pioneering individuals, for example argentatus phenotypes, arrive in the recently deglaciated environment, they are unable to find conspecific mates. Thus, even though their pre-mating isolating mechanisms could be as completely developed as those in the center of the range, such as in the eastern Canadian arctic (Smith, 1966b), the threshhold of the pioneering argentatus will eventually diminish to a low enough level that they will hybridize with glaucescens rather than not reproduce at all (Mayr, cited by Sibley, in Blair, 1961). L. argentatus is distinctly less common than glaucescens within the fjordlands of Glacier Bay. Individual argentatus may not find conspecific mates, and the instinctive mating drive eventually overcomes the inhibitory drive of potentially incorrect species-specific recognition signals and a mixed argentatus x glaucescens pair is formed. The viable offspring, with mixed genomes, may have a selective advantage in the rapidly changing environment.

Man, in addition to catastrophic natural forces, creates new, artificial niches in which hybrid segregants might survive and reproduce (Anderson, 1949). Some of these artificial niches are of definite types. For instance, natural plant hybrids are often restricted to man-disturbed environments, i.e., they are weeds in an ecological sense (Anderson, 1949; Grant, 1971; Moore, 1977). Most stabile hybrid zones appear to occur in ecological conditions which conform to Wright and Lowe's (1968) definition of "weed" habitat (in Moore, 1977). Some of the most important artificial niches for Larus gulls are garbage piles, sewage outfalls, and concentrations of fish offal around canneries and processing plants. The rapid development of coastal and marine fisheries in Alaska, with production of huge amounts of offal in addition to the refuse associated with increased gas and oil development on the continental shelf, is providing large amounts of "loose" energy. L. argentatus is an excellent example of a vertebrate "weedy" species, adapted to man-disturbed environments and to utilize artificial food (Drury, pers. comm.). When humans occupy new areas, barriers between other species are broken down and new ecological niches are created in which hybrid segregants can survive (c.f., Sibley, 1950, 1954; Sibley and West, 1958; Sibley and Sibley, 1954). The effect of human disturbance is to give weedy species, such as *L. argentatus*, much greater opportunities to hybridize with similar forms than would otherwise be encountered. Future development in coastal Alaska, particularly in fisheries and petrochemical industries, will increase contact between *Larus* populations and assist in the survival of hybrid forms in disturbed environments. Hybridization is expected to continue between *Larus* populations in Alaska in coming years, and intermediate gulls will become more common. The gene flow between large white-headed gull populations will be increased in future years as a secondary consequence of human activities, and may lead to a new adaptive peak in these commensal forms.

III. Relation to the Circumpolar Formenkreis through Eastern Siberia

Dr. Kistchinski of the Soviet Academy of Sciences (pers. comm.) reports a similar *Larus* situation to that in Alaska on the eastern side of the Bering Strait. Species composition differs slightly. *L. glaucescens* breeds on the Aleutian Chain and extends into Soviet territory only on the Commander Islands. Ms. Ludmila V. Firsova of the Ornithology Department, Zoological Institute, Leningrad, has been studying the breeding biology of *glaucescens* in this area. *L. schistisagus*, the Slaty-backed Gull, occupies the coastal niche of *glaucescens* on the eastern shores of the Sea of Okhotsk and the Kamchatka Peninsula. *L. argentatus vegae* occupies interior eastern Siberia, as *L. a. smithsonianus* occupies interior Alaska. A zone of overlap and hybridization exists between *schistisagus* and *vegae* where rivers descend from the southern Koryak Highlands and enter the Bering

Sea (Fig. 27). *L. schistisagus* typically nests on cliffs facing the Bering Sea, and *vegae* usually nests in scattered pairs on boreal lakes. However, Portenko (1963) and Kistchinski (pers. comm.) found *vegae* and *schistisagus* breeding sympatrically from Barykov Cape to the Khatyrka River mouth and somewhat to the south on the Siberian coast. Hybrid colonies are found on Koryak river deltas and on sea cliffs in the northern Koryak Highlands. The colonies on river deltas serve as a partial gene bridge connecting coastal with interior populations, forging another link in the circumpolar *Formenkreis*. These settings are remarkably similar to those found in Alaska, e.g., the Alsek River Delta at Dry Bay, and the Susitna River Delta near Anchorage.

The following species composition serves as an example of those gulls breeding on sea cliffs in the northern Koryak Highlands: 5 % *hyperboreus*, 70 % *schistisagus*; 5 % *vegae*; and 20 % intermediates exhibiting a wide variety of characteristics of both *vegae* and *schistisagus*. Portenko (1963) believes that *schistisagus* and *vegae* should be regarded as conspecific. Firsova and Kistchinski (pers. comm.) now believe that the binomial nomenclature should be retained, since parental types are present in the mixed colonies. *L. a. vegae* and *schistisagus* exist in a narrow zone of overlap and hybridization, and should be treated as semispecies.

L. hyperboreus breeds northward from the Koryak Highlands on the coastal lowlands, where it is not in sympatry with *vegae* on the boreal lakes. *L. hyperboreus pallidissimus* nests on arctic shores westward across northern Siberia, and on the periphery of Wrangel

Island. Mixed colonies of _vegae_ and _hyperboreus_ are found in the interior of Wrangel Island, with no interbreeding. A representative composition in these colonies is 70 % _vegae_, 30 % _hyperboreus_. Small numbers of _L_. _a_. _vegae_ enter U.S. territory on St. Lawrence Island, where they breed on cliffs (Fay and Cade, 1959; Searing, 1976; Drury, pers. comm.). St. Lawrence Island is a fragment of the former Bering Strait land bridge, connecting Eurasia with North America, across which the ancestral populations of _argentatus_ moved from Eastern Siberia into North America during the early Pleistocene.

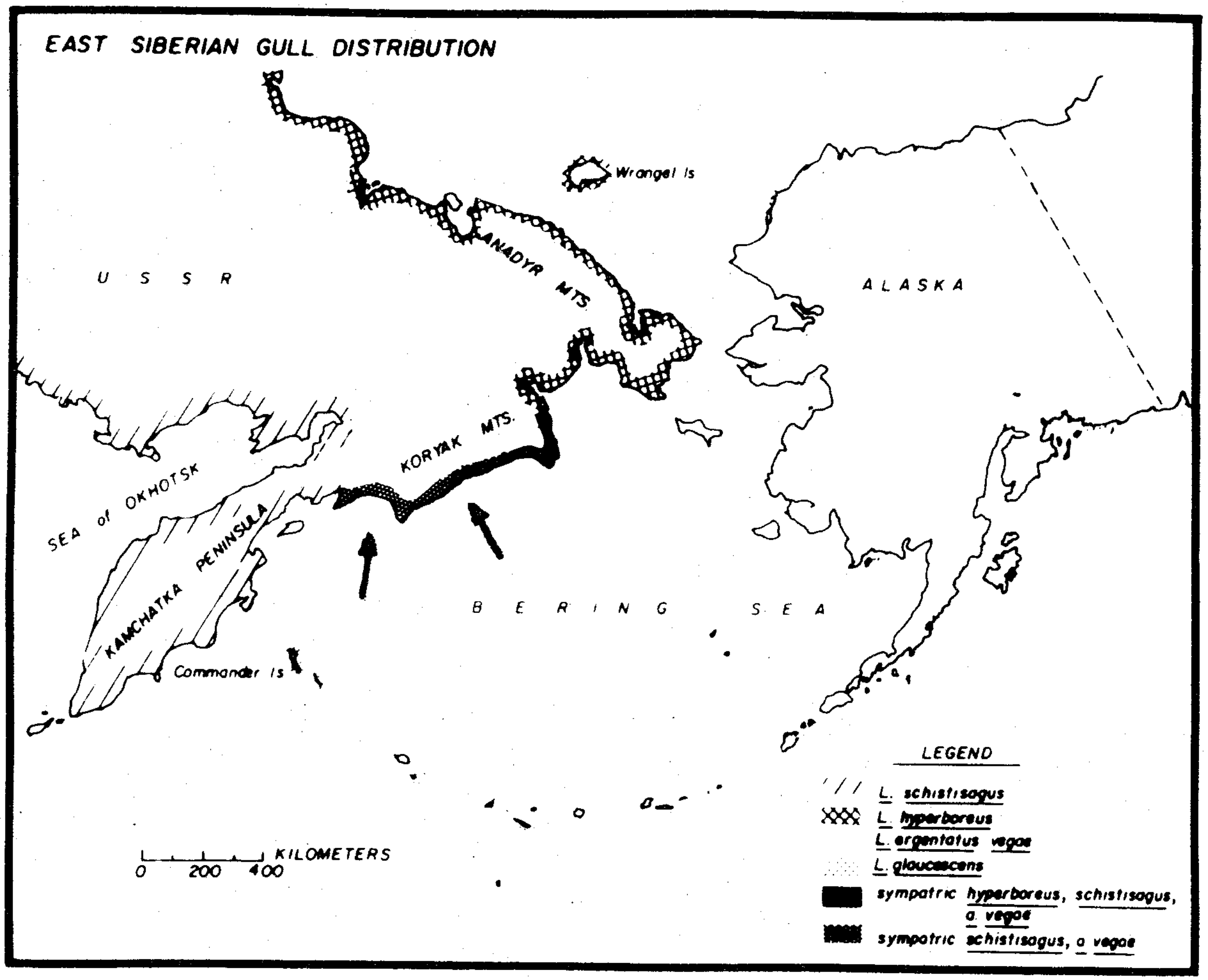

EAST SIBERIAN GULL DISTRIBUTION
Wrangel Is
U S S R
ANADYR MTS.
ALASKA
KORYAK MTS.
SEA of OKHOTSK
KAMCHATKA PENINSULA
BERING SEA
Commander Is
KILOMETERS
0
200
400
LEGEND
L. schistisagus
L. hyperboreus
L. argentatus vegae
L. glaucescens
sympatric hyperboreus, schistisagus, a. vegae
sympatric schistisagus, a vegae

Fig. 27.

IV. Taxonomy of Large White-headed Gulls of the North Pacific Rim

The effects of glaciation, as discussed above, are particularly apparent where pairs of "semispecies" are formed (Rand, 1948). These are cases in which two forms, or groups of forms, meet in conjunction along a narrow belt. The relationships of the forms to each other are neither those of species, nor of subspecies, but combine characteristics of both, in a stage of evolution between that of species and of subspecies. Ripley (1945) called semispecies "emergent interspecies."

Mayr, Linsley, and Usinger (1953) first defined semispecies as the species of which a superspecies is composed; semispecies are a special kind of species, not a category different from the species. However, Mayr (1963) later agreed with Lorkovic (1958) that the term should be broadened to include the additional meaning of populations that have acquired some, but not yet all, attributed of species' rank; borderline cases between species and subspecies. Thus, gene exchange would still be possible among semispecies, but not as freely as among conspecific populations (cf. Amadon, 1966). Hoffman, Wiens, and Scott (1978) suggested that the semispecies concept should be further expanded to include apparently stable zones of overlap and hybridization, such as the glaucescens - occidentalis contact in Western Washington (Fig. 1).

Data gathered in southern Alaska during research for this investigation support the above concept developed by Hoffman et al. (1978). Similar to the glaucescens - occidentalis contact, the analyses of morphology and mating patterns of glaucescens and argentatus demonstrate that Short's (1969) and Mayr's (1963) criteria for conspecifity are not met, i.e., that the zone of contact should be characterized by random mating, complete intergradation, absence of pure parental types, with introgression into the adjacent parental populations. However, evidence from western Alaska suggests that the *hyperboreus* - *glaucescens* contact zone may meet these criteria.

L. hyperboreus barrovianus, breeding in northern and western Alaska, as well as in the western Canadian arctic, is characterized by smaller size and darker mantle than other *hyperboreus* subspecies (Rand, 1952; Manning et al., 1956; Macpherson, 1961). Swarth (1938) found gulls on Nunivak Island off western Alaska to be nearly completely intermediate between *glaucescens* and *barrovianus*. Johansen (1958) suggested that *barrovianus* showed a probable *glaucescens* influence. Strang (1977) found a uniform level of *glaucescens* characters in populations of *barrovianus* on the Yukon-Kuskokwim delta of western Alaska (Fig. 1). However, a character gradient has not been demonstrated between these forms, nor have mixed colonies or mixed pairs been located.[*] The contact between *barrovianus* and *glaucescens* clearly bears further investigation. The available evidence does suggest that the contact between *barrovianus* and *glaucescens* is of considerable antiquity, especially as compared to the parapatric *glaucescens* - *argentatus* zone.

Short (1969) first suggested that *glaucescens* and *argentatus* are semispecies. The results of my research confirm this suggestion. Further, *argentatus*, *glaucescens*, and *occidentalis* form a chain of semispecies. *L. glaucescens* is the 'key' link in this chain, since it interbreeds with every other large white-headed gull with which it comes into

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[*] Drury (pers. comm.) recently reported a mixed pair between *hyperboreus* and *L. argentatus vegae* on the Seward Peninsula of Alaska.

contact, including *hyperboreus*. This chain is in turn linked through *L. schistisagus* and *L. argentatus vegae* of the Siberian coastline with the circumpolar *Formenkreis*.

The appropriate taxonomic treatment for semispecies is to retain the binomial nomenclature. Thus, the Herring Gull of Alaska should remain *Larus argentatus*, and the Glaucous-winged Gull *L. glaucescens*.

SUMMARY

This study investigates mensural characters, plumage and soft-part colors, nesting habitat selection, mating patterns and hatching and fledging success of large gulls (*Larus*) in colonies in southern Alaska. The problem is approached through a comparative field study of allopatric and sympatric gull populations.

After an introduction to the evolution and systematics of the Herring Gull group (*Larus argentatus*) Chapter 1), two Alaskan members of the genus *Larus* are described. Questions are posed in search of answers to pre- and post-mating isolating mechanisms between these two forms. The intent in answering these questions is to clarify taxonomic and ecological relationships between *glaucescens* and *argentatus*, relate the Alaskan situation to the larger *Formenkreis*, and aid in further understanding the complex systematics of the Herring Gull group.

The literature on the morphology and evolution of Palearctic and Nearctic *Larus* gulls is summarized in Chapter II. There is general agreement in the literature on the origin of yellow-footed and pink-footed gulls. An ancestral *Larus* population was divided by the East Siberian Ice Barrier into two major refugia. Populations that evolved into the pink-footed *argentatus* group were forced to the east side of the barrier, and the populations that evolved into the yellow-footed *cachinnans-fuscus* group were displaced to the west side in the Aralo-caspian area. The ancestral *argentatus* dispersed in interglacial times over North America, leading to gradual development of the pink-footed American group, which includes *glaucescens* and *occidentalis*, among others.

Post-glacially, *L. a. smithsonianus* emigrated to Europe from eastern North America, coming into contact with the westward-expanding *cachinnans-fuscus* group, to which *argentatus* is partially isolated. The classic overlap of a "ring" species (*Formenkreis*) is thus formed. The connecting links in the *Formenkreis* are the sympatric populations of *Larus* gulls in central Siberia, which hybridize on a large scale.

Evidence is presented linking the Western North American *Larus* populations with the circumpolar *Formenkreis*. A review of the evolutionary status of large gulls of the West Coast suggests none of these *Larus* populations are completely reproductively isolated by pre-mating mechanisms, since they interbreed in narrow zones of sympatry. Breeding biology of large white-headed gulls is reviewed to assist in understanding dynamics of the interbreeding forms.

The study areas are discussed in Chapter 3. After an introduction to the general environmental conditions on the south coast of Alaska, eight individual study sites are described. These sites consist of six coastal colonies, and one major feeding area, located between Juneau and Prince William Sound. A gull colony on fresh-water lake in interior Alaska, north of Valdez, is included in the study. The geology of the coastal sites is dynamic, due to recent deglaciation, major earthquakes, and floods. Slope and substrate of the study colonies vary from horizontal gravel bars to nearly vertical cliff faces. Two coastal colonies support interbreeding *argentatus* and *glaucescens*. The interior colony at Lake Louise is composed of allopatric *argentatus*. Principal periods of study for these colonies are given.

Materials and Methods are presented in Chapter 4. Techniques of marking nests, chicks, and adults are described in addition to the methods of obtaining morphological measurements of adult gulls. The Hybrid Index is discussed as a method for analyzing hybridization. Numerical scores are assigned to the variation exhibited by the parental types and intermediate forms. Colors analyzed in the study are identified and recorded by the Munsell System of Color Notation.

Chapter 5 contains the Results of the research. Statistical tests reveal that a minor sex-linked difference in bill depth at posterior nares exists between two Copper River Delta glaucescens colonies, and all other populations. There is, however, broad overlap between populations in other mensural characters.

The study therefore includes such colorimetric characters as primary feather pigmentation, iris and orbital ring colors. The primary feather pigmentation of 174 gulls is analyzed. Individual gulls within the study area are highly variable, and the variation includes primaries lighter than the mantle, with no observable pattern of melanin deposition, to a distinctly delimited and extensive black pattern including much of the outermost primaries. The complete range of variation in primary feather pigmentation between glaucescens and argentatus types is found within the individual colony at Dry Bay, at the mouth of the Alsek River, southeast of Yakutat, Alaska. As a general trend, mean wing hybrid indices gradually increase from coastal populations resembling glaucescens forms through intermediate populations in fjords and at river mouths to an interior population of argentatus on a freshwater lake.

The range of iris coloration in gulls within the study area includes very dark brown, dark brown, brown, light brown, light yellow, and bright yellow, forming an uninterrupted continuum from populations most like *glaucescens* to populations clearly identifiable as *argentatus*. Qualitative comparisons of the frequencies of the individual Munsell categories of iris hue, value and chroma, and the combinations thereof, reveal that neighboring colonies on the Copper River Delta have strikingly similar distributions of iris hues; however, the Cordova gull population is qualitatively different in distribution of iris hues from the Copper River Delta populations. The mixed populations at North Marble and Dry Bay share similar, although not identical, distributions of iris hues and values. The distribution of iris values in irides of the Strawberry Reef population resembles that of the population inhabiting Dry Bay. The Copper Sands (S) and Strawberry Reef *glaucescens* populations are closely related, although Strawberry Reef additionally resembles the hybrid population inhabiting Dry Bay.

A Chi-square test demonstrates that iris color is linked with primary feather pigmentation in *Larus* populations in the southern Alaskan study area. Light-eyed gulls tend to have dark primaries, dark-eyed gulls tend to have light primaries, and gulls with intermediate amounts of melanin in the primaries have irides of various intermediate shades.

The variation and distribution of iris color, although linked with primary feather pigmentation, is unlikely to function in species recognition between the light-eyed *argentatus* and the dark-eyed *glaucescens* in southern Alaska, since the two forms are linked by a complete range of intermediates.

The extreme pigments in orbital rings of *glaucescens* and *argentatus* in southern Alaska are dark pink and bright yellow, but six intermediate hues exist, and more than one hue may occur in an individual eye-ring. Each colony examined had a different mean composite orbital ring, but an analysis of variance confirms that the orbital ring colors of the populations at both ends of the distribution are connected by increasing amounts of yellow pigment. Orbital rings of some individual gulls in the study area are uniformly pigmented. Other gulls possess orbital rings with two to three hues. The population at Dry Bay has the greatest distribution of uniformly pigmented orbital rings, as well as the most even distribution of orbital rings with combination hues. The function of orbital ring pigmentation as a species-specific recognition character in southern Alaska is unlikely, due to the spectrum of variation. However, the variability may function as a character for individual or population recognition.

The composite hybrid index demonstrates a cline of increasing argentatus influence along a 480 km axis extending from the northwest to the southeast between Prince William Sound and Glacier Bay. Primary feathers become darker and yellow pigments increase in the irides and orbital rings in gull populations along this axis. The major source of argentatus-like genes along the North Gulf Coast of Alaska is the hybrid colony at Dry Bay, which serves as a bridge between coastal and interior Larus populations.

Three statistical tests are conducted on the mating patterns of gulls in 112 pairs at Dry Bay. These tests indicate that mating patterns are significantly assortative; i.e., gulls tend to choose mates similar to themselves, but in some cases select mates of widely different phenotypes, forming mixed pairs and apparent backcrosses. Statistically, the combination of both iris color and primary feather pigmentation is considerably more important than either as a single factor in mate selection.

Both allopatric and sympatric *argentatus* and *glaucescens* are flexible in nesting habitat selection in southern Alaska. Nest site substrate ranges from gravel bars to cliff faces including from 0% to over 50% slope. Favored sites for both forms are grassy island slopes.

Clutch size, hatching success and fledging success of *Larus* gulls in southern Alaska are examined for evidence of post-zygotic isolating mechanisms. While there are statistically significant temporal and spatial differences in clutch size between *Larus* colonies in southern Alaska, populations of *argentatus* are not significantly different from mixed or *glaucescens* populations. Within the colony at Dry Bay, "pure" pairs of *glaucescens* are not significantly different from mixed pairs in mean clutch size.

The colony with the highest hatching success is the mixed population at Dry Bay in 1977. Rates of egg inviability in all colonies are low, and differences between populations in frequencies of inviable eggs are not significant.

The colonies where interbreeding is occurring, e.g., North Marble and Dry Bay, have higher mean clutch sizes and net productivity than colonies of either *glaucescens* or *argentatus* "pure" types. Although clutch size and fledging success of mixed versus "pure" pairs are not significantly different within the individual colony, the mixed pairs are reproducing slightly better than the *glaucescens* phenotypes, and southern Alaskan colonies with mixed populations are reproducing considerably more offshore per pair than colonies of either *argentatus* or *argentatus* parental types.

Chapter 6 contains a discussion of the research results, beginning with a section on the evolution of ancestral Larus populations. Current conditions for Larus populations in southern Alaska are discussed in the following section. Four theoretical alternative hypotheses for the existence of a narrow hybrid zone between argentatus and glaucescens are explored in search of the most reasonable explanation for the data collected during this research. Aspects of the hybrid superiority hypothesis, combined with evidence that hybridization is occurring in geologically disturbed habitats, ecotones, and disclimax areas, provide an explanation for the Larus contact zone in southern Alaska. The argentatus x glaucescens contact zone is clearly narrow and at the interface between the two parental populations. The mixed populations of gulls are found as argentatus of the boreal lakes meets the marine glaucescens at the mouths of rivers and in recently deglaciated fjords. These conditions correlate with a change in climatic conditions from West Coast Marine to Boreal Interior, or from West Coast Marine to circumstances which mimic arctic conditions. The ecotones probably provided marginal habitats for the forms which represent ecological communities on either side of the ecotone. The gull hybrids are able to survive in the dynamic southern Alaskan contact zone because they do not have to compete in stable communities with species that are well adapted to those communities. The theoretical expected intermediate habitat providing maximum survival for F_2 and subsequent generations is a fresh-water/saltwater mosaic within a mixed West Coast Marine - Boreal Forest environment, precisely the environment near the mouths of the Alsek and Susitna Rivers in southern Alaska.

Pioneering gull populations in recently deglaciated fjordlands may hybridize because conspecific mates are not available. The viable offspring, with mixed genonomes, may be at a selective advantage in the rapidly changing post-glacial environment.

Future development in coastal Alaska, particularly in fisheries and petrochemical industries, will increase contact between _Larus_ populations and assist in the survival of hybrid forms in disturbed environments. Hybridization is expected to continue between _Larus_ populations in Alaska in coming years. The gene flow between large white-headed gull populations will likely increase in future years as a secondary consequence of human activities, and may lead to a new adaptive peak in these commensal forms.

In the concluding section of the Discussion, the interbreeding between _Larus_ gulls in southern Alaska is found to resemble that occurring between _Larus_ gulls on the Siberian coastline, and the relationship to the circumpolar _Formenkreis_ is indicated.

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PART II

Breeding Ecology

Table of Contents

List of Tables

List of Figures

INTRODUCTION

The Larinae (gulls) have a world-wide distribution with 42 species. Gulls as a group may have evolved in the North Pacific and North Atlantic (Fisher & Lockley, 1954). Sixteen species of gulls are found in the North Pacific (Vermeer, 1970). Birds of this family have been considered chiefly inshore feeders, and most coasts support a smaller scavenging species and a larger more piratical type (Cody, 1973). Recent evidence indicates that large white-headed gulls can behave as essentially marine species, feeding far out at sea and coming to land only occasionally or to breed (Sanger, 1973; Isleib & Kessel, 1973; Harrington, 1975; Lensink, pers. comm.). Most gulls live in flocks; they forage together in characteristic patterns the year around and nest in colonies during the breeding season (Tinbergen, 1960). These gregarious birds nest in a wide variety of habitats ranging from vertical cliffs to open marshes (Smith, 1966a). Gulls lend themselves to population analysis, especially productivity, because of their colonial breeding tendency (Kadlec & Drury, 1968).

An important reason for studying gulls is their use as indicators of the health of the environment (Vermeer, 1970). Chemical pollution of the environment poses an increasing and immediate threat to all organisms, including man. A recent survey conducted by the U.S. Fish & Wildlife Service of chemical residues in marine avifauna showed gulls to be among the most contaminated birds examined, probably due to their feeding habits (Ohlendorf, pers. comm.). Since gulls nest in colonies, changes in breeding populations can be monitored and related to environmental conditions, among which are industrial development and the concurrent changes in food supply.

An additional reason for studying gulls is that the age structure, mortality rate, life expectancy and survival rates of gull populations aid in the general understanding of population mechanisms. The mere knowledge of the size of a population from year to year indicates little about population problems without such data (Paynter, 1949).

The size, age structure, growth or decline of a population are a result of fluctuations in time and space of natality and mortality, in addition to movement into or out of a population of a species. Breeding adults form the base of the population structure structure, because only by successful production of young can a population grow or maintain itself (Kadlec & Drury, 1968).

Reproductive rate has an important effect on age structure and growth of the population. The average number of young which a breeding pair can raise to fledging is a good measure of gull reproductive success. Meadow-nesting gulls are excellent subjects for a study of reproductive success because eggs and young are readily accessible. Information is available on breeding biology and dynamics of gulls near large urban centers or in recent post-glacial environments, but comparative base-line data on gulls along the southern coastline of Alaska prior to the development of oil resources is completely lacking.

This report presents results of a study of meadow-nesting gulls in widely-spaced colonies in the northeast Gulf of Alaska. These sites have been selected for research because of the incipient development of oil resources in the vicinity and the necessity to provide base-line information on marine birds along this relatively wild stretch of Alaskan coastline.

The overall objective of this study has been an investigation of the reproductive biology of the "brown rat with wings" to answer the key question of reproductive rate and the factors which influence it prior to the development of oil resources. Reproductive rate in gulls can be measured in chicks produced per nest per year. We have studied colony sites, behavior of adults and young, and feeding areas. We gathered supporting information on distribution and pathologies which will become increasingly important and compared the data to our knowledge of other Alaskan gull populations. We banded a large number of gulls, and color-marked, collected and removed blood samples from others. We carried out a concentrated investigation of the breeding biology of *Larus glaucescens* on Egg Island near the mouth of the Copper River, in Chugach National Forest, near Cordova, Alaska, and surveyed other gull colonies on barrier islands off the Copper River Delta. We examined a mixed colony of *Larus argentatus* and *Larus glaucescens* at Dry Bay, mouth of the Alsek River, in Tongass National Forest near Yakutat, Alaska. Included in this report is information previously gathered on a *L. glaucescens* colony on Haenke Island at Disenchantment Bay (near Yakutat) and data from North Marble Island in Glacier Bay National Monument (Fig. 1).

The Glaucous-winged Gull (*L. glaucescens*), which breeds along the coast from Washington State to the Aleutians, is quite closely related to the Herring Gull (*L. argentatus*), a common and widely distributed species. Herring Gulls make up a low proportion of the breeding gulls in the northeast Gulf of Alaska, but occur more commonly in winter and offshore. The Herring Gull replaces the Glaucous-winged Gull in interior Alaska, British Columbia, and the Yukon. The Glaucous-winged Gull is morphologically similar to the Herring Gull except that the black pigment on the tips of the primaries is replaced by a light grey usually matching the rest of the mantle. Conversely, the eye of the Glaucous-winged Gull is darker than that of the Herring Gull. These two gulls are considered separate species in the A.O.U. *Checklist of North American Birds* (1957), but the taxonomic and ecological relationships between the two have not been clearly defined. In some areas hybrids are common (Fig. 2a,b).

We gathered information on other species of plants and animals inhabiting coastal areas of the northeast Gulf of Alaska to support the main objectives of our study. This final report presents the results and analysis of data collected in 1975-1978 in addition to material from previous years of research.

SCOPE AND SIGNIFICANCE OF THE STUDY

The nature of this study has been to examine reproductive biology in colonies of Herring and Glaucous-winged Gulls in the northeast Gulf of Alaska. This report covers information from 1978 and earlier field seasons. We have studied several aspects of gull breeding biology for comparative purposes. Such information is available in the literature for gull populations outside of Alaska and from Glacier Bay to the southeast of the current study area (see Lit. Cited section). The comparison serves as a basis from which to draw conclusions.

An important aspect of this report is the data on fledging success. As can be seen from the literature review, fledging success can serve as an index to the dynamics of an avian population. If fledging success is poor over a number of seasons, a population will decline through adult mortality and low recruitment of breeding adults. If fledging success is high, one can expect a stable or expanding population. We present here 1975 and 1976 fledging success from the largest gull colony in the northeast Gulf of Alaska. We offer supporting data from other colonies in the NEGOA (1972-1978).

Results from this study provide the National Oceanic and Atmospheric Administration and the Bureau of Land Management with specific information concerning the status of a marine-oriented animal population during successive breeding seasons prior to the development of oil resources. More broadly, this report indicates additional areas to be investigated for a better understanding of an Alaskan marine bird species under environmental conditions certain to change with increasing human activity.

CURRENT STATE OF KNOWLEDGE

The breeding biology of gulls, especially the Herring Gull, has been studied in detail by Goethe (1937), Paludan (1951), Tinbergen (1960), Harris (1964) and Ludwig (1966). Their results consistently indicate that Herring Gulls raise an average of one young per pair per year to fledging. Extremes of variation are shown to be 0.5 by Paludan (1951) and 1.5 by Ludwig (1966) (in Kadlec and Drury, 1968). The population dynamics of the Herring Gull in eastern United States and Canada have been reasonably well investigated by Kadlec and Drury (1968). Kadlec and Drury (loc. cit.) found the usual productivity is apparently 0.8 to 1.4 young per nest in the New England Herring Gull, averaging about 50 percent fledging success. They showed this to be a major factor in the structure of the New England Herring Gull population, which has been rapidly increasing since the turn of the century. In a later paper (Kadlec et al., 1969) they examined the critical period between hatching and fledging for mortality factors.

Their results indicate the average clutch size in the Herring Gull is nearly always three, and variations are small (Keith, 1966; Brown, 1967b; Paynter, 1949; Kadlec and Drury, 1968). Hatching success is usually 60 to 80 percent. Keith (1966) has discussed in detail the problems of accurately measuring success, which are due to predation or cannibalism of eggs and chicks before they can be counted. Critical factors effecting hatching and fledging rate are chick and egg loss through cannibalism, chick mortality due to aggressive behavior of adults, and weather conditions during the breeding season (Paynter, 1949; Paludan, 1951; Tinbergen, 1960; Brown, 1967b).

In contrast to the intensive investigations of Herring Gulls in Europe and eastern North America, few workers have studied gulls along the Pacific Coast of North America. Breeding biology of the Western Gull (Larus occidentalis) has been studied by Coulter (1969), Schreiber (1970), Harpur (1971) and Coulter, et. al. (1971). Aspects of the breeding biology are similar to those of the closely related Herring Gull, but nesting habitat selection and nest materials differ because of the drier conditions on California islands. Recently Hunt and Hunt (1973) and Hunt and McLoon (1975) have investigated supernormal clutches, aberrant pairing, and chick mortality in Western Gulls.

Vermeer (1963) published a major work on the breeding biology of the Glaucous-winged Gull, although Schultz (1951) reported on growth in this species. In most aspects the Glaucous-winged Gull is similar to the Herring Gull, including plumage sequences (Schultz, ms).

Other important papers on gulls are those of Coulson and White (1956, 1958, 1959, 1960) on the Kittiwake (*Rissa tridactyla*), in which they attempt to refute Darling's (1938) contention that egg-laying synchrony in the Herring Gull and the Lesser Black-backed Gull was related to social facilitation. Darling's (1938) hypothesis of social stimulation suggests that stimulation received from other birds in a colony produced greater synchrony of egg-laying within the colony. This in turn resulted in earlier egg-dates and a shorter spread of egg-laying in large colonies. Coulson and White (1956), however, showed that the difference in breeding times between colonies of the Kittiwake was not significant and that the spread of egg-dates increased with the size of the colony. Coulson and White (1960) observed that the greater part of the differences in time of breeding were correlated with density. They found that the spread of breeding was greatest in dense colonies of Kittiwakes, which does not support Darling's contention. Moreover, breeding occurred earlier in the more dense colonies. Hunt and Hunt (1975) have found in the Western Gull, which tends to nest on level ground, that territory size expands and agonistic interactions increase with the hatching of chicks.

Cullen (1957) reported on adaptations of the Kittiwake to cliff-nesting, which was followed by N.G. Smith's (1966a) work on adaptation to cliff-nesting in arctic gulls (Larus), and his more extensive study (1966b) on evolution in arctic gulls. Smith found four sympatric species on Baffin Island to be reproductively isolated due to such mechanisms as species recognition and nesting habitat selection. Ingolfsson (1970) noted rapid evolution in Icelandic gulls (Larus argentatus and Larus hyperboreus) since 1925, probably due to a secondary contact between these species associated with the development of large-scale Atlantic fisheries and the concurrent spread of the Herring Gull to Iceland.

In summary, one finds that the Herring Gull and relatives in North America lay a clutch of three from which they normally fledge one young per nest per year. Predation and attacks by members of the same species are the primary factors responsible for egg and chick loss. Gulls have increased rapidly in Europe and eastern North America within the last seventy years. The increase in gull population is associated with environmental deterioration, due to increases in refuse, fish scraps, and similar garbage (Fig. 6).

Breeding Ecology

Nest Site Selection: Slope, Substrate and Cover

Southern Alaskan argentatus and glaucescens nest on a variety of substrates ranging from bare cliff ledges in fjords in Glacier Bay to flat gravel bars at Dry Bay to sloping grassy meadows at Egg Island, North Marble and Lake Louise.

Glacier Bay is rather interesting in this context. It is recently deglaciated; while not in the arctic, it approximates high arctic conditions in some areas. Smith (1966b) reported that argentatus are present in small numbers at the heads of fjords around Baffin Island in the eastern Canadian arctic. We also found argentatus in Glacier Bay in fjords close to glacier fronts; glaucescens tend to concentrate in lower regions, more marine, in Glacier Bay, around the Marble Islands and the Beardslee Narrows. But argentatus and glaucescens also nest together on cliff faces near the glaciers. There are apparently insufficient isolating mechanisms in both nesting habitat selection and species recognition because they hybridize. From field notes of 24 July 1971, at William Field Cairn #3, 4 km from the front of Johns Hopkins Glacier, on the north side of Johns Hopkins Inlet, facing the glacier:

> "Sea cliffs. Cliffs several hundred meters long and several hundred meters high in near vertical slope. Sat for several hours--in fact all morning--observing birds from cairn #3. Noted Herring Gulls, Glaucous-winged Gulls, and some intergrades between them in the amount of black on the primaries. Herring Gulls have cat-yellow itis. Glaucous-winged have dark iris. All different amounts of black on wing-tips seen--some just very tips of primaries black, some with just ends and tips of primaries black, and some typical of usual Herring Gulls."

We also observed partially fledged chicks on ledges on the cliff face. In subsequent field seasons we found glaucescens and argentatus nesting together in Glacier Bay on low rocky islets, flat gravelly islets, and sloping grassy hillsides (Part I, Table 23).

Dry Bay, at the mouth of the Alsek River, south of Yakutat and northwest of Glacier Bay, provides different conditions. About 500 pairs of gulls nest on flat gravel bars near the river mouth. The low alluvial islands are washed by high waters following summer storms and snow-melt in the mountains. Vegetation as a consequence of unstabilized substrate plus periodic flooding is sparse and indicates a combined maritime and fresh-water influence. Japanese glass floats found on the gravel bars indicate winter storm tides flood Dry Bay with salt-water. The gull population, hybrids between *argentatus* and *glaucescens*, reflects these mixed coastal and interior conditions. Vegetation cover is important for nest site selection, since nests are clumped near drift logs, willow bushes and grass patches. Gravel beds where gulls do not nest divide parts of the island colony at Dry Bay (Pt. I, Figs. 5 & 6). When melt-waters combine with heavy rainfall (as a summer storm follows days of sunshine), the river rises and fills the gravel beds. If gulls nested on these gravel beds or too close to the periphery of the island, their nests would be washed away under these conditions. Physical conditions subject to rapid changes influence nest site selection at Dry Bay and in colonies off the Copper River Delta (see Egg Island study area, *in* Methods), but less so at North Marble and Lake Louise.

L. glaucescens and *L. argentatus* and hybrids must be flexible in nesting habitat selection due to the dynamic conditions in which they nest. *L. glaucescens* and *L. occidentalis* also nest in a variety of habitats when sympatric (Scott, 1971; Hoffman, 1976; see also Vermeer, 1963; Coulter et al., 1971).

Thousands of *glaucescens* at Egg Island nest on stabilized meadow-covered dunes, usually in proximity to old drift logs or *Sambucus* bushes

Slope of the dunes is shallow, averaging less than 3%. The highest dunes are only ten meters above sea level. Egg Island, as North Marble, has highest densities of nesting gulls on completely open meadows. Some sites on North Marble are precipitous, however, approaching 50% slope (Part I, Table 24). Gulls in both colonies tend to select breeding habitat where approaching predators can be easily detected. Few gulls nest in brush fringes on North Marble, but some *glaucescens* nest directly beneath bushes on Egg Island. Brush-nesting *glaucescens* are previously reported by Vermeer (1963) and Manuwal (pers. comm.) in Puget Sound. Tinbergen (1960) noted nesting *argentatus* react positively to bushes. Haycock and Threlfall (1975) observed *argentatus* in Newfoundland nesting in proximity to prominences such as boulders, trees or stumps. This form of nest site attraction may represent previous affinity for cliff-nesting. *L. argentatus* at Lake Louise nest on a grassy islet with similar slope and substrate to North Marble *glaucescens*, *argentatus*, and hybrids (Part I, Table 23).

According to Smith (1966), the *Larus* gulls around Baffin Island freely intermixed only during the few days after arrival in the Arctic, when they occurred together in flocks along the edge of the land-fast ice, and when they moved onto the cliff faces. Habitat separation may reduce the potentiality for mixed matings among gulls in the eastern Canadian Arctic. Knudsen (pers. comm.) is further investigating this topic in Baffin Island and New Brunswick. *L. argentatus* in the eastern Canadian Arctic tends to select a nesting place on small islets in flat marshy areas (Smith 1966). Despite selective pressure exerted by ground predators, *argentatus* has not colonized cliff faces. The isolating effect was apparently greatest in Smith's area between *argentatus*, and the cliff-nesting *hyperboreus*, *thayeri* and *glaucoides kumlieni*. In other areas, such as New Brunswick, Niagara Falls, N.Y., and the Lake Superior shoreline in Wisconsin, argentatus nest on cliffs (Emlen, 1963; Harris and Matteson, 1975; Andrle, 1976), and are otherwise plastic in nest site selection. Drury and Nisbet (1972) find argentatus in New England highly adaptable to changing circumstances, since the seashore is subject to continuous changes in detail.

Territory Size

The definition of territory, as Hinde (1956) states, is "any defended area." This definition does not necessarily imply the defended area is sharply delimited, but in practice many workers on territory (references in Hinde, 1956) imply the existence of such borders by measuring territory size. Using the measure of territory for gulls defined by Harpur (1971), we calculated the area of each nesting territory as a circle with a radius half the distance to the nearest active nest. In reality, gulls do not defend neat circles. Actual territory size depends upon the stage of the reproductive cycle, expanding with hatching of chicks, and declining as chicks grow older (Hunt & Hunt, 1975). Nevertheless we have elected to use Harpur's measure because it is standardized and can be compared to other studies. The distance to nearest neighbor, upon which we calculate territory size, may be an important factor in determining gull chick survival (Hunt & Hunt, 1975).

Patten (1974) previously reported a mean territory size of 18 m^2 for the colony at North Marble, but territory size varied from sub-colony to sub-colony and from year to year (Table 2). At Dry Bay 'A' colony in 1975 mean territory size was 29.8 m^2, suggesting room for more breeding pairs (mean distance to nearest neighbor was 6.16 m^2). Mean territory size at Dry Bay 'A' colony in 1977 was quite similar, 30.9 m^2, with virtually the same number of pairs inhabiting the identical survey area. Dry Bay 'B' colony in 1977, which had not been previously surveyed, was less densely utilized, with a mean territory size of 48.51 m^2 and a relatively large internest distance of 7.86 m. Both 'A' and 'B' colonies produced well over one chick per nest to fledging (Table 1).

Table 1

Gull Reproductive Parameters, Dry Bay 1977

	Colony 'A' - 300 m x 50 m	Colony 'B' - 30 m in Ø
Clutch Size	2.94 (90 nests - 265 eggs)	2.86 (22 nests - 63 eggs)
Egg Loss	10 (3.8%)	7 (11.1%)
Infertile Eggs	8 (3%)	0
'Pipped' but failed to hatch	2 (.8%)	0
Hatching Success	245/265 (92.4%)	59/63 (93.6%)
Chick Loss	111/245 (45.3%)	31/59 (52.5%)
Chicks Fledged	134	28
Fledging Success	1.49 chicks/nest	1.27 chicks/nest
	or 50.5% chicks fledged/ eggs laid	44.4% chicks fledged/ eggs laid
	or 54% chicks fledged/ chicks hatched	47.5% chicks fledged/ chicks hatched

NOTES: 1 supernormal clutch of 4 eggs in 'A' colony, which hatched. (1/90 = 1.1%)

1 replacement clutch of 3 eggs in 'A' colony. (1/90 = 1.1%)

Chick loss was due mostly to sustained, heavy eagle predation (eagle nest within 2 km of the gull colony).

Chick loss was clearly the major factor influencing fledging success at Dry Bay in 1977.

Mean territory size on Egg Island in 1975 was 28.9 m^2. (mean distance to nearest neighbor was 6.06 m) (Table 2). Territory size, as at Dry Bay, remained practically identical the next season surveyed, but there were 20% more nests in the study area (30.2 m^2; mean distance to nearest neighbor 6.2 m^2). This suggests gull pairs distribute themselves due to social attraction at this density but clearly do not use all available space (weighed mean territory size for 1975 and 1976 was 29.6 m^2).

The migratory population of argentatus, breeding at the interior Lake Louise in 1977, showed a mean territory size of 13.5 m^2 and a mean internest distance of 4.3 m. 77 pairs bred in a relatively confined area of 0.36 hectare on a lake islet (Part I, Fig. 13; Part II, Table 2).

We found large differences in internest spacing and territory size for glaucescens breeding on grassy meadows on Egg Island and the mixed colony dominated by glaucescens at North Marble, also nesting on grassy meadows. Hybrid gulls nesting on gravel bars at Dry Bay and glaucescens on meadow-covered dunes on Egg Island had similar territory sizes (Table 2). Notable is the large territory size at both Egg Island and Dry Bay. The study area at Egg Island showed an increased number of pairs the second field season, while the Dry Bay colony did not. The argentatus nesting on the sloping grassy meadows at Bird Island at Lake Louise had small territory sizes, in sharp contrast to large portions of the meadows on Egg Island, not even colonized due to recent ('64) earthquake activity doubling the island surface area. This suggests interior argentatus are close to using all available nesting space, but other argentatus-group populations are flexible in internest distances and are not limited by available nesting space in their northeast Gulf of Alaska breeding sites. It is not unreasonable to expect increasing gull populations in coastal districts, with an increasing food supply due to human activities. This is especially true off the Copper River Delta.

Since territory, as expressed as a multiple of the distance to nearest neighbor, may be important in determining gull reproductive success, we have explored the influence of territory size by plotting various parameters against it. We have plotted mean clutch size, egg loss, chicks hatching, and chicks fledging against mean territory size by colony and by year. The results are presented in the following Figures: clutch size against territory size (Figs. 5, 6, 7, and 8); egg loss against territory size (Figs. 16, 17, 18, 19); chicks hatching against territory size (Figs. 28 29,30,& 31) and chicks fledging against territory size (Figs. 36,37,38 and 39).

Egg-Laying

Gulls at North Marble, Dry Bay, Egg Island, and Lake Louise began to lay eggs in mid- to late May without regard to taxonomy. A remarkable degree of synchronization was apparent when comparing percentages of eggs found in sequential dates of observation through the nesting period (Figs. 9, 10 and 11). There was a strong tendency in these colonies for the majority of eggs to be laid in just over one week.

Egg-laying on North Marble was closely synchronized in all sub-colonies, although most eggs were laid two weeks earlier in 1973 than in 1972. In 1972, 50% of eggs were laid in a seven day period in late May (Fig. 9). In 1973, 60% of eggs were laid between June 5th and June 7th. The evidence from North Marble indicated not only a colony-wide synchrony, but a synchronous egg-laying in four partially contingent colonies, suggesting the gulls on North Marble were acting as one large colony.

The Dry Bay colony demonstrated flexibility in timing of breeding from year to year, as at North Marble (see pp41-43) but synchrony once the process began (Fig. 11). Gulls at Dry Bay laid 50% of eggs in an eight day period between May 15th and May 23rd, a pattern quite similar to North Marble.

The colony at Egg Island had 50% of eggs laid in just over one week, between May 30th and June 7th, similar to Dry Bay and North Marble (Fig. 10).

Incubation in Alaskan glaucescens did not begin until after the clutch of three was completed, usually about a week after the first egg was laid. Mean interval between eggs was two days (Patten, 1974). The onset of incubation at North Marble, Dry Bay, and in the Egg Island study areas was quite synchronized, and began immediately after the week in which most eggs were laid.

Clutch Size

Clutch size is one of the important parameters determining the reproductive success of gulls. The seriousness of hatching failure, or chick loss, is partially determined by the clutch size. Reproduction can be maintained if the mean clutch size is sufficiently high before predation or other egg loss. A gull population with a higher mean clutch size can support a greater rate of hatching failure or chick loss than a population with a lower mean clutch size.

Clutch size in southern Alaskan gull colonies ranged from 3.0 to 2.1, both in North Marble Island colonies (Table 2). The weighted mean clutch size for the North Marble population, however, was quite high (2.80 in 1972; 2.96 in 1973). Only the Top Colony had a significantly lower clutch size compared to other sites in 1972 (2.1; $p < .05$, Duncan Multiple Range Test). This was correlated with significantly larger territory size (Table 2; Fig. 34). There were no significant differences between colony sites in 1973 in either clutch or territory sizes (Table 2; Fig. 35).

Dry Bay 'A' and 'B' colonies were not significantly different from each other in clutch size in 1977, nor were they significantly different from North Marble (1972-73), once again with the exception of the Top Colony in 1972 ($p < .05$, Duncan Multiple Range Test).

The interior argentatus population at Lake Louise had an intermediate mean clutch size of 2.7 and the smallest territories of any colony due to restricted nesting space (Table 2). The colony with the lowest mean clutch size, after the small, marginal Top Colony at North Marble in 1972, was Egg Island (Table 2). The plot of clutch size against average territory size on Egg Island (1975-76), compared to North Marble Island (Figs. 31, 32), showed territory sizes were larger on Egg Island but clutch sizes were smaller.

Table 2. Clutch Size, Number of Fledgl and Territory Size in Southern Alaskan Gull Colonies, 1972-1977

Colony/Year		Number of Nests Examined	Mean Clutch Size	Mean Number of Fledglings	Mean Territory Size (m^2)
North Marble	1972				
East		94	2.8	1.8	14.3
West		36	2.9	2.2	18.3
North		20	2.8	1.5	32.7
Top		12	2.1	0.4	52.1
Total		162	2.8*	1.75*	20.2*
North Marble	1973				
East		104	3.0	1.6	14.0
West		60	2.9	2.2	12.5
North		15	3.0	1.7	36.1
Top		12	2.9	1.6	36.9
Total		191	2.96*	1.80*	16.7*
Dry Bay					
'A' Colony	1975	100	--	--	29.8
	1977	90	2.9	1.5	30.9
'B' Colony	1977	22	2.9	1.3	48.5
Egg Island	1975	153	2.4	1.0	28.8
Egg Island	1976	186	2.4	1.1	30.2
Lake Louise	1977	77	2.7	0.9	13.5

* weighted means

The conspicuous exception was the Top Colony on North Marble in 1972, which resembled Egg Island.

We suggest age of the female as the most important factor influencing clutch size in southern Alaskan gull colonies. Clutch size increased in the North Marble Island Top Colony as the females became older and more experienced. This influenced reproductive success as measured in chicks fledged. Territory size was inversely related to clutch size because of the tendency of young, inexperienced pairs to nest on the periphery of the colony, in marginal sites, or in newly colonized areas, where internest distances (upon which we calculate territory size) were larger. This has important implications for the growth of the Copper River Delta gull populations in that clutch size and fledging success of these populations may increase over time, given sufficient sources of artificial food (see below).

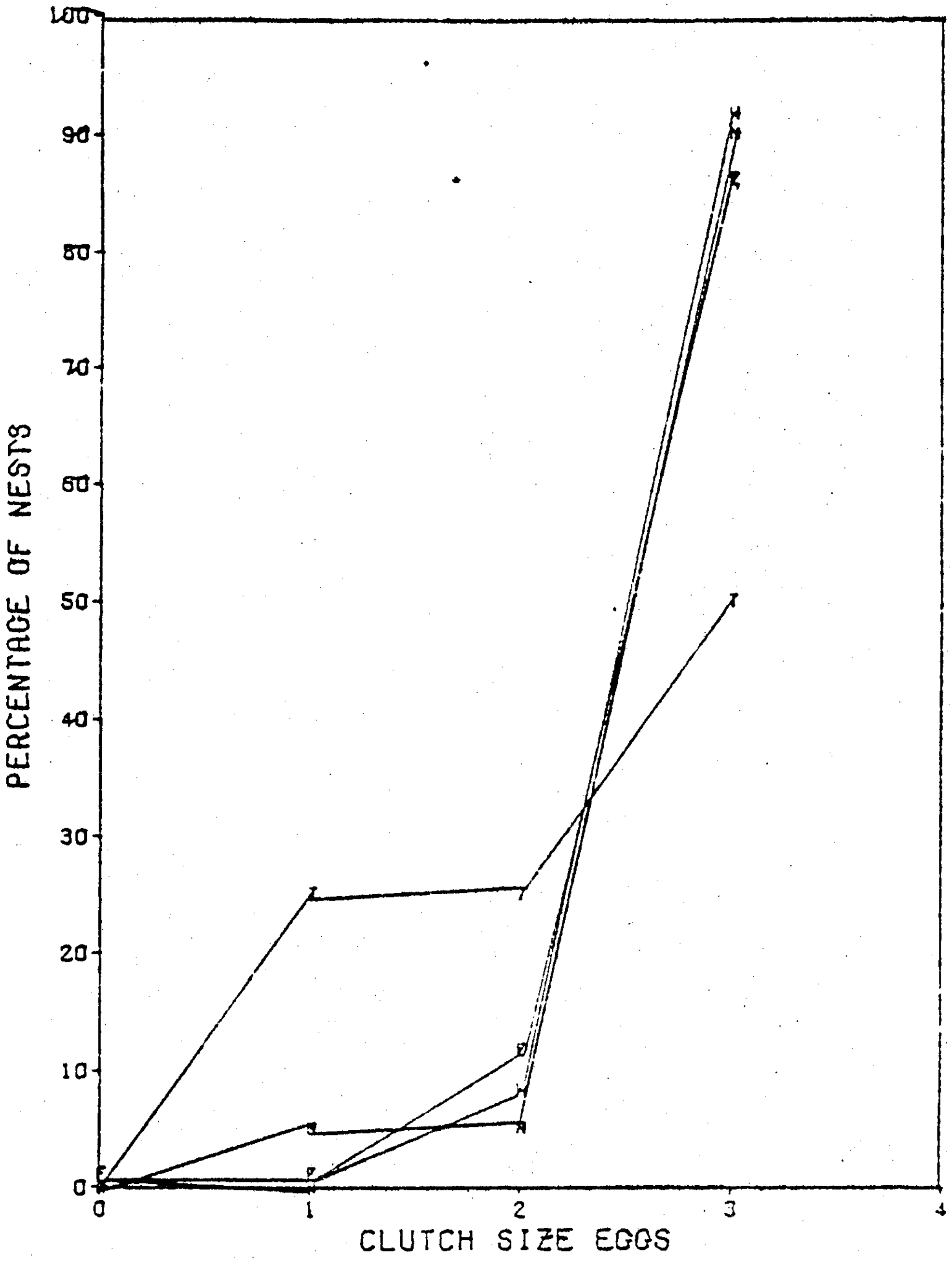

Figure 1. Clutch size plotted against percentage of nests, North Marble Island, 1972.
E = East Colony, W = West Colony, N = North Colony, T = Top Colony.
The Top Colony is different in clutch size; East, West, and North are similar.

The most likely explanation for the difference is young females laying for the first time produce smaller clutches.

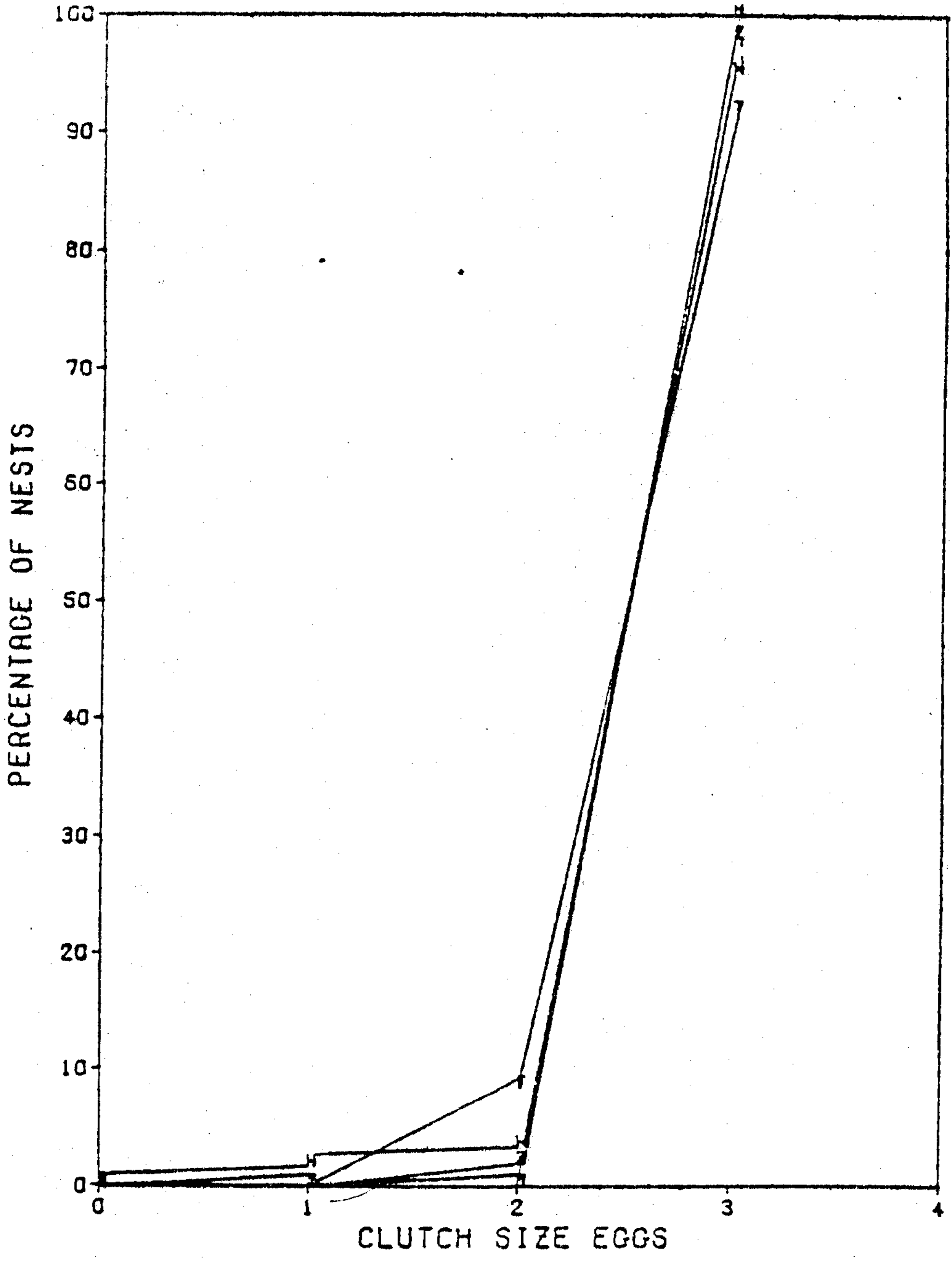

Figure 2. Clutch size plotted against percentage of nests, North Marble Island, 1973.
E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

All colonies show similar tendencies.

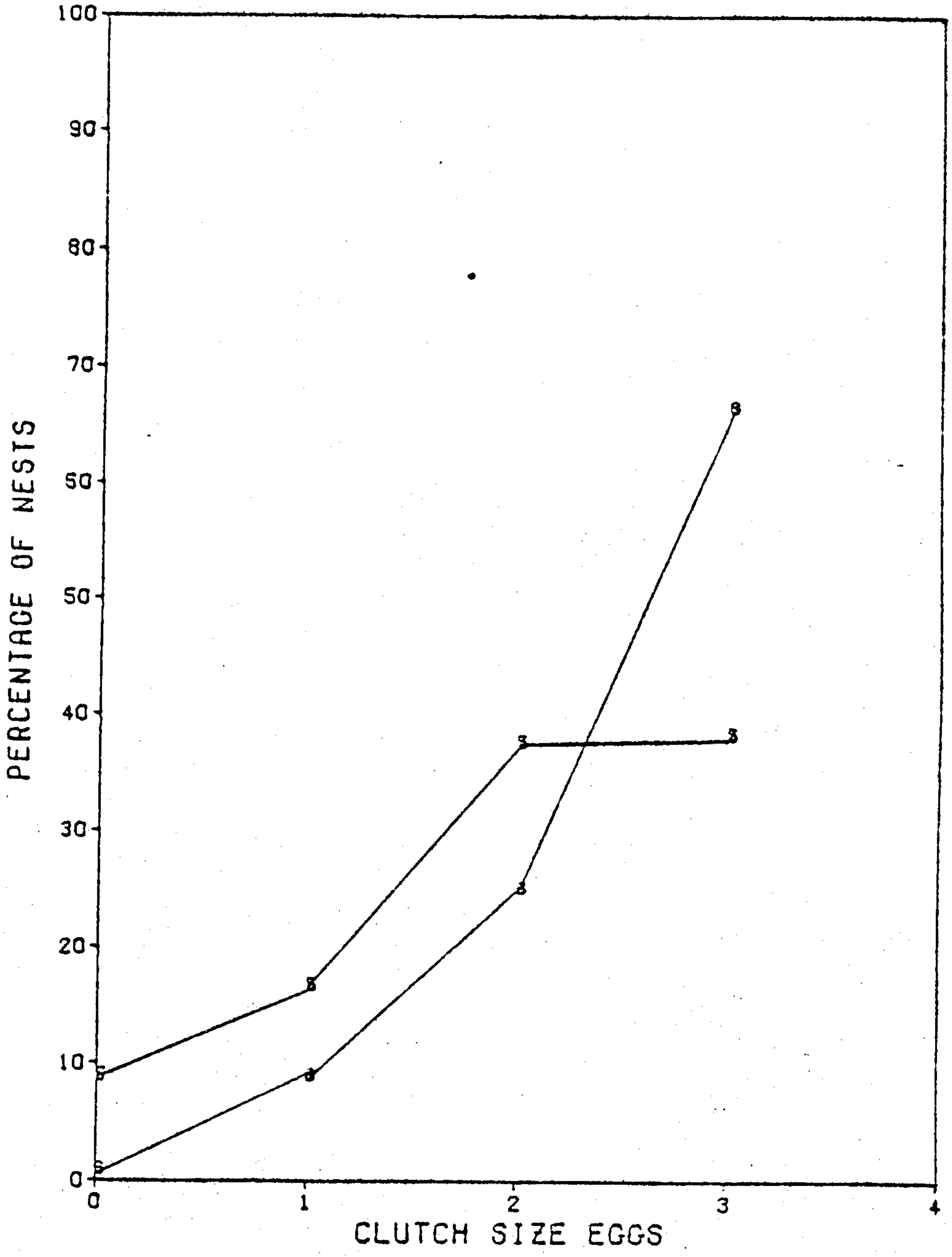

Figure 3. Clutch size plotted against percentage of nests, Egg Island 1975 - 1976.
5 = 1975 survey, 6 = 1976 survey.

Clutch size is smaller on Egg Island than on North Marble, probably due to the expanding population on Egg Island, with a higher percentage of young females producing smaller clutches. Egg Island most resembles the Top Colony on North Marble in 1972.

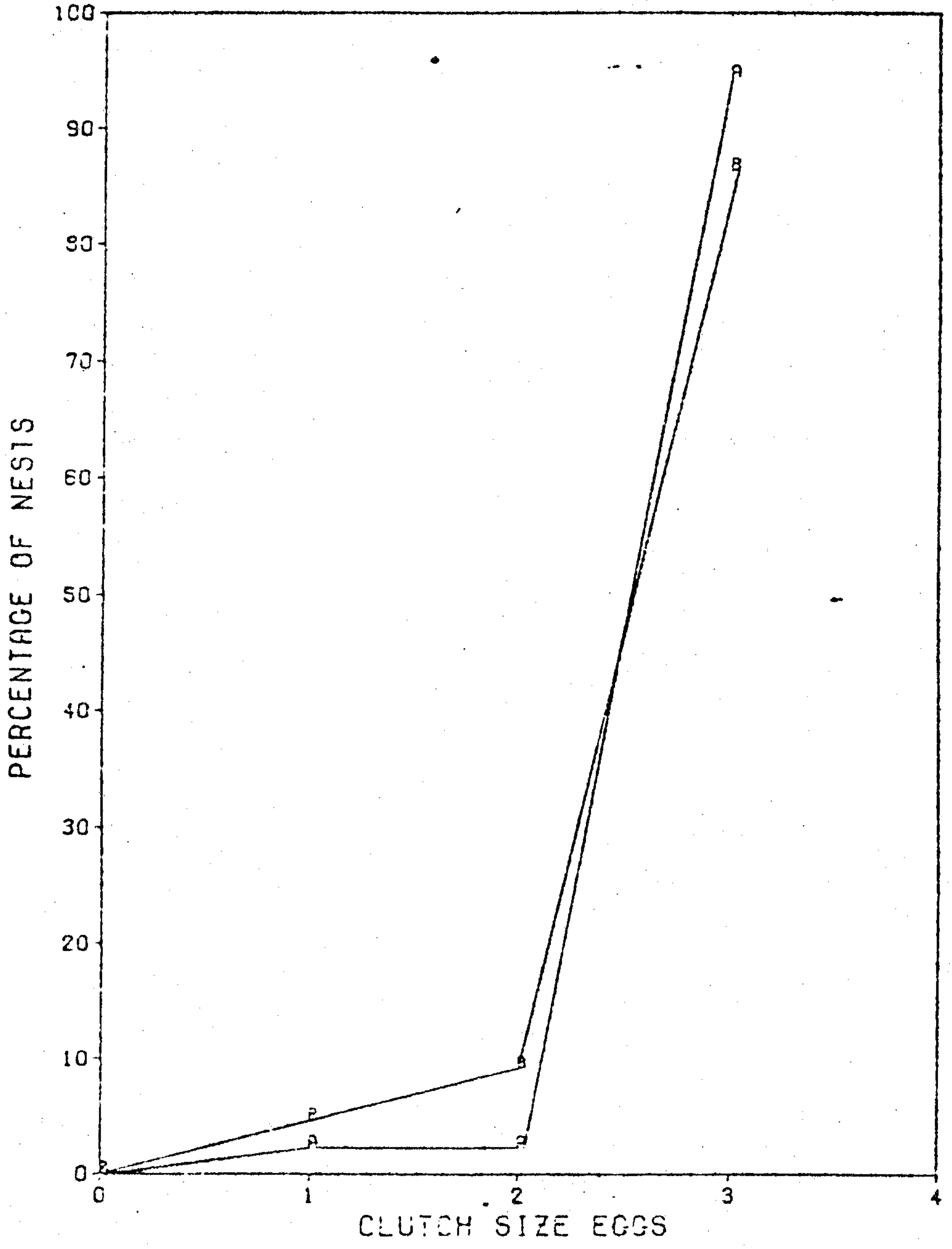

Figure 4. Clutch size plotted against percentage of nests, Dry Bay, 1977.
A = 'A' Colony, B = 'B' Colony

Both colonies are similar in clutch size and resemble clutch sizes on North Marble in 1973.

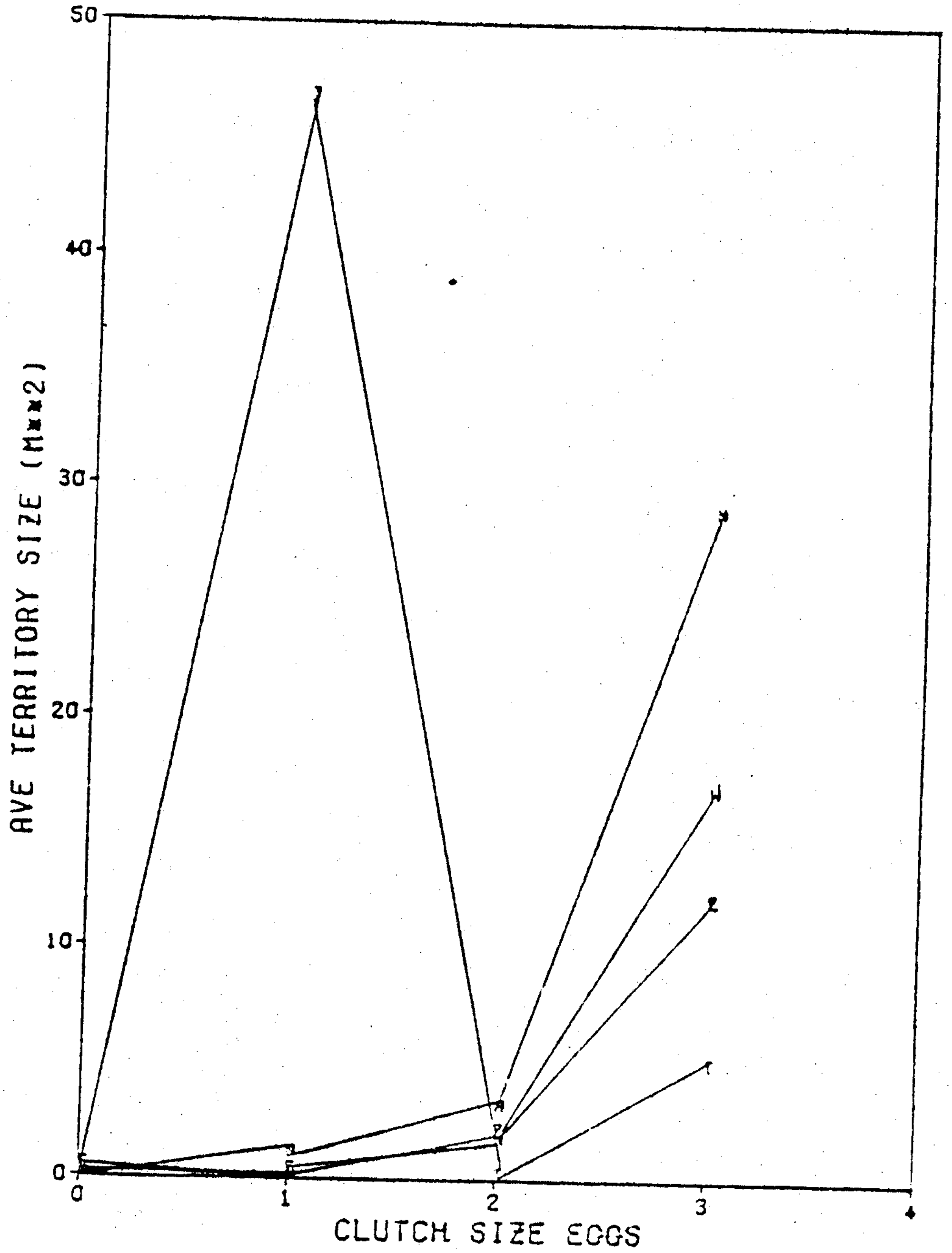

Figure 5. Clutch size plotted against average territory size, North Marble, 1972.
E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

East, West, and North Colonies show rather similar tendencies. Top Colony is strikingly different, with a large mean territory size and concurrent 1-egg clutches.

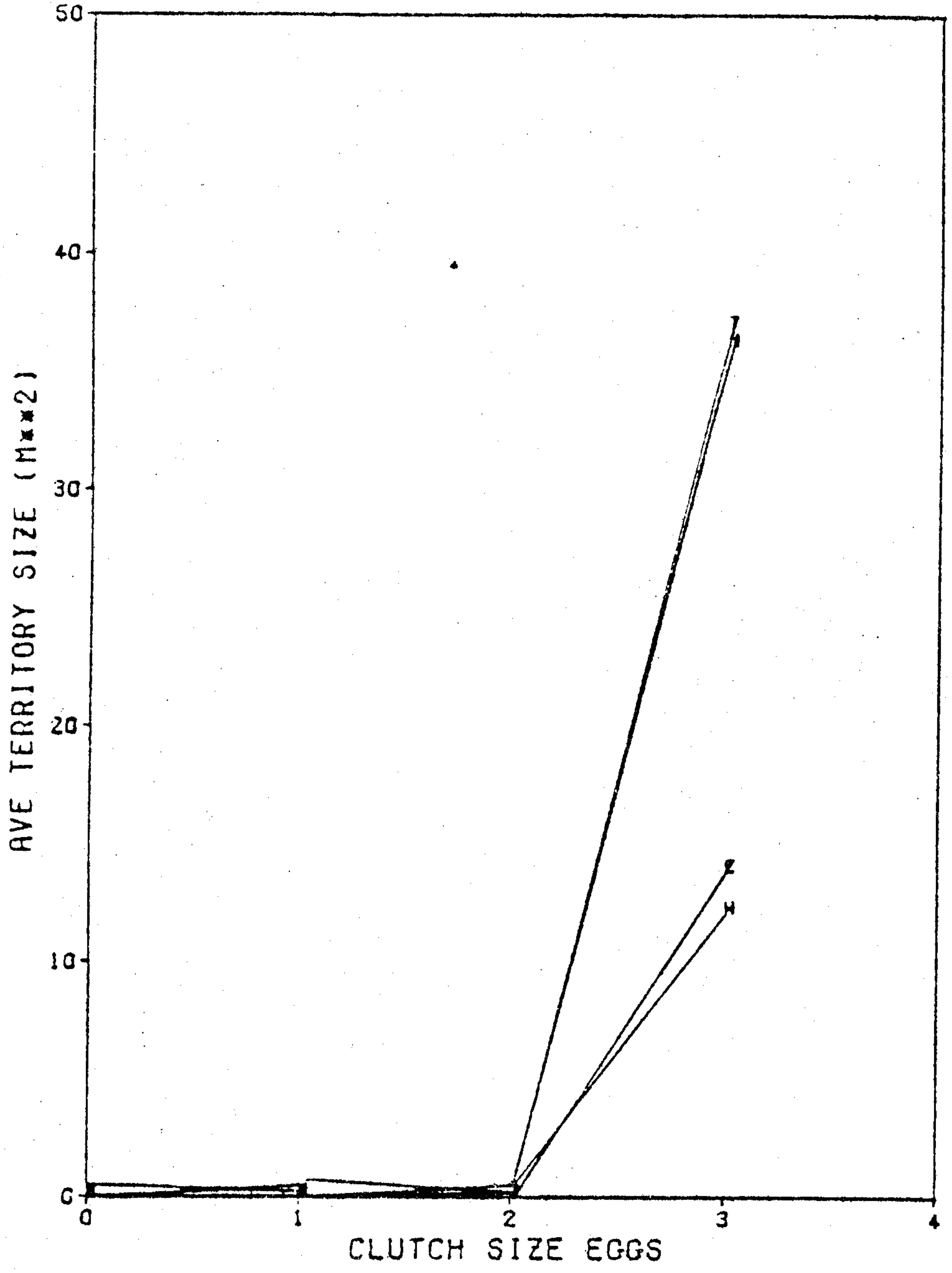

Figure [illegible]. Clutch size plotted against average territory size, North Marble, 1973.
E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

East and West Colonies are close in average territory size, as are Top and North Colonies. However all colonies exhibit a high proportion of three-egg clutches.

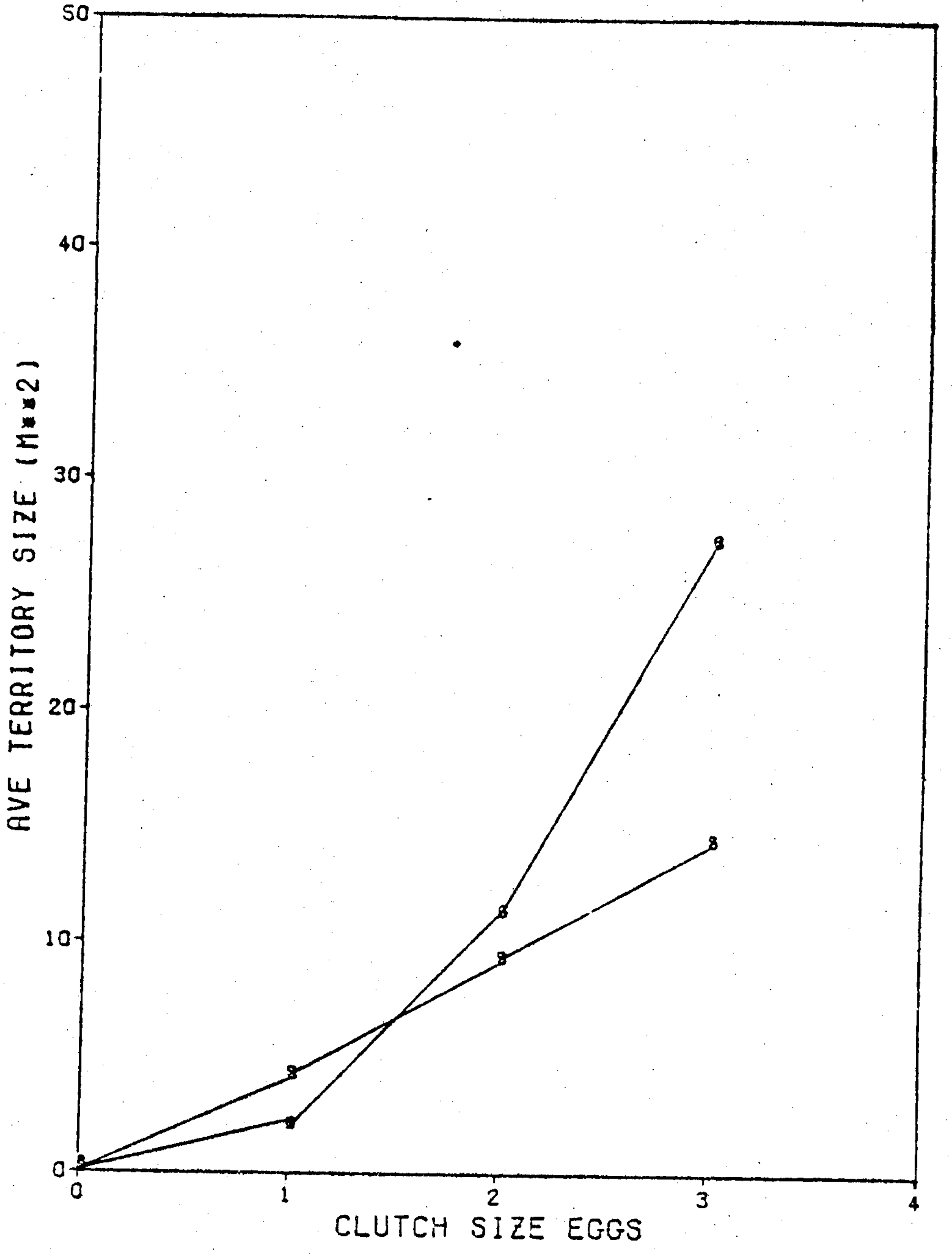

Figure 7. Clutch size plotted against average territory size, Egg Island 1975 - 1976.
5 = 1975 survey, 6 = 1976 survey.

Territory size is significantly larger on Egg Island compared to North Marble, with a smaller percentage of three-egg clutches and a greater proportion of one-egg and two-egg clutches. The conspicuous exception is the Top Colony in 1972 (Figure 6), with large territory size and high percentage of one-egg clutches.

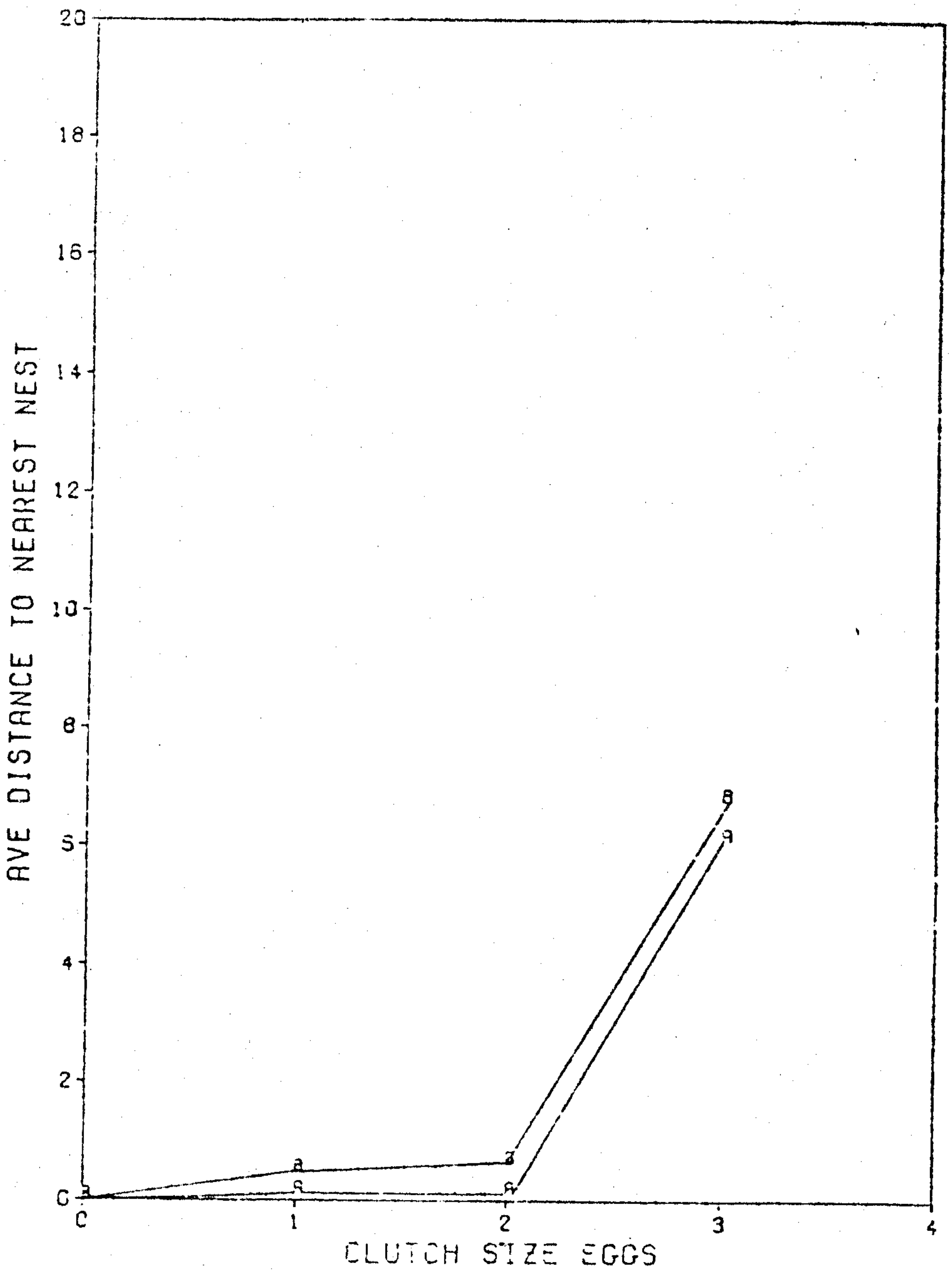

Figure 8. Clutch size plotted against mean distance to nearest nest, Dry Bay 1977. A = 'A' Colony, B = 'B' Colony.

'A' and 'B' Colonies exhibit similar relationships in clutch sizes and distance to nearest neighbor.

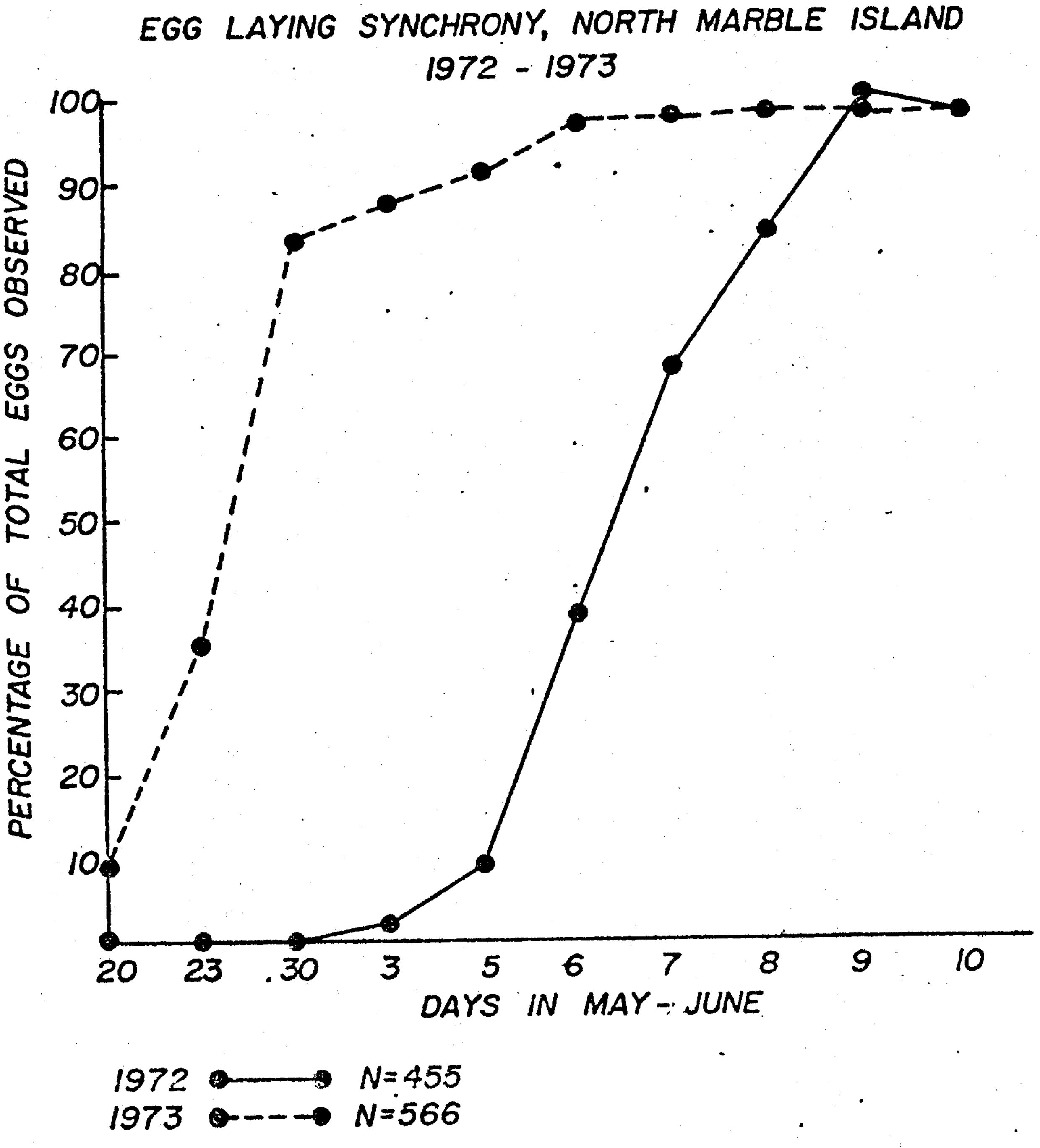
EGG LAYING SYNCHRONY, NORTH MARBLE ISLAND
1972 - 1973
PERCENTAGE OF TOTAL EGGS OBSERVED
100
90
80
70
60
50
40
30
20
10
20
23
30
3
5
6
7
8
9
10
DAYS IN MAY - JUNE
1972 N=455
1973 N=566

Figure 9

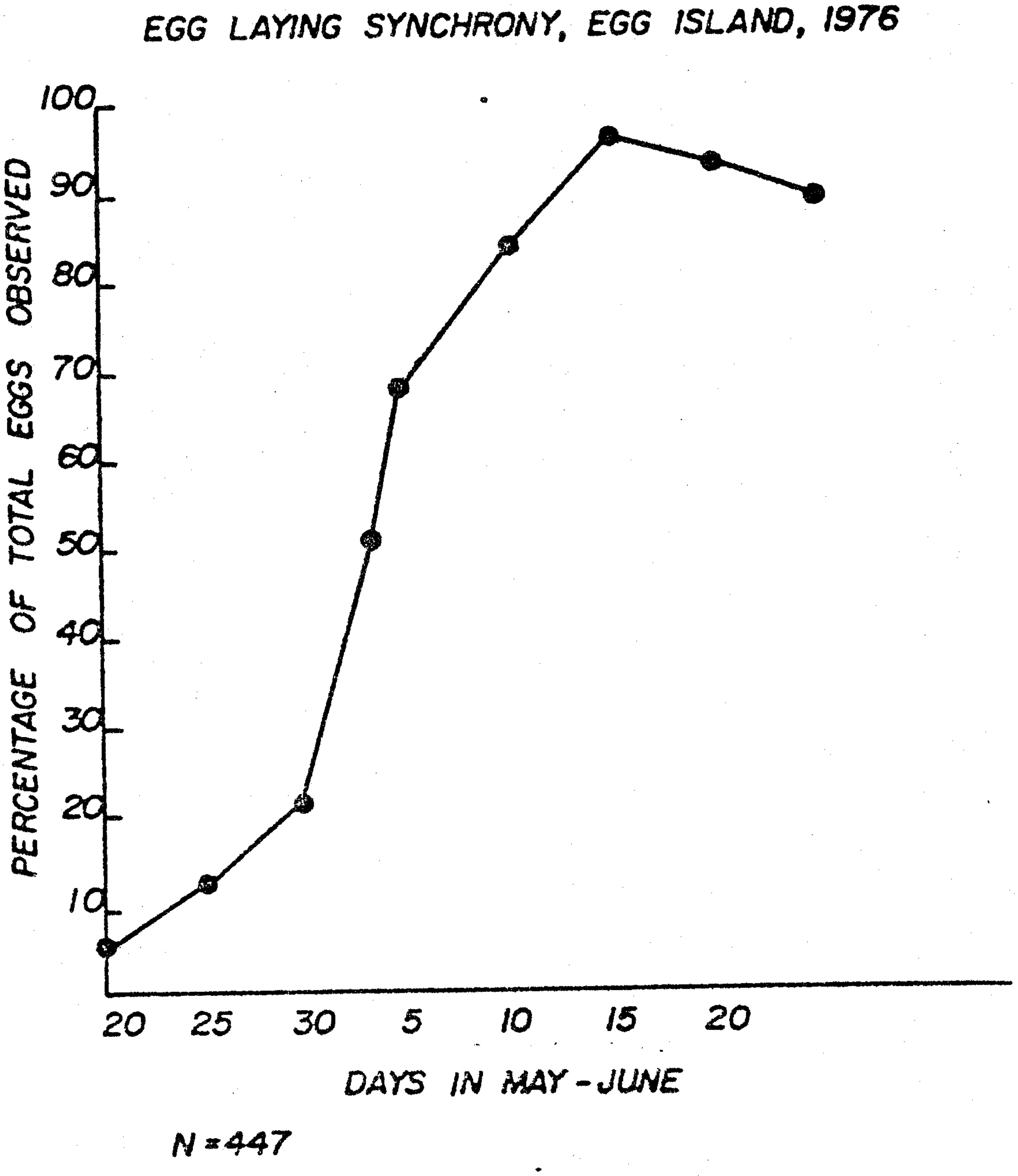
EGG LAYING SYNCHRONY, EGG ISLAND, 1976
PERCENTAGE OF TOTAL EGGS OBSERVED
100
90
80
70
60
50
40
30
20
10
20
25
30
5
10
15
20
DAYS IN MAY - JUNE
N = 447

Figure 10

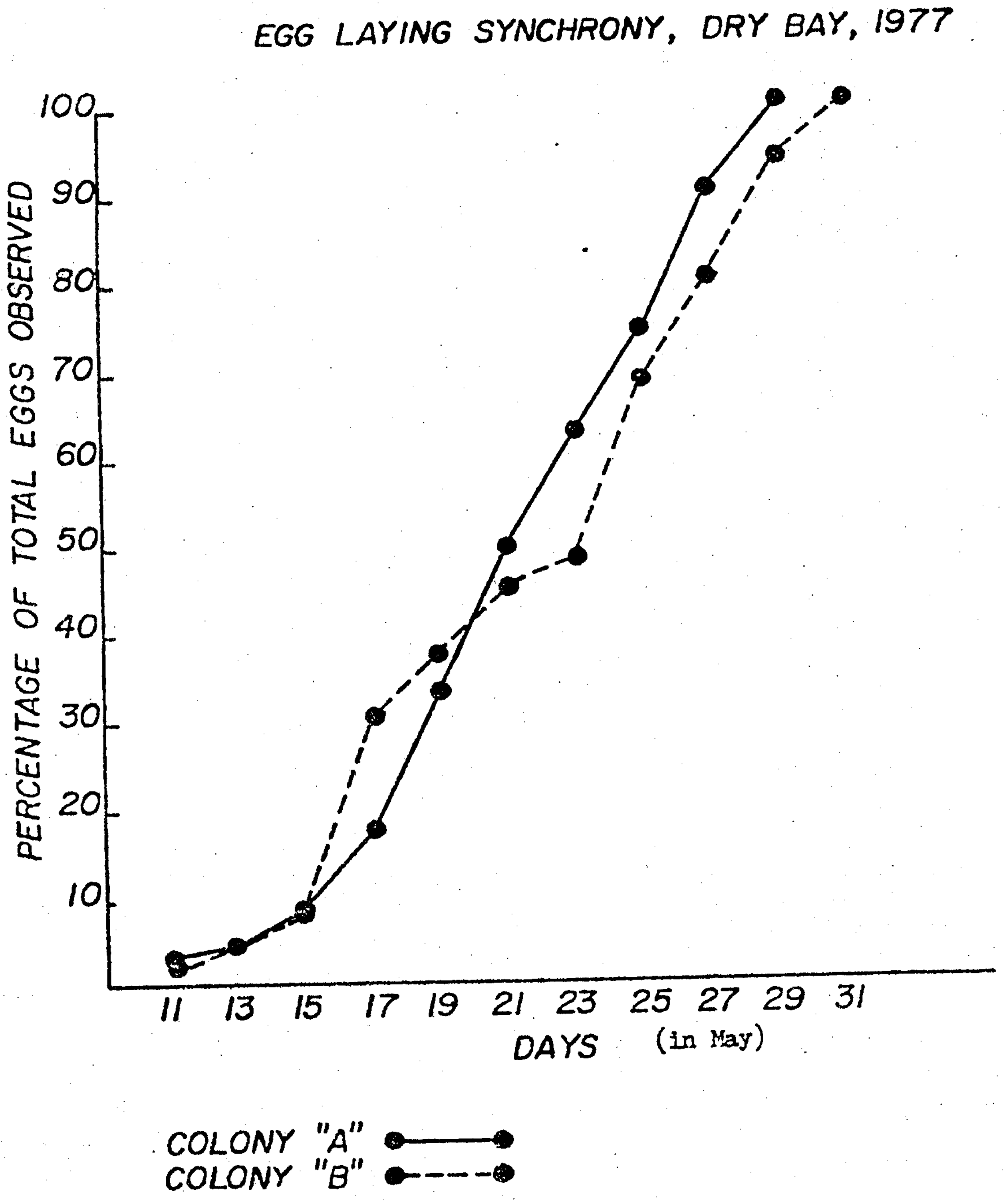
EGG LAYING SYNCHRONY, DRY BAY, 1977
PERCENTAGE OF TOTAL EGGS OBSERVED
100
90
80
70
60
50
40
30
20
10
11
13
15
17
19
21
23
25
27
29
31
DAYS (in May)
COLONY "A"
COLONY "B"

Figure 11

Hatching Failure

We attribute hatching failure in southern Alaskan gull colonies to three factors, using Paynter's (1949) formulation: (1) eggs disappearing (lost) from the nest during incubation; (2) eggs remaining in nests but not hatching (dying); and (3) eggs which pip but the chick dies before emerging. We consider lost eggs to be hatching failures because almost all egg loss was due to predation in which eggs were destroyed.

Loss of eggs through predation was the principle factor influencing hatching rate on North Marble (1972-73) and at Egg Island (1975-76) (Table 3). Results of the 1972-73 North Marble investigation indicated a 26-27% egg loss within a colony of 500 pairs (Table 3). Proportionate egg loss was similar from colony to colony at North Marble in 1972-73. Egg loss plotted against average territory size (Fig. 16) showed the following variations. The East and West colonies in 1972 were quite similar in percentage egg loss, while the Top colony had a high percentage loss of two eggs per nest. The North colony had a 20% complete clutch loss (3 eggs per nest). All colonies showed similar patterns of egg loss plotted against territory size in 1973 (Fig. 17).

The plot of egg loss against average territory size for Egg Island showed a correlation between large territory size and loss of one or two eggs in 1976; egg loss in 1975 resembled the pattern on North Marble (1972-73). Total egg loss in the Egg Island study area (1975-76) was 26% (Table 3). These figures suggest a ±25% egg loss frequently occurs in gull colonies in the Northeast Gulf of Alaska. Natural predation is due to other gulls, ravens, crows and jaegers. Subsistence egging by fishermen and natives causes much higher rates of egg loss in certain areas, notably on Egg Island near Cordova.

Egg loss was significantly lower ($p < .05$) at Dry Bay in 1977, compared to either North Marble or Egg Island. The low rate of egg loss (3% to 11%), was due to few ravens and crows on the Alsek Delta (Table 3). Minor egg loss was due to jaegers and other gulls. Colonies 'A' and 'B' at Dry Bay showed quite similar percentage egg loss suggesting little relationship to distance to nearest nest (Fig. 48 ; Table 3). Dry Bay most resembled North Marble in 1973 in egg loss to predation (Figs. 15,13).

A minor cause of non-productivity on Egg Island, North Marble, Dry Bay, and Lake Louise was eggs remaining in the nests but not hatching (dying). Study of the few decayed eggs did not reveal developed embryos or specific reasons for mortality (as in Paynter, 1949). We tentatively concluded the eggs were infertile since the relative percentage of unhatched eggs was low (Table 3) and eggshells showed no signs of fragility or pesticide contamination.

The last cause of failure to hatch occurred when the chick pipped the shell but failed to emerge and died. There were only two cases in the Egg Island study area (1975-76); two each at Dry Bay and Lake Louise in 1977; and three cases on North Marble (1972-73). The rate at every colony was well below one percent of total eggs laid in the study areas (Table 3). These are not significant rates.

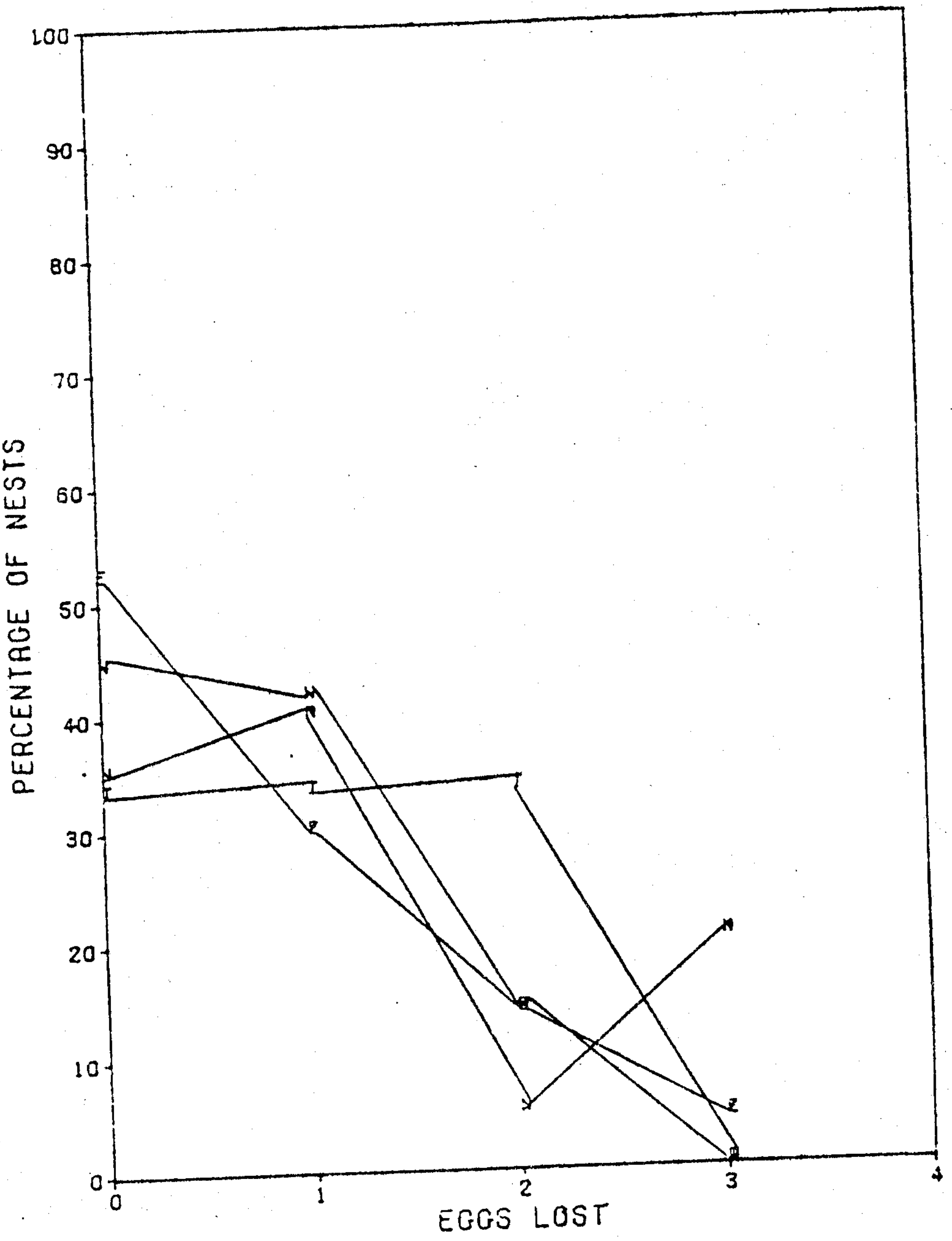

Figure 12. Eggs lost plotted against percentage of nests, North Marble, 1972.
E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

East and West Colonies are quite similar in percentage egg loss. Top Colony had a higher percentage 2-egg loss, and North Colony had 20% complete clutch loss.

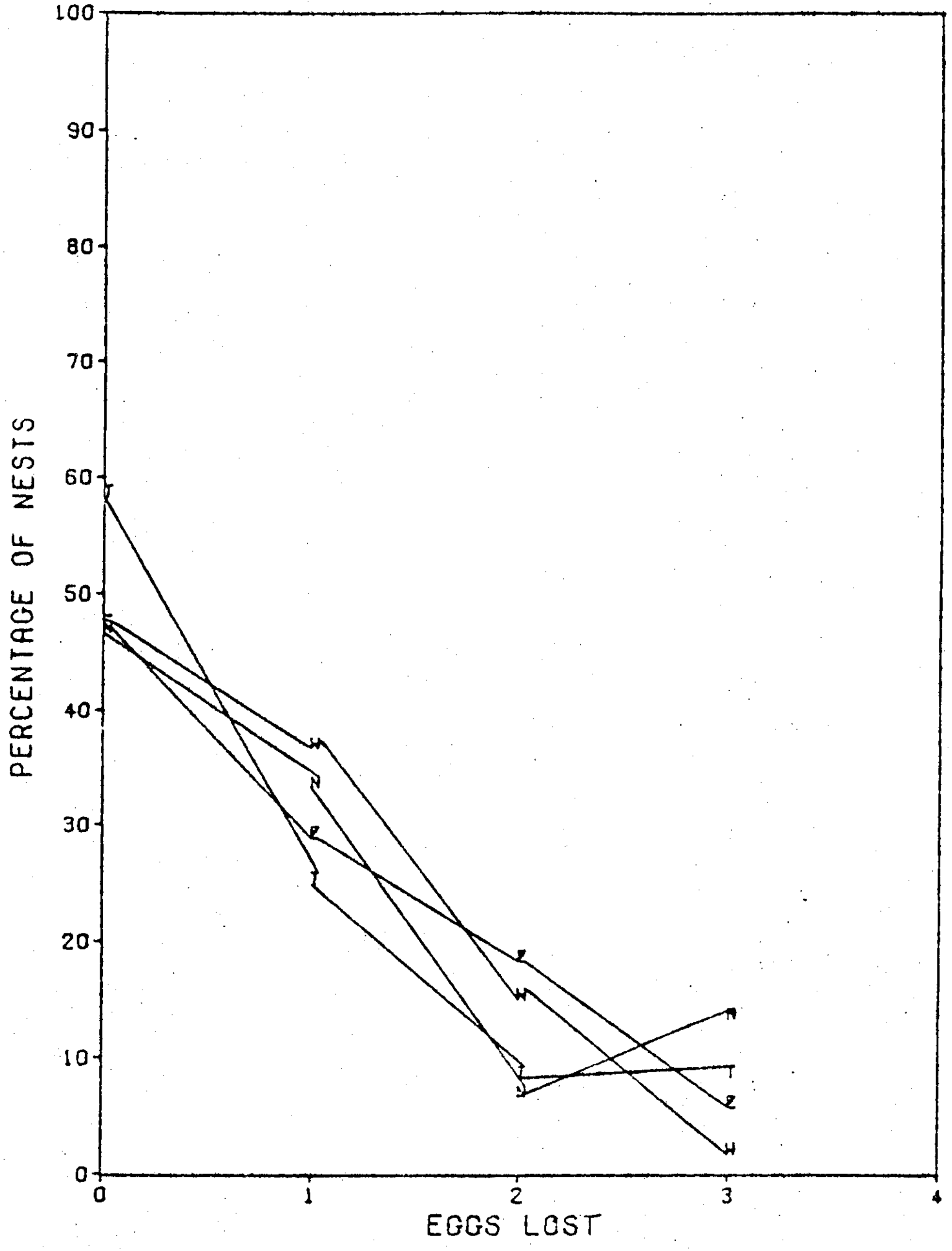

Figure 13. Eggs lost plotted against percentage of nests, North Marble, 1973.

All colonies show highly similar tendencies in eggs lost to predation. Predators are mostly conspecific adults.

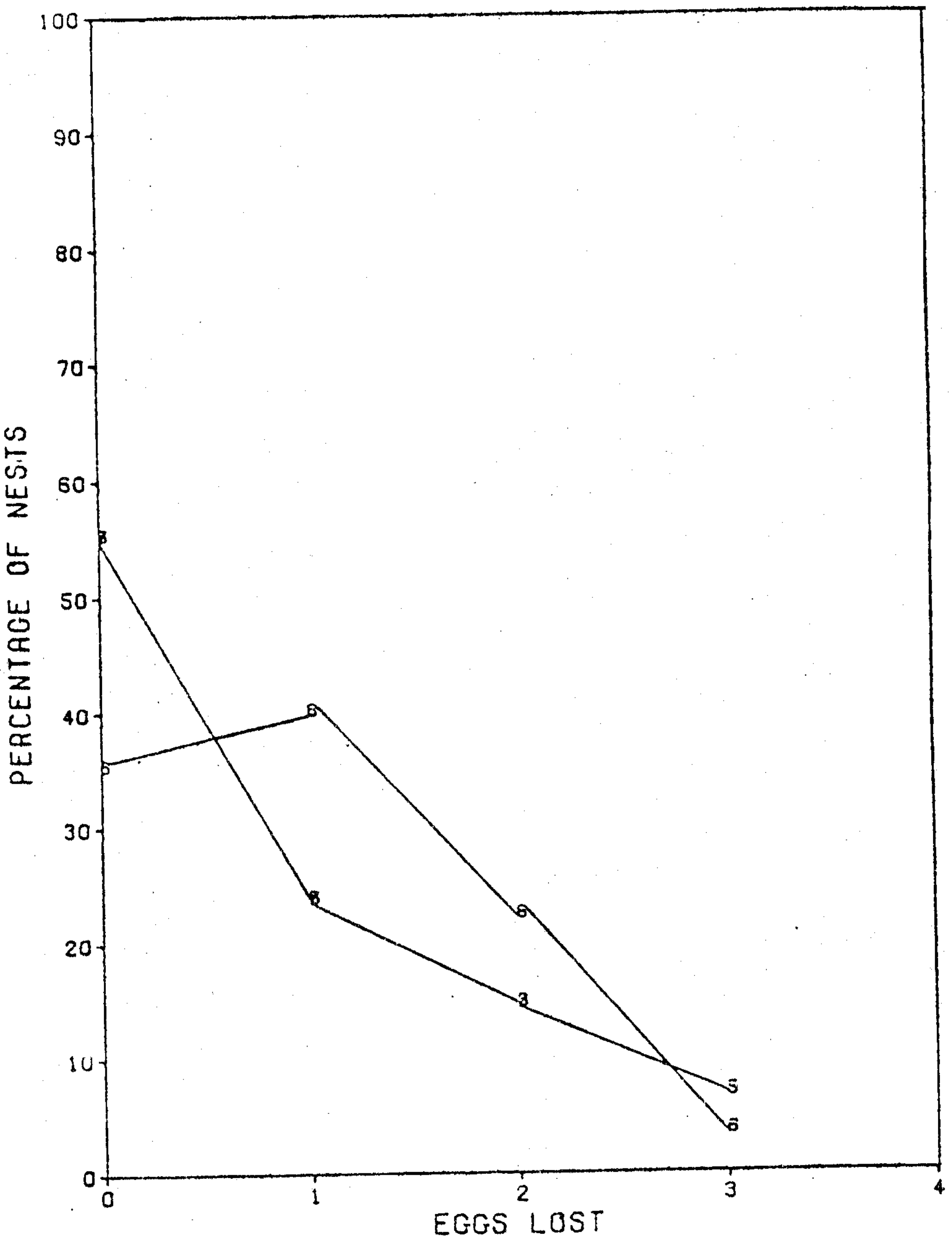

Figure 14. Eggs lost plotted against percentage of nests, Egg Island, 1975 - 1976. 5 = 1975 survey, 6 = 1976 survey.

Egg Island is similar to North Marble in egg loss to predation.

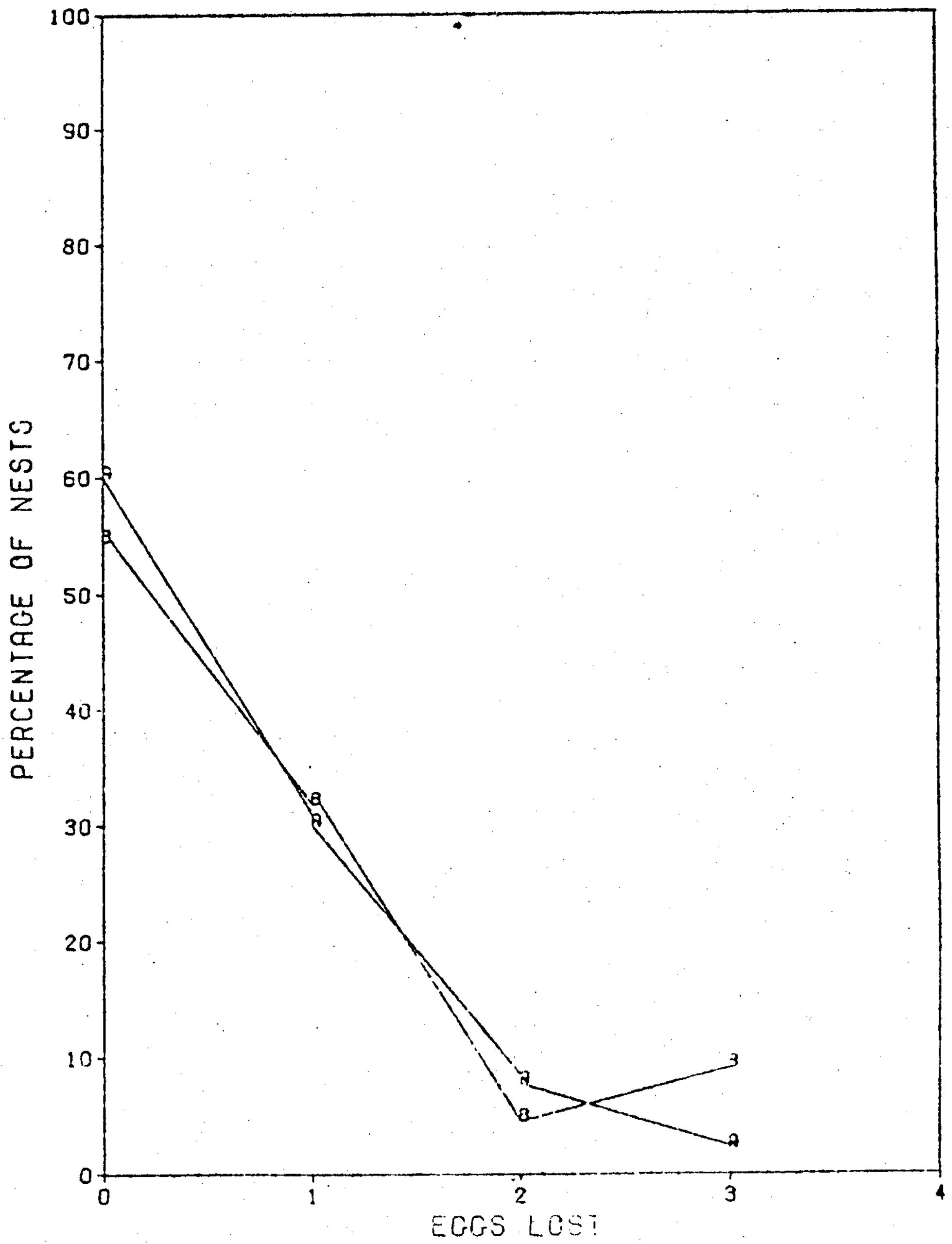

Figure 15. Eggs lost plotted against percentage of nests, Dry Bay, 1977.
A = 'A' Colony, B = 'B' Colony.

Eggs lost to predation at Dry Bay show a rate most similar to North Marble in 1973.

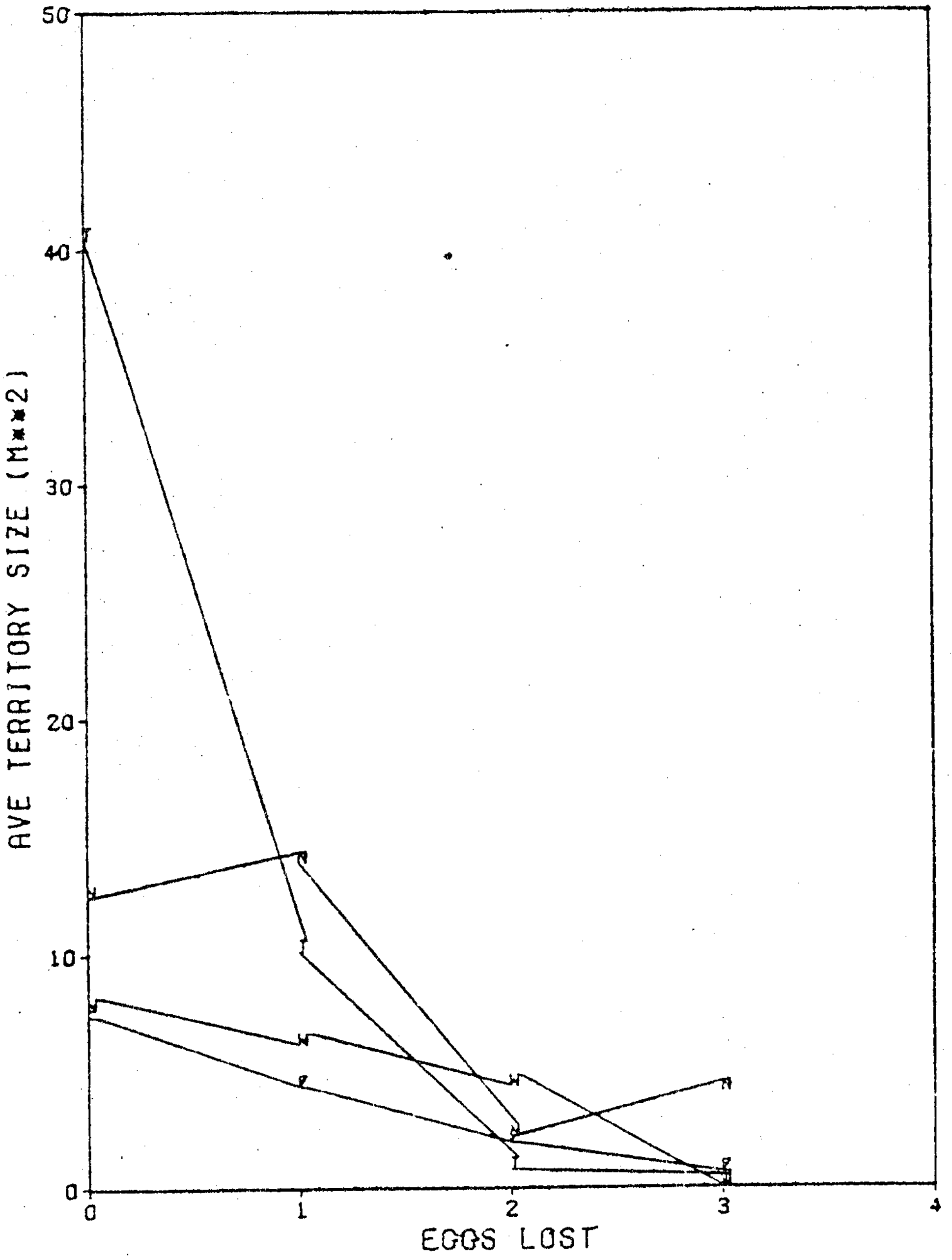

Figure 16. Eggs lost plotted against average territory size, North Marble, 1972.
E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

Although Top Colony is significantly larger in average territory size, proportionate egg loss is similar to other colonies.

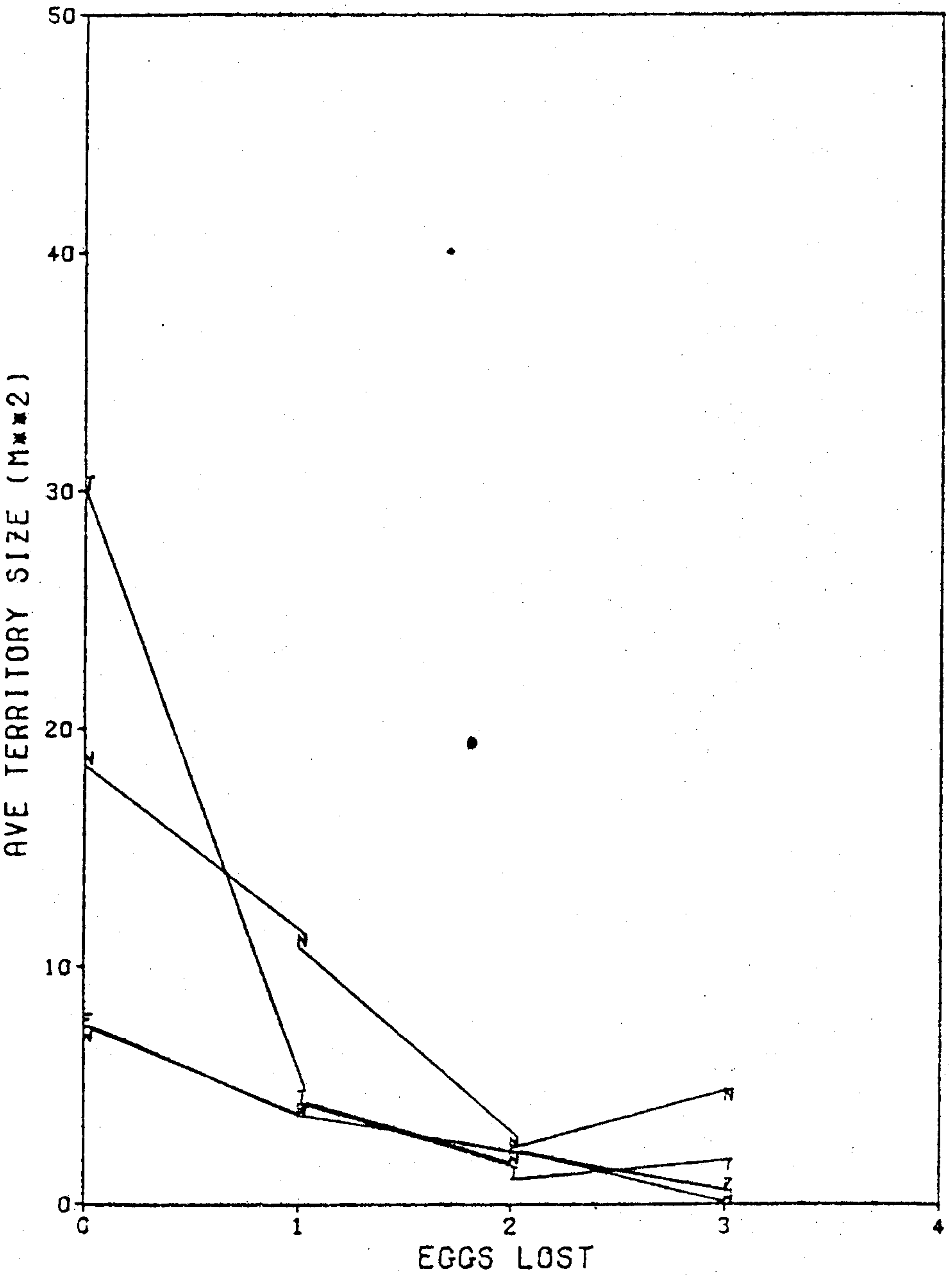

Figure 17. Eggs lost plotted against average territory size, North Marble, 1973.
E = East Colony, W = West Colony, N = North Colony, T = Top Colony.
All colonies show similar trends in eggs lost.

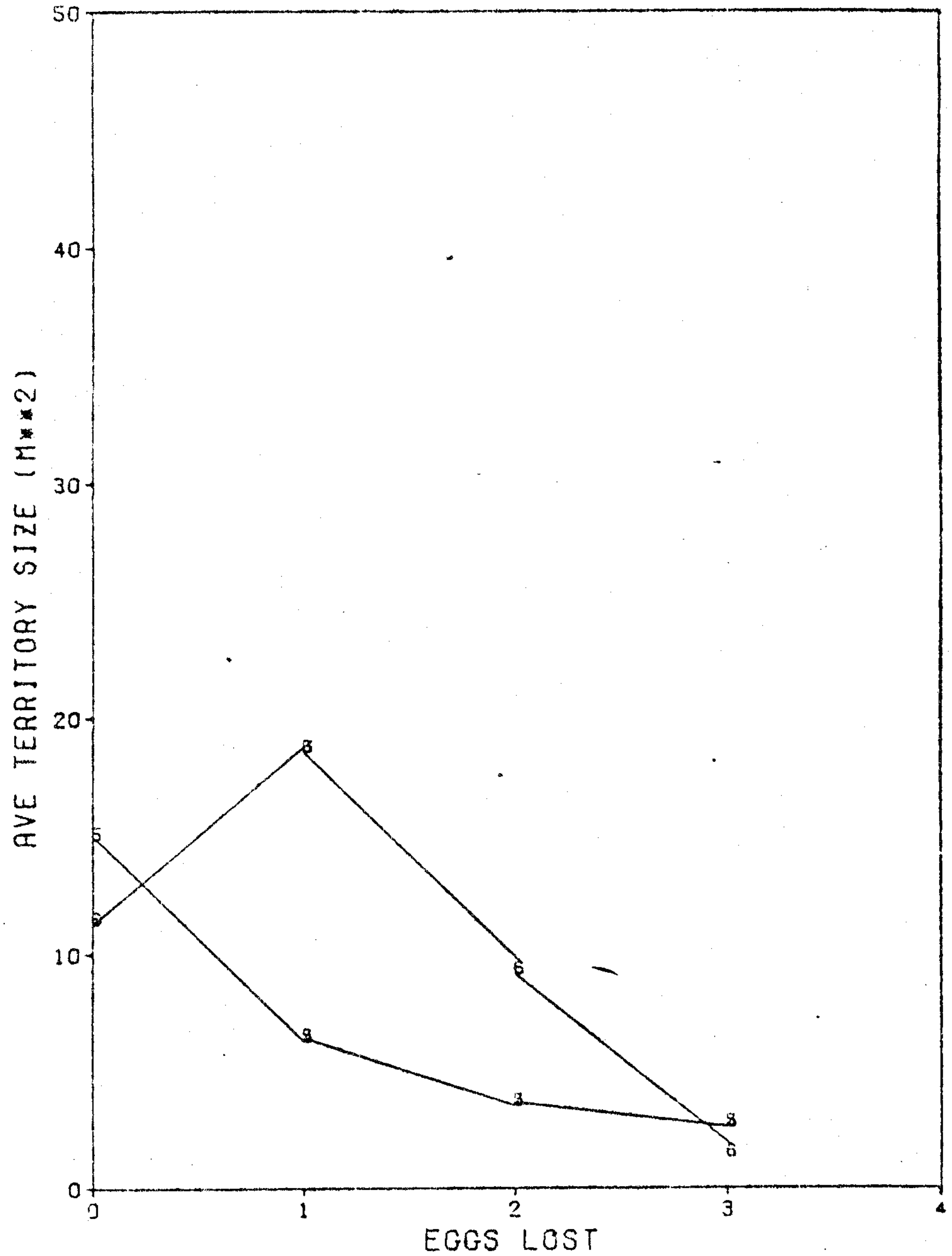

Figure 18. Eggs lost plotted against average territory size Egg Island, 1975 - 1976.
5 = 1975 survey, 6 = 1976 survey.

Gulls with larger territory sizes tended to loose one or two eggs in 1976.
Egg loss in 1975 resembled that of 1972 and 1973 on North Marble.

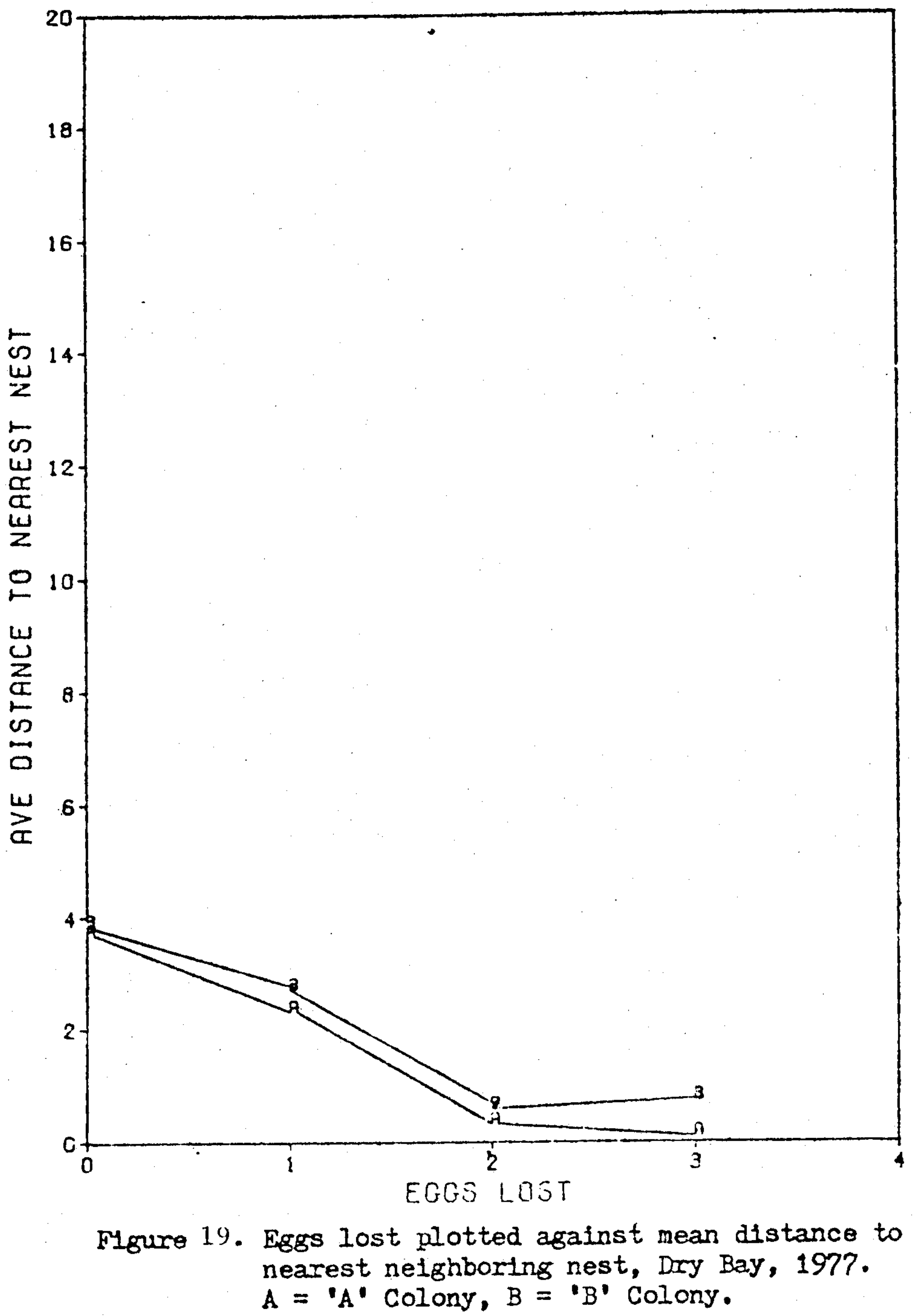

Figure 19. Eggs lost plotted against mean distance to nearest neighboring nest, Dry Bay, 1977. A = 'A' Colony, B = 'B' Colony.

'A' and 'B' Colonies show quite similar tendencies indicating egg loss is little influenced by distance to nearest nest.

Table 3

Numbers of "Lost," "Infertile" and "Pipped" Eggs Which Did Not Hatch in the Study Areas: Egg Island (1975-1976); North Marble (1972-73); Dry Bay and Lake Louise (1977)

Colony & Year	Total Eggs in Study Area	Lost Eggs	Infertile Eggs	Pipped, but did not Hatch
Egg Island (1975)	386	114 (29.5%)	8 (2.0%)	1 (<1%)
Egg Island (1976)	447	104 (23.3%)	9 (2.0%)	1 (<1%)
North Marble (1972)	455	125 (27.5%)	22 (4.8%)	2 (<1%)
North Marble (1973)	566	150 (26.5%)	26 (4.6%)	1 (<1%)
Dry Bay (1977) 'A'	265	10 (3.7%)	8 (3.0%)	2 (<1%)
Dry Bay (1977) 'B'	63	7 (11.1%)	0	0
Lake Louise (1977)	211	N.A.	13 (6.2%)	2 (<1%)

Incubation Period

An incubation period is defined as the time span between the begining of incubation of an egg and the date of hatching. Gulls lay eggs spaced several days apart, but do not begin incubation until the clutch (usually three) is completed. Thus all the eggs in a clutch tend to hatch within a very short time of each other (1-2 days). Not only do eggs within the same clutch tend to hatch within a few days of each other, most of the chicks within a colony tend to hatch within a week of each other, under undisturbed conditions.

Onset of incubation varies by several weeks at an individual colony between years (Fig. 20). The onset of incubation on North Marble ranged from 29 May 1973 to 10 June 1972. The beginning of incubation in colonies at Egg Island and Lake Louise fell within this time range, despite nearly

INCUBATION PERIODS BY COLONY

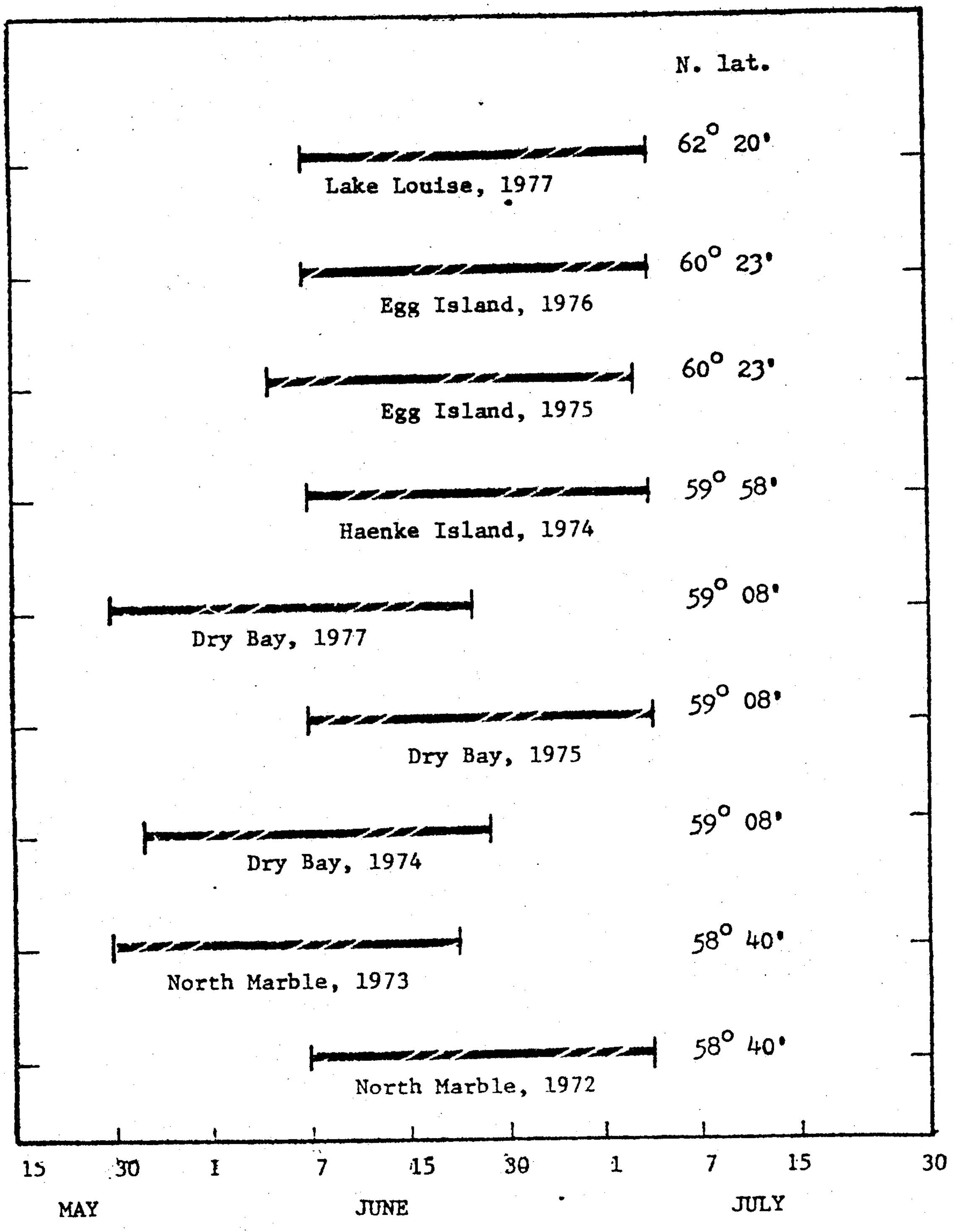

Figure 20

4° change in latitude. This suggests that gulls along this entire stretch of coastline and interior breed at the same time (Fig. 20).

The beginning of incubation was synchronized at North Marble, despite the somewhat larger spread of egg-dates from colony to colony. The abrupt synchrony of chick hatching both years of the North Marble study reflected the synchronized onset of incubation (Fig. 21). Median dates from onset of incubation to hatching established an incubation period of 24 to 27 days on North Marble.

The wider spread of chick ages on Egg Island reflected less synchrony in onset of incubation as well as greater spread of egglaying following egg-collecting by humans (Figs. 20, 23). However, in the study site at Egg Island, 50% of eggs were laid by June 5th, and 50% of eggs hatched by June 30th, demonstrating a median incubation period of 25 days.

At Dry Bay, 50% of eggs were laid by 24 May, and 50% of eggs hatched by 19 June, demonstrating a median incubation period of 26 days. Similar incubation periods have been reported by Tinbergen (1960), Keith (1966), Schreiber (1970), Harpur (1971), and Vermeer (1963) for *argentatus*, *occidentalis* and *glaucescens*.

Chick Hatching

Synchrony is the tendency of a population of colonial birds to reproduce within a short period of time of each other. Synchrony is an adaptative anti-predator strategy.

Chick hatching was quite synchronous both years of the North Marble Island study. In 1972, 70% of the gull chicks hatched between 4 and 9 July; in 1973, 87% of the chicks hatched between 23 and 25 June. Chick hatching in 1973 at North Marble was two weeks earlier than 1972, a result

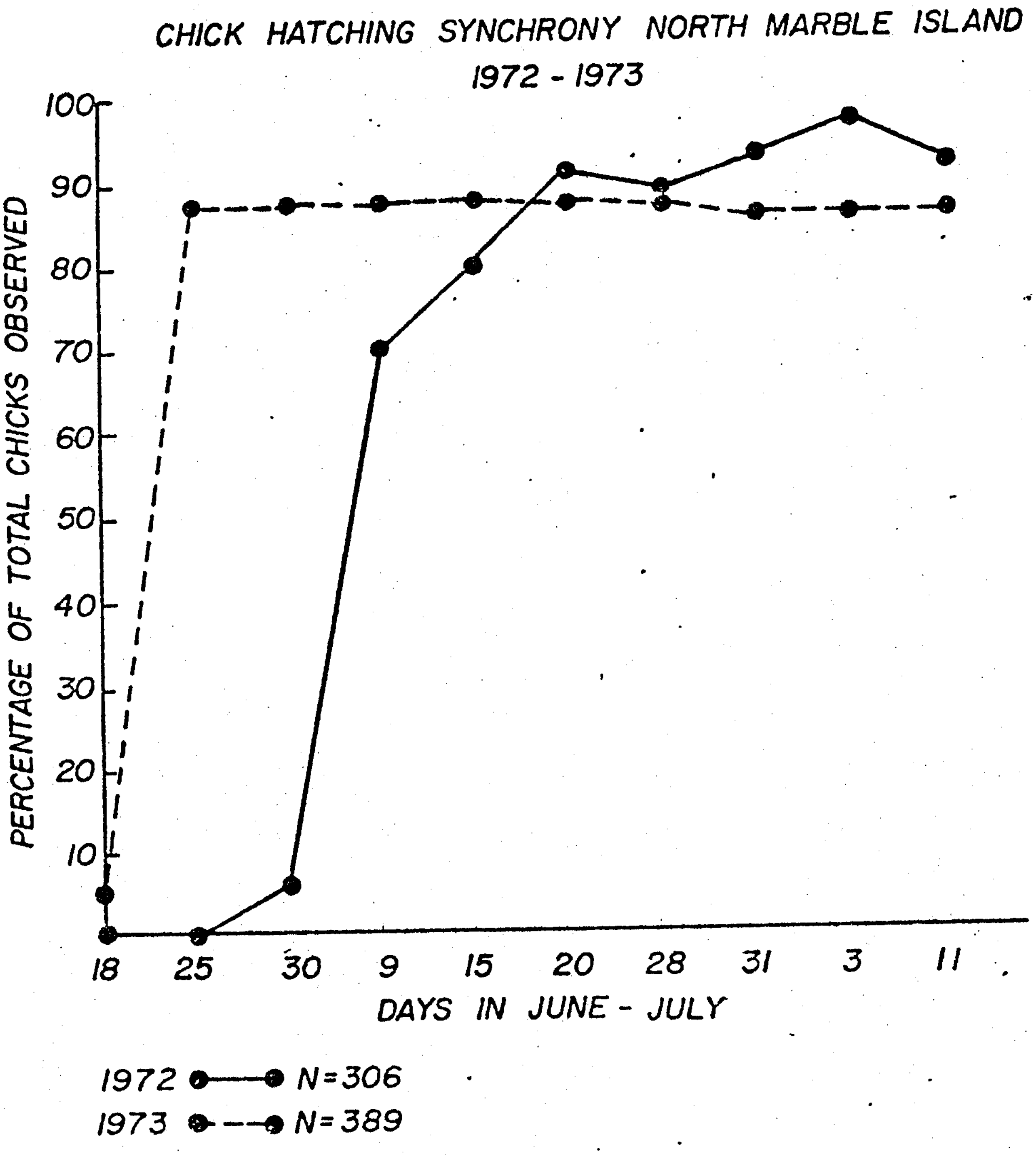
CHICK HATCHING SYNCHRONY NORTH MARBLE ISLAND
1972 - 1973
PERCENTAGE OF TOTAL CHICKS OBSERVED
100
90
80
70
60
50
40
30
20
10
18
25
30
9
15
20
28
31
3
11
DAYS IN JUNE - JULY
1972 ●——● N=306
1973 ●- - -● N=389

Figure 21

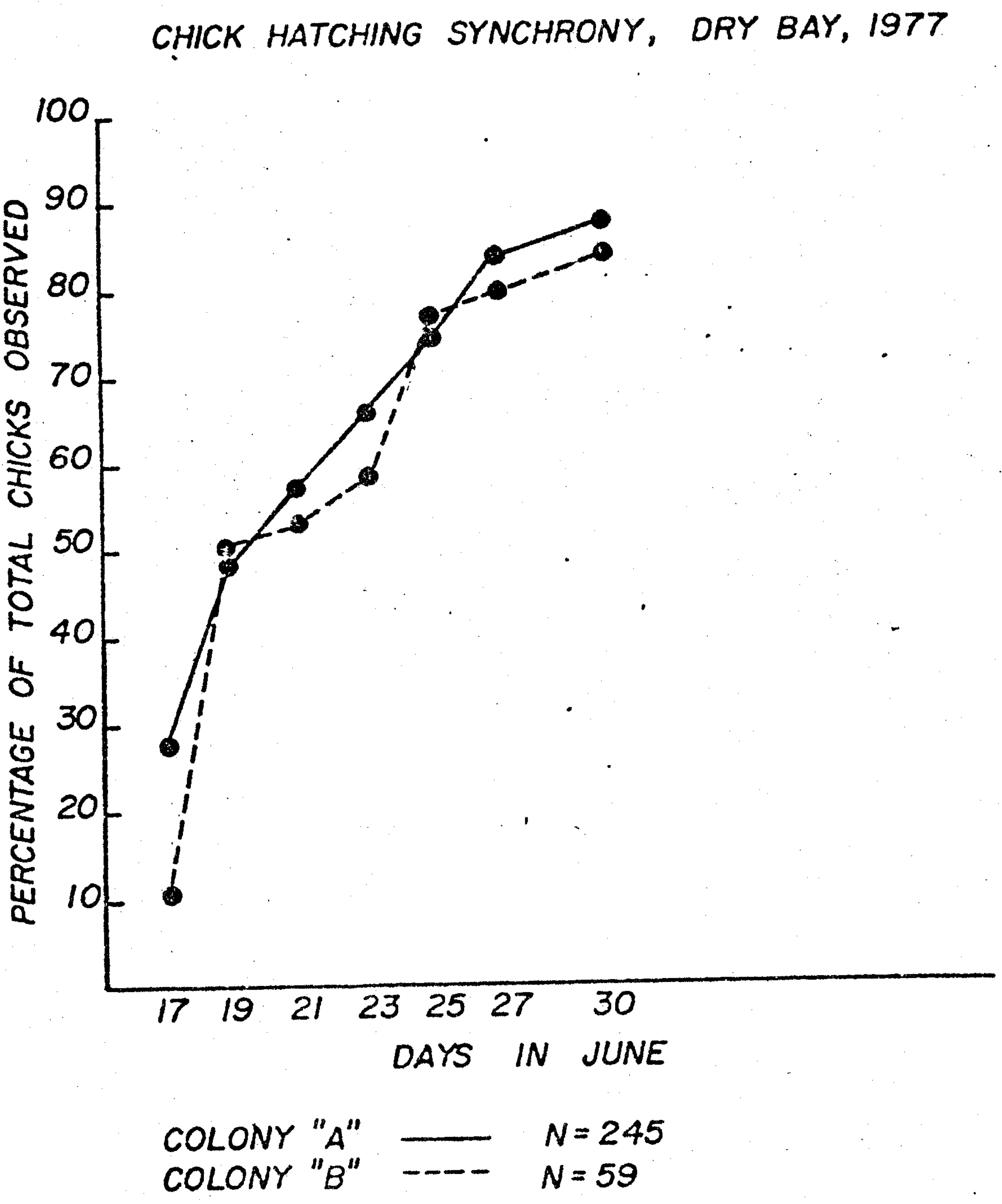
CHICK HATCHING SYNCHRONY, DRY BAY, 1977
PERCENTAGE OF TOTAL CHICKS OBSERVED
100
90
80
70
60
50
40
30
20
10
17
19
21
23
25
27
30
DAYS IN JUNE
COLONY "A" —— N = 245
COLONY "B" ---- N = 59

Figure 22

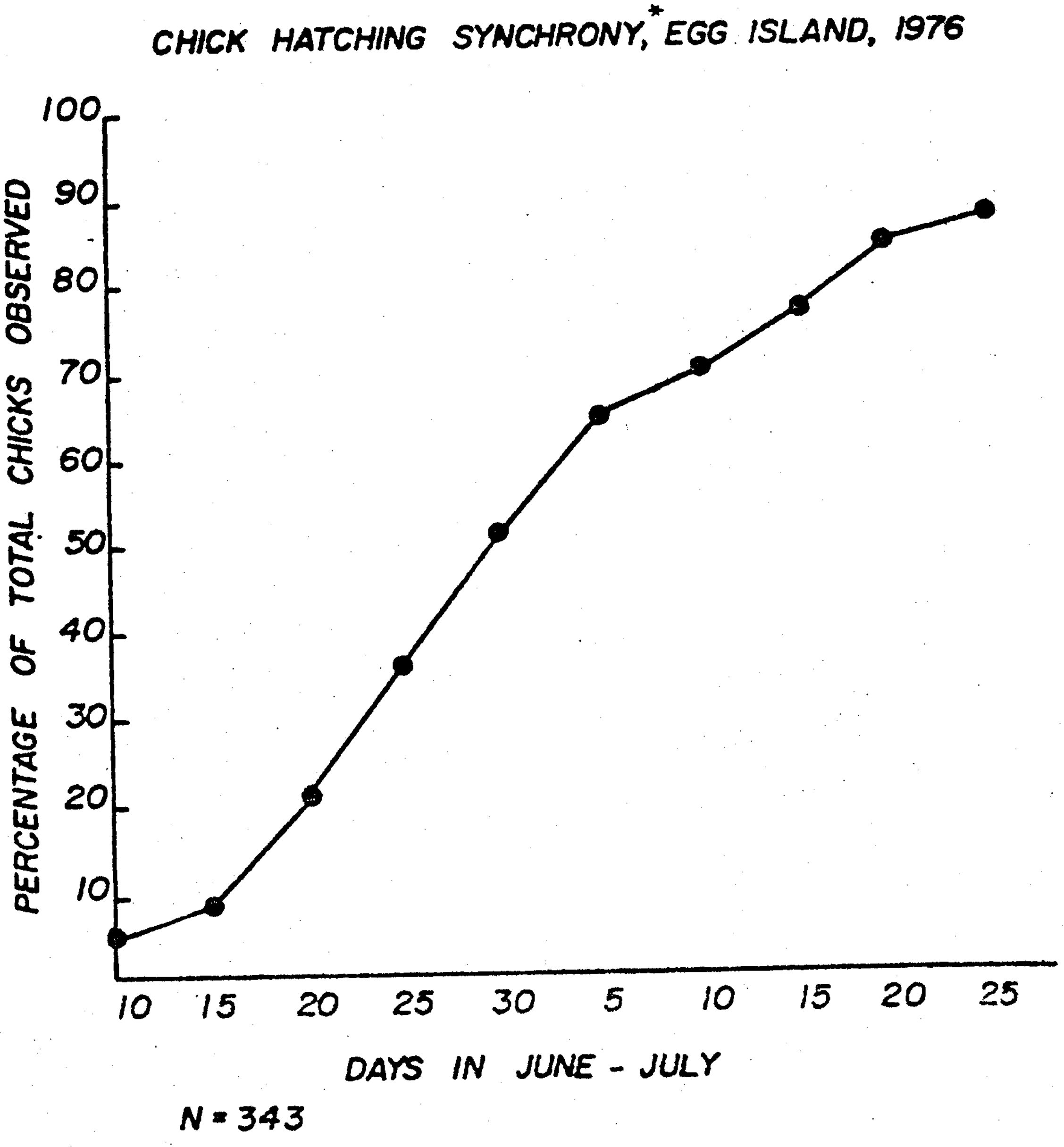

Figure 23

* The slope is nearly directly proportional to time. Therefore synchrony is technically not correct. "Phenology" would be correct. (See text for explanation.)

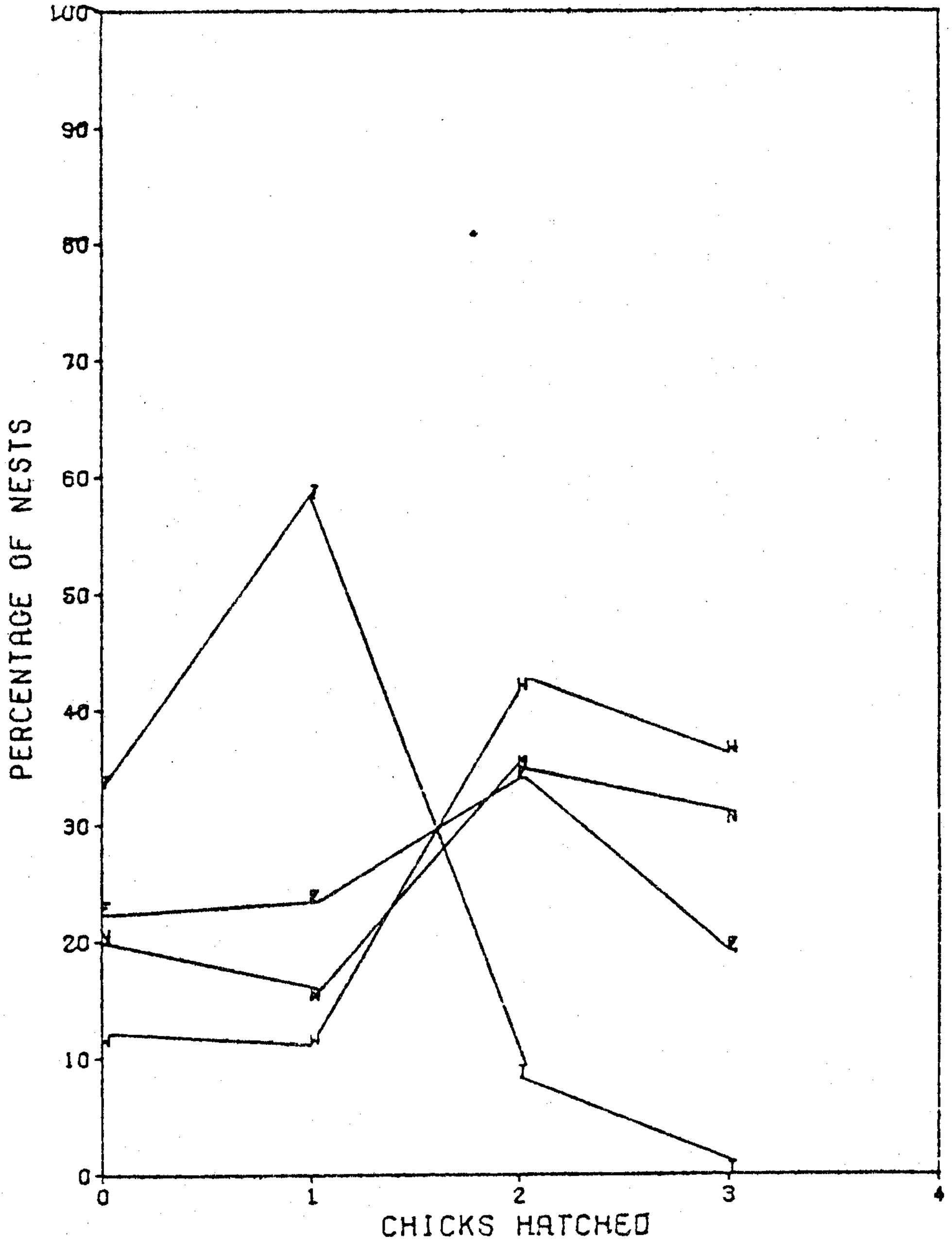

Figure 24. Chicks hatching plotted against percentage of nests, North Marble, 1972.
E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

East, West and North Colonies are quite similar in number of chicks hatching per nest. The Top Colony, due to smaller mean clutch size, produced fewer chicks hatching in proportion.

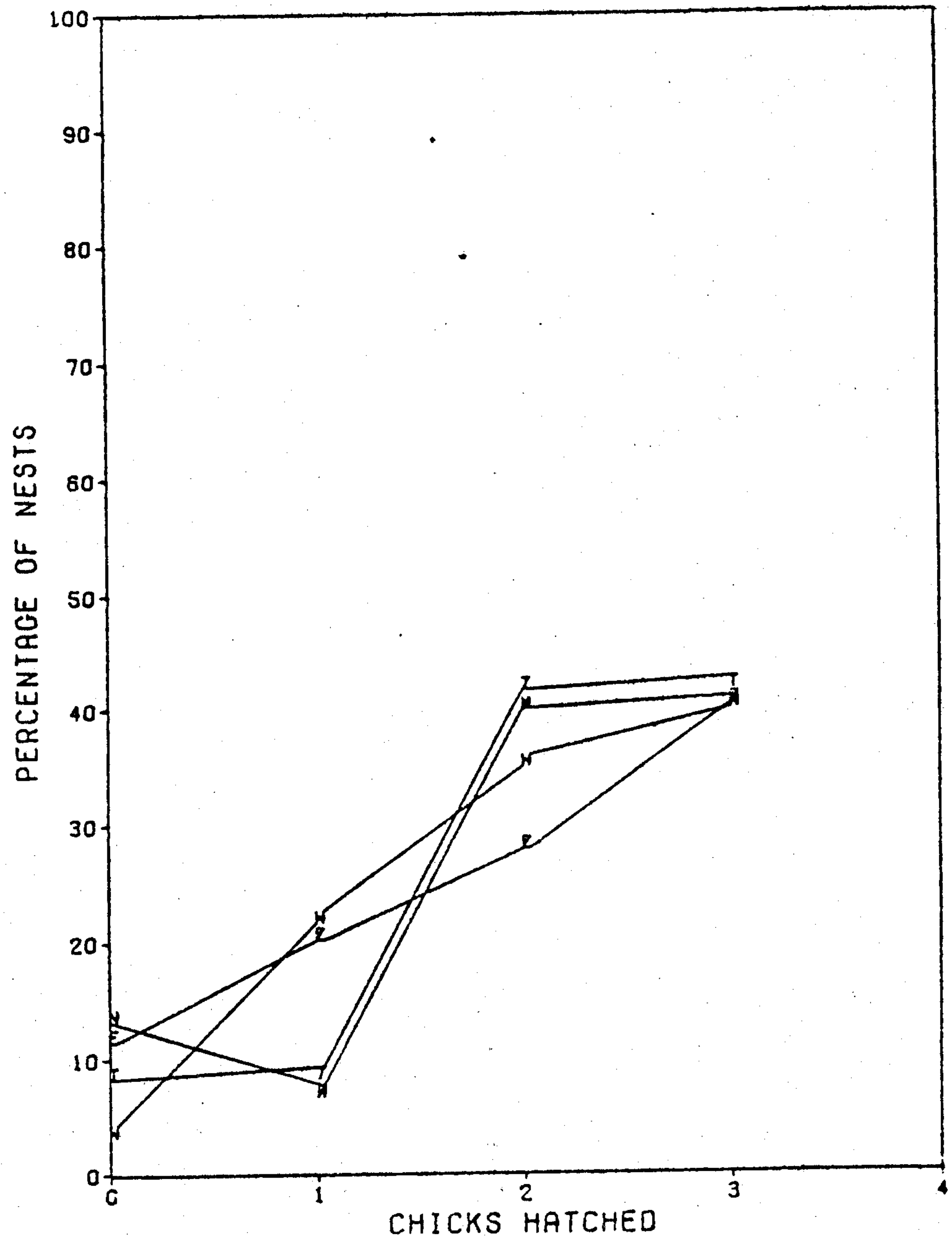

Figure 25 Chicks hatching plotted against percentage of nests, North Marble, 1973.
E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

All colonies show quite similar tendencies in proportion of chicks hatching due to similar mean clutch sizes and rate of predation.

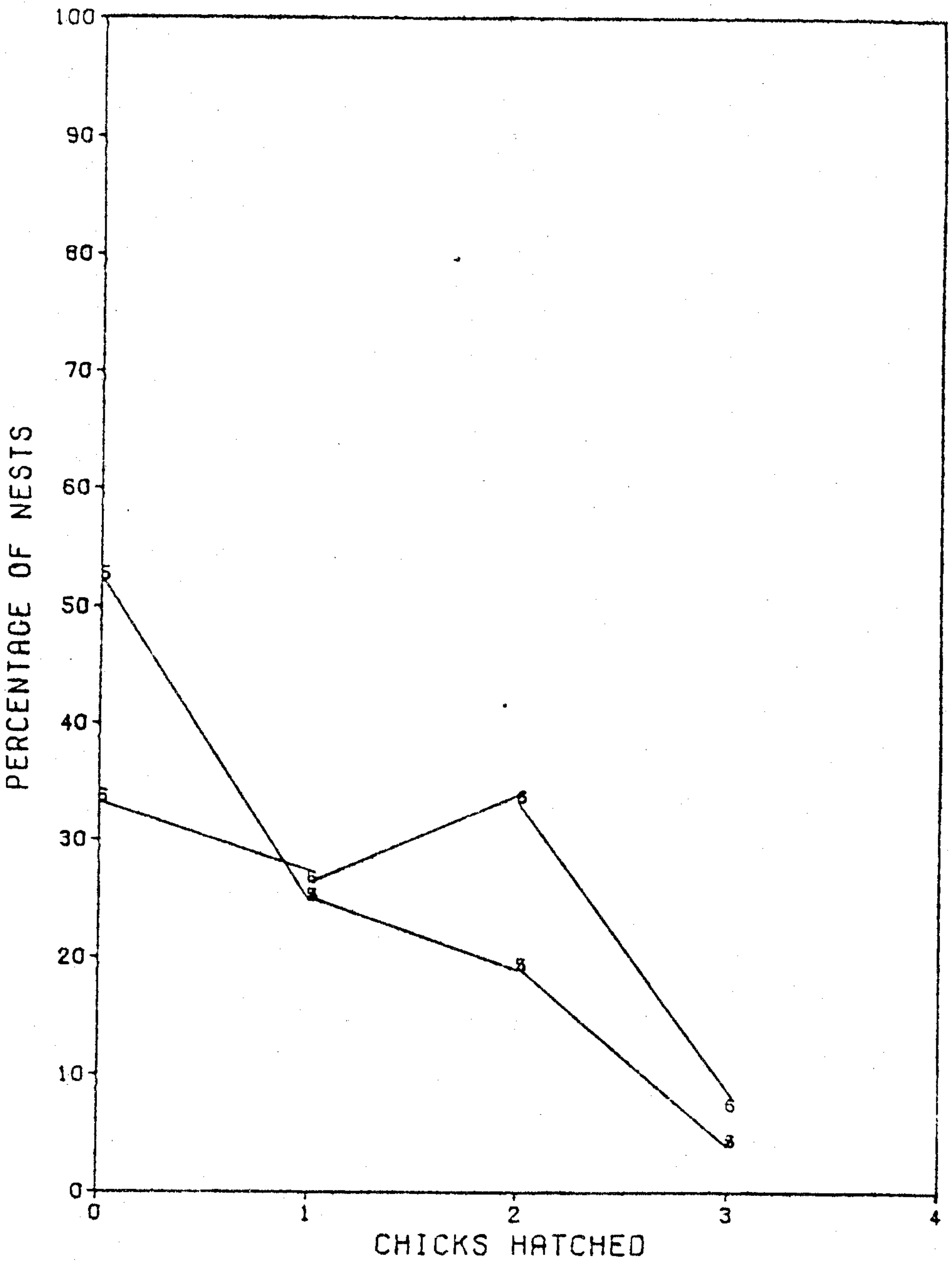

Figure 26. Chicks hatching plotted against percentage of nests, Egg Island, 1975 - 1976. 5 = 1975 survey, 6 = 1976 survey.

Egg Island, due to smaller mean clutch size, shows a reverse tendency in proportion of chicks hatching when compared to North Marble in 1973, but resembles the Top Colony on North Marble in 1972 (Figure 15), although not as extreme.

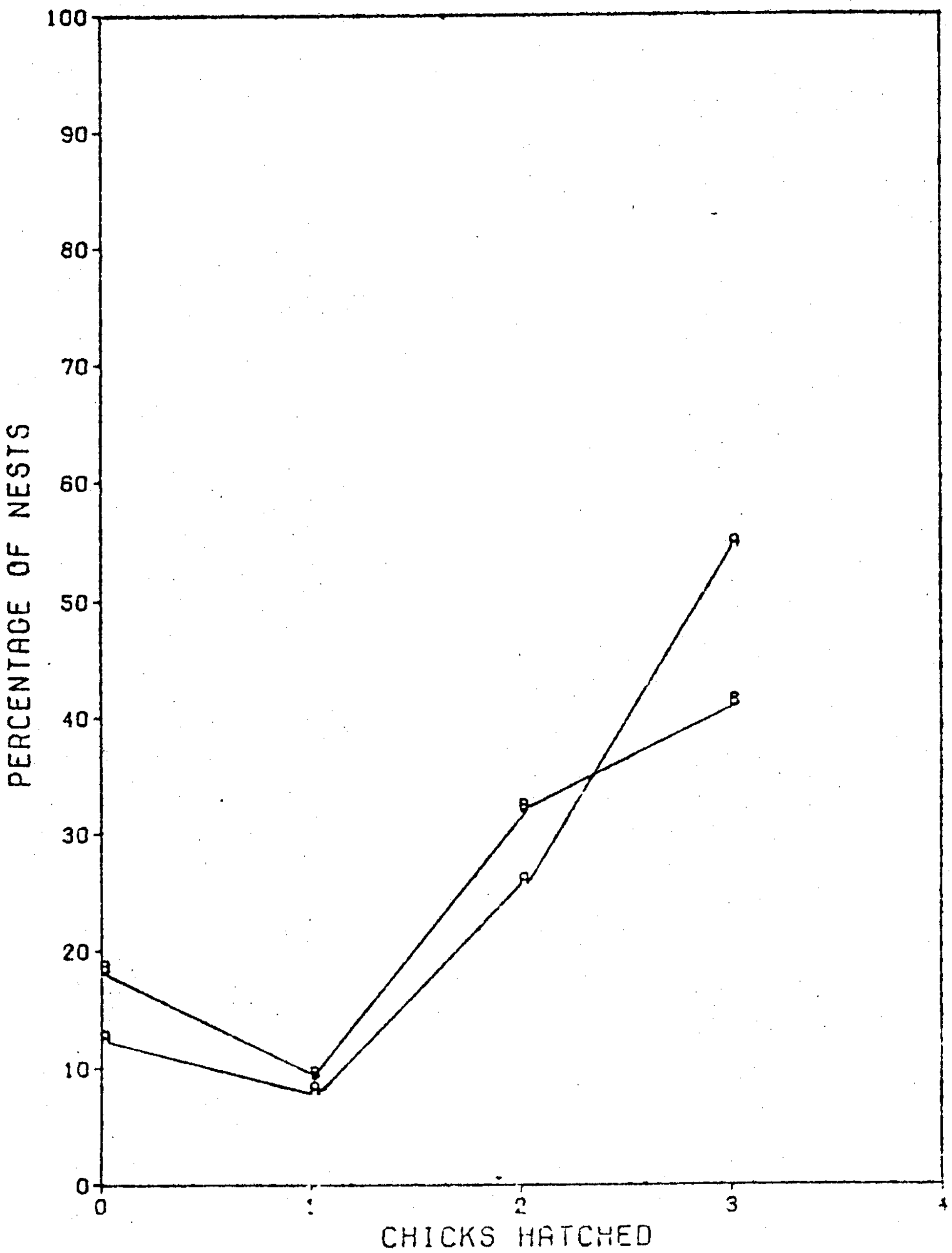

Figure 27. **Chicks hatching plotted against percentage of nests, Dry Bay 1977.**
A = 'A' Colony, B = 'B' Colony.

Dry Bay had the greatest percentage of chicks hatching in this study, due to largest clutch size and lowest rate of egg predation.

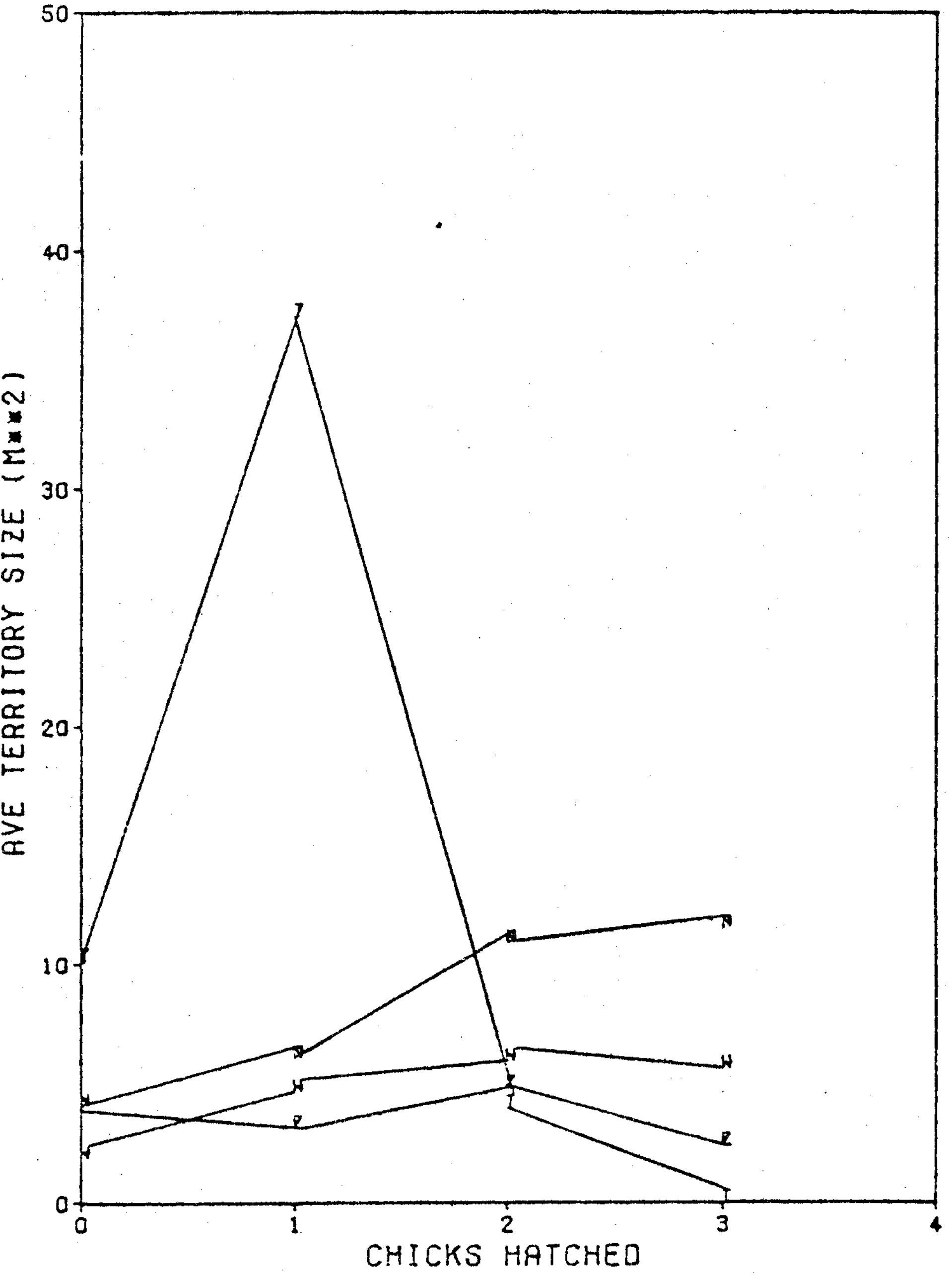

Figure 28. Chicks hatching plotted against average territory size, North Marble, 1972.
E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

East, West and North Colonies are quite similar in number of chicks hatching in relation to average territory size.
Top Colony is significantly different, with large territory size, smaller mean clutch size, and fewer chicks produced.

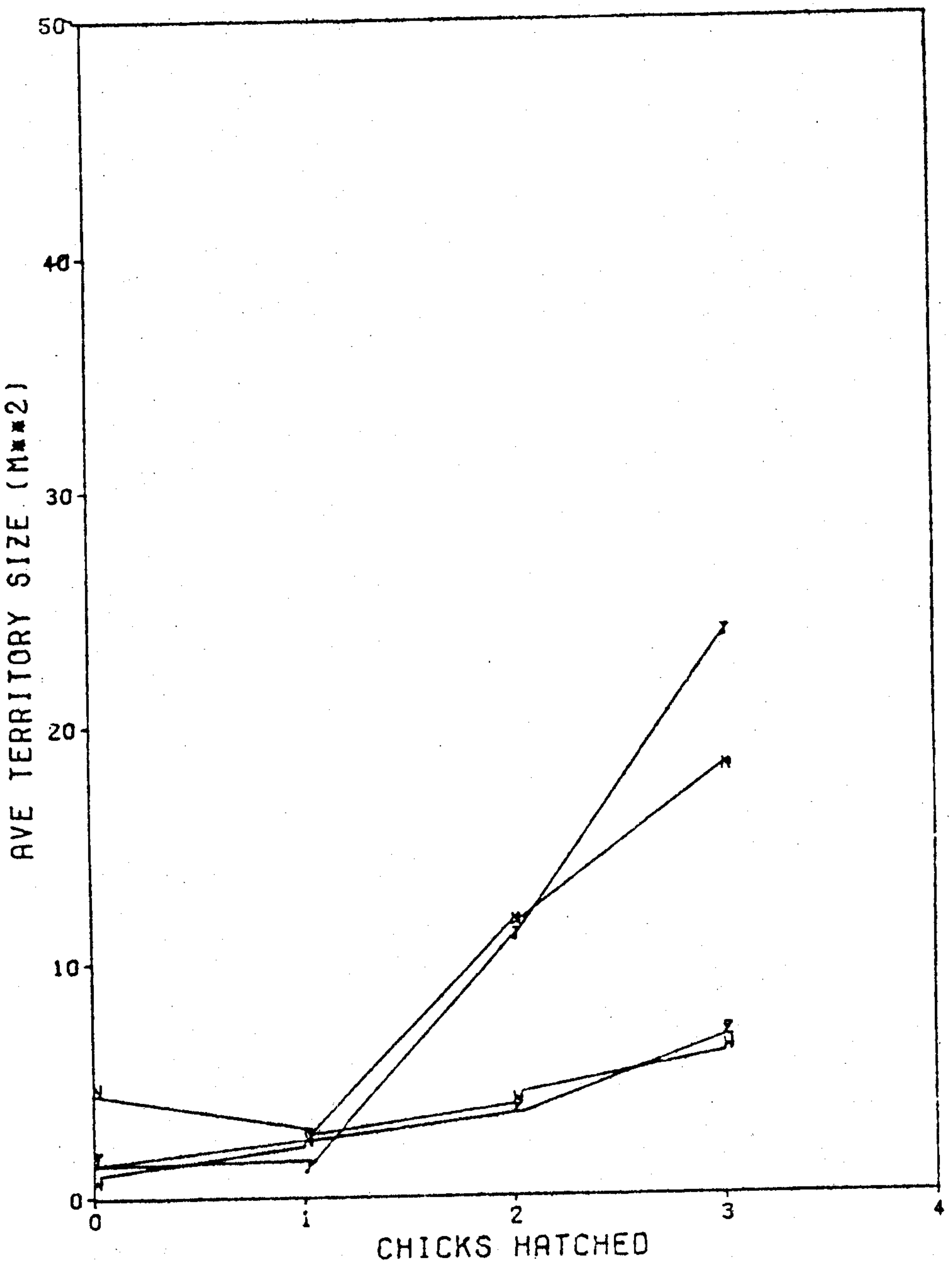

Figure 29. Chicks hatching plotted against average territory size, North Marble, 1973. E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

Top and North Colonies are similar in average territory sizes, as are East and West Colonies, but the two groups are different from each other, probably due to colony sizes. However, all colonies show similar tendencies in number of chicks hatched.

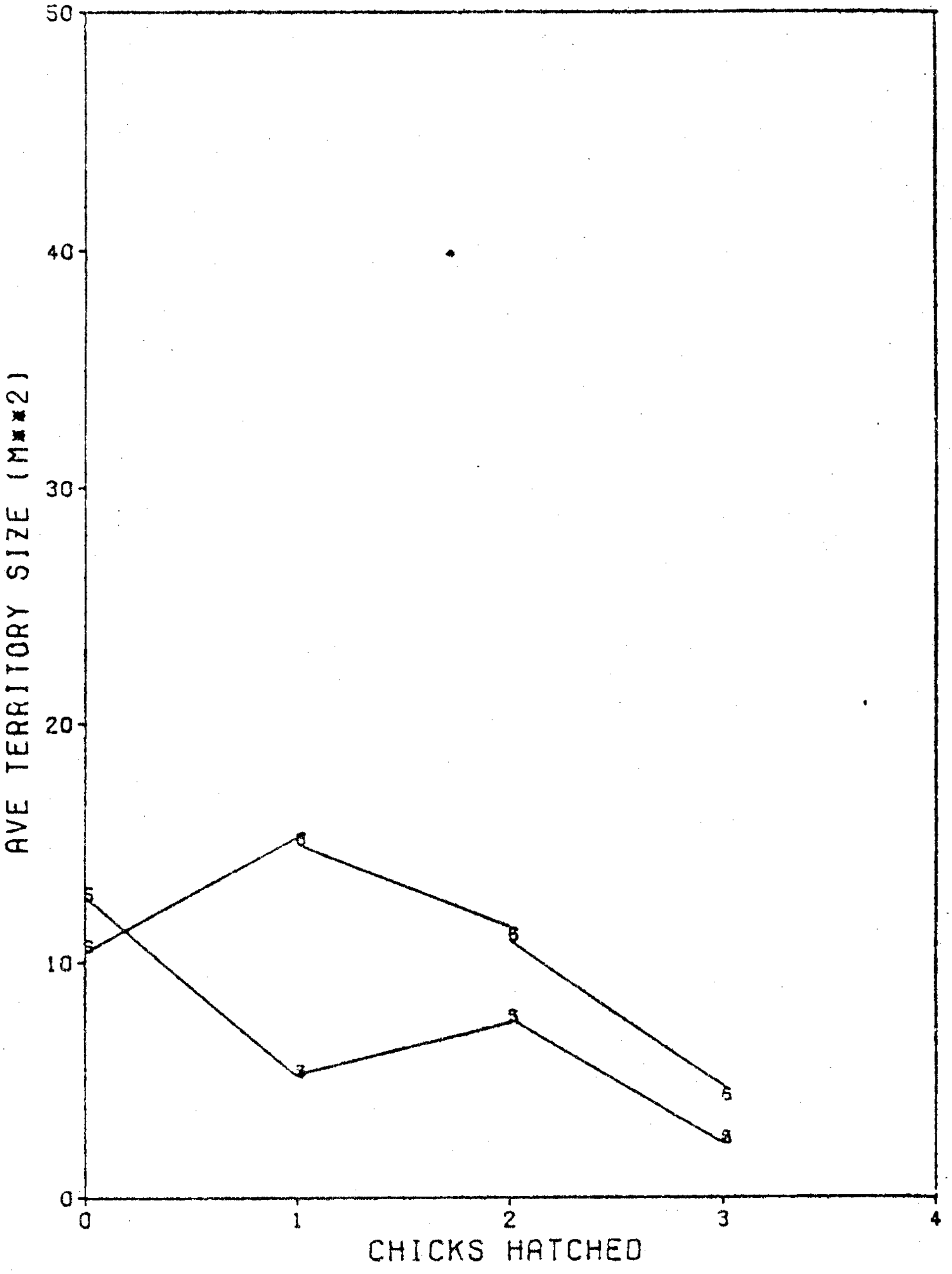

Figure 30. Chicks hatching plotted against average territory size, Egg Island, 1975 - 1976. 5 = 1975 survey, 6 = 1976 survey.

Average territory size on Egg Island in 1976 was larger than in 1975. Both years show a reverse trend from North Marble in 1973 due to smaller mean clutch size.

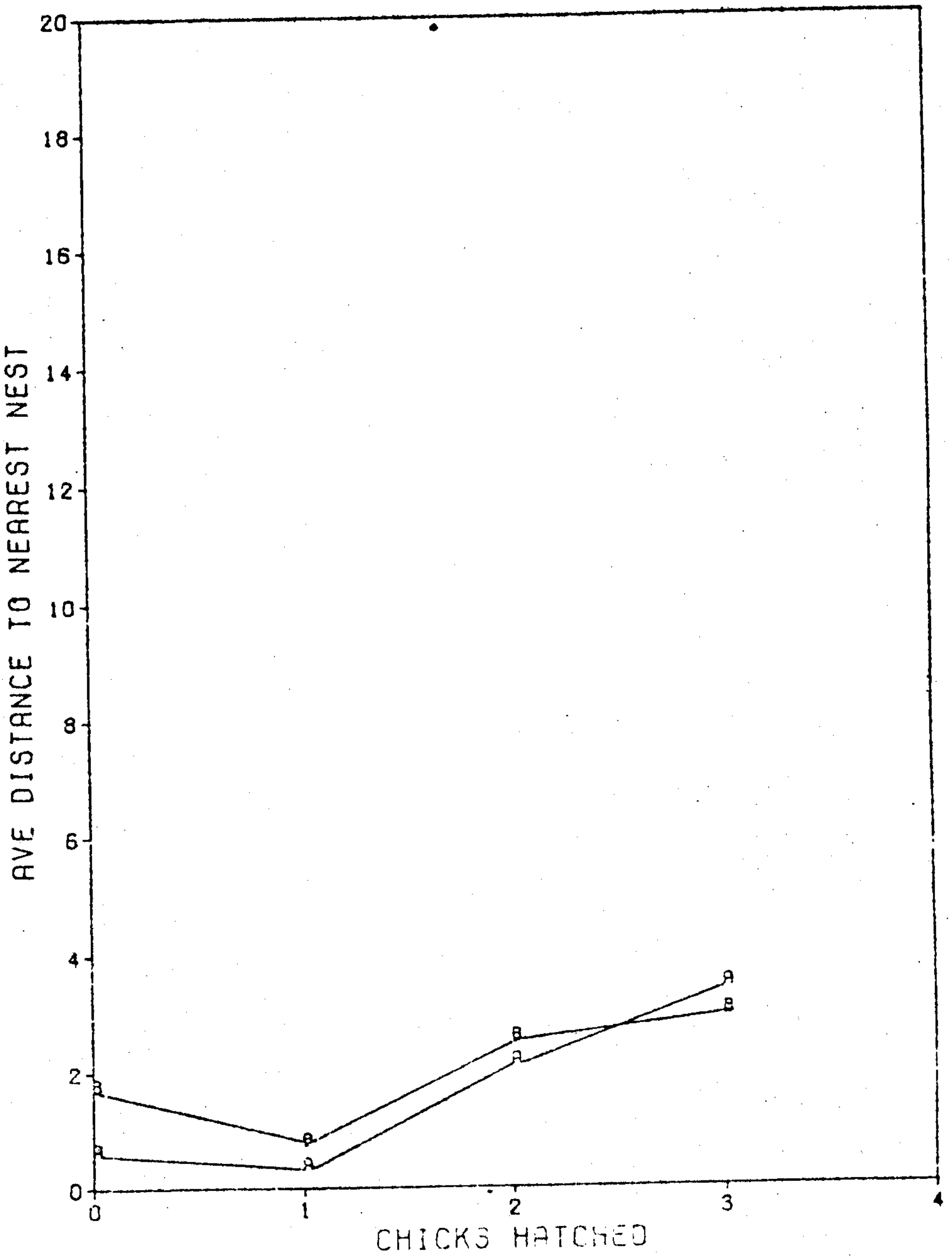

Figure 31. Chicks hatching plotted against mean distance to nearest nest, Dry Bay, 1977. A = 'A' Colony, B = 'B' Colony.

Mean distance to nearest nest influenced number of chicks hatching per nest only slightly.

of a generally earlier breeding season, related to milder weather. Chick hatching was also more synchronous in 1973 (Figs. 20, 21).

Chick hatching was not synchronous at Egg Island in 1976. The increase in chick numbers was nearly directly proportional to time elapsed. Hatching for 50% of the eggs extended over 20 days, in contrast to the two to five day hatching period on North Marble. (Fifty percent of the eggs in the 1976 Egg Island study area were laid in one week.) Re-nesting and clutch replacement following subsistence egging by fishermen in early June was the most likely explanation for this spread of hatching (Figs. 20, 23).

Dry Bay in 1977 was intermediate between Egg Island and North Marble in rate of chicks hatching over time. Chick hatching was more synchronous than egg-laying (Fig. 11, 22) at Dry Bay; 50% of the eggs were laid in an eight-day period in late May, but 50% of the chicks hatched in a three-day period between 17 and 21 June. This suggests a more synchronized onset of incubation than synchronized egg-laying.

North Marble and Dry Bay colonies contained roughly the same number of pairs (about 500) and both were relatively undisturbed areas. Egg Island was a huge colony with disturbance. There was a tendency for groups of birds to breed at the same time, but the synchrony was disrupted by human intervention (egging).

Chick Mortality

Chick mortality in southern Alaskan gull colonies was divided into two classifications: chicks which were observed dead, and chicks which disappeared, were not counted as fledged, and which were presumed dead.

Observed chick mortality in southern Alaskan colonies was low, ranging from 3 to 12% (Table 4). North Marble Island had the highest rate of hatching failure, which was due to egg predation, but the rates of observed chick mortality and disappearance were the lowest of colonies examined, except for Lake Louise, where we have limited data due to restricted time available for investigation (Table 3, Part I).

Chicks which disappeared accounted for a high percentage of the chick loss at both Egg Island and Dry Bay. The figures ranged from 26% to 49% (Table 14). Egg Island, however, had the highest combined egg and chick mortality of coastal colonies studied (Table 5). High egg and chick mortality, added to low clutch size, meant Egg Island had the lowest total reproductive success (in chicks fledged per nest) of the three major coastal colonies examined. Total chick mortality on Egg Island (mean of both seasons) was 38%. The Egg Island situation represented disturbed conditions, with access by boatmen, picnickers, and dogs, which may have accounted for the large number of chicks which disappeared.

Hatching successes at Egg Island and North Marble were within 8% of each other (Table 4). Dry Bay had a much higher rate of hatching, due to a low rate of egg loss, and larger clutch size. Thus Dry Bay had more chicks hatching in proportion to other colonies (Table 4). However, chick disappearance was the main factor influencing chick mortality at Dry Bay in 1977 (Table 4).

The few chicks found dead on the sparsely vegetated gravel bars at Dry Bay in 1977 showed injury due to attacks by adult gulls defending territory. We believe eagle predation (observed on an hourly basis in late June and July) was the main reason for chick disappearance, and thus was the major factor influencing reproductive success in the gullery at Dry Bay. When the

Table 4

Percent Chick Mortality, Egg Island 1975-76; North Marble Island 1972-73; Dry Bay, 1977

Study Area	% Hatching	% Observed Mortality	% Disappeared	Fledged as % hatched
Egg Island 1975 (153 nests)	69	12	26	62
Egg Island 1976 (186 nests)	77	8	31	61
North Marble 1972 (162 nests)	67	5	2	93
North Marble 1973 (191 nests)	69	8	4	88
Dry Bay "A" 1977 (90 nests)	92	6.5	39*	54
Dry Bay "B" 1977 (22 nests)	93	3	49*	47.5

* heavy eagle predation noted.

Table 5

Hatching Success, Mortality, Reproductive Success Egg Island, 1975-76; North Marble Island, 1972-73; Dry Bay, 1977; Lake Louise 1977

Colony	Hatching Success (%)	Egg and Chick Combined Mortality (%)	Total Reprod. Success (%)
Egg Island (153-186 nests)	73	65	44
Dry Bay (22-90 nests)	93	51	49
North Marble (161-192 nests)	68	34	61
Lake Louise (77 nests)	N.A.	N.A.	35

low rate of egg loss, and the high rate of chick loss were combined, Dry Bay had an intermediate rate of mortality compared to other coastal colonies. Total reproductive success at Dry Bay was better than Egg Island, but less than North Marble (Table 5).

Fledging Success

We determined the median length of the fledging period to be 40-45 days on North Marble, similar to Dry Bay, Egg Island, and Lake Louise. Other investigators have reported similar fledging period for argentatus in Michigan (Keith, 1966), occidentalis in California (Schreiber, 1970; Harpur, 1971) and glaucescens in British Columbia (Vermeer, 1963).

At the end of the fledging period at each major colony in this study, we made counts to determine fledging success. Fledging success, while a difficult measurement (Keith, 1966; Schreiber, pers. comm.), is crucial in understanding the reproductive biology of these gulls.

When the number of chicks fledged in 1972 at North Marble was plotted against percentage of nests for four colonies, the East, West, and North Colonies formed a pattern (Fig. 32). The Top Colony was aberrant, with larger territory size (Table 2, Fig. 5), fewer chicks hatching Fig. 24), and fewer chicks fledging (Fig. 32). Territory size was not directly related to number of chicks fledging in the other colonies, since they were all within the same range (Fig. 32).

The situation on North Marble in 1973 was different. The East, West, and Top Colonies formed a pattern.. Productivity was greater in the Top Colony; more chicks fledged. The increase in productivity was correlated with smaller internest distances, larger clutch sizes, and fewer eggs and chicks lost (Figs. 6, 13, 17, 33). The North Colony in 1973 exhibited the unusual, possibly artifactual, pattern. Disturbance associated with boat mooring may have caused nearly fledged chicks to emigrate earlier from the North Colony and not be counted as fledged.

At Dry Bay in 1977, both 'A' and 'B' Colonies fledged similar percentages of one chick per nest, but 'A' Colony had a greater reproductive output of two and three chicks per nest, which accounted for the better fledging success in Colony 'A' (Fig. 35). Mean distance to nearest nest showed little direct relationship to chicks fledging at Dry Bay in 1977 (Fig. 39).

Reproductive success (in chicks fledged per nest) was lower at Egg Island, compared to North Marble or Dry Bay, and was slightly higher than Lake Louise (Table 2). Egg Island exhibited a pattern similar to North Marble in 1972 when number of chicks fledged was plotted against percentage of nests (Fig. 34). On Egg Island, mean territory size was slightly, but not significantly, larger in 1976; productivity was also slightly, but not significantly, better than 1975. When territory size at Egg Island was plotted against number of chicks fledging per nest, the relationship was virtually the same for both study years (1975-76). Most nests fledged one chick (Fig. 38).

Summary of Fledging Rates

The fledging rate of 1.03 - 1.12 glaucescens chicks per nest on Egg Island is normal compared to other gull species (Table 6) but lower compared to a partially mixed argentatus - glaucescens colony at North Marble in post-glacial surroundings (1.77), due to the abundant natural food supply in the "unfilled" niche at Glacier Bay. The fledging rate of 0.95 argentatus chicks per nest at Lake Louise is sufficient to maintain a stable population, but also much lower than the highly mixed argentatus x

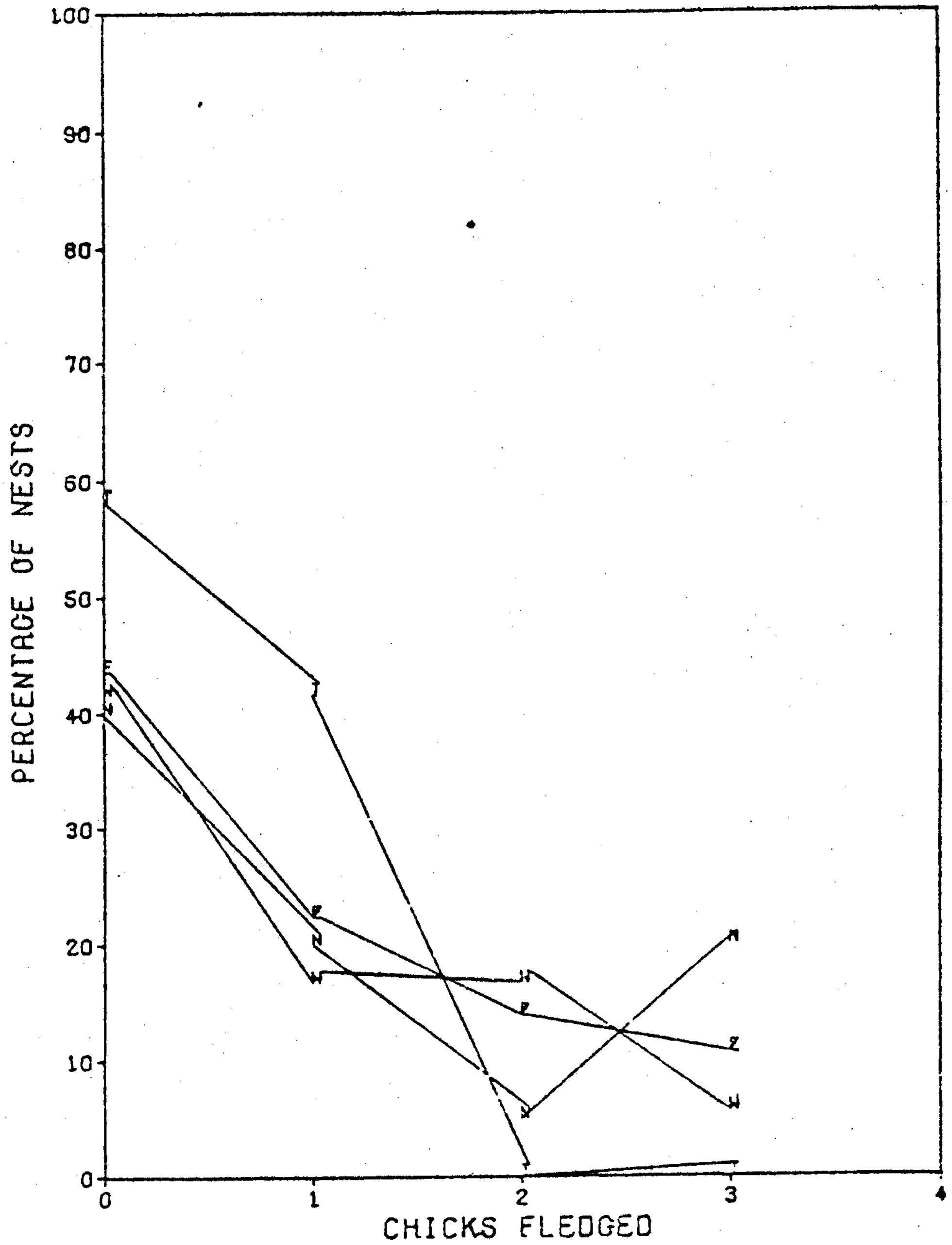

Figure 32. Chicks fledging plotted against percentage of nests, North Marble, 1972.
E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

Once again the East, West and North Colonies form a similar pattern and the Top Colony is aberrant, with large territory sizes, smaller clutches, fewer chicks hatching, greater chick loss, and fewer chicks fledging.

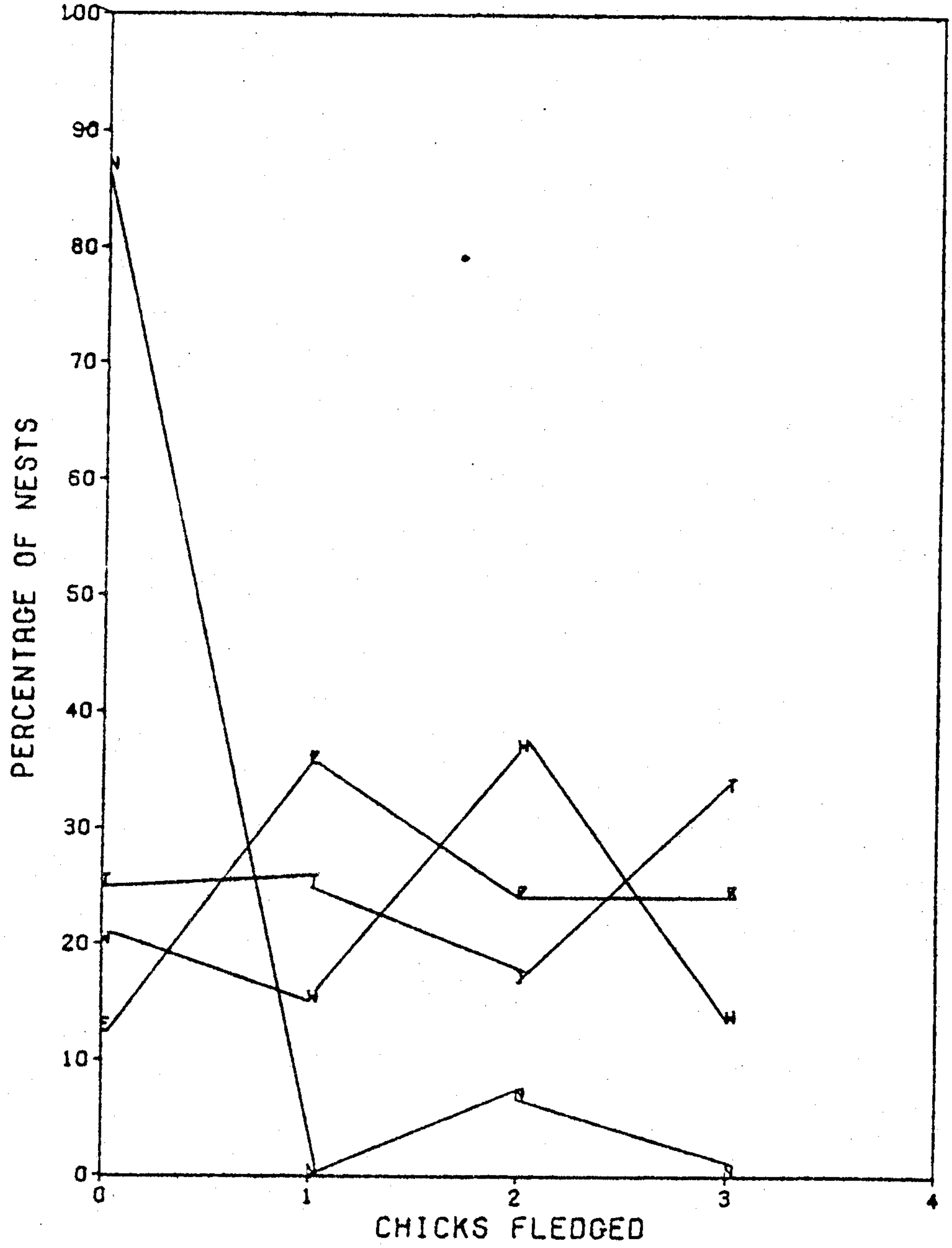

Figure 33. Chicks fledging plotted against percentage of nests, North Marble, 1973.
E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

The North Colony here presents an exception to the usual trend. The East, West and Top Colonies closely fluctuate around a mean, while the North Colony breaks the pattern, with many fewer chicks apparently fledged. This may be due to disturbance due to boat mooring near the colony, causing chicks to emigrate early.

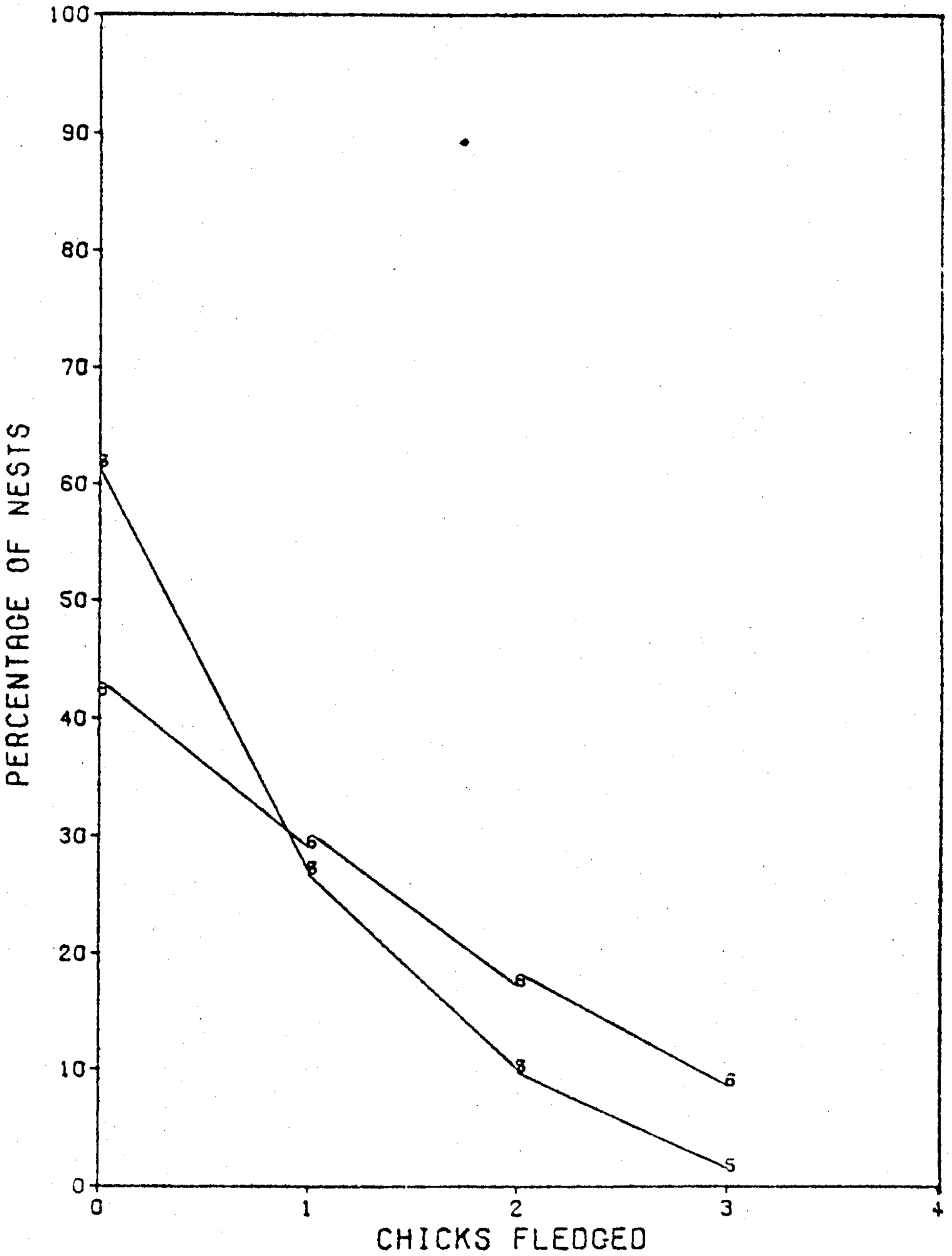

Figure 34. Chicks fledging plotted against percentage of nests, Egg Island, 1975 - 1976. 5 = 1975 survey, 6 = 1976 survey.

Egg Island gulls produce fewer chicks than those on North Marble, in proportion, but Egg Island resembles North Marble in 1972 in chicks fledged. The productivity on Egg Island is expected to increase as the proportion of experienced female breeders expands, given continued access to artificial food from human sources.

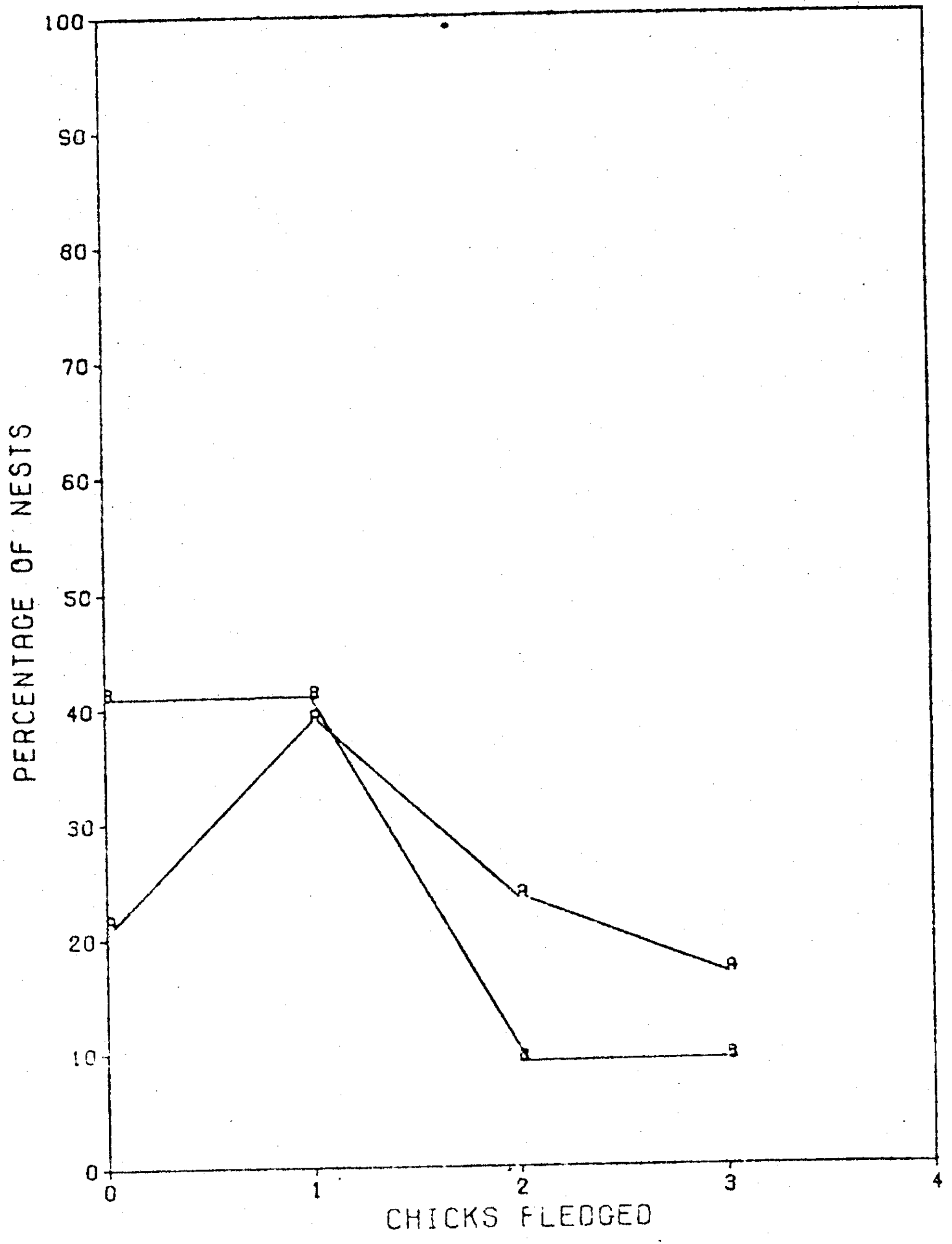

Figure 35. Chicks fledging plotted against percentage of nests, Dry Bay, 1977.
A = 'A' Colony, B = 'B' Colony.

Both 'A' and 'B' Colonies fledged similar percentages of one chick per nest, but 'A' colony fledged more two and three chicks per nest.

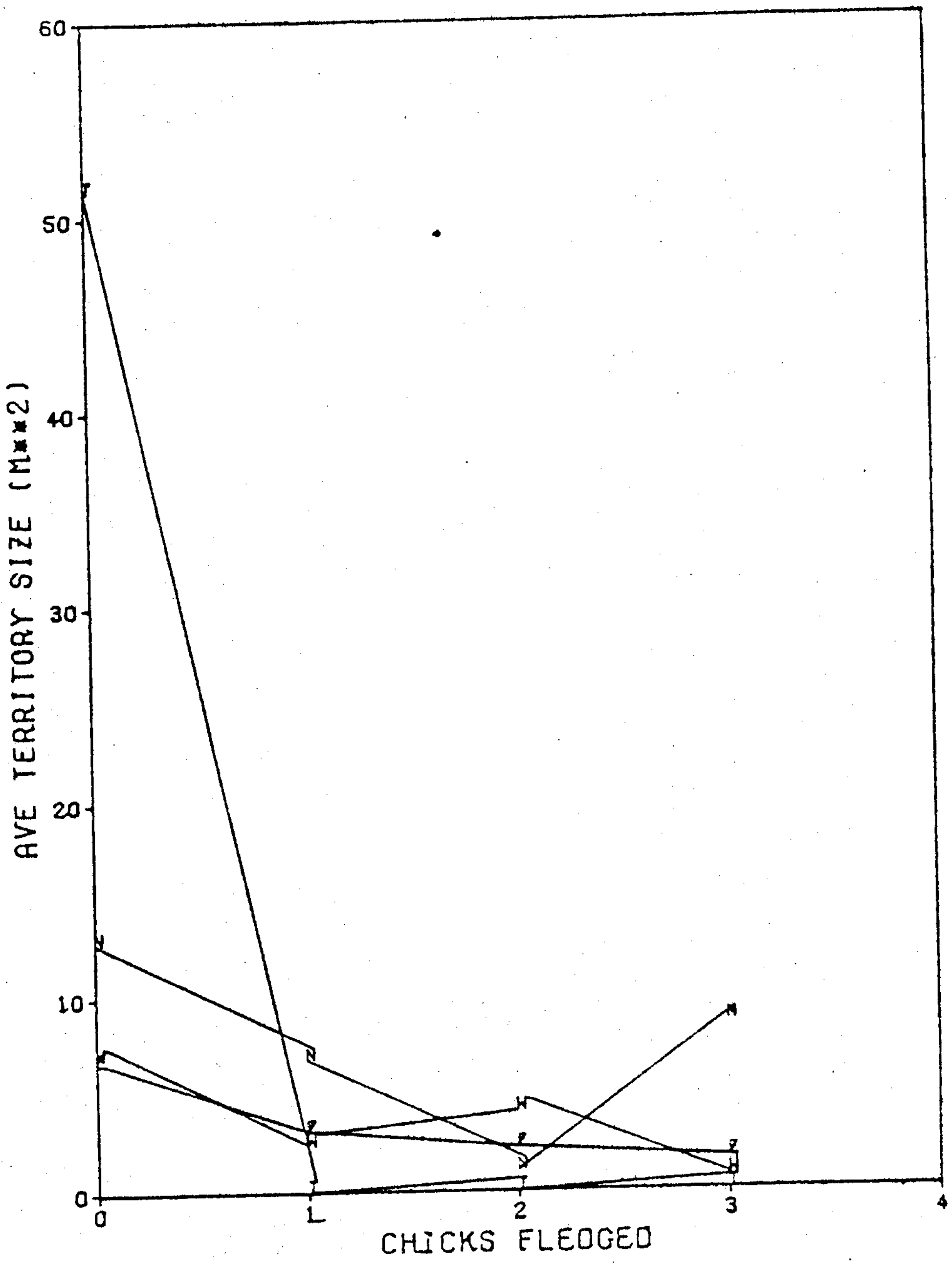

Figure 36. Chicks fledging plotted against average territory size, North Marble, 1972. E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

Gulls with large territory sizes and small clutch sizes in the Top Colony fledged no chicks. Only a few chicks survived from this colony this season. Territory size played only a moderate influence in chicks fledging in the other colonies, since they were all within the same general range.

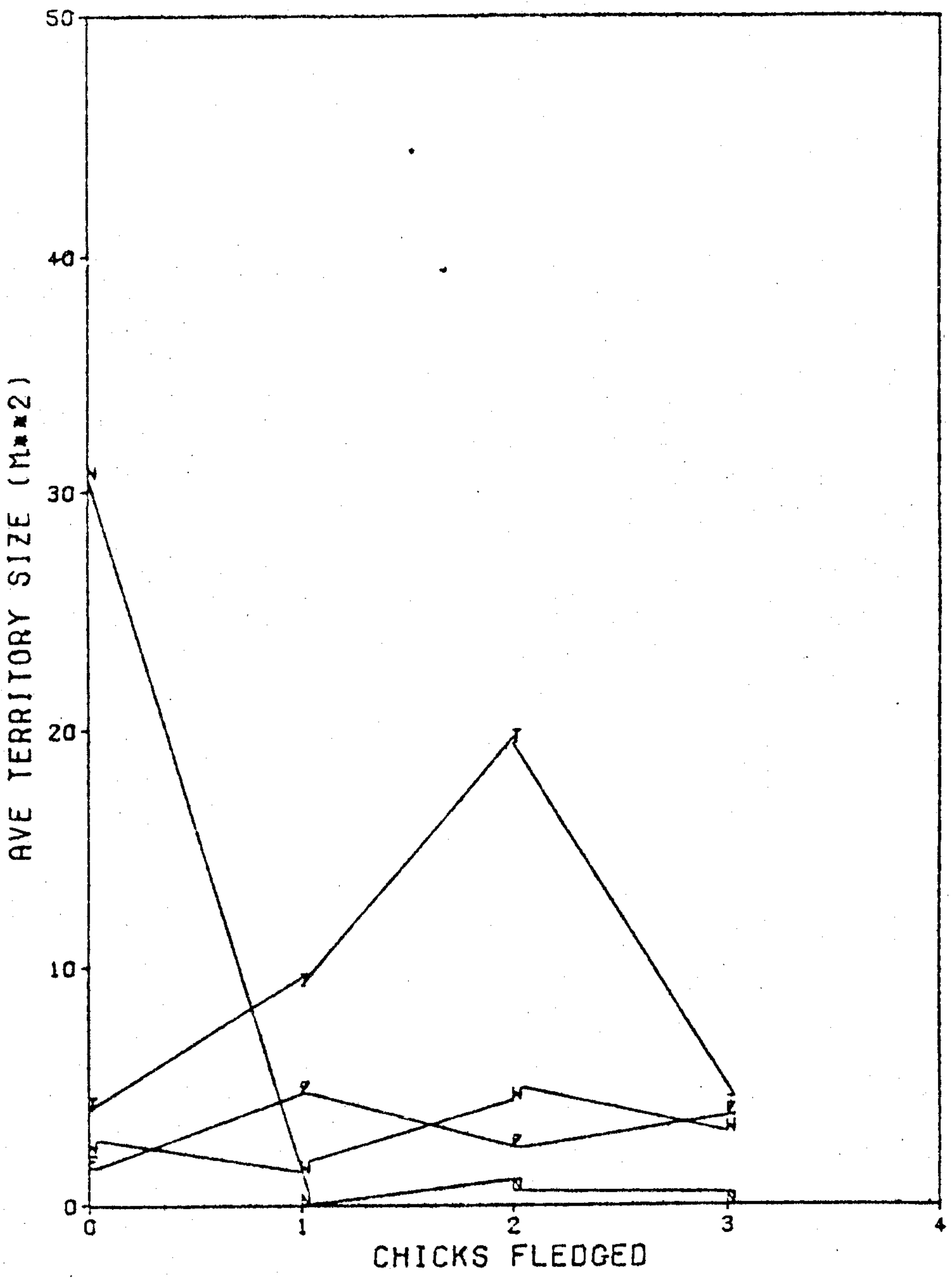

Figure 37. Chicks fledging plotted against average territory size, North Marble, 1973. E = East Colony, W = West Colony, N = North Colony, T = Top Colony.

Productivity was much greater in the Top Colony in 1973, with smaller average territory size, compared to 1972. The North Colony exhibits the unusual trend here, probably due to disturbance.

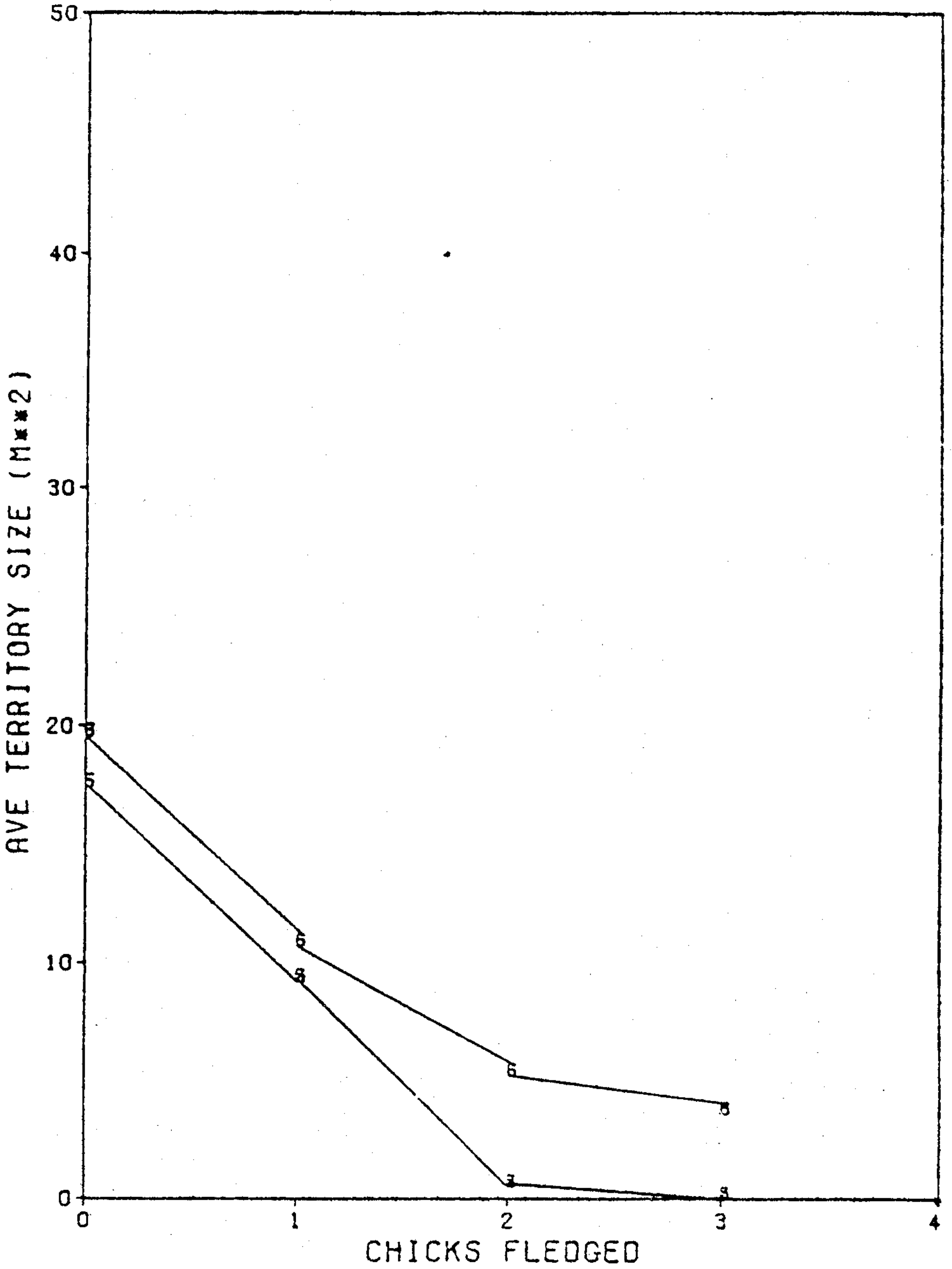

Figure 38. Chicks fledging plotted against average territory size, Egg Island, 1975 - 1976. 5 = 1975, 6 = 1976.

Territory size was slightly larger on the average in 1976, but productivity was also slightly better. However, both years the survey area shows a similar tendency, fledging mostly one chick per territory. Note larger territory size on Egg Island compared to North Marble (Figures 24, 25).

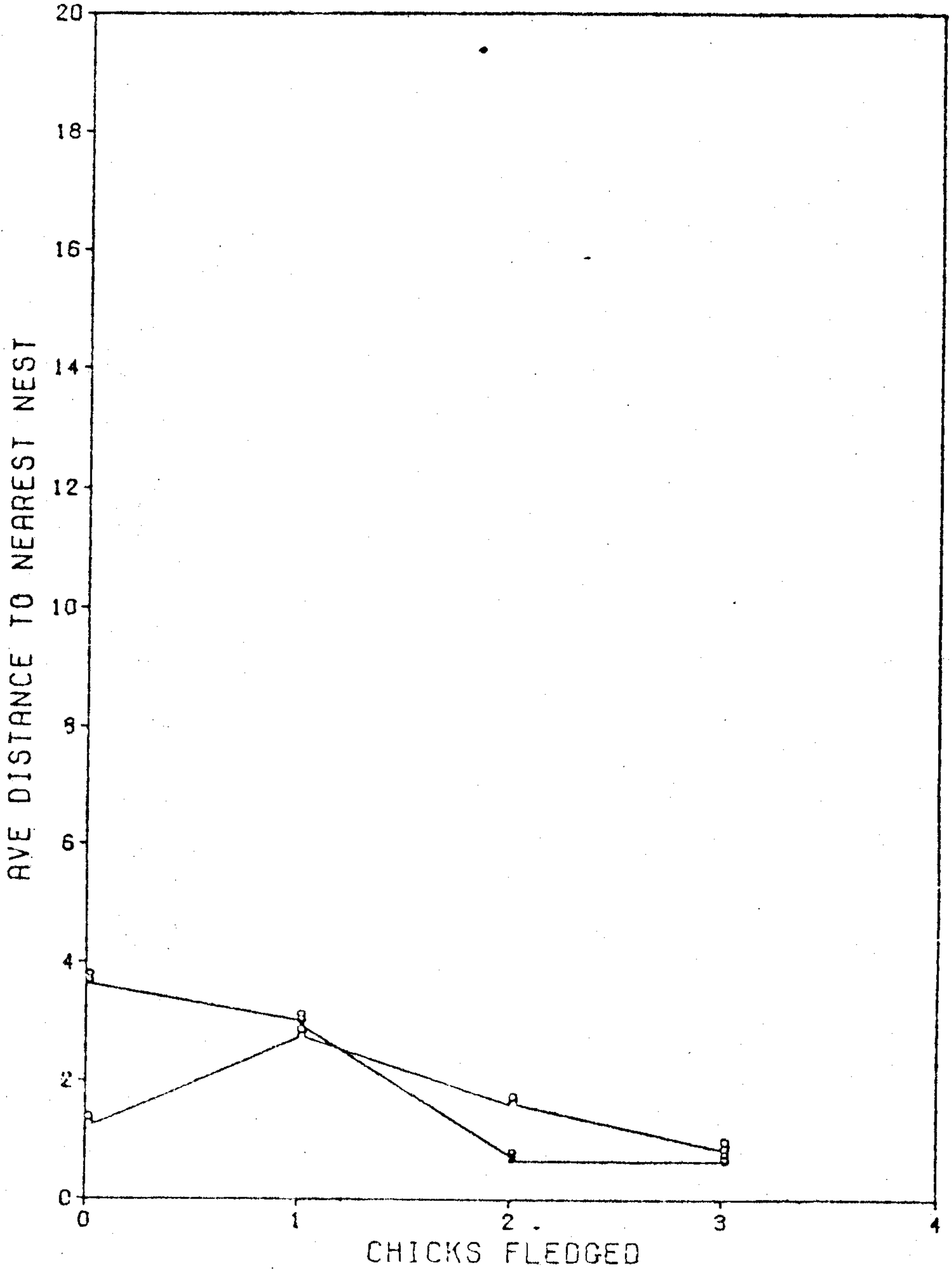

Figure 39. Chicks fledging plotted against mean distance to nearest nest, Dry Bay, 1977.
A = 'A' Colony, B = 'B' Colony.

Mean distance to nearest nest had little effect on chicks fledging per nest at Dry Bay in 1977.

glaucescens colony at Dry Bay (1.44) (Table 6; Fig. 40).

The expanding coastal populations of glaucescens and argentatus x glaucescens hybrids encounter relaxed selection pressures due to unlimited nesting space and abundant natural food in recent-post glacial and river delta environments. L. argentatus genes are entering coastal populations at Glacier Bay, Dry Bay, and the Susitna Flats near Anchorage at the mouth of the Susitna River.

Paynter (1949) reported a production of 0.92 chicks per nest sufficient to maintain a stable population of argentatus on Kent Island, New Brunswick, very close to that we discovered at Lake Louise. Ludwig (1966) found a recruitment rate of 0.63 maintained a stable population of delawarensis on the Great Lakes. L. argentatus studied by Ludwig increased on the Great Lakes between 1960 and 1965 at an annual rate of 13% with a mean fledging rate of 1.47, quite close to the production at Dry Bay (argentatus x glaucescens). The population growth of argentatus on the Great Lakes was due to the abundance of the alewife (Alosa pseudohargenus), a major food source. Populations of delawarensis on the Great Lakes increased during the same period at 30% per year with a mean fledging rate of 1.74 (Ludwig, 1966), practically identical to North Marble. L. glaucescens studied by Vermeer (1963) produced 1.35 chicks per nest per year. Harpur (1971) published fledging rates of 1.33 and 0.96 per pair of occidentalis. The highest mean fledging success in the literature is 2.00 chicks per nest reported by Coulter et al. (1971) for occidentalis on the Farallons. Other fledging successes, summarized by Keith (1966) ranged from 0.3 to 1.17.

The above comparisons indicate the coastal populations of glaucescens and argentatus are reproducing well. North Marble has a very high reproductive rate, indicating a population expanding at 30% per year. Dry Bay has a high reproductive rate, suggesting expansion of 12% per year. The large glaucescens population at Egg Island, partially dependent upon artificial food in Cordova, is expanding at a rate of 4% per year, a "normal" pattern for gulls. For example, at this rate, in five years the 20,000 gulls breeding on Egg Island would number 24,333. This is over a 20% increase in five years, similar to conditions replicated in recent past in the eastern United States, due to the same reason, an increasing food supply due to man's activities. The Lake Louise population of argentatus, with limited nesting space and restricted food availability, is maintaining itself.

Table 6

Comparative Index of Gull Reproductive Success in Chicks Per Nest (Productivity)

Colony Location	Species	Chicks/ Nest	Reference
California	L. occidentalis	2.00	(Coulter et al., '71)
North Marble (1972-73)	mixed glaucescens/ argentatus	1.77	(Patten, 1974)
Great Lakes	L. delawarensis	1.74	(Ludwig, 1966)
Great Lakes	L. argentatus	1.47	(Ludwig, 1966)
Dry Bay (1977)	mixed glaucescens/ argentatus	1.44	(this paper)
British Col.	L. glaucescens	1.35	(Vermeer, 1963)
California	L. occidentalis	1.14	(Harpur, 1971)
Egg Island (1975-76)	L. glaucescens	1.08	(Patten & Patten, 1977)
Lake Louise (1977)	L. argentatus	0.95	(this paper)
New Brunswick	L. argentatus	0.92	(Paynter, 1949)
Michigan	L. argentatus*	0.35*	(Keith, 1966)

* Population contaminated by DDT

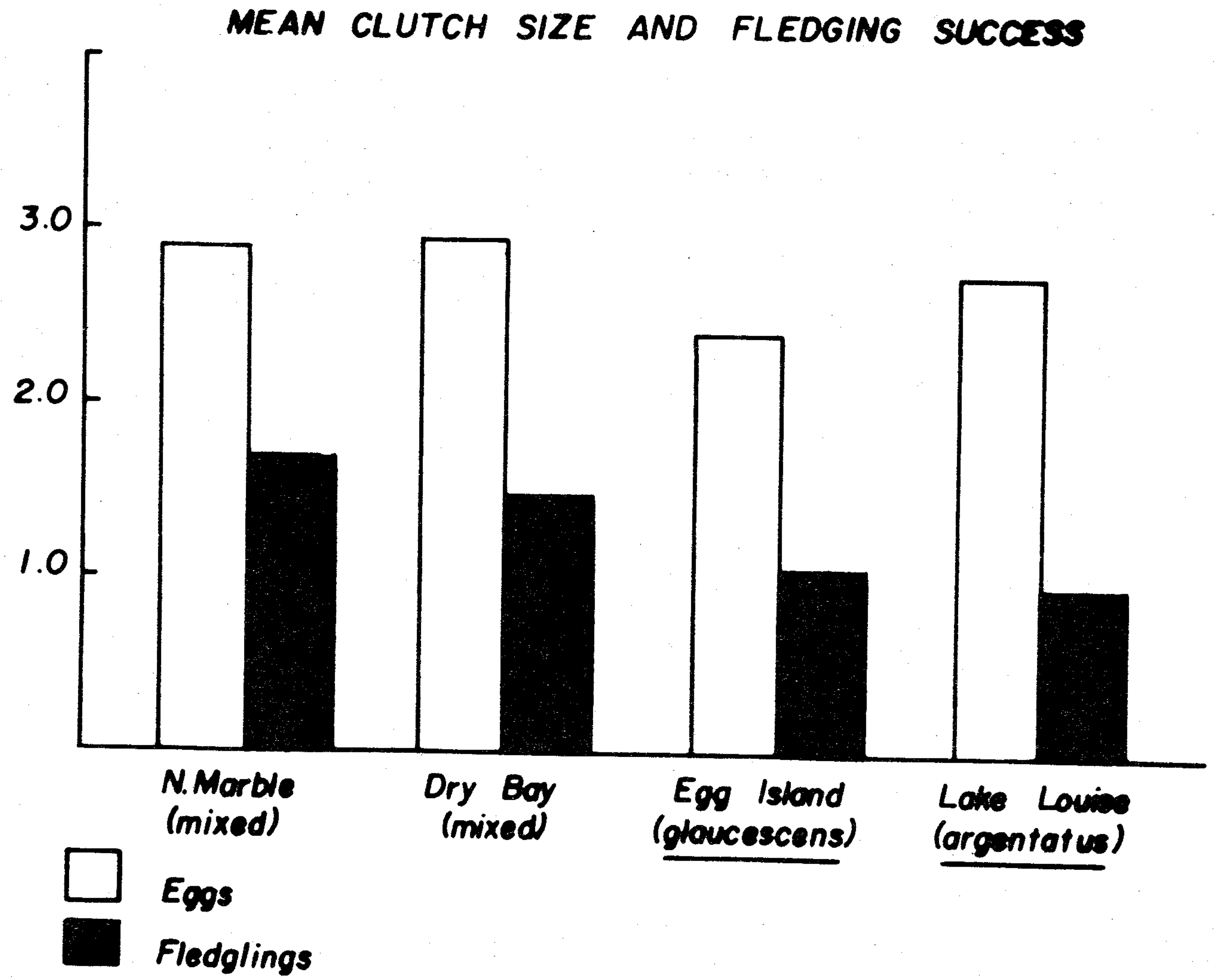
MEAN CLUTCH SIZE AND FLEDGING SUCCESS
3.0
2.0
1.0
N. Marble (mixed)
Dry Bay (mixed)
Egg Island (glaucescens)
Lake Louise (argentatus)
Eggs
Fledglings

Figure 40

Banding Results

The temporal sequence of band recoveries from Egg Island juvenile gulls first suggested strongly migratory tendencies. Additional recoveries now support the emerging migratory pattern of juvenile gulls originating on sandbar barrier islands off the Copper River Delta. Indications are that recently fledged juvenile gulls from Egg Island disperse explosively to Prince William Sound salmon streams within a month of fledging (cf. Moyle, 1966), and reach as far as Anchorage and Valdez before beginning migration south along the Pacific Coastline (Table 7; Fig. 41; Pearse, 1963). Band recoveries in January, from young gulls originating off the Copper River Delta, extend from Ketchikan, AK, to Puget Sound, WA. Several Egg Island juveniles, just over one year old, have been found in their second summer at Valdez. A color-dyed three-year old gull demonstrated lateral movement in July between Egg Island, off the Copper River Delta, and Middleton Island in the Gulf of Alaska (Fig. 42). More band recoveries of young gulls banded at Egg Island are from Valdez (25%) than any other location. Whether this represents environmental disturbances capitalized by gulls or simply concentration of human observers remains to be determined.

Table 7

Banding Recoveries of Juvenile Gulls from Egg Island

Location	Date	Reason
1. Valdez AK	22 Aug 75	aircraft strike
2. Valdez AK	22 Aug 75	aircraft strike
3. Valdez AK	29 Aug 75	dead on road
4. Anchorage AK	30 Aug 75	found dead
5. Copper Delta AK	1 Sept 75	eaten by eagle
6. Yakutat AK	- Oct 75	found dead
7. Juneau AK	4 Oct 75	shot by boy
8. Ketchikan AK	20 Jan 76	oiling
9. Vancouver BC	- Jan 76	found dead
10. Valdez AK	19 Jul 76	injury
11. Valdez AK	19 Jul 76	found dead
12. Cape Hinchinbrook AK	28 Jul 76	collected
13. Seward AK	5 Sept 76	found dead
14. Yakutat AK	8 Oct 76	found dead
15. Juneau AK	31 Oct 76	entangled
16. Olympia WA	23 Nov 76	no information
17. Petersburg AK	10 Dec 76	caught by dog
18. Harris Harbor AK	15 Jan 77	found dead
19. Prince Rupert BC	23 Jan 77	found dead
20. Rivers Inlet BC	-- Feb 77	found dead
21. Lake Tapps WA	-- Feb 77	shot
22. Ketchikan AK	3 Mar 77	hit by car
23. Valdez Arm AK	24 Aug 77	found dead
24. Cordova AK	31 Aug 77	trapped & released

Table 8

Banding Recoveries of Juvenile Gulls From Strawberry Reef, Copper River Delta

	Location	Date	Reason
1.	Vancouver BC	3 Feb 77	found dead
2.	Bainbridge Island WA	16 Feb 77	found dead

Note: Tables 7 & 8. Radiation to Prince William Sound region after breeding seasons and then strongly migratory tendencies exhibited by N - S chronological sequence of banding recoveries.

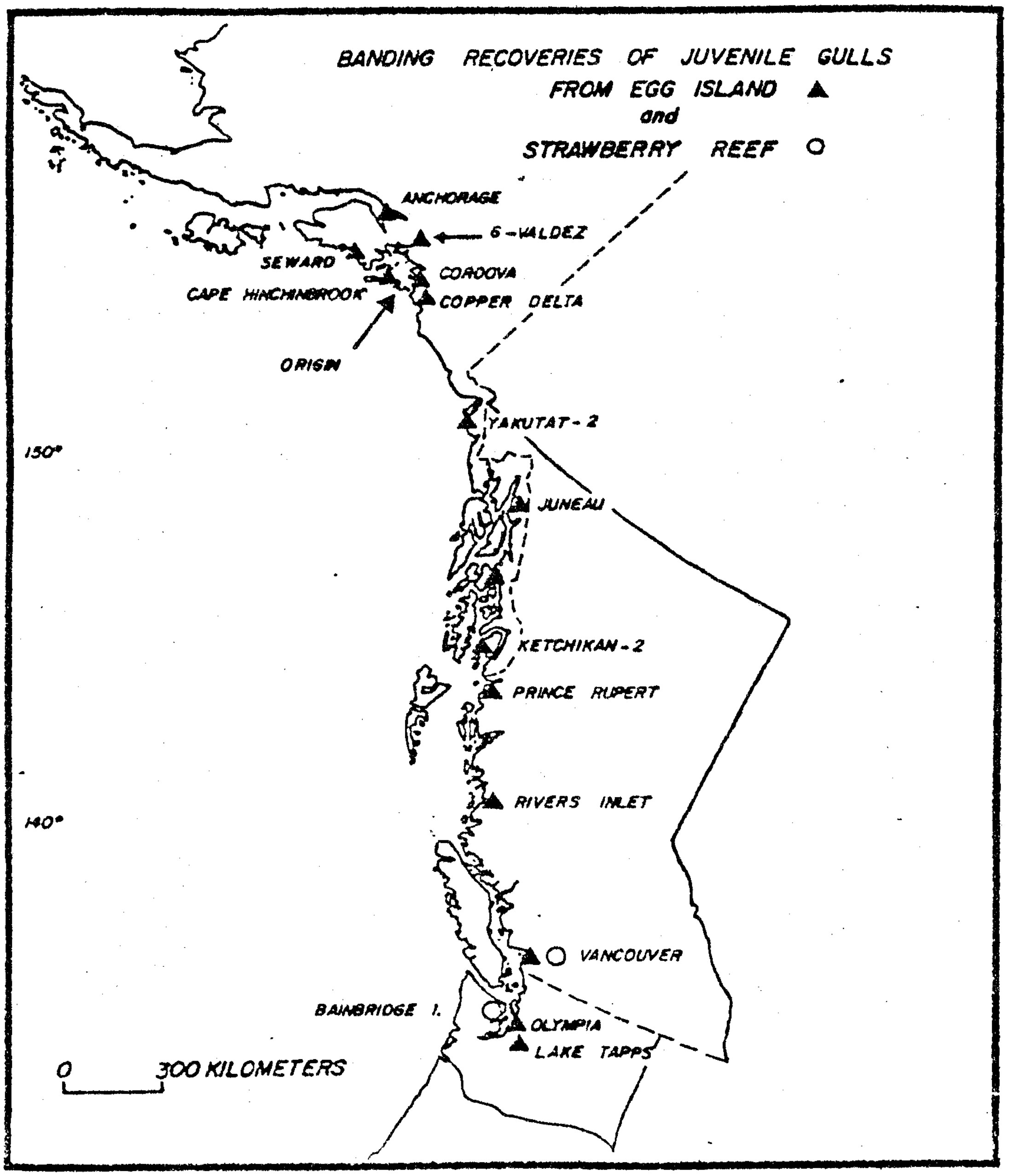
BANDING RECOVERIES OF JUVENILE GULLS
FROM EGG ISLAND ▲
and
STRAWBERRY REEF ○
ANCHORAGE
6-VALDEZ
SEWARD
CORDOVA
CAPE HINCHINBROOK
COPPER DELTA
ORIGIN
YAKUTAT-2
150°
JUNEAU
KETCHIKAN-2
PRINCE RUPERT
RIVERS INLET
140°
VANCOUVER
BAINBRIDGE I.
OLYMPIA
LAKE TAPPS
0
300 KILOMETERS

Figure 41

Table 9

Observations of Color-dyed Gulls (Adults)

	Location	Date	Activity
1)	Cordova docks-canneries	July-Aug 75 Sept-Oct 75	feeding
2)	Cordova dump	July-Aug 75 Sept-Oct 75	feeding
3)	Egg Island	July-Aug 75	breeding
4)	Eyak River, Copper Delta	Aug 75	resting
5)	Hawkins Island, Prince William Sound	Aug 75	flying
6)	Juneau	Sept 75	resting
7)	Cordova docks-cannieries	March 76	resting
8)	Egg Island	June 76	breeding
9)	Middleton Island,* Gulf of Alaska	July 76	resting
10)	Hartney Bay, Orca Inlet	Aug 76	feeding
11)	Cordova City Airport	Aug 76	resting
12)	Cordova dump	July-Aug 76 Sept-Oct 76	feeding

<u>Note</u> artificial food sources, winter absence, suggestion of migration pattern.

* third-year juvenile

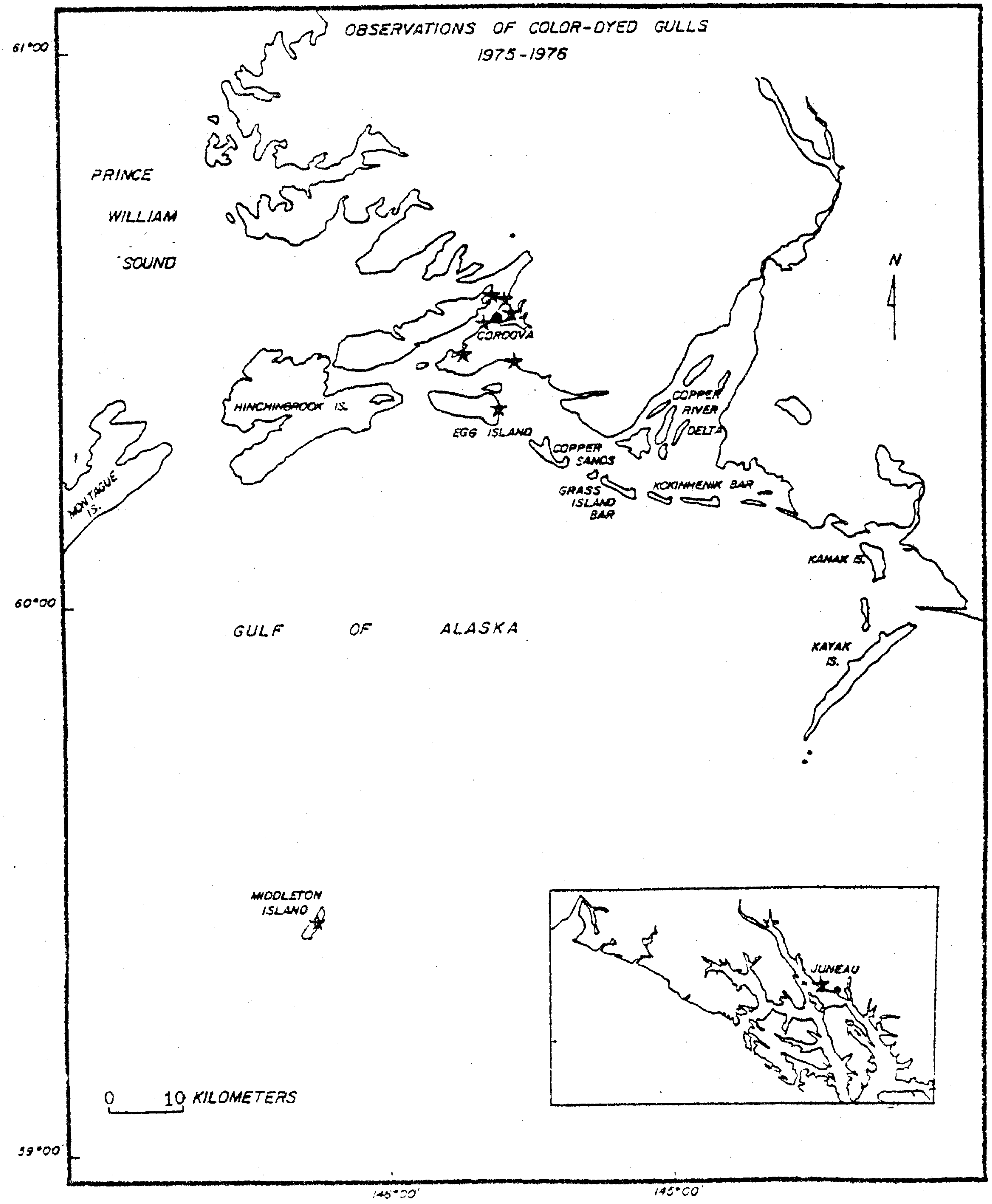
OBSERVATIONS OF COLOR-DYED GULLS
1975-1976
61°00'
60°00'
59°00'
146°00'
145°00'
PRINCE
WILLIAM
SOUND
CORDOVA
HINCHINBROOK IS.
EGG ISLAND
MONTAGUE IS.
COPPER SANDS
GRASS ISLAND BAR
KOKINHENIK BAR
COPPER RIVER DELTA
KANAK IS.
KAYAK IS.
N
GULF OF ALASKA
MIDDLETON ISLAND
JUNEAU
0 10 KILOMETERS

Figure 42

Wintering Areas of argentatus and glaucescens

A review of recent literature on wintering areas and F&WS observations of large gulls in the northeast Gulf of Alaska (Lensink, pers. comm.) amplifies banding and color-dyeing studies.

Isleib and Kessel (1973) suggest part of the northeast Gulf of Alaska glaucescens population winters offshore on the continental shelf. Isleib (pers. comm.) reports argentatus, glaucescens and other hybrids are common in the winter in the Cordova area, where argentatus and hybrids are quite uncommon during the summer. Hoffman (pers. comm.) also finds glaucescens, argentatus and hybrids offshore between Yakutat and Kodiak in November. These observations, with the results of color-dyeing studies showing Egg Island-Cordova adult glaucescens departing the Cordova area and returning in March, indicate major pelagie population shifts and migratory movements southward in fall and winter. (Table 9; Fig. 42).

The Fish & Wildlife Service / NOAA winter cruises (18 Jan - 13 Feb) find highest densities of seabirds in association with trawling operations 65 - 200 km east of Kodiak Island in waters over the continental shelf, or shelf break. Mean density in birds/km^2 for outer continental shelf regions is: British Columbia Shelf: 6.3; Southeast Alaska Shelf: 6.3; Northwest Gulf of Alaska 47.4; and Kodiak Basin: 35.2 (Lensink, 1977).

Larus glaucescens is among the most abundant species on NOAA/F&WS patrols (14-21 Feb; 7 Feb-4March). High numbers are consistently correlated with trawling operations of foreign-flag factory ships on the continental shelf. Larids occur in low but regular numbers in off-shelf areas. Apparently pure glaucescens predominate but a few glaucescens x argentatus hybrids and a very few typical argentatus are sighted off Canada and in the Gulf and Kodiak basins (Lensink,* 1977).

Sanger (1973) and Harrington (1975) report pelagic argentatus and glaucescens 80 - 640 km off southern California from January to April. L. argentatus increase until mid-February, and then rapidly decrease from mid-March to mid-April. Gulls collected in April have enlarged gonads in near breeding condition. Further north, F&WS ship surveys in the northeast Gulf of Alaska find marked shifts in relative abundances of gulls indicating migration from more southern regions:

Table 10

Large Gulls Observed on Transects in the Northeast Gulf of Alaska (Lensink, pers. comm.)

Species	Number/km^2			
	Feb.	Apr.	May	June
Unidentified Gull	0	.08	.05	.07
Glaucous Gull	.02	.23	0	0
Glaucous-winged Gull	3.33	1.69	1.89	.19
Herring Gull	.03	.21	3.23	.41

The sharp increase and then decline in May of argentatus per km^2 represents a migration from more southern regions (e.g., off California) towards interior breeding localities in Alaska, B.C., and the Yukon (Table 10). Herring Gulls appear on interior lakes across Alaska in May just before spring break-up. Non-breeding argentatus may summer at sea, since inland lakes are not especially productive. Breeding pairs on inland lakes are more scattered than colonial and clutch size is smaller than coastal gull populations (Anderson, *viva voce*). Post-breeding adult gulls depart abruptly from interior lakes in late August or early September. Major rivers (Copper, Alsek, Taku, Stikine) provide migratory pathways to the sea.

The more gradual decline in glaucescens per km^2 from Feb. to June represents coastal breeders returning to colonies. From February to April pelagic glaucescens decrease by 50%. Gulls from Mandarte Island, B.C., are on site in February; gulls are present at North Marble in Glacier Bay in March (Streveler, pers. comm.) and appear on territories at Egg Island in April (Isleib, pers. comm.).

F&WS standing stock estimates of pelagic gulls exceed known breeding pairs in the NEGOA (Lensink, pers. comm.). Non-breeders and gulls originating from other than coastal NEGOA colonies comprise a large portion of the pelagic population. Offshore gull populations utilize food resources (including offal from foreign fisheries), reducing competition with onshore breeding populations.

Gull Food Habits

Continued access to food resulting from human activities will increase gull numbers in Alaska. This food supply is not likely to decrease with further industrial development in Alaska. Gene flow among gull populations will follow increasing numbers. Gulls exploit artificial food due to natural plasticity of food selection and dichotomy of foraging pathways. Gull populations in Alaska currently exhibit both food selection under natural conditions, and response to artificial food supply.

Glacier Bay

Alaskan gulls of the *argentatus* group under natural conditions show two major foraging pathways: first, gulls scavenge the intertidal in areas such as Glacier Bay, from the lowermost to the uppermost regions. The rise and fall of the strong tides in Glacier Bay exposes up to ten meters of a rocky, algae-covered zone. Gulls take a wide variety of food items, including cast-up larger fishes such as Gadidae, Scorpaenidae, Cottidae and *Theragra*, and invertebrates such as *Mytilus*, *Thais*, *Balanus*, and *Pagurus* (Table 11). Invertebrates are broken, dropped, pried open, or swallowed whole. Secondly, strong tidal currents in Glacier Bay cause upwelling of soil nutrients deposited in the waters by glaciation (Streveler and Paige, 1971). The nutrients support food chains producing small fishes. Gulls dive for small fishes, stooping from several meters to well beneath water surface, in areas of tidal disturbances, at river mouths, near surfacing whales (Jurasz, pers. comm.; Divoky, 1976), taking

Osmeridae, *Clupea harengus*, *Thaleichthys pacificus*, and small shrimp (*Pandalus*). Gulls take other small fishes (*Pholidae*) from rocky intertidal pools by stalking. Glacier Bay, representing the natural environment, a recently deglaciated "unfilled niche," provides excellent feeding for gulls.

Dry Bay

Gulls feed on outer sandy beaches and at river mouths between Yakutat and Cape Fairweather (cf. Patten & Patten, 1975, for similar observations at Dixon River in Glacier Bay National Monument). Dry Bay is an important feeding area for gulls, cormorants, mergansers, and seals. Eulachon (*Thaleichthys pacificus*), fed heavily upon by gulls, normally spawn in clear rivers in March and April, but a prolonged, late and heavy run continued until the end of May 1977 south of Yakutat, including Williams Creek, a tributary of the Alsek. Gulls also feed heavily on Pacific capelin (*Mallotus villosus*) spawning in the surf during summer high tides. Other gull foods include small crabs (*Cancer magister*) ≤ 4 cm, blackfin poacher (*Bathyagonus nigripinnis*), herring (*Clupea hargengus*) spawning on kelp in April and May, Pacific sandlance (*Ammodytes hexapterus*) and razor clams (*Siliqua patula*). The abundant 1977 eulachon may have accounted for the high clutch size and resultant good reproductive success in the gull colony at Dry Bay.

Salmon offal from Dry Bay Fish Co., a small processing plant, is currently a minor food source for gulls, bears and wolves. Dry Bay supported much heavier commercial fishing earlier this century and the resulting offal may have then supported more gulls. A railroad hauled fish from the Akwe River to a cannery at Dry Bay (Ak. Geo., 1975). The Alsek fishery included both drift and set gill nets (Brogle ADF&G, pers. comm.). Nothing is left of the cannery except pilings. An indian village existed at Dry Bay long before the cannery (Ak. Geo., 1975). Only a dozen fishermen now live along the lower Alsek from late May to October. Their impact upon the biota other than salmon is minimal.

Haenke Island

Alaskan gulls also exploit marine mammals under natural conditions (Divoky, 1976; Tuck, 1960). Seals, for instance, give birth on pack ice at Haenke Island near Yakutat and in Muir Inlet in Glacier Bay. Gulls (both argentatus and glaucescens nesting on nearby fjord cliffs) scavenge seal feces, stillborne pups, other carcasses, and placentae (Streveler & Paige, pers. comm.). Remains of seal placentae, lanugo hair, and ordinary seal hair form the most common item in gull castings and stomach specimens collected at Haenke Island in June (identification courtesy Mr. T. Eley, ADF&G).

The affinity of gulls for sewage has been previously discussed (Patten & Patten, 1977). This behavior may have originated from following marine mammals.

A long stretch of exposed, sandy beaches connects the fjordlands of Glacier and Yakutat Bays with Prince William Sound on the north.

Egg Island

The gull colony at Egg Island, at the end of the chain of sandy beaches between Glacier Bay and Prince William Sound, exhibits parameters of an expanding population as discussed above. The population is expanding for two reasons: a result of increase in nesting space, as plant succession follows earthquake uplift of island colonies, and availability of artificial food in Cordova in the form of offal and garbage.

Fish and crab processing plants in Cordova in 1972 discharged 2.6 million pounds of seafood waste into Orca Inlet (USDI, 1976; underlining mine). EPA regulations require dumping of waste where material is not visible but in summers 1975-76-77 the gulls found the material highly visible, attracting huge foraging flocks (10,000 individuals per hour), notably during salmon-packing season (July-August). This is precisely when gulls feed young on Egg Island 20-30 km away. Color-dyed breeding birds from Egg Island join in these flocks with non-breeding adults and second and third-year juveniles. Gulls constantly interchange from Eyak Lake, Eyak River, and Orca Inlet to the colonies on sandbar islands at the mouth of the Copper River (Fig. 72). The gulls feed on circling swarms on the effluent hosed from the floors of the seafood processing plants, ground up and dumped from pipes at the ends of the wharves. Gulls also feed on detritus in the harbor and on fishing boats.

Newly fledged juveniles appear at the seafood plants in late July and early August. Fewer gulls are found in the area when the seafood plants are not processing, e.g., when ADF&G closes the season or when commercial fishermen strike. The Cordova municipal dump provides a more limited but more constant food supply and is used by fewer birds when effluent is available from seafood plants.

Lake Louise

Lake Louise, across Prince William Sound and 160 km into the interior from Cordova (Fig. 13)*, supports a small, now relatively stable population of *argentatus*. Fish, including lake trout (*Salvelinus namaycush*), greyling (*Thallymus arcticus*), burbot (*Lota lota*) and suckers (Catostomidae), form the most important part of the gull diet at this interior lake, since invertebrates are few in numbers and species. Gulls also scavenge fish scraps, refuse from State campgrounds, and garbage from a dump three km from the lake. Armed Forces recreation centers were located at Lake Louise until the mid-1960's, at which time the lake received heavier fishing pressure than at present. Poe (*viva voce*) stated his impression that gull nesting density on Bird Island is less now than a decade ago, when refuse and fish scraps were more readily available.

Gulls identified as *argentatus* are absent from the Cordova seafood plants during the summers, but Isleib and Kessel (1973) indicate they are common in the winter around the wharves. Most certainly these gulls originate from interior lakes such as Lake Louise, frozen in the winter.

*(Part I).

Table 11

Known Gull Food Items

Colony/ Foraging Area	Glacier Bay	Dry Bay	Strawberry Reef	Copper Sands	Egg Island
Food items:					
Phylum Mollusca Class Pelecypoda					
	Mytilus edulis	*Siliqua patula*			*Siliqua patula*
					Mytilus edulis
					Clinocardium nuttallii
Gastropoda					
	Fusitriton oregonensis *Neptunea lyrata*				
Cephalopoda					
					Octopus sp.
Phylum Arthropoda Class Thoracica					
	Balanus glandula				
Decapoda					
	Pagurus beringanus *Hyas lyratus* *Chionoetes bairdi*	*Cancer magister*	*Pandalus borealis*		
Insecta					
					Tipulidae sp.
Phylum Echinodermata Class Echinoidea					
	Strongylocentrotus drobachiensis				

Table 11 (cont.)

Known Gull Food Items

Colony/ Foraging Area	Glacier Bay	Dry Bay	Strawberry Reef/ Haenke Island	Copper Sands	Egg Island	Valdez Cordova Yakutat Juneau	Lake Louise
Food items:							
Phylum Chordata Class Osteichthyes	Gadidae sp. *Theragra chalcogramma* *Cottidae* sp. *Hemilepidotus hemilepidotus*	*Ammodytes hexapterus* *Clupea harengus* *Bathyagonus nigripinnis* Thaleichthys *pacificus* *Mallotus villosus*		*Clupea harengus* Thaleichthys *pacificus*	*Clupea harengus* *Oncorhynchus* sp. (eggs) *Sebastes* sp. Thaleichthys *pacificus* Pholidae		*Salvelinus namaycush* *Thallymus arcticus* *Lota lota* Catostomidae
Class Aves	*Larus glaucescens* (eggs & chicks)				*Larus glaucescens* (eggs & chicks)		
Class Mammalia	*Phoca vitulina* (carcasses, placentae, feces)		*Phoca vitulina* (carcasses, placentae)		*Phoca vitulina* (carcasses)		
Food of Human Origin						garbage sewage salmon & crab offal	

DISCUSSION

The rapid expansion of coastal settlements with their associated production and accumulations of sewage and refuse, the development of offshore oil fields, the discharge of industrial effluents into the ocean, the development of commercial fisheries with their attendant production of fish offal, and the steady increase of coastal recreational facilities, all have had, and continue to have, an impact on the distribution and number of seabirds (Cramp et al., 1974). Certain species show marked changes associated with the rapid industrial expansion and resource development occurring around the Northern Hemisphere. The large gulls (Larus) in particular, are rapidly reproducing "weedy" commensal species, highly adaptable to changing circumstances and able to withstand and often take advantage of changes in the environment. Commensal species inhabit ecological niches that are directly or indirectly the result of human interference. The most important artificial niches for gulls are garbage piles, sewage outfalls, and fish offal. The brown rat, European Starling (Sturnus vulgaris) in America, and various native "blackbirds" are examples of dramatic population increases that have had effects on other ecologic processes.

Gulls have increased sufficiently on both sides of the North Atlantic to become a major threat to other seabirds, by direct predation on adults and young, by robbing adults of food destined for young, and by usurping vital nesting areas. The rapid increase in Atlantic gull populations in recent years has caused both disquiet to civic authorities and alarm to conservationists.

Recently, we have noticed a marked increase in reproductive rate of Alaskan populations of Glaucous-winged Gulls (*Larus glaucescens*) and similarities in age structure of the arctic Alaskan populations of Glaucous Gulls (*L. hyperboreus*) to expanding populations of North Atlantic species of *Larus*, principally *L. argentatus*, the Herring Gull.

Herring Gulls have increased their numbers and expanded their breeding range since the turn of the century. The New England population has increased by a factor of 15 to 20 (Kadlec and Drury, 1968; Drury and Kadlec, 1974). The breeding range has extended south to North Carolina (Hailman, 1963; Parnell and Soots, 1975). Explanations offered for this increase include a reduction of direct human depredations (e.g. egging and shooting) since the turn of the century, and changes in factors such as availability of food. In recent years, the impact of traditional subsistence upon seabirds in the Atlantic has been minimal, and there have been vast increases in availability of artificial food (offal and garbage).

The expansion in breeding range has been followed by expansion of nesting habitat into salt-marshes (Parnell and Soots, 1975; Burger, 1977). Consequently, Herring Gulls now nest in habitats used by other larids such as Common Terns (*Sterna hirundo*) and Laughing Gulls (*L. atricilla*) and increase in Herring Gull colonies has been associated with a decrease in populations of Laughing Gulls and Common Terns (Drury, 1965; Nisbet, 1971, 1973). Recently Burger and Shisler (1978) have studied nest site selection and competitive interactions of Herring and Laughing Gulls in New Jersey, and suggest continued displacement of breeding Laughing Gulls from sites colonized by Herring Gulls, as Herring Gull populations continue to expand.

There has been a general tendency for a decrease in numbers of both Arctic Terns and Common Terns all along the coasts of the Eastern United States and Canada over the last 30 years as gull populations have expanded (Nettleship and Lock, 1973; Nisbet, 1973; Drury, 1973, 1974). Tern populations are particularly vulnerable to harassment by gulls. The continuing increase in gull numbers along the Atlantic seaboard poses a considerable threat to tern productivity (Nettleship, 1977).

Recently the impact of disturbance by large gulls on the breeding performance and distribution of other birds has become of such magnitude that it is now considered to be quite serious (Nettleship, 1977).

The Herring Gulls and the Great Black-backed Gull (L. marinus) have done so well (increasing in numbers and expanding in range) that they now cause substantial damage to certain specialized species (terns, Atlantic Puffin (Fratercula arctica, among others) by taking eggs and young, by cleptoparasitism (i.e., robbing parents taking food to young) and by physical displacement from optimal nesting locations (Nettleship, 1972, 1975; Nisbet, 1973; Drury, 1973, 1974).

Gulls in Britain have assumed their role as the modern urban scavenger since the late 1800's, accepting cities as safe refuges after protection by law from indiscriminate shooting (Cramp et al., 1974). In urban areas, gulls have increased enormously in the last 50 years and currently exhibit a doubling time of 6-15 years. The Herring Gull has shown steady increases on both sides of the Atlantic. In general, the Herring Gull in Britain has increased around developed parts of the mainland wherever nesting conditions are suitable; even nesting on buildings in populated areas reflect pressures on normal breeding sites caused by population growth. The increasing numbers of Herring Gulls have led to drastic control measures, which have been only partially successful.

The documentation of early signs of an impending explosive growth phase in local Larus population in the northeast Gulf of Alaska has been part of the results of an OCS project supported by BLM/NOAA over the past four years. There now is little question that the potential for explosive increases in the Alaskan populations of large gulls exists. In one week in July 1978, Patten with a field crew provided by the Forest Service, banded over 5,400 gull chicks in one location in southern Alaska. Over 11,000 gulls have been banded in the last four field seasons.

In stable populations of large gulls on the east coast of the United States, the annual chick production rate averages 0.5 chicks/nest and the proportion of subadults in the population averages under 12% (Drury, pers. comm.). Surveys from Juneau, Alaska to Prince William Sound indicate much higher rates (1.08-1.77 chicks/nest). George Divoky (pers. comm.) reporting preliminary 1978 census data from the Beaufort Sea estimated subadult plumaged birds made up 20% of the population and near Barrow, which has a sizeable human population (over 3,000), and with a dump appealing to Glaucous Gulls, the subadult population made up an astounding 40% of the population.

William Drury (pers. comm.) surveyed 1,500 miles of northwestern Alaska coast and concluded that Glaucous Gulls may be in or entering a period of rapid growth of their population. The percentage of subadults in the population are the same as or above those of Herring Gull populations which are known to be rapidly expanding on the east coast of North America, i.e., above 14%. The figures given to us by Drury from 1975 to 1978 are 15, 21, 7, and 23% for populations from Cape Spencer on southern

Seward Peninsula to Tolstoi Point in Norton Sound. The low figure in 1977 resulted from missed age group counts in part of the survey. Comparing northwestern Alaska populations to the east coast populations, the averages are both 18% subadults. The assumption is therefore, that both populations are expanding. If stable populations consist of 12% or less subadult birds, an increase of 6% per year in that category is highly significant.

SIGNIFICANCE

The ecological history of man's relationship to other species has only partially been a recitation of direct extirpations - as exemplified by the Bison, Passenger Pigeon, Carolina Parakeet, California Condor, Snail Darter, and the like. The other side of ecological history demonstrates how man enhances the carrying capacity of the environment for weedy, or nuisance species, which are adapted to disturbed environments and utilize artificial food. This aspect of population change is at least as serious as direct extirpations, both in total historic importance, and in the implications for future impact to man and other species of wildlife. A series of comparisons will be enlightening. Next to the Passenger Pigeon, consider the European Starling. Next to the Bison, consider the Brown Rat. In Alaska, next to the Sea Otter (a history of near extinction) consider the growth of the large gull populations. All signs point to an explosive increase in 'sea gulls' in Alaska, similar to the unfortunate pattern of gull population explosions along the East Coast of North America and in the North Atlantic.

There are at least three serious aspects of unnaturally inflated gull populations in Alaska as elsewhere. First, gulls are a public health hazard, since they have been demonstrated as vectors of human pathogens in an outbreak of Salmonella poisoning at Ketchikan, in which over 100 persons sought medical treatment (Wilson and Baade, 1959). Secondly, gulls are opportunistic, efficient predators on other seabird and shorebird species, threatening, for example, the population stability of Alaskan marine bird species such as Horned (Fratercula corniculata) and Tufted Puffins (Lunda cirrhata), and having a significant effect on nesting by displacement of more abundant species such as the Murres (Uria spp.) (Drury, pers. comm.). In certain areas of the North Atlantic, as gull populations have expanded, the Common Puffin has disappeared from much of its former breeding range. Large gulls, which survive winters in unusually high numbers due to availability of garbage and fish offal, harass puffins during the breeding season, robbing the parent puffins of fish destined for the young, and actually by preying upon the starving puffin chicks which come from their burrows in search of food (Nettleship, 1975).

Geometric population expansion such as observed in Herring Gulls in Britain requires only a total annual increase of about 10%. The total annual increase is accelerated by slightly enhanced survival among juvenile gulls. Survivorship in young gulls is aided by availability of artificial food, such as garbage and commercial fish wastes. A typical demographic profile of a gull population in an explosive growth phase shows 18% of the population to be 0-3 years old, juveniles and subadults. This is excellent survivorship at the most vulnerable part of the age structure. Once adults, past age four, gulls are very long-lived species. Gulls at age four typically have a life expectancy of ten more years, all of which can be reproductively active.

Domestic and industrial onshore and offshore development activities generate large volumes of solid comestible waste in unnatural settings, precisely what may trigger explosive increases in survivorship in juvenile gulls. The aesthetic sight of large flocks of gulls above garbage barges is an example of the third aspect of unnaturally inflated gull populations. Secondary effects of development will without a doubt include spreading onshore garbage dumps, precisely the sort of environment that facilitates increased gull survivorship. Sufficient knowledge of the situation is not yet available even to measure the true dimensions of the coming gull problem. North of the Alaska Peninsula the coastal environment becomes radically different from the Gulf of Alaska, with winter minimal daylight, shore-fast ice, small tidal fluctuations, diminished intertidal life, and low temperatures. These factors require different foraging strategies by gulls. Conditions which may limit the growth of gull populations north of the Alaska Peninsula probably do not come into effect during the breeding season, but during the winter, about which we have little or no data.

Alaska could be on the sill of a major ecological disruption. Coastal towns such as Kodiak, Dutch Harbor, Nome, and Kotzebue represent an unknown potential for facilitating increases in gull populations like those witnessed in the North Atlantic. Offshore oil and gas operations in frontier areas, as well as fisheries, also have the potential of widening and extending the basis for commensalism by gulls.

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PART III

Pathobiology

Table of Contents

List of Tables

- A Review -

The Role of Gulls (*Larus argentatus* & *Larus glaucescens*) in the Transmission of Human Parasitic and Enteric Diseases in Alaska

Human Parasitic Diseases and Gulls

The exposure of untreated or poorly treated sewage to gulls in Alaska may lead to human health hazards from bacterial and helminth infections (cf. Coulson and Monaghan, 1978; Crewe and Owen, 1978). One of the traditional safety factors relied upon for prevention of dispersal of pathogens which may be present in sewage has been the dilution of the effluent with an abundance of river or sea-water (Silverman & Griffiths, 1956). Overloading, however, or construction of new sewage plants with outfalls into already heavily polluted waters, *i.e.*, the Cordova dockfront area (USDI, 1976), reduces the dilution factor, and certain organisms such as gulls may actively concentrate human pathogens through their foraging behavior (Crewe & Owen, 1978). For instance, in primary sewage treatment plants there is little evidence that continuous aeration adversely affects helminth ova, nor is rapid sand filtration an effective means of removing helminth ova from sewage effluent (Silverman & Griffiths, 1956). Varying percentages of viable helminth eggs (*Ascaris*, *Trichurus*, *Enterobius*, *Diphyllobothrium* and *Taenia* - all human pathogens) have been found in sludge of primary sewage treatment (Silverman & Griffiths, *loc. cit.*). Eggs may persist in a viable state in the sludge for years.

The role of birds in the dissemination of helminth ova is difficult to evaluate, but is highly suggestive (Silverman & Griffiths, *loc. cit.*; Crewe & Owen, *loc. cit.*). Götzsche (1951) suggested that gulls might be responsible for dissemination of tapeworm eggs from sewage outfalls. Gulls may come into contact with sewage at every stage of treatment, and it is well known that gulls frequent canneries, fish-packing houses and garbage dumps in Alaska in addition to roosting on municipal water supplies, *i.e.*, Ketchikan and Cordova (Wilson & Baade, 1959; USDI, 1976). Dumping of raw sewage from coastal towns in Alaska attracts gulls, which, as natural scavengers, forage on the fecal matter, e.g. at Valdez (Bayliss, pers. comm.) and Juneau (Williams, pers. comm.) and Ketchikan (Wilson & Baade, 1959) (Fig. 43,44). Silverman and Griffiths (1956) found gulls attracted to sewage outfalls especially in winter (see Ketchikan epidemic below). These authors reported that feeding experiments with Herring Gulls revealed that tapeworm eggs (*Taenia* spp.) can pass through the digestive tract of gulls and still retain infectivity. The eggs appear in the feces about an hour after ingestion. Mature eggs may hatch in the gut of the gull, and the activated hexacanth embryo may be found in the droppings.

Sewage treatment and disposal problems in isolated areas are varied and complex (Silverman & Griffiths, *loc. cit.*). Pollution from inadequate disposal of human excreta is a potential source of health problems along the Alaskan coast, and is complicated by the scavenging nature of abundant Alaskan gull populations.

Naturally Occurring Human Helminth Infections Associated with Gulls in Alaska

Eskimos in western Alaska depend upon several species of fish for much of their food. These fishes are often eaten raw and thus transmit certain species of *Diphyllobothrium* tapeworms for which the fish are intermediate hosts (Rausch *et al.*, 1967). Kuskokwim Eskimos eat raw or partially frozen smelt (*Osmerus*), blackfish (*Dallia*), and sticklebacks (*Pungitus*) which often contain larval tapeworms (Rausch *et al.*, 1967).

Rate of tapeworm infection reached highest level in winter and early spring, after greatest consumption of blackfish and sticklebacks (Rausch et al., loc. cit.). Uncooked fish comprises over a third of the diet of these Eskimos (Heller & Scott, 1967). Levels of infection with Diphyllobothrium tapeworms ranges from 16% to 30% (Rausch et al., loc. cit.).

One of the most frequently found tapeworms in this region was identified by these authors as D. dalliae; the adult stage is in humans and dogs. Early life stages inhabit the blackfish, Dallia pectoralis, an abundant and economically important species in the Kuskokwim River region (Rausch et al., loc. cit.). Rausch (1956) obtained infectious tapeworm plerocercoid larvae from blackfish trapped on the lower Kuskokwim, and raised adult tapeworms from these larvae at the Anchorage laboratory in Glaucous-winged Gulls, which had been hatched in an incubator and maintained parasite-free until the experimental infection. Rausch (1956) stated that the occurrence of the tapeworm Diphyllobothrium dalliae is to be expected in gulls in Alaska. Gulls are implicated in the dissemination of this parasite, transporting eggs to various aquatic areas where the eggs develop through several life stages to plerocercoid larvae in fish infective for humans.

Another cestode commonly found in man in Alaska is a Diphyllobothrium species undetermined. This type appears identical with a tapeworm reared experimentally in humans, dogs, and Glaucous-winged Gulls from plerocercoids (infectious larvae) encysted on the stomach of salmonid and coregonid fishes (Rausch et al., loc. cit.). We report salmon gurry from the Cordova canneries frequently contains large numbers of tapeworms and this gurry is scavenged by gulls. Rausch et al. found Glaucous-winged Gulls naturally infected with the above Diphyllobothrium in Alaska. The presentation of fish gurry harboring tapeworms to gulls provides ample opportunity for parasite dissemination.

Rausch (1956) collected other adult cestodes morphologically resembling _D. dendriticum_ from various species of gulls in Alaska. Kuhlow (1953)* established infections by feeding encysted tapeworm plerocercoids from the stomach of _Osmerus eperlanus_, a smelt. Chizhova (_in_ Rausch, 1956) observed a tapeworm parasitizing Herring Gulls, humans, and dogs at Lake Baikal; similar cross-parasitism is expected in Alaska. Rausch (1954) observed specimens of still another _Diphyllobothrium_ species in dogs, foxes, cats, and gulls in Alaska after feeding plerocercoids from infected steelhead (rainbow) trout. Rausch (1954) experimentally infected Glaucous-winged Gulls with the tapeworm _Diphyllobothrium ursi_, a parasite of brown bears. It is readily apparent that tapeworms associated with gulls infect a variety of hosts including humans.

Thomas (1938) reported the life cycle of the tapeworm _Diphyllobothrium oblongatum_ involved Herring Gulls, herring (_Leucichthys_ sp.), and copepods. Tapeworm eggs were deposited in the feces of the gulls. Thomas (1938) reported that freezing the tapeworm eggs solid in ice for a month did not destroy their ability to hatch normal coracidia (early developmental stages). This suggests tapeworm ova survive through the Alaskan winter to continue their life cycle in the spring.

Although the pernicious-like anaemia associated with human _Diphyllobothrium_ tapeworm infection in Eurasia has not been observed in Alaska, the potential for such disease has been examined by Rausch _et al_. (1967). These authors reported that there was no evidence that infection of Alaska

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*_In_ Rausch, 1956.

natives by diphyllobothriid tapeworms contributed to the development of microcytic anaemia. However, in view of the often poor nutritional level of these people, the infection may be detrimental due to tapeworm absorption of B-vitamins (Rausch et al., 1967). Caucasians, however, especially those descended from northern European stock, may be genetically susceptible to anaemia associated with Diphyllobothrium tapeworm infections (Tötterman, 1947).

In addition to fish tapeworms, gulls have been demonstrated as part of the marine cycle of trichinosis, a roundworm which typically infects Eskimos in arctic Alaska. Marine mammals may become infected through consumption of encysted trichinae in the feces of carrion feeding birds such as gulls (Schwabe, 1964). Eskimos become infected with trichinosis upon consuming raw flesh of marine mammals, including polar bears, seals, walrus, and beluga whales, all of which carry Trichinella spiralis (Rausch et al., 1956).

Summarizing Parts I & II: Alaskan gulls associated with cannery effluent and sewage outfalls are implicated with the dissemination of human cestode and nematode parasites.

Gulls and Enteric Disease in Alaska

Reports originating from all parts of Alaska of human gastroenteric diseases associated with high fever, marked diarrhea, and dysentery have been received by Alaska Department of Health and Social Services on occasion (Williams, 1950). Outbreaks of intestinal diseases occur in Alaska where water supplies are unprotected (Foster, 1954). Alaska Public Health Laboratories have conducted studies indicating improper sewage disposal, Herring and Glaucous-winged Gulls, and public water supplies in the spread of the pathogenic bacteria Salmonella manhatten. First, a definition:

salmonellosis is the term applied to infections caused by any of a group of more than 1,100 microorganisms (Steele & Galton, 1969). Salmonellosis usually occurs as an intestinal infection resulting in enteritis, or may terminate in septicemia and death (Steele & Galton, 1969).

Technically, the bacterial genus *Salmonella* is composed of gram-negative, aerobic, non-spore-forming microorganisms that grow well on artificial media and reduce nitrate to nitrite (Edwards & Galton, 1967). All members of the genus are potentially pathogenic for man and animals. Salmonellae inhabit most species of warm-blooded animals (Steele & Galton, *loc*. *cit*.). *Salmonella typhimurium* has been recovered from gulls found dead near a cannery (Nielson, 1960). *S*. *paratyphi* B has been discovered in Herring Gulls (Wilson & MacDonald, 1967) as well as *S*. *derby* (Faddoul & Fellows, 1966, *in* Steele & Galton, 1969). Gulls carry many other kinds of *Salmonella* (Steele & Galton, 1967). Enteritis in gulls may be the only sign of infection, increasing the probability of disease transmission (Nielson, 1960).

Herring and Glaucous-winged Gulls became suspect in the Ketchikan *Salmonella* epidemic at Ketchikan because of scavenger feeding habits at the city sewer outfall (Foster, 1954). Gulls leave the Ketchikan waterfront with the advent of winter storms and fly approximately four km to Ketchikan Lake, the municipal water supply (Wilson & Baade, 1959). Epidemics of gastrointestinal disease have occurred at this time of year. Subsequent epidemiological investigation indicated a common vehicle (the community water supply) for the etiological agent. Literally thousands of gulls roosted on the lake at the time of the 1953 epidemic, and the water showed gross contamination not explainable by any other source (Wilson & Baade, 1959).

Specimens from gulls collected at the lake proved positive for Salmonella manhatten (Paratyphoid C group). Cultures from gulls as well as patients hospitalized with gastroenteritis were verified by CDC, Atlanta, GA. Over 100 persons in Ketchikan were treated by physicians. At the time of the outbreak, drinking water was not purified by any method. Subsequent chlorination of the water supply drastically reduced the incidence of this disease in Ketchikan, but the situation must be monitored to assure constant levels of chlorination. Similarly, gulls roost on the lake forming the Cordova water supply and the chlorination is monitored (Morley AEH, pers. comm.).

The city of Valdez in September 1976 was still dumping raw sewage below waterline in that harbor (Bayliss, pers. comm.). Photographs show gulls at Valdez foraging directly at the sewage outfall with slick extending some hundred of meters downwind. Bayliss (pers. comm.) informs us Valdez will soon complete sewage treatment facilities.

Pollution of reservoirs by aquatic birds has been recorded from Massachusetts, New York City, San Francisco, Los Angeles, Vancouver, B.C., and London, England (Wilson & Baade, loc. cit.). Typhoid bacillus has been isolated from gull excreta collected in the vicinity of a town in Scotland where typhoid epidemics had first occurred (Wilson & Baade, loc. cit.). Salmonellae were recovered from 78% of gull droppings collected near sewage disposal works at Hamburg, Germany. Samples taken from sewage-free areas were consistently negative (Muller, 1965).

According to Pauls (1953), providing safe and adequate water supply and sewage disposal is intricately linked with prevention of enteric disease outbreak. The role of gulls is an added phase to the study of both enteric and parasitic diseases in Alaska. The Ketchikan Salmonella outbreak underlines the need for proper, adequate sewage disposal systems preventing gull contamination with disease organisms transportable to public water or food supplies. Sewage disposal in many smaller communities in Alaska is accomplished by single premises or scavenger systems (underlining mine) (Pauls, in Alaska's Health, 1954). Contaminated water supplies and improper sewage disposal have historically (since 1807, the first reporting date) been major causes of gastrointestinal disease outbreaks in Alaska (Pauls, 1953).

The influx of people to Alaska will increase health hazards since carriers of typhoid and parasitic infections are undetected within this group (Pauls, 1953). The present explosive immigration to Alaska and projected rapid industrial growth of offshore oil operations may lead to conditions where gulls act as vectors for rapidly spreading human diseases.

Influenza in Avian Populations - A Review

Interactions between human and gull populations will increase with the development of coastal oil resources in Alaska. We include here under Task A - 28 a discussion of another potential aspect of the increase in gulls in Alaska as it relates to oil development.

Animals can be important as potential reservoirs or contributors to new pandemic strains of influenza virus (Kaplan and Beveridge, 1972). Pandemics of type-A influenza are caused by "new" strains of virus appearing suddenly in human populations. These new strains may arise by genetic recombination with animal or avian influenza viruses. For instance, Hong Kong virus (A/Hong Kong/1/68) probably arose as a genetic recombinant formed as a result of a mixed infection of an animal or bird with an animal or bird influenza virus and a human A/Asian (Asian flu) strain (Kaplan and Beveridge, 1972).

Individual influenza viruses contain two different virus-coded surface antigens, known as the haemaglutinin and the neuraminidase. Webster and Laver (1972) suggest that because the haemaglutinin of Hong Kong virus is completely different from the preceding Asian strains, such a great difference is not likely to have arisen by mutation. It seems more likely that the new Hong Kong virus arose by recombination. An animal or avian virus could have donated the haemaglutinin of A/Hong Kong/1/68 and the neuraminidase could have come from the human A/Asian strain. This sort of genetic recombination can be produced in live animals under experimental conditions. Since this kind of recombination can occur in laboratory animals it could occur in nature.

Avian influenza is caused by type-A viruses and infects both wild and domestic species around the world. Depending upon the virus strain, host species, and age of bird infected, avian influenza produces symptoms ranging from a drop in egg production to extraordinarily high mortality (Beard, 1970). The virus A/tern/South Africa/61 caused very severe disease in terns, with mortality running into the millions (Becker, 1966). The epizootic in terns was first noted because of the high mortality, but high mortality rates are probably an exception. Becker (1966) suggested that wild birds might act as inapparent carriers of avian influenza viruses. This has since been demonstrated by Homme and Easterday (1970), who showed that exposed ducks were infected for two weeks, long enough to carry the virus long distances and transmit the infection to wild and domestic birds along the way.

Antibodies specific for type-A influenza viruses have been demonstrated by serological surveys of wild birds in the U.S., Australia, and the USSR (Slemons et al., 1974). At least 100 distinct types of avian influenza virus have been isolated from various bird species with signs of respiratory illness or from flocks showing mortalities of unknown origin. Influenza viruses in birds not only affects the upper respiratory system, but also causes a drop in egg production, fertility, and hatchability. Experiments have indicated that strains of avian influenza have a marked effect upon the reproductive systems of birds (Samadieh & Bankowski, 1970). Kleven et al. (1970) reported chalky-white, unpigmented, soft-shelled eggs increased up to 30% when breeding flocks are struck by influenza. The effect of influenza upon wild bird population reproduction is completely unexplored (see above discussions of egg pathologies, in Egg Loss section)

Environmental factors can play a very important role in infection and disease, and it is here we relate influenza and offshore petroleum development. Studies have revealed that more severe manifestations of influenza result from interactions of virus and other factors, particularly cold stress. For instance, apparently recovered birds stressed by chilling show further infection as measured by virus isolations and rises in antibody titers (Homme et al., 1970). There was a consistent correlation between cold stress and disease; birds subjected to low ambient temperatures developed much more severe, chronic virus disease. Petroleum exposure is known to lead in hypothermia in birds (McEwan & Koelink, 1973). Logically petroleum exposure could lead to the onset of virus disease. We point out the complete lack of information concerning the interactions between petroleum exposure, hypothermia and disease, especially in seabird populations in northern seas. (See above Chick Mortality section for a discussion of weather factors on survivorship).

Avian influenza viruses can be dispersed by migrating birds. Becker (1966) suggested that some species of seabirds carry virus in a latent state. Under stress, such as stormy weather, or oil exposure, the viruses become active, resulting in epizootics. During migrations, seabirds with active virus infect susceptible species with which they come into contact. Rosenberger et al. (1974) isolated type-A influenza viruses from migratory waterfowl. In this study, the cloaca appear to be a better site than the trachea for isolations of the virus. If the cloaca or feces are a prime site of influenza isolations, this is an important implication for dissemination of these viruses.

Sera collected from seabirds in the northern USSR, among which were Herring Gulls, have shown antibody activity not only to avian influenza virus but also to A/Hong Kong/1/68 (Zakstel'skaja et al., 1972). Webster and Laver (1972) found sera from Australian pelagic birds specifically inhibited the neuraminidase of Asian/57 strain of human influenza, in addition to the neuraminidase of A/Hong Kong/1/68, indicating presence of specific antibodies to these viruses. The antibodies to A/57 neuraminidase were found in sera of Short-tailed Shearwaters (Puffinus tenuirostris) and several other species. Webster and Laver (1972) suggest that these birds exchange avian influenza virus from areas in the Northern Hemisphere with Australian coastal waters. The Short-tailed Shearwaters possessing antibody to A/57 neuraminidase are known to migrate around the Pacific from Australia to the Bering Strait off Alaska (underlining mine), returning to Australia (Webster & Laver, 1972).

Slemons et al. (1974) showed that ducks in the California Flyway, which includes Alaskan birds, are involved in the natural history of type-A influenza viruses, and that the migration patterns and daily foraging flights provide one mechanism by which the viruses can be transported over long distances and be disseminated at each stopping place. Multiple strains of virus circulating simultaneously in bird populations provide excellent conditions for genetic recombination in nature. Thus wild birds play an important role in the dissemination of type-A influenza viruses, and may provide conditions for genetic interaction of type-A viruses of both human and animal types, resulting in new hybrid strains.

Experimental Challenge of Gulls with Human Influenza

To test susceptibility of partially immune and non-immune gulls to human influenza virus, Messrs. J. Klein, M.Sc., J. Markowitz, M.Sc., and S. Patten, M.Sc., under the direction of I.L. Graves, DVM, innoculated two species of gulls (Larus argentatus and Larus delawarensis) with the virus Influenza A/Port Chalmers/1/73 (H3N2), a recent human strain. Both test animals had been caught in the wild and maintained in captivity in Johns Hopkins Animal Facilities. The Herring Gull showed a weak antibody titer in serum (1:16) prior to laboratory challenge; the Ring-billed Gull showed no such titer. The presence of antibodies specific to Port Chalmers influenza in the Herring Gull serum was confirmed by Radial Diffusion (Ouchterlony) test, and replicated three (3) times. The gull could have been exposed previously to the influenza strain in the wild or in captivity.

Under experimental conditions, both gulls were innoculated intranasally and into the trachea with .2cc undiluted stock virus. Under normal circumstances influenza is spread by droplet (respiratory) transmission.

Incubation period is one to three days. Characteristically an abrupt onset of disease follows, indicated in humans by chills, fever, headache and myalgia. Recovery of uncomplicated cases begins three to four days after onset of symptoms. Immune-competent individuals should be able to mount a response to an influenza infection within five days. Passage of the test virus used in this experiment through embryonated chicken eggs showed the strain to be very infectious to the 10^{-7} dilution.

Four days after the initial challenge with the virus, the non-immune gull was found dead. The first day post-challenge, the gull showed a slight rise in temperature. On the third day the gull still exhibited good reactions and normal behavior. Gross pathology observed in autopsy was consolidation of the lower left lung (evidence of a pneumonia-like infection). Heart, brain, kidneys, lung and liver were cultured for bacteria with mostly negative results. Only the brain evidenced presence of a slight bacterial growth, likely a post-mortem occurrence.

Five days post-challenge with the virus, the partially immune Herring Gull showed poor behavior, with nyctitating membrane fibrillation (CNS symptom), loss of weight, cyanotic soft-parts (pneumonia-like symptoms), and died with a very acute illness on the evening of the fifth day. Autopsy revealed no lung consolidation, air sacks asymptomatic, no tracheal blockage or other gross pathology other than infestation with mallophaga. Bacteria were cultured on nutrient agar plates from several organs, indicating possible bacteremia.

Tissue specimens from trachea, pharynx and internal organs were cultured for viruses and passed again through egg and tissue culture to determine which organs were virus-positive. Virus recovery was confined to specimens from the upper respiratory tract of both birds, suggesting a response similar to the course of fulminating human influenza infections.

Influenza Virus Antibody Assay

To answer the question of whether gull populations in the northeast Gulf of Alaska have been exposed to Type-A influenza viruses, we performed a series of tests on gull sera collected during the course of this investigation.

Methods involved the use of multiple-well Single Radial Diffusion Plates supplied by WHO with the following antigens in gel medium: 1) Bel RNP (all influenzas); 2) A/Chick "N" Ger RNP (all avian influenzas); and 3) A/Hong Kong/68 (a human influenza).

Results are as follows: 1) Adult gull sera (n=19) ran against Bel RNP (all influenzas) showed 5% exposure to influenza virus of unspecified nature. Positive serum was from an adult gull breeding at the Alsek River (Dry Bay) in 1975. 2) Gull chick sera (n=56) collected from the large population at Egg Island in 1976 and ran against A/Chick "N" Ger RNP (all avian influenzas) gave positive antibody response in 7% of the cases and a weak response in 1.7% of the cases. 3) In the initial run against the A/Hong Kong/68 antigen (human influenza), 16% of the adult gull sera (n=19) showed positive antibody response. These reactive sera were from adult gulls collected at Egg Island and Dry Bay. However, on the second run against the HK antigen, the previous positives did not react, giving equivocal results. On the third run, 9.5% of sera collected from adult gulls breeding at Egg Island in 1975 (n=21) indicated some response to the Hong Kong antigen, forming precipitin rings around the wells in which the sera had been deposited. These precipitin rings were not as strong as the positive control, suggesting either a weak antibody response, exposure at some time in the past with subsequent decreasing antibody titer, or cross-reactivity with another influenza antigen.

These results to date indicate avian influenza is present in the NEGOA gull populations and some exposure to a Hong Kong or similar antigen.

Newcastle Disease Virus Antibody Assay

Newcastle disease virus (NDV) is considered a pathogen for most avian species (Hanson, 1972). Newcastle disease can be a mild illness with transient respiratory signs or it can be fatal with severe respiratory and neurological symptoms (Beard and Brugh, 1975). It can also cause hemorrhage and necrosis of the intestinal tract (Beard and Brugh, loc. cit.). Bradshaw and Trainer (1966) gave evidence of NDV infection in wild ducks and Canada geese by demonstrating hemaglutination-inhibiting (HI) antibody in 14-17% of birds tested. Palmer and Trainer (1970) reported 31% of Canada goose sera contained antibody to NDV. Rosenberger et al.(1974) described isolation of NDV from several species of migratory waterfowl. The cloaca or feces may be a prime site of virus isolations in migratory waterfowl, with implications for dissemination (Rosenberger et al., 1974).

We observed three dead or dying immature Black-legged Kittiwakes and many Glaucous-winged Gull chicks in the meadows on Egg Island; the kittiwakes and some gull chicks showed no external injury (see Chick Stage and Mortality Factors, above). The kittiwakes were totally unexpected in the meadows since they are cliff-nesters and pelagic feeders. In the Hopkins laboratories we are examining an adequate sample (250) of sera from Egg Island gull chicks for evidence of common virus diseases, among which is NDV. We are using the HI test, which is the most convenient, rapid and economical method for evaluating antibody titer to NDV (Beard and Brugh, 1975).

Our procedures are as follows: all sera are heat-treated at 56°C for 30 minutes to remove non-specific inhibitors; positive control is NDV hyperimmune chicken antisera; negative control is normal chicken serum (both controls heat-treated 56°C, 30 min.). HI tests are performed on microtiter plates using 0.5 or 1.0% chicken red blood cells in buffered saline. In the initial screening antibody activity has been detected in 8 of 125 sera (6.4%). We are continuing our examination of these sera and suggest an NDV strain in this gull population.

Botulism, Toxoplasma, and Q Fever Antibody Assays

Gull sera from the Northeast Gulf of Alaska, collected as part of the NOAA OCSEAP RU96 research program, were further examined for antibody titers against botulism, toxoplasma, and Q Fever, animal-borne diseases which can be transmitted to humans. The antibody testing was conducted on a cooperative basis by the Department of Epidemiology and Preventative Medicine of the School of Veterinary Medicine, University of California, Davis.

All Alaskan gull sera examined were negative for antibodies against botulism. Investigators in Denmark reported isolating botulism bacteria from gulls that fed in brackish waters of the North Sea. However, the Danish researchers failed to find antibodies to the botulism bacteria. The lack of antibodies with the bacteria present is an unusual situation. More work needs to be done on the resistance of gulls to botulism toxins (Behymer, pers. comm.).

The Davis group tested 61 Alaskan gull sera, both chick and adult, for antibodies against toxoplasma and Q Fever. All 31 chick sera were negative to both antigens. However, of 30 adult gull sera tested, 4 (13%) were positive for toxoplasma.

The sera identification numbers, location of collection, titers and dates of collection are presented in Table 1 .

Table 1 . Toxoplasma Titers in Alaskan Gulls

Site	Sera ID #	Titer	Date
Egg Island	EI 40	(1:64)	July 10, 1975
Egg Island	EI 44	(1:256)	"
Egg Island	EI 44 (duplicate)	(1:4096)	"
Dry Bay	AR 37	(1:2048)	June 30, 1975
Cordova docks	CO 50*	(1:128)	July 12, 1975

*Note: gull CO 50, collected on the Cordova Ocean Docks, Cordova, Alaska, at the canneries and fish-processing plants, had antibody titers to both toxoplasma and Q Fever.

There were also low titers against Q Fever in 7 of 30 adult gulls (23%) as follows in Table 2 .

Table 2. Q Fever Titers in Alaskan Gulls

Site	Sera ID#	Titer	Date
Egg Island	EI 45	(1:2)	July 10, 1975
Egg Island	EI 46	(1:2)	"
Egg Island	EI 47	(1:2)	"
Dry Bay	AR 33	(1:2)	June 30, 1975
Dry Bay	AR 34	(1:2)	"
Dry Bay	AR 40	(1:2)	"
Cordova docks	CO 50*	(1:4)	July 12, 1975

*See previous table for note regarding CO 50.

Here follows a brief discussion of toxoplasmosis and Q Fever.

Toxoplasmosis is a sytemic protozoan disease. A primary infection in human females during the early gestational period of pregnancy may lead to death of the fetus; later infection to chorioretinitis, brain damage with intracerebral calcification, hydrocephaly, microcephaly, fever, jaundice, rash, hepatomegaly and splenomegaly. The occurrence of this disease is worldwide in animals and man. Infection in man is common but clinical disease exceptional. The infectious agent is Toxoplasma gondii, an intracellular coccidian parasite belonging to the Sporozoa and closely related to the Isosporoa. The taxonomy and complete life cycle of this parasite are uncertainly known. Birds and mammals appear to be intermediate reservoir hosts of T. gondii (APHA, 1975).

Q Fever is an acute febrile-rickettsial disease; onset may be sudden. A pneumonitis occurs in most cases, with cough and chest pain. Chronic endocarditis, hepatitis, and generalized infections have been reported. This disease is endemic in many areas. The infectious agent is Coxiella burneti, an organism with unusual viability in the free state. Wild and domestic animals are the reservoir hosts, with infection inapparent. The mode of transmission is commonly by airborne dissemination of ricketssiae in dust or near premises contaminated by placental tissues, birth fluids and excreta of infected animals. The disease is also contracted by direct contact with infected animals or other contaminated materials. Susceptibility of humans is general (APHA, 1975). The scavenging of seal placentae by gulls may link these birds to the natural cycle of this disease.

SUMMARY

Alaskan gulls, associated with sewage outfalls and cannery effluent, are implicated with the transmission of Salmonella, an enteric disease, and in the dissemination of human cestode and nematode parasites. The Ketchikan Salmonella epidemic, in which over 100 persons sought medical treatment, emphasizes the need for proper and adequate sewage disposal systems preventing the contamination of gulls with disease organisms transportable to public water or food supplies. Gulls are demonstrated to be susceptible to human influenza strains, and to display antibody titers to avian influenzas, Newcastle Disease virus, toxoplasma, and Q-fever. A review of the literature on avian influenzas indicates a complete lack of information concerning interactions between petroleum exposure, hypothermia, and onset of virus disease, particularly in seabird populations in northern seas.

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PART IV

Effects of Petroleum Exposure on the Breeding Ecology of Gulls and Kittiwakes

Table of Contents

List of Tables

List of Figures

Objectives and Rationale of Petroleum Exposure

This research is addressed to the following task: an analysis of the effects of petroleum exposure on the breeding ecology, including incubation behavior and hatching success, of the Gulf of Alaska Herring Gull group (*Larus argentatus* x *Larus glaucescens*) and on Black-legged Kittiwakes (*Rissa tridactyla*).

The devastating effects of massive oil spills on seabird survival are widely reported, but little is known of the effects of low-level oil pollution on avian reproduction (Grau *et al*., 1977). Previous studies of petroleum effects on seabird eggs suggest hatchability is markedly reduced (Gross 1950; Birkhead *et al*., 1973; Patten & Patten, 1977). Rittinghaus (1956) and Hartung (1963, 1964, 1965) reported that marine birds contaminate eggs with oil from the environment and hatching success of eggs thus exposed to petroleum was markedly reduced even after extended periods of incubation. Abbott, Craig and Keith (1964) suggested that oil interfered with normal respiratory exchange through the eggshell, while Szaro and Albers (1976) found hatching success of eider (*Somateria mollissima*) eggs was significantly reduced by microliters of petroleum exposure, that is, very small quantities. Patten and Patten (1977) have recently found unweathered North Slope Crude Oil 22 times more toxic than equivalent amounts of mineral oil under field conditions. Grau *et al*. (1977) have confirmed in laboratory experiments that small amounts of bunker C oil significantly depress bird reproduction. Indeed, oil exposure has been used in the past to control gull populations along the Eastern Seaboard of the United States and in several western U.S. wildfowl refuges (Gross, 1950; R. King, USF&WS, pers. comm.).

In summary, literature on the effects of oil exposure on the reproduction of marine birds is limited. Studies that do exist suggest high toxicity of petroleum to eggs, and marked effects upon the reproductive productivity of females. Complete knowledge of the effects of petroleum exposure in various forms is needed to evaluate and predict the full impact of oil pollution on the annual productivity of marine bird populations.

This current research is to provide information on the effects of both weathered and "raw" North Slope Crude Oil on the hatching success and incubation behavior of key seabird species nesting on Alaskan islands in proximity to Valdez tanker lanes and offshore oil lease areas.

Species examined are Herring Gulls (*Larus argentatus*) and Glaucous-winged Gulls (*Larus glaucescens*), which are common inshore and marine scavengers nesting in colonies and Black-legged kittiwakes (*Rissa tridactyla*) common pelagic feeders nesting on cliffs. The study sites are the largest gull colony in the northeast Gulf of Alaska, Egg Island, located 10 km SE of Point Whitshed and 20 km south of Cordova (60° 23' N, 145° 46' W), Dry Bay, 75 km SE of Yakutat (59° 10' N, 138° 35' W), and Middleton Island, 130 km S of Cordova (58° 24' N, 146° 19' W).

Our research objectives are thus defined as:

(1) to determine threshold levels of petroleum effects to gull and kittiwake reproduction under field conditions, including both "raw" and weathered oils,

(2) to test alteration of incubation behavior and ability to

produce second (replacement) clutches following experimental mortality due to petroleum exposure,

(3) to analyze gull and kittiwake population ecology in order to determine factors influencing "normal" reproductive success in other colonies in the northeast Gulf of Alaska.

NOTE: Study areas and itinerary are discussed in Part I (Evolution Section) with the exception of Middleton Island (see below).

Materials and Methods of Petroleum Exposure

Our methods include analysis of reproductive productivity at a series of nest sites marked with survey flags. Petroleum exposure to eggs is by drops from microliter syringes with repeating dispensers, with equivalent amounts of non-toxic mineral oil applied to a control sample. Reproductive success/mortality is compared to further controls of "normal" (unexposed) colonies adjacent to the experimental areas. The use of microliter syringes allows for precise manipulation of tiny amounts of petroleum exposure, which is in 20, 50, and 100 microliter doses at three (3) stages of incubation. Petroleum used is North Slope Crude Oil provided by NMFS Auke Bay Laboratory, with commercially available mineral oil as the control.

Experimental results are compared to the standards previously established for "normal" Alaskan gull reproduction (Patten, 1974; Patten & Patten, 1975, 1976, 1977). Egg loss through conspecific predation has been the principal factor influencing hatching success and fledging rate in previous studies.

Results of Petroleum Exposure to Eggs

To determine threshold levels of petroleum exposure to gull reproduction, we conducted an oiling experiment in a colony at Dry Bay, mouth of the Alsek River, 75 km SE of Yakutat, Alaska. The oil experiment was carried out in an experimental area adjacent to controls known as 'A' and 'B' colonies. Receptors were a mixed group of Glaucous-winged x Herring Gulls (Table 4).

Table 1

Petroleum Exposure Parameters

Sample size		Dose	Date	Approx. Day of Incubation
10 nests	30 eggs	20ul	24 May	1
20 nests	60 eggs	50ul	1 June	8
20 nests	60 eggs	100ul	4 June	11

Petroleum Exposure Results

Table 2

Nests 1 - 10   Time: Onset of Incubation

Dose: 20µl	30 eggs	Date: 24 May	
9/30	=	30%	hatch
6/30	=	20%	"lost" (predated)
15/30	=	50%	failed to hatch

Table 3

Nests 11 - 30   8th day of Incubation

Dose: 50µl	60 eggs	Date: 1 June	
16/60	=	27%	hatch
14/60	=	23%	"lost"
30/60	=	50%	failed to hatch
early (1-2 days) chick mortality 3/60 eggs	=	5%	

Table 4

Nests 31 - 50   11th day of Incubation

Dose: 100µl	60 eggs	Date: 4 June	
41/60	=	68.3%	hatch
11/60	=	18.3%	"lost"
8/60	=	13.3%	failed to hatch
early (1-2 days) chick mortality 2/60 eggs	=	3%	

KNOWN EGG LOSS, DRY BAY 1977
EXPERIMENTAL AND CONTROL COLONIES

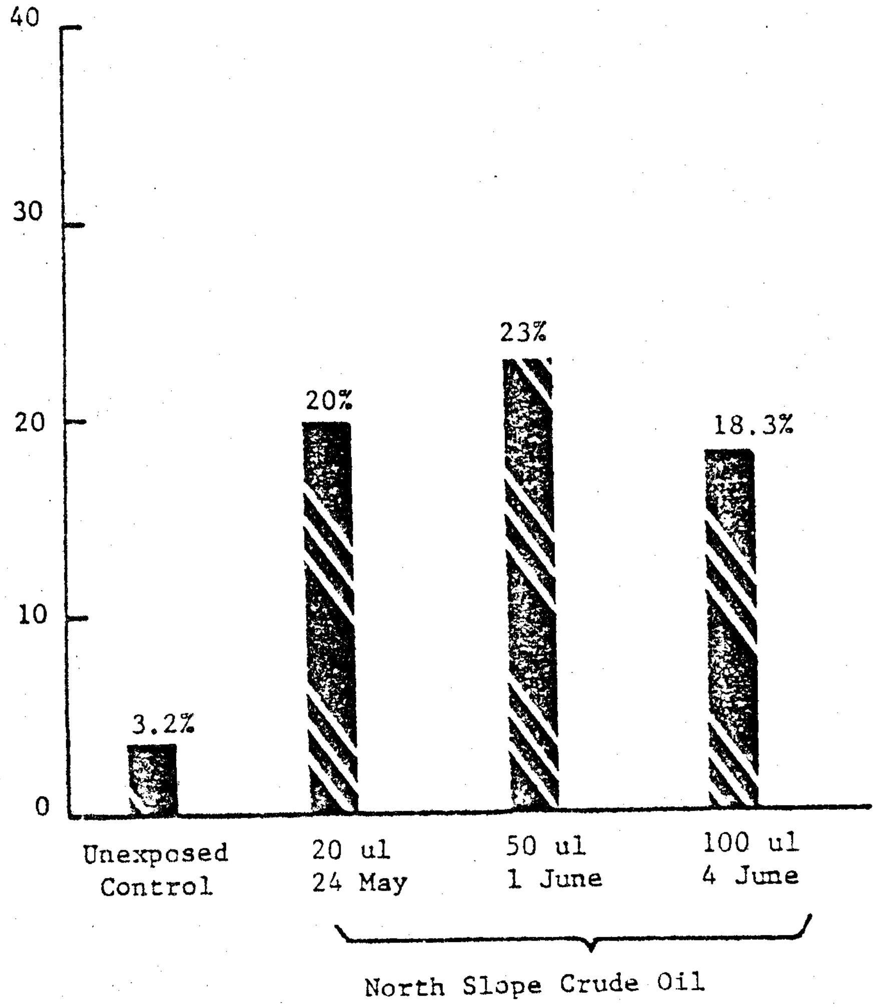


Figure 1

PERCENTAGE EGGS REMAINING IN NESTS (FAILED TO HATCH)
IN EXPERIMENTAL AND CONTROL COLONIES, DRY BAY, 1977

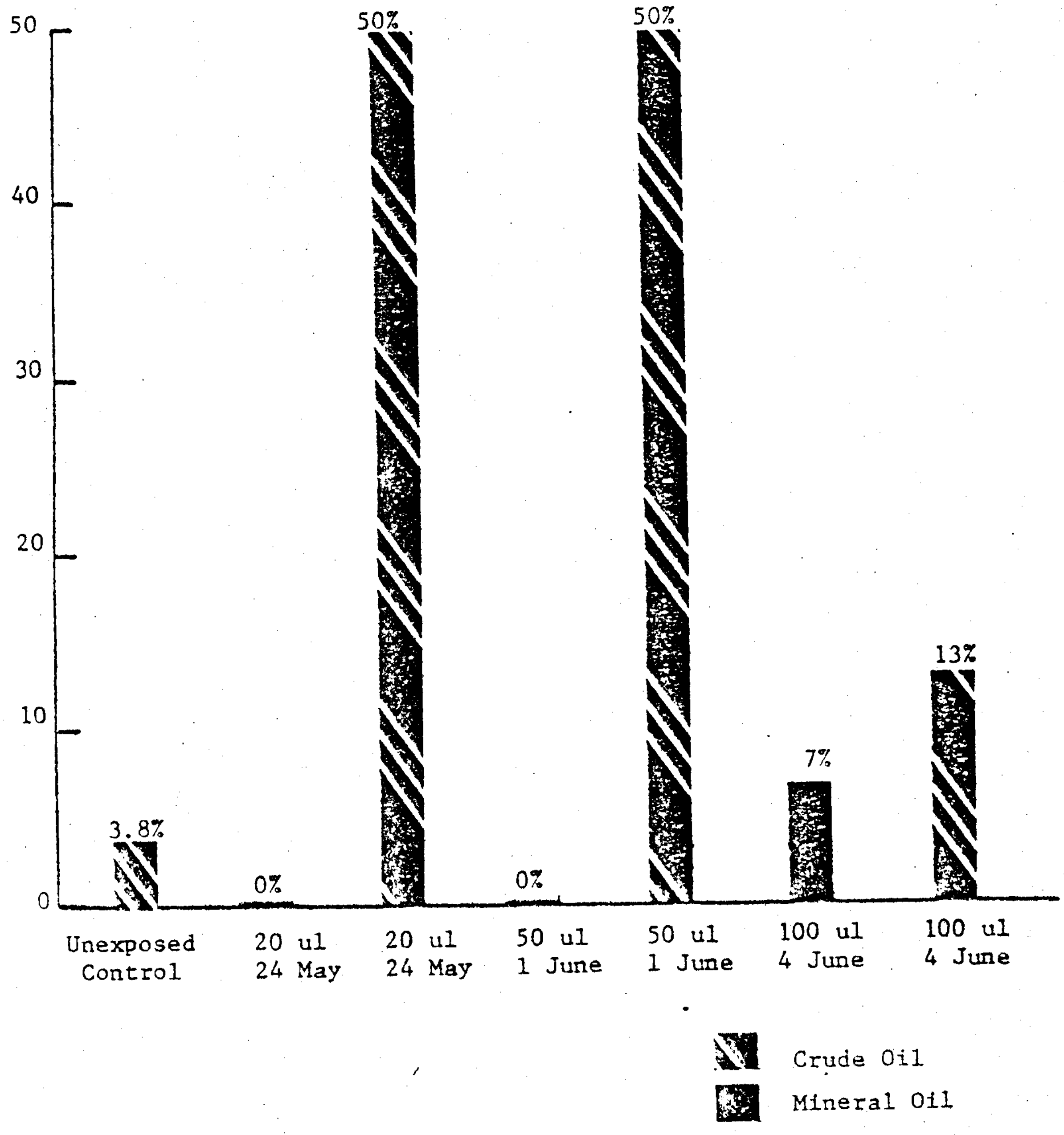


Figure 2

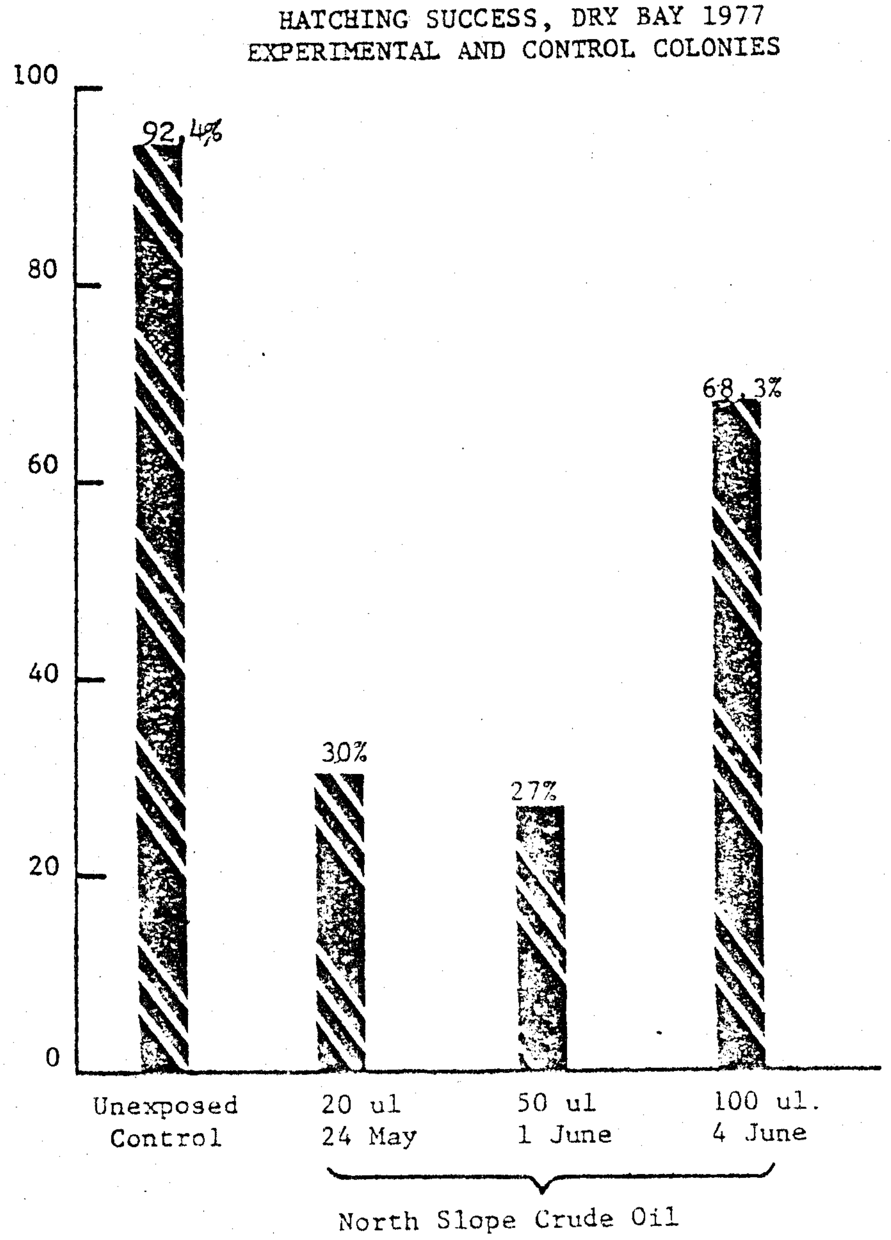

HATCHING SUCCESS, DRY BAY 1977
EXPERIMENTAL AND CONTROL COLONIES
100
80
60
40
20
0
92.4%
30%
27%
68.3%
Unexposed Control
20 ul 24 May
50 ul 1 June
100 ul. 4 June
North Slope Crude Oil

Figure 3

Table 5

Mineral Oil Experiment

7th day of incubation

Nest #	# Eggs	Dose in ul	Failed to Hatch (Eggs Remaining)	Chick Mortality (Known)
51	3	20	0	
52	3	20	0	
53	3	20	0	
54	2	20	0	
55	3	20	0	
56	3	50	0	
58	3	50	0	
59	2	50	0	
60	2	50	0	
61	3	100	0	
62	3	100	0	
63	2	100	0	
64	2	100	0	
65	3	100	1 died pipping	1 dead chick (5 days)
15 nests	40 eggs	3 different doses	mortality not significant	

Our conclusions from the above experiments are: very small amounts of North Slope Crude Oil exposure to gull eggs in the field, at early stages of incubation, lead to high embryonic mortality (Tables 5 , 6). Embryonic resistance to petroleum exposure increases with the duration of incubation (Table 7). Mineral oil in equivalent microliter doses causes no significant mortality (Table 8).

Results of Egg Petroleum Exposure on Incubation Behavior

To test alteration of incubation behavior and ability to produce second (replacement) clutches following experimental egg mortality due to petroleum exposure, we conducted the following experiment: at Egg Island, the largest gull colony in the northeast Gulf of Alaska, located 20 km south of Cordova, we chose our experimental and control areas to coincide with our established study site (RU #96 - 76). There were 75 nests in the experimental area, compared to 186 in the adjacent "normal" control colony. The experimental and control areas are located on the ocean slope of stabilized meadow-covered dunes at the east end of Egg Island in proximity to the U.S. Coast Guard Light Tower (Figures 9,10, 11).

Oil was delivered to completed clutches of three eggs at the tenth day of incubation. Fifty clutches (150 eggs) received 1 cc/egg surface application of North Slope Crude Oil, and 25 clutches (75 eggs) received the identical does of mineral oil. Both treatments were delivered by drops from calibrated syringes. The initial dose was selected to be well below the lethal level of oiling for adult waterfowl (7.0 - 3.5 gms) reported by Hartung (1963), but is nearly completely lethal for eggs. Most evidence of petroleum exposure <u>disappeared the next day</u> except for slight petroleum odor.

Observed clutch size in the oiling experimental area initially declined at a rate compatible with normal predation from other gulls (Fig. 23), but in July egg loss accelerated

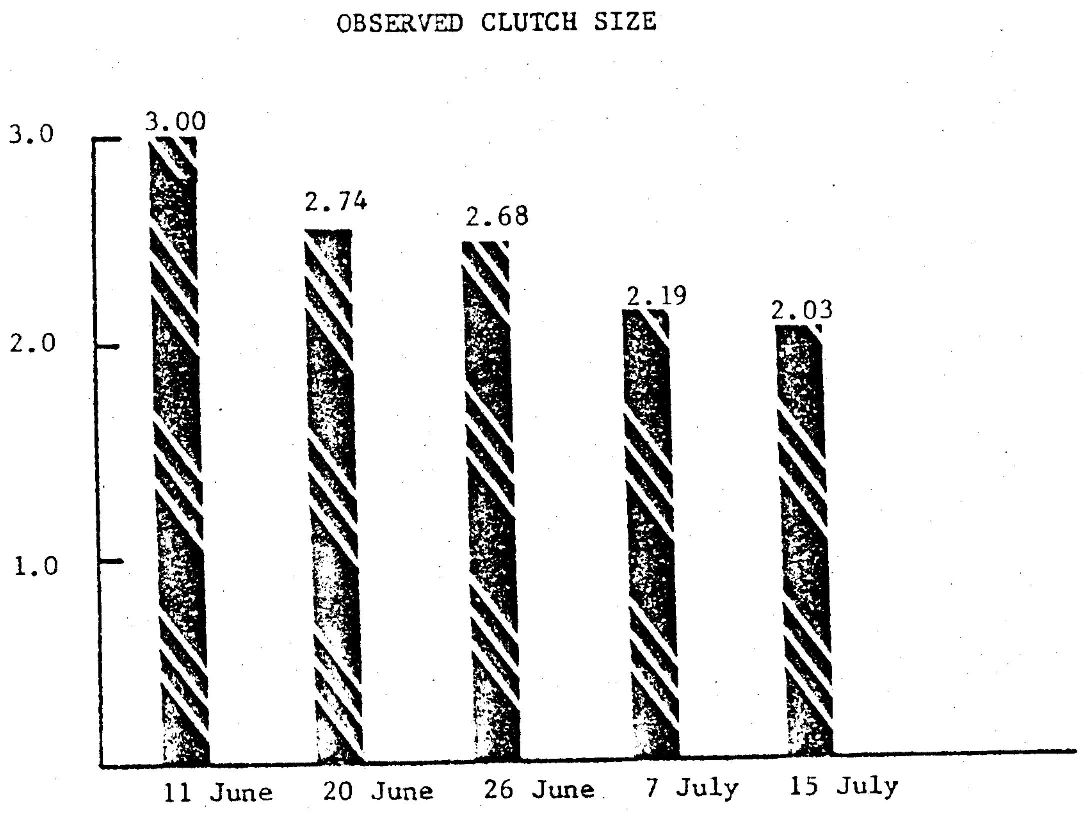


Figure 4. Observed clutch size in the oiling experimental area initially declined at a rate compatible with normal predation from other gulls.

due to adult gulls abandoning unhatched clutches after incubation prolonged 100% longer than normal. At this time we terminated the experiment. A month after hatching began in the adjacent control colony, 33% of eggs oiled with North Slope Crude and 24.4% of eggs to which mineral oil had been applied remained in the nests on 15 July. These figures can be compared to 2% of eggs in the adjacent control area remaining in nests at the end of incubation, a "normal" infertility rate (Figs. 24, 25).

Hatching success in eggs exposed to this nearly completely lethal dose of North Slope Crude was 0.67% (Fig. 26). Mineral oil applied in equivalent amounts to gull eggs led to a hatching rate of 14.6%. North Slope Crude Oil is thus calculated to be 22 times more toxic than equivalent amounts of mineral oil. Hatching success in the adjacent "normal" control colony was 77%; the normal range for these gulls in Alska is 67% - 77%. Adults continued to incubate almost all unhatched clutches at least 20 days longer than normal. Eggs opened at the close of the experiment were highly decomposed and no living embryos were found. Adult gulls nesting in the oiling area produced no more replacement clutches than the neighboring control colony (4.0% vs. 4.8%) (Figs. 28, 29).

Gull behavior is thus altered by the continued incubation of dead eggs. Adults fail to respond with the normal production of replacement clutches, which normally follow clutch loss to natural causes. The combination of high egg mortality and alteration of adult behavior virtually eliminated gull reproduction in the experimentally oiled area.

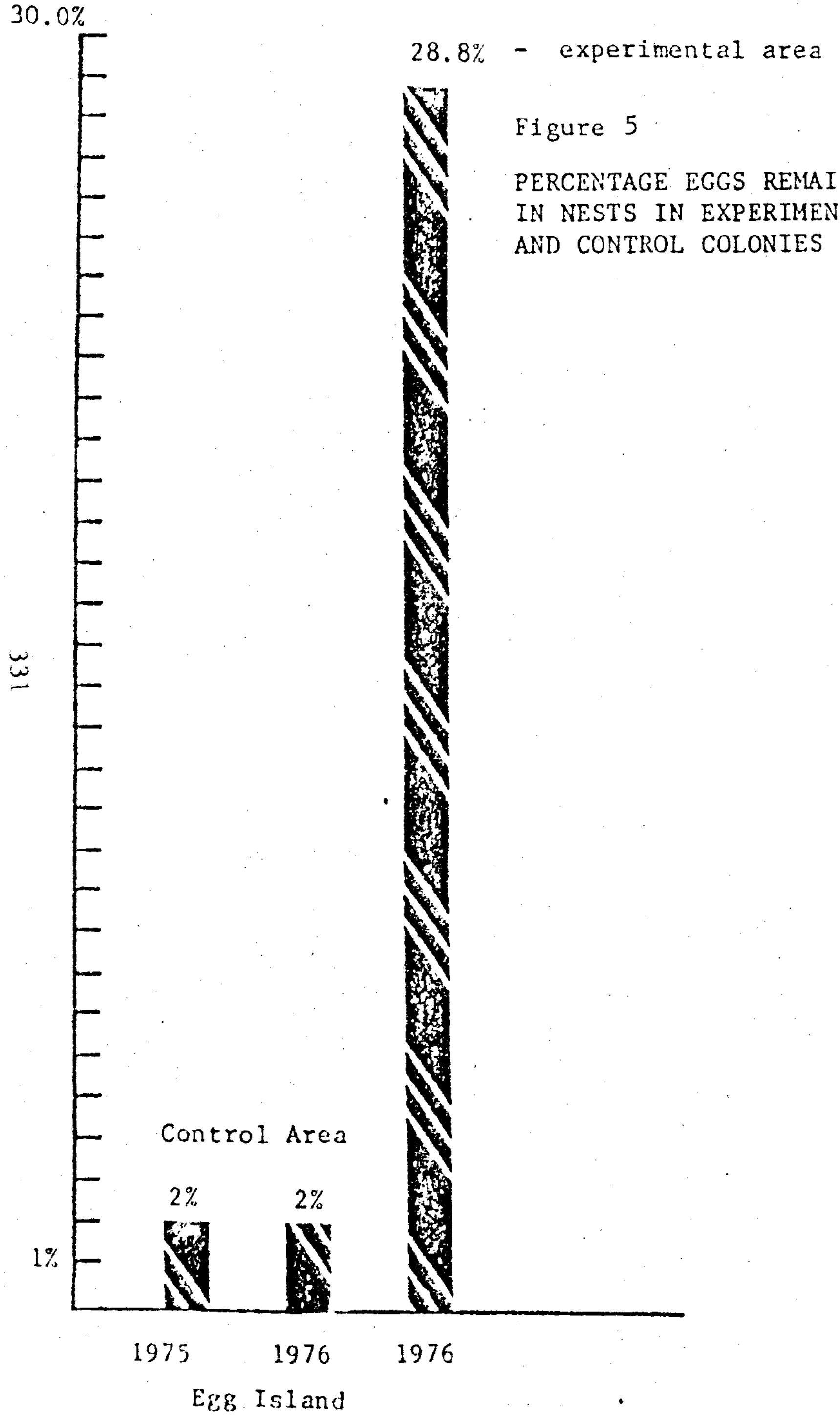


Figure 5

PERCENTAGE EGGS REMAINING IN NESTS IN EXPERIMENTAL AND CONTROL COLONIES

Figure 5. Percentage eggs remaining in nests at close of incubation or experimental period, experimental and control colonies, Egg Island, 1975-76.

Figure 6. A month after hatching began in the adjacent control colony, 33% of eggs oiled with North Slope Crude and 24.4% of eggs to which mineral oil had been applied remained in the nests.

Figure 6

PERCENTAGE EGGS REMAINING IN NESTS WITH NS CRUDE OR MINERAL OIL

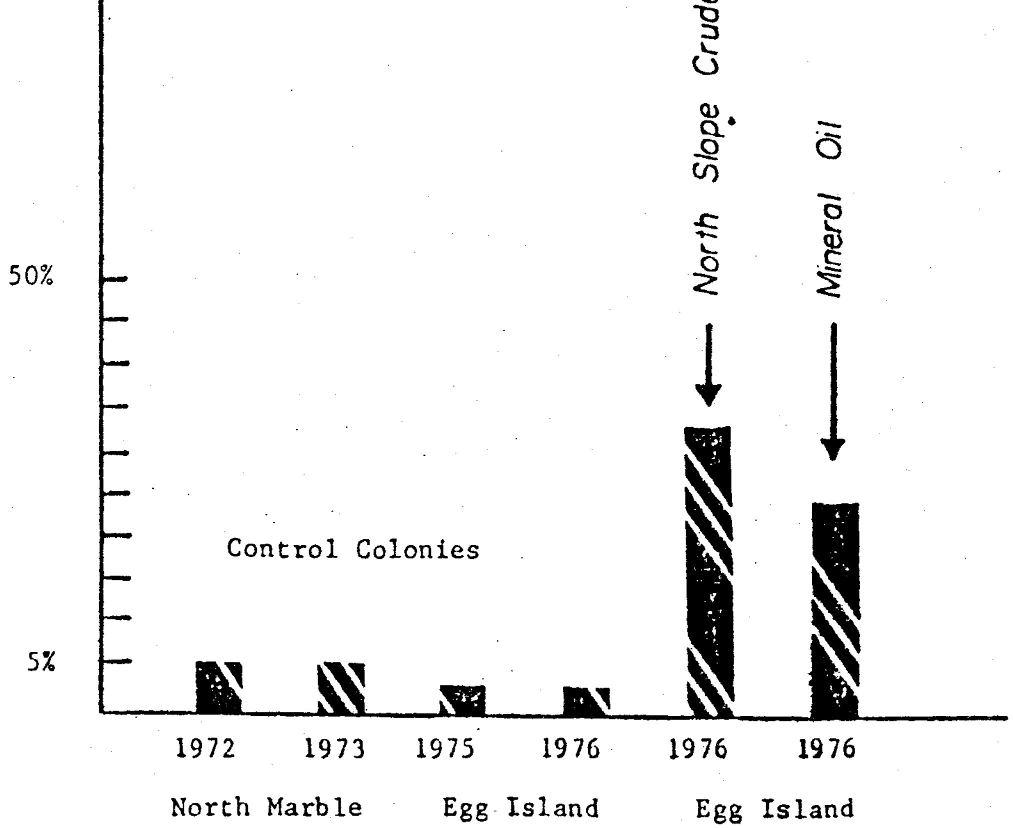


Figure 7

HATCHING SUCCESS

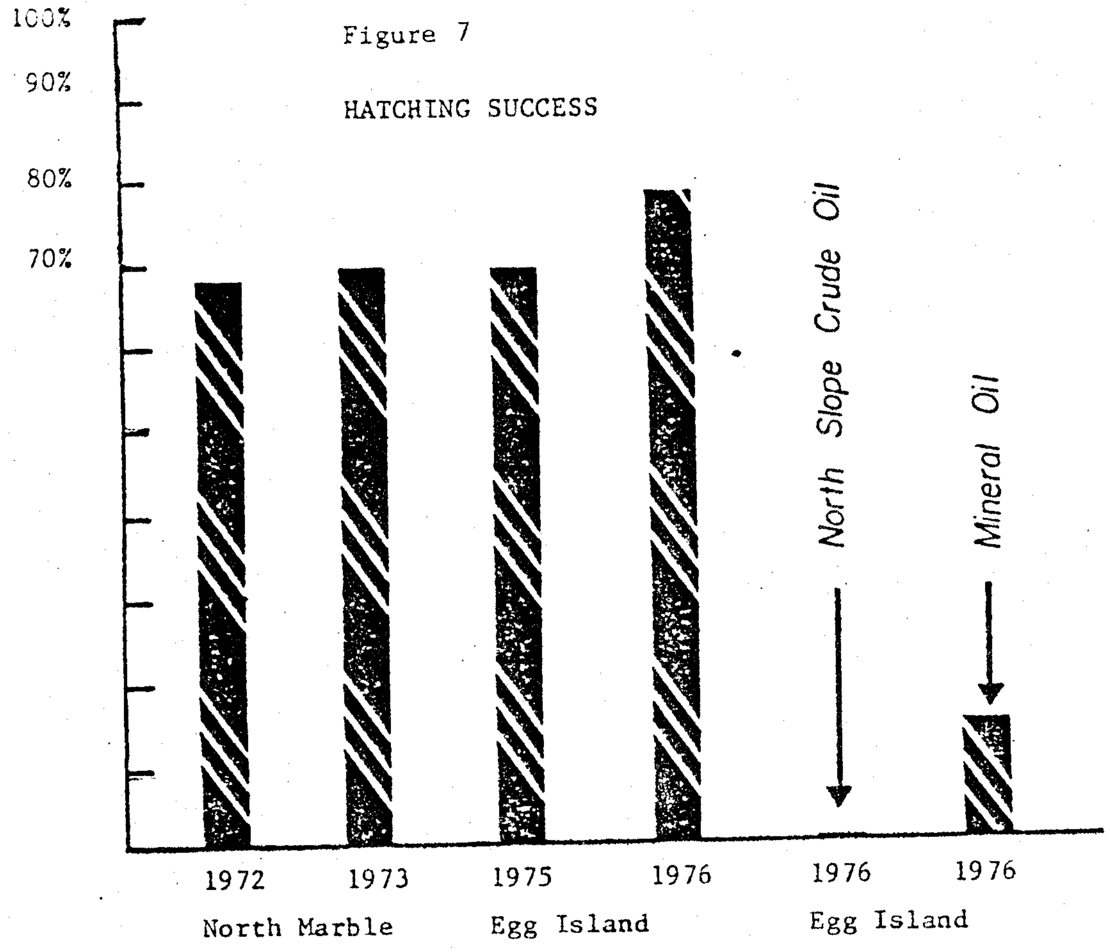


Figure 8

KNOWN EGG LOSS

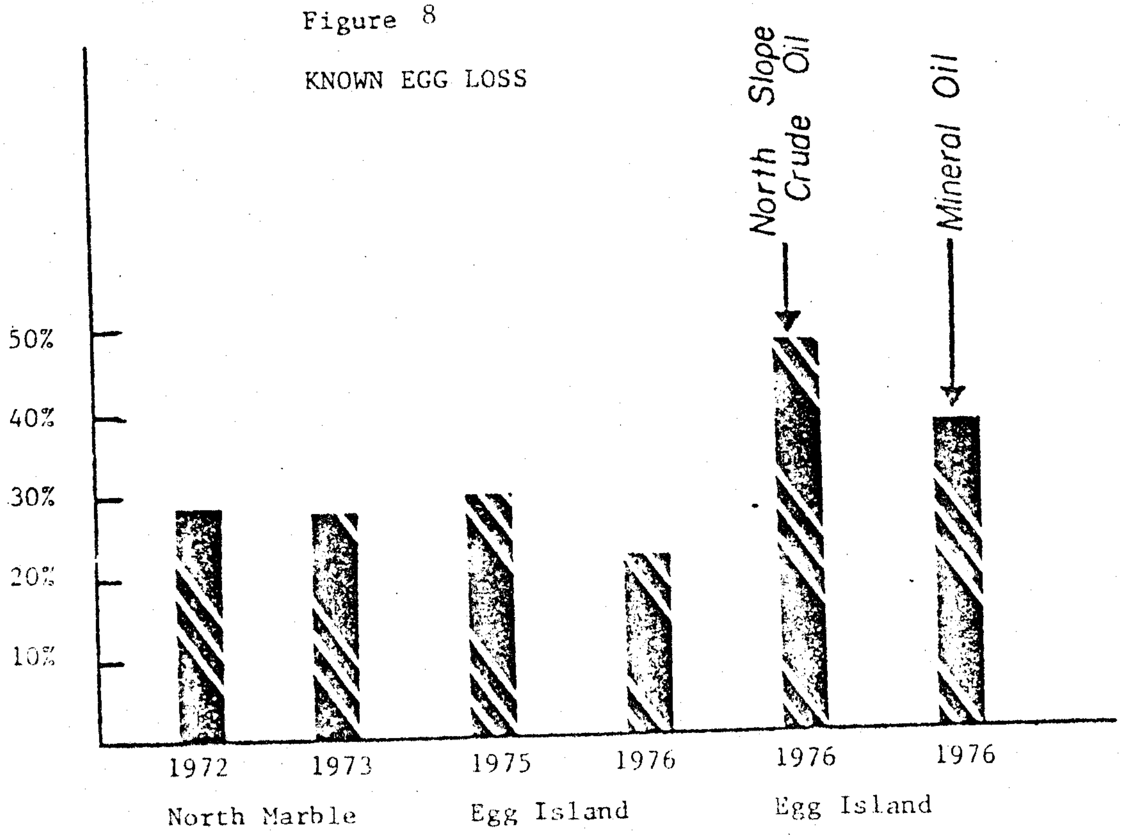


Figure 9

MEDIAN INCUBATION PERIODS, EXPERIMENTAL AND CONTROL COLONIES

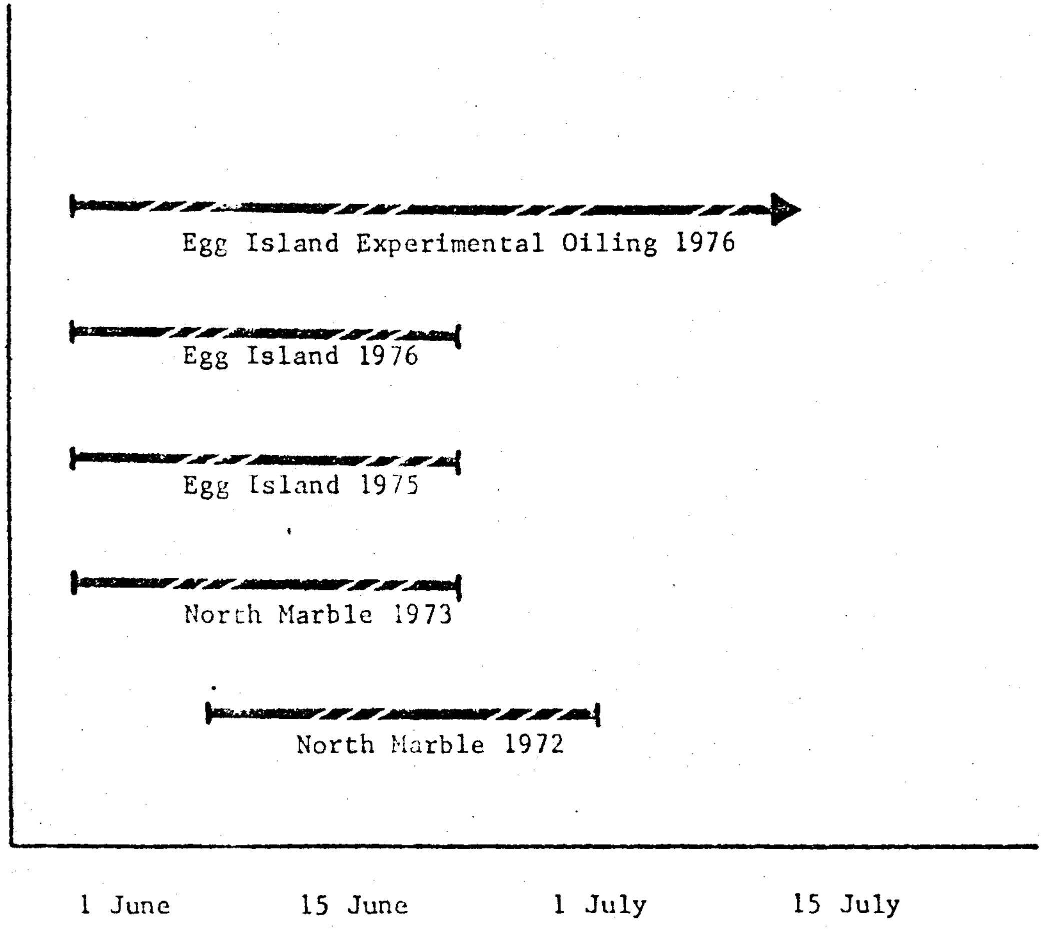
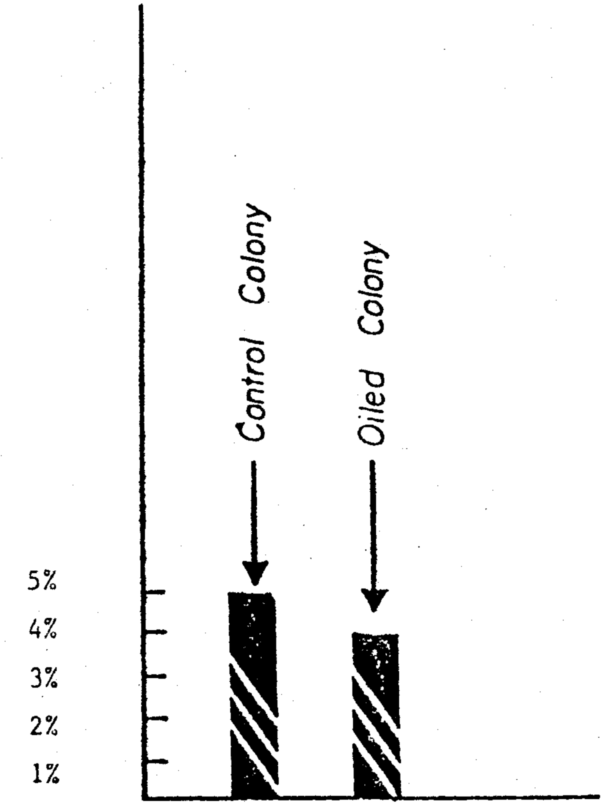


Figure 10

PERCENTAGE REPLACEMENT CLUTCHES, EXPERIMENTAL AND CONTROL COLONIES



MIDDLETON ISLAND STUDY AREA

Middleton Island (58° 24' N, 164° 19' W) lies in the Gulf of Alaska, 130 km south of Cordova (Figure 42).* It is situated directly in the Valdez tanker lanes. Oil-laden tankers regularly pass within 20 km west of Middleton Island. Oil spill danger to Middleton Island is considered high (BLM, 1976). For this reason, RU 96, as part of its activities, conducted experiments at this site during the 1978 field season to determine effects of petroleum on marine bird reproduction.

The history of Middleton Island has been reviewed in an anonymous report in FAA and USF&WS (OBS-CE) files; the geology and geography of Middleton Island have been reviewed by Miller (1953); vascular plants by Thomas (1957); occurrence and distribution of birds by Rausch (1958); wintering birds by O'Farrell and Sheets (1962); introduced rabbits by O'Farrell (1965), and the breeding of seabirds by Frazer and Howe (1977).

The island bedrock is composed of Cenozoic glacial conglomerate mud and sandstone, dotted with occasional, large Pleistocene boulders known as "glacial erractics." The surface of the island consists of a series of step-like terraces above former sea cliffs. The terraces originated during earthquake uplifts, which caused the island to rise above sea level at irregular intervals, the last of which was in 1964 when the strong earthquake of that year raised the island level 4.5 m. The eroding cliffs below the terraces are now bordered by sandy and marshy areas above the intertidal. The terraces merge into sand dunes above a sandy spit at the north end of the island. The island gradually gains elevation from north to south. At the southern end, rows of conical to ellipsoidal mounds rise

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* in Part II.

to heights of 6 m above the level of the highest terrace, which is approximately 42.5 m above sea level. The climate on Middleton Island is quite mild, but rainy, with strong winds. Prevailing gales are southeasterly.

The terraces are covered with wet, grass-forb meadows, dominated by Calamagrostris spp., Carex spp., and Heracleum lanatum. Willows (Salix barclayi) and salmonberry (Rubus spectabulus) form thickets on meadow margins and terrace slopes. A few Sitka spruce (Picea sitchensis) are scattered over the island.

The island extends approximately 8 km along a NE - SW axis, is 1.6 km wide, and covers about 890 hectares. The shoreline, nearly completely enclosed by driftwood, reefs, rocks and heavy kelp, offers shelter to small boats only at the north end of the island, immediately west of the FAA communications station. (The FAA station was manned by six persons during the Summer of 1978.) The central portion of the island consists of a gravel airstrip and inactivated U.S. Air Force base, now under private ownership.

Middleton Island was the site of commercial fox farming during the early years of this century (Parker, 1923), but no known foxes remain. Large numbers of feral rabbits (Oryctolagus cuniculus), descended from a few individuals released in 1954, now inhabit the island and cause localized damage to vegetation and soils. The damage is particularly evident in the vicinity of the FAA station, the site of the original introduction. The summer population of rabbits may reach 10,000 individuals.

Among the more numerous seabirds breeding on Middleton Island in 1978 were the Black-legged Kittiwake (Rissa tridactyla) and the Glaucous-winged Gull (Larus glaucescens). Kittiwakes numbered about 120,000 and gulls approximately 2,000 individuals of which FWS estimates approximately 750 breeding gull pairs. Rausch (1958) reported only a few thousand kittiwakes and gulls as non-breeders. Our observations indicate that populations of both species are expanding.

METHODS

We experimented with both kittiwakes and gulls to determine the effects of small amounts of petroleum on their reproductive success. Petroleum used on kittiwakes included both "raw" and weathered Prudhoe Bay (North Slope) Crude Oil. Petroleum used on gulls was weathered oil only. Effects of raw oil on gull reproduction were previously tested by RU 96 - 77. Mineral oil served as the control in both kittiwake and gull experiments. Microliter syringes were used to apply drops of oil in microliter doses to the surface of kittiwake and gull eggs. The doses were applied to the eggs within several days of clutch completion. This time has been demonstrated as being the most vulnerable period for oil contamination (cf. RU 96 - 77).

The kittiwake experiment was thus divided into four treatment groups: "raw" Prudhoe Bay Crude Oil; weathered Prudhoe Bay Crude Oil; Mineral Oil, and Control (no treatment). The weathered oil, provided by Battelle Northwest Marine Research Laboratory (RU 454), was weathered by a combination of light and water parameters. We express our gratitude to RU 454 for the donation of this oil. We selected weathered oil known as "Tank #2" as our experimental substance, since oil from "Tank #1" was too thick to pass through a microliter syringe, and oil from "Tank #3" was not exposed to sunlight in order to reduce photooxidation of hydrocarbons (cf. Anderson, Augenfeld, Crecelius and Riley, 1978: RU 454

Quarterly Report, October). Thus the weathered oil from "Tank #2" appeared most suitable for our experiments. The kittiwake eggs were dosed with uniform amounts (20 ul) of the three treatment oils at the beginning of incubation. Our previous results from experiments involving the effect of raw oil on gulls led us to expect an LD_{50} with a 20 ul dose applied to eggs at the beginning of the incubation period.

The Glaucous-winged Gull experiment used similar but not identical methods, involving the use of weathered oil and mineral oil treatments. Each treatment was applied in three different doses: 20 ul; 50 ul; and 100 ul. The results of these oil doses were compared to an unexposed control group.

RESULTS AND DISCUSSION

The results of both kittiwake and gull experiments were divied into three categories: hatching success, loss to predation, and failure to hatch. Loss to predation, while an uncontrolled variable, was an unavoidable part of these field experiments. Table 6 and Figure 11 contain the results of the kittiwake oiling experiment. The results are quite unexpected. All four groups cannot effectively be distinguished from each other in hatching success, loss to predation, or failure to hatch. While there is variation between the treatment groups, the three oil treatment groups do not differ significantly from the control (p .05). The phenomena which occurred in the 1978 kittiwake oiling experiment were thus independent of treatment effect. Stated otherwise, we could determine no effect of oil treatment on kittiwake hatchability at the 20 ul dose, whether with raw, weathered, or mineral oil, a distinct contrast to the markedly depressed hatching success of gull eggs exposed to 20 ul doses of raw oil (RU 96 - 77).

The results of the 1978 Glaucous-winged Gull experiment, involving the exposure of eggs to weathered and mineral oil doses, are contained in Table 7 and Figures 12, 13, and 14. Note that hatching success at each dose of weathered oil is less than that of equivalent amounts of mineral oil. Similarly, hatching failure is greater at each dose of weathered oil when compared to equivalent amounts of mineral oil. Hatching success of either oil treatment is less than the unexposed control (Table 7), suggesting both physical and chemical effects. The comparison between equivalent 20 ul doses of weathered oil on gulls and kittiwakes indicates that gulls had lower hatching success (44% vs. 62%), higher hatching failure (33% vs. 8%) and similar loss to predation (33% vs. 29%) (Tables 6 & 7).

When the results of the kittiwake and gull oiling experiments are compared, there is a strong suggestion of species-specific response to petroleum exposure on egg surfaces. The kittiwakes are apparently more resistant than the gulls to the toxic and respiratory-inhibitive effects of oil exposure to egg surfaces. Based upon our knowledge of the size, adaptability, and niche breath of these two species, we would have expected the robust, intrusive, "weedy" gulls to be more tolerant of oil exposure than the kittiwakes. We emphasize that these results are indicative of further research. The species-specific response to minute amounts of petroleum on egg surfaces reveals an unexplored realm of marine bird conservation, at the interface of physiology, organic chemistry, and field biology.

Table 6

Kittiwake Oiling Experiment - Middleton Island, 1978
Oil dose: 20 ul

Oil Treatment	Hatching Success (%)	Loss to Predation (%)	Failure to Hatch (%)	n eggs
"raw" Prudhoe Bay Crude Oil	57.7	26.9	15.4	29
weathered Prudhoe Bay Crude Oil	62.5	29.2	8.3	24
mineral oil (non-toxic)	70.8	20.8	8.4	24
control (no treatment)	54.2	29.2	16.6	24

Table 7

Glaucous-winged Gull Oiling Experiment
Middleton Island, 1978

Weathered Oil/ Mineral Oil Dose	Hatching Success (%)	Loss to Predation (%)	Failure to Hatch (%)	n eggs
100 ul weathered	41.6	16.6	41.6	24
100 ul mineral	55.0	11.1	33.3	18
50 ul w	58.3	8.3	33.3	24
50 ul m	100.0	0.0	0.0	18
20 ul w	44.4	22.2	33.3	18
20 ul m	66.0	16.6	16.6	12
unexposed control	82.0	12.0	6.0	150

Table 8

Productivity of Black-legged Kittiwakes
Middleton Island, 1978
'C' Area*

Colony I. D. Number	Nests with Eggs/ Nests Built	(%)	Clutch Size	% 3-egg Clutches	Chicks Fledged/ Nests with Eggs (%)
1	33/40	(82)	1.96	2/33 (6)	1/33 (3)
2	63.75	(84)	1.81	1/63 (1.5)	0/63 (0)
3	48/55	(87)	1.93	0/48 (0)	4/48 (8.3)
4	168/175	(96)	1.79	1/168 (0.6)	19/168 (11.3)
USFWS Study Areas**	145/180	(81)	1.94	--	-- (17.2)

* This study area is closest to the FAA station and is disturbed daily. Compare to the USFWS study areas, which were relatively undisturbed by human intrusion.

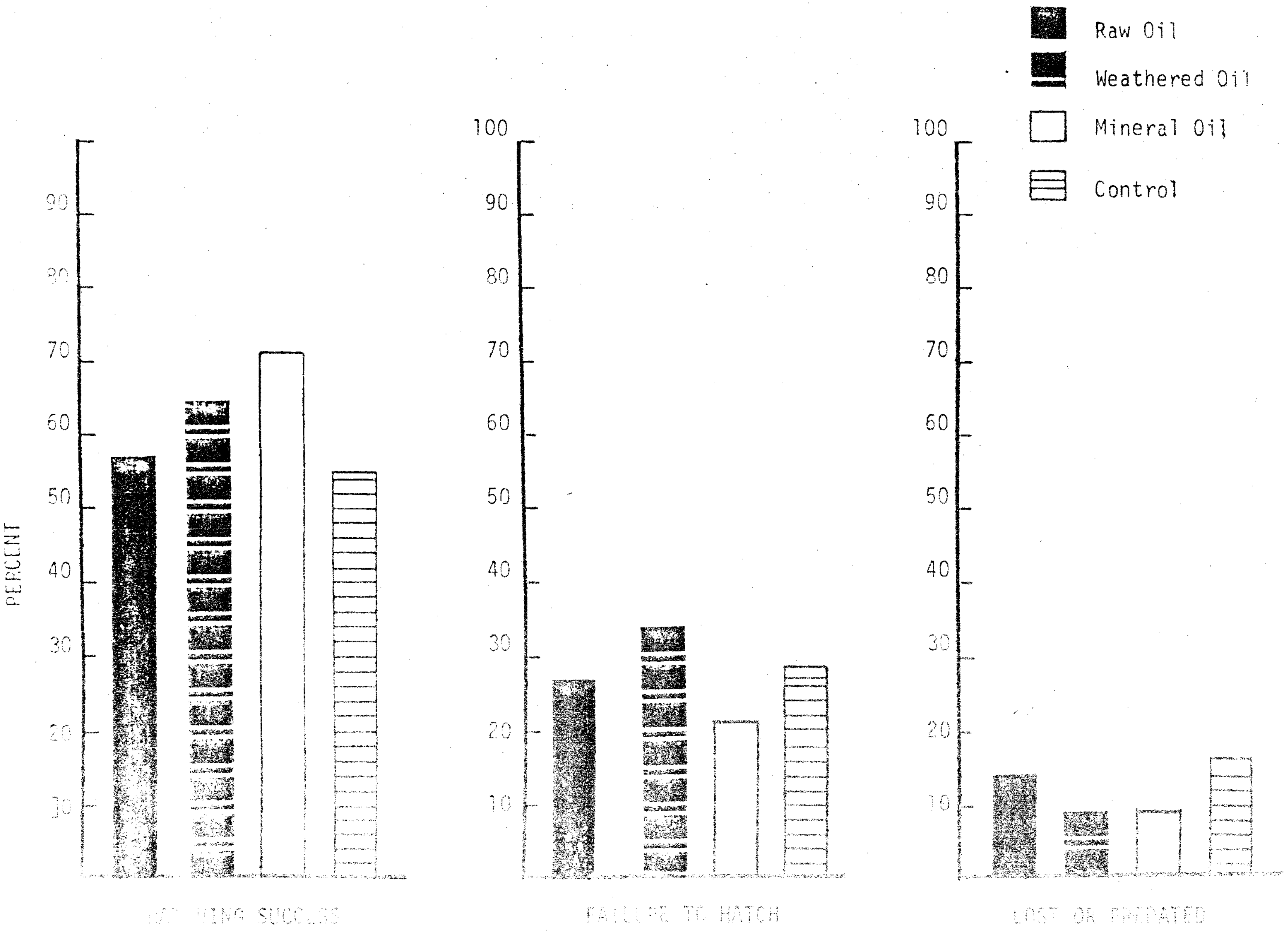
** cf. Hatch, Pearson, & Gould. (1979) RU 341.

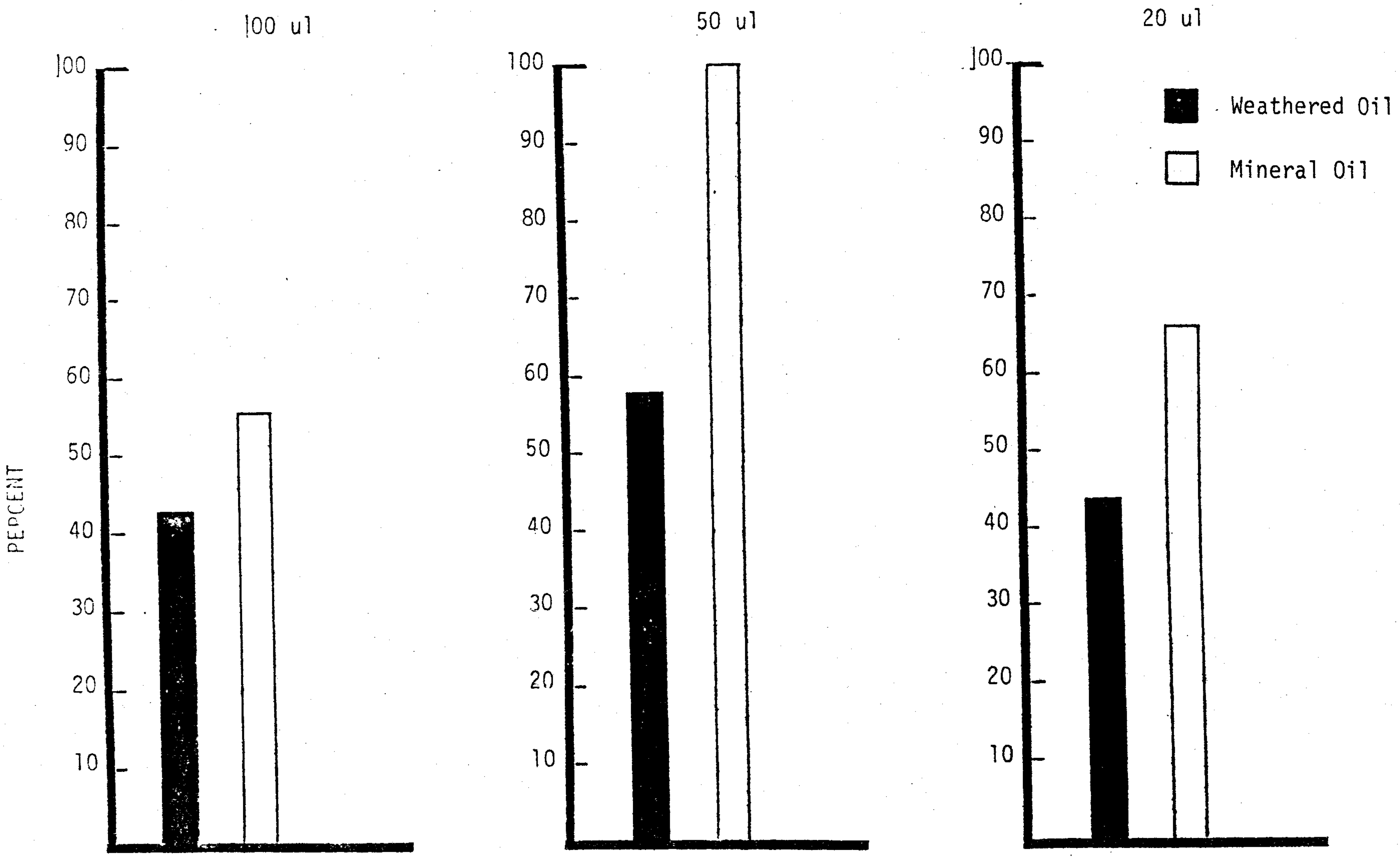
Kittiwake Breeding Biology in Disturbed Colonies

In addition to our petroleum experiments we monitored four colonies of kittiwakes in "C" area, directly east of the FAA station and immediately south of the dirt road which bisects the north end of the island. These four colonies, numbered sequentially from North to South, are disturbed daily by recreational activities and the movement of people, including biologists in transit to other areas. The colonies provide an example of the potentially disruptive nature of human development in proximity to seabird colonies. The four colonies are located on shallow 10 - 15 m dirt cliffs. These four kittiwake colonies experienced essentially marginal to complete reproductive failure in 1978 (Table 8; Figures 15, 16, 17, 18). The proximate cause of reproductive failure was human disturbance and subsequent gull predation on eggs, and to a greater degree, on chicks. However, when compared to the relatively undisturbed USFWS study areas at the south end of Middleton Island, these four disturbed sites do not differ greatly from the general trend, which in 1978 was a poor year for kittiwake productivity (cf. RU 341).

Figure 11.

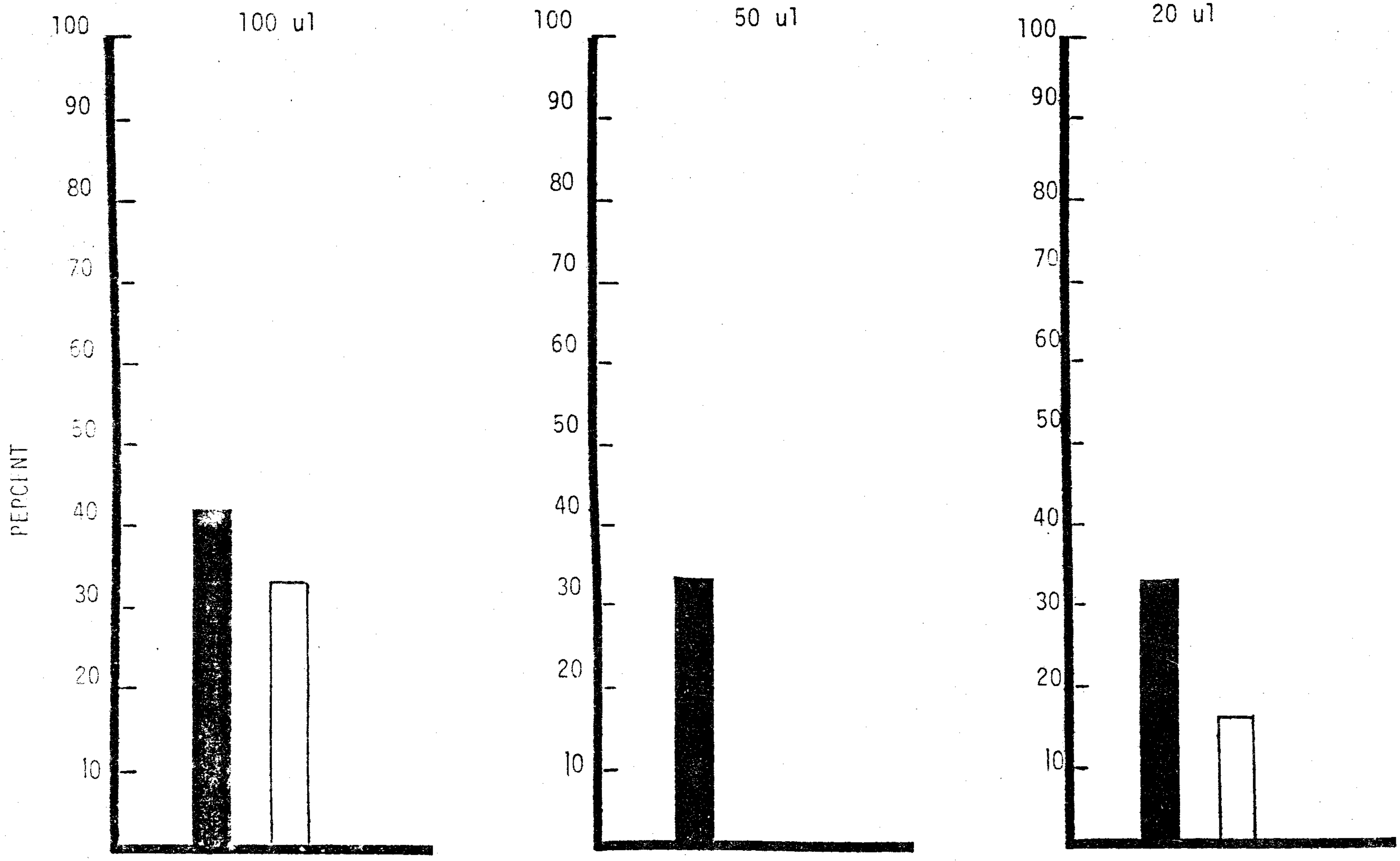
KITTIWAKE OILING EXPERIMENT, MIDDLETON ISLAND, 1978





GLAUCOUS-WINGED GULL HATCHING SUCCESS, 1978, MIDDLETON ISLAND, ALASKA

Figure 12.

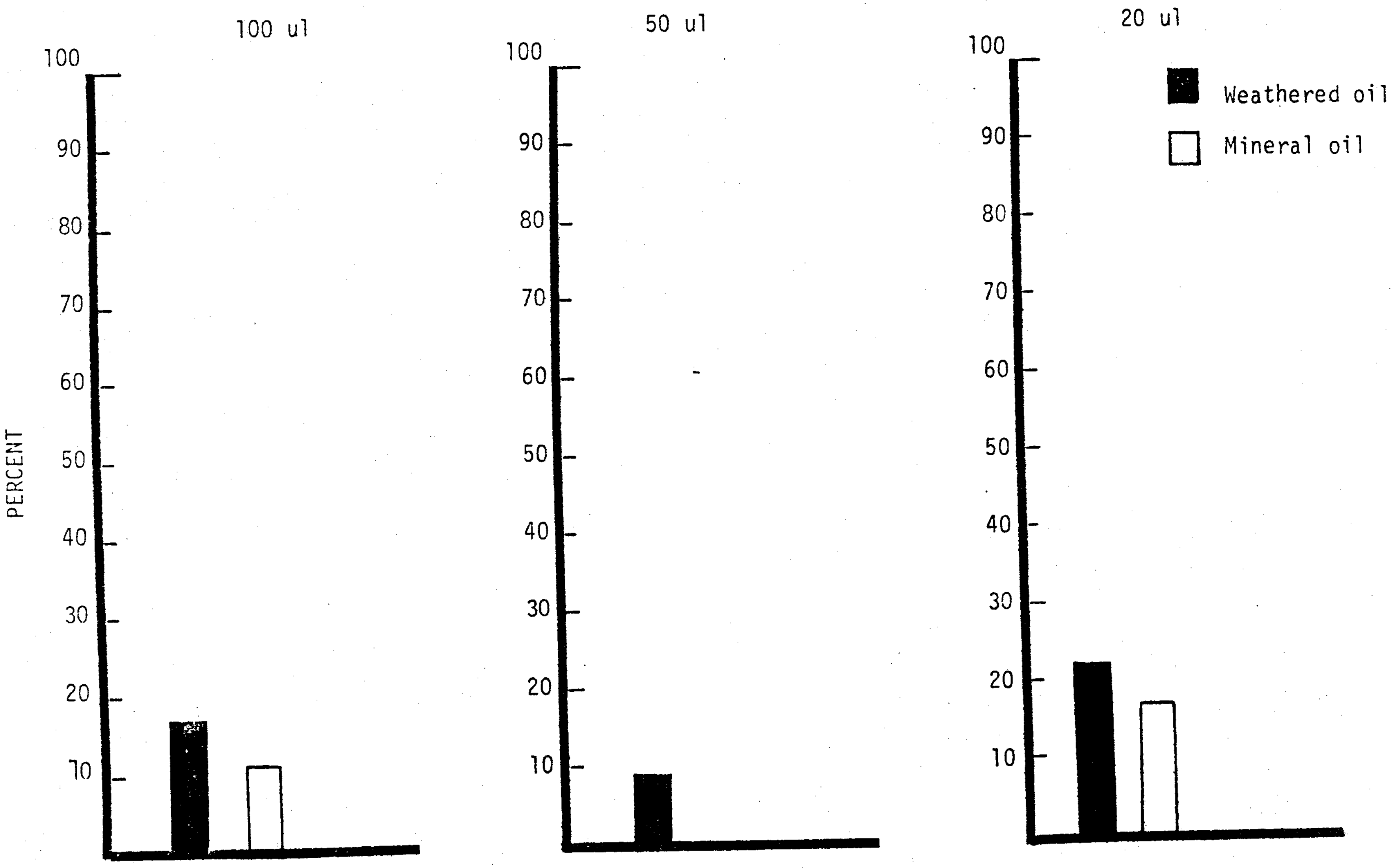


GLAUCOUS-WINGED GULL HATCHING FAILURE, MIDDLETON ISLAND, 1978,

▨ Weathered oil

☐ Mineral oil

Figure 13.



GLAUCOUS-WINGED GULL, EGGS LOST OR PREDATED, 1978 MIDDLETON ISLAND, ALASKA

Figure 14.

Figure 15

NESTING ACTIVITY AND FLEDGING SUCCESS PER NEST,
KITTIWAKE "C" AREA, MIDDLETON ISLAND, 1978

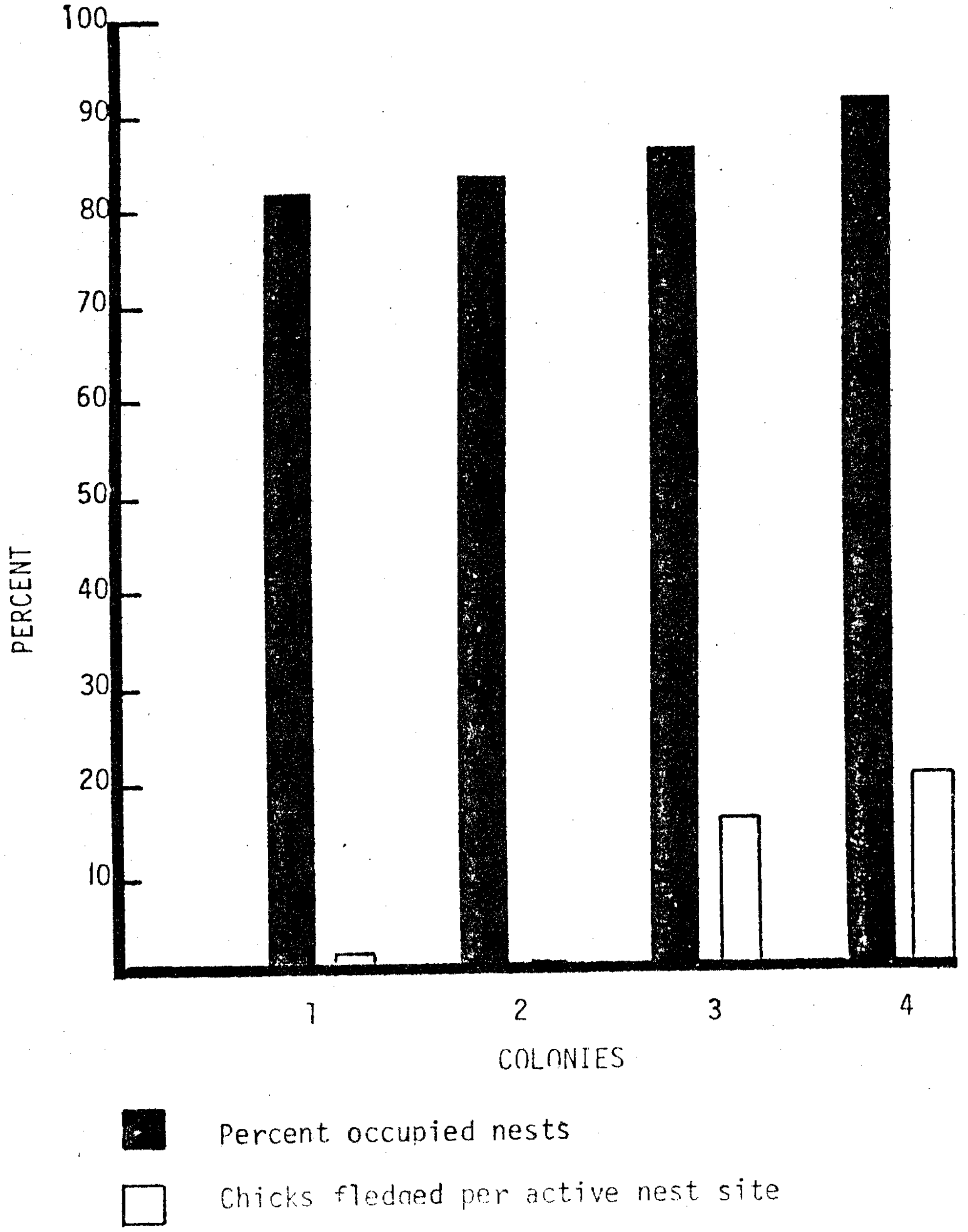


Figure 16.

1978

KITTIWAKE CLUTCH SIZE, "C" AREA, MIDDLETON ISLAND

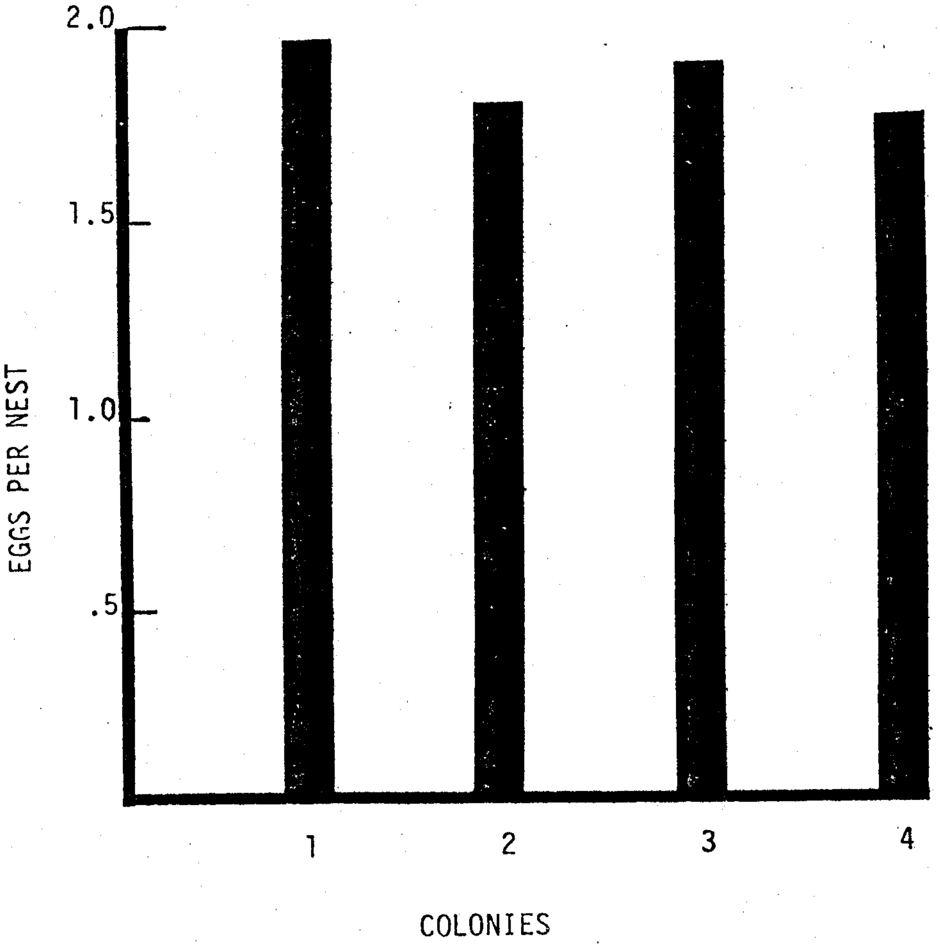


Figure 17

PERCENT THREE EGG CLUTCHES IN KITTIWAKE "C" AREA

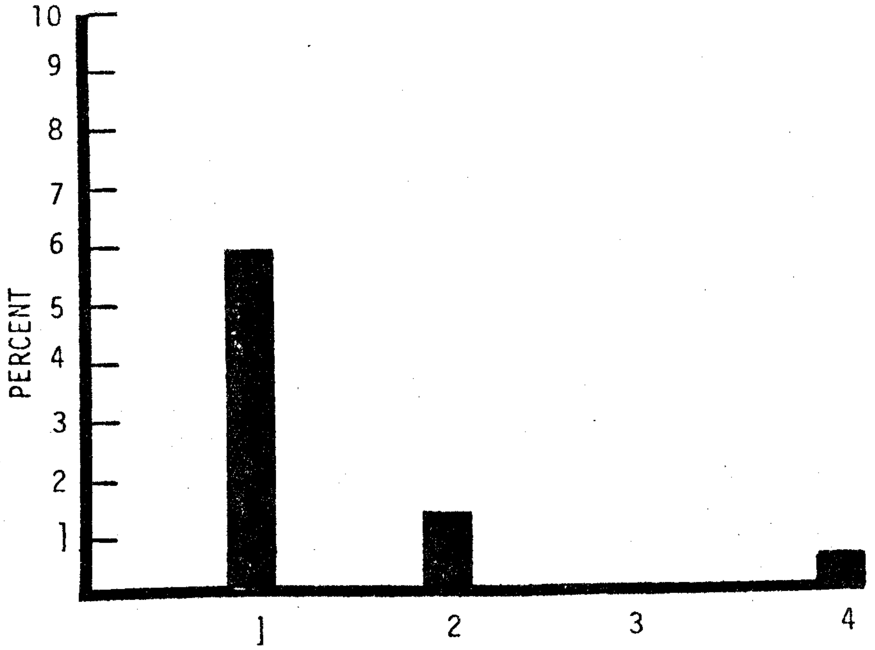
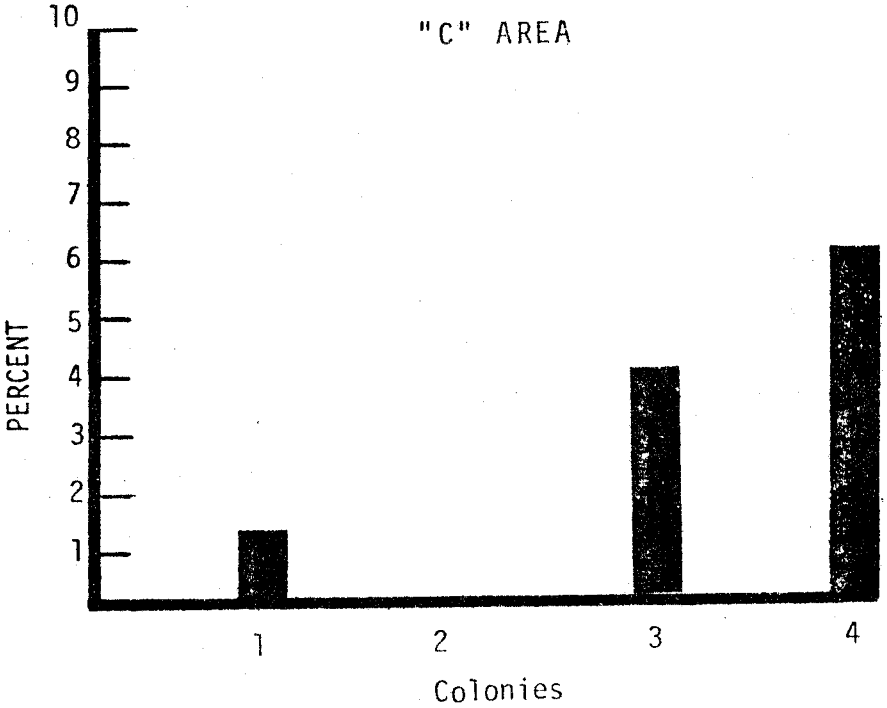


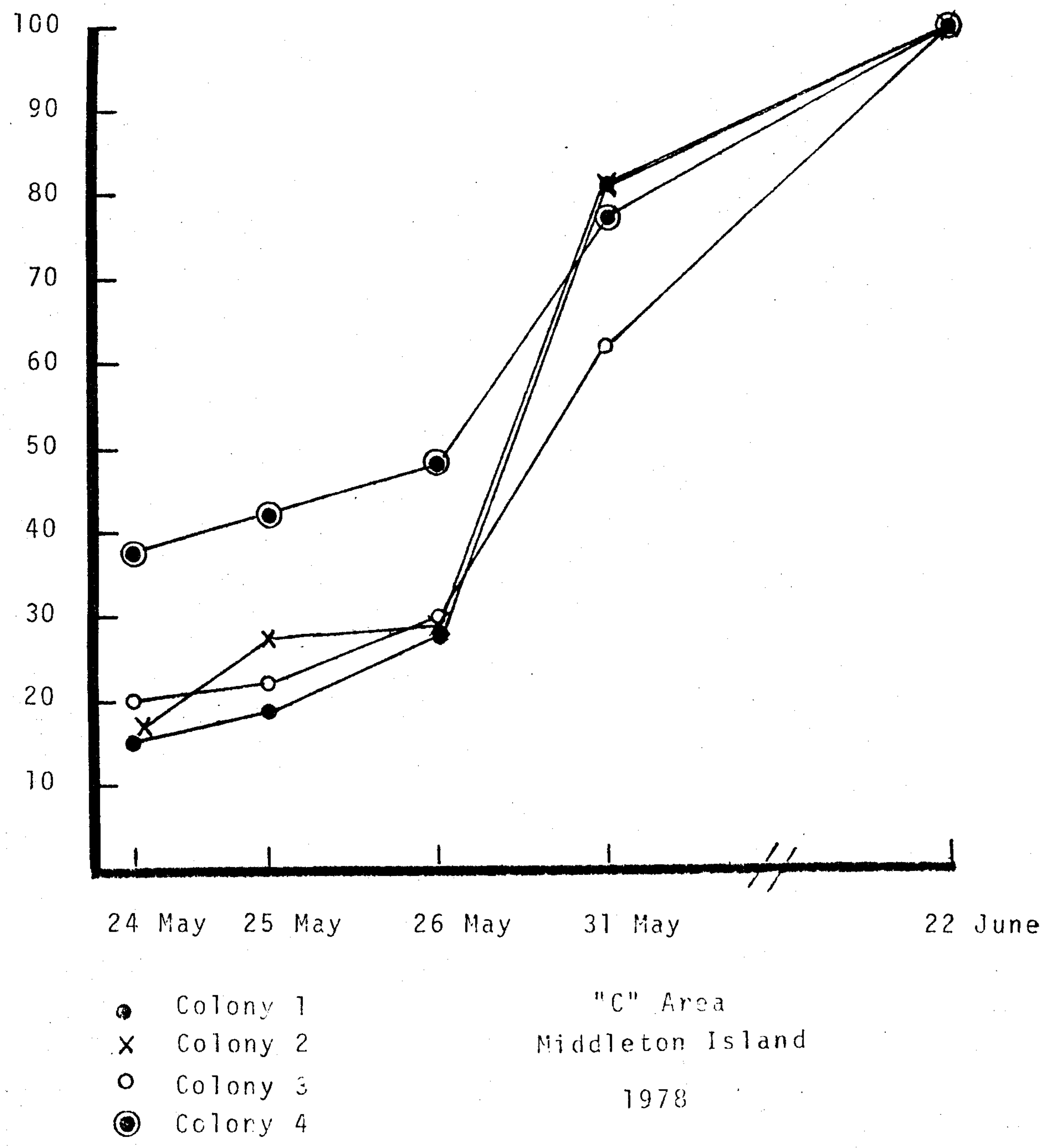
Figure 18
PERCENT EGGS LAID TO CHICKS FLEDGED
"C" AREA



MIDDLETON ISLAND, 1978

Figure 19.

Percentages of Clutch Initiation Per Active Nest Site



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PACIFIC SEABIRD GROUP

RESOLUTION

ON THE

STATUS OF LARGE GULL POPULATIONS IN ALASKA

Whereas the populations of Atlantic Coast Herring Gulls (Larus argentatus) have increased exponentially within the last seven decades,

Whereas studies from Juneau to the Prince William Sound region of the Northeast Gulf of Alaska indicate that the populations of Glaucous-winged Gulls (Larus glaucescens) are increasing,

Whereas recent observations along the Northwest Coast of Alaska indicate that the age structure of Glaucous Gulls (Larus hyperboreus) is close to that of the Atlantic Coast Herring Gull population,

Whereas experience in other areas such as the British Isles, Western Europe, Australia and New Zealand indicates that increase in gull populations is a secondary effect associated with economic development,

Whereas observations in other areas also indicate that increasing populations of large gulls are a public health risk and have both positive and negative effects on other seabirds, shorebirds and waterfowl,

We conclude that these are reasons to predict that a secondary effect of industrial development associated with Outer Continental Shelf Gas and Oil Exploration and Production and the rapidly developing coastal and marine fisheries will be increasing populations of large gulls in Alaska,

We therefore recommend that studies should be made now to:

a) establish the distribution and numbers of large gulls (Larus) in Alaska both during the breeding season and during the winter, a critical period of survival,

b) establish the age structure of these large gulls,

c) establish the relationship of successful breeding and subsequent survival to sources of food resulting from human waste, garbage and fish offal,

d) observe the effects of dense large gull populations on other wildlife species in order to assess the potential magnitude of ecological disruption through increased predation and competitive interactions.

FINAL REPORT

NOAA-OCSEAP Contract: 03-7-022-35140
Research Unit: 196
Principal Investigator: G.J. Divoky

BIRD USE OF COASTAL HABITATS IN NORTON SOUND

By

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April 30, 1982

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We are thankful to the people of Norton Sound who granted us access to their lands. Special thanks to White Mountain villagers for allowing our intensive studies on the Fish River Delta. We are also grateful to the people of Golovin for accepting us into their community, where we lived in 1981.

Henry Springer was of immense help; he provided us with his home in 1980 and shared his extensive knowledge of local birds. We are likewise grateful to Florence Doyle for allowing us to live in her Golovin home.

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Field assistants with the project were Steven Allison, John Blackham, Sally Blackham, David (Jim) Blick, Steve Chance, John Drury, Mary Hausler, and Ken Warheit.

Of all the people who helped us, David Olson was most instrumental. His skill in flying made our surveys safe and his knowledge of the coast and bird concentrations simplified our work.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

Page

IV. STUDY AREA

V. SOURCES, METHODS . . .

VI. RESULTS, Part One: Bird Groups
A. All Birds

B. Loons

C. Waterfowl

LIST OF FIGURES (Continued)

Page

D. Swans

E. Geese

F. Ducks

G. Cranes

LIST OF FIGURES (Continued)

Page

H. Shorebirds

J. Gulls

K. Terns

L. Passerines

LIST OF FIGURES (Continued)

Page

VI. RESULTS, Part Two: Trophics

VII. DISCUSSION

LIST OF TABLES

Page

IV. STUDY AREA

V. SOURCES, METHODS . . .

VI. RESULTS, Part One: Bird Groups

A. All Birds

C. Waterfowl

D. Swans

E. Geese

F. Ducks

LIST OF TABLES (Continued)

G. Cranes

H. Shorebirds

J. Gulls

VI. TROPHICS

VII. DISCUSSION

LIST OF TABLES (Continued)

LIST OF APPENDICES

LIST OF APPENDICES (Continued)

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

This project's primary objectives were the delineation of coastal bird habitats in Norton Sound and documentation of their bird use. Observations of temporal and geographic patterns of bird abundance were made from May through October 1980 and May through September 1981 to provide OCSEAP with data on the habitats and areas most important to large numbers of birds. With this information OCS-related impacts on Norton Sound birds can be anticipated and mitigated.

The coast of Norton Sound from the eastern margin of the Yukon Delta to Bering Strait contains many habitats: cliffs, uplands, wetlands, lagoons, and embayments. It is perhaps the most varied shoreline in Alaska. Unlike other extensive coastal wetlands of the state, the wetlands of coastal Norton Sound are located in pockets between cliffs and other raised relief. These wetlands (wet tundra) had the highest bird densities of all habitats in Norton Sound, supporting major populations of breeding shorebirds and some breeding waterfowl, as well as shorebirds, cranes, and waterfowl migrating to or from mostly arctic breeding grounds. In other areas (except cliff colonies) bird use of Norton Sound coastal habitats was sparse.

The littoral habitats of Norton Sound showed major variability in bird use. Protected (lagoonal) waters supported many swans, geese, and ducks in late summer, especially near areas of wet tundra. Unprotected (exposed to surf) littoral habitats typically had low densities (except for cliff colonies, large gulls in fall, and shorebirds feeding at Koyuk from June through August). The low bird densities of the exposed littoral and offshore (Appendix 36), in contrast to the high densities of wet tundra, demonstrate the low productivity of the Sound's marine waters.

The areas of Norton Sound richest in birds were found between Cape Nome and Cape Denbeigh in the northeast and immediately southwest of Stebbins in the south. Except for the Imuruk Basin in the interior of Seward Peninsula, the northwest was relatively bird-poor. Most waterbirds of the Norton Sound coast were found in the twelve wetland areas identified in this report. Therefore, many impacts of OCS develoment on Norton Sound birds could be decreased by not siting activities in wet tundra. There are other habitats in Norton Sound with low bird densities where OCS development impacts on birds should be minimal.

The potential impacts of oil spills in wet tundra areas are large, since oil adheres to the vegetation and sediments of wet tundra, and many of these areas are associated with lagoonal systems periodically flooded by autumn storm surf. Low offshore and littoral bird densities in Norton Sound mean that spills not entering lagoons or fouling mudflats or wet tundra should affect relatively few birds (except for spills near seabird cliff colonies). This is true only in the Sound proper, as the adjacent open ocean supports high bird densities. Development may also impact wetland bird populations indirectly through increased hunting and other abuses accompanying growth in the local human population.

II. INTRODUCTION

A. General Nature and Scope

This project was designed to delineate the coastal bird habitats in Norton Sound and to document their use by censusing bird populations found in those habitats. In 1980 and 1981 coastal habitats of Norton Sound were censused from Cape Prince of Wales south and east to the northeast end of the Yukon Delta. Emphasis of fieldwork was placed on bird use of shorelines and littoral habitats with special attention given to large areas of wetlands.

Maps delineating coastal habitats based on topography and our observations are presented. Habitat use, seasonal abundance, and geographic distribution are described for the common waterfowl, shorebirds, gulls, loons, cranes, and songbirds. An analysis of food habits of the more common ducks and shorebirds is given as well.

B. Specific Objectives

(1) To identify and delineate the major bird habitats present on the Norton Sound coast.
(2) To assess the seasonal abundance of birds in these habitats.
(3) To determine those areas and habitats of coastal Norton Sound that are most critical to birds.
(4) To assess the food dependencies of the most common birds.

C. Relevance to OCS Development

Oil exploration, exploitation, and transportation will have a wide range of impacts on coastal ecosystems. Many of these impacts will be planned, such as the location of onshore facilities. Knowledge of the areas and habitats that are most important to birds will allow the placement of facilities in locations where impacts will be low. For unplanned catastrophic events, such as oil spills, knowledge of an area and its habitats will allow the impact of an unplanned event to be anticipated, and thus mitigating measures can be used to minimize the impact. This report also provides information that can be compared to post-development data to assess changes associated with development. Impacts on specific birds and habitats are elaborated in the discussion section.

III. CURRENT STATE OF KNOWLEDGE

A. Early Work

Knowledge of the seasonal abundance of birds and their habitat use has been an integral part of the consciousness and lifestyles of the native peoples of Norton Sound for several millenia. The earliest evidence of human occupation of Norton Sound dates to 5,000 years ago (Giddings 1967). Native awareness of bird life was, and is, traditionally utilitarian, though legends and mythology about animals were also part of native cultures.

Western science made its first observations of bird life in Norton Sound when Turner (1886) and Nelson (1883, 1887) recorded their observations of birds, mostly at St. Michael. Nelson's (1883) note on Spectacled Eiders west of Stuart Island remains one of the few records of molting areas for these ducks. Grinnell (1900) made observations at Cape Nome while gold mining, and McGregor (1902) collected a variety of birds in Norton Sound, though his notes offer little insight into their abundance. Hersey (1917) made useful observations of abundance for the St. Michael and Stebbins area. Murie visited St. Michael in 1920, obtaining a few observations (Gabrielson and Lincoln 1959).

B. Recent Work

Bailey (1943, 1948) made extensive notes on birds at Wales and points north, providing a sound basis for comparison with more recent observations. Birds of Sledge Island were reported by Cade (1952), while Kenyon and Brooks (1960) published observations of birds on Little Diomede Island.

Kessel (1968) has listed birds observed on the Seward Peninsula during extensive surveys, and made an outline of the bird habitats in Alaska based in part on this work (Kessel 1979). A complete report of her work is forthcoming. H. Springer (formerly of Nome) is also preparing a publication on Seward Peninsula avifauna gleaned from numerous years of residence and travels there.

Much of our understanding of the bird life in Norton Sound has come during the past two decades, with ANSCA (Alaska Native Claim Settlement Act) and OCSEAP work. Cliff colonies received careful study by Drury (1980) for the OSCEAP. His aerial surveys of the major wetlands in Norton Sound and identification of major information gaps provided direction for the present study. Another OCSEAP study (Shields and Peyton 1979) described the abundance and seasonality of birds in the Inglutalik Delta south of Koyuk; this provided site intensive data on a small area. Other OSCEAP work includes Woodby's shipboard observations in Norton Sound in September 1976 (NOAA ship **Discoverer**), observations from 2 June to 10 September 1977 by Woodby and Hirsch at Wales (in Connors 1978), and related work by Flock (1972) and Flock and Hubbard (1979) on spring migration at Wales. Erckmann (1981) reports a study of shorebird ecology recently completed at Wales.

A summary catalog of seabird colonies of Alaska was recently assembled by the US Fish and Wildlife Service (Sowls et al. 1978). USFWS indices of waterfowl populations, derived in part from flights in the Norton Sound area, are published yearly in their Pacific Flyway Waterfowl Reports and Waterfowl Status Reports (USFWS and CWS 1981).

Summaries of waterfowl resources by King and Dau (1981) and of shorebirds by Gill and Handel (1981) for the eastern Bearing Sea (including Norton Sound) emphasize littoral habitat use. These two works provide a broad perspective lacking in the present report.

IV. STUDY AREA

Norton Sound is a shallow embayment of the Bering Sea, approximately 220 km in east-west length and 150 km in north-south length. It lies at the northern edge of the Pacific Basin just south of the transition zone from the subarctic to the arctic bioregions. The coast surrounding the Sound encompasses as great a diversity of habitats as can be found anywhere along Alaska's shoreline. These include cliffs, bays, lagoons, dry rocky tundra, moist tundra, wet tundra, broad river deltas, and spruce forests. Norton Sound shores are quite different from the coasts to the north and south. To the south the great expanse of the Yukon-Kuskokwim Delta, with low coastal relief, is one of the most important wet tundra areas in North America. To the north the south side of Kotzebue Sound is characterized by a barier island chain and associated lagoon backed by sand dunes and wet tundra. Both these coasts have rather homogeneous shores when compared to the diversity found in Norton Sound.

Norton Sound shorelines have several gradients from the southeast corner at the edge of the Yukon-Kuskokwim Delta to the Bering Strait. Large expanses of wet tundra lagoons and broad river deltas are characteristic of the eastern section of the sound, while west of Nome the shore, in general, lacks such features, with headlands being more common. There is also a change in vegetation, with the flora becoming more arctic in nature closer to the Bering Strait.

While Norton Sound is part of the biologically productive Bering Sea, the Sound itself has a rather unproductive marine environment. This is due to its shallowness (20 m) and a stratified water column that has little vertical mixing except at the western edge of the Sound (Muench et al. 1981). Tidal amplitudes are low, averaging less than a meter.

Ice first forms in protected waters in October, with extensive ice cover over the Sound by December, generally lasting through April. Snow cover on land persists from late September or October through May.

Norton Sound lies at the junction of a number of important flyways for migratory birds. Many species that breed on the extensive tundra areas of the Alaskan North Slope, Arctic Canada, and Siberia use the Bering Sea as a migratory pathway and pass through the rather narrow Bering Strait-Seward Peninsula area on their migratory passages. There is also the movement of species that winter in either North America or Asia and breed on the other continent. Many of these species cross the Nearctic-Palearctic boundary in the region of Norton Sound.

The study area covered by this report is the coast from Cape Prince of Wales south and east to the Yukon-Kuskokwim Delta. Note that a strict definition of the Norton Sound coast would be the area from Cape Rodney to the north edge of the Yukon-Kuskokwim Delta. Our inclusion of Cape Prince of Wales to Cape Rodney was done in order to obtain an overview of bird use of the south side of the Seward Peninsula. We ignored the Yukon-Kuskokwim Delta, since bird use of habitats there has been well studied by the USFWS service, which has jurisdiction in the area (Gill and Handel 1981; King and Dau 1981).

For the purposes of discussion we have divided the study area coastline into 15 geographical sections (Figure 1). An attempt has been made to make each section as homogeneous as possible with regard to physiography and habitat, although the sections are primarily geographic in nature. In the following descriptions of each section, the percentage of shoreline habitats in each as well as the areas of "wetlands" in each will be given. The habitats mentioned are defined in the next section of the report. A brief indication of bird and human use is given.

A. Physiography of Coastal Sections

1. Wales to Brevig Mission

Shorelines:

31% Exposed moist tundra/uplands
19% Protected spits
18% Exposed spits
15% Protected moist tundra/uplands
13% Exposed cliffs
3% River delta
1% River mouths

Wetland Areas:

6.6 km^2, Brevig Lagoon.

Cape Prince of Wales marks the western terminus of the North American continental divide. This coastal section is typified by rocky and mostly barren ground with steep terrain in the western part and a lagoon system in the east.

Ten km of bedrock cliffs and sloping talus hillsides extend southeast from Wales ending at near vertical cliffs of basalt immediately west of Tin City; a small colony of Horned Puffins, Pelagic Cormorants, and Glaucous Gulls nests on these outcrops. Dry and mostly barren talus slopes interspersed with steep cliffs abut the shore from Tin City east to Brevig lagoon. These are backed, in places, by a 200 meter high plateau with higher mountains to the north.

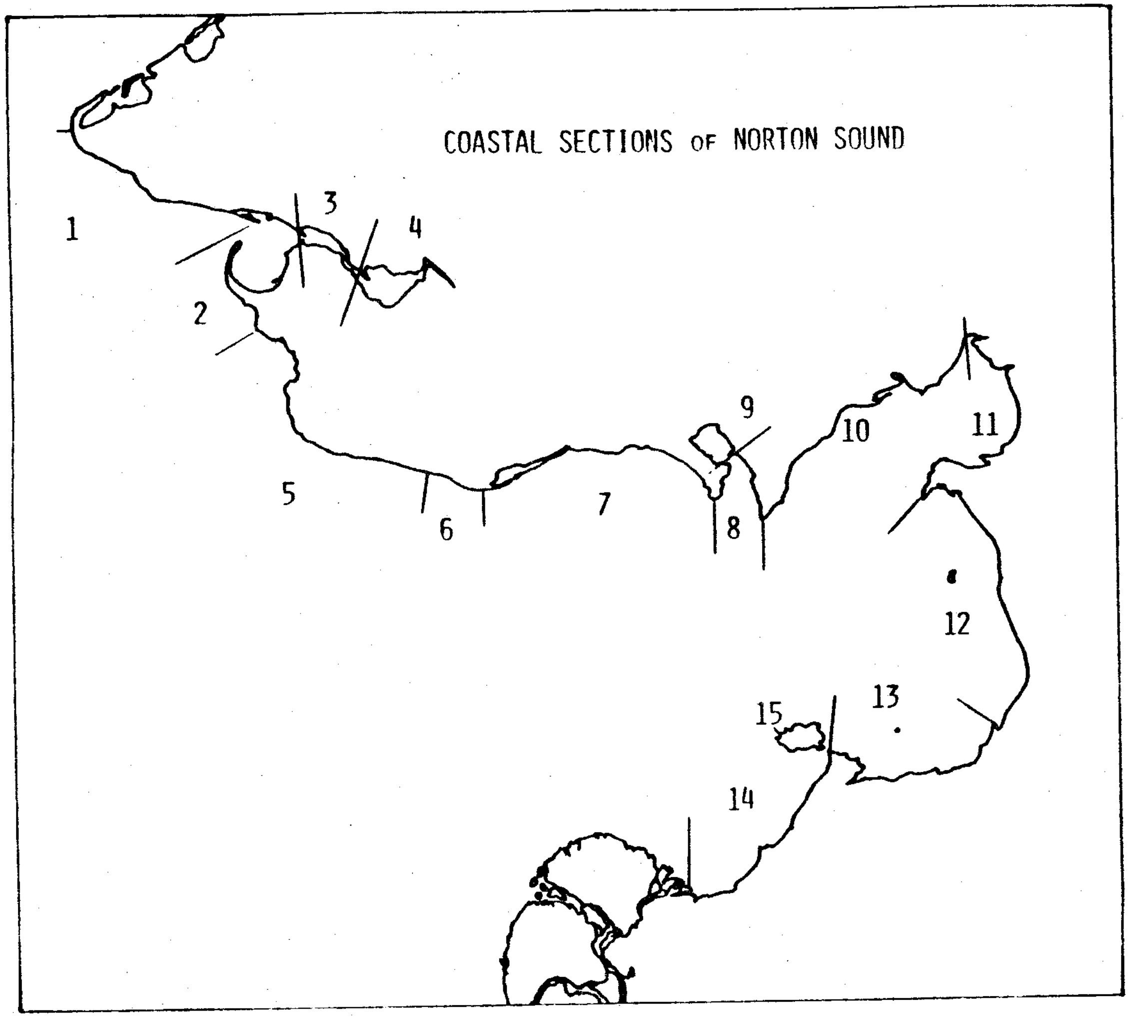

Figure 1. Coastal sections; based on physiography and used as divisions for shoreline aerial surveys. See Appendices 3 and 4 for survey dates.

Brevig Lagoon is over 20 km long and is protected by a gravel barrier beach strip with a single channel on the east end, allowing exchange of lagoon and Bering Sea water. The lagoon is a concentration point for small numbers of waterfowl and shore birds, whereas the nearby substrates are rocky, dry, and sparsely vegetated, thus limiting productivity.

Bird use is generally low with occasionally high populations of migrating seabirds and waterfowl in spring and late summer. Settlements in this section are Wales, the Tin City Air Force station, and Brevig Mission. Ground surveys were walked on the beaches and low tundra immediately north of Wales and along the shores and low tundra of Brevig Lagoon. No wetland air surveys were flown in this section.

People of Wales and Brevig practice relatively traditional subsistence lifestyles.

2. Brevig Mission to Cape Douglas; Port Clarence Area

Shorelines:

30%	Protected spits
22%	Exposed spits
19%	Protected moist tundra/uplands
13%	Protected wetlands
8%	Exposed moist tundra/uplands
3%	Protected cliffs
3%	Exposed wetlands
1%	River mouths

Wetland Areas:

13.4 km^2, along south shore of Port Clarence.

The spit of Point Spencer encloses the 18 km wide embayment of Port Clarence, which has a variety of surrounding habitats and supports a moderate population of migratory and nesting birds.

The bay itself reaches depths of 10 meters and provides the best sheltered anchorage in the Bering Strait region; 19th century whalers used it regularly (Brower 1942). Shore ice is retained later here than on nearby exposed waters, lasting into early June in both 1980 and 1981. The long western spit is of coarse sand and fine gravel with poorly vegetated beach ridges serving primarily as roosting sites for gulls and waterfowl. Southwestern shores are low and occasionally flooded by high wind-blown tides and are thus vegetated by salt tolerant plants. Shorebirds and waterfowl concentrate there. Southeastern shores are backed by higher moist tundra and protected by 6 km long Jones spit. Seventy-meter cliffs meet the eastern shore south of Teller spit and support a colony of cormorants, gulls, guillemots, and puffins.

Teller is the only native village in this section, and it lies on the spit separating Port Clarence from Grantley Harbor. It is home to a small population of people on a subsistence economy though it is connected by road to Nome and the people make more use of commercial resources than do people of more isolated villages. Several dozen Coast Guard personnel staff a Loran station at Point Spencer.

Ground surveys were walked on the marshy wetlands along the south shore of Port Clarence and along the beaches of the long spit of Point Spencer. Wetland aerial surveys were flown over the same marshy wetlands as were walked.

3. Grantley Harbor and Tuksuk Channel

Shorelines:

95% Protected moist tundra/uplands
2% Protected cliffs
2% River mouths
1% Protected spits

Wetland Areas:

Few and small.

Grantley Harbor is a well protected embayment that receives fresh water from Imuruk Basin via Tuksuk Channel and drains into Port Clarence at Teller spit. Shorelines are mostly gravel with sloping and well-drained tussock tundra. We noted minimal use by waterbirds, although spring ice openings at the mouth and in Tuksuk Channel had resting ducks. About 1 km of low cliffs at Six Mile Point support a very few nesting cormorants, Pigeon Guillemots, and Horned Puffins. Human use during the ice-free months is mostly by Teller residents summering at fish camps.

The area was visited on land for two days only (June 30 and July 1, 1980), when a few transects were walked along Tuksuk Channel. No wetland aerial surveys were flown in this section.

4. Imuruk Basin

Shorelines:

60% Protected moist tundra/uplands
30% River delta
7% Protected wetlands
3% River mouths

Wetland Areas:

41.0 km^2, Agiapuk Delta, Kuzitrin Delta.

This shallow basin is well removed from the sea and is enclosed by a variety of habitats with a uniquely inland character. The north and east shores are backed by low delta wetlands along distributory streams of the

Agiapuk and Kuzitrin Rivers; these are sandier and shrubbier than other coastal wetlands of Norton Sound. Other shorelines are bounded by higher steeper slopes and moist tundra uplands.

Migrant waterfowl and cranes pass through in large numbers, and shorebirds make extensive use of the lowlands for nesting and feeding. There are no permanent settlements today, though the basin is rich in history of Kauwerak peoples (Oquillok 1973).

Ground surveys were made on the Agiapuk Delta on the north side of the basin, and wetland aerial surveys were flown over both the the Agiapuk and Kuzitrin Deltas.

5. Cape Douglas to Nome

Shorelines:

46% Exposed moist tundra/uplands
16% Protected moist tundra/uplands
13% Exposed spits
13% Protected spits
10% Protected wetlands
1% River mouths

Wetland Areas:

6.8 km^2, on east shore of Woolley Lagoon.

This section has a low profile of sandy beaches and occasional rock outcrops that projects into a narrow stream of Alaskan coastal water. Most of this coast is fully exposed to the brunt of Bering Sea weather, except for a narrow 20 km long lagoon stretching south from Cape Douglas to Cape Woolley. Locally known as Woolley Lagoon, this shallow, brackish enclosure receives fresh water from the Feather and Tisuk Rivers and drains via two channels cutting through the beach ridge. The Sinuk is the only other major river, and drains directly into the sea southeast of Cape Rodney.

Terrain behind the coast rises gently to limestone hills several kilometers inland, between the Feather and Sinuk Rivers. Coastal tundra is well drained and somewhat xeric with a stony substrate and a thin soil layer. Wetlands are mostly limited to the shores of Woolley Lagoon, and these are salt-washed pool complexes with wet sedge meadows. Aquatic productivity at Woolley Lagoon appeared low, and this is possibly due to a nutrient-poor, highly inorganic sediment load delivered by the two rivers and various small streams. The lagoon substrate is sandy with few or no rooted plants. Waterfowl and cranes use the Woolley Lagoon area mostly as a stopover, particularly in spring, though year to year use may be quite variable (H. Springer, pers. comm.).

Series of narrow pools and lakes on the frozen tundra lie behind the beach from Cape Woolley to Sinuk. These are fed by small creeks but have no outlets to the sea other than seepage through the sand.

Bird use of this coast is moderately low, while offshore to the north on King Island and to the south on Sledge Island are major seabird colonies.

Human use of this section is greatly limited by access. Some Nome residents regularly travel the coast to Sinuk, and a camp on the beach strip of Woolley Lagoon near the Feather River mouth is occupied seasonally by King Island people. Subsistence on local game is of prime importance to them.

Ground surveys were walked along the beaches and nearshore tundra of Woolley Lagoon, as well as on the beach north of Woolley Lagoon to Cape Douglas. Wetland aerial surveys were flown from Cape Woolley to Sinuk, approximately 1 to 2 km inland of the shore.

6. Nome to Cape Nome

Shorelines:

90% Exposed moist tundra/uplands
7% Disturbed beach
3% River mouths

Wetland Areas:

Few and small.

This short coastal strip is backed by a raised and sloping plain of moist tundra. This terrain has been heavily excavated by gold dredging, creating one of the most heavily modified landscapes in Alaska.

The Snake River mouth on the west end of Nome is contained by concrete and steel jetties, rip-rap and a breakwater stretches east 2 km to protect the Nome waterfront. The sea beach is backed by a gravel road from town to Cape Nome with concrete bridges crossing several streams.

Bird use is quite low. Local dependence on waterfowl for food is low, mostly because birds do not abound in this region. Much of the hunting near shore is recreational or concentrated to Safety Lagoon east of the cape.

Ground surveys were walked on the raised moist tundra approximately 5 km north of Nome and along the Nome River on both wet and moist tundra. Beach transects were walked 2 km east and west of Nome. No wetland aerial surveys were flown in this section.

7. Cape Nome to Rocky Point

Shorelines:

- 26% Exposed moist tundra/uplands
- 21% Protected spits
- 21% Exposed spits
- 17% Protected moist tundra/uplands
- 8% Exposed cliffs
- 6% Protected wetlands
- < 1% River mouths

Wetland Areas:

54.8 km^2, along shores of Safety Lagoon and mouths of Flambeau and Eldorado Rivers.

This section resembles a flattened crescent wedged between two high capes. It presents a diversity of land forms and habitats with heavy bird use and easy access for people.

Safety Lagoon provides the principal wetland habitats. A sandy spit swings northeast from Cape Nome to enclose the lagoon, and freshwater input is provided by the Flambeau and Eldorado Rivers. Bonanza Slough and Taylor Lagoon extend the Safety wetlands in a narrow band east towards Topkok. Lagoon waters drain through a main channel mid-lagoon, and Solomon River water drains southeast of the old Solomon town site. Depths in Safety Lagoon average less than 2 meters, and extensive mud flats are exposed at low tides. Widespread eelgrass beds develop over the summer, thriving on the brackish bath of nutrients and rich sediments.

Steep cliffs at Topkok and Bluff highlight a rocky shore extending east from Taylor Lagoon to Rocky Point. These are the summer home for large colonies of seabirds, principally murres and kittiwakes, as well as cormorants, puffins, and gulls.

The road from Nome runs along the beach spit to Solomon, providing ready access to the wildlife resources at Safety Lagoon. Subsistence activities are concentrated near the road and upstream along the Flambeau and Eldorado channels. A relic mining camp at Solomon is occasionally occupied. Subsistence peoples from White Mountain hunt seals between Topkok and Rocky Point and in the past people from Nome, Golovin, and White Mountain have gathered eggs from the seabird colonies.

Ground surveys were walked on the beaches, wetlands, and moist tundra surrounding Safety Lagoon, at the mouths of the Flambeau and Eldorado Rivers, and near Solomon. Wetland aerial surveys were flown from Taylor Lagoon to the northeast end of Safety Lagoon and over the Flambeau and Eldorado River mouths.

8. Rocky Point to Cape Darby; Golovin Bay

Shorelines:

72% Exposed moist tundra/uplands
20% Exposed cliffs
3% Exposed spits
2% Protected moist tundra/uplands
1% Protected spits
1% River mouths

Wetland Areas:

Few and small.

Two rocky headlands project south into the Sound to form Golovin Bay, providing only limited protection to the enclosed shores from stormy weather. The bay is shallow with maximum depths less than 13 meters. Terrain behind the beaches is steepest near the capes with low extensive, sloping cliffs near Rocky Point and Cape Darby. Terrain is progressively gentler towards Golovin at the head of the bay. Shrubby, moist tundra is the predominant habitat on the slopes, and is home to songbirds, ptarmigan, and other land birds. Coastal waters near the capes are feeding grounds for diving ducks and cormorants. Narrow eelgrass beds are found near shore at the head of the bay.

Peoples of Golovin and White Mountain hunt seals along the ice edge on the bay's mouth and fish the bay for salmon in the spring and summer and for other food fishes at other times. Mudflats exposed at low tides provide clams (Mya sp.), particularly in fall.

Ground surveys were walked immediately east of Golovin; no wetland aerial surveys were flown in this section.

9. Golovin Lagoon

Shorelines:

52% Protected moist tundra/uplands
26% River delta
13% Protected spits
9% Protected wetlands
1% River mouths

Wetland Areas:

38.5 km^2, Fish River Delta, including Kachavik wetlands.

A sand spit at Golovin pinches the head of Golovin Bay and concentrates outflow from Golovin Lagoon, a shallow, tidally washed enclosure. The Fish River Delta caps the head of the lagoon and provides freshwater and nutrient inputs. Distributional mudflats extend 2 to 3 km southeast of the delta at low tide. Both the bay and lagoon were river valleys during glacial time.

Shrubby, moist tundra backs the beaches between Golovin and the delta on both sides of the lagoon; eelgrass beds are found near shores. Nesting and migrant waterfowl and shorebirds abound on the delta wetlands, and the lagoon shores and nearby tundra are important feeding and gathering sites for swans, geese, and cranes, particularly in late summer.

White Mountain and Golovin peoples depend on waterfowl concentrations for their subsistence harvest and on salmon runs for commercial as well as subsistence fisheries.

Ground surveys were walked on the Fish River Delta and nearby shores and moist tundra within 6 km of the lagoon shore; wetland aerial surveys were flown over the same area.

10. Cape Darby to Koyuk

Shorelines:

28%	Exposed cliffs (generally low)
23%	Exposed moist tundra/uplands
20%	Exposed wetlands
10%	Exposed spits
10%	Protected spits
8%	Protected wetlands
1%	River mouths

Wetland Areas:

49.9 km^2, Kwiniuk and Kwik Rivers, west of Koyuk; 15.4 km^2, southwest of Koyuk to Isaac's Point (Bald Head).

Low cliffs and uplands dominate the southwest end of this section with forests of white spruce. Wetlands back the low coast to the northeast where waterfowl and sandpipers are seasonally abundant.

A sandy spit stretches 11 km to Moses Point, forming Kwiniuk Inlet. Depositional fans of the Kwik, the Kwiniuk, and Tubutulik Rivers bound the inlet with productive marshy tundra. Low tide exposes extensive mudflats, particularly between the Kwik River mouth and Bald Head (Isaacs Point). Further to the northeast, in Norton Bay, a narrow band of low, wet tundra borders the mouth of Koyuk River inlet on the west. This receives moderate use by waterfowl, particularly in late summer and fall. Mudflats are exposed at low water and the beach is an eroding peat bank.

People of Elim hunt in the Kwiniuk inlet wetlands and seasonally inhabit a small village on the Moses Point spit for commercial fishing. Access is now easier via a new road from Elim to the former Moses Point FAA station and landing strip on the sand beach.

Ground surveys were walked on beaches and wetlands at the Kwiniuk and Kwik River mouths. Wetland aerial surveys were flown over these same sites, as well as over Kwiniuk Inlet inside of the Moses Point spit.

11. Koyuk to Cape Denbeigh

Shorelines:

34% Exposed moist tundra/uplands
29% River delta
17% Exposed wetlands
16% Exposed cliffs
1% Exposed spits
1% Protected spits
1% River mouths

Wetland Areas:

61.4 km^2, south of Koyuk River to Inglutalik wetlands; 9.4 km^2, from Ungalik River southwest to Island Point.

Extensive wetlands bound the east shores of Norton Bay. On the south end the high cliffs of the Reindeer Hills and Cape Denbeigh mark the bay's boundary.

The Koyuk River feeds freshwater into shallow Norton Bay, and over time, has deposited its heavy load of fine-grained sediment into a broad fan stretching south from its mouth. It joins the Inglutalik fan to form a low wetland coast 16 km long, providing productive nesting grounds for shorebirds and some ducks. Low eroding peat bluffs interface with extensive mudflats that are exploited by birds when exposed at low water.

Raised moist tundra and high peat bluffs extend south from the Inglutalik fan to the Ungalik River mouth where a small delta system marks the eastern boundary of the low wetlands on the Island Point Peninsula. Reindeer Cove, south of Island Point is a shallow embayment serving as a stopover site for migrant waterfowl. Its south shores are backed by raised moist tundra running west to Point Dexter.

Cliffs and steep terrain descend from the west face of the Reindeer Hills, providing well-populated ledge sites on the south end for nesting murres, kittiwakes, puffins, and cormorants.

Bird life is particularly rich on the northwest shores of Norton Bay. Koyuk people harvest waterfowl from the nearby wetlands, and Shaktoolik people have traditionally egged the Denbeigh colonies. Southeastern shores of Norton Bay are productive salmon waters, particularly near the Ungalik River.

Ground surveys were walked on the wetlands within 6 km of the shore south from Koyuk to the Akulik River. Aerial wetland surveys were flown over the same site and further south to the Inglutalik River.

12. Cape Denbeigh to Tolstoi Point

Shorelines:

26%	Exposed moist tundra/uplands
16%	Protected spits
15%	Exposed cliffs (generally low)
14%	Exposed spits
10%	River delta
9%	Exposed wetlands
9%	Protected wetlands
1%	River mouths
1%	Disturbed beach

Wetland Areas:

51.3 km^2, from Denbeigh to Beeson Slough; 14.6 km^2, behind Unalakleet.

This coastal section features a low-lying, boggy wetland in the north, high earth cliffs to the east, and low basalt cliffs to the very south. Malikfik Bay and the Sineak River inlet receive drainage from the moist tundra of the Reindeer Peninsula and are fronted by mudflats at low tide. Shaktoolik spit encloses Shaktoolik Bay, which receives fresh water from the river by the same name. The spit also directs the flow of the Tagoomenik River, which serves as a harbor and freshwater supply for the village. Beeson Slough, 10 km south of town, is a brackish "lagoon" with no outlet save for possible seepage through the beach ridge. Nesting populations of waterfowl and shorebirds are rather low here for such a seemingly productive expanse of wetlands. Migrant waterfowl come in moderate numbers in both spring and late summer.

Crumbling cliffs back the shore from Beeson Slough south to Unalakleet, except for a shallow cut at Egavik. The Unalakleet River winds through a broad valley south of which earthen cliffs again hang behind the shore. These give way to low basalt cliffs at Tolstoi Point. Mixed alder and spruce woods dominate the vegetation on the uplands above the cliffs south to Poker Creek, immediately northeast of Tolstoi Point.

Besboro Island lies 16 km offshore of Junction Creek and is steeply shored. Horned Puffins, Pelagic Cormorants, and Glaucous Gulls nest there, while a small colony of cormorants, gulls, and puffins has been reported at Tolstoi (Sowls et al. 1978).

Coastal bird use is generally low throughout this section. Waterfowl are taken for subsistence purposes, particularly near Shaktoolik, and commercial fishing is a main source of cash income for many residents.

Ground surveys were walked from the tip of Shaktoolik spit south to Beeson Slough on wetlands, moist tundra, and beaches. In the Unalakleet area, surveys were walked from town 27 km south to Poker Creek on beaches and nearby moist tundra and lakeshores. Wetland aerial surveys were flown from Shaktoolik north over Malikfik Bay wetlands and also along the Unalakleet River upstream from town for 10 km.

13. Tolstoi Point to Cape Stephens

Shorelines:

88% Exposed moist tundra/uplands
8% Exposed cliffs
3% River mouths
1% Exposed wetlands

Wetland Areas:

Few and small.

This is a rocky section with low basaltic cliffs extending its entire length, save for the low shores along St. Michael Bay. Bird use is moderate to low.

A multitude of convoluted bays and rocky heads provide feeding waters for Common Eiders, scoters, and other diving birds. These shores are backed by raised, shrubby, moist tundra with numerous volcanoes and ancient lava flows far to the south. Small seabird colonies occur at the more prominent cliffs including Cape Stephens. Egg Island, 15 km offshore at Wood Point, hosts a moderately large colony of murres, kittiwakes, and puffins (Sowls et al. 1978).

Saint Michael Bay is shallow with extensive mudflats at low tides, as well as tidal canals and narrow wetlands. St. Michael Island is high ground with low waterbird populations.

Subsistence waterfowl use by people of St. Michael is concentrated on the wetlands to the west and south of Stebbins as described in the next section. Egg Island is so named for its traditional use by natives.

No ground surveys were walked in this section, and no wetland aerial surveys were flown here. The St. Michael area was visited occasionally by small boat.

14. Stebbins to Apoon Mouth, Yukon River

Shorelines:

58% Exposed wetlands
37% Exposed moist tundra/uplands
5% River mouths

Wetland Areas:

169.0 km^2, southwest of Stebbins to Nokrot.

Low peat shores line this section of low relief. Birds concentrate on shore, especially towards the northeast on some of Norton Sound's most productive wetlands.

Southwest of Stebbins, the lake-studded and canal-ridden wetland plain is home to dense nesting populations of shorebirds and some ducks, and serves as a feeding site for many waterfowl. At Nokrot, the land rises slightly to become shrubby moist tundra; a fan of coastal wetlands reaches 14 km east of Apoon Mouth to meet this. Low tides expose a narrow band of peaty mudflats along the shore and mud banks on the canals. These canal banks receive concentrated use by feeding shorebirds, while the shoreline flats are rarely visited by waterfowl or shorebirds.

People of Stebbins and St. Michael hunt extensively on the flats southwest of St. Michael Island for waterfowl.

Ground surveys were walked on the wetlands and nearby moist tundra southwest of Stebbins and mostly north of the St. Michael Canal. Wetland aerial surveys were flown over the same area.

15. Stuart Island

Shorelines:

93%	Exposed moist tundra/uplands
3%	Exposed cliffs
2%	Exposed wetlands
1%	River mouths

Wetland Areas:

22.0 km^2, along the cross-island canal.

Shorelines of this island are low rocky cliffs, similar to those east of St. Michael. A wide canal cuts the island into eastern and western halves, providing rich wetlands along its shores. Bird use parallels that of the Stebbins area, though at a lower level, and is especially prominent during migration.

Tundra above the cliffs is well drained with occasional shrubs. A few small groups of puffins and cormorants nest on the northwestern and southwestern shores (Sowls et al. 1978).

The canal is a popular route for subsistence waterfowl hunters, and the uplands have been used for reindeer grazing.

B. Coastal Habitat Descriptions

Potential bird use of an area depends on the types and amounts of habitat available, and the availability of habitats is dictated by physiography and erosion patterns. With this in mind, we identified 14 separate habitat types along the Norton Sound coast. Eleven of these are along shorelines; these are linear and contain the littoral zone. Three are areal and refer to tundra habitats adjacent to the coast. Descriptive accounts of

Table 1. Habitat lengths (km) in 15 coastal sections of Norton Sound.

Area	Exposed Shores				Protected Shores				Other Shores			Total
	C[1]	MT/U[2]	W[3]	S[4]	C[1]	MT/U[2]	W[3]	S[4]	RD[5]	RM[6]	D[7]	
1. Wales to Brevig	16.8	41.3		24.0		20.3		24.8	4.5	1.4		133.1
2. Port Clarence		8.8	3.2	25.0	3.4	21.6	15.0	33.8		0.7		111.5
3. Grantley Harbor and Tuksuk Harbor					1.4	69.2		1.0		1.4		73.0
4. Imuruk Basin						45.6	5.5		22.4	1.9		75.4
5. C. Douglas to Nome (Woolley Lagoon)		76.2	21.6			26.9	16.8	21.6		1.0		164.1
6. Nome to C. Nome		17.9								0.6	1.3	19.8
7. C. Nome to Rocky Pt.	14.4	50.2		40.0		31.5	12.3	40.8		0.6		189.8
8. Golovin Bay	12.5	44.0		1.9		1.0		0.8		0.8		61.0
9. Golovin Lagoon						28.8	4.8	7.0	14.4	0.7		55.7
10. C. Darby to Koyuk	38.7	31.4	27.0	13.8			11.2	13.6		1.7		137.4
11. Koyuk to C. Denbigh	17.6	37.1	18.4	0.8		0.8		0.8	32.0	1.5		109.0
12. C. Denbigh to Tolstoi Pt.	21.6	39.4	14.2	21.0			13.3	25.3	15.5	1.7	1.4	153.4
13. Tolstoi Pt. to Stebbins	9.6	100.0	0.8							3.6		114.0
14. Stebbins to Apoon Mouth		24.0	37.8							3.2		65.0
15. Stuart Island	2.2	69.0	1.8							1.0		74.0
Total	133.4	539.3	103.2	148.1	4.8	245.7	78.9	169.5	88.8	21.8	2.7	1,535.4

[1] Cliffs. [2] Moist Tundra/Uplands. [3] Wetlands. [4] Spits. [5] River Delta. [6] River Mouth. [7] Disturbed.

each are given below. Table 1 lists the lengths of the shoreline habitats in each section of coast.

Our basis for segregating habitats was guided by descriptions of Kessel (1979) and of Holmes and Black (1973); though the coastal and broad-scale nature of our surveys limited us to broad habitat categories. An oil spill vulnerability assessment is given below for each shoreline habitat; this is taken directly from Hayes and Gundlach (1980).

Coastal habitats are mapped in Appendices 27 through 35; these distinguish wet tundra, moist tundra, cliffs, and spits.

1. Classification Scheme

A. Shorelines — Shoreline habitats were classified by exposure:
   (1) Exposed coasts, open to strong wave action.
   (2) Protected shores as in lagoons or sheltered embayments.
   Each of these two classes is divided into four habitat types, based on the terrain behind the beach:
      (a) Shoreline backed by cliffs.
      (b) Shoreline backed by moist tundra or uplands with shrubs or spruce.
      (c) Shoreline backed by wet tundra (wetlands).
      (d) Shoreline on a spit.
   (3) We identified three additional shoreline habitats without regard to exposure:
      (a) Disturbed beaches, e.g. at Nome and Unalakleet.
      (b) River mouths.
      (c) River deltas.

B. Tundra — We classified near shore tundra habitats according to wetness. These are areal in nature and do not include the littoral zone:
   (1) Wet tundra (or wetlands).
   (2) Salt-washed wet tundra — a type of wet tundra (wetlands).
   (3) Moist tundra.

It is important to note that while the shoreline habitats are linear, the tundra habitats are areal of often extend several kilometers inland from the beach. The differences in sampling these two classes of habitats will be discussed in the Methods section.

2. Descriptions.

A. Shoreline Habitats

(1) Exposed Coasts

(a) **Exposed coasts with cliffs**

Extent — 9% of shoreline.

Description — Nearly vertical rocks at least 5 m high abutting the sea, sometimes with a narrow rocky, gravel, or sand beach. Often with moist tundra, shrublands, or spruce forest above the cliffs.

Substrate — Rock.

Vegetation — Sparse on cliff faces and below.

Bird Use — Principally used by local concentrations of seabirds, murres, kittiwakes, Glaucous Gulls, and cormorants for nest sites inaccessible to mammalian predators.

Locations — Extensive cliffs near Tin City, at Topkok and Bluff, Rocky Point, Cape Darby from Pt. Dexter to Cape Denbeigh on the Reindeer Peninsula, and at Cape Stephens.

Oil Spill Vulnerability — Low due to wave washing, though seabirds resting on water near cliffs would be highly susceptible.

(b) **Exposed Coasts with Moist Tundra or Uplands**

Extent — 35% of shoreline.

Description — A general habitat including all exposed shores backed by fairly well-drained terrain with a gentle or steeply sloping surface; often with sedge tussocks and occasional tundra polygons. This coastline includes many projections of rocky shorelines.

Substrate — Gravel or sand, sometimes with a sloughed peat layer from eroding peat bluffs, or possibly with rock.

Vegetation — Scarce on the beach, often limited to Sandwort (Honckenya peploides), Beach Pea (Lathyrus maritimus), and various grasses (Elymus arenarius and Calamagrostis spp.) on sandy beaches; with alders (Alnus spp.) and willows (Salix spp.) abutting the beach where steep ground is present.

Bird Use — Limited to large gulls, and occasional use by sandpipers and songbirds for feeding in the drift zone; occasional use by diving ducks and loons offshore. Rocky shorelines are important feeding areas for diving sea ducks.
Locations — Extensive and throughout the Sound.
Oil Spill Vulnerability — Usually low on sand beaches, moderate on gravel beaches, and high where the shore is a peat platform (Norton Bay) or along basalt boulder beaches (Tolstoi Point to St. Michael).

(c) **Exposed Coasts with Wet Tundra (Wetlands)**
Extent — 7% of shoreline.
Description — Shorelines backed by poorly drained marshy terrain dotted with ponds and lakes. Nearly identical to river delta shorelines, but not bounded by river channels. This is one of the three wetland shoreline habitats.
Substrate — Peat (often from a low eroding peat bank) or sand, rarely gravel.
Vegetation — If the nearshore substrate is peat, plant communities include various grasses (Elymus, Calamagrostis, and with Puccinellia in salt-washed areas) and/or various sedges (Carex spp.); if sand or gravel beach, vegetation is sparse and limited to Sandwort, Beach Pea, and Lyme Grass (Elymus arenarius).
Bird Use — Variable; sometimes used as a feeding area for shorebirds and waterfowl if mudflats are exposed at low tide.
Locations — Mostly in Norton Bay near Shaktoolik, and southwest of Stebbins.
Oil Spill Vulnerability — Usually low on sand beaches, moderate on gravel beaches, and high along peat banks (Norton Bay and from Stebbins southwest to Apoon Mouth).

(d) **Exposed Coasts with Spits**

Extent — 10% of shoreline.

Description — Sand or gravel beaches on narrow spits protecting a lagoon or within a similar body of water.

Substrate — Sand or gravel.

Vegetation — Usually bare or with sparse clumps of Elymus or sandwort, with Elymus forming the most visible layer. Occasionally with Crowberry (Empetrum nigrum) and willow on higher beach ridges where the spit is fairly wide (more than 100 m).

Bird Use — Nesting habitat for terns; roosting area for gulls, terns, and some waterfowl.

Locations — Brevig Lagoon, Port Clarence, Woolley Lagoon, Safety Lagoon, Moses Point, Shaktoolik, and to a limited degree at Unalakleet.

Oil Spill Vulnerability — Usually low.

(2) Protected Shores

(a) Protected Shores with Cliffs

Extent — 0.3% of shoreline.

Description — Nearly vertical cliffs at least 5 m high abutting a lagoon or other protected body of water; sometimes with a narrow sand or gravel beach at the base.

Substrate — Rock.

Vegetation — Sparse.

Bird Use — Used for nest sites by seabirds that feed in shallow water, e.g. Pelagic Cormorants, Pigeon Guillemots, Horned Ruffins, and Glaucous Gulls.

Locations — Restricted to Port Clarence south of Teller, and at Six Mile Point in Grantley Harbor.

Oil Spill Vulnerability — High due to low wave energy, though it is unlikely that oil would reach these interior sites.

(b) **Protected Shores with Moist Tundra or Uplands.**
Extent — 16% of shoreline.
Description, Substrate, and Vegetation — Similar to those given for exposed coasts backed by moist tundra.
Locations — The predominant habitat in Grantley Harbor, Imuruk Basin, and Golovin Lagoon, and extensive in Brevig Lagoon, Port Clarence, Woolley Lagoon, and Safety Lagoon.
Oil Spill Vulnerability — Moderate to high due to low wave action, particularly where substrate is peat (some shores of Safety Lagoon).

(c) **Protected Shores with Wet Tundra (Wetlands)**
Extent — 5% of shoreline.
Description — Similar to that for exposed coasts backed by wetlands; this is one of three wetland shoreline habitats.
Substrate — Almost always a low, eroding peat bank, with either a sandy or peat-laden flat offshore.
Vegetation — A grass-sedge community including Elymus, Calamagrostis, Puccinellia (in salt-washed areas) and various sedges (Carex subspathacea if salt-washed).
Bird Use — Often extensive use by feeding waterfowl; less extensive use by shorebirds.
Locations — Port Clarence, Imuruk Basin, Woolley Lagoon, Safety Lagoon, Golovin Lagoon, Moses Point, Malikfik Bay, and Shaktoolik Bay.
Oil Spill Vulnerability — High; tide flats and vegetated zones will retain oil for several years, grass would die, and many birds would be exposed to oiling.

(d) **Protected Shores with Spits**
Extent — 11% of shoreline.
Description — Sand or gravel beaches on narrow spits facing a lagoon or other protected body of water. Often a convoluted shoreline with side spits, spurs, and small embayments, including pockets of wetlands and muddy ponds.

Substrate — Sand or gravel, often with a mud or peat organic component.

Vegetation — Usually more richly vegetated than exposed shores of spits, with Elymus, Calamagrostis, Puccinellia, and sedges. Crowberry may approach the water's edge where beach ridge vegetation has succeeded the dune grass stage.

Bird Use — Nesting habitat for terns and shorebirds; roosting and feeding area for gulls, shorebirds, and waterfowl.

Locations — Brevig Lagoon, Point Spencer, Woolley Lagoon, Safety Lagoon, Golovin Lagoon, Moses Point, Shaktoolik, and Unalakleet.

(3) Other Shorelines

(a) River Delta Shorelines

Extent — 6% of shoreline.

Description — All shores between river mouths of branching channels of the same river; muddy sand flats are often exposed at low tide and may be extensive. This is one of three wetland shoreline habitats. Extended to include similar habitat at the edge of depositional fans in the Imuruk Basin, at Koyuk, and near Shaktoolik, but not at Moses Point. This was a somewhat arbitrary exclusion; the Moses Point-Kwik River fan was considered to be best described as wet tundra (wetlands).

Substrate — Usually peat and sand matrix.

Vegetation — Usually with a grass-sedge community near the shore composed of Elymus, Calamagrostis, Puccinellia, and sedges. Sometimes with a low marshy mat of mosses and sedges beyond the grass-sedge zone.

Bird Use — Often very great for feeding birds, particularly waterfowl and shorebirds. Waterfowl also use it as an escape from hunters.

Locations — Brevig Lagoon (California and Don Rivers), Imuruk Basin (Agiapuk and Kuzitrin Rivers), Golovin Lagoon (Fish River), Norton Bay (Koyuk-Inglutalik River complex), and Shaktoolik (Shaktoolik River and nearby streams to the north).

Oil Spill Vulnerability — High due to organic sediments and vegetation; also a high use area for birds.

(b) **River Mouths**
Extent — 1% of shoreline.
Description — Water and nearby shore at a river or stream outflow, not including channel mouths or river mouths of delta systems.
Substrate — Sand and/or silt.
Vegetation — Generally sparse due to flooding and ice-flow at spring break-up
Bird Use — Ducks, gulls, and shorebirds concentrate in these areas.
Locations — In all coastal sections.
Oil Spill Vulnerability — Low (with sand substrates) to moderate (with gravel substrates); higher in sheltered waters.

(c) **Disturbed Beaches**
Extent — 0.2% of shorelines.
Description — Sea beaches with seawalls (Nome) or road grades, disturbed by noise from generators and vehicles, vehicle traffic, and human presence. Garbage and junk litter the beach and wastes are often dumped untreated into the sea.
Substrate — Sand, gravel, steel, and pampers.
Vegetation — Often removed; if present, usually limited to Elymus and sandwort.
Bird Use — Roosting sites for larger gulls, visited during quiet hours by ravens.
Locations — Larger townsites, notably Nome and Unalakleet.
Oil Spill Vulnerability — Low to moderate.

B. **Tundra Habitats.** The tundra habitats listed below refer to areal habitats extending from the coast inland. They differ from the preceding coastline habitats in that they do not contain the littoral zone, nor are they linear. Throughout this report we often use the term "wetlands" to refer to wet tundra habitats. Note that "wet tundra" and "salt-washed" wet tundra" are lumped in all analyses of habitats and that the areal tundra habitats occur inland of other shoreline habitats, discussed above.

(1) **Wet Tundra (Wetlands)**

Description — Low, poorly drained ground usually with an abundance of lakes and small ponds and wet, grassy meadows. Includes wet meadows and small patches of grass meadow described by Kessel (1979).

Substrate — Organic layers.

Vegetation — Sedges, cottongrass (Eriophorum spp.) with a moss (Sphagnum most common) underlayer dominating the wetter areas. Dwarf birch and heath mats cover slightly raised terrain.

Bird Use — Principal nesting grounds for small sandpipers, many waterfowl, and loons.

Locations — Throughout the Sound, particularly the eastern end, on river deltas and near lagoons.

(2) **Salt-Washed Wet Tundra.**

Description — A type of wetland (we sometimes had difficulty distinguishing this type from rarely flooded wetlands, and they are lumped in all analyses of habitat use by birds). Low-lying terrain subject to saltwater inundations, usually at the highest tides or during periodic storms. These inundations generally occur one or more times each year. Equivalent to the salt grass meadow of Kessel (1979).

Substrate — Often sandy, with silt and some organics.

Vegetation — Characterized by salt-tolerant grasses and sedges (Puccinellia phryganodes and Carex subspathacea).

Bird Use — Nesting area for some shorebirds, waterfowl, gulls, and terns.

Locations — Limited to the lowest areas of wetlands, including those at Wales, Port Clarence, Woolley Lagoon, Safety Lagoon, Golovin Lagoon, Moses Point, Koyuk, and Stebbins. Also very common coastally on the Y-K Delta.

(3) **Moist Tundra or Uplands**

Description — Raised, gently to steeply sloping ground with hummocks and/or tussocks. This is mainly the dwarf shrub meadow and dwarf shrubmat habitats of Kessel (1979), but also includes her taller shrub habitats.

Substrate — Organic, probably thinner than on wetlands.
Vegetation — On moderate slopes, tufts of cottongrass or other sedges form tussocks with interstitial mosses and lichens. Flatter ground is usually covered by a dwarf shrub and heath mat with a basal layer of mosses and colorful lichens. The dominant shrubs are prostrate willows, dwarf birch (Betula nana), Crowberry, Labrador Tea (Ledum palustre), and bluberries (Vaccinium spp.).
Locations — Covers extensive areas in coastal Norton Sound.

C. Wetlands of Norton Sound

Most of Norton Sound's birds (except cliff-nesting species) concentrate on the low wetlands near the coast. These wetlands are primarily expanses of wet tundra (wet meadows and salt grass meadows of Kessel (1979)), although each wetland is unique from all others due to its: size, substrate, vegetative cover, frequency of coastal flooding, number and density of lakes and ponds, and presence of a river delta, lagoon with barier spits, and tidal canals or channels. These wetlands are presented below and our census methods are indicated (land survey = LS, wetland aerial survey = WAS; see Chapter V). Some of the information given below appears in Section A, "Physiography," of this chapter and is repeated here for clarity.

Wales — many km^2, surveyed by LS. Wetlands here are at the margin of our study area and extend far to the northeast towards Kotzebue Sound. Vegetation is lush and the terrain is dotted with many lakes and ponds. Landward of the sea beach are brackish pools, and mudflats are common along the lagoons here where salt-tolerant plants indicate occasional flooding.

Brevig Lagoon — 7 km^2, censused by LS. This is a minor wetland area bordering a brackish lagoon. Vegetation is sparse and a gravel substrate is predominant, especially along the braided streams.

Port Clarence — 13 km^2, censused by LS and WAS. This is a small but productive wetland on the south side of the embayment. There are many lakes and ponds. Salt-tolerant sedges and grasses are common, suggesting frequent flooding.

Imuruk Basin — 41 km^2, censused by LS and WAS. Wetlands are most extensive on the north and northeast sides of the basin at the Agiapuk and Kuzitrin River Deltas. Water was fresh (when visited in June) and the area is characterized by the dominance of shrubs. Lakes and ponds abound at this inland site.

Woolley Lagoon — 7 km^2, censused by LS. Substrates surrounding the lagoon are generally sandy or stony and ponds are relatively few. Wet meadows are not as lush here as at wetlands to the east.

Cape Woolley to Sinak — 30 km^2, censused once by WAS. This is not a very "wet" wetland, rather it is a series of lakes and ponds about 1 km inland that often attracted small flocks of waterfowl in late summer. Surrounding vegetation is more similar to moist tundra/uplands.

Safety Lagoon — 55 km^2, censused by LS and WAS. This includes the wetlands around Safety Lagoon, near Solomon, around Taylor Lagoon, and at the mouths of the Flambeau and Eldorado Rivers. Vegetation is usually a lush sedge meadow (with a lush organic substrate) mixed with patches of moist tundra near uplands or with low salt-washed flats nearest to the water. Lakes and ponds are numerous and there are a few brackish channels.

Fish River Delta — 39 km^2, surveyed by LS and WAS. A gradual rise from the lagoon shore towards the trees to the northwest dictates the wetlands characteristics here. Mudflats are extensive at the terminus of the delta, with frequently flooded grass and sedge meadows to landward. Lakes and ponds are common, and marshes border quiet banks of the numerous river channels. Wet meadows give way to drier grassy meadows, and then shrubs, before the tree border is reached upriver. Substrates are richest along pond margins and silty or sandy on slightly higher ground.

Moses Point — 50 km^2, surveyed by LS and WAS. Wetlands here are in two units. One is at the mouth of the Kwiniuk River, where many ponds, lakes, and channels are protected by short spits. This extends eastward to Kwiniuk Inlet. The other borders the Kwik River mouth, and this has a greater mix of moist tundra patches with scattered shrubs and small spruces. Mudflats border the mouth of the Kwik River and Moses Point spit offers some protection from southwest weather.

Koyuk — 61 km^2, surveyed by LS and WAS. Wetlands border the Koyuk River Inlet to both the southwest and southeast, and are most extensive in the latter direction. Lakes, ponds, and channels abound. Vegetation is lush and marshy, and the area is underlain by a deep peat layer. Mudflats are extensive to the southeast.

Shaktoolik — 51 km^2, surveyed by LS and WAS. Wetlands here are extensive but quickly grade into moist tundra inland. Lakes, ponds, and channels are common, and some protection is provided by intermittent spits; mudflats are exposed at low tides near major river channel mouths.

Unalakleet — 15 km^2, surveyed by LS (only once by WAS). The small but heavily channeled and pond-rich Unalakleet River Delta is protected by short spits. Unalakleet is the largest town adjacent to any wetland in the Sound, and the area is disturbed by jet traffic and numerous outboards.

Stuart Island — 22 km^2, surveyed by WAS. Wetlands are confined to a strip 1 km on either side of Stuart Island Canal, which divides the island in two. Ponds, lakes, and marshy channels are common.

Stebbins — 169 km^2, surveyed by LS and WAS. Extensive wetlands stretch from St. Michael Bay, south of Stebbins and to the southwest. Relief is low and ponds, lakes, and channels are abundant, with many kilometers of wide canals. Mud canal banks are exposed at low tide; and with storm surges, the entire wetlands floods easily due to the low, level relief. Vegetation and substrates are richest along lake and pond margins and the area is underlain by a deep peat layer.

V. RATIONALE, SOURCES, AND METHODS OF DATA COLLECTED

A. Rationale

The diversity of coastal habitats along the Norton Sound shoreline as well as its great length present a number of major sampling and logistical problems when attempting to assess the seasonal importance of specific habitats and areas to birds. These are compounded by the relatively short period when large numbers of birds are present (May through October) and the changes in habitat and geographical area use that occur during this time. The activities of birds while in Norton Sound include spring migration, pre-nesting activities, nesting, post-nesting movements to feeding grounds, pre-migratory staging, and fall migration. Frequently the different requirements of birds during each activity and seasonal differences in the productivities of habitats mean that a species will occupy different habitats and areas as it progresses through these activities.

In order to deal with the above problems and with the limits of the time and resources that could be spent on this project we attempted to obtain a broad overview of the seasonal abundance, habitat use, and geographic distribution of birds in Norton Sound. Large-scale surveys were conducted, instead of site-specific work that would allow a look at the processes determining bird abundance and patterns of habitat use. We hope the data presented here provide a background for such studies. In order to maximize the amount of data directly related to OCSEAP concerns the following decisions and assumptions were made:

(1) **Cliff colonies of seabirds would not be included in our surveys of coastal bird use.** The seabird nesting cliffs and adjacent nearshore waters as well as offshore feeding areas used by cliff nesting species are areas of high bird use and high sensitivity to oil spills and other disturbances. This appears to be a generally accepted fact. We did not want to compare the bird use of habitats such as lagoons with nesting cliffs since any sort of quantitative differences would be worthless due to the different processes involved in each habitat. The locations and sizes of cliff colonies are given in Drury (1980) and in Sowls et al. (1978).

(2) **Regular aerial surveys of shorelines would be conducted along the coast to provide general information on habitat and geographic use.** This would allow broad-scale determinations of habitat use and the locations of any large bird aggregations.

(3) **Large areas of coastal wet tundra (wetlands) would be given special attention.** Wet tundra areas identified by Drury (1980) and by our coastal habitat mapping were sampled both on non-shoreline aerial surveys (wetland aerial surveys) and on ground-based surveys (land surveys). Both of these census methods provided information on densities for the areal tundra habitats of the wetlands. In addition, the land surveys provided shoreline densities. No other areas received censusing of birds from the air in habitats adjacent to the shore and few other areas had ground-based surveys. We gave these areas extra attention because:

(a) Drury (1980) found them to be important to large numbers of birds when compared with other areas and habitats of Norton Sound.

(b) We felt that for many species the majority of their Norton Sound populations are found in the wetland areas we studied.

(c) These areas have little coastal relief and are periodically covered by storm surges; thus, they are more vulnerable to marine pollution than areas with cliffs or bluffs abutting the sea.

(d) Many of these areas have regular contact with seawater by tidal movement through lagoonal systems, river deltas, or canals (Stebbins). Such protected littoral areas are the most sensitive to oil spills in Norton sound (Hayes and Gundlach 1980), since their fine sediments and vegetation entrap the oil, causing it to persist for a much longer period than in areas with more wave action and unvegetated rocky shores.

Thus, for many species all or much of the data we present are from wetland aerial surveys or from land surveys conducted either in wetlands or in shoreline habitats directly adjacent to wetlands. The reader should thus limit extrapolation of most of this data to other wetland areas only.

B. Sources

The primary sources of information for this report are two seasons of fieldwork: 5 May to 27 October 1980 and 29 April to 12 September 1981. Extensive coastal surveys by air and land dominated the first year of fieldwork. This required clear definitions and delineations of coastal habitats, which are presented in Chapter IV, Section B, "Coastal Habitat

Descriptions." Many of the 1980 surveys were repeated in 1981 to measure yearly variability. The second season of fieldwork also allowed us to study prey availability and trophic preferences for two major bird groups.

Previous air surveys of waterfowl concentrations by Drury (1980) in 1975, 1976, and 1977 provide a firm base of comparative data, as well as clear insights into habitat use. Analyses in the present report that include Drury's data are clearly noted. Additional data were gleaned from observations by Woodby at sea in September, 1976 (NOAA ship **Discoverer**, RU 196) and at Wales on the Bering Strait from 2 June to 10 September 1977 (RU 72).

Habitat lengths were measured by hand with a map wheel from USGS 1:63,360 series maps. Wetland areas were measured from these same maps by tracing wetland outlines on graph paper and counting the enclosed squares. Ground-based knowledge of habitats and extent of wetland aided these measurements considerably.

C. Methods

1. Habitat Use Surveys

Surveys were designed to analyze three patterns:

(1) **Habitat Use** — variation in the numbers of birds in the 13 habitats described in Chapter IV, "Study Area."

(2) **Seasonal Use** — population changes from May through October on a monthly or twice-monthly basis.

(3) **Geographical Area Use** — variations in the numbers of birds in each of 15 coastal sections and 12 wetlands (see Chapter IV and Figures 1 to 3), and also wetlands northeast of Wales.

Survey techniques are described below, followed by a listing of the technique used for specific groups or species of birds.

(a) Land Surveys. Land surveys were done at 14 sites (all wetlands except at Nome) from Wales to Stebbins (Figure 2; see also Chapter IV, "Study Area"). We virtually ignored large expanses of raised moist tundra and uplands. We consider this prudent for two reasons. First, low-lying wetlands are more vulnerable to oil on water than are raised areas; and second, low wetlands are the richest nesting and feeding sites for water birds. The high density of birds requires more frequent sampling because of the tendency for natural variation in numbers to increase with the magnitude of the populations. Thus, more samples are needed to make reliable estimates of average bird use. Our sampling effort in land habitats reflects this (Table 2).

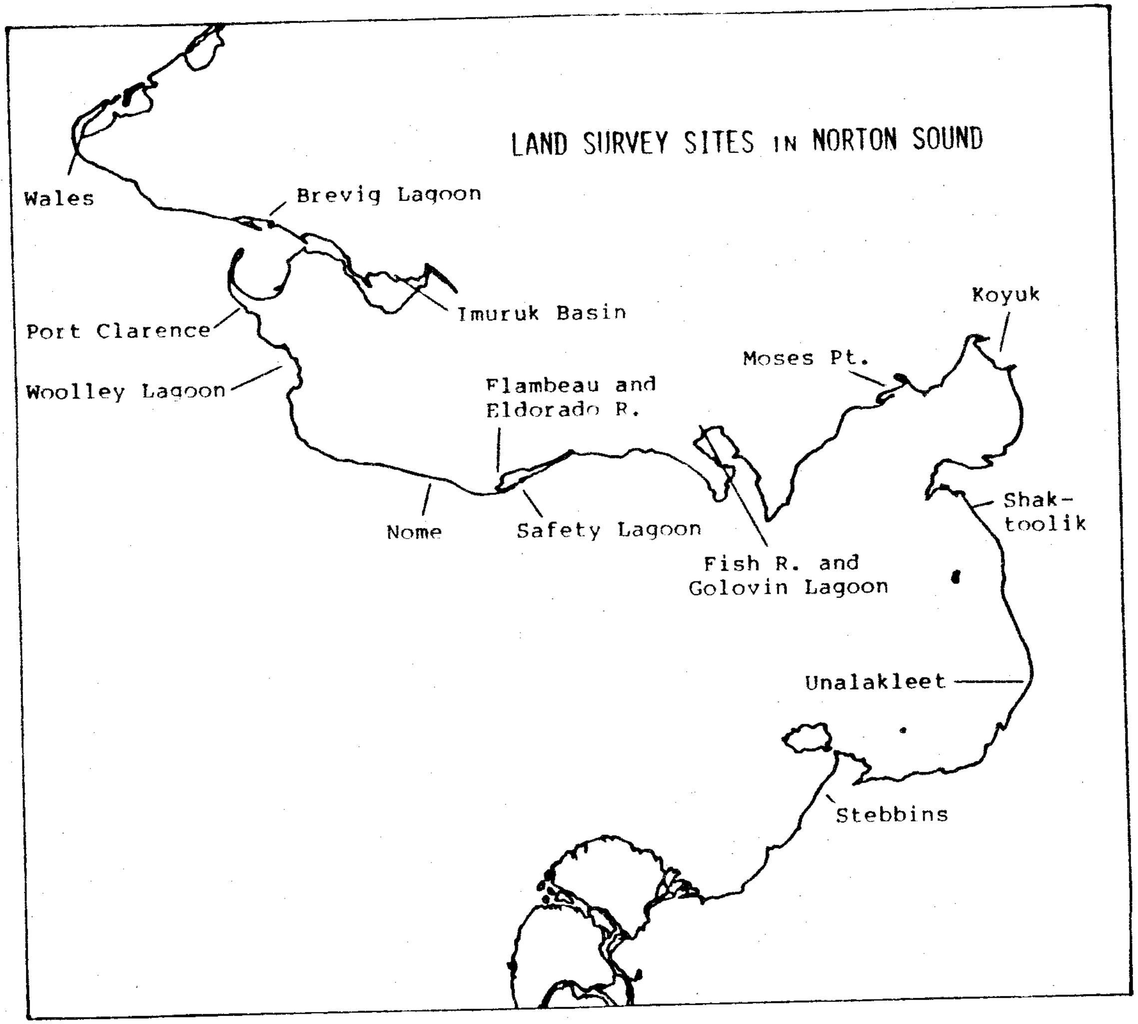

Figure 2. Locations of land surveys. See chapter IV part A for details on locations and Appendices 1 and 2 for dates.

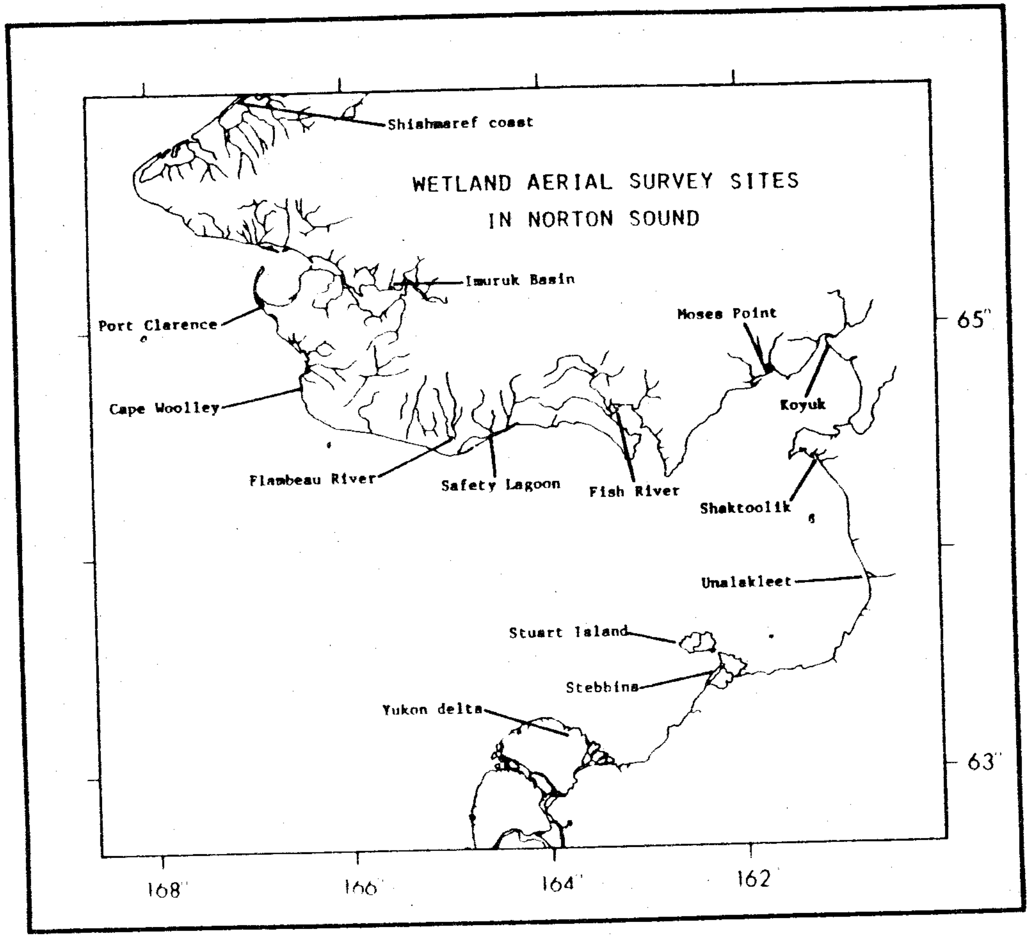

Figure 3. Locations of wetland aerial surveys. See chapter IV parts A and C for details on locations and Appendices 5 and 6 for dates.

Table 2. Lengths of coastal habitats censused by land surveys, 1980 and 1981.

Habitat Type	**Km Walked** 1980	 1981	**Total**	**%**
Shorelines				
Exposed Shores:				
With Cliffs	5	0	5	0.2
With Moist Tundra/Uplands	82	9	91	4.5
With Wet Tundra	52	16	68	6.3
On Spits	220	16	236	11.6
Protected Shores:				
With Moist Tundra/Uplands	25	15	40	2.0
With Wet Tundra	21	11	32	1.6
On Spits	174	11	185	9.1
Other Shores:				
River Mouth	19	0	19	0.9
Disturbed Shore	75	3	78	3.8
Shoreline Subtotal	673	81	754	40.0
Tundra				
Moist Tundra/Uplands	210	118	328	16.1
Wet Tundra	716	234	950	46.8
Tundra Subtotal	926	352	1,278	59.9
Total	1,599	433	2,032	99.9

Most sites were visited monthly in 1980 (see Appendix 1), except when we were limited by poor weather or lack of personnel. Imuruk Basin was surveyed only once because of its relative remoteness from the impacts of offshore oil development. Fewer sites were visited in 1981 (see Appendix 2). In 1981, the Fish River Delta was visited two to three times a month except for July, and Stebbins was visited once a month in June, July, and August. Safety Lagoon was visited twice, and Koyuk and Shaktoolik once.

Transects were used as our sampling unit on land. These provide an index of abundance for birds in each habitat expressed as a number of individuals per linear kilometer. Our technique was adapted from prior studies of shorebirds in arctic Alaska (Connors et al. 1979), simplified for the wide varieties of terrain in Norton Sound. The technique consisted of walking a staked line from 1 to 4 km through one or more habitats, counting birds along the way. Notes were made on species, numbers, age, sex, and behavior. Transects were 50 m wide on beaches, including 500 m of nearby waters, and were 100 m wide on tundra.

The difference in transect widths necessitates caution when comparing shoreline and tundra data; this is compounded by the conceptual distinction between linear and areal habitats. Birds concentrate along the shore because of the narrow littoral interface of land and water. Birds using the tundra are more dispersed, and are responding to habitat values broadly spread over two dimensions. This distinction is made clear in our analysis, though we do compare shoreline and tundra use where appropriate.

Transects are most appropriate for censusing small birds such as sandpipers, terns, and songbirds. Larger birds, particularly waterfowl and cranes, are easily frightened and flush at great distances from a walking observer. This creates gross underestimates of their abundance when counted from land.

Besides transect data, land surveys provided parameters on nesting phenology for most tundra nesters. Whenever possible, we determined the dates of egg laying, egg hatching, and chick fledging. If these data were not observed directly, we aged eggs by floating (Westerkov 1950) or, rarely, candling (Weller, 1956). Chicks were aged by approximation, using keys for waterfowl (Gallup and Marshall in Giles 1969), or estimates for other groups. For almost all species we extrapolated unknown laying, hatching, or fleding dates from known dates.

(b) Aerial Surveys. We made extensive surveys of Norton Sound shores from small planes, visiting many otherwise inaccessible areas. These surveys were of two distinct types: (1) along shorelines, and (2) over wetlands; each of these required different techniques and analyses. The shoreline surveys, described first, were intended to completely sample all shoreline habitats on a regular basis. The wetland transects, described last, were aimed at sampling significant portions of the most productive wetlands where birds were most abundant.

All habitats covered on shoreline aerial surveys were censused in close proportion to their frequency (Table 3) by surveying the entire coast in one flight. This was not always true for lagoon habitats. In lagoons, we centered the flight path over the barrier spit so as to census both the lagoon side and the sea side of the spit, and only occasionally flew the inland shores of lagoons. In 1980, shoreline aerial surveys were flown at least once a month in all coastal sections, and more frequently in those along the north shore of the Sound (Appendix 3). This was due in part to the high cost of long flights away from our base in Nome (1980) and because we flew surveys whenever we transported personnel by air charter to our numerous field sites on the north shore. Fewer surveys were flown in 1981 (Appendix 4), covering all coastal sections in May, June, August, and September.

(i) Shoreline Aerial Surveys. When surveying the coast we flew about 50 m offshore parallel to the coastline with an observer on each side of the plane, counting birds within 200 m of the flight path. Air speed averaged 200 km/hour, and altitude averaged 40 m. Data from shoreline aerial surveys are expressed in birds per kilometer of habitat, allowing comparisons between habitats, areas, and months.

(ii) Wetland Aerial Surveys. These were flown repeatedly at 13 sites in Norton Sound, and once along the Shishmaref coast (Figure 3). These wetland sites are described in Chapter IV, "Study Area." Ninety-two were flown from 31 May to 27 October in 1980 (Appendix 5) and 50 from 6 May to 15 September in 1981 (Appendix 6). These were most frequent from Safety Lagoon to Koyuk in late summer, when waterfowl were most abundant. Our efforts add considerably to those of Drury (1980) from 1975 to 1977 and used the same methods and approximately the same flight paths as his surveys. Together, our data provide the best description of waterfowl distributions in Norton Sound.

On wetland aerial surveys birds were censused from the same altitude and over the same transect width as on shoreline surveys, but the speed was slower (177 km/hour) and the density of birds was computed as the number per minute of flight time. In some cases we converted birds per minute to birds per square kilometer to compute the total population for a wetland. A slower speed than used on shoreline aerial surveys was necessary because birds are more concentrated in wetlands. Data from wetlands transects are not directly comparable to those from coastal surveys due to the conceptual difference between linear and areal habitats.

Table 3. **Lengths of shoreline habitats surveyed by air in Norton Sound, 1980 and 1981.**

Habitat Type[1]	Km Flown 1980	Km Flown 1981	Total	Percent	Percent Available
Exposed Shore:					
Cliffs	828	433	1,261	12.1	8.7
Moist Tundra/Uplands	2,666	1,389	4,055	38.8	35.2
Wetlands	575	360	935	8.9	6.7
Spits	833	262	1,145	11.0	9.7
Protected Shore:					
Cliffs	22	7	29	0.3	0.3
Moist Tundra/Uplands	906	192	1,098	10.5	16.0
Wetlands	298	95	393	3.8	5.1
Spits	678	197	875	8.4	11.0
River Delta	364	201	565	5.4	5.8
River Mouth	60	34	94	0.9	1.4
Total	7,647	3,321	10,968	100.1	99.9

[1] Does not include disturbed beach, which was not censused by air. Frequent landings and takeoffs of our survey planes near these beaches made it impractical to backtrack to these shorelines to census such short distances (sum = 2.7 km).

(c) Survey Techniques for Specific Groups or Species. One or more of our survey techniques, shoreline aerial surveys (SAS), wetland aerial surveys (WAS), or land surveys (LS), were used to census the following species or species groups:

(1) Loons — LS.
(2) Waterfowl —
    Swans:
        Habitat use — SAS.
        Seasonal abundance and geographic distribution — WAS.
    Geese:
        Habitat use — SAS.
        Seasonal abundance — WAS (SAS for Brant).
        Geographic distribution — WAS.
    Dabbling Ducks:
        Habitat use — SAS.
        Seasonal abundance — WAS (LS for Green-winged Teal and Northern Shoveler).
        Geographic Dsibribution — WAS.
    Diving Ducks — SAS.
(3) Cranes —
    Habitat use — SAS.
    Seasonal abundance and geographic distribution — WAS.
(4) Shorebirds — LS.
(5) Jaegers — LS.
(6) Gulls —
    Habitat use and geographic distribution — SAS (LS for Sabine's Gull).
    Seasonal abundance — SAS, WAS, LS.
(7) Terns — LS.
(8) Passerines — LS.

The above list gives the primary method(s) only; supplementary data is occasionally presented from other methods.

(d) Projected Populations. Land and air surveys of wetland habitats and shorelines provided us with bird densities that lend themselves to extrapolation. Extrapolation is justified when the following conditions are met:

(1) The density applies to a representative sample of the wetland or shoreline habitat.
(2) The area (km^2) or distance (km) of habitat to which the density applies is well delineated.

Multiplying the density by the area or linear distance yields relative population estimates only as reliable as the density and delineation on which they are based. The wetland sites for which densities can be most reliably measured are the most monotypic in habitat. The Stebbins wetlands are especially homogeneous, and since our transects of this area were well dispersed we are most confident of our projected populations for that area. This is fortunate, since this area is also the largest and had some of the greatest densities, and therefore very large populations.

Our most uncertain population values are derived from surveys of wetlands at Shaktoolik, Moses Point, and Safety Lagoon, since these sites have a conglomerate of wet and moist tundras, making habitat delineation difficult. Data for the remaining sites are more reliable.

2. Trophics Studies

Bird densities are frequently related to the distribution and abundance of prey organisms and thus an attempt was made to ascertain the primary prey of common Norton Sound birds. There is a fair amount of literature describing avian foods, demonstrating that food habits depend greatly on locale and prey availability. Our intent was to secure modest samples of the commonest bird species to determine the primary prey items by stomach contents analysis. To assess the availability of foods we sampled mud substrates and pond surfaces as described below. All trophics studies were performed in 1981.

(a) Food Habits. We collected 157 birds using a shotgun, 55 ducks and 102 shorebirds (Appendix 7). Most were secured at the Fish River Delta or southwest of Stebbins. All were taken when they appeared to be feeding, and immediately after retrieving each bird the stomach and esophagus were removed and preserved in isopropyl alcohol. Contents of the tract were sorted, identified, and counted, and voucher specimens of common or unusual prey types were saved within a week of collection. Analysis was based on the total numbers of each prey type and the frequency with which it was found. A biomass analysis was not made, although average lengths are given for each type of food. Gizzard as well as esophageal contents were combined for ducks despite the biases introduced using gizzard contents, particularly seeds, which may be relatively indigestible (Swanson and Bartonek 1970). This was done because few ducks had sizeable quantities of food in their esophagi, and because we based our composition analyses on non-seed items.

(b) Food Availability. Mud substrates of the intertidal zone and pond margins were sampled to measure food availability for probing and pecking shorebirds. Five cores 20 x 25 cm and 4 cm deep were collected in each of the two habitats every 10 days at the Fish River Delta on

Golovin Lagoon. The same sample size was obtained once per visit at other sites. This scheme was patterned after the methods of Holmes (1966a).

We made infrequent plankton tows on ponds using a 20 x 60 cm floating net towed by hand. These gave only qualitative information on surface-active forms, aiding our stomach contents analysis.

We attempted to sample emergent insects using funnel traps (McCauley 1976) because of the dependence of young ducklings on these foods. Our attempt failed due to the fragility of the traps, and information on duckling foods is still needed.

VI. RESULTS
Part One. Bird Groups

A. All Birds: An Overview

Our discussion of all birds provides an overview of results and introduces the presentations of data. The first purpose is met by examining the overall patterns of relative and seasonal abundance, habitat use, and geographic distribution for all birds (excluding cliff nesting species) in Norton Sound. The second purpose is met with explanatory comments accompanying figures and tables of data.

Caution is advised when interpreting patterns for all birds considered together since some species or groups of species exhibit trends out of synchrony with the those of other species. Thus individual species or group trends may be masked. This is especially true for the less common birds. Therefore, dicussions of each group or principal species will often be more revealing than the general discussion for all birds presented here.

1. Relative Abundance of Eight Bird Groups: Appropriate Census Techniques

We grouped birds into eight taxonomic categories for the purpose of analysis: (1) loons, (2) waterfowl, (3) cranes, (4) shorebirds, (5) jaegers, (6) gulls, (7) terns, and (8) songbirds. See Appendix 26 for species included in each group. Note that certain species, notably grebes and hawks, are not included in this scheme because of their relative scarcity in coastal habitats. Peregrine Falcons are discussed briefly in a later section due to their endangered status. (Again, see Drury (1980) for a discussion of cliff colony birds.)

Relative abundances for these groups were derived using the three census techniques: (1) land surveys, (2) shoreline aerial surveys, and (3) wetland aerial surveys (Figure 4). Each survey technique gave different results due to:

(1) Size: Large birds are easier to see from the air than small birds.

(2) Wariness: Waterfowl in particular flush far from walking observers, making them difficult to census from land.

(3) Location: Wetland aerial data were gathered only over wetlands, biasing them towards waterfowl; while shoreline aerial data were gathered only along the shore, biasing them towards such birds as gulls. Land data were gathered for both shoreline and non-shoreline habitat but surveys were done only on and adjacent to wetlands.

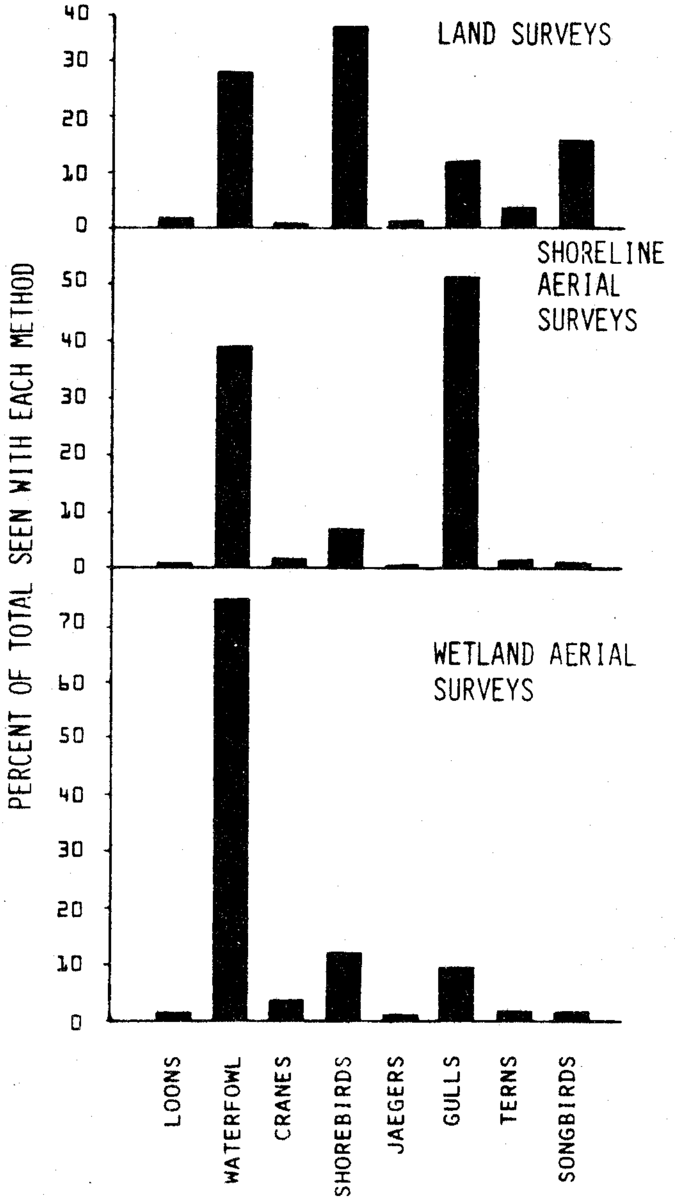

Figure 4. Relative abundance of eight bird groups with three survey methods. Data are from 1980. This shows that wetland aerial surveys census mostly waterfowl, shoreline aerial surveys mostly gulls and waterfowl, and land surveys mostly shorebirds and waterfowl as well as gulls and songbirds.

Clearly, shorebirds and songbirds are more easily censused on land than from the air, and we used data gathered by ground surveys to discuss patterns for these groups. Diving ducks are principally coastal birds, and as with gulls, shoreline aerial survey results describe their patterns best because we flew many coastal areas where we could not walk. Terns and jaegers were censused best from land, though aerial data is sometimes adequate and is referred to occasionally. Loons were adequately censused by all methods, whereas cranes and most waterfowl (excluding diving ducks) were best censused by aerial surveys over wetlands.

Land and aerial survey data rarely agree exactly on bird densities. An exception is for Glaucous Gulls seen along shorelines (Figure 5). When on tundra, these gulls exhibit great curiosity (or animosity) near their nests and will fly towards walking observers. This tends to exaggerate estimates of their abundance. Along shorelines, however, they usually ignore walking bird counters, except to fly away on close approach, and are therefore more accurately censused on the coast.

2. Habitat Use

Shoreline aerial surveys (Figure 6) reveal the habitat preferences primarily of gulls, waterfowl, and other large birds. These data are densities averaged from both the 1980 and 1981 surveys, and are best used to compare concentrations between habitats. Aerial surveys are better than ground surveys in this regard, because they covered the entire coast.

River delta shorelines and river mouths received the most concentrated use, followed by protected wet tundra shores (on lagoons). Except for river mouths, these habitats are the characteristic types fronting wetlands, and for this reason we concentrated our land surveys there, and this is why we employed wetland aerial surveys.

Sea cliffs were also well used, particularly by gulls, and the murres, kittiwakes, cormorants, and various alcids not dealt with in this report. Their average densities typically exceeded 200 birds per km of all cliffs in Norton Sound, and would be far higher than the values presented in Figure 6. Cliffs on lagoon shores received low use; these are principally confined to Port Clarence and were inhabited by gulls and over 200 cormorants.

Moist tundra, the commonest coastal habitat in both protected and exposed areas of Norton Sound, were sparsely used, as were spit habitats. Exposed beaches fronting wetlands were moderately used, though those at Koyuk were shown to have high densities of smaller birds as censued by land (see below).

Overall, shoreline aerial surveys showed approximately equal use of protected and exposed shores by non-cliff nesting birds (17.5 birds/km compared to 16.5 birds/km). When cliff habitats are excluded from this

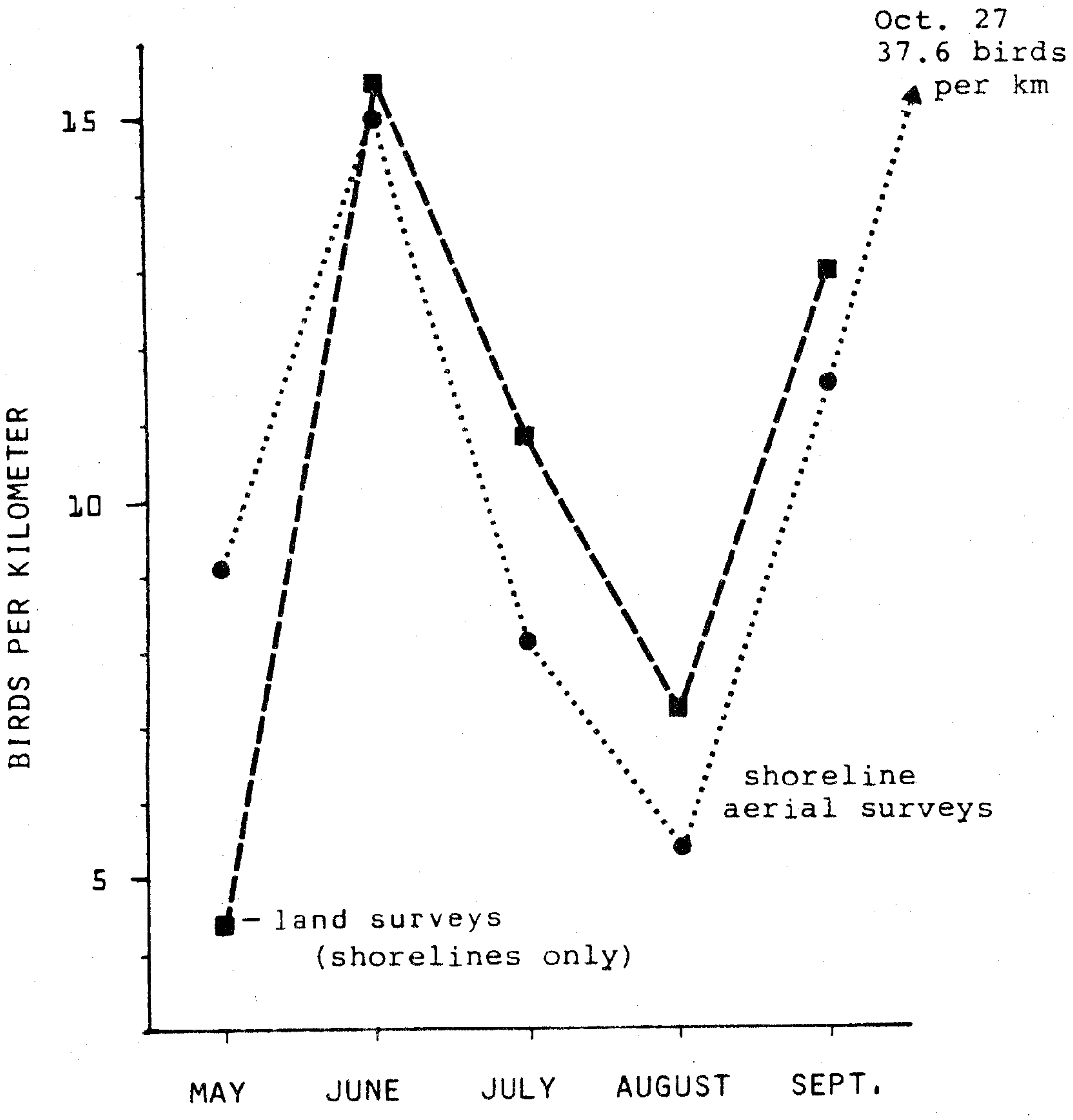

Figure 5. Seasonal abundance of Glaucous Gulls, Data from 1980. This shows the close correspondence between land and aerial data for conspicuous birds gathered on shorelines.

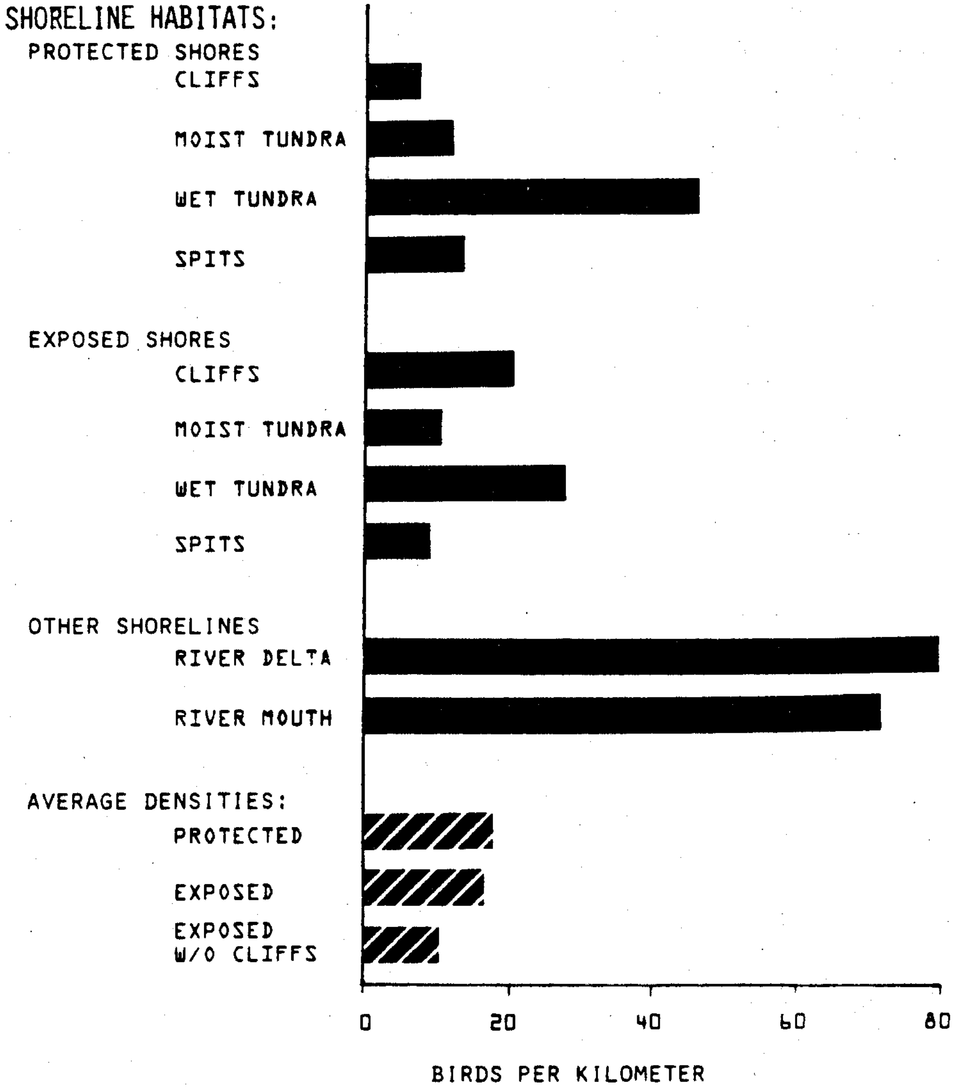

Figure 6. Shoreline habitat use by all birds seen on shoreline aerial surveys; 1980 ans 1981. Shorelines of river deltas and wet tundra are wetland shorelines, and these had high densities. River mouths also had high densities yet these are limited in extent.

comparison, protected shores received greater use (17.2 birds/km) than exposed shores (12.8 birds/km). In general, use of exposed shores is mostly by gulls, except at Koyuk, and these use the beach (the high littoral). Protected shores receive greater use by waterfowl, and overall the exposed waters are little used by birds actually on the water, except for cliff-nesting species.

Shoreline aerial surveys can provide total numbers of birds in each habitat. River delta shorelines and exposed coasts backed by moist tundra/uplands each supported nearly one-quarter of all birds seen (Table 4). Shores with tundra/uplands had high numbers because of their expanse (35% of shorelines), whereas river delta shores (only 6% of shorelines) were highly productive.

Birds observed on land transects, particularly shorebirds, waterfowl, and songbirds, showed habitat preferences as depicted in Figure 7. These land data primarily describe habitat use near wetlands, as this is where we put our effort. Protected shores had concentrations slightly greater than exposed shores (43.6 birds/km compared to 35.4 birds/km, respectively). Landward of the beach, wet tundra supported over twice the densities observed on moist tundra. This reflects the greater abundance of insects and food plants in wetter habitats.

3. Seasonal Use

Spring came early to Norton Sound in 1980 and 1981. Various estimates by residents placed snowmelt and break-up at one to two weeks earlier than in "average" years. Birds respond to an early spring by migrating north and nesting early, and our observations are of early bird chronologies. Years with later springs could be expected to have later chronologies. A late spring is likely to reduce the nesting success of certain species, notably swans (Lensink 1973).

Compounding this yearly variation are the seasonal differences between east and west sectors of the Sound. Sea ice remains from Port Clarence to the Bering Strait a few weeks after ice clears from seacoasts in eastern Norton Sound, and ice may remain at Wales until mid or even late June (AEIDC 1975). Snow cover also remains late on the west end of the Seward Peninsula, delaying nesting by tundra breeders. A similar but more moderate cooling effect is felt on the Y-K Delta, causing later snow retention than on more inland sites.

Few birds were present near shore or on land before May each year. King Eiders moved north through leads offshore of western Norton Sound at that time, and some murres and cormorants moved north into the Sound as the ice retreated. By the second week of May, waterfowl, notably Pintails and Canada Geese, arrived and occupied ice openings and flooded areas

Table 4. **Habitat use by all birds on shoreline aerial surveys. Data are average values for 1980 and 1981 uncorrected for effort in each habitat.**

Habitat	Percent of All Birds	Percent of Shoreline
Protected Shores		
Cliffs	0.1	9
Moist Tundra/Uplands	6.9	35
Wet Tundra	9.5	7
Spits	5.5	10
Exposed Shores		
Cliffs	9.6	0.3
Moist Tundra/Uplands	22.1	16
Wet Tundra	14.3	5
Spits	4.8	11
Other Shorelines		
River Delta	23.0	6
River Mouths	3.2	1

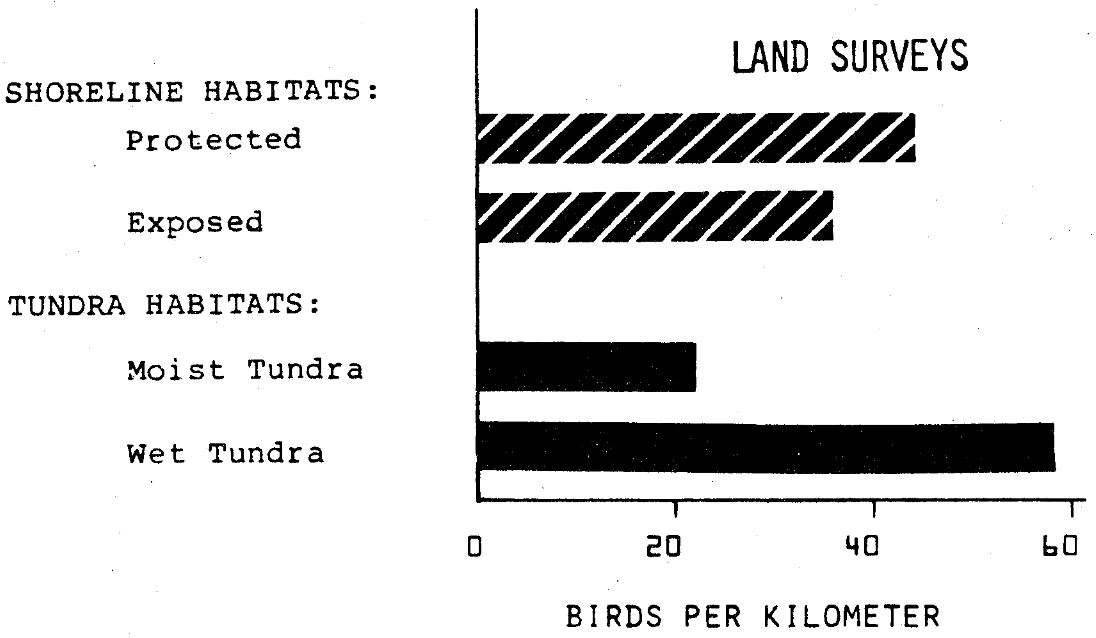

Figure 7. Habitat use by all birds censused on land surveys; 1980. Protected shorelines had somewhat higher densities than exposed shorelines, and wet tundra had over twice the density of birds found on moist tundra. Shoreline and tundra densities cannot be directly compared; see methods for explanation.

near river and stream mouths. Cranes were migrating in numbers by this time, traveling west towards Siberia along the north coast, many passing by Nome.

An increase in bird numbers through June is shown by all census methods (Figure 8). This represents breeding populations as well as migrants moving farther north. Numbers drop in July, when only the locally nesting birds are present. At this time many shorebirds have begun heading south, and waterfowl begin their molt, becoming inconspicuous.

Populations build again in August, reaching a peak in September when waterfowl stage before heading south. This is the prime use of Norton Sound wetlands. Smaller birds, shorebirds, and songbirds are on the decline in September as shown by land surveys. In October gulls are abundant along shores, having come south as ice advances in the Beaufort and Chukchi Seas. Many are immatures.

4. Geographic Distribution

Populations vary considerably between coastal sectors, and these differences can be shown with data from all of our survey methods. The choice of data set depends on the bird group in question. This section will look at distributions of all birds along Norton Sound coasts, with all three methods, to explain the interpretation of each. Note that our data may be expressed as either densities or total numbers. Densities are useful when comparing the relative uses of unequal areas, such as coastlines, while totals make it easy to compare the absolute use of discrete geographic units. Since it is not possible to count all birds on a wetland area from the air or the ground the samples taken must be projected to totals (see Chapter V, "Sources, Methods, and Rationale of Data Collected"), and the results may not always be reliable.

Shoreline aerial surveys averaged for 1980 and 1981 (Figure 9) show peak shoreline densities in Golovin Lagoon (86.2 birds/km), with next highest densities from Koyuk to Cape Denbeigh (33.7 birds/km). The lowest densities were found from Nome to Cape Nome (5.0 birds/km). The average number of birds per flight in each section was highest along the shores of Golovin Lagoon (4,800 bires) and nearly as high from Cape Nome to Rocky Point (Safety Lagoon area) and from Koyuk to Cape Denbeigh (about 4,000 birds each).

Wetland aerial data are given in Figure 10. These data describe populations on the wet tundra landward of the beach, as densities of birds (birds per minute) and also as projected totals. The highest densities are found again at the Fish River Delta on Golovin Lagoon, with slightly lower densities at Moses Point, Koyuk, and southwest of Stebbins. Due to the very large area at Stebbins, its wetlands harbored an average projected

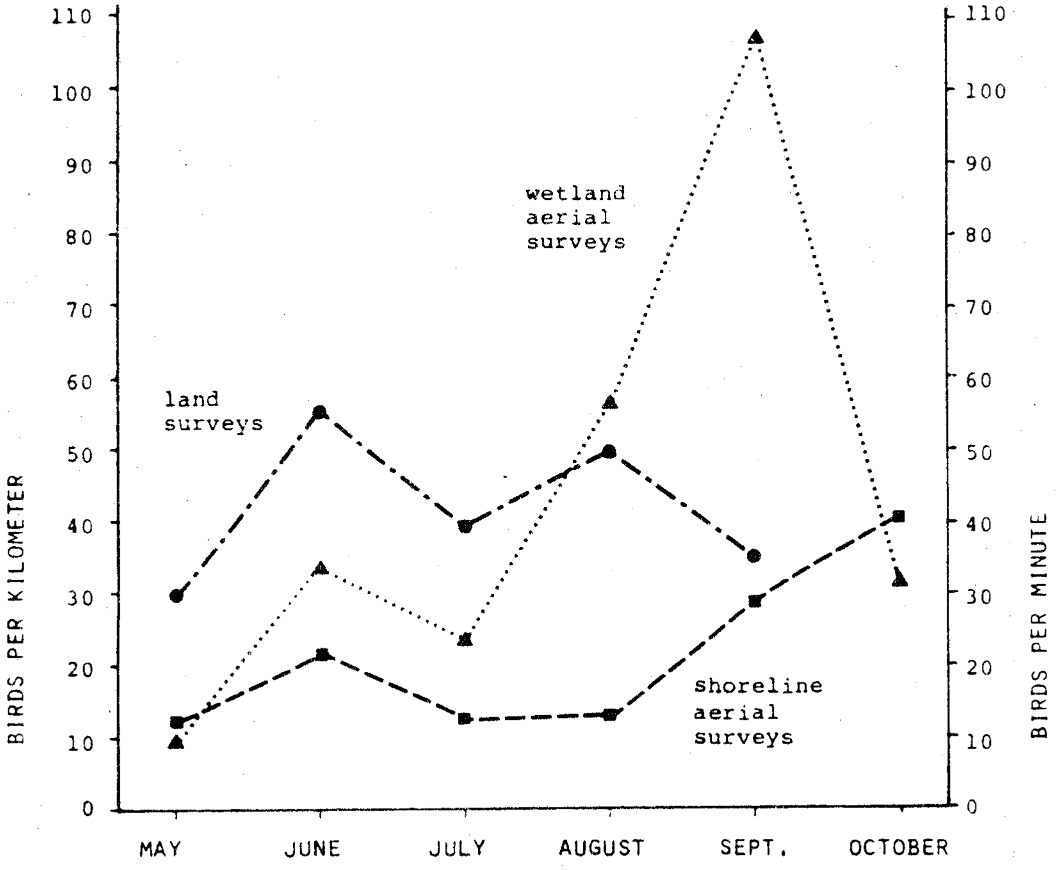

Figure 8. Seasonal abundance of all birds with three census methods; land surveys (birds/km), shoreline aerial surveys (birds/km), and wetland aerial surveys (birds/minute). Data are from 1980. The June high represents breeding birds and some migrants, the July low indicates the egress of some shorebirds and the inconspicuousness of molting waterfowl, and the August and September high mostly represents coastal concentrations of waterfowl. The October high of shoreline aerial surveys is of Glaucous Gulls.

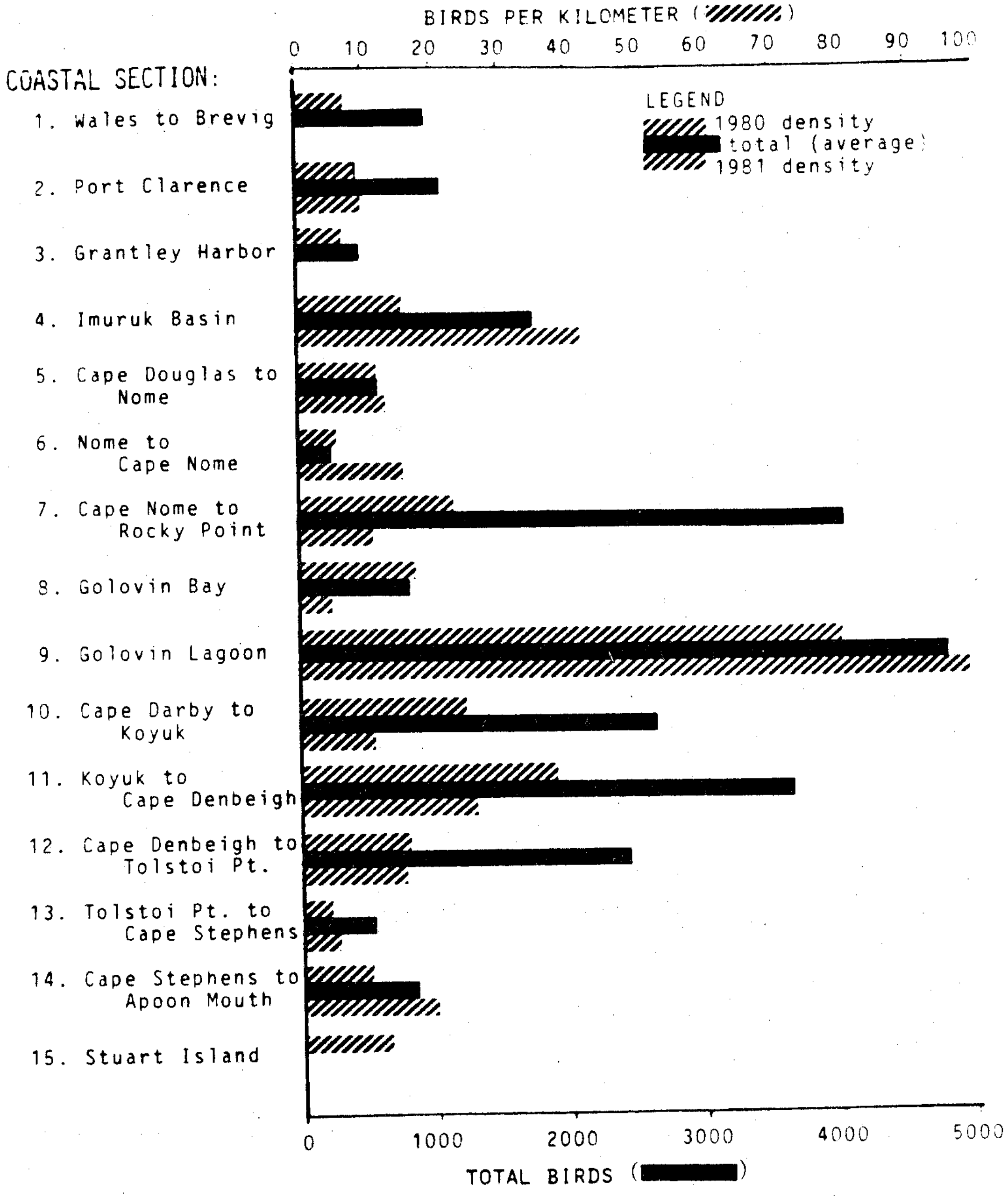

Figure 9. Geographic distribution of all birds seen on shoreline aerial surveys. Densities are total birds/total miles in each section in each year. Totals (solid bars) are projected values averaged for both years together. Northeast sections had the highest totals. This does not include birds on wetlands landward of the beach.

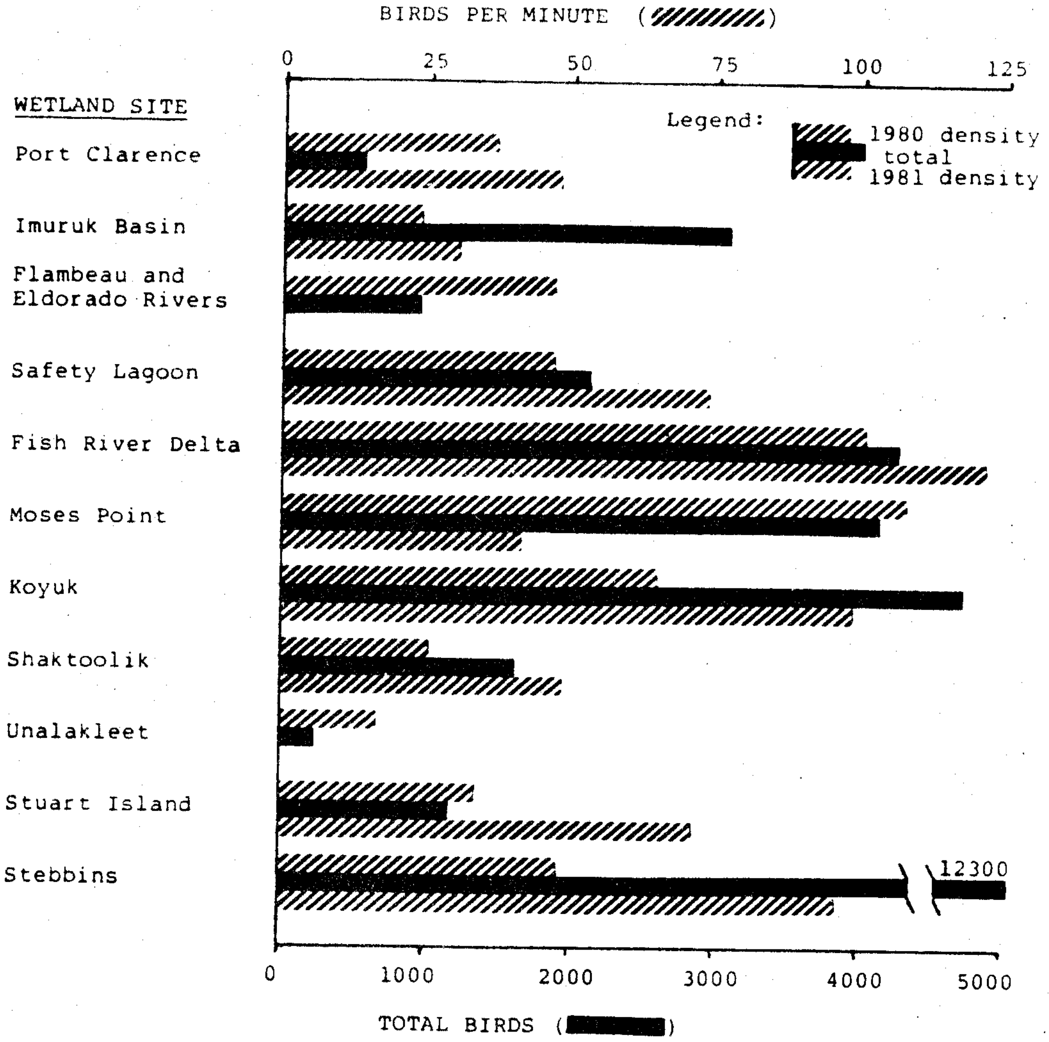

Figure 10. Geographic distribution of birds on wetlands censused on wetland aerial surveys. Densities are birds/minute averaged for each wetland each year; totals (solid bars) are average projected populations for both years together and these are based on wetland size. Northeast wetlands and those at Stebbins had the most birds, primarily waterfowl.

total of over 12,000 birds in each flight. This result is quite different from that found on shoreline surveys (Figure 9, Section 14), because the shoreline southwest of Stebbins received low bird usage, whereas the wetlands behind the shore were heavily used.

Projected totals of approximately 3,000 to 5,000 birds per flight resulted for wetlands at Imuruk Basin, Fish River, Moses Point, and Koyuk. Lesser numbers were found at Safety Lagoon, with progressively fewer at Shaktoolik, Stuart Island, the Flambeau/Eldorado Rivers, and then Port Clarence. Unalakleet was little used. All these data were highest in late August and September (except for Port Clarence, where spring totals are highest), and primarily represent waterfowl and gulls.

Land surveys (Figure 11) show peak concentrations of waterfowl, shorebirds, and songbirds at Port Clarence, Safety Lagoon, Koyuk, and Stebbins (70 to 80 birds/km). These data are for wetland transects in 1980 and do not include shoreline counts. The lowest concentrations were at Nome and Shaktoolik (16.8 and 13.2 birds/km), with fairly low densities at Woolley Lagoon (23.1 birds/km). The projected totals of birds on land are quite high for the Stebbins wetlands (134,000), with large populations at Koyuk (44,000), Safety Lagoon (28,000), and Moses Point (24,000).

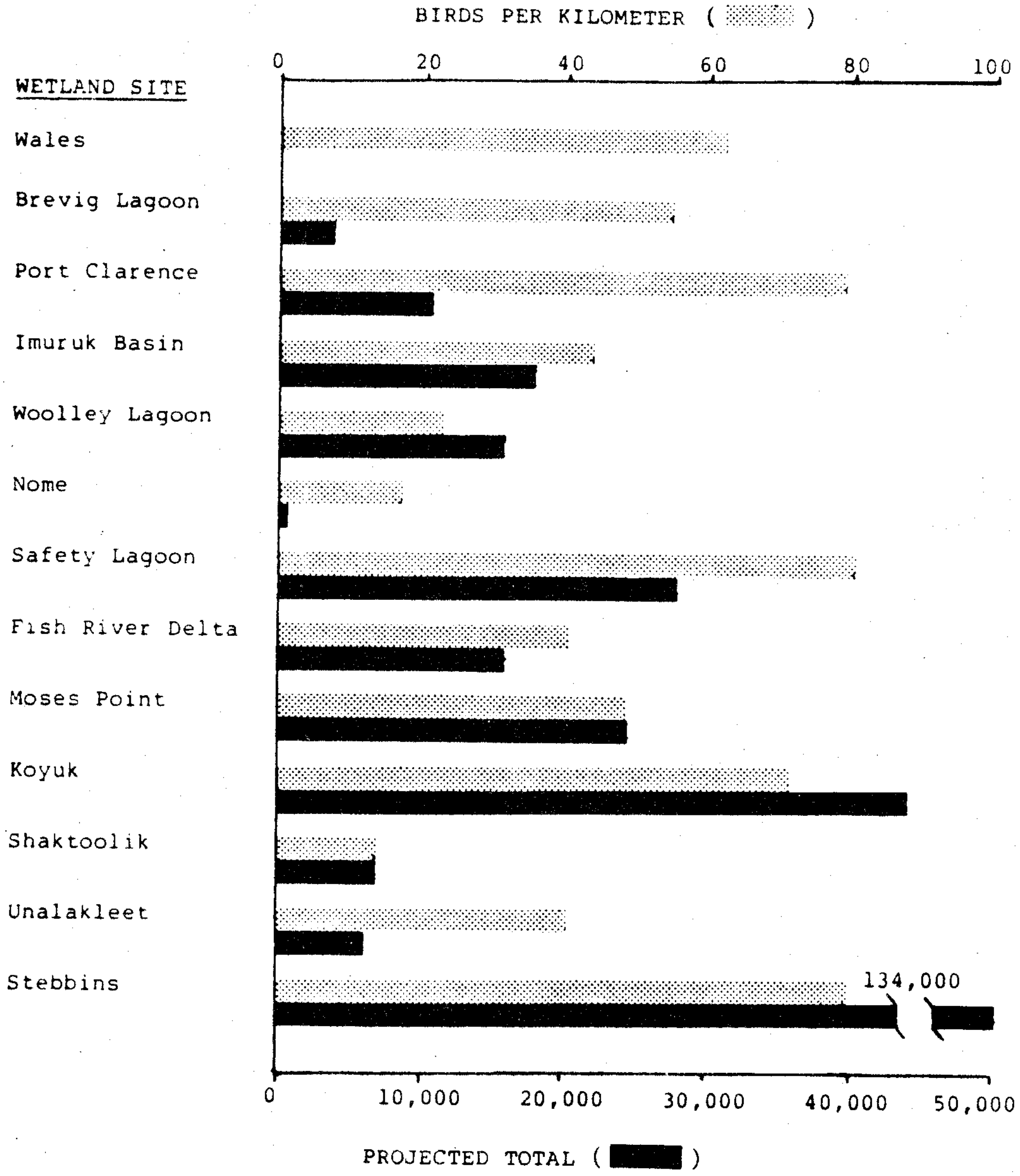

Figure 11. Geographic distribution of all birds censused on land surveys; 1980. These data primarily represent shorebirds, waterfowl and songbirds.

B. Loons

Loons are a conspicuous part of the avifauna of Alaska. All four species of loons occur in Norton Sound. The Red-throated Loon and the Arctic Loon are common breeders and migrants, whereas the Yellow-Billed Loon and the Common Loon are rare migrants or strays. With large, streamlined bodies they are adapted for swimming and diving, and are found on land only when breeding. In the following discussion data from land surveys are used almost exclusively because aerial densities were so low as to be relatively uninformative.

In coastal Norton Sound, both Red-throated and Arctic Loons nest predominantly in low-lying, coastal wet tundra. Red-throated Loons feed almost exclusively at sea during both breeding and migration, while Arctic Loons feed mainly in tundra ponds during breeding, and offshore during migration (Bergman and Derksen 1977). Both species vacate Norton Sound from October through April, migrating down the coast to winter in near-coastal waters from southern Alaska to Baja California (Gabrielson and Lincoln 1959). These patterns of habitat use make both species quite vulnerable to oil spills throughout their yearly cycle.

1. Habitat Use

The most important breeding habitat for loons was wet tundra, with its mosaic of lakes, ponds, and channels (Figure 12). Arctic Loons select larger, deeper, and more open lakes for nesting sites than Red-throated Loons (Bergman and Derksen 1977). Moist tundra had low loon densities.

The two loon species often feed in different habitats. Bergman and Derksen (1977) report that in the Beaufort Sea Red-throated Loons, in particular, feed mainly on marine fish, and bring these fish back to their young. They found that Arctic Loons feed both in marine waters and wetland ponds, and almost always feed their young invertebrates from tundra ponds. Although we did no feeding studies of loons our habitat use data suggest a similar pattern for Norton Sound. Arctic Loons were seen 80% of the time on wet tundra, as compared to only 63% of the time for Red-throated Loons. Arctic Loons were far more common on channels (e.g. at Stebbins and the Fish River Delta) than were Red-throated Loons, although we made no quantitative observations to support this. Red-Throateds were seen more often (32% of observations) in shoreline habitats, particularly exposed shores (29%), than were Arctic Loons (16% of all shorelines, 12% of exposed shorelines). For both species, exposed shorelines were more often used than protected lagoonal waters, indicating that less prey may be available in the lagoons. Exposed shores of moist tundra/uplands and of spits both hosted much higher densities than did exposed shores of wet tundra.

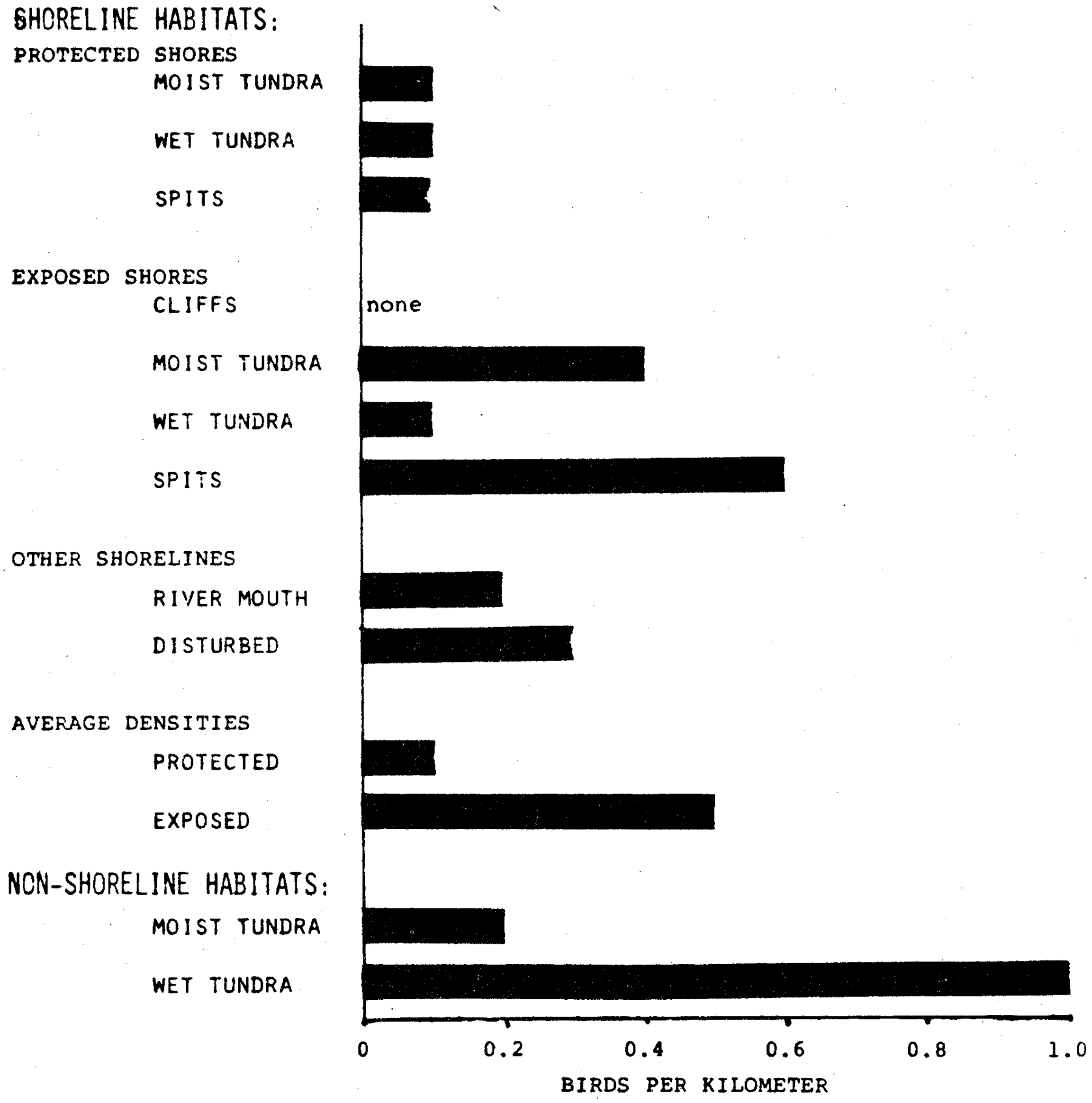

Figure 12. Habitat use by Arctic and Red-throated Loons. Data are from 1980 land surveys. Exposed shorelines received greater use than did protected shores, and on land, wet tundra had many more loons than did moist tundra.

This implies that exposed shores of moist tundra/uplands and of spits offer more food to loons than may be found along shorelines near their nests.

2. Seasonal Use

May loon densities were quite low (Figure 13) because loons were still arriving from the south. Densities remained fairly constant in June and July. Red-throated Loons began leaving Norton Sound soon after their young fledged in early to mid August, thus the large drop in density from July to August. Arctic Loon chicks did not fledge until late August, so densities remained high until September.

3. Geographic Distribution

Stebbins had the highest loon densities in coastal Norton Sound. Koyuk, Imuruk Basin, Moses Point, the Fish River Delta, and Port Clarence also had high densities of loons (Figure 14). Stebbins had the largest population of Arctic Loons (largest wetland and highest density). They were much more common there than Red-throated Loons, though Hersey (1917) and Nelson (1887) reported that Red-throated Loons were the most abundant of the two. Koyuk, Moses Point, and the Fish River Delta also had relatively high densities of Arctic Loons. The deltas of the Agiupuk and Kuzitrin Rivers, which drain into Imuruk Basin, had the highest Red-throated Loon densities. Port Clarence and Koyuk also had high densities while those at Stebbins were quite low.

The differences seen in the geographic distributions of the two species may be directly related to differences in their feeding habits. Red-throated Loons are most common in the western Sound where the marine environment is most productive; they are principally marine fish eaters (see the "Habitat" section, above). The areas where Arctic Loon densities were highest are where ponds and lakes associated with wet tundra are most common; these loons feed mainly in tundra ponds and channels (see the "Habitat" section). Waterfowl densities were highest (see Figure 20 in the "Waterfowl" section, below).

4. Nesting Phenology

Arctic Loons arrive one to two weeks later than Red-throated Loons, and also have a longer fledging period. Consequently, they leave later than Red-throated Loons. Both species leave shortly after their young fledge. Few birds of either species were seen in winter plumage, so they apparently do not molt in Norton Sound.

The first Red-throated Loons were spotted on 11 May 1980 and 6 May 1981. We found four nests in each year. Eggs were laid as early as 24 May, with peak laying around 29 May (Figure 15). The normal clutch size

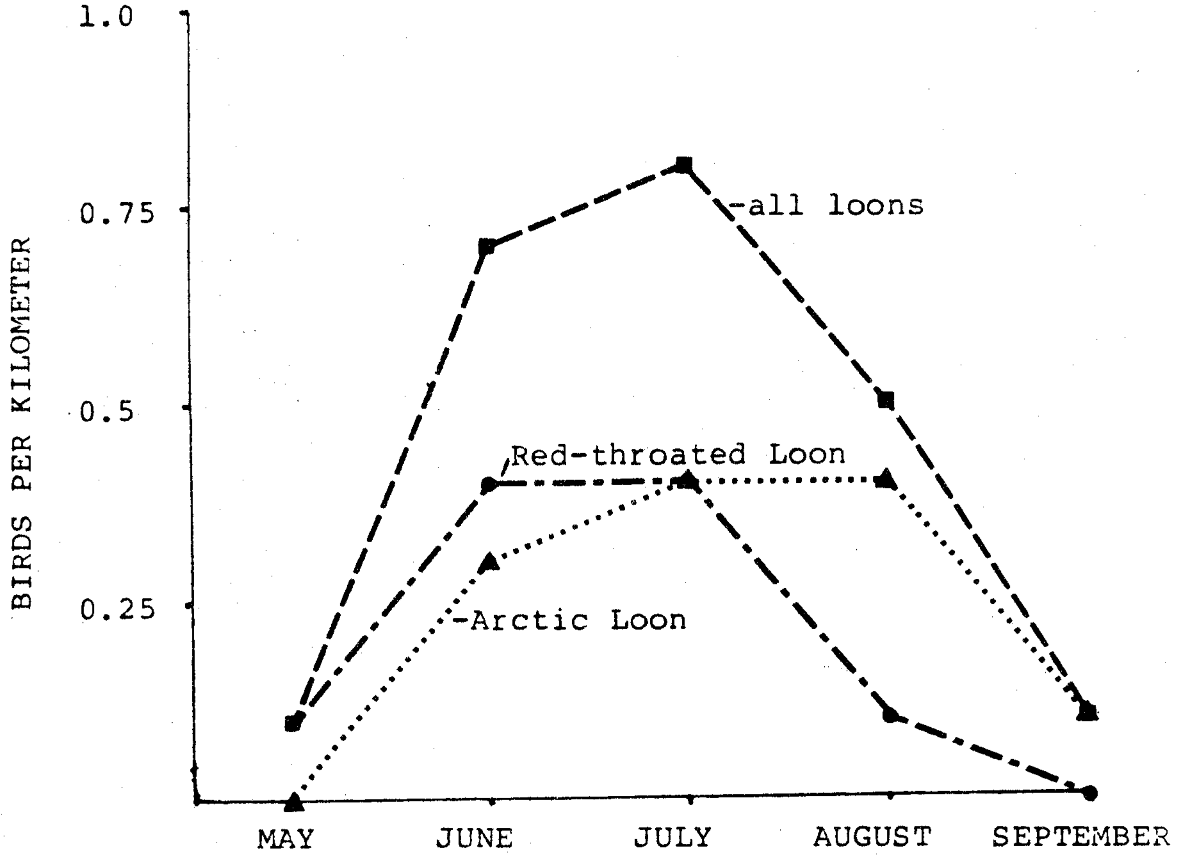

Figure 13. Seasonal abundance of Arctic and Red-throated Loons. Data are from 1980 land surveys. Red-throated Loons departed earlier than Arctic Loons because their young fledged earlier.

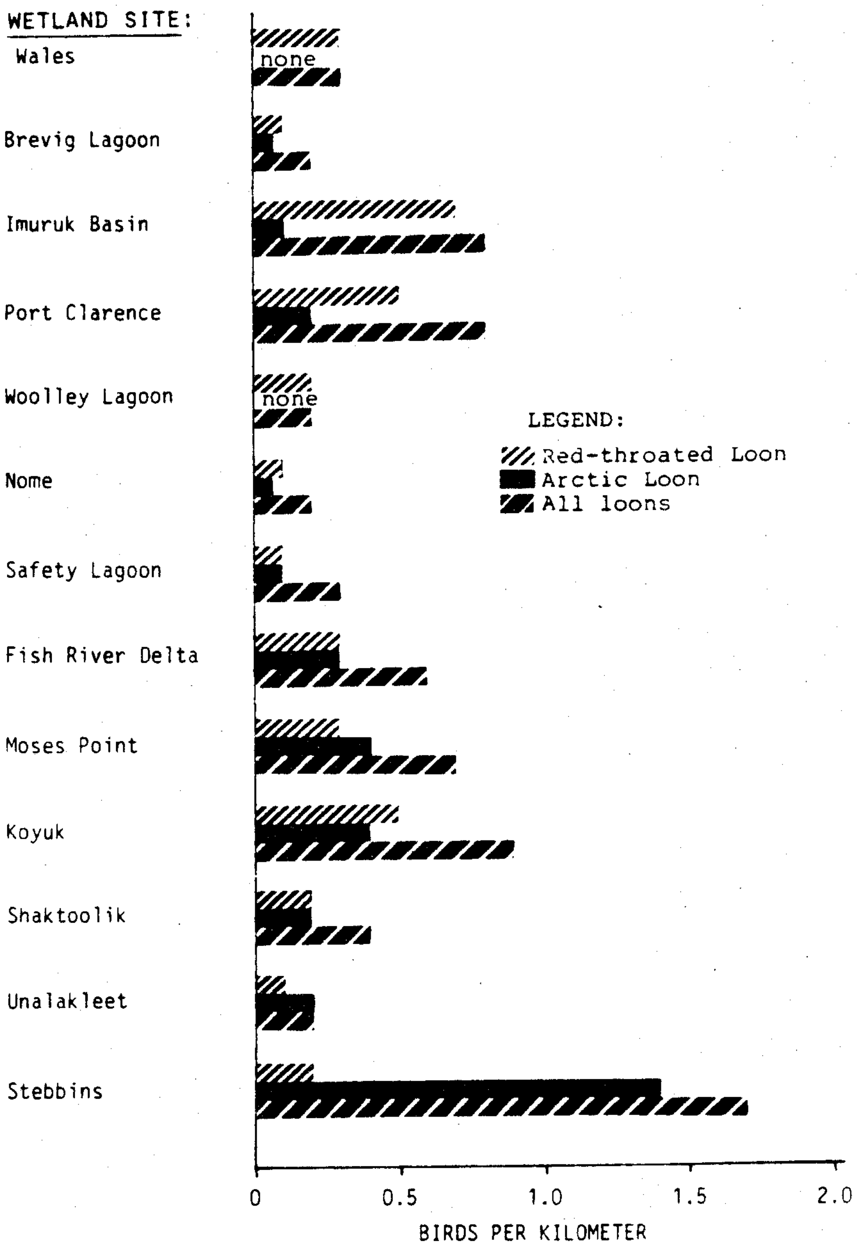

Figure 14. Geographic distribution of Arctic and Red throated Loons. Data are from 1980 land surveys. Red-throated loons are more common on the northwest wetlands whereas in the inner Sound the two species have more equal populations. Stebbins, in the south, had the highest loon densities and those there were almost all Arctic Loons.

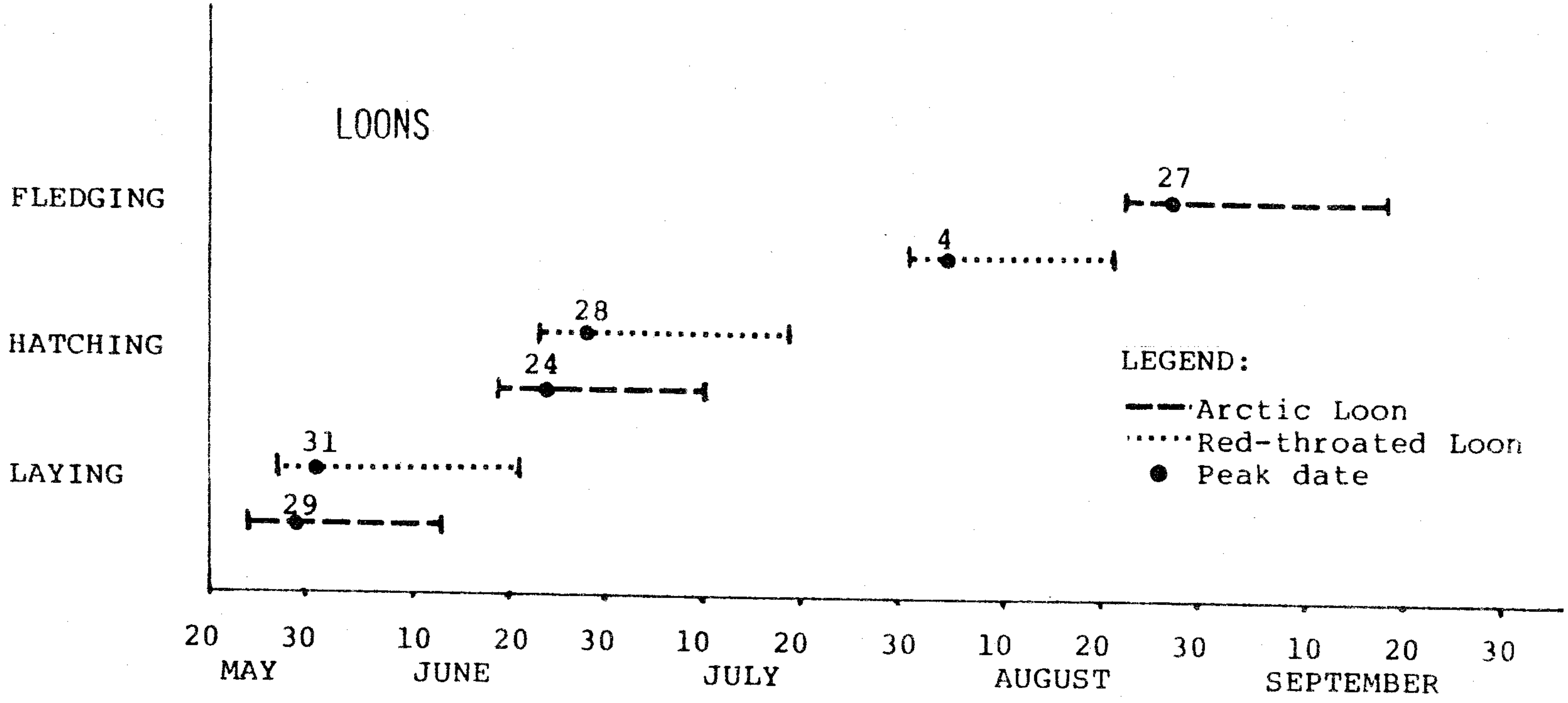

Figure 15. Nesting phenologies of Arctic and Red-throated Loons. Data are combined from 1980 and 1981 and based on four nests of each species in each year plus additional observations of young. Note that the breeding period for Arctic Loons lasts nearly a month longer than for Red-throated Loons.

was two. These began hatching 19 June, with peak hatching around 24 June. The incubation period is 24 to 29 days (Harrison 1978); a 27 day period was assumed for Figure 15. Although both chicks generally hatch out one of them usually dies before it is 14 days old (Bergman and Derksen 1977, Bundy 1976). Fledging began about 31 July, with a peak around 4 August; this happens about 6 weeks after hatching (Bundy 1976). Loons left the breeding grounds shortly thereafter, and failed breeders may leave even earlier. No Red-throated Loons were seen after 6 September 1981 (no record, 1980).

The first Arctic Loons were seen on 19 May 1981 (no record, 1980). They appear to be paired when they arrive, or pair shortly thereafter. In each year we located 4 nests. We found the first eggs on 27 May, with peak laying around 31 May. The incubation period is 28 to 29 days (Harrison 1978). Hatching began 23 June, with a peak around 28 June. Eggs that hatched later than 7 July were probably replacement clutches. Normal clutch size was 2 eggs, but Arctic Loons will lay a single egg to replace a clutch lost in the first week of incubation (Bergman and Derksen 1977). Fledging occurs about 8 weeks from hatching (Harrison 1978). The first fledglings appeared 22 August, with most fledged by 27 August. Arctic Loons began leaving the area at the end of August, though some birds were seen on 29 September 1980.

C. Waterfowl

This section examines the general trends of seasonal abundance, habitat use, and distribution of all waterfowl in Norton Sound. Waterfowl will be discussed in three groups: swans, geese, and ducks. The swan group contains one species, the geese five, and ducks 24. Ducks are further divided into dabblers and divers based on feeding strategies. More detailed accounts of each of these groups will be found in subsequent sections. Trends unique to any of these groups may be masked in the following generalized account. This section ends with an overview of subsistence waterfowl use.

Ducks made up 69% of the total waterfowl population in the study area (Figure 16), with Pintails being the most abundant. Geese accounted for about 26% of the total, and Canada Geese were the most abundant of these. Whistling Swan, the only species of swan in Norton Sound, totaled 5% of all waterfowl. These proportions are virtually identical to those found by Drury (1980) for surveys from Point Spencer to Shaktoolik in late August, 1977.

Norton Sound was most important to waterfowl during fall migration when thousands of ducks, geese and swans converge upon the wetlands, developing fat reserves before their trip south. Norton Sound plays a relatively minor role in the production of waterfowl in Alaska, while the nearby Y-K Delta and areas north of the Sound are prime nesting grounds (King and Lensink 1971; King and Dau 1981). The birds that did breed in Norton Sound began nesting by the third week in May, and the first chicks hatched during the second week in June. Most chicks fledged during late July or early August. Swans did not fledge until late August or early September.

Wetland aerial transect data and shoreline aerial survey data were used to analyze patterns of waterfowl use in Norton Sound. Wetland aerial transects were most useful for examining differences between areas and differences in seasonal use, because the vast majority of waterfowl occurred in wetland habitats. Shoreline aerial surveys were best used to describe differences in shoreline habitat use, while land transects were most useful for collecting nesting data.

1. Habitat Use

Waterfowl were most abundant on river deltas and wet tundra (wetlands) adjacent to lagoon shores (Figure 17). These habitat types provide suitable nesting areas and adequate food supply for most species. The many ponds act as refuges and feeding areas for juveniles or molting birds. Wetlands adjacent to sea beaches were fairly important for water-

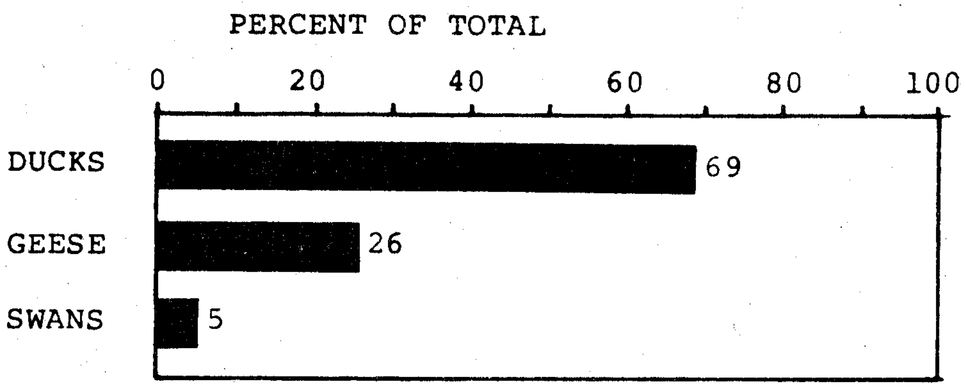

Figure 16. Relative abundance of waterfowl. Data are from 1980 wetland aerial surveys.

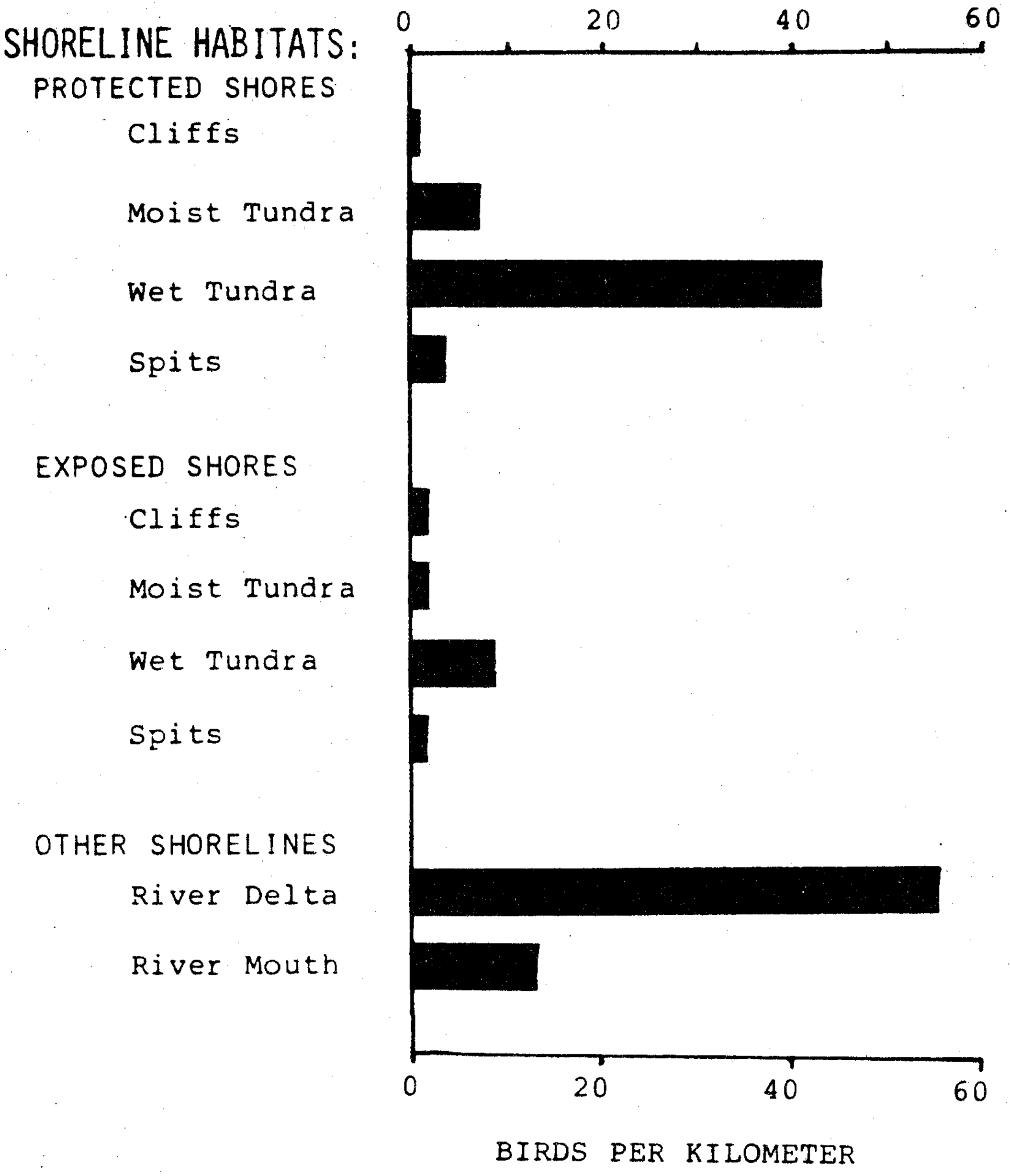

Figure 17. Habitat use by waterfowl. Data are from 1980 shoreline aerial surveys. River delta and wet tundra shorelines were the most heavily used and these are wetland shorelines. Note the heavier use of protected versus exposed wet tundra shores.

fowl, but less so than the wetlands associated with lagoons. River mouths were used regularly by waterfowl, but mainly for feeding purposes or when these sites offered the only open water in early May. Moist tundra contains ripe berries (Crowberries, Empetrum nigrum, and blueberries, Vaccinium spp.) in the fall and was frequented by Canada Geese. These berry-rich areas next to lagoons were preferred over the same habitat next to exposed coasts.

Shorelines associated with cliffs were used by diving ducks but only as feeding areas. Consequently, these ducks were present at cliffs in very low numbers throughout the season. Late migrants used this habitat through October, since the water around cliffs was some of the last to freeze. The sand spits associated with lagoons were used chiefly by ducks for molting and roosting, and these areas were of minor importance to waterfowl in general. Before break-up, ice-free areas on or near wet tundra were used extensively, while little use was made of the offshore ice edge.

2. Seasonal Use

Spring populations of most waterfowl were far lower than in late summer (Figure 18). The arrival of most waterfowl to Norton Sound in spring coincided with the breakup of river and sea ice. In early May, open water was scarce, and waterfowl were mostly restricted to these openings. Most migrants had passed through Norton Sound by the first of June, and those birds that remained were either paired adults that nested in the area or flocks of non-breeders (see "Ducks — Prarie Droughts" later in this report). Nesting occurred between late May and mid-July and was followed by a month-long molt, when most waterfowl were flightless. Some males and non-breeders left coastal wetlands and sought out inland sites to molt, while those that remained, including parents with broods, became inconspicuous and sought cover in tall vegetation until they sprouted new flight feathers. These phenomena caused the July low in our census estimates.

Waterfowl began to concentrate in Norton Sound in early August. By late August, many large flocks of staging birds were present in the river deltas and wetlands. These huge aggregations remained in the area until mid to late September, and some species stayed into October.

3. Geographic Distribution

Late summer distributions are discussed before spring distributions because that is when waterfowl populations in the Sound are greatest. In late summer waterfowl were concentrated at wetlands in northeastern Norton Sound and at Stebbins. Projected populations (Table 5), based on wetland aerial survey densities, were greatest at wetlands of Stebbins, Moses Point, the Fish River Delta, and Koyuk, though there was much variation between

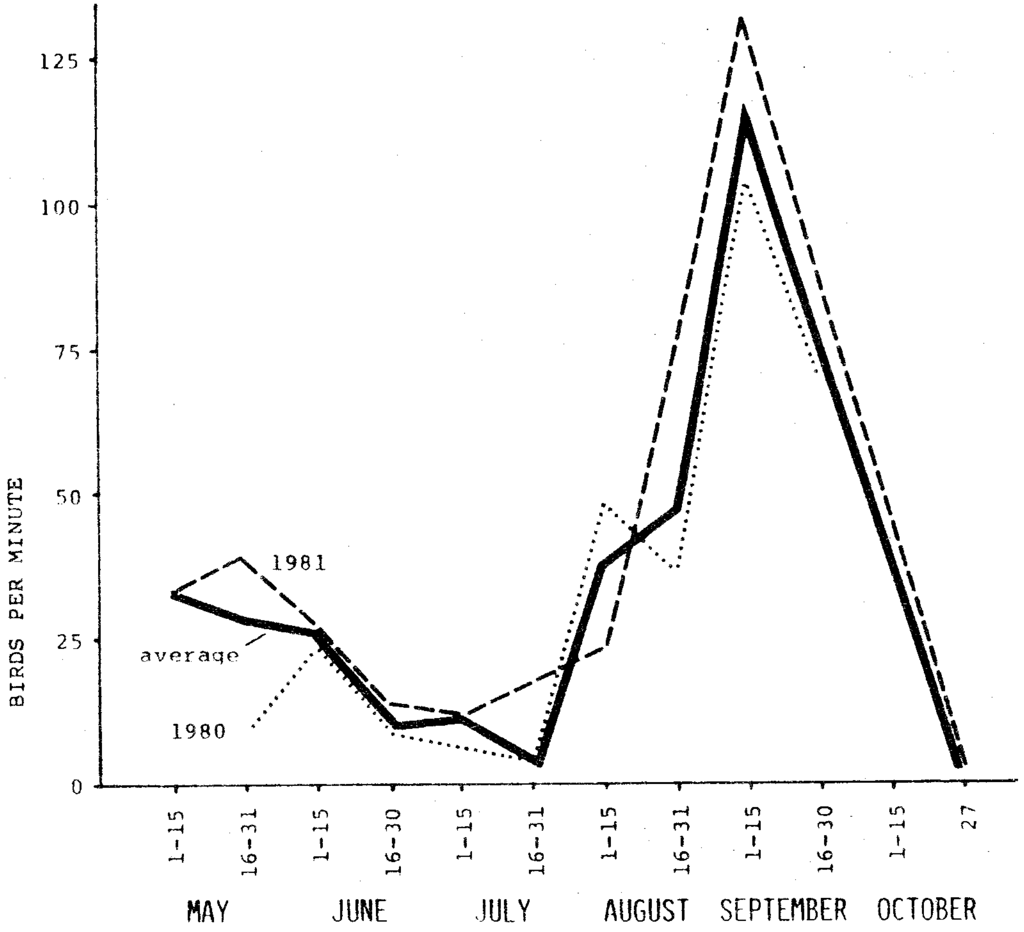

Figure 18. Seasonal abundance of waterfowl. Data are from 1980 and 1981 wetland aerial surveys. Also included is an average of both years. Spring peak is of migrants and nesting birds; fall peak is of pre-migratory flocks gathering to feed on wetlands. This illustrates the importance of Norton Sound wetlands to waterfowl in fall (late August and September).

Table 5. Maximum late summer waterfowl populations on wetlands.

		1980				1981				1977
Wetland Area	Km^2	No.	BPOM[1]	Proj.[2] Pop.	Mo./ Date	No.	BPOM[1]	Proj.[2] Pop.	Mo./ Date	No.[3]
Port Clarence	13.4	405	20.3	405[4]	6/30	811	36.9	811[4]	9/5	650
Imuruk Basin	116.5	1,456	33.1	3,247	8/16	989	38.0	3,728	9/5	--
Cape Woolley to Sinuk	29.8	101	7.2	181	9/17					570
Eldorado and Flambeau Rivers	20.2	710	88.8	1,510	8/23					2,351
Safety Lagoon	34.6	1,199	85.6	2,688	9/23	1,070	150.0	4,711	9/12	1,962
Fish River Delta	38.5	6,381	145.0	6,381[4]	9/6	9,099	239.4	9,099[4]	9/10	14,288
Moses Point	49.9	8,734	311.9	13,105	9/3	1,519	63.3	2,660	9/10	10,266
Koyuk	61.4	3,174	158.7	8,205	9/23	3,361	150.0	5,428	9/10	5,475
Shaktoolik	51.3	896	64.0	2,764	9/23	1,251	89.4	3,861	9/10	1,758
Unalakleet	14.6	30	26.6	327	9/6					
Stuart Island	22.0	422	35.2	652	9/6	666	83.3	1,543	9/10	
Stebbins	169.0	1,850	115.6	16,450	9/23	4,082	81.6	11,612	9/10	

[1] Birds per observer minute (wetland aerial survey densities).

[2] Based on BPOM, an average flight speed of 177 km/hr, and an observation swath of 400m for each observer.

[3] Data from Drury (1980).

[4] Actual counts are higher than projected values, due to long census periods.

1980 and 1981, particularly at Moses Point. We consider these projected numbers to be reasonably representative of relative populations, as they are based on systematically gathered densities projected over a reliable estimate of habitat area used by waterfowl. They are surely conservative, as we have not used correction factors to account for the percentage of birds missed by aerial surveys. Actual counts were highest at the Fish River Delta.

Low counts on wetlands at Port Clarence, from Cape Woolley to Sinuk, at the Eldorado and Flambeau Rivers, at Unalakleet, and at Stuart Island are principally due to the small extent of suitable habitat in these areas. Shaktoolik wetlands are not as favored by waterfowl as are similar areas at nearby Koyuk, and we do not have an explanation of this. Drury (1980) made the same observation and was also without an answer.

High populations at the heavily used sites may stem from their position on migration routes, their attractiveness to waterfowl for feeding, and their productivity of young waterfowl in summer. Migration routes are detailed later in the group accounts. Briefly, routes from the Arctic over the Seward Peninsula may channel birds into Golovin Lagoon and to Koyuk. Stebbins may receive an overflow of birds from the Y-K Delta. High quality habitat for feeding and nesting may be similar, possibly due to periodic flooding, both from spring runoff and from coastal storms. These floods (discussed more in the "Trophic Systems" section) serve to replenish wetlands with nutrients.

Maximum late summer densities varied considerably between 1980 and 1981 for certain areas (Figure 19). A major gain from 1980 to 1981 was shown for the Safety Lagoon system, and for the wetlands at Koyuk, Shaktoolik, Stuart Island, and Stebbins. The Moses Point area showed a steep decline between years. These differences reflect the variability in northern waterfowl populations, and in their choice of staging and feeding areas. Whether these reflect changes in wetland qualities or shifts in migration patterns is not known.

Of note are the high counts of ducks, geese, and swans made in 1977 by Drury (1980, Table 5). These are higher than 1980 and 1981 numbers, partly because the flight covered more area at each wetland in search of flocks, while our flights were over established courses. They may, however, be higher because of actual differences in populations, and this may be due to drought conditions in the prairie regions. Briefly, many prairie ducks, finding dry conditions on their nesting grounds, continue migration to the north and west, resulting in markedly higher populations in Alaska. Although both 1980 and 1981 were dry years for prairie ducks, as was 1977, refugee populations in 1977 may have been greater. This phenomenon is more fully discussed in the duck section.

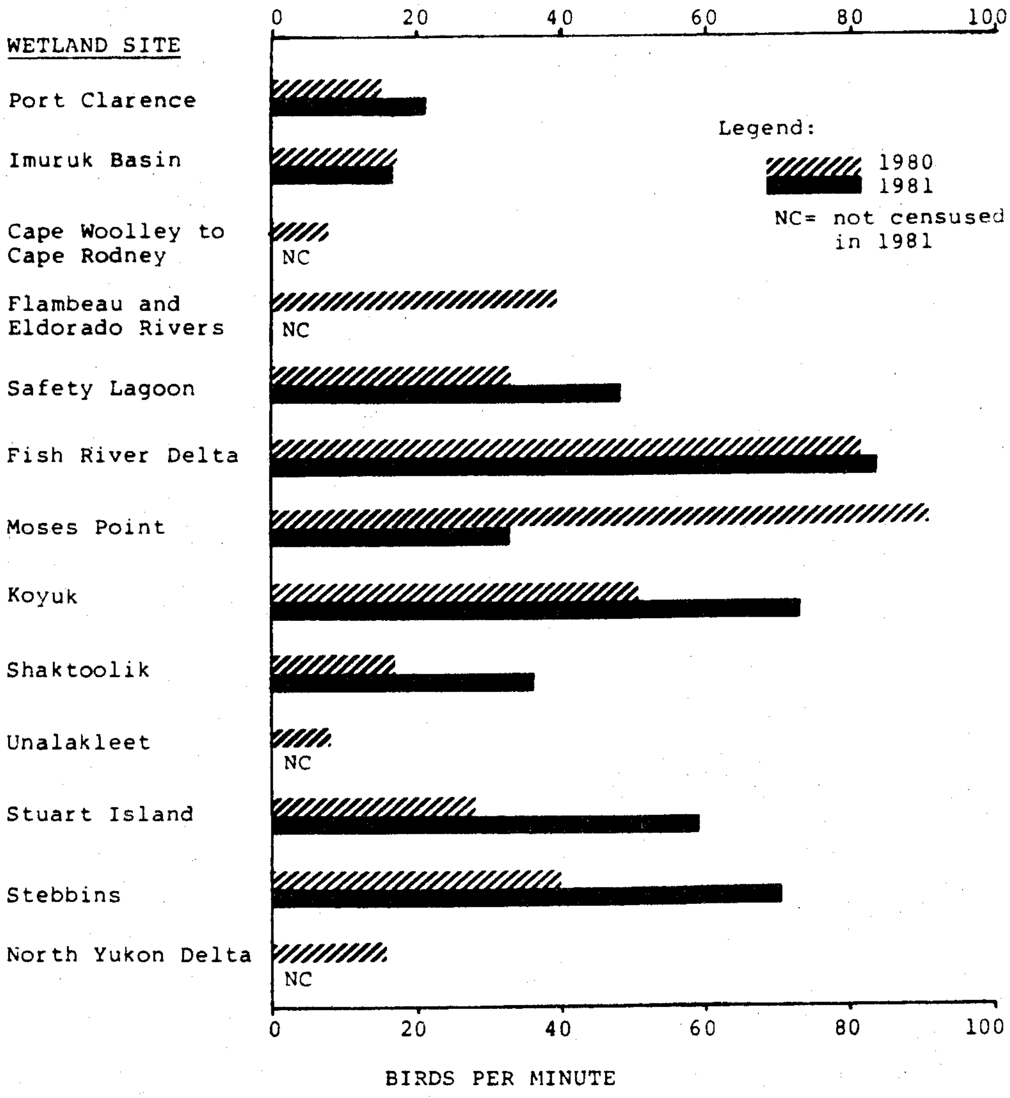

Figure 19. Maximum late summer densities of waterfowl on wetlands. Data are from late August and September 1980 and 1981 wetland aerial surveys. Highest densities are in the northeastern Sound. Note the high year to year variability, particularly for the Moses Point wetlands.

Spring densities (June) showed great variation as well, generally with higher densities in 1981 (Figure 20). This was true at Moses Point and is the opposite of the trend noted for late summer peak densities (Figure 19). The Fish River Delta showed a decline from 1980 to 1981, and as for late summer, the eastern wetlands at Port Clarence, Imuruk Basin, and Safety Lagoon were relatively stable.

Projected populations for each major wetland in spring show year to year changes paralleling those of densities (Table 6). The biggest shift was shown for wetlands at Stebbins.

4. Subsistence Use

Subsistence use of waterfowl deserves full attention when addressing possible impacts of petroleum development and mitigating measures. Waterfowl are exploited by natives for subsistence purposes primarily during spring and fall migration. Little hunting is done during the breeding season, and egging is only occasional. During spring migration when ice covers much of the land and sea, waterfowl are concentrated in the few areas of open water. Pintails are the main species taken during this time, but Canada Geese and other species are also taken. During the last two weeks of May, migrating Brant funnel into wetland areas in northern Norton Sound and western Seward Peninsula. The predictability of their migration paths makes them a much exploited species during their short passage. Hunters told us of kills as high as 50 birds per day, and 10 per day is not uncommon on Golovin Lagoon in spring. These Brant are an important dietary item during these times.

During fall migration, Pintails are again the duck species most taken, while Canada Geese are present in much greater numbers than in spring and are an important food species as well. Brant are an important food at Wales.

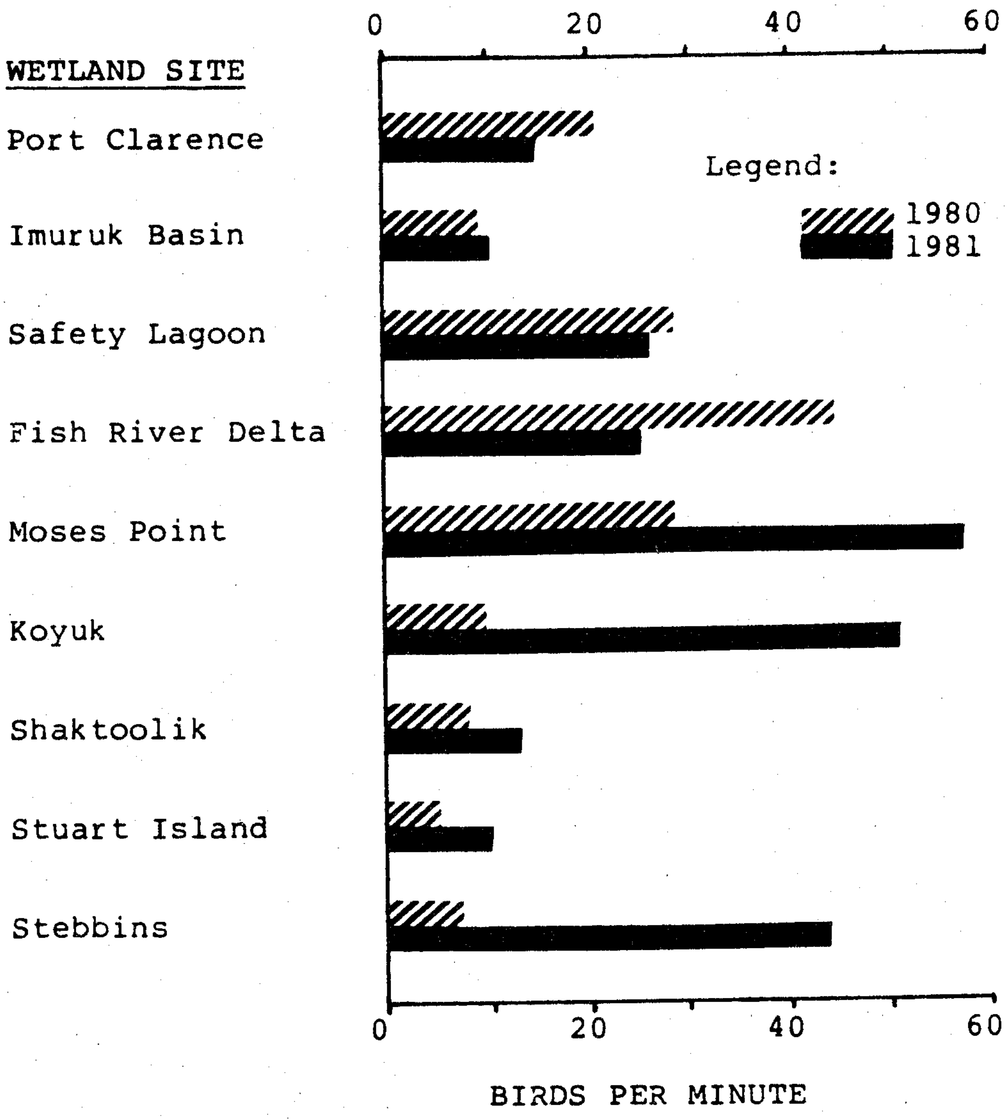

Figure 20. June densities of waterfowl. Data are from 1980 and 1981 wetland aerial surveys. Year to year variation was high particularly in the northeastern Sound and at Stebbins with generally higher densities in 1981.

Table 6. Waterfowl populations in June, projected mean values.[1]

Wetland Area	Km^2	Projected Numbers 1980	Projected Numbers 1981
Port Clarence	13.4	237	164
Imuruk Basin	116.5	873	981
Safety and Taylor Lagoons	37.3	883	817
Fish River Delta	38.5	1,446	807
Moses Point	49.9	866	2,429
Koyuk	61.4	424	2,626
Shaktoolik	51.3	307	553
Stuart Island	22.0	778	1,815
Stebbins	169.0	939	7,656

[1] Projections based on wetland aerial survey data, Figure 20; air speed averaged 177 km/hr, and each observed viewed a 480 m wide path.

D. Swans

Swans reach Norton Sound via interior migration routes from the Atlantic coast. 60,000 adult Whistling Swans occur on Alaskan breeding grounds each year, compared to 30,000 in Canada, and 40,000 of those breed on the Y-K Delta. The estimated breeding population for the Seward Peninsula (both north and south sides) is 1,000 birds, and for St. Lawrence Island, 100 birds (King in Bellrose 1976).

Many of the swans encountered during this study were non-breeders, i.e., birds in their first or second year. These birds were seen in flocks of up to 175 birds in late May, but those flocks dispersed into smaller flocks numbering less than 15 birds each during June. The breeding adults, birds three years and older, were mostly paired when they arrived on the breeding grounds. Only three nests were found in 1980 and three in 1981, although numerous broods were observed from the air.

1. Habitat Use

Habitats most preferred by Whistling Swans in Norton Sound during migration and staging were shorelines of river deltas and similar wetland habitats (Figure 21). Nesting occurred in wetlands as well as on lakeshores well above wetlands; their preferred nesting habitat is a mixture of wet and upland tundras (King and Dau 1981). Shallow waters provide the aquatic tubers and other submerged vegetation that adult swans feed on almost exclusively (Bellrose 1976). Larger ponds were also used as refuge by the unfledged cygnets as well as the flightless adults during mid-summer.

2. Geographic Distribution

Swans were most numerous in the inner and southern sectors of the Sound. The Fish River Delta, in particular, the wetlands of Koyuk, and those southwest of Stebbins were the areas most used by swans (Table 7). These areas were especially important as staging sites in the fall (see below), whereas the Fish River Delta was home to a small population of 200 or more non-breeders in spring and early summer before the molt.

Small numbers seen in other sites may represent gatherings of local breeders prior to staging with the larger congregations.

3. Seasonal Use

Swans that nest in Norton Sound arrive early. Though the tundra was still under a nearly complete cover of snow, the first swan egg was laid at Koyuk on or near the 10th of May, 1980 (Figure 22). First egg dates for the Fish River Delta in 1981 were 17 May and 30 May. Early nesting is highly advantageous for swans, as their nesting season may last 95 to 100

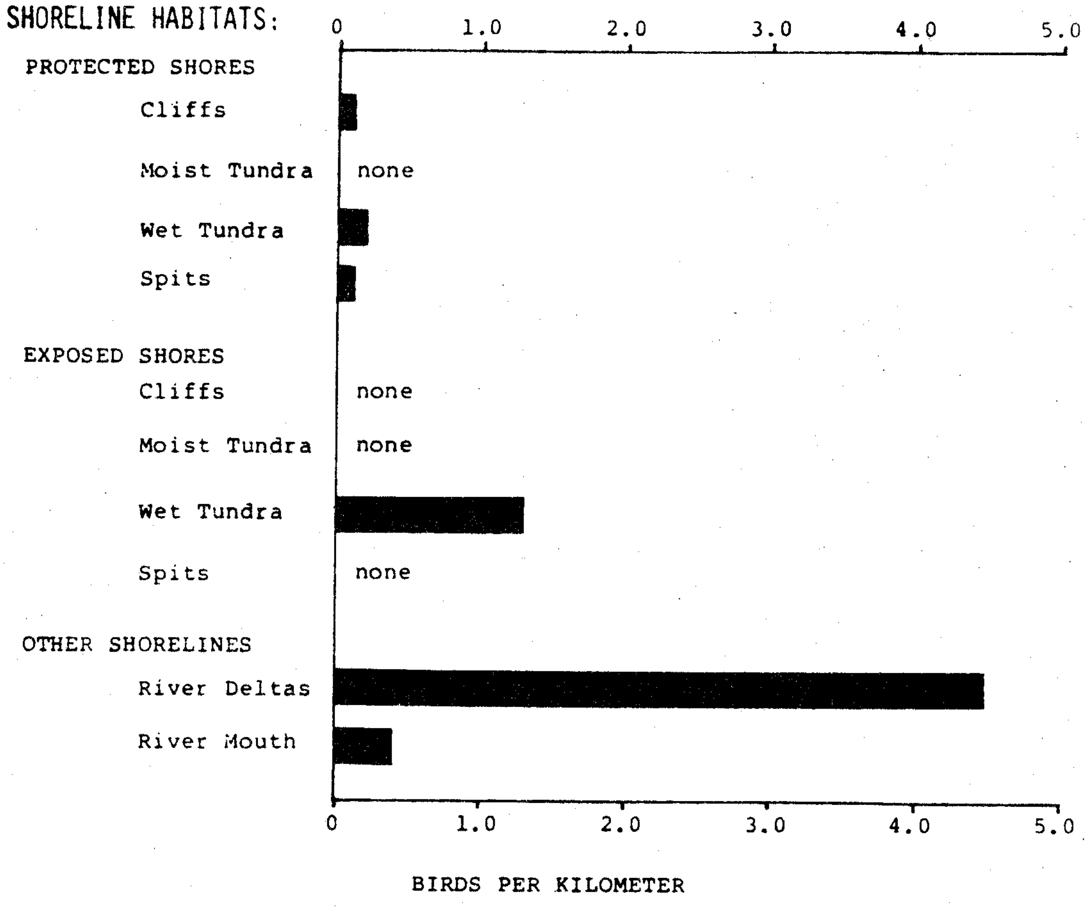

Figure 21. Habitat use by swans. Data are from 1980 shoreline aerial surveys. This shows a strong affinity for wetland shores.

Table 7. Peak numbers of swans observed on wetland aerial surveys.

	1980		1981		1975-1977[1]	
Wetland Area	No.	Mo/Date	No.	Mo/Date	No.	Mo/Date/Yr
Port Clarence	20	8/16	42	9/5	37	8/11-20/76
Imuruk Basin	24	9/2	40	9/5	--	
C. Woolley to Sinuk	10	8/16	--		54	8/29/75
Safety Lagoon	150	6/11	77	9/12	57	8/26-31/77
Fish River Delta	445	9/3	1,602	9/10	1,085	8/26-31/77
Moses Point	30	9/3	63	8/28	25	8/26-31/77
Koyuk	477	9/3	284	8/28	442	10/1/76
Shaktoolik	31	6/9	65	9/10	118	8/26-31/77
Stuart Island	139	9/23	22	9/10	--	
Stebbins	500	9/6	985	9/10	--	

[1] Data from Drury (1980).

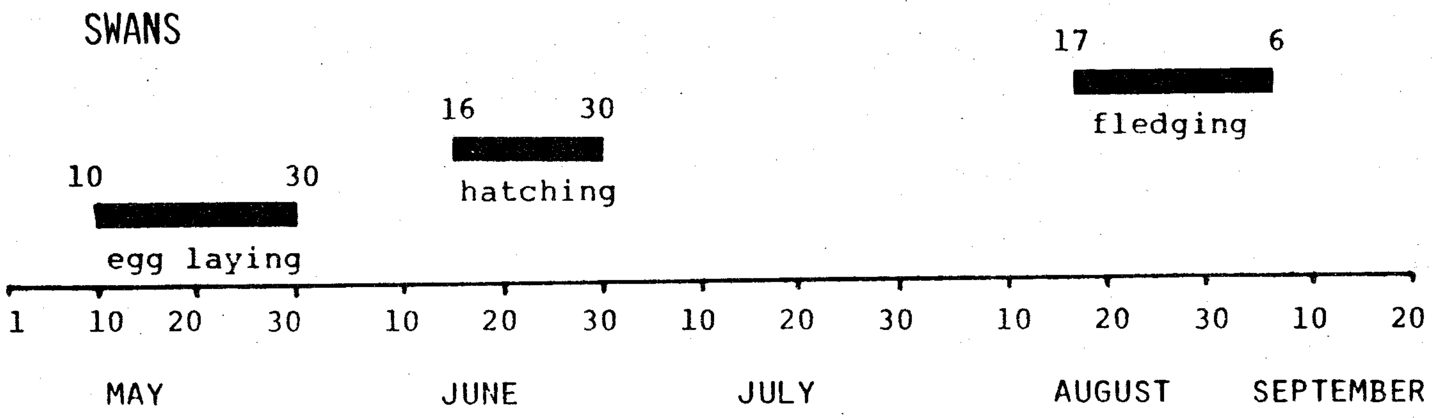

Figure 22. Nesting phenology of swans. Data are from 1980 and 1981, with three nests and numerous post-nesting observations in each year. Swans have the most protracted nesting period of any bird in the Sound.

days (Bellrose 1976). Late springs reduce productivity of swans, and Lensink (1973) has found the timing of break-up and snow melt on the Y-K Delta to be a fairly reliable predictor of swan production there, having more effect than factors such as predation. Thus, a lack of any aggregation of birds in May (Figure 23) may be explained by breeders heading directly for their nesting grounds. The small numbers present in coastal flocks in June and July are mostly non-breeders.

In July, after the cygnets hatch, all but juvenile swans enter a molting period when they are flightless for 30 to 40 days (Bellrose 1976). In preparation for the molt, non-breeding flocks apparently move to areas with higher vegetation, causing a low in coastal populations in late July. Swans present in coastal wetlands at this time may be mostly breeding adults that remain with their young in the vicinity of the nest.

By late August and early September, most young began to fly, and staging populations reached their peak in the first two weeks of September. The sequence of fall events at the three major sites are as follows (Figure 24 and Table 7):

Fish River Delta. Swan numbers increased slightly in early August and rapidly in late August, peaking in early September at 445 in 1980, 1,602 in 1981, and 1,085 at the end of August in 1977 (Table 7). Numbers dropped drastically in late September, and a few stragglers may have remained into early October.

Koyuk Wetlands. Numbers at Koyuk peaked somewhat earlier than at the Fish River Delta but both areas had similar peak numbers on 3 September 1980 (Table 7). The 1981 maximum for Koyuk was considerably below that of the Fish River Delta, however. Birds stayed later at Koyuk, and 442 were observed there by Drury (1980) on 1 October 1977.

Stebbins Wetlands. Swans gathering here probably come mostly from the Y-K Delta, as well as from nearby nesting areas. Numbers peaked in early September as at the Fish River, and lingered as at Koyuk, with maximum numbers of 50 on 6 September 1980 and 985 on 10 September 1981.

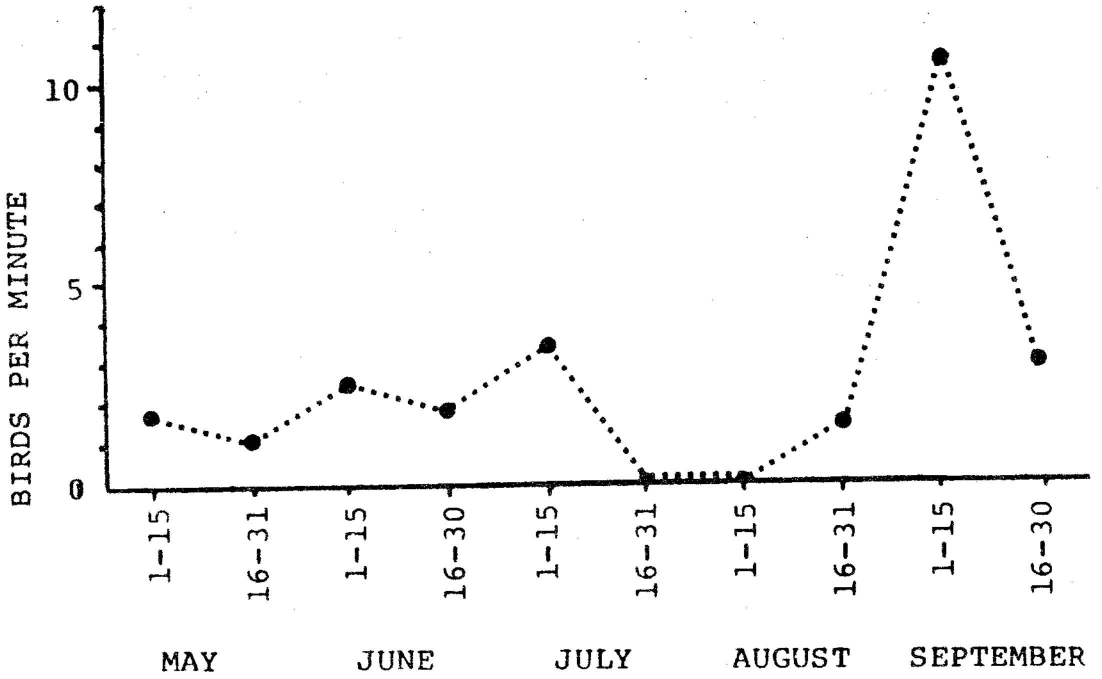

Figure 23. Seasonal abundance of swans. Data are averaged from 1980 and 1981 wetland aerial surveys. September peak populations are of swans gathering on wetlands after nesting to feed and build up fat reserves for their long flight across the continent. The July peak is mostly of non-breeders.

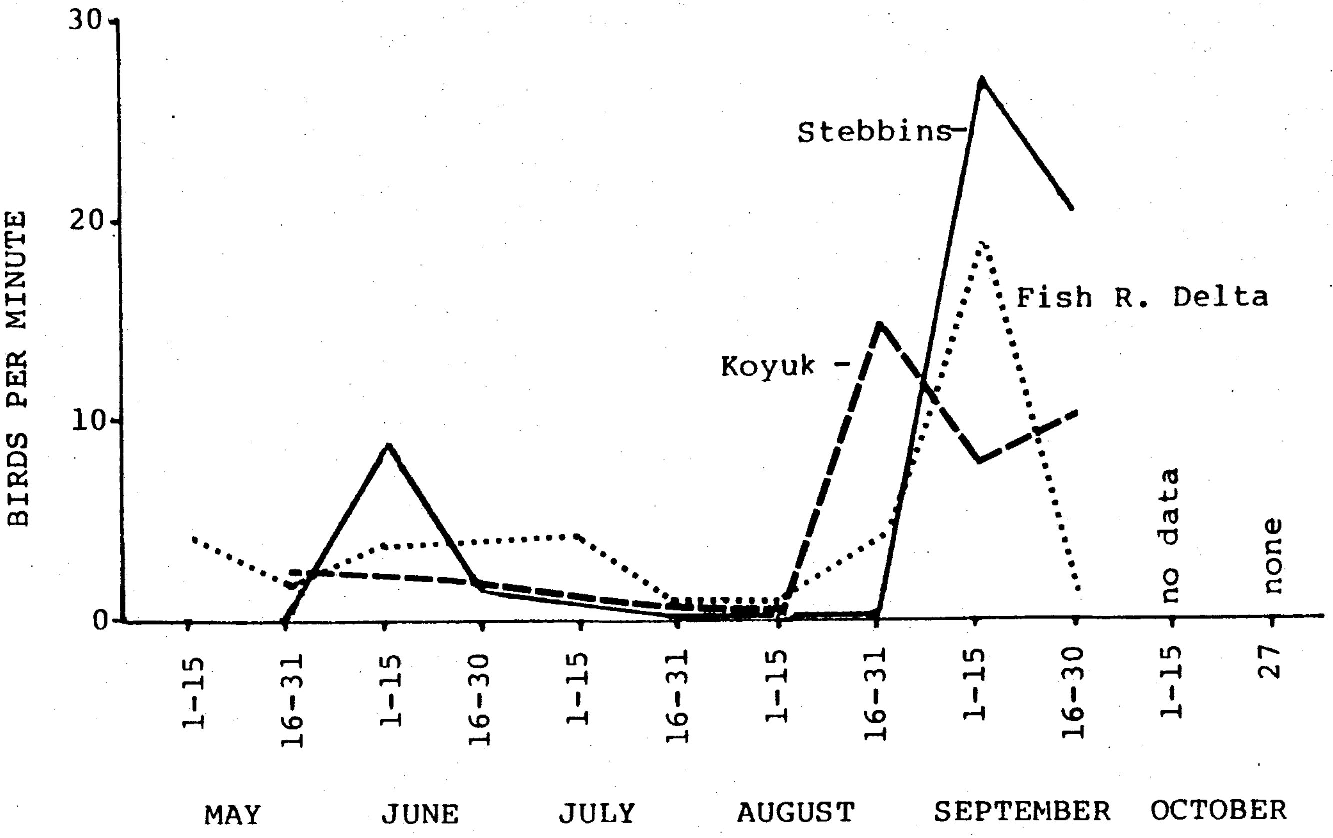

Figure 24. Seasonal abundance of swans at the Fish River Delta, Koyuk, and Stebbins, the three most important areas for swans in Norton Sound. Data are averaged from 1980 and 1981 wetland aerial surveys. Swan populations peakecd earliest at Koyuk and the and the peak population at the Fish River Delta was of relatively short duration..

E. Geese

Most geese seen in Norton Sound were either en route to more northerly breeding grounds during spring, or returning from those areas and congregating in northern Norton Sound during fall migration. Few nested in the study area.

We observed five species: Canada Geese, Brant, Snow Geese, Emperor Geese, and White-fronted Geese. Canadas were by far the most abundant, making up 86% of all geese seen. Brant were second in abundance at 10%, followed by Snow Geese at 5%, Emperor Geese at 1%, and White-fronted Geese were rare.

Except for Snow Geese, the major nesting area for all species in Alaska is on the Y-K Delta; Kotzebue Sound (Selawik area) also attracts some breeding Canada and White-fronted Geese (King and Lensink 1971). Only Canada and Emperor Geese bred within the study area, and the number of nests was minimal.

1. Canada Geese

At least two races of Canada Geese breed along the west coast of Alaska. The entire population of one, the Cackling Goose, can be found on a 16 km wide strip of coastal tundra between the Yukon and Kuskokwim Rivers. Lesser Canada Geese, the race present in Norton Sound, breed throughout interior Alaska as well as on the arctic coastal plain. They are the only Canada Goose known to migrate north along an entirely different route from that used in the fall (Bellrose 1976). This clockwise migration corridor leads them along inland routes in spring. In fall, almost the entire Alaska population of Lesser Canadas funnel south from Kotzebue Sound through Norton Sound, to the Y-K Delta and Izembek Bay, where they stage before heading further south. This population numbers about 100,000 birds in fall (King and Lensink 1971).

As mentioned earlier, few geese nest in Norton Sound, and we found only three nests in two years, all on the Fish River Delta. Two of these were probably by the same pair nesting on a hummock used in both 1980 and 1981.

(a) Habitat Use. Canada Geese were in concentrated flocks during their south migration with few habitats being exploited (Figure 25). Densities were highest at river deltas and similar wetlands which offer the aquatic plants, including eelgrass, that many geese consume. Canadas were also common on moist tundra, where they fed extensively on berries (Empetrum nigrum and Vaccinium spp.) that grow abundantly on moist tundra hillsides. We observed flocks of several thousand on the southwest side of Golovin Lagoon foraging in the moist tundra, and these later moved to the

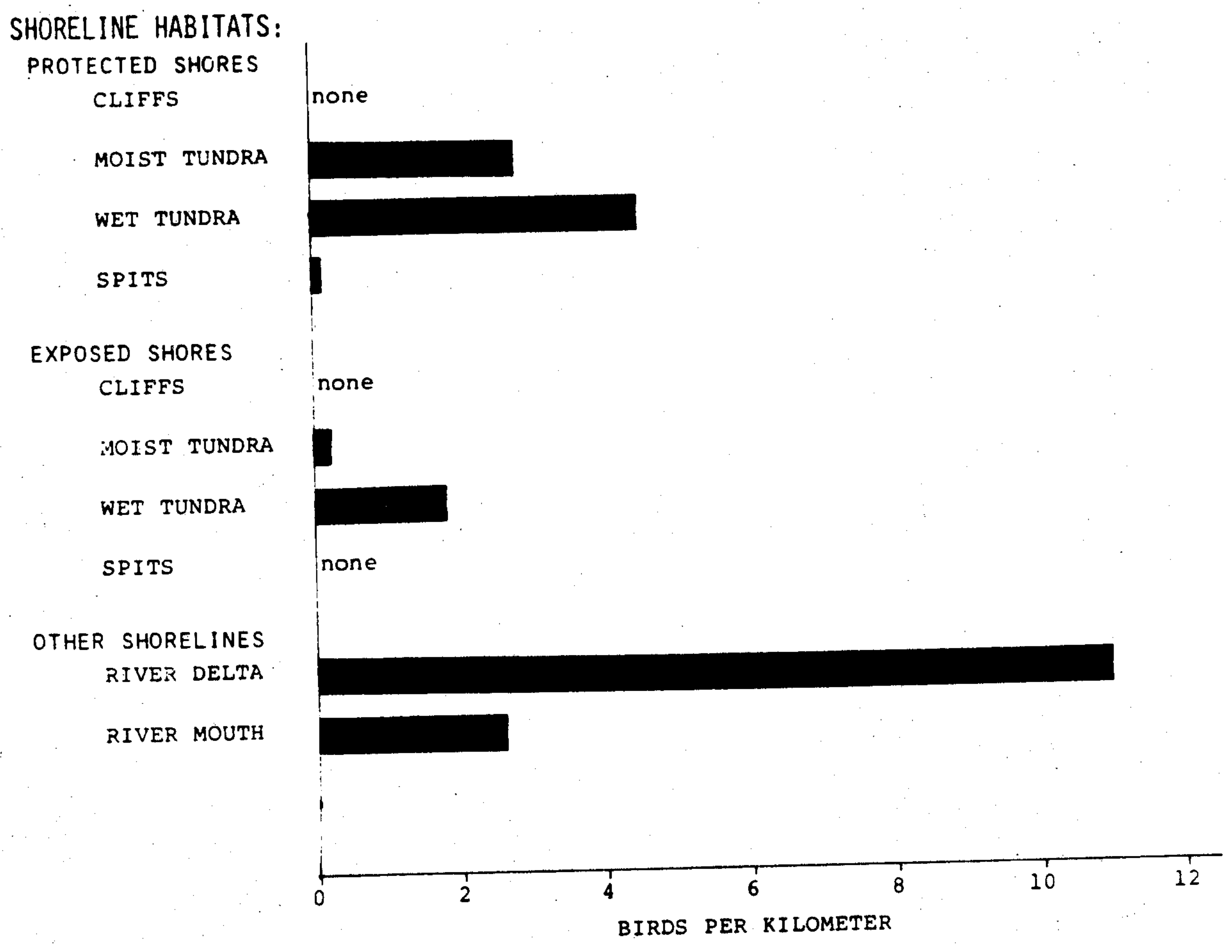

Figure 25. Habitat use by Canada Geese. Data are from 1980 shoreline aerial surveys. Highest densities were along wetland shorelines (river delta and wet tundra shores) and these were in late summer and fall.

tidal flats at the head of the Fish River Delta. Daily movements from one foraging area to another, or to roosting sites, are probably common for Canadas, particularly with occasional blasts by hunters that may prompt thousands of birds to take to the air.

(b) Seasonal Use. Very few Canada Geese were present in Norton Sound during spring of 1980 and 1981 (Figure 26), and no significant migration was noted at the Akulik-Inglutalik Delta south of Koyuk in spring 1977 by Shields and Peyton (1979). The few flocks seen by them and by us were probably stragglers from the inland migration routes used by birds en route to Kotzebue Sound.

In July, the Canada Goose population was near zero except for the few breeders. By late August, they became increasingly abundant in the wetlands around the Sound, and in mid-September they reached peak abundance, decreasing rapidly soon afterwards. We are not sure of the residency period of a flock in Norton Sound. The evidence suggests that they may pass through in a matter of a few days, as there are from 70,000 to 100,000 passing through (Bellrose 1976), and our greatest counts do not total more than 5,000 to 10,000 (see "Distribution" below).

Shields and Peyton (1979) noted only a minor fall migration in 1977 south of Koyuk, and this peaked fairly early (16 August) with only 200 birds that day.

(c) Geographic Distribution. All areas were used minimally by Canada Geese in May, June, and July. In August, geese became common at wetlands of Koyuk, Moses Point, and the Fish River Delta with lesser numbers at all other sites and almost none near Stebbins and on Stuart Island (Table 8). During peak migration, the Fish River Delta and adjacent areas of Golovin Lagoon received the heaviest use. This was also true in 1976 and 1977 (Drury 1980). Higher counts in those years are probably due to more extensive surveying of all available habitat on Golovin Lagoon, as well as real population differences. Note that the high count of 5,600 (in 1979) was reached in late August, well before migration peaked in the later survey years.

We observed Canada Goose flocks coming into Golovin Lagoon from the northwest (9 September 1980) and reason that many of the geese there had followed river drainages across the Seward Peninsula (Figure 27). A similar situation is found at Koyuk, where geese probably arrive after flying from interior Kotzebue Sound over the low passes. Canada Geese my also fly past the western tip of the peninsula and may then head south and east towards the Imuruk Basin from Wales and then into Golovin Lagoon. Otherwise, they may continue south from Wales, stopping along Norton Sound's outer coast, or head directly south for Izembek Bay. A remarkable lack of Canada Geese at Stebbins suggests offshore or far inland migration

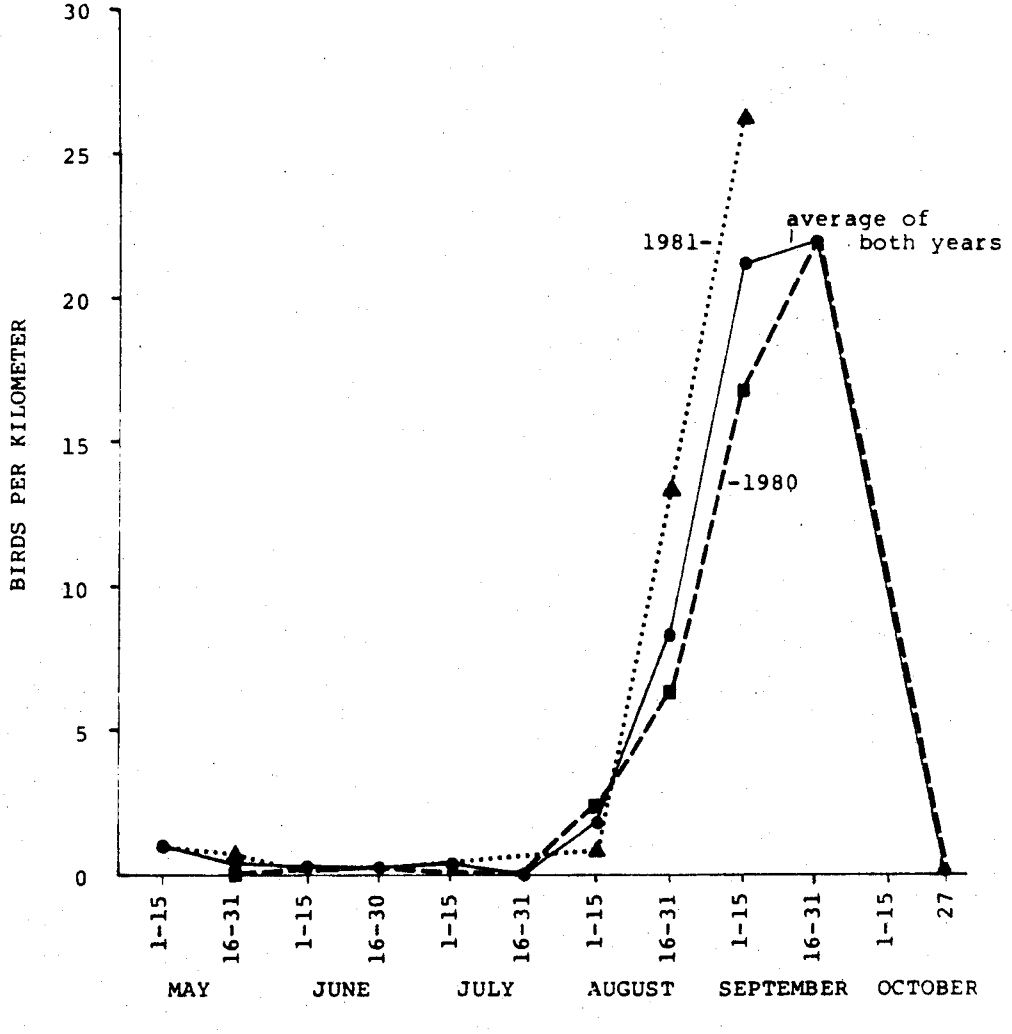

Figure 26. Seasonal abundance of Canada Geese. Data are from 1980 and 1981 wetland aerial surveys; average data are also given. Canada Geese are virtually absent from Norton Sound until late summer when they become abundant.

Table 8. **Maximum counts of Canada Geese at Norton Sound wetlands. Data are from wetland aerial surveys in 1976, 1977, 1980, and 1981.**

	1980		1981		1976[1]		1977[1] 8/26-31
Wetland Area	No.	Mo/Date	No.	Mo/Date	No.	Mo/Date	No.
Port Clarence	330	8/16	561	9/5	141	9/24	200
Imuruk Basin	200	9/2	331	9/5			
C. Woolley to Sinuk	112	8/23			239	9/24	347
Flambeau and Eldorado Rivers	430	9/24					
Safety Lagoon	600	9/23	240	9/12	408	9/24	375
Fish River Delta	1,935	9/10	1616	9/5	3,860	9/9	5,620
Moses Point	872	9/23	574	9/10	902	9/9	1,630
Koyuk	1,019	9/23	1,025	8/28	570	10/1	719
Shaktoolik	608	9/29	572	9/10	185	10/1	854
Stuart Island	35	9/6	50	9/10			
Stebbins	0		100	8/28			

[1] Data from Drury (1980).

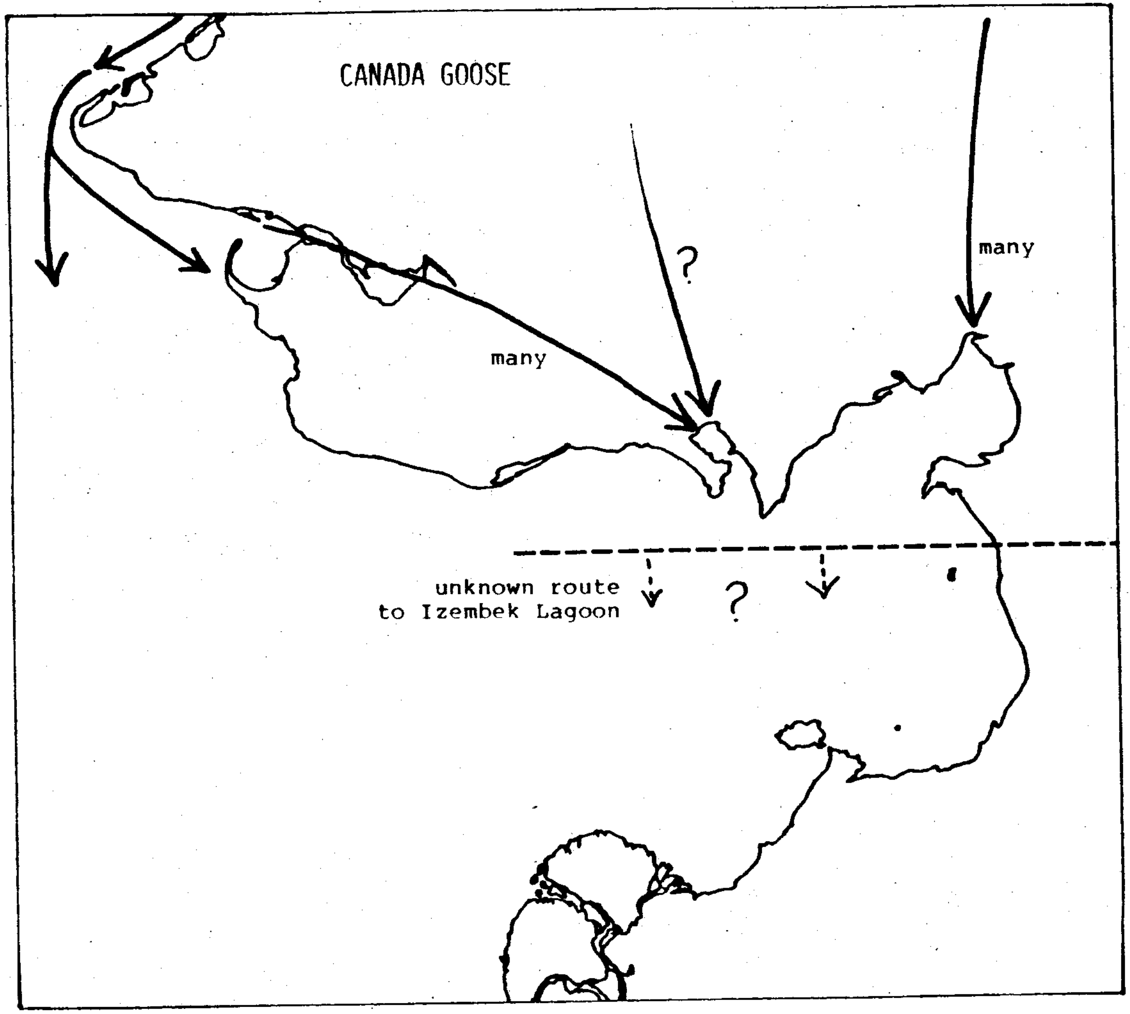

Figure 27. Migration routes of Canada Geese through Norton Sound in late summer and fall. Many use cross-peninsula routes, and few are seen in the south.

routes that bypass this otherwise productive area.

2. Brant

Brant were migrants in Norton Sound and were not found to nest there. They were mostly found along protected shorelines and along river delta shorelines (73% of shoreline aerial survey sightings).

(a) Spring Migration. They are most common in spring (Figure 28). On their way north, Brant cross the Gulf of Alaska from their Pacific coast wintering grounds to gather at Izembek Bay on the Alaska Peninsula. In mid-May, they depart northward (Gill et al. 1979) to breeding sites along the coast of the Y-K Delta, Kotzebue Sound, and the arctic coasts of Alaska, Canada, and Siberia.

Bailey (1948) judged that most Brant cut across the base of Seward Peninsula rather than passing through Bering Strait (Figure 29). Observations by Woodby (unpublished) at Wales in 1977 support this, as few Brant were seen from 2 June on into the summer.

Many Brant are seen (and eaten) each spring in eastern Norton Sound, though our survey turned up large numbers only at the Fish River Delta (Table 9). We did not fly wetland surveys until 31 May in 1980, so 1981 counts during Brant migration in mid to late May are higher. Shields and Peyton (1979) noted a peak migration of 1,800 Brant heading north along the east shore of Norton Bay on 25 May 1977, and they estimate that 3,000 Brant used this route between 19 May and 2 June. These Brant may have come via the Yukon basin (interior Alaska) as noted by Cade (1955) and Irving (1960). Many of these probably continue north of Koyuk across the Seward Peninsula into Kotzebue Sound. An annual spring migration of Brant move west from inner Kotzebue Sound along the north shore towards Cape Krusenstern (Bob Uhl, pers. comm.), and these may include the birds passing through Norton Bay as well as birds coming from the interior and bypassing Norton Sound.

At Golovin, Brant make an annual passage in late May into Golovin Lagoon and then on towards the northwest (David Olson, pers. comm.). We observed this between 15 and 31 May, and on 18 May estimated a peak passage of 1,500 birds with a maximum rate of 800 per hour. These came from the southwest. Total spring migration through the Golovin area was at least 4,000 birds in 1981. The first migrants are adults, while later birds are immatures (less than three years old) and non-breeders (Gill et al. 1979; Stanley Amarok, pers. comm.)

Migrants moving north across western Norton Sound may touch down at Port Clarence and nearby areas before passing through the strait. We noted small flocks totaling 101 at the base of Cape Spencer between 29 May and 3 June 1980, and spotted a flock of 117 from the air on 3 June

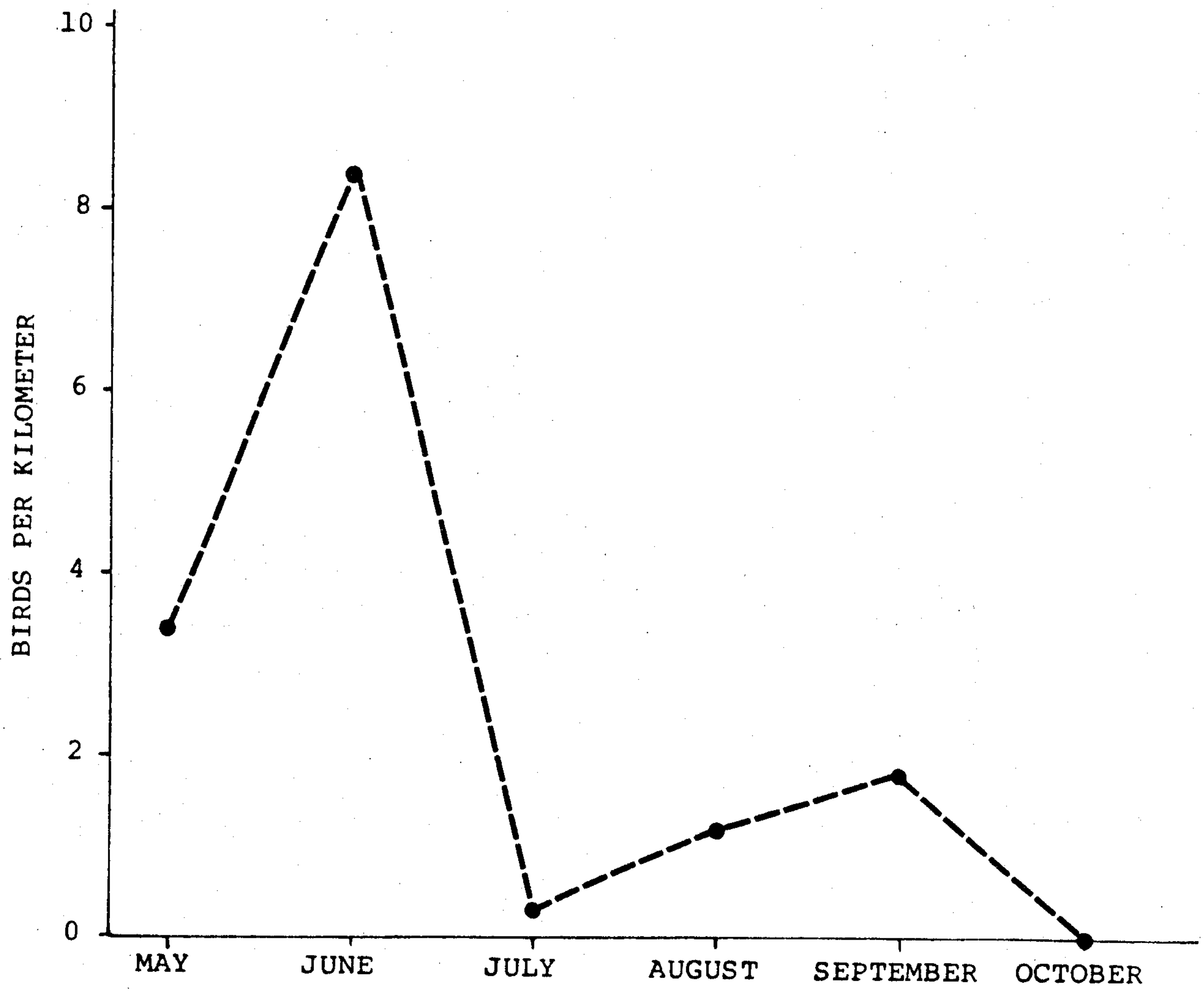

Figure 28. Seasonal abundance of Brant. Data are from 1980 shoreline aerial surveys. Brant are most common in spring when they pass through the inner Sound; in August and September they head south across the outer Sound and are less frequently seen.

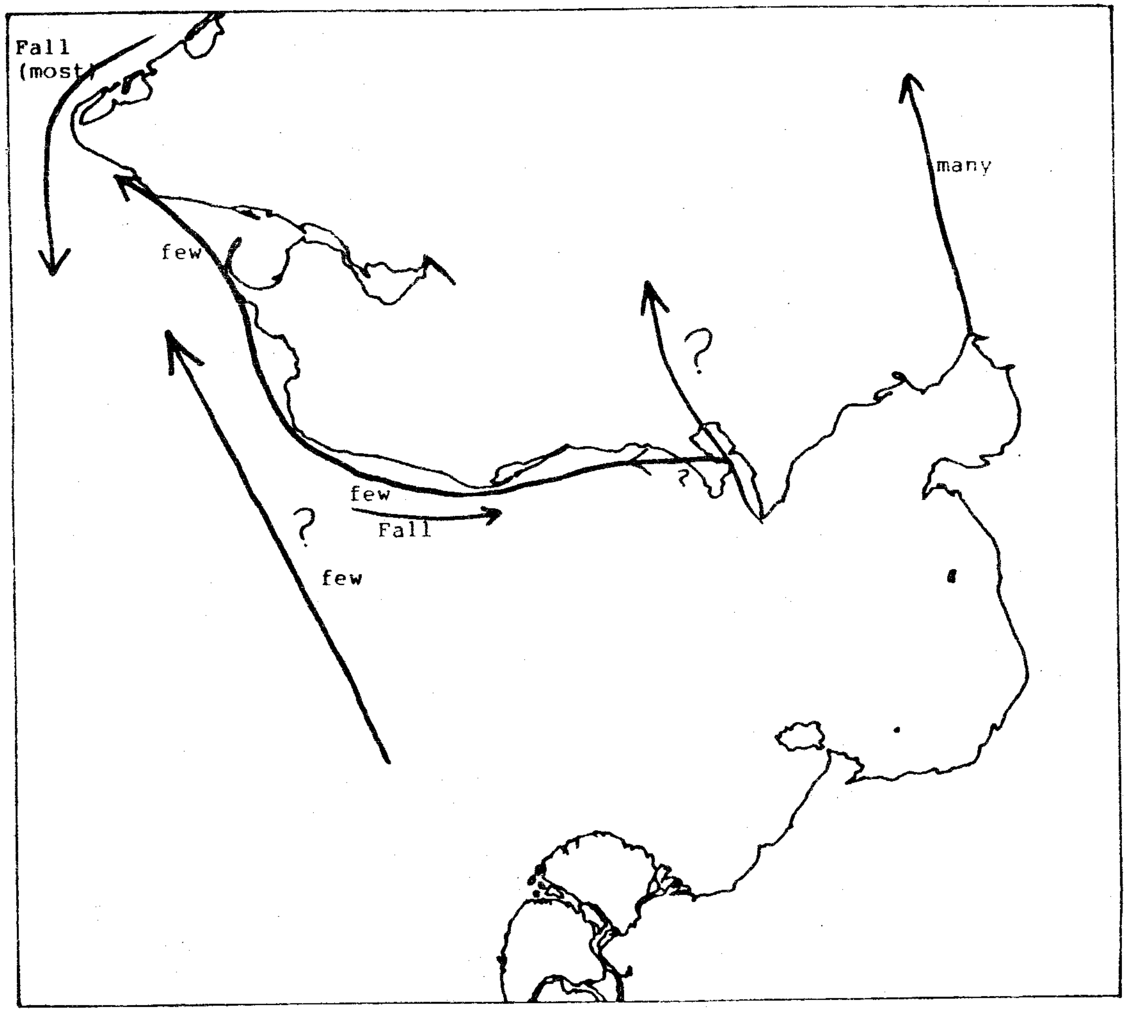

Figure 29. Migration routes of Brant through Norton Sound in spring and in late summer and fall. Coastal areas are visited most heavily in spring.

Table 9. **Maximum counts of Brant at Norton Sound wetlands. Data are from wetland aerial surveys in 1980 and 1981.**

Wetland Area	1980[1] No.	1980[1] Mo/Date	1981 No.	1981 Mo/Date
Port Clarence	553	6/30	117	6/3
Imuruk Basin	72	8/16		
Cape Woolley to Sinuk	25	9/17		
Safety Lagoon	161	6/11	220	6/3
Fish River Delta	255	6/7	1,532	5/18
Moses Point	275	5/31	604	5/18
Koyuk	185	9/6	15	5/18

[1] Earliest survey date in 1980 was 31 May, and most adult Brant had probably passed north by then.

1981.

Migrant Brant flocks appeared to remain along shorelines for short periods and were not making extensive use of the littoral habitats.

(b) Late Summer Migration. Adults and young returning in late summer may pass exclusively through Bering Strait. Wales people depend on this heavy migration in late August, for subsistence hunting. We found very few in late summer in Norton Sound wetlands, and conclude that most fly directly south towards Izembek Bay, where they stage for their migration across the Gulf of Alaska. Norton Sound migration routes are summarized in Figure 29.

The estimated adult population of Brant nesting in the arctic is approximately 17,000 (King in Bellrose 1976). Since the estimates given above for migrant numbers at Koyuk and Golovin are low (as uncorrected counts invariably are), it is reasonable to conclude that much of the arctic Brant population passes through eastern Norton Sound in spring. Lehnhausen and Quinlan (1982) have evidence verifying overland migration routes from the Bering Sea to the Arctic, bypassing their study site at Icy Cape in the Chuckchi Sea.

Brant are strictly sea geese and feed mainly on eelgrass in the winter (Einarsen 1965). Eelgrass beds in Golovin Lagoon may attract them there in spring, since Brant commonly arrive at Golovin around 24 May (Phillip Dexter, pers. comm.) shortly after the average date of ice break-up (23 May, AEIDC 1975). McRoy (1969) found viable eelgrass under the ice at Safety Lagoon in March metabolizing and growing new tissue. Brant were found to arrive at nesting grounds on the Colville River near Prudhoe Bay when growth of sedge and grass shoots peaked (Kiera 1982). Brant stomachs taken at Golovin are often full of shoots (Tommy Punguk, pers. comm.). Eelgrass may be important in their diet there, though Pintails find an adequate sedge shoot crop on flooded tundra in spring, and Brant may do the same (see "Trophic Systems").

3. Snow Geese

Except for a few scattered pairs on the arctic coast and a small colony on Howe Island in Prudhoe Bay, virtually all Snow Geese encountered in western Alaska nest on Wrangel Island, in the Soviet Chukchi Sea. In Norton Sound, they are strictly migrants. In spring, a segment of the population follows an interior route from Alberta, across interior Alaska, and then into Norton Sound (Bellrose 1976). A major corridor of migrants heads north from the Alaska Peninsula then across the mouth of Norton Sound passing through Bering Strait. These are joined by the migrants from interior Alaska along a spur route. We probably observed part of this spur route on 6 May 1981 along the south coast of the sound near the

Pikmiktalik River (32 km southwest of Stebbins in Pastol Bay), where 300 or more Snow Geese were moving southwest (Table 10).

The bulk of spring migrants entering Norton Sound from the interior probably pass north over Koyuk and across the Seward Peninsula. Several Koyuk residents spoke to us of this movement north, and thought it was a common route for other species of geese as well (see "Brant"). Shields and Peyton (1979) estimated a passage of 5,000 Snow Geese at the Akulik-Inglutalik Delta between 10 and 25 May 1977. Most of our sightings of large flocks are from eastern Norton Bay.

The "great bands" seen by Bailey (1948) at Wales in late May are surely an annual event. Most of these northbound migrants must stay offshore, as we noted only 50 along the west coast from Wales to Brevig in our two years of spring census work, and these were at the base of Point Spencer on 1 June 1980. During their passage in late May, shore-fast ice is common from Sledge Island to the strait, and they may follow the ice edge.

Few birds were seen in fall with most on Norton Sound's northwest coast. 3,400 seen on central and southern St. Lawrence Island on 18 September 1980 lead us to believe that most Wrangel Island Snow Geese head south towards the Alaska Peninsula via a mid to western Bering Sea route; Palmer (1976) supports this. During the spring we found Snow Geese primarily in wet tundra and on river deltas. Although their use of wetlands does not last long, feeding stops for northbound birds in eastern Norton Bay may be beneficial or necessary to their nesting success.

4. Emperor Geese

Emperor Geese are true sea geese. Their preferred habitats are rocky shores and salt-washed meadows, and like Brant, they are principally grazers of marine plants (Bellrose 1976). Their restriction to the coast has subjected them to heavy subsistence hunting pressure resulting in currently reduced populations (Lensink, pers. comm.). Emperor Geese were few in Norton Sound with most breeding taking place to the south. They are essentially confined to the Bering Sea region all year. The vast majority nest in Alaska (60,000 to 75,000 adults), with 90% of these on the Y-K Delta and about 1,000 along the Shishmaref coast of Kotzebue Sound (King in Bellrose 1976). Small numbers also nest along the Siberian Chukchi coast (Kistchinski 1971). Almost all winter along the Alaska Peninsula and Aleutians, except for 2,000 to 3,000 in the Kodiak area (Bellrose 1976). Fay (1961) estimated that less than 1,000 to 2,000 Emperors nested on St. Lawrence Island and recent nesting there has not been substantiated (Bellrose 1976).

Table 10. Snow Goose sightings in Norton Sound, 1980 and 1981.

Wetland Area	Spring No.	Spring Mo/Da/Yr	Summer/Fall No.	Summer/Fall Mo/Da/Yr
Port Clarence	50	6/ 1/80	150	9/ 2/80
			55	9/ 5/81
			175	9/17/81
Cape Wolley			46	9/ 2/80
			20	9/17/80
Safety Lagoon	8	5/14/80	12	9/21/80
Fish River Delta	50	5/21/81	2	9/ 6/80
Moses Point	100	5/18/81		
Koyuk	21	5/ 6/81	190	9/ 3/80
	640	5/ 8/80	20	9/29/80
	800	5/18/81		
Unalakleet	25[1]	5/ 6/81	20[2]	9/23/80
	16	5/22/80		
Stuart Island	25	5/ 6/81	25	9/ 6/80
			10	9/23/80
Stebbins	300[3]	5/ 6/81	14	8/28/80
	1	6/ 8/81		
	1	6/18/80		

[1] 10 km south of Unalakleet.

[2] 50 km southwest of Unalakleet.

[3] Near Pikmiktalik River on Pastol Bay.

(a) Spring. In spring, Emperors migrate north from the Alaska Peninsula along the coast to the Y-K Delta (Gill et al. 1979) and those heading north to southern Kotzebue Sound probably cross over western Norton Sound (Palmer 1976). The 24 Emperors we observed at Port Clarence in late May 1980, in family flocks and pairs, were probably enroute to Kotzebue Sound, as were the others seen in northern Norton Sound in spring (Table 11).

(b) Breeding. We found two nests of Emperor Geese near Stebbins in 1981, one with seven eggs (10 June) and the other with six eggs (13 June). These were part of a small local population at the northern extent of coastal meadows of the Y-K Delta system. Minor patches of this salt-washed wet tundra occur in other wetlands of Norton Sound, though we have no evidence of Emperor Geese nesting on these.

In mid-summer, near the time when young Emperor Geese are hatching, a massive molt migration occurs from the breeding grounds on the Y-K Delta to St. Lawrence Island. The birds involved are non-breeding immatures and failed breeders (Jones 1972). Fay (1961) reports between ten and twenty thousand Emperor Geese mainly along the southern coast of the island, congregating in large "herds" during the molt. He estimates that in a flock of approximately 5,000 geese on 21 July, not more than 10 were capable of sustained flight. From this evidence, Fay and Cade (1959) suggest that St. Lawrence Island is the principal summering area for the entire population of non-breeders produced in Alaska and Siberia.

(c) Late Summer. Fall migration is usually more prolonged than spring migration, comprised of family groups numbering less than 20 birds, and spread over a greater portion of the range (Gill et al. 1979). Emperor Geese were more common in fall than in spring, but still in very low numbers and occurring sporadically throughout the wetland areas (Table 11). Stebbins is the only area where they were regularly seen.

5. White-fronted Geese

White-fronted Geese were scarce as migrants in Norton Sound during spring and fall, and the nearest nest record is 12 km northeast of Wales with six eggs on 18 June 1977 (Woodby, unpublished). Their major nesting grounds in North America are at the Y-K Delta where about 80,000 adults gather (Bellrose 1976). Minor populations nest in Alaska's interior, around Kotzebue Sound, on the arctic slope, and in the Canadian arctic. Small numbers of migrants were observed in eastern Norton Bay by Shields and Peyton (1979) in both spring and fall, and these migrate via interior routes (King and Dau 1981). Nearly all of the White-fronted Geese we saw (99%) were in late summer in the northern Sound, and these were flocks of no more than 120 birds.

Table 11. Emperor Goose sightings at Norton Sound wetlands, 1980 and 1981.

	Spring		Summer/Fall	
Wetland Area	No.	Mo/Da/Yr	No.	Mo/Da/Yr
Port Clarence	24	6/ 4/80	5	7/ 9/80
			21	8/ 7/80
			1	9/ 5/81
Cape Wolley			10	8/16/80
			2	9/ 2/80
			12	9/ 5/81
Safety Lagoon	3	6/13/80		
Fish River Delta	3	5/19/81	1	8/ 4/81
Moses Point	2	5/18/81	8	8/15/80
	1	6/ 9/80		
Koyuk	4	5/18/81	1	8/23/80
Shaktoolik			10	9/10/81
Stuart Island			6	9/10/81
Stebbins	5	5/31/80	5	8/15/81
	3[1]	6/10-14/81	80	8/28/81
	2	6/21/80	10	8/29/81
			67	9/10/81

[1] One nest with 7 eggs on 10 June 1981 and another with 6 eggs on 13 June 1981.

F. Ducks

Ducks are a dominant bird group in Norton Sound wetlands, particularly in late summer. Many come to nest, though the bulk are found in Norton Sound after nesting in more northern and inland areas. We observed a total of 23 species, 9 commonly and 13 with evidence of nesting (Appendix 26).

We divided our analysis of duck populations according to the two recognized functional taxonomic categories, dabblers and divers. The basis for separation is feeding method. Dabblers are puddle ducks, typified by Mallards and Pintails, that often feed by dabbling at the surface of lakes or ponds. Their legs are centered amidships, allowing them to walk easily on land and "tip up" to feed on the bottoms of shallow ponds. We observed six species of these, and they comprised 75% of the ducks on shoreline aerial surveys. Though a more diverse group in Norton Sound, the 17 species of divers counted by us were only one-quarter of the duck population. These typically stout birds have their legs mounted farther astern, providing propulsion for deep dives to feed on benthos, fish, or sometimes zooplankton. They also feed at the surface, particularly on invertebrates of tundra ponds during the nesting and chick-rearing months.

1. Relative Abundance

(a) Dabbling Ducks. Pintails far outnumbered all other ducks in Norton Sound and comprised at least three-quarters of the dabbling duck population seen on wetlands (Table 12). On the basis of 1980 wetland aerial surveys, American Wigeon were the next most common at 17%, while Mallards, Green-winged Teal, and Northern Shovelers together made up less than 6% of the dabblers. Gadwalls were rare.

Teal and Shovelers were usually underestimated by aerial surveys, especially in late summer when they resemble Pintails. Relative abundance estimates derived from land surveys place their populations at 7% and 5% of dabblers, respectively (Table 12, column 3). Land surveys may under-represent wigeon and Mallards, as these often flocked in sites inaccessible to walking observers.

Relative abundance of nesting dabblers is best shown by proportions of nests or broods found of each species (Table 12, column 4). This was calculated by summing the number of nests and broods observed in all areas during both years. Clearly, Pintails were considerably less important as nesters than their total numbers would suggest (compare columns 3 and 4), though still the most common nesting dabbler. This may indicate a surplus of refugees from drought-stricken prairies (see below), as well as large populations of migrants to and from major nesting grounds around Kotzebue

Table 12. Relative abundance of dabbling ducks in coastal Norton Sound.

Species	Percent Total Ducks[1]	Percent Tot. Dabblers (a)[2]	(b)[3]	Percent Nesting Dabblers[4]	Percent Nesting Ducks[4]	No. Nests and Broods
Pintail	58.5	77.3	77.6	34	18	32
American Wigeon	10.3	16.8	9.0	5	3	5
Green-winged Teal	0.5	1.3	6.8	30	16	28
Northern Shoveler	0.5	0.7	4.9	29	15	27
Mallard	3.2	3.9	1.6	1	< 1	1
Gadwall	< 0.1	< 0.1	0.1	1	< 1	1
Total	73.0	100.0	100.0	100	53	94

[1] Data from shoreline aerial surveys, 1980; total = 22,232.

[2] Data from wetland aerial surveys, 1980; total = 36,453.

[3] Data from land surveys, 1980; total = 12,248.

[4] Data from nest and brood counts, 1980 and 1981.

Sound and the northern Seward Peninsula where at least 150,000 nest (King and Lensink 1971). If Pintails are 77% of the dabblers but only 34% of those that nest, then less than half of the Pintails seen actually nest in Norton Sound. Teal and Shovelers were relatively common nesters, wigeon were uncommon, and we found only one brood each of Mallards and Gadwalls. Abundance estimates based on nest records are biased, because nests and broods are harder to find for some species than for others; teal and wigeon hide their nests particularly well.

(b) Diving Ducks. Seventeen species of diving ducks comprised only 27% of all ducks (1980 coastal air surveys). Black Scoters and Common Eiders were the most numerous of the divers, each totalling about one-quarter of those seen (Table 13). Greater Scaup and Oldsquaw were also common, and Red-breasted Mergansers were fairly common. Twelve other species made up only 11% of the diving duck populations, and these were either members of small local populations or were vagrants from southern and inland breeding grounds. An exception is the King Eider, which migrates by the hundreds of thousands offshore across the mouth of Norton Sound and through the Bering Strait in early spring and late fall. They were infrequent in the nearshore coastal waters from May through October, except at the Strait.

Divers were common nesters, accounting for 47% of all duck nests or broods seen. This percentage is nearly twice as great as their overall abundance relative to dabbling ducks (shoreline aerial surveys) and is due to the preponderance of non-breeding dabblers.

Greater Scaup were by far the most common of the nesting divers, while Oldsquaw, Common Eiders, and Red-breasted Mergansers were fairly common. Black Scoters, though common in some coastal waters, nest inland and on raised tundra and were rarely found with eggs or young in coastal wetlands. A lone nest and two broods belonging to Redheads illustrate the range expansion capabilities of inland breeding ducks seeking refuge from drought. Redhead breeding in Alaska usually occur only in the eastern interior and they are typically found as breeders in the Canadian prairie provinces (Palmer 1976; Weller 1964).

2. Habitat Use

Dabbling ducks showed a more specialized habitat choice than diving ducks (Figure 30, top scale) and will be treated as a group because of the similarity in habitat preferences of all six species. They are typically birds of wetlands (wet tundra), and we found high densities along the shores of river deltas and lagoon wetlands. Moderately high densities occurred at river mouths, though this actually represents only a few hundred birds in a limited habitat. Moderate densities were seen along exposed coasts

Table 13. **Relative abundance of diving ducks in coastal Norton Sound.**

Species	Percent Total Ducks[1]	Percent Diving Ducks[1]	Percent Nesting Divers[2]	Percent All Nesting Ducks[2]	Number of Nests and Broods[2]
Black Scoter	6.8	25.2	1	< 1	1
Common Eider	6.4	23.5	20	9	17
Greater Scaup	4.6	17.0	40	19	34
Oldsquaw	4.1	15.0	24	11	20
Red-breasted Merganser	2.3	8.5	11	5	9
Surf Scoter	0.8	2.9			
Harlequin Duck	0.6	2.2			
Spectacled Eider	0.6	2.1	1	< 1	1
Steller's Eider	0.4	1.6			
Canvasback	0.4	1.6	1.3		
King Eider	0.2	0.6			
White-winged Scoter	< 0.1	0.1			
Common Merganser	<<0.1	<<0.1			
Redhead	<<0.1	<<0.1	4	2	3
Lesser Scaup	<<0.1	<<0.1			
Common Goldeneye	<<0.1	<<0.1			
Bufflehead	<<0.1	<<0.1			
Total	27.0	100.0	101	47	85

[1] Data from shoreline aerial surveys, 1980; total = 6,017 divers.

[2] Data from nest and brood counts, 1980 and 1981.

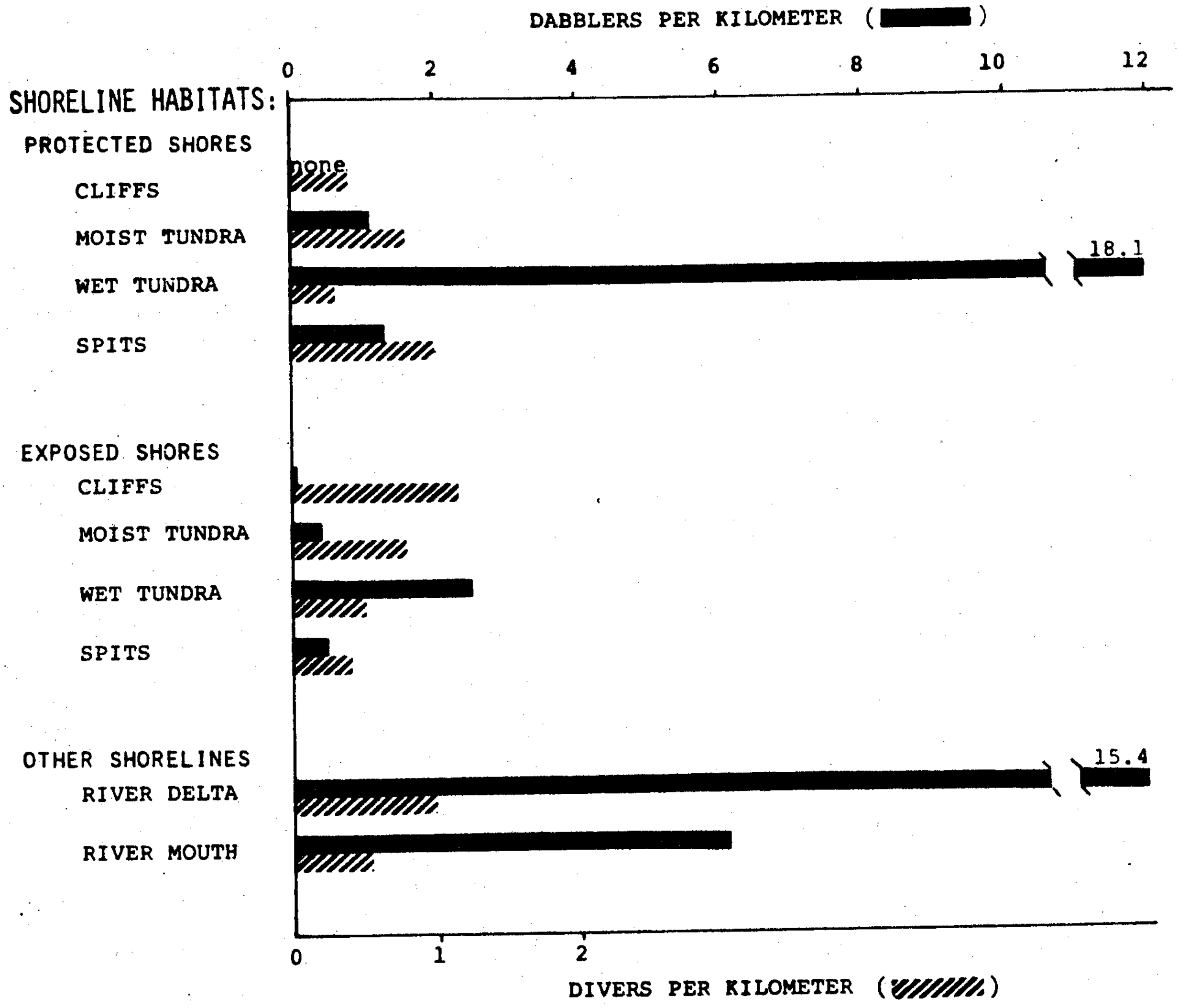

Figure 30. Habitat use by ducks. Data are from 1980 shoreline aerial surveys. Note the difference in scale for dabbler and diver densities. Dabbling ducks are most common along wetland shorelines (river delta and wet tundra shores) and diving ducks are fairly well represented along all shoreline types.

bordering wetlands. Lesser concentrations found in the remaining habitats primarily represent resting flocks of migrant Pintails.

Diving ducks were less specific in habitat selection than dabblers and were in moderately low concentrations throughout all habitats (Figure 30, bottom scale). Eiders and scoters were most common near exposed rocky shores of cliffs and along moist tundra beaches, particularly near rock outcrops (Figure 31), sites that presumably offer the molluscs and other benthos associated with rocky substrates. Oldsquaw were common along spits in protected waters, particularly as spring migrants and during the July molt at Port Clarence and Brevig Lagoon. Greater Scaup resembled dabblers in habitat preference, choosing river delta shores with shallow water and mud substrates to feed in. Mergansers were most concentrated near river mouths; these areas apparently provide a reliable supply of small fish, their major prey.

3. Seasonal Use

Ducks were most abundant in coastal Norton Sound when staging (premigratory flocks gathering to feed) after nesting (Figures 32-34.) They were also common in spring immediately prior to nesting and appeared least commonly during the brood and molt periods of July or August. Their abundance is greatly dependent on nesting phenologies, as discussed later, and will be shown to vary between species, paralleling differences in phenologies.

Molt schedules are an important factor in seasonal abundance. All adult ducks in Alaska shed their wing feathers during the summer and grow new ones for the long trip south, leaving them flightless for several weeks to over a month. This is a highly vulnerable time. Dabblers will remain in coastal wetlands or move inland where they can hide in tall grass. Sea ducks, notably eiders, may move to isolated nearshore sites, such as the rocky headlands near Cape Woolley or Cape Nome, while Oldsquaws may gather in lagoons as at Brevig.

Most males leave their mates shortly after incubation begins to gather with other males in preparation for the molt. They lose much of their bright body plumage, adding to their inconspicuousness, and are thus poorly censused by aerial survey as well as by land counts. Males of some species do not abandon their mates immediately but linger nearby for a week or so. This includes Oldsquaws, Common and Spectacled Eiders, and Shovelers, while all of the other dabblers, along with scaup, mergansers, Redheads, and scoters, depart more hastily (Bellrose 1976).

Hens generally become flightless shortly before their young are able to fly (Johnsgard 1975). This is not true for Common and Spectacled Eiders, which lose their flight feathers when they are with their broods so

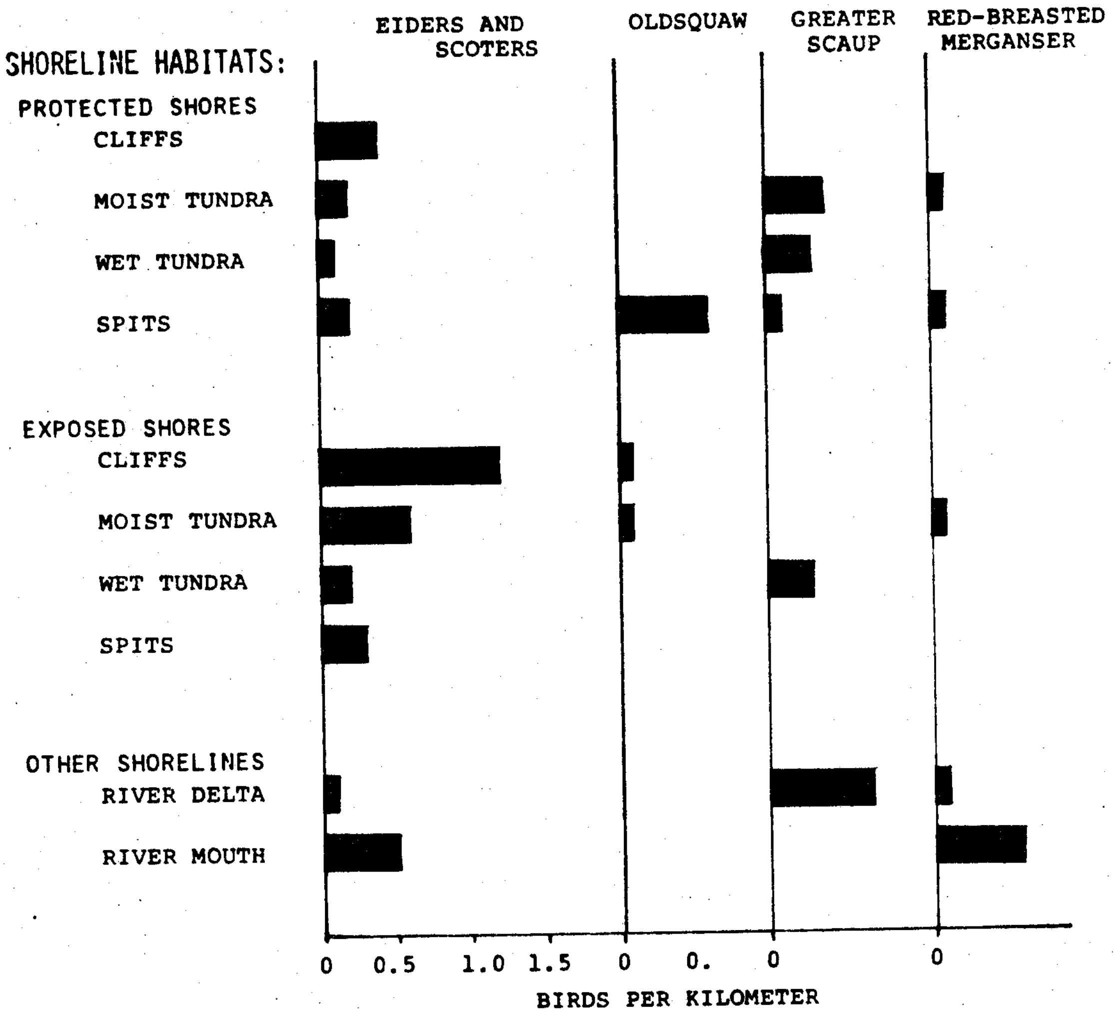

Figure 31. Habitat use by diving ducks. Data are from 1980 shoreline aerial surveys. Eiders and scoters were using rocky shorelines, particularly along cliffs. Oldsquaw were most concentrated along spits in protected (lagoonal) waters once nesting began. Greater Scaup chose wetland shorelines. Red-breasted Mergansers stayed close to river mouths.

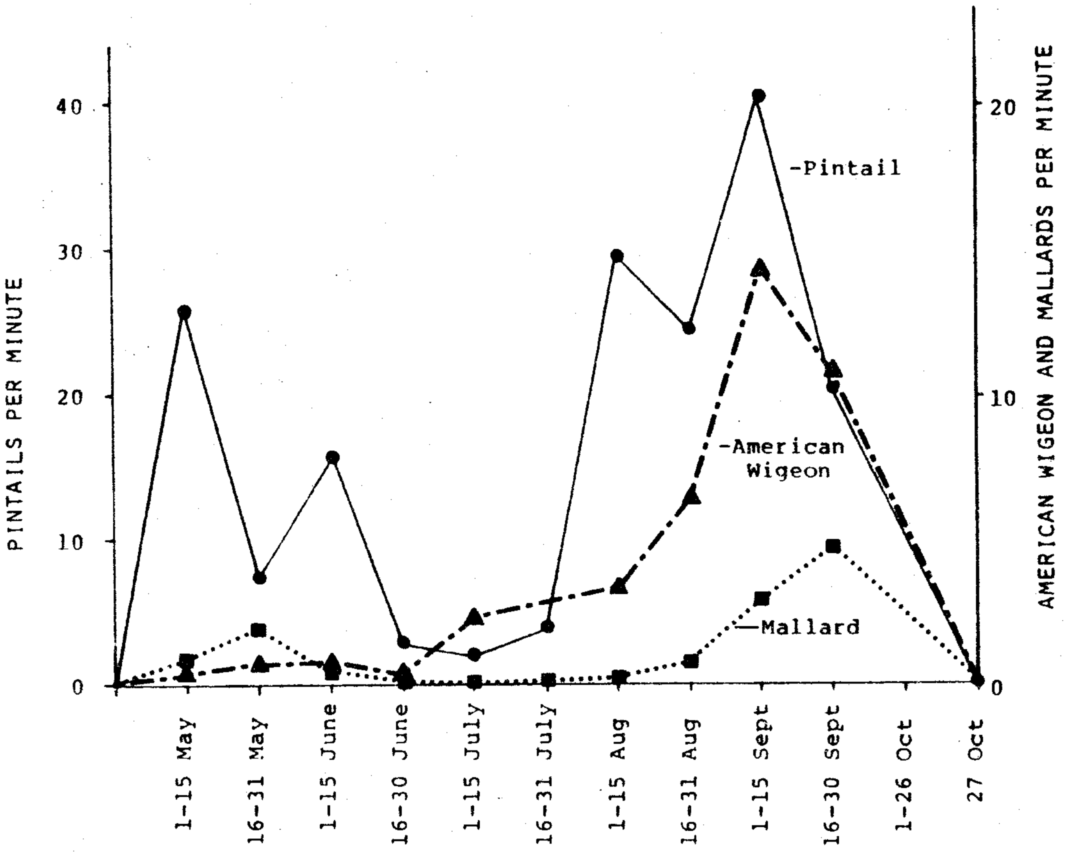

Figure 32. Seasonal abundance of Pintails, American Wigeon, and Mallards. Data are averaged from 1980 and 1981 wetland aerial surveys. Note the different scales. Pintails had peak populations before and after nesting, whereas wigeon and Mallards peaked in September only.

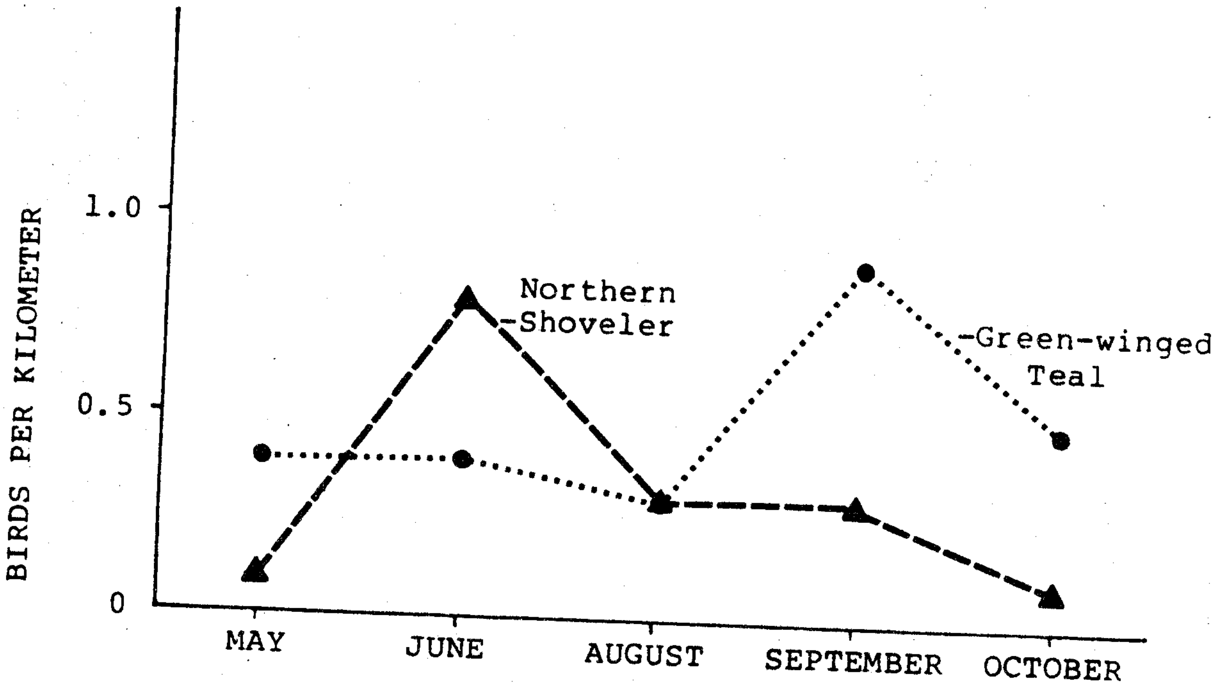

Figure 33. Seasonal abundance of Green-winged Teal and Northern Shovelers. Data are from 1980 land surveys. Teal had a relatively short breeding season and gathered in August prior to flying south. Shovelers peaked in June and apparently did not gather prior to their south migration.

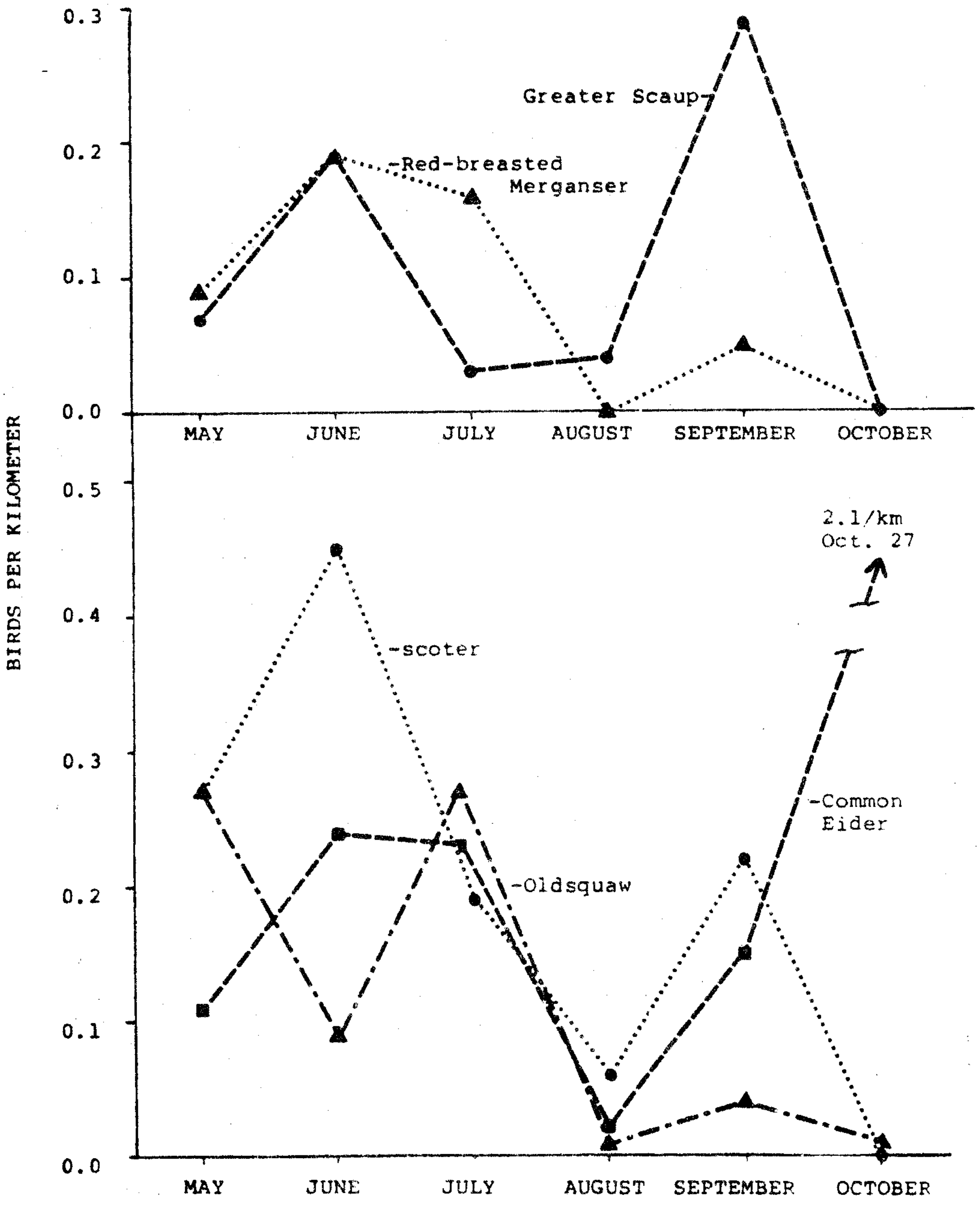

Figure 34. **Seasonal abundance of diving ducks.** Data are from 1980 **shoreline** aerial surveys. Note the general trend of spring and fall peaks with a low during the late July and August molt period. Common Eiders were most abundant in October and there were few other divers (or other ducks) at that time in Norton Sound.

as to gain flight when their young do.

Figures 32, 33, and 34 illustrate the general differences in seasonality between dabblers and divers. Biweekly data are graphed for the less common dabblers, and monthly data are graphed for the three most common species. Overall, dabblers arrived earlier in spring, were inconspicuous in July, and gathered mostly in August and September prior to migration. Divers arrived mostly in June, and were consistent as a group in becoming scarce in August, when molting was most intense. Pre-migratory staging populations peaked in September for all divers.

(a) Dabbling Ducks. Wetland populations of ducks were dominated by Pintails (Figure 32, left ordinate scale). They were the first dabblers to arrive in large numbers as of 7 May in 1980 and 6 May in 1981, when most ponds were frozen and much of the tundra was under snow. The second spring peak of Pintails in early June signaled the onset of incubation, when drakes abandoned their mates and gathered in wetlands. By late June, they had sought cover for molting and were not again obvious until late July and early August. By then, young were beginning to fledge, and in September the Pintail population was at its greatest. The initial August peak represents drakes that gathered prior to heading south, while the large September peak was mostly hens and their young. Non-breeders may have been a substantial component of both peaks. Pintail numbers dropped drastically by the second half of September, when they were still the most common duck. None were seen on an October 27, 1980 survey, and a late date for departure from western Alaska is given as 9 October at Nunivak Island (Gabrielson and Lincoln 1959).

American Wigeon were uncommon nesters in Norton Sound and became common in late summer as they gathered from northern and inland areas (Figure 31). They arrived early, coming with Pintails by the end of the first week in May in both years. They increaseed in the second half of September and were mostly gone by the end of the month (1980). A minor peak in July probably represents pre-molting males and non-breeders gathering from areas outside of Norton Sound. In Alaska, their densest nesting concentrations are inland, with densities only one-third as great on coastal tundra, notably on the Y-K Delta and around Kotzebue Sound (King and Lensink 1971).

Mallards were also common nesters in our study area, with a spring migration peak in late May and a fall peak coinciding with the abundance of wigeon (Figure 32). As with wigeon, most Mallards came to Norton Sound to stage following a breeding effort elsewhere, mostly inland as well as on the Y-K Delta (King and Lensink 1971).

Figure 33 depicts seasonal abundance for shovelers and Green-winged Teal derived from ground surveys; these two species, particularly teal, were easily overlooked from the air. Teal were fairly common nesters in May and June and were most common in August, when young were fledged and molt was finished for many adults. They were not common in spring until the second half of May, and became scarce by mid-September, managing to complete nesting relatively quickly.

Shovelers were also fairly common during the nesting months. Some arrived at the end of the first week in May with the first Pintail flocks, and they were mostly departed by mid-September. They were unique in not showing a post-breeding peak that would normally indicate pre-migratory staging. This might be explained by an egress of males to molt elsewhere, or a quick departure of broods after fledging.

(b) Divers. Scoters, mostly Black Scoters, typified the seasonality of divers, peaking in spring during migration, becoming scarce in August during their molt, and amassing again in September prior to their trip south (Figure 34). Unlike dabblers, scoters were not common in low wetlands. Those nesting around Norton Sound do so adjacent to inland rivers where shrubby alder and willows are common, though open tundra nesting may be frequent elsewhere, as on the Y-K Delta where over 100,000 nest (Bellrose 1976). After incubation began, small flocks of males were common along rocky headlands, except in August during their molt. They probably gather farther offshore at this time, as Drury (1980) observed molting Surf Scoters north of the Y-K Delta, while 7 to 28 thousand molting scoters have been seen from mid-July through August west of the Y-K Delta from Cape Romanzof to Cape Avinof (Dau, in prep.).

Common Eiders exhibit a seasonal pattern similar to that of scoters, except for an October peak long after most other ducks have gone south. On 27 October 1980, there were at least 760 female plumaged eiders, mostly Common, from Nome to Koyuk in flocks of 40 to 100 and one of 250. Common Eiders winter as far north as the Bering Strait if ice permits (King and Dau 1981).

We saw King Eiders infrequently; yet they are an abundant migrant offshore in late April and early to mid-May, particularly near the Bering Strait. Peak passage at Dall Point, south of Norton Sound, has occurred from 11 to 15 May (Conover 1926, Murie in Gabrielson and Lincoln 1959), while peak migration at Wales has been observed on about 21 April (Flock and Hubbard 1979) and in early May (Bailey 1948). An inshore passage was noted from 10 April to 1 May at Sinuk about 40 km west of Nome (Hill 1923). Most winter south of the Bering Sea ice edge (Gill et al. 1979), while some may winter in ice-free polynyas south of Nunivak Island (Dau, in prep.) or south of other Bering Sea islands. They have been known to appear in offshore leads at Wales by mid-March (Bailey 1943). Fall migrants have passed through the Bering Strait as early as 11 July (Bailey 1943), though these were on the Siberian shore. Males were noticeably absent in late September at Nunivak Island (Dau in Gill et al. 1979); they may come south later or migrate much farther west, possibly along the Siberian coast.

Spectacled Eiders nest mostly on the Y-K Delta and in the American and Siberian arctic (Dau and Kistchinski 1977) but apparently use Norton Sound to a limited extent for molting and have been seen in molt 40 km west of Stuart Island on 15 September, 100 years ago (Nelson 1883). Woodby noted 420 Spectacled Eiders in mottled plumage 24 km east of Cape Darby on 11 September 1977. We also found 500 to 1,000 mottled male plumaged birds along the south shore of St. Lawrence Island on 18 September 1980. The location of molting females with young is uncertain; they may occur with males in flocks far offshore (Dau and Kistchinski 1977).

Oldsquaw were early migrants. Many follow the King Eiders north to the arctic (Woodby and Divoky, in prep.), while some remain to nest in western Alaska. The June low (Figure 34) represents their move to tundra nest sites, while the July peak indicates male flocks in near shore waters, principally along spits at Brevig Lagoon and along rocky headlands, readying for their molt.

The seasonal patterns of scaup and mergansers mimic the scoter pattern closely. More frequent sampling would probably have shown a lag in merganser schedules, as they were relatively late nesters.

4. Geographic Distribution

Ducks are unevenly distributed throughout Norton Sound, and this is due to the uneven distribution of productive habitats and to the concentrating effect of migration routes. Patterns of distribution will be presented first in terms of duck densities, and then on the basis of population estimates.

Most ducks, and particularly dabblers, concentrate in wetlands, and their average densities in 14 wetland areas is shown in Figure 35. This graph shows that densities vary greatly between wetland areas and from year to year at certain sites. These figures are strongly biased towards the post-breeding season, especially September censuses of each year.

Wetlands of the Fish River (Golovin Lagoon), Moses Point, Koyuk, Stuart Island, and Stebbins had the highest densities of ducks. Port Clarence, the Woolley Lagoon to Sinuk area, and Unalakleet wetlands had low densities. The Shismaref coast was censused only once, on 16 August 1980, and its low density may be unrealistic.

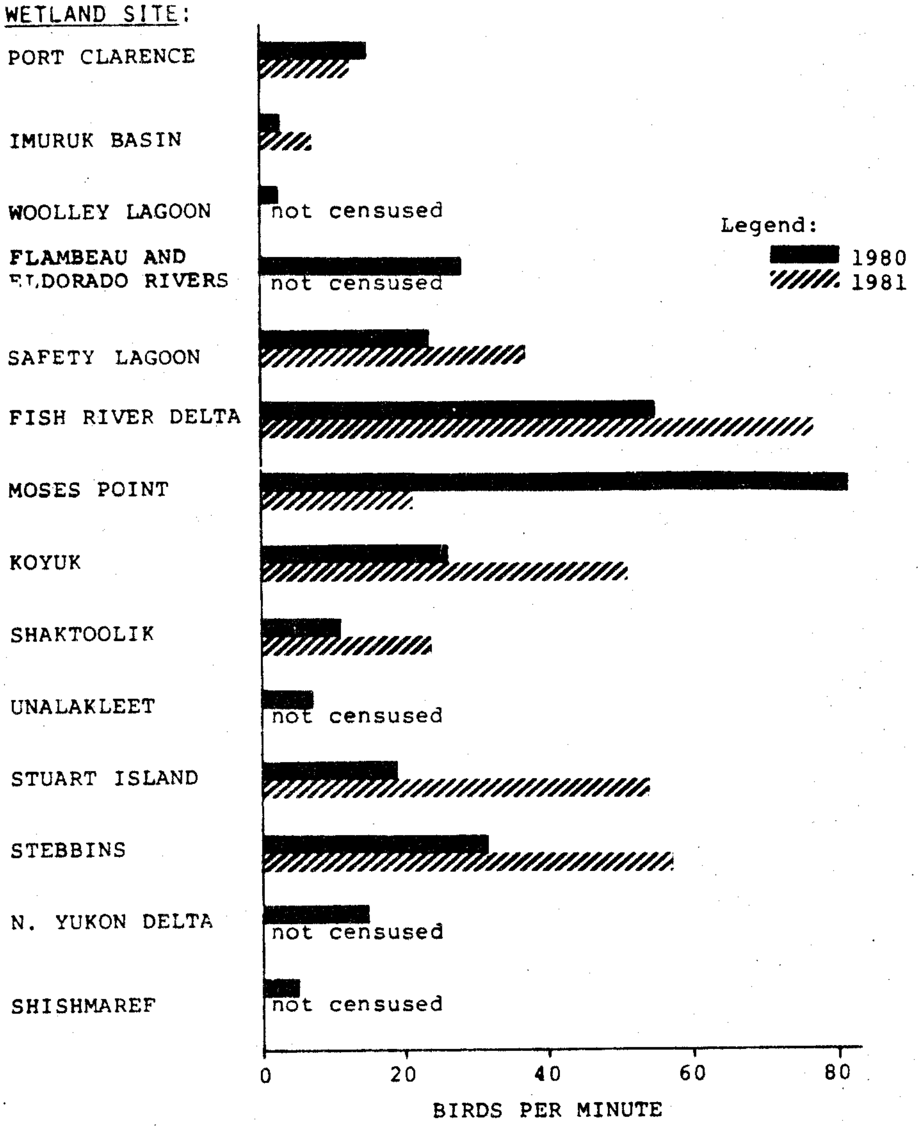

Figure 35. Geographic distribution of ducks. Data are from 1980 and 1981 wetland aerial surveys. Highest densities are in the northeast Sound. Densities varied greatly between the two years for most wetlands.

1981 densities were considerably higher than 1980 densities at the Fish River, Koyuk, Shaktoolik, Stuart Island, and Stebbins wetlands. A dramatic drop was found at Moses Point from the first year to the second.

Diving ducks are noticeably more prevalent along the coast than on wetlands; their density distribution across 15 coastal sections is shown in Figure 36. This graph shows that diving duck distributions are fairly homogeneous along the Sound from year to year, but that exceptionally high local concentrations may occur. The 1980 peak in the Nome to Cape Nome (No. 6) section represents only a few hundred birds, mostly eiders and scoters, gathered off the rocks of Cape Nome. The highest density of 15.1 birds/km in 1981 is due to a single observation of over 1,000 scaup in Golovin Lagoon on 10 September. Scaup concentrations are probably a regular phenomenon there, since 1,530 were seen in the same area on 10 September 1980.

Actual populations of ducks in each wetland area vary greatly, depending on size of the wetlands and densities of birds in each. We estimated these by extrapolating our highest densities in each wetland, using our wetland aerial surveys from 1980 and 1981 and a ground-based mapping of productive habitat (Table 14). Our results should be used with caution; they are subject to error, and they are only estimates of maximum populations on our census dates. Our counts were probably low, as uncorrected duck surveys often are, and larger populations may have occurred on days we did not census (see "Methods").

Stebbins, Moses Point, and Fish River wetlands clearly had more ducks on peak census dates than did the other areas, each holding about 10,000 or more. These all occurred in the first half of September near the end of staging. Koyuk also had a large count with slightly over 5,000.

Shaktoolik wetlands had only moderately low densities and a projected total of over 2,000 ducks, principally due to its large area. The same is true of the Imuruk Basin with nearly 3,000. Safety Sound, the Flambeau/Eldorado area, and Stuart Island held somewhat lower populations. Extremely low totals for Port Clarence, the area from Cape Woolley to Sinuk, and the Unalakleet Delta are all probably not realistic. Higher populations probably occurred for short periods during migration, although these three areas appear to be less important for ducks.

Routes chosen by migrant dabblers may be similar to those used by geese. When northbound, many come on inland routes over the upper Yukon Valley, and this is especially true for prairie drought populations. Others may move coastally from the Y-K Delta, and most scoters, Oldsquaws, and eiders reach Norton Sound via a coastal route. Most Greater Scaup in Alaska winter on the Atlantic coast and migrate across Alaska's interior (Bellrose 1976).

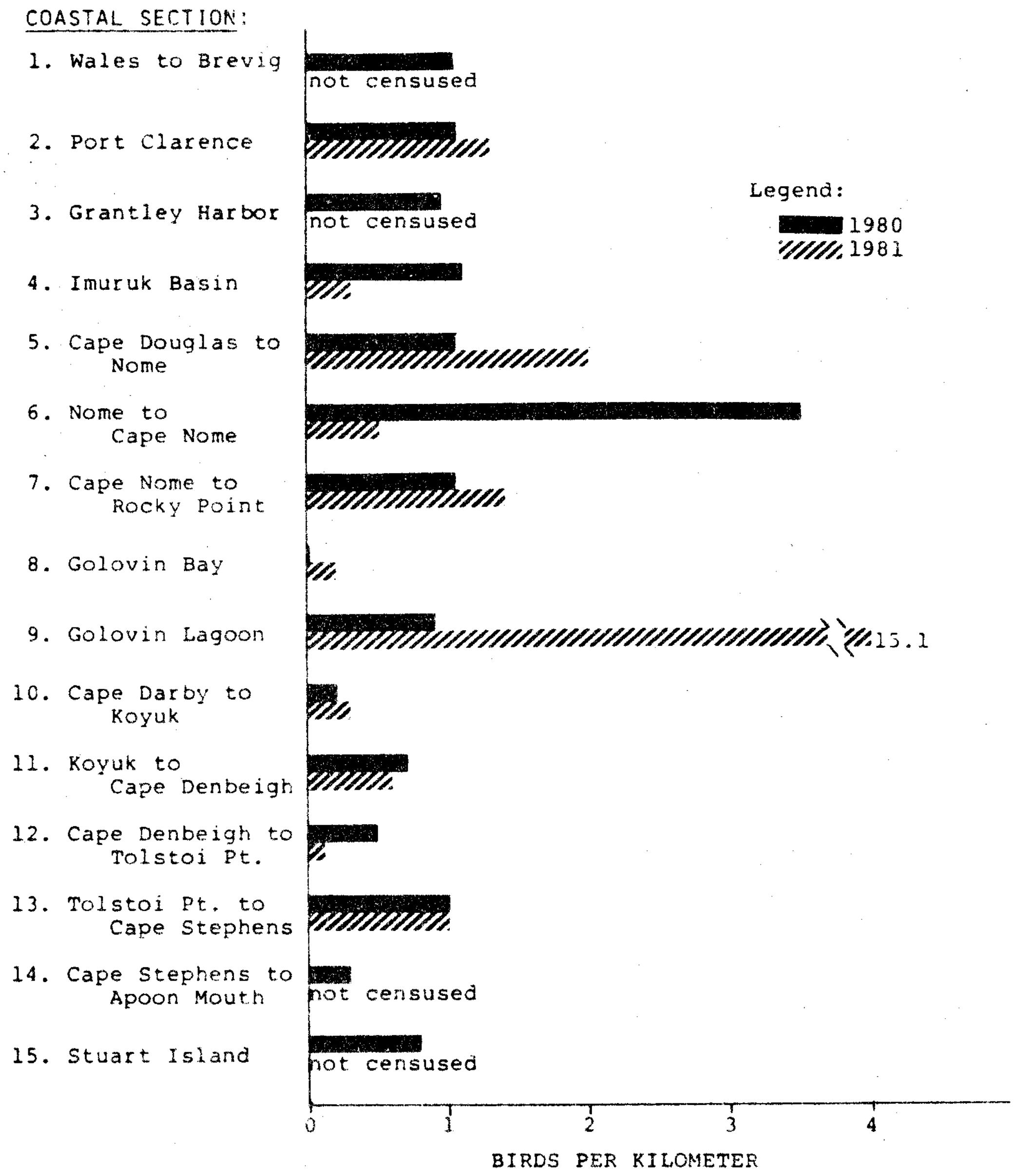

Figure 36. Geographic distribution of diving ducks. Data are from 1980 and 1981 shoreline aerial surveys. Densities are fairly regular across all coastal sections with locally high densities in some areas that are usually due to short lived concentrations. The peak at Golovin in 1981 is due to a large flock of scaup in early September.

Table 14. Maximum projected duck populations at 12 wetlands in Norton Sound.

Area	Mo/Dy/Yr	Ducks/ Minute	Km^2	Projected Population
Port Clarence	9/5/81	9.4	13.4	206[2]
Imuruk Basin	8/16/80	29.5	116.5	2,895
Cape Woolley to Sinuk	9/17/80	5.4	29.8	136[2]
Eldorado and Flambeau Rivers	8/23/80	83.7	20.2	1,424
Safety Lagoon	9/23/80	77.0	37.3	2,420
Fish River Delta	9/10/80	300.7	38.5	9,753
Moses Point	9/3/80	283.4	49.9	11,913
Koyuk	9/23/80	98.5	61.4	5,095
Shaktoolik	9/23/80	50.8	51.3	2,194
Unalakleet	9/6/80	26.6	14.6	92[2]
Stuart Island	9/10/81	73.5	22.0	1,362
Stebbins	9/10/81	60.4	169.8	13,482

[1] Based on a flight speed of 177 km/hr and a 400 m observation path for each observer; see "Methods."

[2] These low counts are surely not indicative of actual maximum levels.

Many of the Pintails concentrating in Norton Sound's northeastern wetlands in late summer may come south from Kotzebue Sound, where they are abundant nesters (Bellrose 1976). Cross-peninsula routes are probably similar to those of Canada Geese. Emigration routes away from these wetlands probably go inland, while Pintails near Stebbins are likely to head southwest and join the coastal migrants of the Y-K Delta.

5. Nesting Phenologies

Most female ducks commit nearly one-quarter of each year to nesting and raising a brood. One week or longer is needed to complete an average clutch of seven to eight eggs, laying one each day. These are incubated for three to four weeks, and the hatched brood is guarded for up to two months. Fledging periods for ducklings in Alaska are typically 80 to 90 percent those of ducklings in temperate zones. This is due to increased daylight; broods are able to feed for a larger time in a 24-hour period and can thus grow relatively quickly, reaching flight stage sooner than fledglings in temperate zones. This makes arctic areas attractive places for ducks to nest.

Figure 37 illustrates nesting chronologies for dabblers and divers as derived from 179 observations of nests (n = 130) or broods (n = 49) in 1980 and 1981 (Table 15). In both years ice breakup and snowmelt on the tundra was one to two weeks earlier and this allowed early nesting. The range in dates for laying, hatching, and fledging results from: (1) individual variation within a species, (2) differences between species, and (3) latitudinal differences, with northern and western phenologies averaging later than those from the inner sound.

Dabblers began nesting earlier than did divers, and were laying eggs over a longer period. In both years, the earliest nesting dabblers were Pintails, starting in mid-May, two to three weeks earlier than the first nesting Oldsquaw, the earliest divers. The bulk of dabblers began laying eggs in early June. Thus, in 1980, the average date of clutch completion was roughly the same for divers as it was for dabblers, though divers were about nine days later than dabblers in 1981.

Most divers take longer than dabblers to complete their nesting period, thereby extending the duck nesting season. Their eggs require a few more days of incubation than do most dabbler eggs, and their young need a week or more longer than dabblers to attain flight. Combining this protraction with a later start, as in 1981, results in a nesting commitment lasting two weeks beyond that of dabblers. Thus, ducks were engaged in the nesting cycle from mid-May, when the first dabbler egg were laid, until mid-September when the last divers fledged.

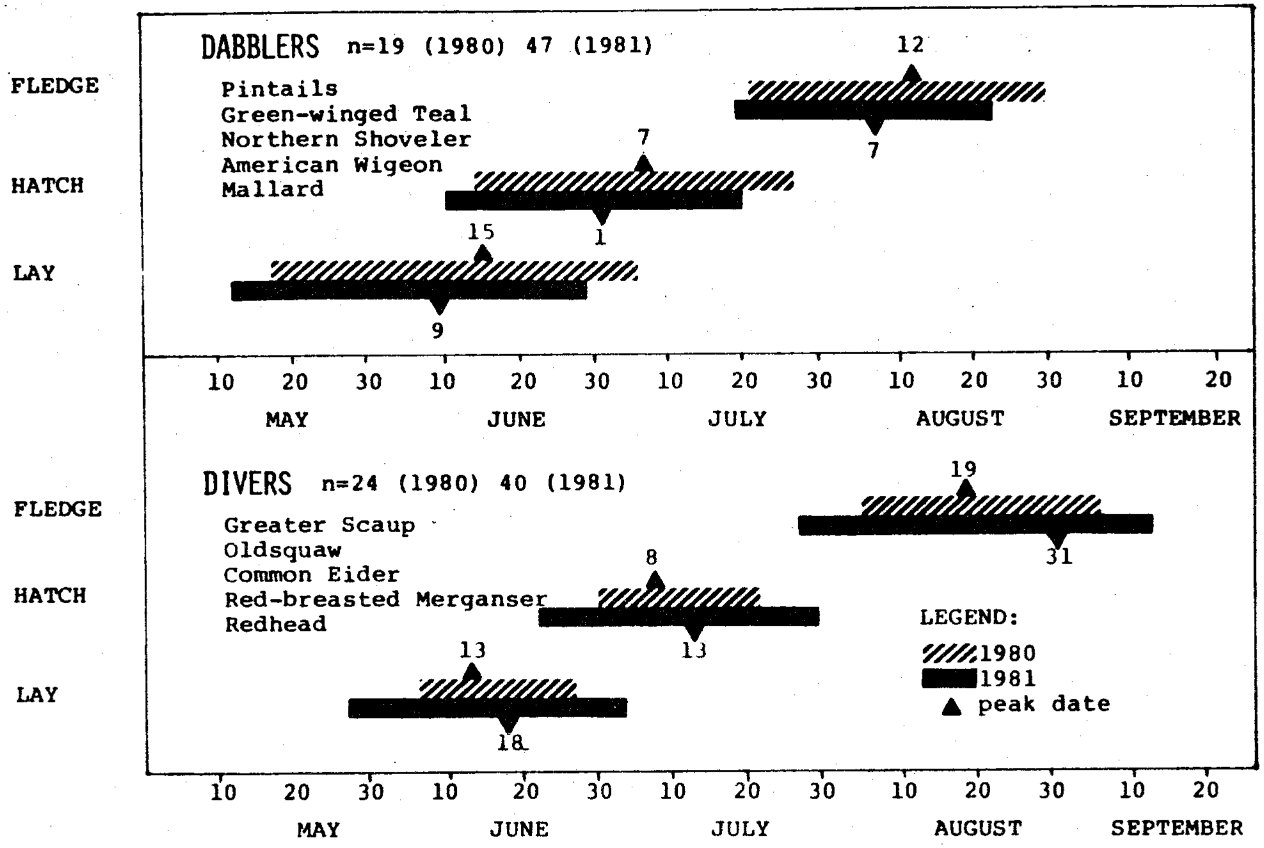

Figure 37. Nesting phenologies of ducks. Dabblers nested earlier than divers and their young usually fledged earlier. Compared to 1980, 1981 was an earlier year for dabbling ducks and a later year for diving ducks (mean dates).

Table 15. Nesting phenologies of eleven duck species in Norton Sound, 1980 and 1981.

	Hatching Dates (Mo/Day)									
	1980				1981				Incubation	Fledging
Species	Early	Late	Mean	(n)	Early	Late	Mean	(n)	Period[1]	Period[1]
Pintail	6/14	7/15	7/4	(5)	6/10	7/18	7/4	(15)	22-23d	36-43d
A. Wigeon					6/19	7/13	7/3	(3)	23-25	37-44
N. Shoveler	6/30	7/19	7/5	(4)	6/14	7/17	6/25	(16)	23-25	36-39
G.-w. Teal	6/17	7/27	7/9	(10)	6/15	7/20	7/5	(13)	21-23	34
Redhead	6/30	7/10	7/8	(3)					24-28	56-73
Greater Scaup	7/6	7/22	7/13	(7)	7/4	7/29	7/18	(23)	23-28	45-47[2]
Common Eider					6/30	7/18	7/4	(11)	26	56
Spectacled Eider			7/2	(1)					24	50
Oldsquaw	7/1	7/15	7/5	(11)	6/22	7/18	7/2	(4)	26	35-40[3]
Black Scoter							7/16	(1)	27-28	42-49
Red-breasted Merganser	7/11	7/14	7/13	(2)			7/25	(1)	30	<65?

[1] Bellrose, 1976, except where noted. Fledging periods are possibly shorter for most species. Periods given are generally from more southern areas, whereas northern ducklings grow faster with more daylight feeding hours.

[2] Fledging period of lesser scaup.

[3] Alison, 1975.

6. Prairie Drought Populations

Droughts in high density duck nesting areas of the northern prairies encourage many ducks that otherwise nest in those regions to continue their north migration. This results in an influx to the arctic and subarctic (Hansen and McKnight 1964). Noteworthy refugee populations of Pintails have been found in Alaska's interior (Smith 1970), in Siberia (Henny 1973), and on the arctic coastal plain where R. King (in Derksen and Eldridge 1980) found seven-fold differences in Pintail numbers between a prairie drought year (1977) and the following wet year. Other species known to show this response are Blue-winged Teal, Shovelers, Mallards, Redheads, Canvasbacks, Ruddy Ducks, and Ring-necked Ducks (Hansen and McKnight 1964).

Both 1980 and 1981 were drought years in the prairies (as were 1973 and 1977), and this resulted in emigration to northern breeding grounds (USFWS and CWS 1981). That these refugees reached Norton Sound is supported by our numerous observations of Canvasbacks (Table 16) and Redheads (Table 17) which are normally quite rare there (Kessel and Gibson 1978). Even though our surveys were less extensive in 1981 than in 1980, total numbers and frequency of sightings of Canvasbacks were greater in the second year, suggesting a compounding effect of the continued drought. Redheads were also more common in 1981.

Unusual Pintail immigrations are less obvious, as these birds are normally common in Norton Sound. Our prime evidence for a large refugee population is their low productivity. This may approach zero for refugees in northern areas (Derksen and Eldridge 1980). We found a noticeably low proportion of Pintail nests and broods relative to those of other ducks (12% in 1980, 22% in 1981) compared to their high proportion in the June duck populations (76% in 1980 and 80% in 1981). The same is true when comparing the proportion of Pintail nest or brood records in the dabbler totals (26% in 1980, 38% in 1981). A crude estimate would then place the non-breeding Pintail population at three-quarters of all Pintails present.

Hansen and McKnight (1964) postulate that refugee ducks are the later migrants to the prairies which move north to find unoccupied suitable habitat. Many of these may be young and inexperienced breeders, and this would partly explain their low production in the north.

The importance of this emigration from the prairies may be great. These overflights may reduce excessive competition on the prairies during poor years, and they probably enhance survivorship in the summer as well as the physical conditions of winter birds (Calverley and Boag 1977). Once precipitation brings the prairie habitat back to normal, the surplus of ducks that spent the previous summer in the north can then reoccupy the prairies (Smith 1970). Prairie droughts are not unusual, as there have been four

Table 16. Canvasback sightings in Norton Sound, 1980 and 1981.

Location	1980		1981	
	Number	Mo/Day	Number	Mo/Day
Imuruk Basin	21	5/26	17	6/3
Nome			10	6/3
Safety Lagoon	40	6/13	6	5/23
			4	6/3
			14	6/23
Golovin Lagoon	20	5/8	3	5/18
			1	6/3
			5	6/6-8
			1	6/22
Moses Point			2	5/18
			2	6/8
Koyuk	2	5/31	2	5/6
	1	6/9	6	5/18
			18	5/26-27
Shaktoolik			2	6/8
Stebbins	3	6/21	2	5/6
			11	6/9-14
			9	8/29
Total	87		115	
Frequency		6		18

Table 17. Redhead sightings in Norton Sound, 1980 and 1981.

Location	1980 Number	1980 Mo/Day	1981 Number	1981 Mo/Day
Brevig Lagoon	4	7/7		
Imuruk Basin			4	6/3
Port Clarence	2	5/30		
Safety Sound	8	6/29		
Golovin Lagoon			2	6/3
			7	9/10
Moses Point	1	6/16	2	5/18
	10[1]	7/17		
Koyuk	2[2]	6/9	2	5/18
			11	5/26
Stebbins	24	6/21	19	6/9
	10[1]	7/18	1	8/29
			12	9/10
Total	61		60	
Frequency		8		9

[1] Hen with 9 chicks for both sightings.

[2] Nest with 7 eggs.

drought years from 1969 to 1981 (USFWS and CWS 1981). This points to the importance of northern wetlands as reservoirs for the surplus populations.

G. Sandhill Cranes

Sandhill Cranes are uncommon breeders in wetlands of Norton Sound. They nest from northeastern Siberia throughout most of Alaska and in northern Canada. During both spring and fall large flocks of cranes pass through Norton Sound, using wetlands as staging and feeding areas. Many are headed for Siberian breeding grounds.

1. Habitat Use

Cranes were primarily found in wetlands, and were concentrated near river delta shorelines and near protected and exposed shores with wet tundra, as censused by air (Figure 38). The highest density was found along protected shores with moist tundra, though this is almost entirely due to 1,300 cranes found on one flight in the Imuruk Basin on 5 September 1981. High densities along river mouths was due to a little over 100 birds in the limited habitat.

2. Seasonal Use

(a) Spring Migration, May. The Norton Sound coastal areas experience two population peaks of Sandhill Cranes, a small one during spring migration and a much larger peak during the fall migration (Figure 39). Snowmelt and ice break-up were relatively early in both 1980 and 1981, and led to an early migration of cranes in spring and fall of both years. Flocks of cranes were already flying past Nome when we arrived in 1980 on 5 May. The bulk of the migration appeared to pass through from 5 to 10 May. A few stragglers were seen as late as 26 May. Flock and Hubbard (1979) reported similar dates from Wales with the major crane migration occurring from 5 to 15 May 1978 and on 10 May 1970. In 1980 we did not fly aerial wetland surveys until 31 May, so Figure 39 does not show 1980 spring migration densities.

In 1981 our first shoreline aerial survey was on 1 May (from Nome to Koyuk) and no cranes were seen. On 4 May several flocks of up to 180 birds were seen heading west between Nome and Golovin and migration continued until 12 May. On 18 May, however, there were still over 300 birds on wet tundra at Koyuk and small flocks elsewhere. Peyton and Shields (1979) report that the crane migration peaked on 19 May 1977 on the wet tundra at the Inglutalik delta (near Koyuk) with 2,800 birds per day.

We have no total estimates for the spring crane migration, but Shields and Peyton (1979) estimated that 6,000 cranes used the Inglutalik delta (near Koyuk) in May 1977. On 23 May 1964 two observers (Breckenridge and Cline 1967) witnessed an estimated 15,000 to 20,000 Sandhill Cranes

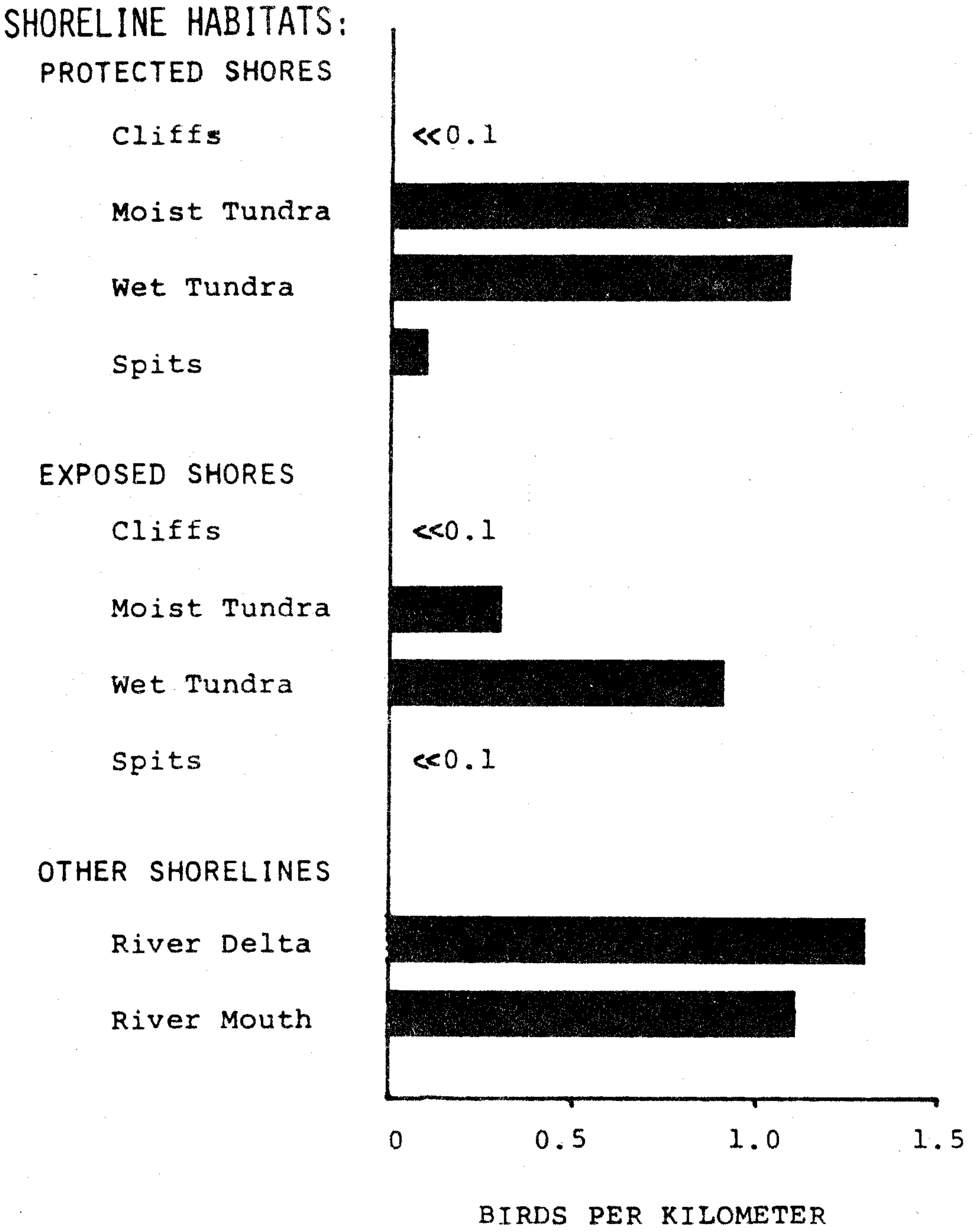

Figure 38. Habitat use by cranes. Data are from 1980 and 1981 shoreline aerial surveys. Cranes were most concentrated along wetland shorelines (river delta and wet tundra shores) and on moist tundra along protected shorelines. In this latter habitat cranes feed on berries, especially in late August and September. The high density at river mouths represents a little over 100 cranes in a limited habitat.

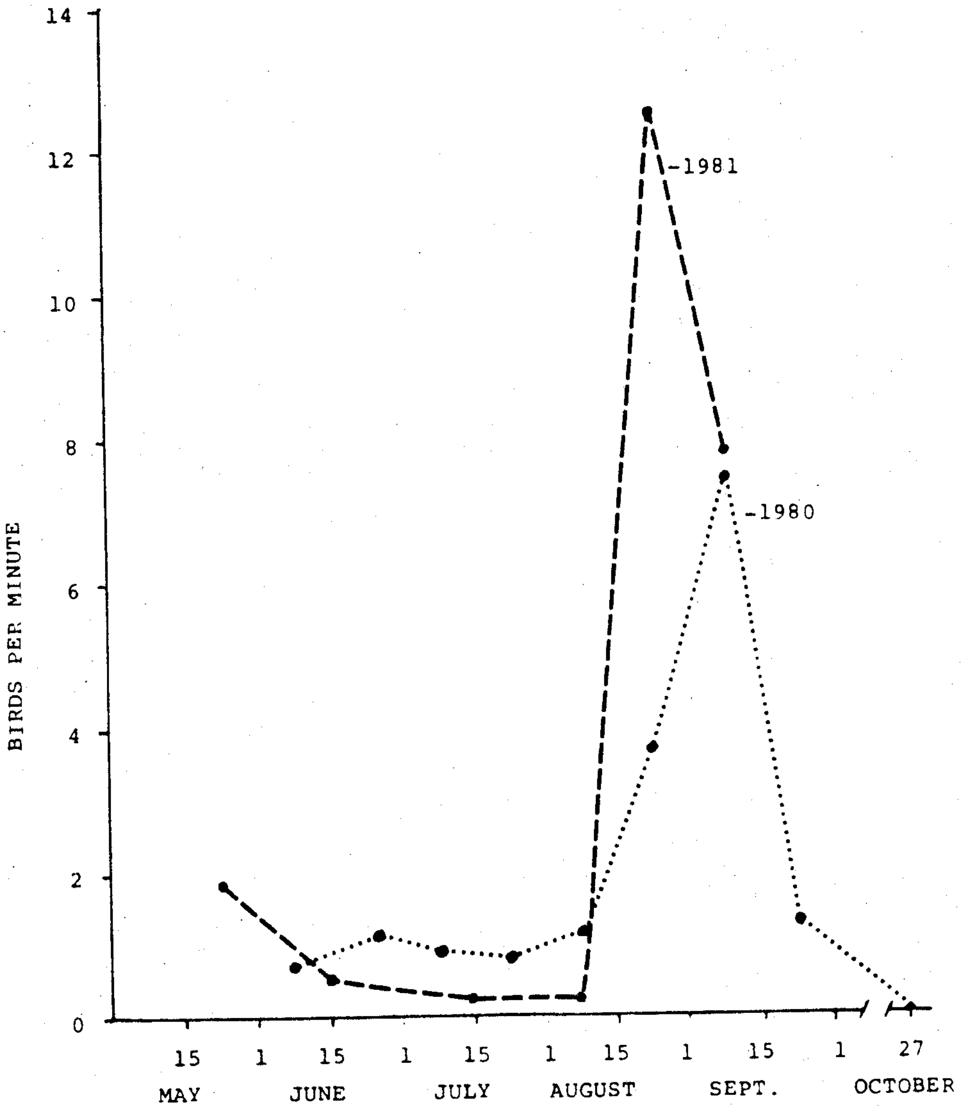

Figure 39. Seasonal abundance of cranes. Data are from 1980 and 1981 wetland aerial surveys. Peak crane populations occur in late summer in Norton Sound. The 1981 peak came later than in 1980, although this lag may be an artifact of sampling dates in the second year. In spring the cranes passed through the Sound in early May before the wetlands were free of ice and snow, and before we had flown wetland surveys.

heading across the Bering Strait from Wales. In 1964 spring was very late, and several days of bad weather apparently held up and consolidated the migration. Most of these cranes passed through Norton Sound en route to Wales, and given such conditions the number of cranes present in Norton Sound could be large.

(b) Breeding, June-August. Breeding densities were far below those of migration. Only three nests were located each year. We have conservatively estimated the breeding population of the 13 major wetlands as 200 pairs. The entire breeding population of Norton Sound coastal areas is probably much higher. Koyuk and Stebbins had the largest number of breeders, 40 to 50 apiece. The Fish River delta and Safety Lagoon had breeding populations of 20 to 30 cranes.

(c) Fall Migration, Late August-September. Large flocks of several hundred to more than one thousand cranes congregated on some of the Norton Sound wetlands during the peak of fall migration. Fall crane migration in 1980 and 1981 was considerably earlier than in 1975, when it peaked on 19 September (4,500 to 5,000 cranes (Drury 1976)). In 1980 it peaked around 6 September, while the 1981 peak was about 31 August. We did not census past 12 September in 1981. Migrating cranes were still abundant, and many undoubtedly moved through the area after this date. Higher fall densities in 1981 were probably due to sampling at peak passage rather than reflecting an increase in population from 1980.

Peyton and Shields (1979) noted on the Akulik-Inglutalik Delta that the highest densities of cranes occurred in the evenings. Large numbers of cranes left the delta early in the morning, suggesting that most birds remained only one day. They observed about 16,000 cranes moving through the delta on 16 September 1977, the peak of migration. Drury (1976) counted about 10,000 cranes passing the Bluff colonies the first three weeks of September 1975. Numerous other flocks were heard, but not counted. He estimates that they probably saw only 20 to 30 percent of the small flocks of cranes that flew by. Surprisingly, we saw little coastal migration of cranes.

3. Geographic Distribution

Sandhill Cranes were present in all of the major wetlands (no data for Unalakleet, which was not censused during crane migration), but some areas were obviously more important than others (Figures 40 and 41), particularly for feeding and stopover during migration. May densities in 1980 are low, since the areas were not censused until after the crane migration. May data for 1981 show that Koyuk was a major stopping point for migrating cranes in the spring. We saw many flocks of cranes flying over Golovin, heading toward the Fish River delta, from 5 to 12 May 1981. It is unlikely

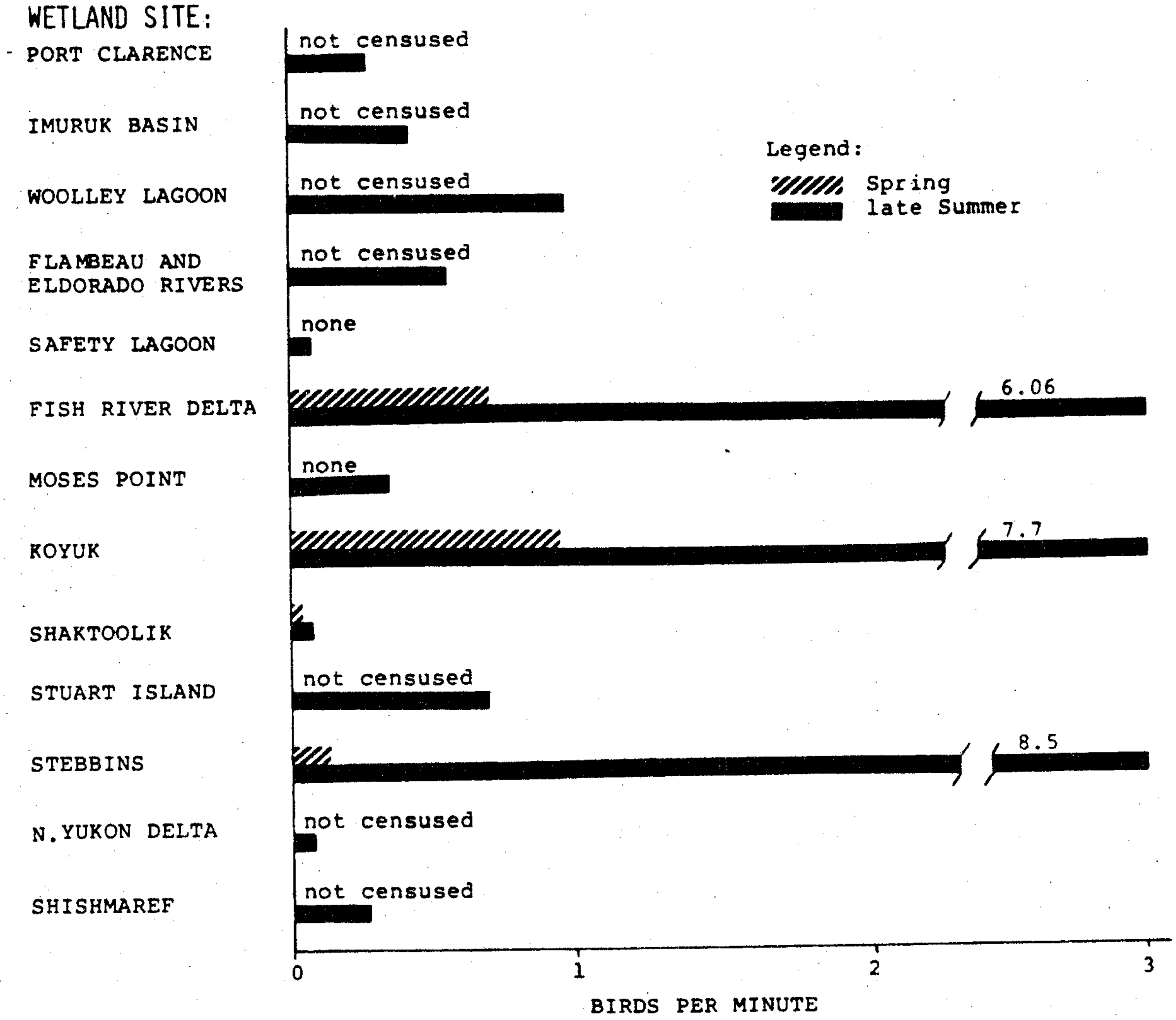

Figure 40. Geographic distribution of cranes in spring (May) and late summer (late August to mid-September), 1980. Data are from wetland aerial surveys. Spring migration was mostly uncensused; late summer concentrations were at the Fish River Delta, Koyuk, and Stebbins. Compare to Figure 41 (1981 data) below.

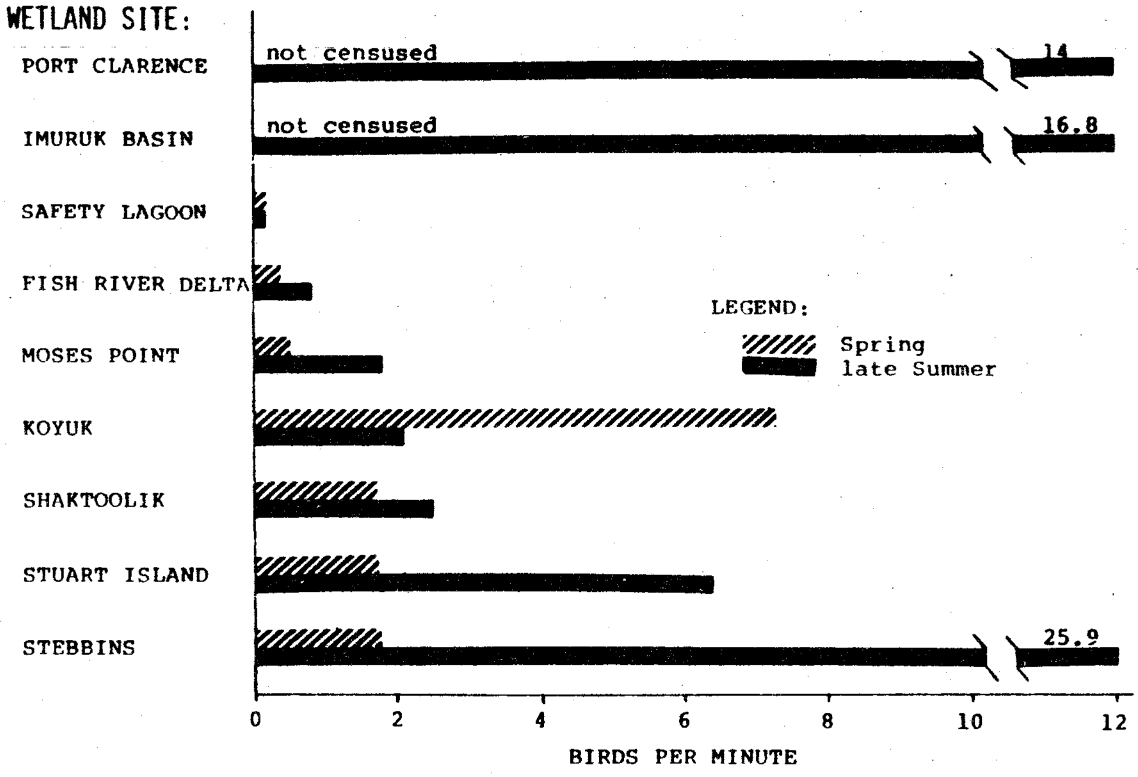

Figure 41. Geographic distribution of cranes in spring (May) and late summer (late August to mid-September), 1981. Data are from wetland aerial surveys. Koyuk was the major spring concentration point, and Stebbins was a major stopover in late summer (as in 1980, see Figure 40). Note the heavy use of Port Clarence and the Imuruk Basin wetlands and the low use of the Fish River Delta and the Koyuk area in late summer relative to 1980.

that many stopped, since break-up there was so late (15 May 1981). We suspect that they bypassed the delta for Safety Lagoon or Imuruk Basin. It is apparent that many cranes take a coastal route between Koyuk and Wales in spring (Figure 42), and overland routes to Kotzebue Sound and the Imuruk Basin are possible.

Shaktoolik (Malikfik Bay) also had fairly high densities on 6 May 1981. Imuruk Basin and the Port Clarence "Bicep" were not censused in May in either 1980 or 1981. They have high fall migration densities (see below), and may be important stopover points during spring migration.

The highest densities during fall migration occurred at Stebbins in both 1980 and 1981. Koyuk had high fall densities in 1980, though 1981 densities were relatively low. It is possible that the bulk of the cranes moved past the Koyuk delta between our census on 28 August and the next census on 10 September 1981. Several other areas — Imuruk Basin, Port Clarence, the Fish River Delta, and Shaktoolik — had quite different fall migration densities for 1980 and 1981. We may have missed major movements of cranes through these wetlands. It is also possible, however, the use of some of these areas is quite variable. Maximum projected populations for each of the wetland areas are given in Table 18 (see Chapter V for an explanation of how these figures were derived). Highest populations are projected for Stebbins and for the Imuruk Basin.

Fall migration routes are similar to those in spring and the overland route southeast from Imuruk Basin towards the Fish River Delta or Koyuk is likely, considering the high fall numbers at the Imuruk Basin.

In summary, the most important areas for cranes in Norton Sound were the Koyuk wetlands in spring and the Stebbins and Imuruk Basin wetlands in fall. The Fish River Delta and the Port Clarence "Bicep" were also important stopover areas.

4. Nesting Phenology

Our information on the phenology of cranes is based on only three nests each year. In 1980 nesting began on 13 May, and in 1981 on 20 May. Hatching began 12 June in 1980 and 20 June in 1981. The late hatching date of 19 July 1980 was possibly a re-nesting attempt.

On the Inglutalik delta just south of Koyuk, Shields and Peyton (1979) found a mean hatching date for cranes of 13 June and 6 June in 1976 and 1977, respectively.

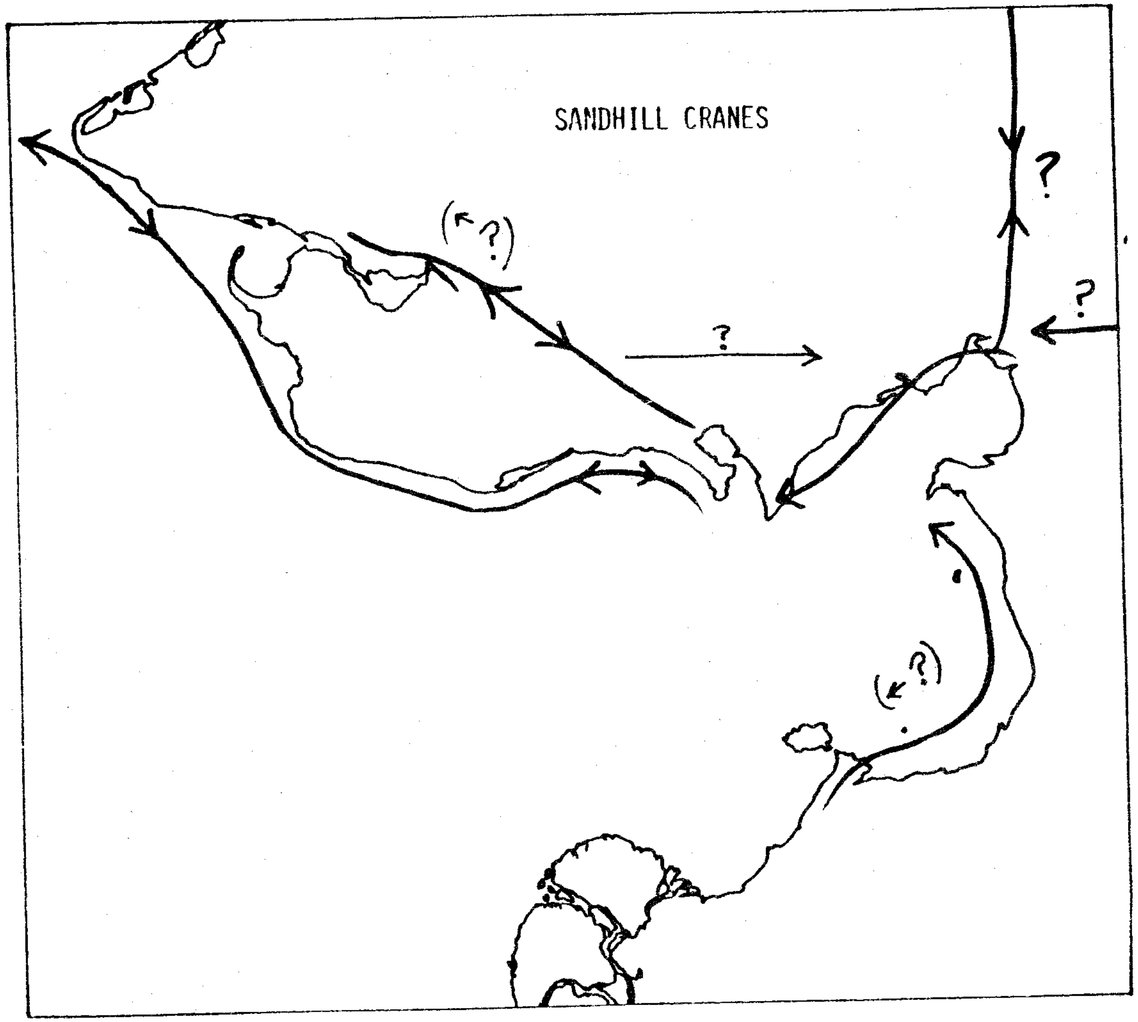

Figure 42. Migration routes of cranes in Norton Sound. The main spring route of cranes is from eastern Norton Sound along the north shore, passing by Nome, and then crossing the Strait to Siberia. The return in late summer follows much the same route as in spring. Probable overland routes are shown.

Table 18. Maximum projected migrant crane populations at 12 wetlands in Norton Sound.

Wetland Area	Mo/Da/Yr	Cranes/ Minute	km^2	Projected Population[1]
Port Clarence	9/5/81	53.4	13.4	603
Imuruk Basin	9/5/81	68.7	116.5[2]	6,739
C. Woolley to Sinuk	9/16/80	3.1	29.8	78
Eldorado and Flambeau Rivers	8/15/80	2.7	20.2	46
Safety Lagoon	6/13/80	1.9	34.6	55
Fish River Delta	9/6/80	41.1	38.5	1,332
Moses Point	8/28/81	7.2	49.9	303
Koyuk	9/6/80	56.6	61.4	2,926
Shaktoolik	9/10/81	5.7	99.3[2]	477
Stuart Island	8/28/81	25.0	22.0	463
Stebbins	8/28/81	53.4	169.0	7,599

[1] Based on a flight speed of 177 km/hr and a 400 m observation path for each observer (see the "Methods" chapter).

[2] Square km of wetlands given here for Imuruk Basin and Shaktoolik are greater than those in Tables 21 and 22, used for calculating shorebird populations. Cranes at Imuruk and Shaktoolik were more widespread over a mix of moist and wet tundra, and thus a large wetland size was assumed to include this additional habitat.

H. Shorebirds

Shorebirds were an important element of the Norton Sound avifauna, comprising 35% of all birds encountered on land surveys in or near wetlands (see Chapter VI-A, "All Birds"). This section addresses habitat use and the dependence of shorebirds on various habitat types. Seasonal and yearly variations in habitat use and the geographic distribution of shorebirds in Norton Sound are also discussed. All data are from land surveys since shorebirds are small and best surveyed from land rather than air. This limits our discussion of habitat use and distribution to wet tundra (wetlands) and adjacent areas, since this is where we concentrated our samples. These are the areas and habitats that could be expected to have the highest shorebird densities. Gill and Handel (1981) present an overview of shorebird resources in the eastern Bering Sea with emphasis on use of littoral habitats.

1. Relative Abundance

For this discussion we have divided the shorebird fauna into five groups, based on their status in Norton Sound. The most important group is the common "wetland breeders," composed of Semipalmated and Western Sandpipers, Dunlin, and Northern Phalaropes. These four are the most common species of shorebird in Norton Sound, comprising 82% of the total shorebird population (Table 19). Also discussed are three species of uncommon wetland breeders that nest in low numbers (6%) in the area, and four species of upland breeders (6%). A few other shorebird species nest occasionally on or near the coastal wetlands (less than 1%). Also discussed are species that primarily nest elsewhere or in small numbers in coastal Norton Sound, but are present as migrants (5.5%).

Overall, Northern Phalaropes were the most abundant shorebird (22.5%), closely followed by Semipalmated Sandpipers (21%). Semipalmated Sandpipers were actually more abundant as breeders, comprising 43.9% of the breeding shorebird population, compared with 25.9% for phalaropes. Their early departure from the breeding grounds made them relatively less abundant than phalaropes over the whole season. Collectively, the four common wetland breeders constituted 92.7% of the total breeding population of shorebirds in Norton Sound.

Table 19. Relative abundance of shorebirds in coastal Norton Sound.

Group	Species	Percent of Pop.	Percent of Breeders
Common Wetland Breeders	Semipalmated Sandpiper	21.0	43.9
	Western Sandpiper	17.2	11.9
	Dunlin	9.6	9.9
	Northern Phalarope	22.5	25.9
	Unidentified Sandpipers	11.8	1.1
	Total	82.1	92.7
Uncommon Wetland Breeders	Black Turnstone	0.8	1.6
	Common Snipe	0.5	0.4
	Long-billed Dowitcher	4.4	0.5
	Total	5.7	2.5
Upland Breeders	American Golden Plover	2.0	1.2
	Whimbrel	1.3	1.0
	Bar-tailed Godwit	2.4	2.2
	Total	5.7	4.3
Occasional Breeders	Black-bellied Plover	0.2	0.1
	Semipalmated Plover	< 0.1	< 0.1
	Solitary Sandpiper	< 0.1	< 0.1
	Lesser Yellowlegs	< 0.1	< 0.1
	Spotted Sandpiper	0.3	< 0.1
	Least Sandpiper	< 0.1	< 0.1
	Hudsonian Godwit	< 0.1	< 0.1
	Total	0.5	0.2
Migrants	Ruddy Turnstone	0.4	<<0.1
	Surfbird	0.2	
	Wandering Tattler	< 0.1	
	Red Knot	0.2	
	Pectoral Sandpiper	2.3	< 0.1
	Sharp-tailed Sandpiper	0.3	
	Rock Sandpiper	0.2	
	Rufous-necked Sandpiper	0.3	
	Baird's Sandpiper	0.2	
	Sanderling	< 0.1	
	Red Phalarope	1.6	< 0.1
	Total	5.5	
Unidentified Shorebirds		0.5	
	TOTAL	100.0	100.0

2. Common Wetland Breeders

(a) Habitat Use

(i) Breeding — June. Western and Semipalmated Sandpipers, Dunlin, and Northern Phalaropes are all common wetland breeders, yet they have different habitat needs. Figure 43 illustrates habitat use by the four common wetland shorebirds in June when all are breeding. The most important shoreline habitat was exposed south shores with wet tundra (especially for Semipalmated Sandpipers). Protected shores with moist tundra, wet tundra, and spits also received concentrated use. Away from the shore, wet tundra was more important for all species than was moist tundra, except for Western Sandpipers.

Tundra Habitats. The characteristics of wet tundra (a non-shoreline habitat) have been enumerated in Chapter IV, "Study Area." It can be briefly summarized as a generally flat, low-lying area, primarily vegetated with grasses and sedges. A mosaic of ponds and lakes sometimes cover as much as 50% of the total area. Many ponds are surrounded by lush sedges, and mare's-tail (Hippurus), an emergent aquatic, is common in shallow ponds. Most of the Norton Sound coastal wetlands are periodically flooded by fresh or salt water, and this probably contributes to their productivity. These areas are often part of or associated with river deltas. Subarctic shorebirds are primarily insectivores on their breeding grounds (Holmes 1966a), and the abundance of insects on wet tundra is the primary factor for shorebirds' choosing this habitat (see Chapter VI, Part Two, "Trophic Systems").

Semipalmated Sandpipers reached their greatest breeding densities on wet tundra (268 birds/km^2 at Koyuk, 170/km^2 average for all wetlands in Norton Sound; see Table 21 below). They use this habitat for nesting, and they also do most of their feeding here, both on and off their territories (Ashkenazie and Safriel 1979). They also nest on vegetated spits and feed on the lagoon shores of these spits. Dunlin also nested on wet tundra in areas very similar to those chosen by Semipalmated Sandpipers, though at considerably lower densities (maximum of 96/km^2 at Stebbins, average of 51/km^2 for all wetlands). They fed primarily along pond edges, but their feeding is much more likely to be limited to their own territories (Holmes 1970).

Northern Phalaropes also rely primarily on wet tundra, where their densities (maximum of 151 km^2 at Stebbins, average of 110/km^2 for all wetlands) were second only to those of Semipalmated Sandpipers. Generally, they nest in wetter microhabitats than the other species. Their nests are usually close to a pond and the vegetation is higher than that surrounding Semipalmated Sandpiper or Dunlin nests. Unlike the other three species, which feed primarily on the pond edges, Northern Phalaropes often feed

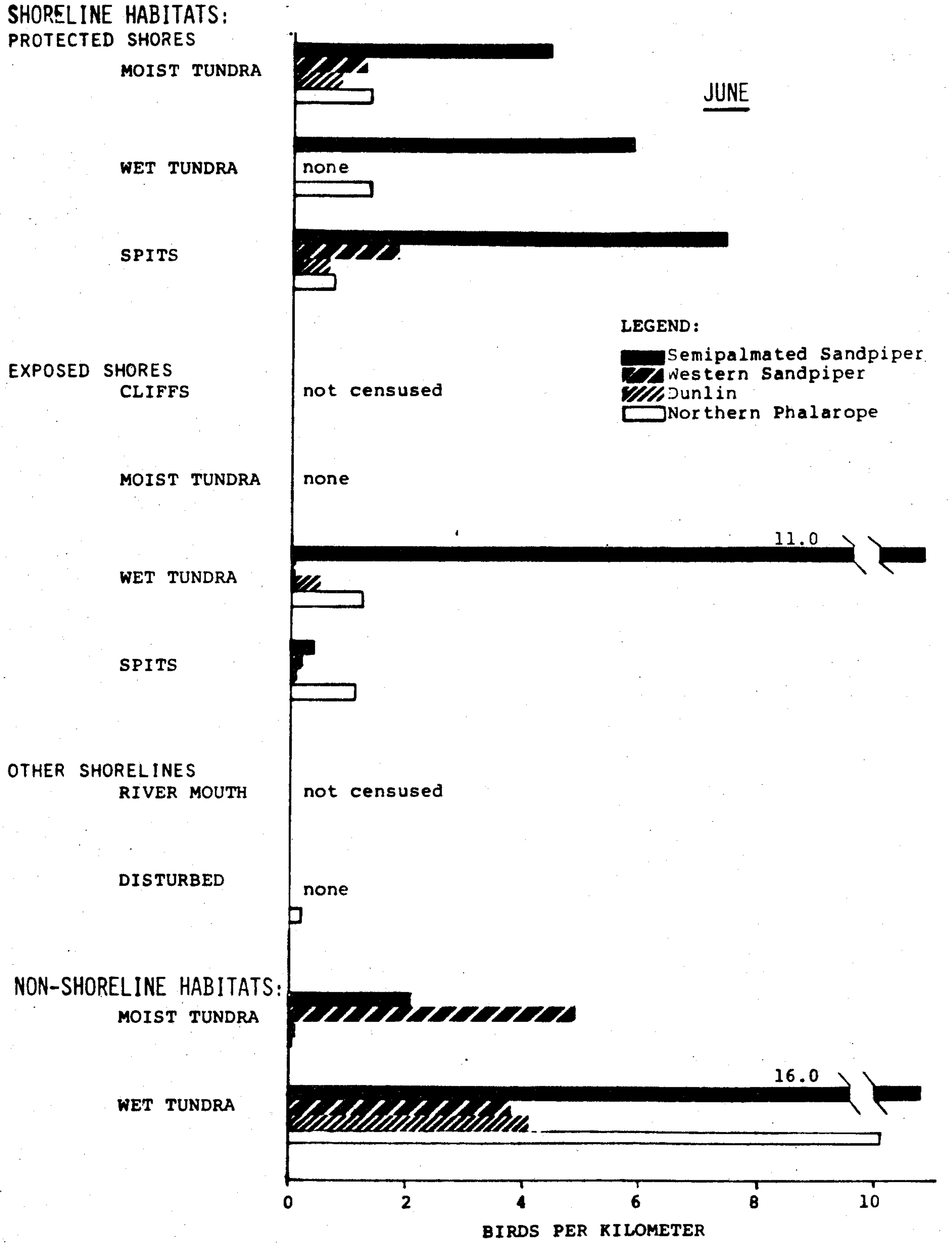

Figure 43. Habitat use by the common wetland shorebirds in June. Data are from 1980 land surveys and apply to habitats in the immediate vicinity of wetlands. Shorelines received moderate use in June, mostly by Semipalmated Sandpipers. Of the non-shoreline habitats wet tundra was more used by breeding shorebirds than was moist tundra, except by Western Sandpipers. Since these data were collected near wetlands, the densities for moist tundra and for shorelines are probably higher than would be expected away from wetlands.

while sitting on the surface of the ponds. They may employ one of several feeding methods; these include spinning in a circle while pecking at the surface, "up-ending" like a dabbling duck, or snapping at flying insects (Hohn 1979). Red Phalaropes often feed along pond edges (Ridley 1980), and we observed Northern Phalaropes feeding there, primarily upon adult insects.

Before chick hatching Western Sandpipers were most common on moist tundra (Figure 43), but moved to adjacent wet tundra after hatching (Figure 44). Moist tundra vegetation probably allows for greater breeding success, since the nests and young are harder to find there than on wet tundra (Holmes 1971). This advantage is probably enough to offset the extra energy adults must expend traveling from moist tundra nest sites to the wet tundra where they usually feed. Feeding on moist tundra nesting territories is less frequent and mainly occurs early in the breeding season (Holmes 1972). Because of this, smaller territories suffice, and breeding densities on moist tundra are higher than they otherwise could be if the birds fed exclusively on territory (Holmes 1971). A few days after the young hatch, the parents lead them away from the nest site to more productive wet tundra habitat and to protected (lagoonal) shore habitats and river mouths (Figure 44). By mid-July these moist tundra areas in Norton Sound support few Western Sandpipers (Figure 44).

The other three common wetland shorebirds make minimal use of moist tundra habitats in Norton Sound. Semipalmated Sandpipers sometimes nest here, and when they do they occupy different microhabitats than those chosen by Western Sandpipers. Westerns prefer a more hummocky tundra composed of a rich assemblage of grasses, sedges, lichens, mosses, and small shrubs such as Crowberry (Empetrum nigrum) and Dwarf Birch (Betula nana). It is both structurally and vegetatively more complex than either the moist or wet tundra sites preferred by Semipalmated Sandpipers. Semipalmated Sandpiper nesting sites on moist tundra are generally flatter, drier, and with less vegetation.

The moist tundra densities shown in Figure 43 are higher than would be found on moist tundra away from wetlands. These densities were compiled mainly from hummocky moist tundra (hummocks are of heaths) adjacent to or intermixed with wet tundra. The tussocky moist tundra (tussocks are of sedges or grasses) which covers large areas of coastal Norton Sound (see Chapter IV, "Study Area") has fewer small shorebirds.

Shoreline Habitats. Although tundra habitats were used most extensively by the breeding shorebirds, they also made use of shoreline habitats in June. Semipalmated Sandpipers were quite numerous on exposed beach backed by wet tundra, principally at Koyuk. They nested on the tundra close to the beach, and often fed upon the mudflats there. No other

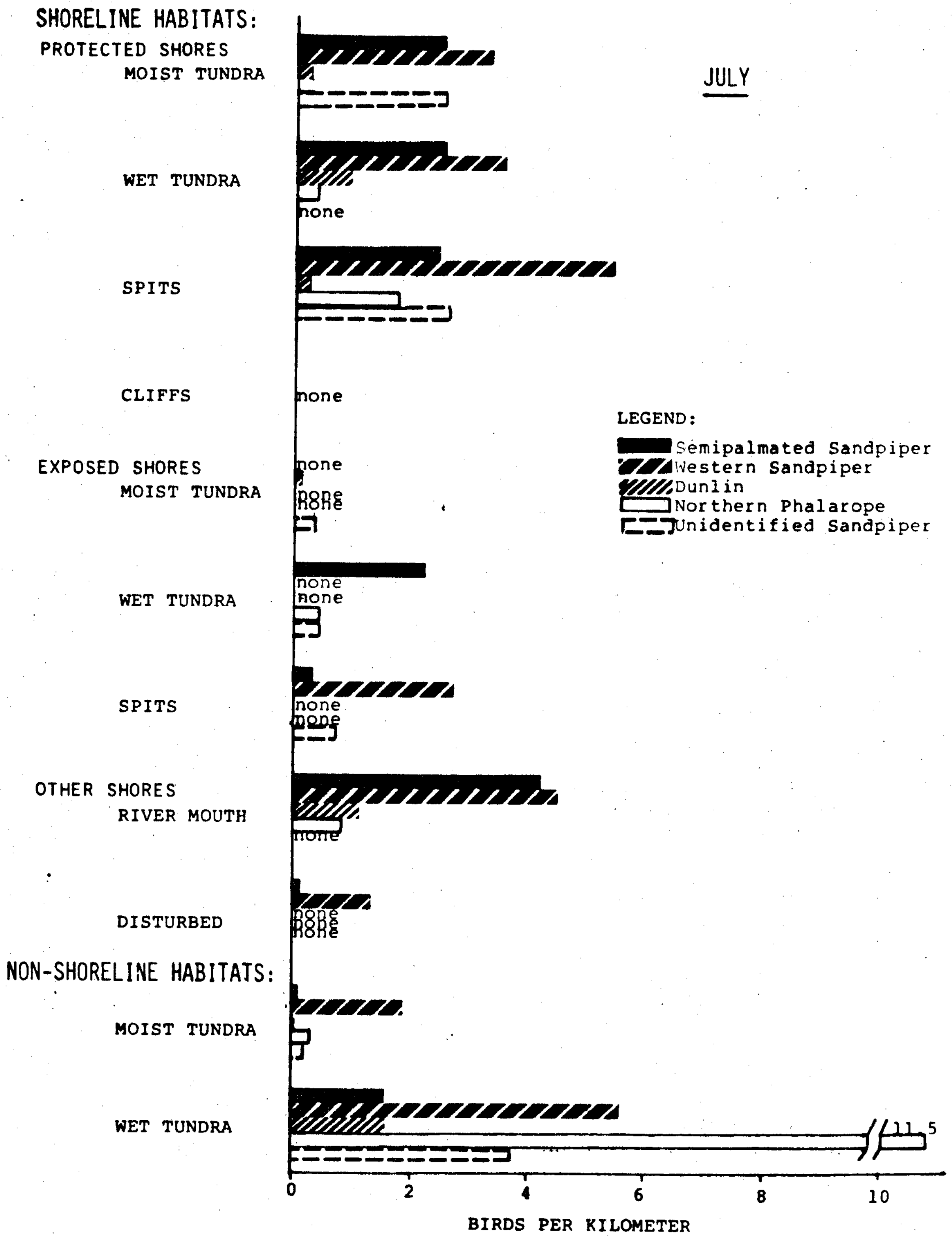

Figure 44. Habitat use by the common wetland shorebirds in July. Data are from 1980 land surveys and apply to habitats in the immediate vicinity of wetlands. Semipalmated Sandpiper densities dropped on shorelines and tundra since June while phalaropes became more common on wet tundra (non-shoreline) and this was mostly due to the production of young. Western Sandpipers became more common along protected (lagoonal) shores, Dunlin densities dropped on wet tundra (non-shoreline).

shorebird species was common in this habitat in June, nor were any other exposed shoreline habitats very much used in this month.

Semipalmated Sandpipers were common in all lagoonal (protected shoreline) habitats. Shorebirds in such areas are able to feed along the lagoon shores and nest on the adjacent tundra, where they also feed. The tidal range is generally quite small in June, but the lagoons are often so shallow that even with fluctuations of one meter extensive tide flats are exposed. Dunlin, Western Sandpipers, and Northern Phalaropes were present in low densities on lagoon beach shorelines.

(ii) Post-Breeding (Except Koyuk) — July. The four major wetland breeders exhibited post-breeding changes in habitat use (Figures 44 and 45). These are related to the temporal productivity of various habitats and the energy demands of molt and migration. July and August are shown separately, because habitat use for some species differs between months. Koyuk is discussed separately (Figures 46 and 47) because it showed habitat use patterns different from those of other areas.

Tundra Habitats. In July (Figure 44) Semipalmated Sandpiper densities dropped drastically at both shoreline and non-shoreline habitats. Wet tundra densities of both Western Sandpipers and Northern Phalaropes increased while Dunlin densities dropped. Densities of both Semipalmated and Western Sandpipers on moist tundra dropped in July.

Shoreline Habitats. Semipalmated Sandpipers and Northern Phalaropes were less common at all shoreline habitats than they were in June. Western Sandpipers increased on shorelines, particularly in lagoonal habitats (protected shores) as they moved from tundra habitats to the littoral zone. Dunlin densities remained at the same low levels as in June. Northern Phalaropes continued their low use of shoreline habitats.

(iii) Post-Breeding (Except Koyuk) — August.

Tundra Habitats. The main change in wet tundra habitats in August was the decrease of all species except Dunlin, whose densities remained similar to July levels (Figure 45). Western Sandpiper, the only shorebird commonly found on moist tundra in July, decreased in that habitat in August, leaving few shorebirds associated with moist tundra.

Shoreline Habitats. The increase in Western Sandpipers on protected shorelines that began in July continued in August. Many of the unidentified sandpipers seen on protected shores in August were probably Western Sandpipers. Semipalmated Sandpipers were few on all shorelines, as nearly all had left the area. Both Dunlin and Northern Phalaropes were still at low densities along shorelines, though phalaropes were somewhat more common along lagoonal (protected) shores.

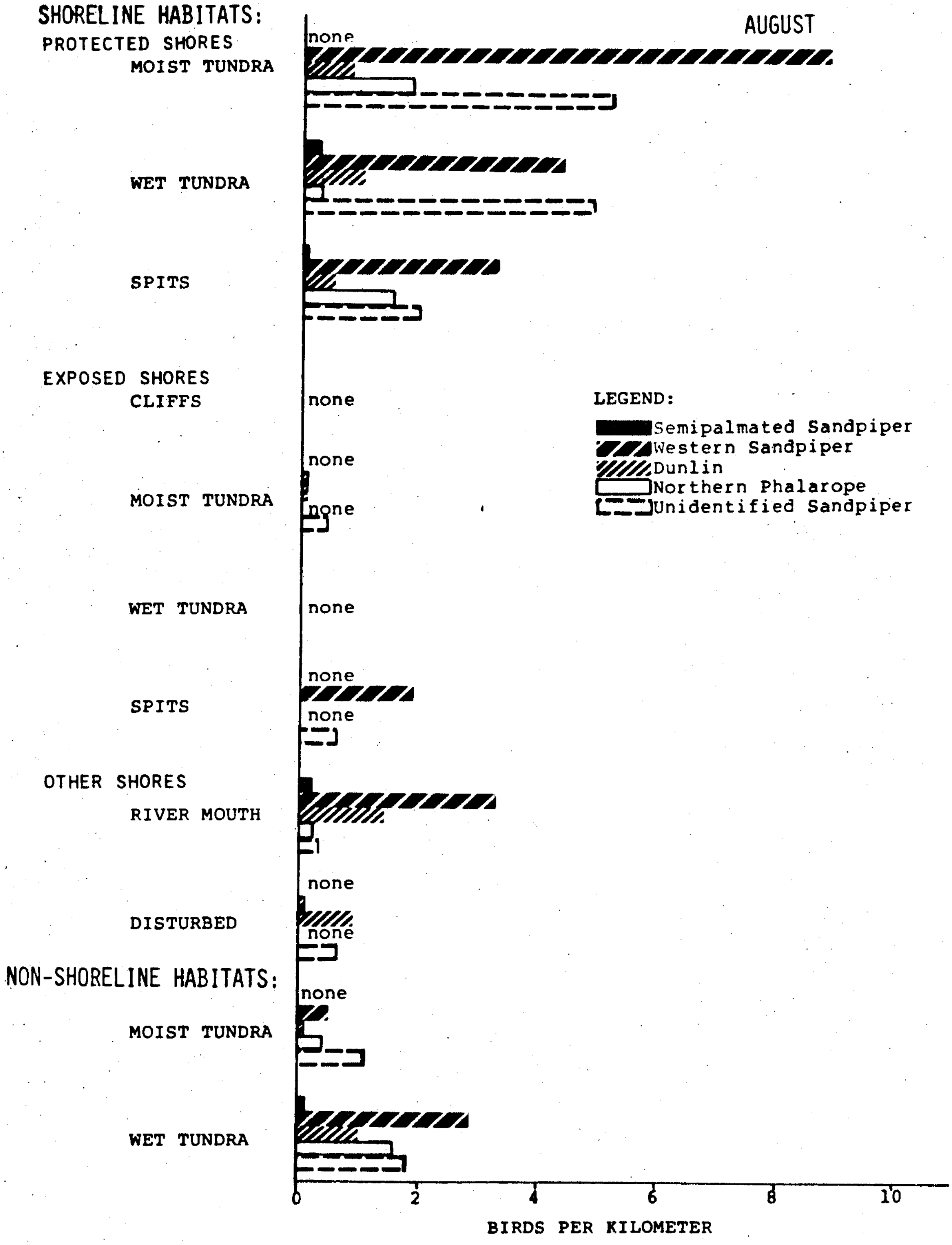

Figure 45. Habitat use by the common wetland shorebirds in August. Data are from 1980 land surveys and apply to habitats in the immediate vicinity of wetlands. Few Semipalmated Sandpipers remained in any habitats since July, and all species, except Dunlin, decreased on tundra (non-shoreline) habitats. Western Sandpipers continued to increase in densities along protected shores, and these were almost entirely juveniles.

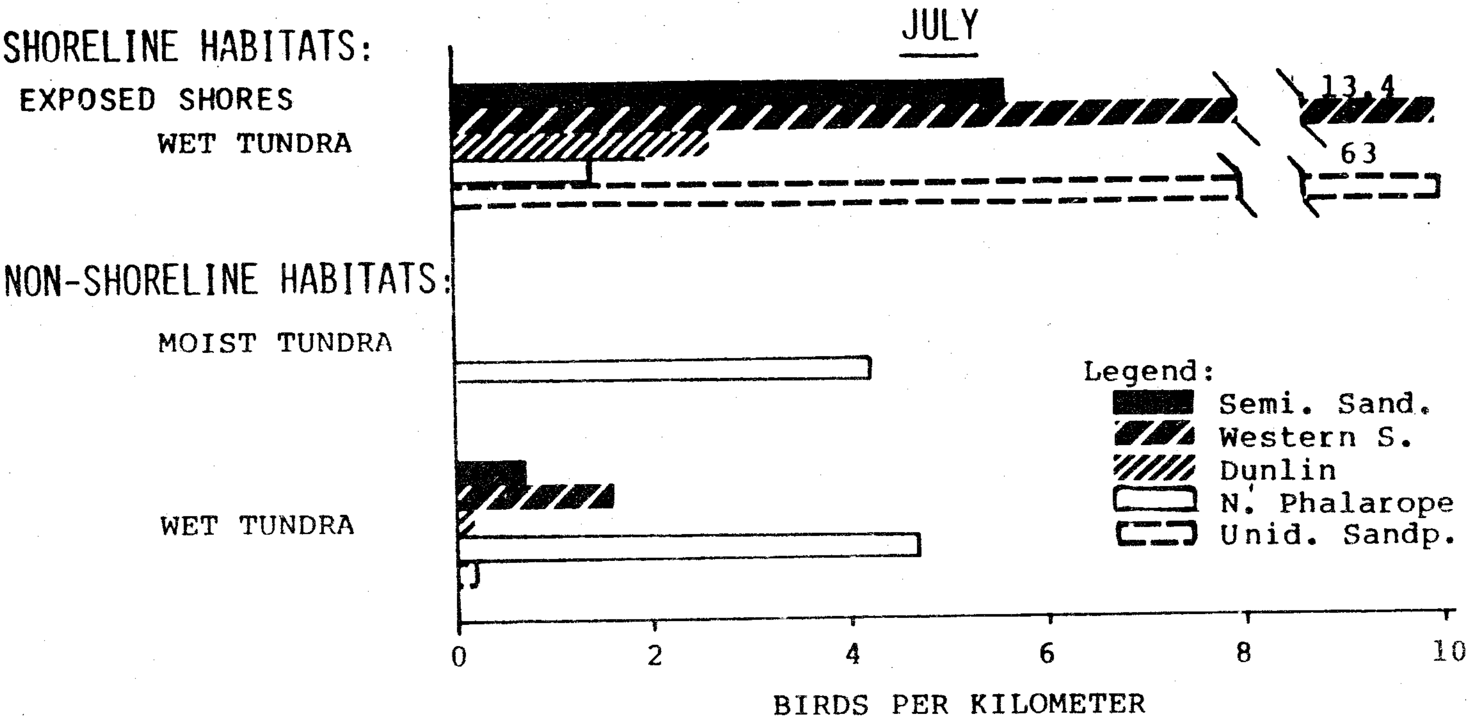

Figure 46. Habitat use by the common wetland shorebirds at Koyuk in July. Data are from 1980 land surveys and apply to habitats in the immediate vicinity of the wetland. Koyuk is the only area where shorebirds made considerable use of shorelines backed by wet tundra. The mudflats exposed at low tide there received greater use than did mudflats elsewhere in the Sound. Western Sandpipers (including many of the unidentified sandpipers) were the most abundant of all. On the tundra (non-shoreline) habitats phalaropes with their young were the most abundant.

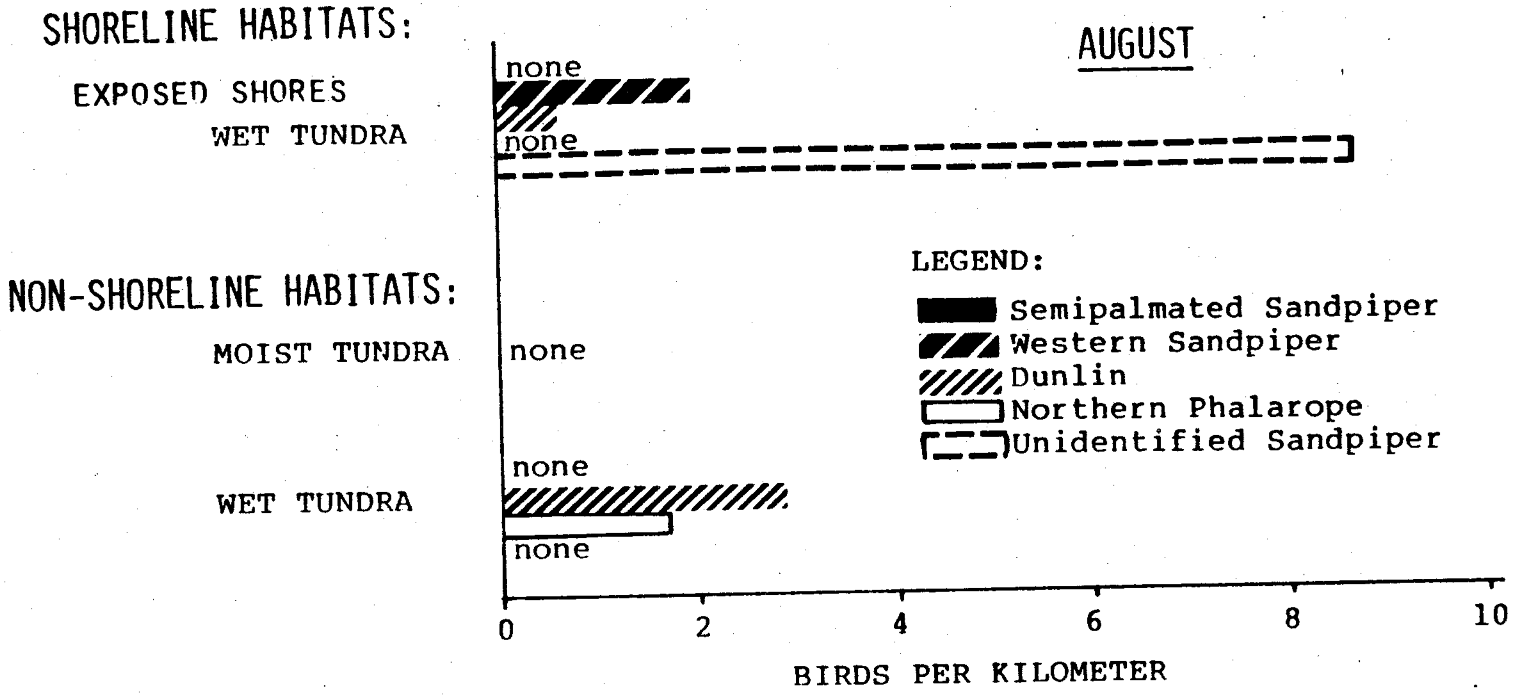

Figure 47. Habitat use by the common wetland shorebirds at Koyuk in August. Data are from 1980 land surveys and apply to habitats in the immediate vicinity of the wetland. The unidentified shorebirds remaining on the shoreline (mudflat) were mostly Western Sandpiper juveniles. Only Dunlin and Northern Phalaropes remained on the wet tundra (non shoreline). Semipalmated Sandpipers, once abundant in May, June, and July, have almost entirely departed (some may have been unidentified). See the caption to Figure 46 for additional information.

(iv) Post-Breeding (Koyuk). Koyuk (Figures 46 and 47) was the only area where shorebirds made considerable use of an exposed shoreline backed by wet tundra. The mudflats there received far greater use than those of any other wetlands in the Sound. Semipalmated Sandpipers were common on the mudflats in both June and July, though July densities were proportionately larger. Western Sandpiper numbers increased from June to July, despite a decrease on the wet tundra (see Tables 20 and 21). Mudflat populations of Westerns were surely higher than shown because the majority of the unidentified sandpipers were probably Westerns. Dunlin and Northern Phalaropes showed a similar pattern, though their overall numbers decreased. These trends imply a shift from wet tundra to shorelines from June to July.

In August at Koyuk, unlike other areas, Western Sandpiper numbers decreased, while Dunlin numbers increased. Westerns were almost exclusively on the mudflats. Dunlin were primarily on wet tundra, though large flocks could occasionally be seen feeding on the mudflats. Shields and Peyton (1979) report that late August to early September was the peak time for shorebird use of intertidal mudflats on the Akulik-Inglutalik Delta. We found peak mudflat densities in mid to late July at the nearby Koyuk delta.

(v) Tundra vs. Shoreline. The degree of shorebird use of and dependence on littoral habitats is of particular interest, since these habitats are most susceptible to such disturbances as oil spills. Shoreline usage patterns tend to vary with the season (see Figure 49). The densities shown in Figures 48 and 49 for tundra and littoral habitats are not directly comparable due to inherent differences between linear and areal habitats.

In May the bulk of Semipalmated Sandpipers were to be found on tundra habitats, but they also fed commonly in littoral areas. The population size increased considerably in June, but littoral densities decreased since most Semipalmated Sandpipers were feeding along pond edges and other tundra habitats. July showed further decreases in littoral densities, but this was mainly due to an exodus from Norton Sound in this month. Juvenile Semipalmated Sandpipers were still quite common in many littoral areas in early to mid-July. By August there were very few Semipalmated Sandpipers left in Norton Sound.

Western Sandpipers could be found feeding in littoral habitats in both May and June, but they were much more common on tundra habitats. In July there was a noticeable influx of juvenile Westerns onto littoral habitats, resulting in the highest littoral densities for this species. By August the southward migration of most adult and many juvenile Westerns had lowered densities. Juvenile Westerns were still fairly common in littoral habitats, though by September very few remained in Norton Sound.

Table 20. Summary of shorebird migration in Norton Sound.[1]

Species	Spring Migration		Fall Migration	
	Range or 1st Date	Peak Date	Range or last Date	Peak Date
American Golden Plover	5/12	NN[2]	9/13	9/9
Black-bellied Plover	5/21	NN	9/13	NN
Whimbrel	5/14	NN	8/28	8/17
Bar-tailed Godwit	5/11	NN	9/9	8/25
Long-billed Dowitcher	5/14	5/15	7/30-9/27	9/7
Ruddy Turnstone	5/14	NN	8/8	7/3
Black Turnstone	5/12	NN	7/15-8/31	Late July
Rock Sandpiper	6/1	NN	8/3-9/27	NN
Pectoral Sandpiper	5/11-6/3	NN	7/2-9/14	9/5
Red Knot	5/29-6/8	6/4	7/27-8/12	NN
Dunlin	5/7	NN	8/25-9/21	9/12
Baird's Sandpiper	--	--	7/4-9/27	--
Semipalmated Sandpiper	5/11	NN	6/28-8/5	7/10
Western Sandpiper	5/11	NN	7/10-8/31	7/25
Red Phalarope	5/30-6/21	6/4	--	--
Northern Phalarope	5/11	NN	6/25-8/31	7/31

[1] Dates include information from both 1980 and 1981, and differences between these years did not exceed seven days for any event. Peak dates are based on observations of migrant flocks.

[2] NN = Migration peak was not noticeable.

Table 21. Shorebird breeding populations on Norton Sound wetlands in June, 1980.[1]

Wetland Areas	Km^2	Semipalmated Sandpiper		Western Sandpiper		Dunlin		Northern Phalarope		Total Population	
		No. of Indiv.	% of Total	No. of Indiv.	% of Total	No. of Indiv.	% of Total	No. of Indiv.	% of Total	No. of Indiv.	% of Total
Brevig Lagoon	6.6	211	0.3	92	1.1	125	0.5	86	0.2	514	0.3
Port Clarence	13.4	750	0.9	2,425	29.6	898	3.8	509	1.0	4,582	2.8
Imuruk Basin	41.0	4,141	5.2	369	4.5	41	0.2	4,182	8.1	8,733	5.3
Woolley Lagoon	6.8	456	0.6	218	2.7	326	1.4	116	0.2	1,116	0.7
Nome	0.5	27	0.03	0	0	0	0	4	0.01	31	0.02
Safety Lagoon	34.6	2,160	2.7	2,630	32.1	1,003	4.2	2,041	3.9	7,834	4.8
Fish River Delta	38.5	4,659	5.8	655	8.0	1,386	5.8	2,695	5.2	9,395	5.7
Moses Point	49.9	7,385	9.2	50	0.6	848	3.5	7,435	14.3	15,718	9.6
Koyuk	61.4	16,455	20.5	553	6.8	3,070	12.8	8,228	15.9	28,306	17.2
Shaktoolik	51.3	359	0.4	513	6.3	0	0	1,026	2.0	1,898	1.2
Unalakleet	14.6	NC[2]	NC	NC	NC	NC	NC	NC	NC	NC	NC
Stebbins	169.0	43,602	54.4	676	8.3	16,224	67.8	25,519	49.2	86,021	52.4
Totals	487.6	80,205		8,181		23,921		51,841		164,148	
Percent Total Population		48.8		5.0		14.6		31.6			
Average Density[3]		170/km^2		17/km^2		51/km^2		110/km^2		349/km^2	

[1] Data were derived by multiplying mean birds/km^2 at each area in June by total area of each wetland (non-shoreline wet tundra habitats only).

[2] Not censused.

[3] Data were derived by dividing the total population by 470 km^2, the total area of wetlands excluding Unalakleet.

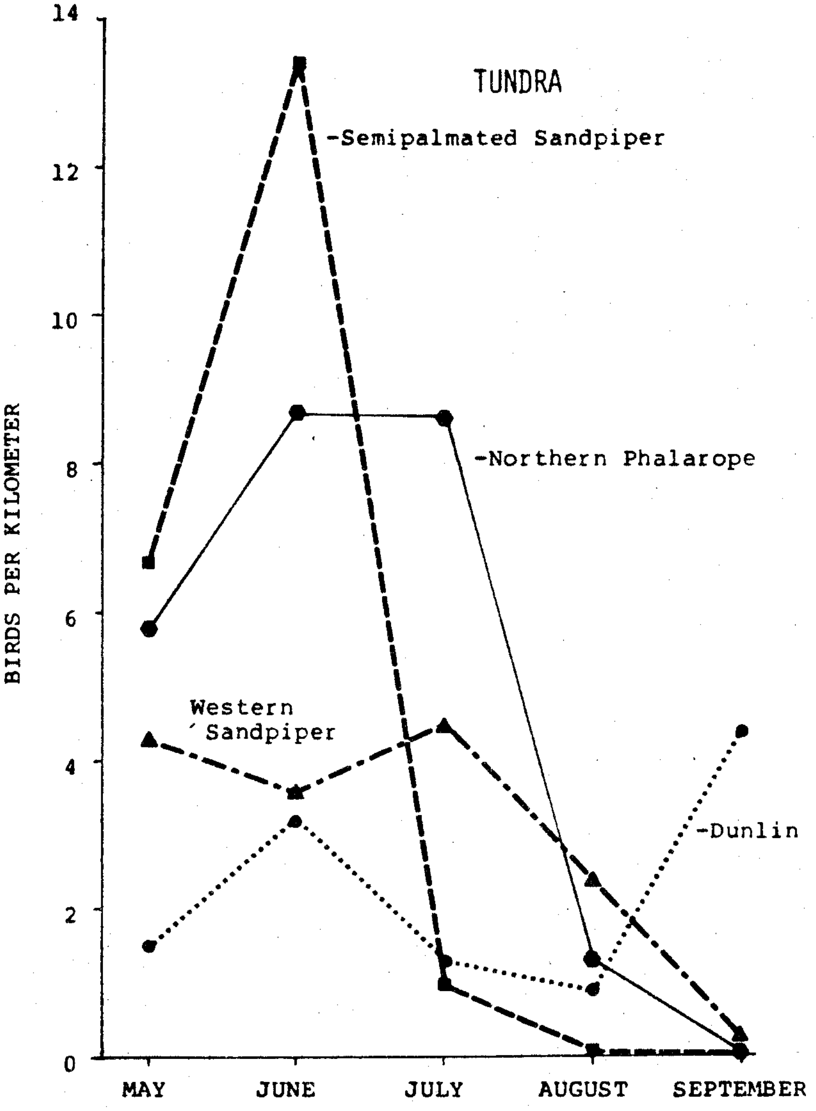

Figure 48. Seasonal abundance of the common wetland shorebirds on tundra (non-shoreline) habitats. Data are from 1980 land surveys except in May which includes 1981 data. Tundra densities fall in July and August after the nesting season, particularly for Semipalmated and Western Sandpipers. Dunlin increase in September due to an influx of birds, apparently from the north.

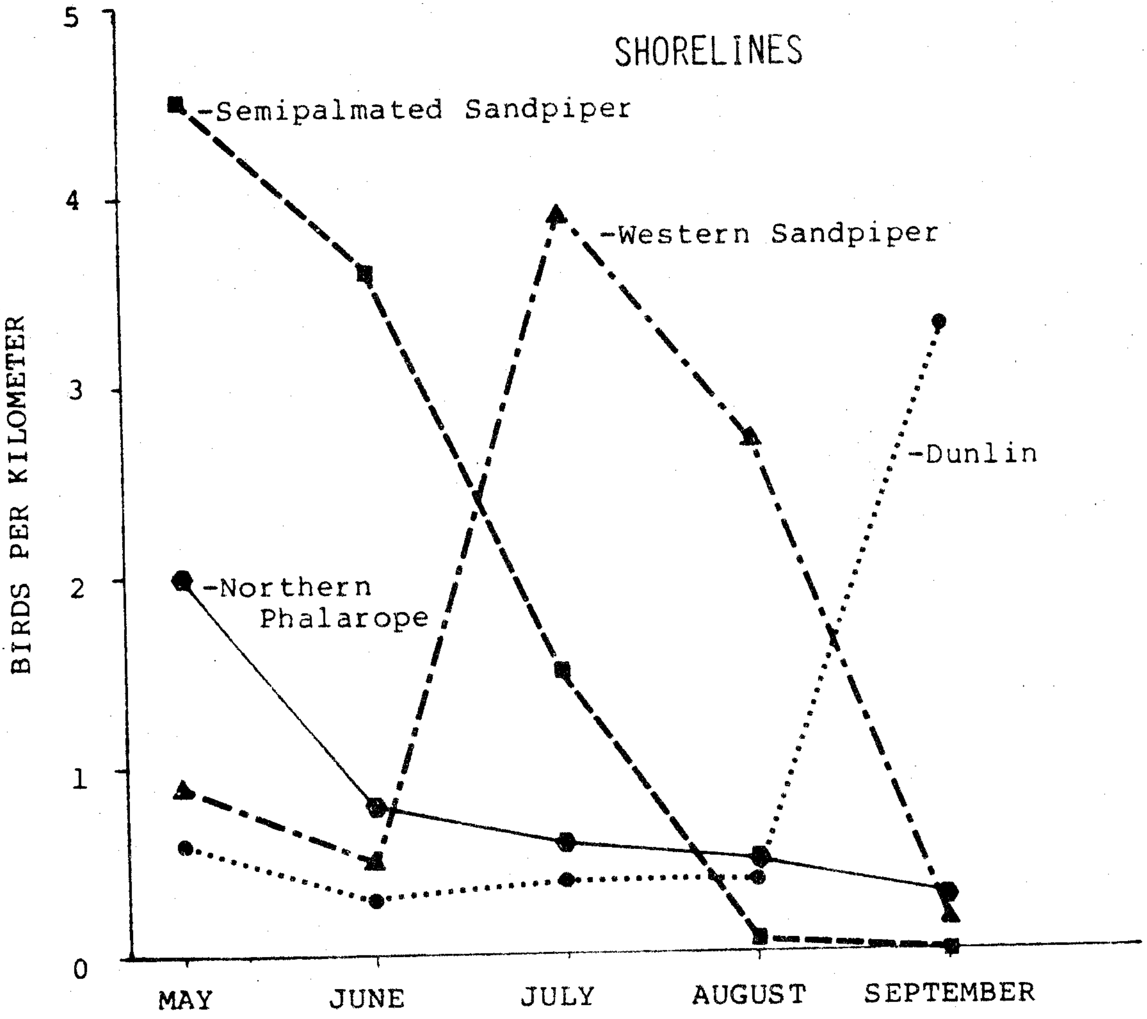

Figure 49. Seasonal abundance of the common wetland shorebirds on shoreline habitats. Data are averaged from 1980 and 1981 land surveys. Shoreline habitats were most used in May by Semipalmated Sandpipers and phalaropes. Western Sandpipers, mostly juveniles, moved to shorelines in July and were the most common shorebird there in that month as well as in August when densities dropped somewhat. Dunlin were most abundant on shorelines in September when they were virtually the only shorebirds present.

Dunlin made little use of littoral habitats throughout most of the summer in Norton Sound. By mid-August littoral densities began to increase, and adult and juvenile Dunlin were common in both littoral and tundra habitats in September. These were probably birds from arctic breeding grounds (Holmes 1966b).

Northern Phalaropes also made little use of littoral habitats. Though they could occasionally be seen feeding on tidal mudflats along with other shorebirds, they generally fed in or along the edges of tundra ponds and lakes. Their littoral densities were highest in May, when they were arriving on the breeding grounds; and it is possible that they feed offshore in Norton Sound during spring migration.

Figure 49 also suggests resource partitioning of the littoral zone by the three sandpipers. As Semipalmated Sandpiper densities on littoral areas began to drop, Western densities increased. Similarly, as Western densities tapered off, Dunlin densities rose.

(b) Seasonal Abundance

(i) May. Migration in spring is short-lived compared to the protracted fall movements. In May most of the shorebirds that nest on Norton Sound wetlands arrive on the breeding grounds. Individuals of the four common wetland breeders appeared within a few days of each other, with Northern Phalaropes the last to arrive (Table 20). The earliest arriving birds congregated around patches of open tundra during the first week of May. But the end of the third week in May, most of the snow had melted and the birds had dispersed to breeding sites. By the end of the month, most shorebirds had begun incubating.

Figures 48 and 49, showing seasonal use of shoreline and non-shoreline habitats, combine May data from both 1980 and 1981, since only five of the 13 study areas were censused in May 1980. Three of these five areas proved to have fairly insignificant populations of breeding shorebirds (see Table 21). The insertion of the May 1981 data gathered at three of the more productive wetland sites gives a more accurate picture of May densities than the 1980 data alone. Densities for all other months were compiled from 1980 data only.

(ii) June. Shoreline densities for all species decreased from May to June, while non-shoreline (tundra) densities increased for all species except Western Sandpipers (Figures 48 and 49).

By mid-June small flocks of failed or non-breeders were noted, though most birds were on eggs and displaying males were evident. The hatching of young further increased June densities, despite their adeptness at hiding. After hatching in mid to late June, Westerns, Semipalmated Sandpipers, and Dunlin frequently left their territories with their young for communal feeding areas.

(iii) July. The most dramatic change in July was the precipitous drop in Semipalmated Sandpiper densities, in both shoreline and tundra habitats. By early July nearly all young had hatched, and many were fledged. The females desert their broods two to eight days after hatching (Ashkenazie and Safriel 1979), and by fledging most had probably begun their southward migration. The males remain with the young until fledging, at which time both parents and juveniles join flocks of other sandpipers. By the end of July, most Semipalmated Sandpipers had left Norton Sound, and only a few juveniles remained.

Western Sandpiper densities increased in July, particularly at Safety Lagoon. This increase was probably due mainly to the production of young by birds nesting in coastal Norton Sound. Mixed flocks of both juveniles and adults were common in early July, but by the end of the month many adult Westerns had departed.

Northern Phalarope densities remained fairly stable from June to July. By early July most female phalaropes had departed. Mixed flocks of males and juveniles formed in mid-July and began to move out of the area by the end of the month.

Dunlin densities decreased on tundra habitats but remained stable on shorelines in July, indicating a major movement out of the Sound by this species. Holmes (1966b) has reported that given favorable weather and a good food source, many Dunlin will remain in the arctic or sub-arctic to molt. First primaries, then body feathers are molted; and this is generally completed before the birds migrate south. Our data indicate that many Dunlin, particularly adults, left Norton Sound before they had time to finish their molt. It is possible that many were females. Soikkeli (1967) reports that in southern Finland the females desert their broods shortly after hatching and head south around ten days after the young hatch. The departure of Dunlin from Norton Sound before molting is an indication that prey densities are too low to support molting.

Semipalmated Sandpipers exhibit quite a different molt pattern. They leave the breeding grounds in mid-summer and do not molt until they reach their wintering grounds (Holmes 1972).

Both Western Sandpipers and Northern Phalaropes exhibit an intermediate strategy. Westerns begin molting in late June, suspend the molt during migration, and complete it when they reach their wintering grounds (Holmes 1972). We observed some Northern Phalarope adults molting body plumage on the breeding grounds. Some males were in nearly complete winter plumage before southward migration. Many birds, however, appeared to leave before molting, and all of them wait until reaching the wintering grounds before they molt their flight feathers (Palmer 1972). Those birds that do begin molt on the breeding grounds probably arrest it before migrating.

Both molt and migration are energy-demanding processes and it is most likely that the different patterns shown by these four species of shorebirds are directly related to the energy demands of their particular migration routes. Semipalmated Sandpipers winter in the southern hemisphere, and thus leave their breeding grounds early and postpone molting until arrival on the wintering grounds. This early departure may allow them to escape the mid and late summer food shortages that often occur on the tundra (Holmes 1972). Westerns winter in the southern part of the northern hemisphere and do not have as far to go as Semipalmated Sandpipers. They can afford the energy expenditure of beginning their molt in the north. Dunlin winter even further north, so if weather and food conditions permit they can complete their molt before migrating. Northern Phalaropes also winter in the southern hemisphere. They probably find plentiful food supplies on their journey south over the ocean, and thus are able to initiate a body molt on their breeding grounds.

(iv) August. On tundra habitats the four principal species of shorebirds showed a decrease in numbers from July to August. Tundra phalarope densities dropped most sharply, indicating a major movement out of Norton Sound by this species. This was heralded by mixed flocks of up to 200 adults and juveniles forming on wetland ponds in mid to late July. Very few Semipalmated Sandpipers remained by August.

Dunlin densities in August were similar to those of July for both shoreline and tundra habiats. This is probably due to movements of local birds out of Norton Sound, while Dunlin from arctic areas drift in (Holmes 1966b).

Western Sandpiper densities decreased on shoreline and tundra habitats from July to August. Even so, they were the most abundant shorebird in August. Since most of the adults left in late July, this further decrease is caused by the wave of migrant juveniles which leave by mid to late August (Holmes 1972).

(v) September. Three of the four common wetland breeding shorebirds left Norton Sound by early September. Dunlin was the only one of the four species to remain, and was more abundant in September than in previous months in both shoreline and tundra habitats. Flocks of up to 100 Dunlin were common. Both adult and juvenile Dunlin from arctic breeding grounds moved into coastal western Alaska in late August and September. They feed there on wetlands and tide flats until late September or October, when they depart on a direct and rapid flight to their wintering grounds (Holmes 1966b).

(c) Geographic Distribution

(i) Breeding Season. Breeding shorebird populations vary considerably between the major wetlands of Norton Sound. Differences between these areas will be presented for the four principal nesting species. June distributions, when shorebirds are nesting and at peak density, will be discussed first, with the post-breeding distributions in July and August presented last.

Table 21 lists the total breeding population for each of the primary species of breeding shorebirds in each major coastal wetland; this shows some general trends in shorebird distribution around Norton Sound. Semipalmated Sandpipers were fairly common at all of the larger wetland sites with the exception of Shaktoolik. The same is also true of Northern Phalaropes. Dunlin showed an east-west gradient, being most abundant in the eastern and southeastern Sound and decreasing to the west. Western Sandpipers demonstrated a pattern in reverse of that for Dunlin, having low numbers in the east and higher populations at two western sites. Low numbers of all species at the extensive Shaktoolik wetlands indicate that this area is less biologically productive than superficially similar habitat elsewhere. The ensuing discussion begins with wetlands having the highest populations and ends with the least-used wetlands.

Stebbins had by far the largest populations of Semipalmated Sandpipers, Dunlin, and Northern Phalaropes. This is due both to its larger size and to its greater densities of breeding birds when compared with other wetland sites. This area contains a profusion of ponds, lakes and channels, and an apparently very productive wetland habitat. Because of its low-lying nature and exposed coastline it is subject to periodic flooding. This generally happens during fall storms, but sometimes during the breeding season. A major result of flooding is to replenish the nutrients of this wetland ecosystem. Its proximity to the Y-K Delta probably also contributes to the remarkable size of the Stebbins shorebird populations. Hersey (1917) reported that Western Sandpipers were the most common shorebird at Stebbins and did not even mention Semipalmated Sandpipers. Either the shorebird populations of Stebbins have changed significantly since 1915 (when he lived there) or Hersey mistook Western for Semipalmated Sandpipers.

The distributional fan of the Koyuk River is similar to the Stebbins area in many respects, and it has the second largest population of breeding shorebirds. Our data show that about 17% of the total breeding population of the four major species of shorebirds in Norton Sound nested here. The densities for Semipalmated Sandpipers and Northern Phalaropes are comparable to those of Stebbins, but the Koyuk area is only one-third as large. The Koyuk delta has a similar mosaic of ponds and lakes surrounded by wet tundra vegetation. It is also periodically flooded by storm tides, but this probably does not happen as frequently as at Stebbins, because the ice forms earlier at Koyuk and acts as a buffer to prevent flooding. The Koyuk area also differs from Stebbins in that it has much more extensive mud flats.

The wetlands of Moses Point, Imuruk Basin, the Fish River Delta, and Safety Lagoon all have protected (lagoonal) shorelines with river input. Although with not as many ponds as Stebbins and Koyuk, the ponds they do have coupled with their lagoons attract moderately high densities of shorebirds.

Moses Point is a large wetland area enclosing the mouths of the Kwik, Tubutulik, and Kwiniuk Rivers. Its Northern Phalarope densities were comparable to those of Stebbins and Koyuk, but densities for the other species were considerably lower. Imuruk Basin is much shrubbier than the other wetland areas because of its protected inland location. It also had moderately high densities and numbers of Semipalmated Sandpipers and phalaropes.

Although Safety Lagoon also has prime wetland habitat it is not as monotypic as the other wetlands. It contains a patchwork of moist tundra, wet tundra, and spit habitats, which probably contributes to its high Western Sandpiper densities and numbers (32.1% of the total, Table 21). The remaining areas all had small populations of breeding shorebirds.

The Port Clarence wetlands are characterized by salt-washed tundra sprinkled with large ponds and lakes intermixed with moist tundra. Though shorebird numbers were generally low there, it had the highest density of Western Sandpipers.

Shaktoolik wetlands cover a sizeable area, but had little suitable habitat for breeding shorebirds. Logistical problems kept us from censusing north of the Shaktoolik River. This area (including Malikfik Bay, 5 km north of Shaktoolik) appears to have more suitable habitat than where we surveyed, so our shorebird densities and populations for this area are probably low. From the air, however, we saw low productivity for most species, so it is not likely that this area is significant for shorebird breeding.

Woolley Lagoon has good wetland habitat, and due to its exposed coast is subject to periodic flooding. It is very limited in size, and had only moderate breeding densities and low populations. The Brevig Lagoon area possesses limited wetland habitat, and is mostly dry and sparsely vegetated with low shorebird densities.

Both Nome and Unalakleet (which was not censused in June) had very little suitable habitat, and this is reflected in low densities and populations at both sites.

(ii) Post-Breeding — July. This and the succeeding discussion for August are arranged by species. By July many Norton Sound shorebirds had begun their southward migrations. Wetland sites supported large post-breeding concentrations of shorebirds that were often quite different from breeding concentrations.

Semipalmated Sandpipers were first to leave (See sub-section (b), "Seasonal Use"). In July their numbers decreased dramatically from June (Tables 21 and 22). Stebbins remained the most important area for these birds in Norton Sound. Though the density there was less than that of Koyuk, its larger size supported a larger population of Semipalmated Sandpipers (Table 22). Nearly all of these birds at both locations were juveniles, probably the young of local breeding pairs. By early July most adult birds had left. Safety Sound and the Fish River Delta all contained significant populations of Semipalmated Sandpipers, though they were much reduced from June levels. Brevig Lagoon had a fairly high density but small total population.

Western Sandpipers. Safety Sound was the most important area for Western Sandpipers in July. There were over four times as many as in June, and these were mostly juveniles (94%). These probably came from nearby and inland nesting areas, and possibly from farther north.

Koyuk also had significant numbers of Westerns in July, exceeding the June populations more than eight times. Most were juveniles, often found feeding on the tidal flats. Port Clarence and the Fish River Delta also had fairly sizeable populations of Western Sandpipers in July.

Dunlin. Stebbins also had the greatest number of Dunlin in Norton Sound in July. This population was much smaller than the breeding population, indicating that most birds had already left by mid-July when Stebbins was censused. The 1980 census (16 to 22 July) indicated that adults were slightly more numerous than juveniles. The young, however, are more easily overlooked, particularly before fledging. In 1981 (22 to 29 July) juveniles were twice as numerous as adults.

Koyuk and the Fish River Delta also had sizeable Dunlin populations, though these were far below breeding levels. Most birds appear to have left soon after fledging, and it is possible that some adults, probably females, leave before the young have fledged.

Northern Phalaropes. Stebbins was the overwhelming population center for Northern Phalaropes in July, with over twice as many as in June. These birds were nearly all juveniles and adult males, because the adult females leave early. It is likely that these were all local birds. The population size and composition indicate that in 1980 Northern Phalaropes at Stebbins had a breeding success of 2.6 fledged young per pair of feeding adults. Data for 1981 are not available. By mid-July Northern Phalaropes

Table 22. Shorebird post-breeding populations on Norton Sound wetlands in July and August 1980.[1]

Wetland Areas	Km^2	Semipalmated Sandpiper		Western Sandpiper		Dunlin			Northern Phalarope		Unidentified Small Sandpipers		Total Population	
		July	Aug.	July	Aug.	July	Aug.	Sept.	July	Aug.	July	Aug.	No.	%
Brevig Lagoon	6.6	211	0	92	0	125	13	NC	86	112	0	13	652	0.5
Port Clarence	13.4	228	5	1,072	1,273	147	40	NC	1,300	188	415	670	5,388	4.3
Imuruk Basin[2]	41.0	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	—	—
Woolley Lagoon	6.8	20	53	109	401	34	75	204	129	0	75	510	1,610	1.3
Nome	0.5	5	0	52	7	0	0	0	2	0	4	0	70	0.06
Safety Lagoon	34.6	1,384	35	11,280	3,218	484	1,419	2,526	1,453	727	4,360	1,003	27,889	22.4
Fish River Delta	38.5	616	39	963	154	655	154	847	2,002	732	2,041	1,194	9,397	7.6
Moses Point	49.9	0	0	200	0	250	50	3,393	2,695	1,248	1,597	0	9,433	7.6
Koyuk	61.4	468	0	1,221	36	169	1,792	NC	2,603	1,044	1,244	155	8,732	7
Shaktoolik	51.3	0	NC	0	NC	0	NC	NC	266	NC	0	NC	266	0.2
Unalakleet	14.6	730	0	0	0	0	0	NC	173	0	0	0	903	0.7
Stebbins	169.0	3,211	0	338	169	4,732	845	NC	46,306	1,104	2,028	1,521	60,164	48.3
Totals		6,873	132	15,327	5,258	6,596	4,375	6,970	57,015	5,065	11,764	5,066	124,454	
% of Total Population		5.5	0.1	12.3	4.2	5.3	3.5	5.6	45.8	4.0	9.5	4.0		
% of Total Population July & Aug. Combined		5.6		16.5			14.4		14.9		13.5			

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[1] Data were derived by multiplying mean birds/km^2 at each area in July and August by total area of each wetland (non-shoreline wet tundra habitats only).

[2] Not censused.

were flocking in groups of 100 or more birds. By late July the phalarope populations of Safety Lagoon, the Fish River Delta, Moses Point, and Koyuk were smaller than the breeding populations at those sites. Phalaropes remained in Stebbins later in the year than they did in the more northerly wetlands.

(iii) Post-Breeding — August.

Semipalmated Sandpipers. August shorebird populations were considerably lower than those of June. Very few Semipalmated Sandpipers remained in any area. Those that did were all juveniles and were probably traveling through Norton Sound on their way south from arctic breeding grounds.

Western Sandpiper numbers were also reduced, though not so drastically. They were most numerous at Safety Sound, and the majority were juveniles. Port Clarence also had a sizeable population, showing a marked increase over July. These birds probably came from arctic breeding areas. Koyuk would likely have shown a much larger population if it had been censused in early rather than late August.

Dunlin numbers at Stebbins decreased by 86% from July to August. Most other areas showed a decrease from July, whereas Koyuk maintained a fairly high population, and Safety Sound's Dunlin population increased. These included juveniles and adults, and most were probably from arctic breeding grounds (Holmes 1966b).

Northern Phalarope populations also dropped in August, particularly at Stebbins, where they were only 2% of July's population. Moses Point and the Fish River Delta were the two other major areas for this species in August.

(iv) Post-Breeding — September. In September, Dunlin were the only one of the four common species present in any number. The other three were either totally absent or present in only very small numbers. Dunlin populations actually increased in September due to an influx of birds, probably from arctic breeding grounds. Although only a few areas were censused in September, they all showed significant increases, particularly at Moses Point, with its 50-fold increase. Other areas had three- to seven-fold increases of both juvenile and adult Dunlin. It is likely that both Stebbins and Koyuk (which were not censused in September) experienced a similar influx of Dunlin, and that our total September population estimate for this species is too low.

Our wetland aerial surveys in September indicate that Koyuk had shorebird numbers similar to those of Moses Point, while densities at Stebbins were only half those of Koyuk. The aerial data also indicate that the Fish River Delta had shorebird densities comparable to Moses Point very early in September (Table 23).

Table 23. **Small shorebirds on wetland air surveys in September 1980.**[1]

				September			
Area	2	3	6	10	17	23	29
Port Clarence	202		262				
Imuruk Basin	60						
Woolley Lagoon					1,213		
Safety Lagoon		152		108		14	5
Fish River Delta		386	1,392	40		10	7
Moses Point		795	382	399		103	52
Koyuk		693	354			50	4
Shaktoolik		248				153	176
Unalakleet		0					
Stebbins		80				112	

[1] These data are actual counts from wetland aerial surveys.

To summarize, for the post-breeding distribution of the four common wetland shorebirds in Norton Sound, Stebbins is the most important area in July, mostly due to a very large population of Northern Phalaropes. It also had significant numbers of Dunlin and Semipalmated Sandpipers. Safety Lagoon also had a large shorebird population in July, particularly of Western Sandpipers. The Fish River Delta, Koyuk, and Moses Point were also important wetland areas for migrating shorebirds in July.

In August, Safety Lagoon had the largest shorebird population, consisting mainly of Western Sandpipers and Dunlin. Stebbins, Koyuk, and the Fish River Delta were also important staging areas for shorebirds in August.

By September few shorebirds except Dunlin were left. They concentrated on wetlands and tide flats at Moses Point, Safety Lagoon, and the Fish River Delta. Koyuk and Stebbins probably had significant concentrations of Dunlin in September, but were not censused.

(d) Nesting Phenologies

Many shorebirds deal effectively with the shortness of arctic summers by having a shortened breeding cycle. They often depart within six to eight weeks after their arrival, having successfully raised their young to independence.

All four of the common wetland breeders arrived on the breeding grounds as soon as the snow began to disappear from the tundra. The date of their arrival varies from year to year depending on the weather. Both 1980 and 1981 had relatively early springs, and the first birds arrived around 7 May (Table 20). They formed small flocks at first, gathering to feed in snow-free areas and on melt pond edges. As the snow and ice melted from the tundra the birds dispersed. Aggressive behavior increased as males (females in the case of the phalaropes) established and defended territories. Courtship displays were much in evidence and pair formation occurred a few days after the territories were established. Nesting began within two weeks (and often sooner) of the birds' arrival on the breeding grounds.

(i) Semipalmated Sandpipers. In 1980 the peak laying date for Semipalmated Sandpipers was 5 June (Figure 50). Laying began earlier in 1981, with a peak on 27 May. The average clutch size was 3.6 eggs per nest (38 nests). Semipalmated Sandpipers (and the other three species discussed here) will sometimes re-nest if a clutch is lost or damaged early in the incubation period (Ashekenazie and Safriel 1979). Hatching is generally synchronous, and in 1980 it peaked around 24 June. In 1981 the peak date was over a week earlier, on 16 June. The incubation period is 20 days (Askhenazie and Safriel 1979). The young leave the nest within a few hours of hatching, and like the other three species they are preco-

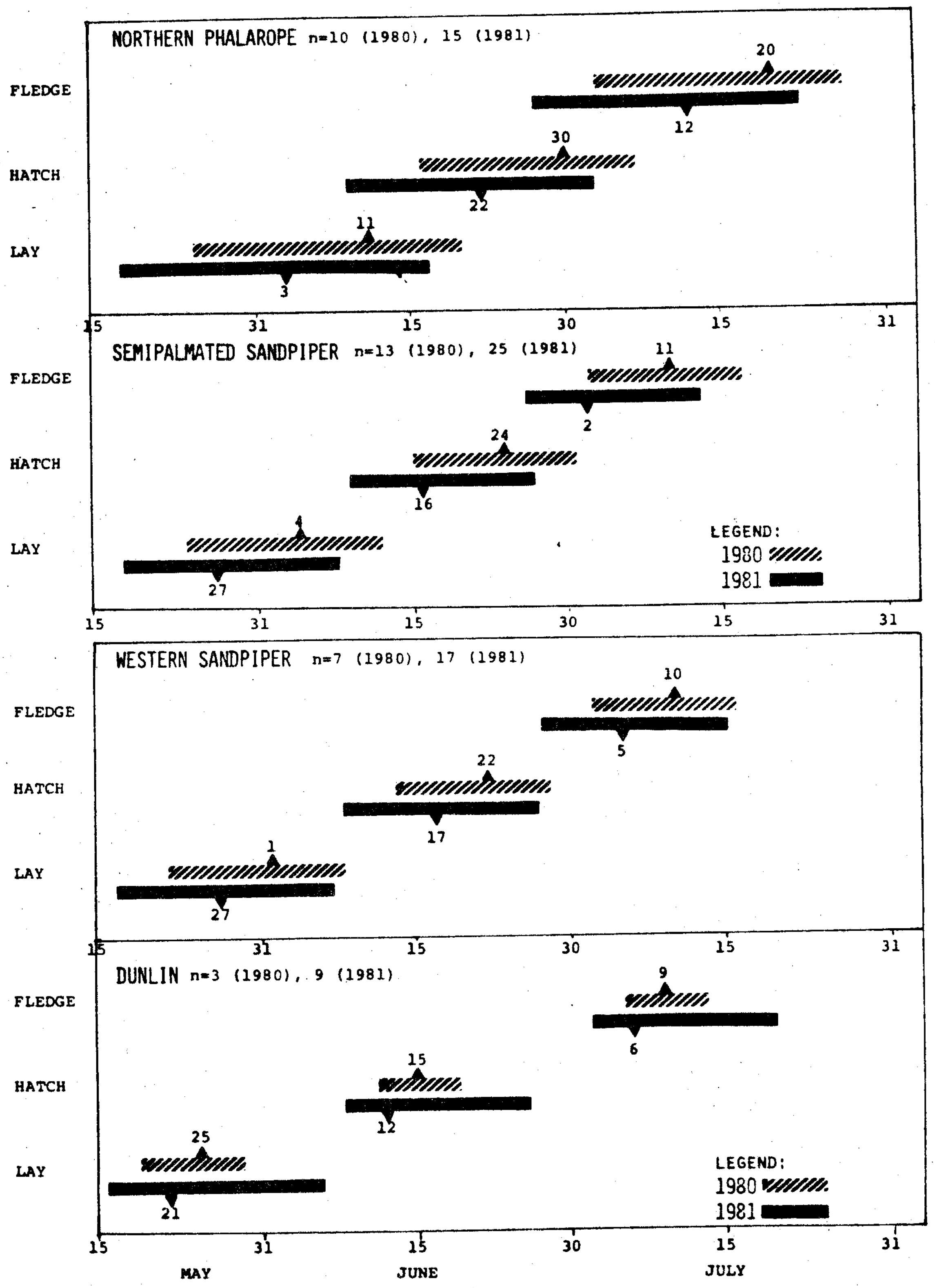


Figure 50. Nesting phenologies of the common wetland shorebirds. Data are for 1980 and 1981. Sample sizes are given in the figure and these are sometimes different from those given in the text for clutch sizes; this is because these data include observations of chicks and fledglings as well as eggs. Overall, shorebirds began nesting earlier in 1981 than in 1980. Semipalmated Sandpipers were the first to complete nesting and phalaropes were the last.

cious. They feed themselves, relying on their parents only for brooding, protection, and being led to good feeding areas. The female generally deserts her brood two to eight days after they hatch, but the male remains until they fledge (Ashkenazie and Safriel 1979). Fledging occurs about 16 days after hatching (Ashkenazie and Safriel 1979). The peak in 1980 occurred on 10 July, while in 1981 it was 2 July. The adults migrate south soon after the young fledge, and the juveniles follow shortly thereafter. By mid-July, few Semipalmated Sandpipers remain in Norton Sound.

(ii) Western Sandpipers. The breeding schedule of Western Sandpipers is similar to that of the Semipalmated Sandpipers. In 1980 their peak laying date was 1 June, while in 1981 it was 27 May. Average clutch size was 3.8 eggs (19 nests). The incubation period is 21 days (Holmes 1972). Hatching peaked on 22 June 1980 and 18 June in 1981. Fledging generally occurs 18 days after hatching (Harrison 1978). It peaked on 10 July in 1980 and 5 July in 1981. After fledging the adults and juveniles form separate flocks. The adults depart soon afterwards for their southern wintering grounds, arriving on California estuaries from early to mid-July. The young depart two to three weeks later and a second wave of Western Sandpipers hits the California beaches in mid to late August (Holmes 1972).

(iii) Dunlin. Dunlin also exhibited a breeding schedule similar to that of Semipalmated and Western Sandpipers, though they began nesting earlier. In 1980 the peak laying date was 25 May. In 1981 the peak date was 22 May, and laying lasted until 6 June. These later dates probably represent re-nesting attempts by birds that lost their first set of eggs (Holmes 1966b). Average clutch size was four eggs (nine nests). The incubation period is 21 to 23 days (Norton 1972). Hatching peaked around 15 June in 1980 and 12 June in 1981. The fledging period averages 21 days (Holmes 1966b), and in 1980 the fledging peak was 9 July, while in 1981 it was 6 July. After fledging Dunlin began to flock. Mixed flocks of adults and juveniles were seen, but generally the two age groups tend to be segregated.

(iv) Northern Phalaropes. Northern Phalaropes have a somewhat different breeding system than that of the three Calidris species discussed above. In this group the female rather than the male has the brightest colored breeding plumage. This role-reversal is also carried over to other parts of the breeding cycle. It is the male rather than the female who does the primary job of incubating the eggs and caring for the precocious young. The females desert soon after the eggs are laid, flock together, and most have left the Norton Sound wetlands by early July.

Northern Phalaropes were the last of the four species to nest, while Dunlin were the first. Dunlin probably lay earlier because they have longer incubation periods, and because they still have fat reserves when they arrive on the breeding grounds that Semipalmated and Western Sandpipers may not have (Senner 1979). Northern Phalaropes may also arrive quite depleted and may need to feed a while before they are able to produce eggs. They nested, on average, a week later than Semipalmated Sandpipers and two weeks later than Dunlin. In 1980 the peak laying date was 11 June (10 nests) while in 1981 it was 3 June (15 nests). The incubation period is about 20 days (Harrison 1978), and hatching peaked on 30 June 1980 and 22 June 1981. Fledging occurs 18 to 22 days later (Harrison 1978), and peaked 20 July 1980 and 12 July 1981. After fledging the male adults and the young formed flocks of up to 200 on tundra ponds. By early August the majority of birds had left Norton Sound wetlands.

3. Uncommon Wetland Breeders

Besides the four common wetland breeders in Norton Sound, there are several other shorebird species which also nest on these wetlands in relatively small numbers. These include Common Snipe, Long-billed Dowitchers, and Black Turnstones (Table 19). A few nesting pairs of Least Sandpipers were also seen, but they are included as an occasional breeder in Norton Sound (see below).

(a) Common Snipe. Snipe were the most common breeder of the three species listed. Although their nesting densities were low, they occurred at most of the 13 wetland sites. They were most common at Nome, where they nested along the marshy banks of tailing ponds. Overall breeding densities for Norton Sound wetlands were 0.8 per km^2. During the breeding season, snipe were often seen displaying above the moist tundra areas of the wetlands. After the young had fledged (mid-July) and during migration, they became more common on wet tundra. Migration was not very noticeable. Snipe rarely occurred in groups of more than four. In the first half of September densities were still similar to breeding densities (0.9 per km^2).

(b) Long-billed Dowtichers. Overall breeding densities for Long-billed Dowitchers were comparable to those of snipe, though their distribution tended to be much patchier. They were commonest in the western parts of the Sound. Many eastern areas had no breeding dowitchers. Breeding birds were found at Imuruk Basin (4 per km^2), Port Clarence (10 per km^2), Safety Lagoon (3 per km^2), and Wales (2 per km^2). Hersey (1917) reported them as abundant breeders at Stebbins, second only to Western Sandpipers. This is no longer true.

Long-billed Dowitchers are typically arctic breeders, and are mainly migrants in Norton Sound. Spring migration was less intense than that of fall, but still quite noticeable. The first migrants were seen on 14 May 1980 at Safety Lagoon. On 15 May we saw a flock of 159 at Unalakleet.

Many dowitchers may pass through the Stebbins area in spring, since large flocks are common during fall migration. We are not able to verify this, since we did not census Stebbins in early spring.

Koyuk and the Fish River Delta also had appreciable numbers of dowitchers during spring migration. These migrants were often found on wet tundra, but were most common in littoral habitats.

Fall migration of adults began in late July. Flocks of 80 to 100 adults were common near Stebbins both years at this time. A later migration of juveniles was of greater magnitude. They began appearing in mid-August and peaked about 7 September. Connors (1978) reports a large movement of juvenile dowitchers through Wales in late August. In 1977 at the Akulik-Inglutalik delta the dowitcher migration peaked on 11 September (Shields and Peyton 1979).

We saw juvenile dowitchers on most of the major wetland areas, though Stebbins, Koyuk, Moses Point, Safety Sound, and the Fish River Delta had the greatest numbers. Imuruk Basin had some large flocks (100 birds) of dowitchers on 5 September. Overall population densities for August (1980) were 12 dowitchers per km^2. September densities were higher, at 16 birds per km^2.

Dowitchers foraged mainly on wet tundra except at Koyuk (this study) where they fed on the mudflats of the exposed wet tundra shore, and at Wales (Connors 1978) where they fed mainly in protected shores with wet tundra. They also commonly fed on the canal mud flats at Stebbins in late August.

(c) Black Turnstones. Black Turnstones nest in coastal areas from Southeast Alaska to Wales. They were common breeders at Stebbins and fairly common at Imuruk Basin. Elsewhere in Norton Sound they were rare to uncommon breeders. At Stebbins breeding densities were 24 birds per km^2, and at Imuruk Basin seven birds per km^2. We suspect that these densities were too high, since Black Turnstones will fly far from their territories to distract intruders. There are probably at least 1,000 Black Turnstones nesting at Stebbins, and more than 100 birds at Imuruk. By mid to late July over 80% of the Black Turnstones (both juveniles and adults) had left Stebbins.

Black Turnstones usually fed along pond edges on wet tundra, but occasionally in littoral areas. Use of shorelines increased during fall migration, and by August nearly all turnstones were feeding in the littoral zone.

4. Upland Breeders

Three shorebird species are regular nesters in raised moist tundra habitats of Norton Sound: Whimbrels, Bar-tailed Godwits, and Golden Plovers. Our data on these species comes from moist tundra near wetlands, and they are probably more common near this edge habitat than on moist tundra far from wetlands.

(a) Whimbrel. Whimbrels were a fairly common feature of the uplands, where they nested among the tussocks. At Imuruk Basin, where they were particularly numerous in late June, they were most common feeding on lagoon beach habitats. Some of these were undoubtedly breeders, but others were in small flocks of up to 35 birds and were probably failed breeders. Moses Point also had a substantial number of Whimbrels in June, and most of these occurred on wet tundra.

In July, Whimbrel densities were similar on both wet and moist tundra sites, with the highest densities at Nome and Shaktoolik. Fewer birds were seen than in June (Figure 52).

August showed the highest densities of any month. This was due to the appearance of fledged young and an influx of birds from other areas. Moses Point had the highest densities, with relatively high densities on the Fish River Delta. Moist and wet tundra densities were similar. Whimbrels on moist tundra in August were often feeding on berries. By September very few Whimbrels remained in Norton Sound, but had begun their southward migration to wintering grounds from southern California to Ecuador.

(b) Bar-Tailed Godwits. Godwits were more common in wetlands than either Whimbrels or Golden Plovers. They were most common at Koyuk wetlands in June. They were not as common in Norton Sound as a whole due to the greater abundance of the other two upland species on the vast stretches of upland tundra.

Although they occasionally nest in raised areas of wet tundra meadow, Bar-tailed Godwits prefer upland tundra slopes. They probably select suitable nesting habitat near wet tundra areas, since they can often be found feeding there during the breeding season. We saw parents with nearly fledged young on the wetlands in mid-July, and it appears that they leave the uplands for wet tundra feeding areas soon after hatching. Our data support this since few godwits were seen on moist tundra habitats in July; most were on wet tundra or shoreline habitats. Densities in July were higher than in June, except at Koyuk. There, the June concentrations were mostly non-breeders that were gone by July.

By August godwits were flocking and overall wetland densities had doubled since July. The highest concentrations were at Moses Point, but Koyuk and Stebbins also had relatively high densities. Wet tundra was the most important habitat in August, though at Safety Lagoon and Moses Point

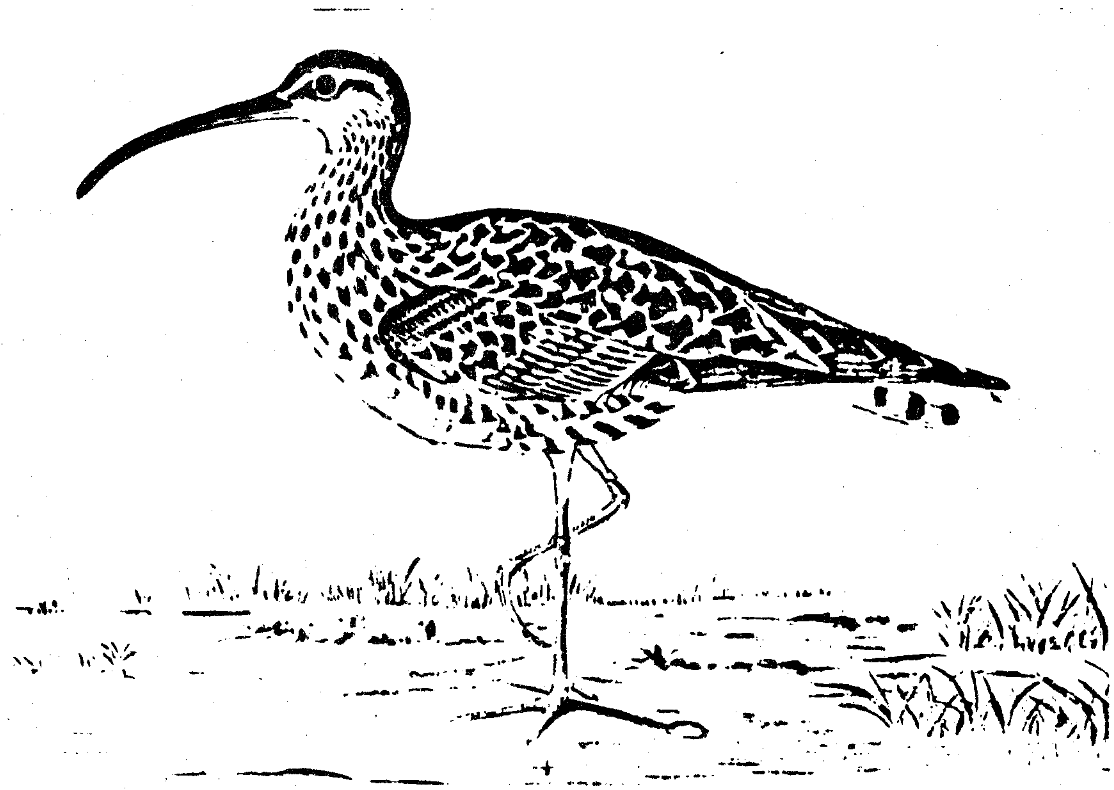


Figure 51. Bristle-thighed Curlew. From Nelson (1887).

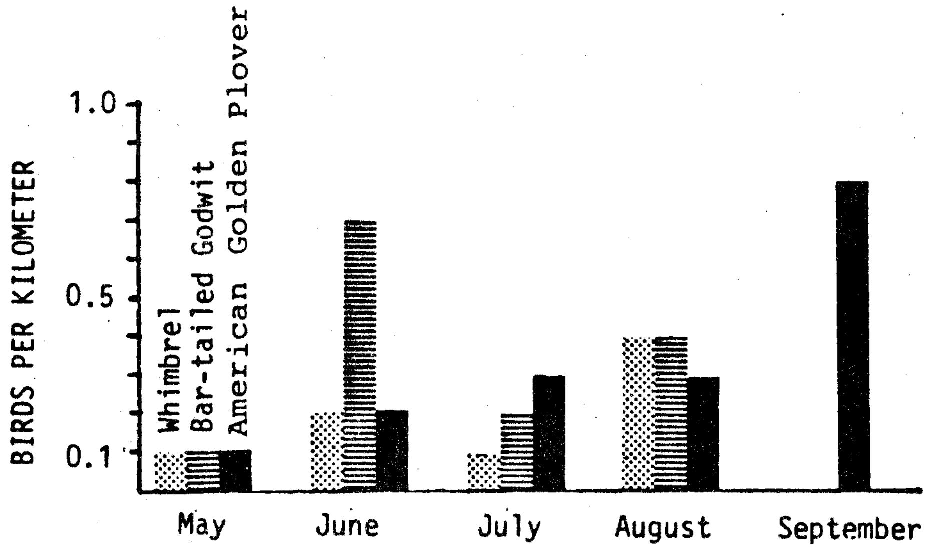


Figure 52. Seasonal abundance of upland shorebirds. Data are from 1980 land surveys primarily in habitats in the vicinity of wetlands. Bar-tailed Godwits reached peak abundance in June, Whimbrels in August, and golden plovers in September.

exposed spit habitats were also important. Hersey (1917) reported large flocks of godwits at Stebbins in August, feeding on muddy canal banks. We noted mixed flocks of juveniles and adults feeding in the same areas. At the Akulik-Inglutalik Delta, Shields and Peyton (1979) recorded a sporadic migration from 15 August to 12 September 1976. By September in our study years, only a few Bar-tailed Godwits remained. The rest had begun their migration to the South Pacific.

(c) American Golden Plover. Golden Plovers are also an upland breeder, yet they are quite different from the Whimbrel and Bar-tailed Godwit in that they prefer the dry tundra slopes, areas often covered by gravel and lichens (Sauer 1962).

Plovers arrived in early to mid-May. Few areas were censused in May, and of these Woolley Lagoon had the highest densities. We found them on both moist and wet tundra, though more commonly on moist tundra in small feeding flocks in early May. It is likely that they were feeding on the previous year's crop of Lingonberries (Vaccinium vitis-idaea) and crowberries (Empetrum nigrum). They frequented the wet tundra in May once the snow and ice had melted.

By June plovers had begun nesting and displays were frequently heard in some areas. Their densities were highest in upland tundra areas, but were only slightly lower on wet tundra where they could be found feeding. Nome had the greatest density of Golden Plovers, and densities at Woolley Lagoon were also relatively high. We also noted high densities of Golden Plovers along inland roads heading north from Nome towards the mountains.

In late June the young plovers begin to hatch and the overall density increase in July reflects this. Although there are still many plovers on the upland sites in July they begin deserting the nesting areas for areas with higher prey densities (Sauer 1962). We found plovers using both wet tundra and lagoon shorelines in July. The male plovers (and possibly the females) begin molting during incubation and by mid-July are in "eclipse" plumage, looking much like the drabber females (Sauer 1962).

In August the overall density for the Sound is the same as in July, but habitat use has changed. Many birds have moved down from the uplands onto wet tundra and shoreline habitats. This includes both fledged juveniles and adults. Moses Point had the highest density and largest population of plovers in August. It appeared to be the most important staging area for plovers nesting in the Norton Sound region. Most of the adults, and probably many of the juveniles, leave Norton Sound in August.

In late August and early September the area experiences an influx of plovers from arctic breeding grounds and these were mostly, if not all, juveniles. They were common in flocks of three to 30 birds on the canal mud flats and wet tundra at Stebbins in late August. Woolley Lagoon had the highest September densities (120 per km^2).

5. Occasional Breeders

Several species of shorebirds nested in Norton Sound coastal areas in small numbers. These included Solitary Sandpipers, Lesser Yellowlegs, Semipalmated Plovers, Ruddy Turnstones, and Black-bellied Plovers. Bristle-thighed Curlews and Spotted Sandpipers are probably breeders. The Semipalmated Plovers and Lesser Yellowlegs were most common around Nome. Yellowlegs, in particular, seemed to prefer the tall shrubs growing near old tailing piles which are common in the vicinity of Nome.

Bristle-Thighed Curlews were uncommon to rare everywhere in Norton Sound, but most (seven) were seen at Imuruk Basin. These prefer dry exposed ridges as nesting sites (Gabrielson and Lincoln 1959), and probably nest in interior Seward Peninsula.

Solitary and Spotted Sandpipers were uncommon within a few miles of the coast, but probably nest on many of the river drainages in the region. Black-bellied Plovers were uncommon nesters in the uplands.

6. Migrants

Apart from their importance as breeding sites for many shorebirds, the Norton Sound wetlands are also important as feeding and staging areas for migrating shorebirds. Table 20 lists the shorebird species we saw during migration in Norton Sound wetlands. Some species pass through in very small numbers, whereas others exhibit very noticeable migratory movements, with larger fluctuations in population occurring over a short period of time. The migratory movements of most species that breed in Norton Sound have been discussed. This section's emphasis is on migrants that do not breed in significant numbers in Norton Sound. Of these species, those that occur in the greatest numbers are the Pectoral Sandpiper, the Sharp-tailed Sandpiper, and the Red Phalarope.

(a) Pectoral Sandpiper. Except for the four wetland breeders discussed previously, Pectoral Sandpipers were the most common migrant shorebird in Norton Sound. Although never abundant, they were quite common on wet tundra in many wetlands during both spring and fall migrations. They mainly breed along the arctic coast of eastern Siberia, the western and northern coasts of Alaska from Bristol Bay to the Canadian border, and along much of the Canadian arctic coast. We found them nesting at Wales and in small numbers at Brevig Lagoon. They probably nest occasionally in other areas of Norton Sound. Hersey (1917) reported them as a rare breeder at St. Michaels.

We first spotted Pectoral Sandpipers on 12 May 1981. Peak migration was from 26 to 29 May, and at the Fish River Delta these were mostly females. During both spring and fall migrations, most (90%) of the Pectorals were on wet tundra, but about 10% were in shoreline habitats. These habitat use patterns may vary from year to year. Connors (1978) reports that in 1977 Pectoral Sandpipers at Barrow made extensive use of littoral habitats during the July migration. In 1975, however, littoral habitats were seldom used by Pectorals at Barrow. At Wales, in 1977 he reported high Pectoral densities in littoral areas, particularly in July.

Pectoral Sandpipers usually reach the North Slope the first week of June. Males begin heading south at the end of June after the females are on eggs, and most are gone from the breeding grounds by 15 July (Pitelka 1959). They first appeared in Norton Sound on 2 July 1980. These early arrivals are probably males, since most females do not begin to leave the breeding grounds until the end of July (Pitelka 1959). In Norton Sound peak numbers in fall occurred from 25 August to 9 September in both years. These were probably juveniles, since most females have left the breeding grounds by 10 August. The young begin leaving by the end of August, and their migration continued until 14 September (Table 20). The fall migration is larger than in the spring, due to the summer's production of young.

(b) Sharp-tailed Sandpipers. Sharp-tailed Sandpipers are very rare spring migrants in western Alaska (Kessel and Gibson 1978). They also list it as a rare to uncommon fall migrant, but we found it to be fairly common in the fall in many Norton Sound coastal areas. They nest in northern Siberia, and the birds that move down the Alaskan coast in the fall are juveniles. The adults migrate down the Siberian coast.

The first Sharp-tails appeared on 2 August 1980. All birds observed were juveniles. They continued to move through singly or in small flocks until at least 13 September. All birds were on wet tundra and we found the greatest concentrations of Sharp-tails at Stebbins. Connors (1978) reported a fairly heavy movement of juveniles through Wales, peaking in late August and early September. Here they foraged on both tundra and littoral areas.

(c) Red Phalaropes. Red Phalaropes occurred in greatest numbers in coastal Norton Sound as a spring migrant. It is also a common breeder at Wales, and an uncommon one at Brevig Lagoon. It has been reported as nesting at St. Michael (Gabrielson and Lincoln 1959) and Cade (1950) lists it is as a common breeder on St. Lawrence Island. This species, however, is primarily an arctic breeder.

The spring migration of Red Phalaropes was mainly along the coast from Safety Lagoon to Wales. A few were seen at Stebbins and Shaktoolik. We saw the first Red Phalaropes on 30 May at Point Clarence. The peak of migration was on 4 June when several thousand birds were seen at Safety Lagoon. Most were feeding or resting within 100 meters of the shoreline of the Sound, and some were in the lagoon. These birds winter at sea and it is likely that many Red Phalaropes passed by farther offshore. This is evidently the case in the fall, when we saw no Red Phalaropes along the coast. Drury (1976) saw a few in mid-September feeding in the surf off Bluff.

(d) Other Species. Several other species of shorebirds migrate through Norton Sound coastal areas in smaller numbers. These include Hudsonian Godwits, Ruddy Turnstones, Baird's Sandpipers, Red Knots, Rock Sandpipers, Sanderlings, Wandering Tattlers, Rufous-necked Sandpipers, Surfbirds, and Buff-breasted Sandpipers. Some of these species nested in small numbers in the Norton Sound Region (See Appendix 26). The last four species listed were rare migrants in Norton Sound, while the rest were uncommon migrants. Most of these species used littoral habitats during their migration through the region. Hudsonian Godwits also made use of wet tundra habitats. Many of these species were most common along the coast from Wales to Nome.

I. Jaegers

Seasonal Abundance, Habitat Use, and Geographic Distribution

Three species of jaegers are found in Norton Sound, though only Parasitic (54% of land observations) and Long-tailed Jaegers (44%) nest there. Pomarine Jaegers (2%) were fairly common spring migrants and were occasionally seen in the fall, but they nest farther north. All three are predators and pirates feeding on a variety of items, including birds and bird eggs, small mammals, and insects, as well as stealing prey from other birds. We also saw them scavenging fish scraps near villages and fish processing plants. Parasitic Jaeger pairs work together in hunting small birds. Their diet consists of more birds than that of other jaegers, possibly because this cooperative hunting makes them more successful at capturing them (Maher 1974).

Pomarine Jaeger spring migration peaked the last few days of May in both 1980 and 1981. Parasitic and Long-tailed Jaegers arrived 7 May and 9 May, respectively, in 1981, and they were fairly common by 15 May.

Parasitic and Long-tailed Jaeger densities peaked in June (0.6 per square kilometer; data are from 1980 land surveys). They were most abundant at Stebbins (0.13 birds per km^2), Shaktoolik (0.07 birds per km^2), and Moses Point (0.06 birds per km^2). Densities were highest on moist tundra since both species usually nested there. They also hunted on moist tundra, and commonly patrolled wet tundra and shorelines. A few fledged young were seen in mid-July (both years) and by the end of the month most young had fledged. In mid-August jaegers were still fairly common in many areas, but by the end of the month few remained.

J. Gulls

Gulls were the most common birds along shorelines (51% not including sea cliff birds, shoreline aerial surveys; see Section A, "All Birds") though they were less common on wetlands (9% on shoreline aerial surveys). Nearly all were Glaucous Gulls, although there were small populations of Mew, Glaucous-winged, Herring, Sabine's, and a few Slaty-backed Gulls (Table 24). Only Glaucous, Mew, and Sabine's Gulls nest in Norton Sound, and these will be discussed further. Black-legged Kittiwakes were most abundant at cliff colonies and much less common at other Norton Sound coastal habitats.

Glaucous-winged and Herring Gulls were not regularly seen in either year until late July and August, and many of these were immatures congregating near Nome and Unalakleet. Both species nest to the south, and those in Norton Sound were exploiting seasonally abundant foods, notably spawning salmon.

1. Glaucous Gulls

The large, pale Glaucous Gull is the most common gull of northwestern and arctic Alaska. In Norton Sound it was by far the most numerous of any gull species, and in fall composed a major part of the avifauna. In Alaska it nests from Demarcation Bay to Bristol Bay, and although primarily coastal, some pairs nest on ponds far inland (Gabrielson and Lincoln 1959). Nesting sites in Norton Sound include: (1) single pairs on tundra ponds, (2) colonies of up to 100 pairs on islands or peninsulas in large wetland ponds, (3) single pairs or colonies of up to 50 pairs on cliffs adjacent to seabird colonies, and (4) in groups of a few to a dozen pairs on smaller cliffs (Drury 1980).

Many of the adult plumaged Glaucous Gulls in Norton Sound appear to be non-breeders. Glaucous Gulls do not usually raise chicks to fledging until the adults are at least six years old, probably because of the importance of learned behavior in successfully exploiting food resources. Thus a small percentage of adults raise the majority of the young in any given year (Drury 1980).

(a) Habitat Use. Shoreline aerial surveys showed river mouths and exposed cliffs had the greatest concentrations of Glaucous Gulls (Figure 53). River mouths were important feeding areas and had large concentrations in late fall. They were also one of the first areas where openings formed in early spring and attracted flocks of gulls then. River deltas were important nesting areas, and were also used as feeding areas. The remaining shoreline habitats, particularly on exposed coasts, were frequently used by gulls as feeding and roosting sites. Glaucous Gulls appeared to be more common on shorelines at low tides, as Strang (1976) observed on the

Table 24. Relative abundance of gulls, 1980.

Species	Shoreline Aerial Surveys (%)[1]	Land Surveys (%)[2]
Glaucous Gull	98.8	75.7
Mew Gull	1.0	17.0
Glaucous-winged Gull	0.1	4.7
Sabine's Gull	< 0.1	1.7
Herring Gull	0.1	0.9
Slaty-Backed Gull	< 0.1	< 0.1
Total	100.0	100.0

[1] Shoreline aerial surveys covered all coasts.

[2] Land surveys were concentrated near wetlands and do not represent abundance on all coasts.

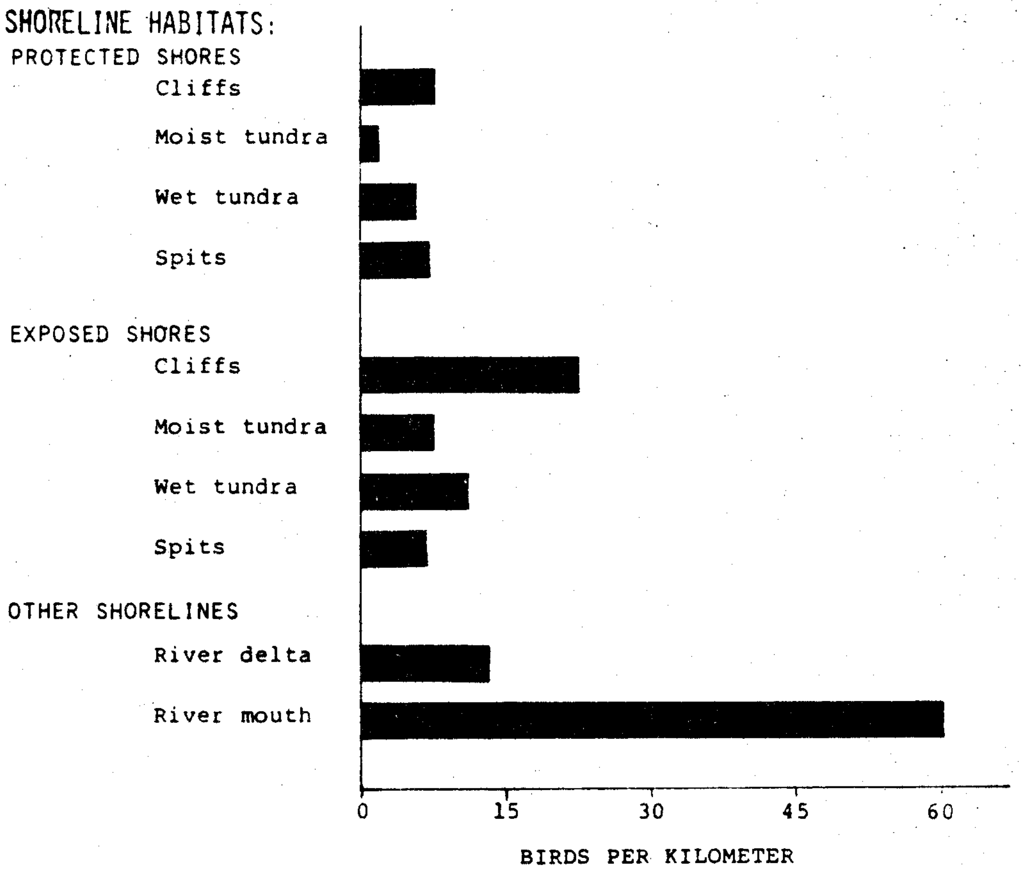


Figure 53. Habitat use by Glaucous Gulls. Data are from 1980 shoreline aerial surveys. River mouths had large concentrations because these areas opened up early in spring and because in late summer gulls gathered there to feed on spawning salmon. Exposed cliffs were favored nesting sites for Glaucous Gulls; many also nested on river deltas.

Y-K Delta. Glaucous Gulls also tended to concentrate at lagoon outlets, village dumps, fish camps, and fish processing plants. During salmon runs many Glaucous Gulls followed the spawning fish upstream.

(b) Seasonal Use. Variations in seasonal abundance of Glaucous Gulls in coastal Norton Sound are shown in Figure 54. Shoreline aerial surveys and coastal land surveys show a rise in population density from May to June, due to a continued influx of gulls into the region. Some of these were probably heading north to the arctic. Coastal densities (aerial surveys) dropped in July, and this is due mostly to movements inland from the coast, particularly of gulls following salmon upstream, and is partly due to the departure of northbound migrants. A further decrease in August may be due to a movement out of the Sound as well as to more gulls heading up streams. Densities climbed again in September with breeders and young of the year moving to the beaches. Many Glaucous Gulls moved into Norton Sound as northerly areas became ice covered. The greatest gull densities were seen on 27 October 1980, the latest census date.

The tundra land transects show a relatively stable population of gulls throughout the breeding seasons. Michelson (1979) noted a similar pattern for the Cape Espenberg area.

(c) Geographic Distribution. In 1980 the eastern part of the north coast from Cape Nome to Cape Darby had the greatest density of Glaucous Gulls (Figure 55). This coastal strip includes important breeding sites on cliffs at Bluff, Topkok, Square Rock, and Rocky Point. It also contains many suitable tundra nesting sites, the Safety Lagoon entrance, where gulls gather to feed and roost, and numerous salmon runs.

The northeast coast of the Sound from Koyuk to Tolstoi Point also had large gull densities, due to good wetland nesting habitat on the Koyuk and Akulik-Ingutalik Deltas. The town of Koyuk, various fish camps, and numerous salmon runs attract gulls, particularly sub-adults, to the area. Unalakleet and Shaktoolik also attract gulls with their dumps and fish processing plants.

The high densities for Golovin Bay are mainly due to concentrations in late October. Without the October data densities there drop to 5.3 birds per km. In October we only censused part of the coast and areas west of Nome and east of Koyuk do not include October densities.

The densities for Stuart Island are for June only, when gull densities are relatively high and comparisons between Stuart Island and other areas are not possible.

(d) Nesting Phenology. Glaucous Gulls follow the opening ice leads, arriving in Norton Sound in late April (Bent 1921; Bailey 1948).

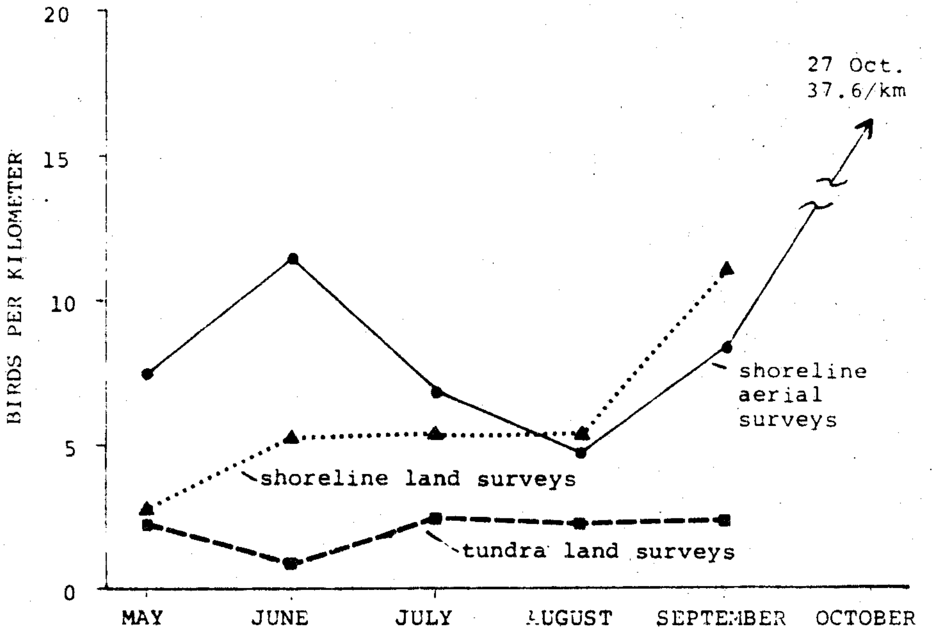


Figure 54. Seasonal abundance of Glaucous Gulls. Data are from two survey methods in 1980. The drop in gull densities along shorelines (censused by air) is due to sub-adult gulls moving up streams to follow spawning salmon. The land surveys do not show this because they were made near wetlands where many of the gulls are tied into the nesting effort. The rise in September and October shows the influx of arctic birds into the Sound as arctic areas became ice-covered.

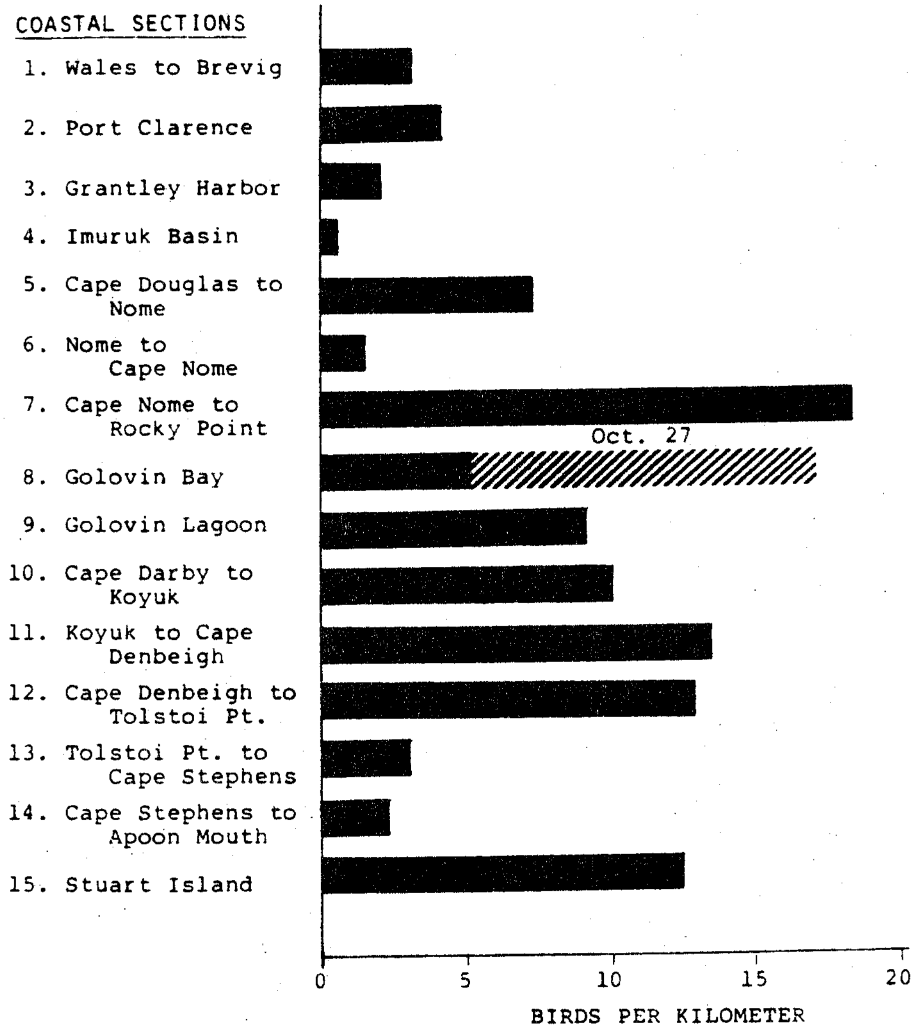


Figure 55. Geographic distribution of Glaucous Gulls. Data are from 1980 shoreline aerial surveys. Northeastern Norton Sound had the most gulls (from Cape Nome to Tolstoi Pt., sections 7 to 12). This is mostly due to the presence of salmon spawning streams and fish processing plants. High gull densities on 27 October were found on a census from Nome to Koyuk, particularly at Golovin Bay. Sections other than 7, 8, and 10 were not censused and thus do not include October data.

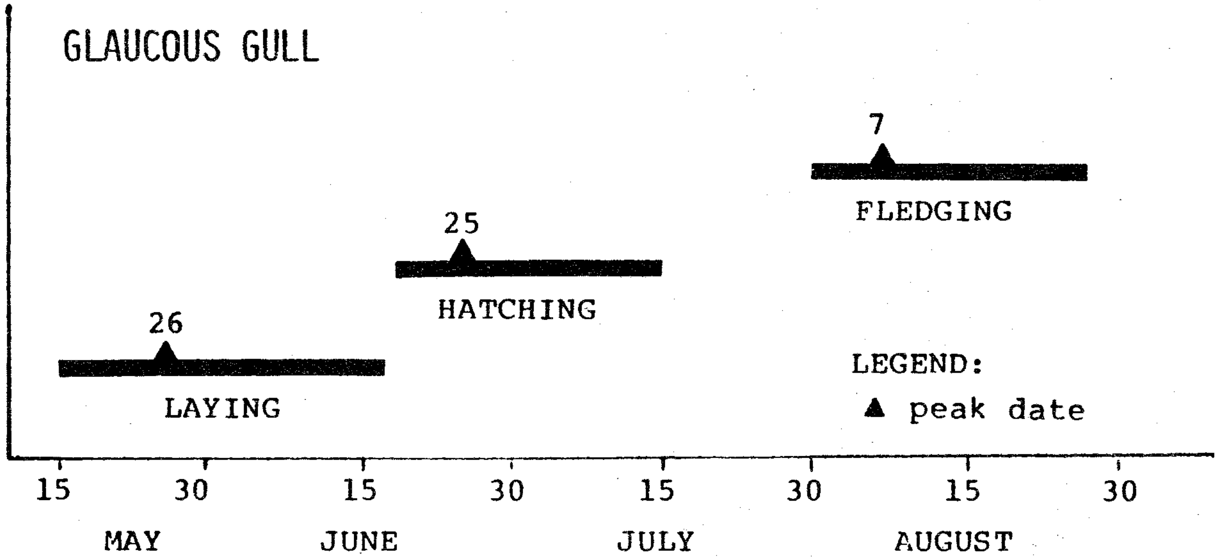


Figure 56. Nesting phenology of Glaucous Gulls on Norton Sound wetlands. Data are from 9 nests in 1980 and 20 nests in 1981.

The phenology data in Figure 56 were collected from gulls nesting at wetland sites. At such sites Glaucous Gulls usually nest on islands or peninsulas in large tundra ponds. Island nest sites are preferred, probably because of the protection they provide against fox predation (Larson 1960; Strang 1976). Many occupy their previous year's territories even before the snow has left the tundra (Strang 1976).

Nesting data from both 1980 (nine nests or observations of chicks) and 1981 (20 nests or observations of chicks) were combined, since breeding phenologies were similar in both years. The peak laying date was 27 May. The incubation period ranges from 22 to 28 days (Strang 1976), and peak hatching was about 25 June. The average clutch size for 15 nests was 2.3 eggs, slightly less than the mean clutch size of 2.7 found on Y-K Delta sites (Strang 1976). The first fledgling was seen on 30 July, and fledging peaked about 7 August.

(e) Food Habits. Glaucous Gulls are generalists in their diet. Drury (1980) reports that in Norton Sound Glaucous Gulls feed on such items as the eggs and young of other birds, dead salmon, walrus carrion, salmon and herring eggs, and berries. Although we collected no gulls, we noted them feeding on similar items. We also found them concentrating near villages and fish processing plants to feed on garbage and fish scraps. Strang (1976) reports that at Kochekik Baby (Y-K Delta), Glaucous Gulls fed primarily on fish, particularly tomcod (*Eleginus gracilus*). Further inland at another Y-K Delta site birds were the main food items. At both sites Glaucous Gulls are usually the main non-human waterfowl egg and chick predator (in some years foxes were). Although the gulls tended to concentrate on certain food items (probably according to their abundance), Strang (1976) found that they ate a wide variety of items, including marine and terrestrial invertebrates, eggs and chicks of small birds, and small mammals.

It is likely that Glaucous Gull diets in Norton Sound are similar to those of the Y-K Delta, at least in the range of items taken if not in the proportions of various foods. Fewer waterfowl eggs and chicks are probably taken, since nesting densities of waterfowl are generally lower in Norton Sound than on the Y-K Delta (see Section C, "Waterfowl"). Nevertheless, Glaucous Gulls are probably the major avian predators of the eggs and young of nesting birds in Norton Sound.

(f) Population Increase. A noteworthy aspect of Glaucous Gull populations in Norton Sound (and elsewhere in the northern Bering/southern Chuckchi areas) is the large number of birds in immature plumage. Drury (pers. comm.) has suggested Glaucous Gulls in these areas may be beginning or have already commenced a population outburst similar to that of the Herring Gull in the North Atlantic. Kadlec and Drury (1968) estimate that the Herring Gull population there has been doubling every 12 to 15 years since the early 1900's, with the exception of the 1940's.

Although we did not always record gull ages on aerial surveys, this was consistently done on land transects in 1980 (Table 25). Our data for August and September 1980 (when young are fledging or already fledged) shows the following age structure: 55% adult, 30% immatures, and 15% juveniles (young of the year). Drury's data (pers. comm., Table 25) from shoreline aerial surveys flown from 1975 to 1978 from Port Clarence to Tolstoi Point (Wainwright to Tolstoi Point in 1978) show more adults, with ranges from 65% to 88% adults, 7% to 23% immatures, and 5% to 14% juveniles. These had an average of 74% adults, 18% immatures, and 8% juveniles.

A comparison of the two sets of data (Table 25) suggests an increase in the numbers of immatures since 1978 and a productive season for Glaucous Gulls in 1980, though there are other factors which may account for the differences in the two sets of data. Our data were collected on land on both tundra and shoreline transects at wetland sites. Drury's data are from shoreline aerial surveys, and there may be fewer young along the coast. We cannot use our aerial shoreline data to support this, as our age data are not complete for air surveys. In addition, Drury noted certain limitations on his data: the low juvenile count in 1978 (6%) was possibly due to censusing in mid-August before the juveniles had moved to the beaches, and the low counts of sub-adults in 1977 (7%) may be due to a lack of age data from the coast between Koyuk and Unalakleet where sub-adults are typically common.

The percentage of immatures in both sets of data indicate good reproductive success and recruitment into the population. Without other parameters such as the survival rate of adult Glaucous Gulls in Alaska, it would be impossible to predict with confidence the status of this population, but both Drury's estimate for juveniles (8%) and ours (19%) indicate a growing population. The 18% to 25% of immatures particulary suggests that the northwestern population of Glaucous Gulls is growing, since this indicates both reproductive success and survival over a period of several years.

Human activities may be largely responsible for these changes as they were in the case of Herring Gulls. Garbage dumps and fish processing wastes supply abundant food for scavenging gulls all summer. Bering Sea fisheries provide additional food for gulls at other times. Increased food availability is almost certainly the cause of the decreased mortality of subadult birds.

Table 25. Glaucous Gull population age structues, with comparative data on Herring Gulls.

Glaucous Gull[1] (Western Alakska)	1980 No.		1978 No.		1977 No.		1976 No.		1975 No.		Average 1975-1978 No.	
Adults	1,007	55%	3,652	70%	2,420	88%	1,385	65%	392	71%	7,849	74%
Immatures	544	30%	1,211	23%	196	7%	440	21%	83	15%	1,930	18%
Juveniles	276	15%	329	6%	139	5%	300	14%	79	14%	838	8%

Herring Gull[2] (Atlantic Coast, U.S.A.)	No.	
Adults	426,000	68%
Immatures	105,000	18%
Juveniles	91,000	15%

[1] 1980 data are ours, from land surveys; 1975-1978 data are Drury's (pers. comm.), from shoreline aerial surveys; see text for explanation.

[2] Kadlec and Drury (1968).

2. Mew Gull

Mew Gulls were a common sight in summer along the beaches and wetlands of Norton Sound, though they were not nearly as abundant as Glaucous Gulls (Table 24). Their breeding range in Alaska extends from Kotzebue Sound to southeastern Alaska at both coatal and inland sites. In coastal Norton Sound they usually nested in wetlands near pond edges. We found the highest densities in the Northeast Sound on the wet tundra near Unalakleet (1.9/km), Koyuk (1.5/km), and Moses Point (1.8/km, data from 1980 land surveys). Overall, densities were highest in July, when the young were fledging. After fledging they gathered at river deltas and around river mouths. Strang (1976) noted Mew Gulls feeding on fish, marine invertebrates, and small mammals on the Y-K Delta, and suggested that indirect competition for food may exist between Mew Gulls and Glaucous Gulls in western Alaska.

3. Sabine's Gull

Sabine's Gull constitutes a small but interesting part of the Norton Sound avifauna. This diminutive, dark-headed gull breeds along the arctic coast of Alaska, south to Bristol Bay, as well as in other arctic regions. Its winter distribution is poorly known, though it is common along certain parts of the Peruvian coast in the winter (Godfrey 1966). It migrates well offshore on its way down the Alaska coast (Gabrielson and Lincoln 1959).

Sabine's Gulls nest on wet tundra, and 97% of those we saw on land surveys were in that habitat. They are characteristic birds of salt-washed tundra (Kessel 1979).

We found Sabine's Gulls nesting near Wales, Koyuk, and Stebbins though it was not common in any of these localities (Table 26). It probably also breeds in low numbers on the south side of Port Clarence. The Stebbins-St. Michael area had the largest population of Sabine's gulls in Norton Sound (though the Y-K Delta is a more significant population center for this species). The population here was once larger. Nelson (1887) reports the Sabine's Gull to be the most numerous gull at St. Michael's, which is certainly no longer true. He also mentions finding a colony with more than one hundred birds in it. This decrease in numbers since Nelson's time may indicate a population decrease or it could signify that Sabine's Gulls, like Aleutian Terms, move their colony sites frequently.

Gabrielson and Lincoln (1959) report that Sabine's Gulls arrive in the southern Sound the first week of May. Our earliest sighting was 6 May 1981. Nesting began in late May, and most birds finished laying by 7 June. They occasionally nest as single pairs, but usually form small colonies. The incubation period has been variously given as 21 days (Godfrey 1966) and 23 to 26 days (Harrison 1978). Hatching begins around mid-June with a

Table 26. Sabine's Gull sightings in Norton Sound, 1980 and 1981.

Wetland Site	Number or Density	Date	Comments
Port Clarence	2	29 May 1980	Probably at least 1 breeding pair.
	1	3 June 1980	
	1	3 June 1981	
	2	30 June 1980	
	3	4 July 1980	
	4	16 August 1980	
Woolley Lagoon	2	16 August 1980	Migrants.
Nome	1	17 June 1980	Migrant.
Safety Lagoon	2	24 May 1981	Migrants.
Fish River Delta	10	18 May 1981	Migrants.
	1	8 June 1981	
Koyuk	14	18 May 1981	Probably at least 2 breeding pairs in 1980, 1 in 1981.
	2	24 May 1981	
	1	8 June 1981	
	5	9 June 1980	
	3	16 July 1980	
	2	24 July 1980	
Moses Point	2	18 May 1981	
Shaktoolik	4	10 June 1981	
Stebbins	4	6 May 1981	A fairly common breeder at Stebbins. These began leaving about mid-July and by the end of July few remained.
	1.3/km	9 June 1981	
	1.4/km	20 June 1980	
	0.9/km	18 July 1980	
	10	25 July 1981	

fledging period of only 20 days (Michelson 1979). Most young were fledged by mid-July. After fledging, the young and adults leave the breeding grounds for the beaches, and leave the area shortly thereafter. By the end of July there were no juveniles left at Stebbins and few adults. Michelson (1979) reports a similar exodus around the end of July from Cape Espenberg.

4. Black-legged Kittiwake

This gull is a common species in the Norton Sound region, with major nesting colonies on St. Lawrence Island and at Bluff, and smaller colonies elsewhere in the Sound. Total population for Norton Sound colonies is 11,265 (Sowls et al. 1978). Adults feed primarily offshore, and of the 22,00 kittiwakes we saw in coastal areas away from nesting cliffs, 80% were along exposed shores on spits (land surveys, 1980 and 1981). Further information on this species can be obtained from Drury (1980), who has made intensive studies at the Bluff colony.

K. Terns

1. Arctic Terns

Arctic Terns are common nesters in coastal and interior Alaska, and are familiar because of their aggressiveness near their nests. They are perhaps most famous for their arctic to antarctic migration of up to 40,000 kilometers each year. They generally nest in small colonies or isolated pairs, though colonies of over 100 pairs have been reported (Bailey 1948). We found them nesting in groups as large as eight pairs. The nest is a small hollow in grass, sand, or gravel. In coastal Norton Sound it is generally found on spits, beaches, islands, or wetlands near a lake or pond. They feed primarily on small fish and invertebrates in coastal inshore waters or in tundra ponds.

(a) Habitat Use. We found that spit habitats had the highest densities of Arctic Terns, with the sea side receiving greater use than the lagoon side (Figure 57, land survey data). These were important feeding areas all season, and many Arctic Terns also nested high on the spit among Elymus or other vegetation as well as on open gravel above the tide line. Wet tundra and lagoon beaches backed by wet tundra were also important as both nesting and feeding sites. Though wet tundra densities were lower than those of spit habitats, wet tundra was more extensive and supported a greater number of terns. Many terns which nested on tundra fed in marine habitats. Shoreline aerial censusing showed concentrations of terns around river mouths, particularly in June (3.6/km).

(b) Seasonal Use. Figure 58 illustrates the seasonal abundance of Arctic Terns with some indications of habitat use. Arctic Terns were first observed on 12 May 1980 and on 19 May 1981; the peak arrival time was 21 to 27 May of both years. The birds arrived with no indication of a coastal onshore migration, and may have come overland. Tundra transect data show a descending trend from high density in May to no birds in September. May densities are probably highest due to an influx of both local breeders not yet dispersed to breeding sites and terns headed for arctic or inland sites. The high June density for beach transects was due to large concentrations of terns on spit habitats at Safety Lagoon. These may have been non-breeders, as well as breeding terns coming from distant nesting areas to feed, mostly on small fish such as Sandlance (Ammodytes hexapterus). In general, June densities were lower than those of May.

Despite the production of young, July densities also dropped from June, perhaps because failed breeders and some adults with fledged young had already left. August densities decreased further from July due to the departure of young and adult birds. By September, Arctic Terns were quite rare.

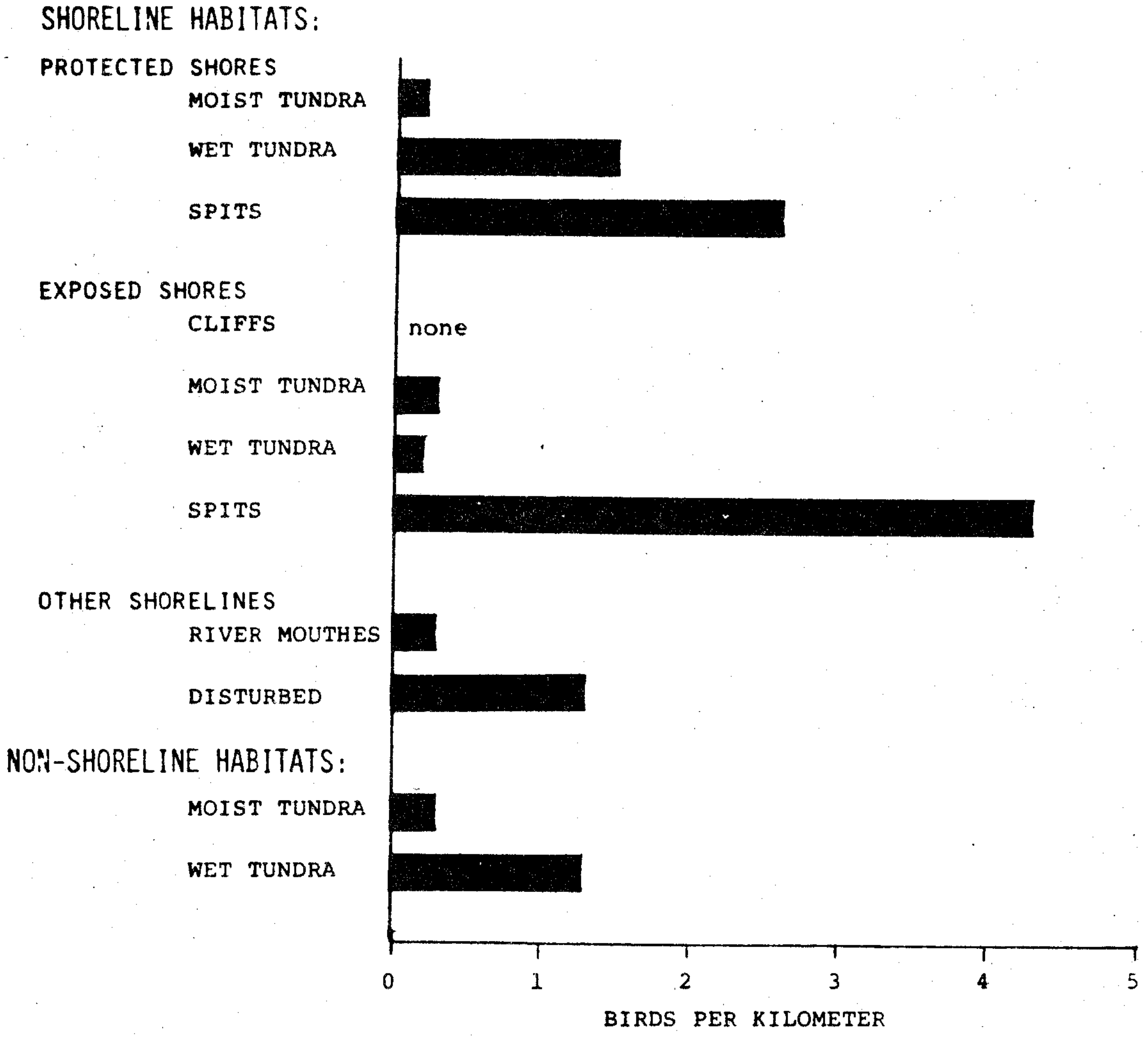


Figure 57. Habitat use by Arctic Terns. Data are from 1980 land surveys. Of the shoreline habitats, spits were the most heavily used; these provided nest sites as well as feeding areas near lagoon entrances. On the tundra (non-shoreline) wet tundra was used more than moist tundra for nesting and feeding.

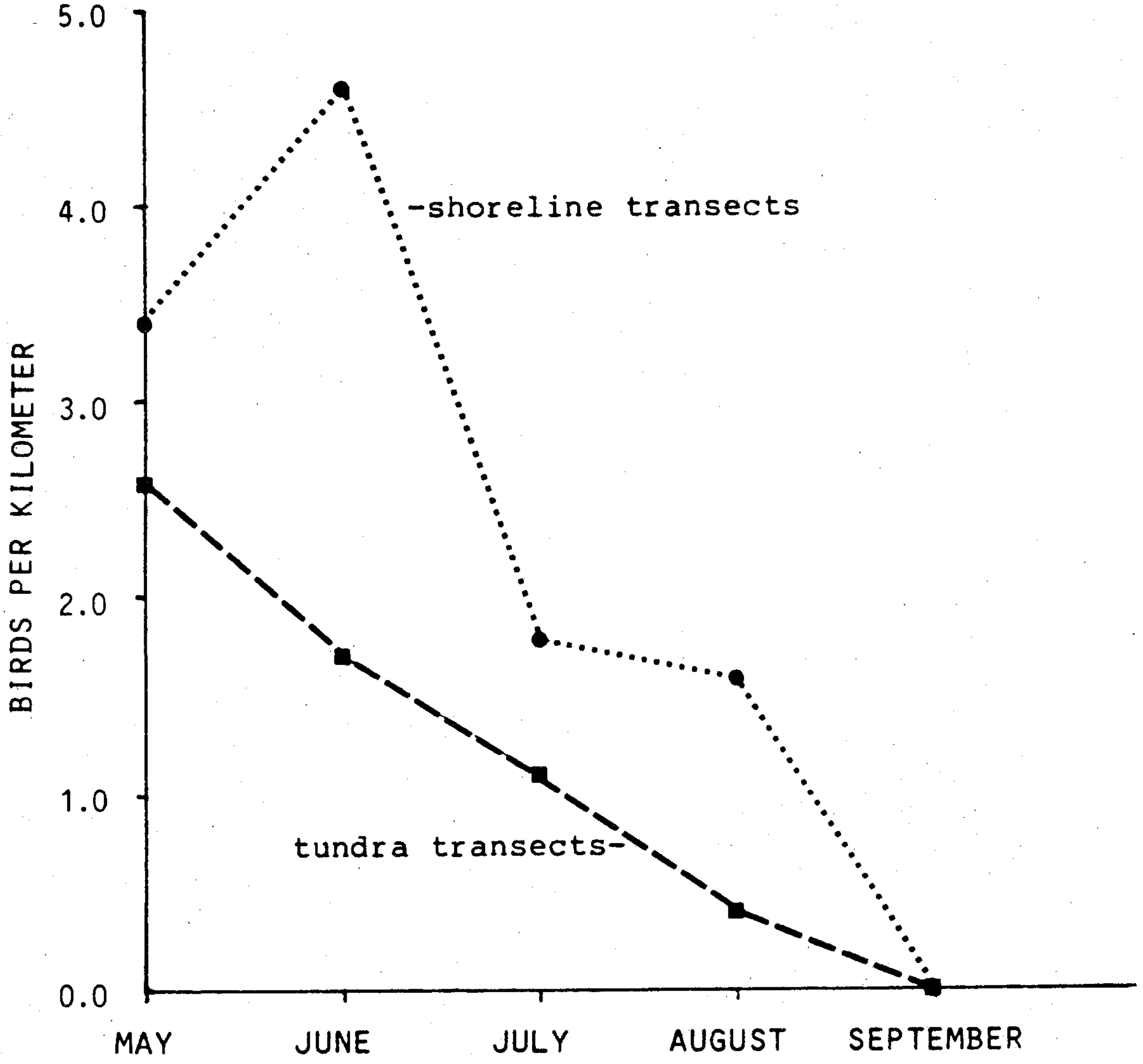


Figure 58. Seasonal abundance of Arctic Terns. Data are from 1980 land surveys; values for shoreline and tundra (non-shoreline) transects are given separately. Tern densities dropped all season soon after the arrival of breeding birds in May. The peak on shorelines in June is due to concentrations in spit habitats at Safety Lagoon.

(c) Geographic Distribution. Arctic Tern densities for the major Norton Sound wetlands are shown in Figure 59. Safety Lagoon had the highest Arctic Tern densities in the Sound. Imuruk Basin and Stebbins also had high densities and were important breeding areas for Arctic Terns. Port Clarence had higher densities than the two aforementioned areas, but due to its smaller size, the number of terns there was less.

Both Safety Lagoon and Port Clarence contain a great deal of the spit habitat that Arctic Terns favor. Imuruk Basin offers a delta system with inland qualities, though we are not certain how these factors are related to the high tern densities. The Stebbins wetlands are rich in ponds where many terns fed. After fledging many adults and juveniles shifted to the canals, where Nine-spine Sticklebacks (<u>Pungitius pungitius</u>) schooled in the shallows and were frequently taken.

The Koyuk-Inglutalik area had relatively low breeding densities, but aerial surveys showed high coastal densities of Arctic Terns in this area in mid to late July (9.6 terns/km along river delta shoreline).

(d) Nesting Phenology. The breeding schedules of Arctic Terns were similar in both 1980 and 1981, so the phenological data from both years were combined in Figure 60. Information from 15 nests and various pre- and post-breeding observations is included. Many birds began nesting within a week of their arrival on the breeding grounds. Laying began on about 20 May of both years, with a peak from 30 May to 6 June. Average clutch size was 2.1 eggs per nest (15 nests) and replacement clutches were sometimes laid. Hatching peaked from 20 to 27 June, and fledging peaked from 11 to 18 July, after which adults continued to feed young. In late July and early August the terns began to form flocks of up to 60 birds and appeared to be in family groups with some adults still feeding young. Observations in northern Alaska (Boekelhide and Divoky 1980) suggest that many juveniles become independent of their parents prior to extensive migratory flights. By mid-August most terns had moved offshore, and very few remained in September.

2. Aleutian Terns

The Aleutian Tern is an uncommon colonial breeder endemic to the northern Pacific Ocean. It nests from Sakhalin Island (U.S.S.R.) north along the Pacific and Bering Sea coasts of Siberia, and in Alaska from the southern Chukchi Sea at Tasaychek Lagoon (northwest of Kotzebue) to Dry Bay in southeastern Alaska (Kessel and Gibson 1978). Recent discoveries of the arctic colonies probably represent a northward extension of range, as native observers have remarked that this species with its distinctive markings and shorebird-like calls is new to the Kotzebue area. We have found, as has H. Springer (pers. comm.) that Aleutian Terns often shift their

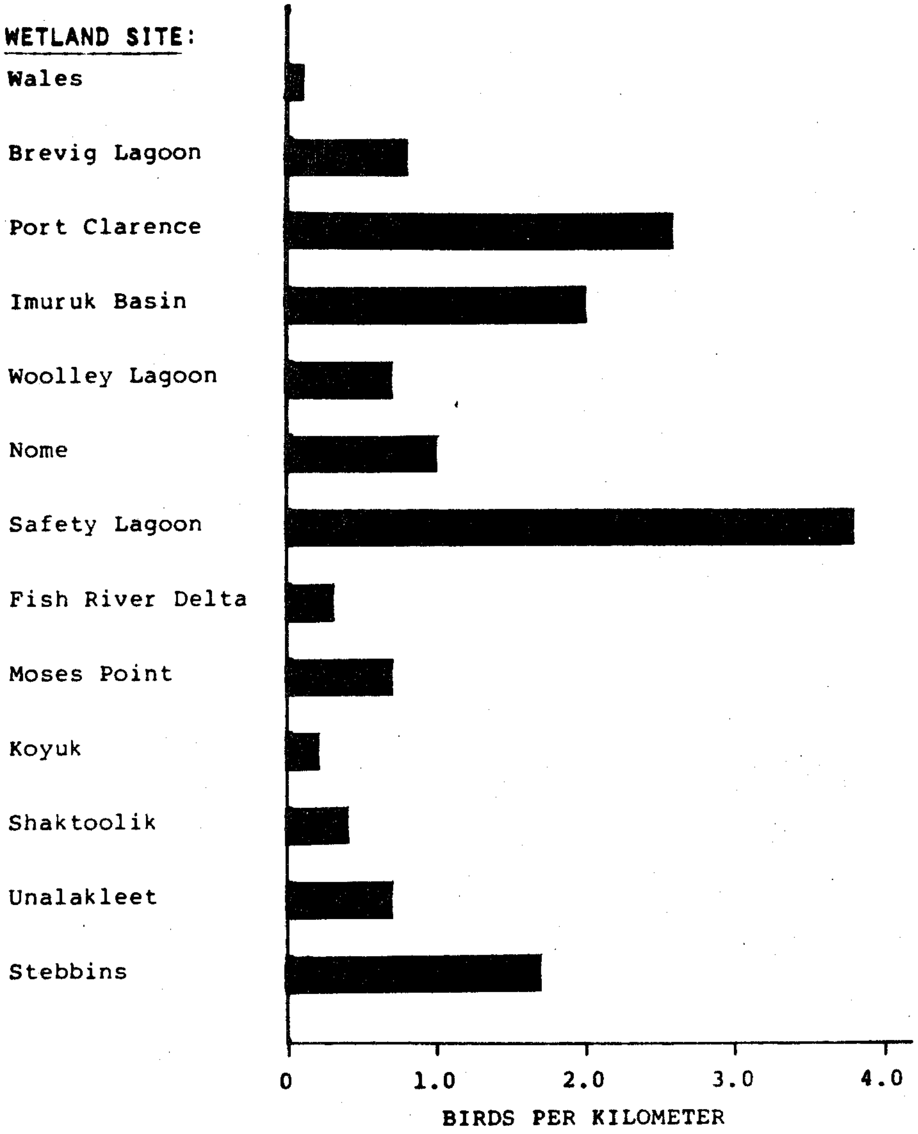


Figure 59. Geographic distribution of Arctic Terns on Norton Sound wetlands. Data are from 1980 land surveys. Both Safety Lagoon and Port Clarence offer spit habitats where terns congregate.

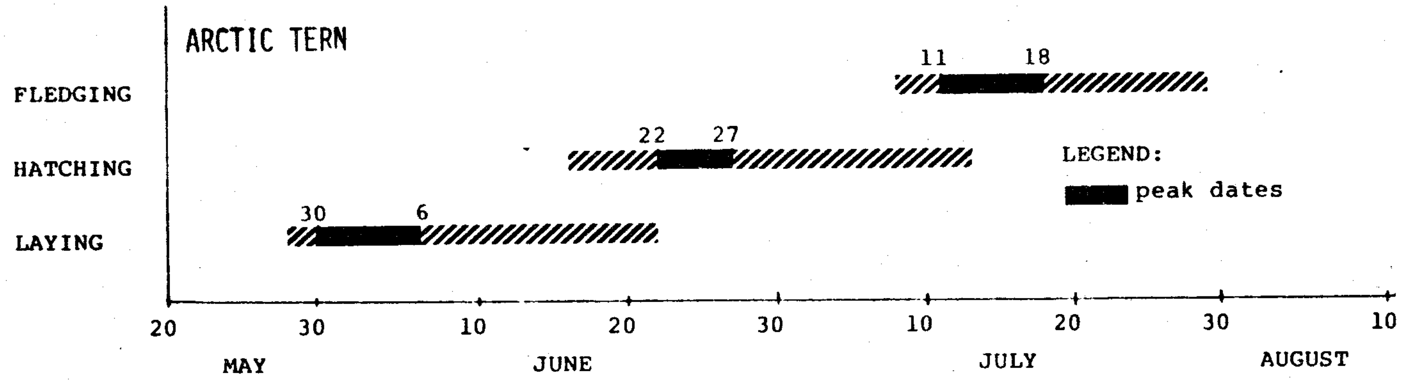


Figure 60. Nesting phenology of Arctic Terns. Data are combined from 1980 and 1981.(15 nests plus various post-breeding observations). Arctic Terns have a fairly compressed breeding schedule. Soon after the young fledge in mid to late August Arctic Terns depart from coastal Norton Sound.

colony sites from year to year. The present population of Aleutian Terns in Alaska has been estimated at 10,000 birds (Sowls et al. 1978). We estimate the size of the population in our study area to be at least 500 birds.

Throughout their breeding range Aleutian Terns generally nest on spits, or small islands, on or near river mouths and lagoons. In Norton Sound we found them nesting primarily in *Elymus* stands on spits or small islands, generally higher on the beach than Arctic Terns. We also found one colony on moist tundra east of Golovin.

Adults were observed returning from offshore feeding forays with Sandlance for their young. They are believed to sometimes feed as far as 50 or more kilometers from the colony (Kessel and Gibson 1979), though at Golovin we observed adults feeding in tundra ponds. No onshore coastal migration has ever been noted for Aleutian Terns. They appear to arrive at and leave their nesting sites directly from the open sea (Kessel and Gibson 1978); thus we have very little habitat information.

(a) Colony Sites. We found several colonies of Aleutian Terns around Norton Sound, but they were most numerous at Safety Lagoon (Appendix 21). We monitored one colony of at least 40 adults on an island immediately west of the lagoon outlet in both 1980 and 1981 for phenological information. The 1980 colony was in a stand of *Elymus* while the 1981 colony was further west on the island in an area of small, closely spaced ponds. This was the only colony we actually located at Safety Lagoon, though H. Springer has located several in past years. He reports 160 adults in 1976, 320 plus in 1977, 80 in 1978, and 480 in 1979. These were on at least ten islands, though only as many seven islands had colonies in any one year.

At Brevig Lagoon we found two colonies, one with six birds and the other with 16. Both were on the spit south of Brevig Lagoon in *Elymus* (Appendix 22). A flock of about 30 Aleutian Terns was seen at Point Clarence in early June in both 1980 and 1981, and there may have been a nearby colony. We also frequently saw Aleutian Terns near the mouth of the Kwiniuk River. A local resident, Ralph Segeok (pers. comm.), reported that they nested near the tip of the Moses Point spit (Appendix 23). We never visited this colony, but did see adults in the vicinity throughout the breeding season. Both Drury (1980) and Kessel and Gibson (1978) report Aleutian Terns there.

Thirty-five Aleutian Terns were seen on an island southeast of Unalakleet in the mouth of the Unalakleet River in early August 1980. It is highly likely that there was a colony at this site, though we did not investigate it. We also saw four birds at Shaktoolik in June 1980 and one on Little St. Michael Canal southwest of Stebbins and St. Michael in July 1981. One of the earliest colonies of Aleutian Terns reported was found by

Nelson in 1877 on an island near St. Michael's. We found no evidence of Aleutian Terns nesting on that island.

In June 1981 we found a colony of about 30 adults nesting on the raised moist tundra portion of the Golovin spit (Appendix 25). This is the only colony we found in this habitat though the colonies Nelson (1887) described near St. Michael were also on moist tundra.

(b) Nesting Phenology. Breeding schedules of Aleutian Terns were quite similar in both 1980 and 1981, so phenological data from both years were lumped (Figure 61). They include 17 nests in 1980 and 13 in 1981 at Safety Lagoon, and 12 nests from a colony near Golovin in 1981. The terns first arrived on the breeding colonies from the open sea in late May and continued to arrive through early June. Egg laying began one to two weeks later. Laying dates were extrapolated from hatching dates and laying peaked about 15 June. The incubation period is about 21 days (Harrison 1978). Hatching began in both years on 1 July, continuing through 17 July with a peak around 7 July. The fledging period was about 28 days, and birds began fledging 28 July with a peak around 4 August. Most young fledged by 14 August and the birds disappeared from the colonies shortly thereafter.

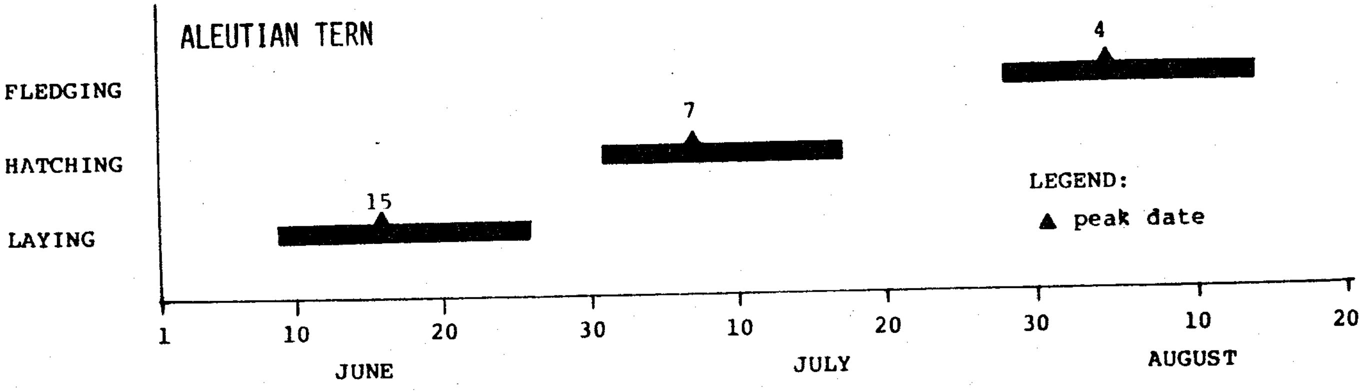


Figure 61. Nesting phenology of Aleutian Terns. Data are combined from 1980 and 1981 (39 nests). Laying dates are extrapolated from hatching dates based on a 21 day incubation period. Aleutian Terns begin nesting about one week later then Arctic Terns and finish about two weeks later (see Figure 60).

L. Passerines

Passerines are not as major a component of the coastal avian communities in Norton Sound as waterfowl or shorebirds, but they do constitute 10 to 15 percent of the population of birds censused by land. Many species nest in the moist tundra uplands, willow/alder-lined streams, and spruce forest and do not use the shoreline and low-lying wetland habitats most prone to oil-related impacts. The two most numerous species, Lapland Longspurs and Savannah Sparrows, do rely on these habitats. Savannah Sparrows are ubiquitous, breeding throughout much of North America, while Lapland Longspurs nest primarily in the coastal regions of arctic and subarctic America. Together longspurs and Savannah Sparrows comprise about 85 percent of the passerine population in or near wetlands of coastal Norton Sound and the following discussion primarily concerns them. Ravens were fairly common near cliffs, wetlands, shorelines, and village sites, and are important as predators of birds and other animals. For the status of other passerine species in coastal Norton Sound, see Appendix 26.

1. Habitat Use

Habitat use by Lapland Longspurs, Savannah Sparrows, and all passerines combined is illustrated in Figure 62. River mouths had the highest densities for all species of passerines combined and also for longspurs. These high densities were entirely attributable to concentrations in early August at river mouths emptying into Brevig Lagoon. Juvenile Yellow Wagtails and Lapland Longspurs were particularly numerous there. Although river mouths did attract birds of many species, particularly during fall migration, they composed a small percentage of the Norton Sound habitats. Despite high densities this habitat was less important than many of the more extensive habitats, such as wet tundra.

Protected shores backed by moist tundra also had high densities of passerines. These occurred in June and July and were due to Savannah Sparrows, Lapland Longspurs, and Yellow Wagtails. Many of these protected (lagoon) beach shores were backed by banks that rose steeply to 6 to 10 meters above the beach, and were covered with alder and willow shrubs. Redpolls, Tree Sparrows, Fox Sparrows, wagtails, warblers, and thrushes nested in these shrubs and were occasionally seen on the beach.

Wet tundra (non-shoreline) was important throughout the breeding season for both feeding and nesting (some species). For many passerines, particularly Lapland Longspurs, it was most important before and after nesting. Longspurs nest primarily on moist tundra, but in Norton Sound they often fed on wet tundra or shorelines. This was particularly true of fledged young and migrating birds. Seastedt (1980) found that the diet of

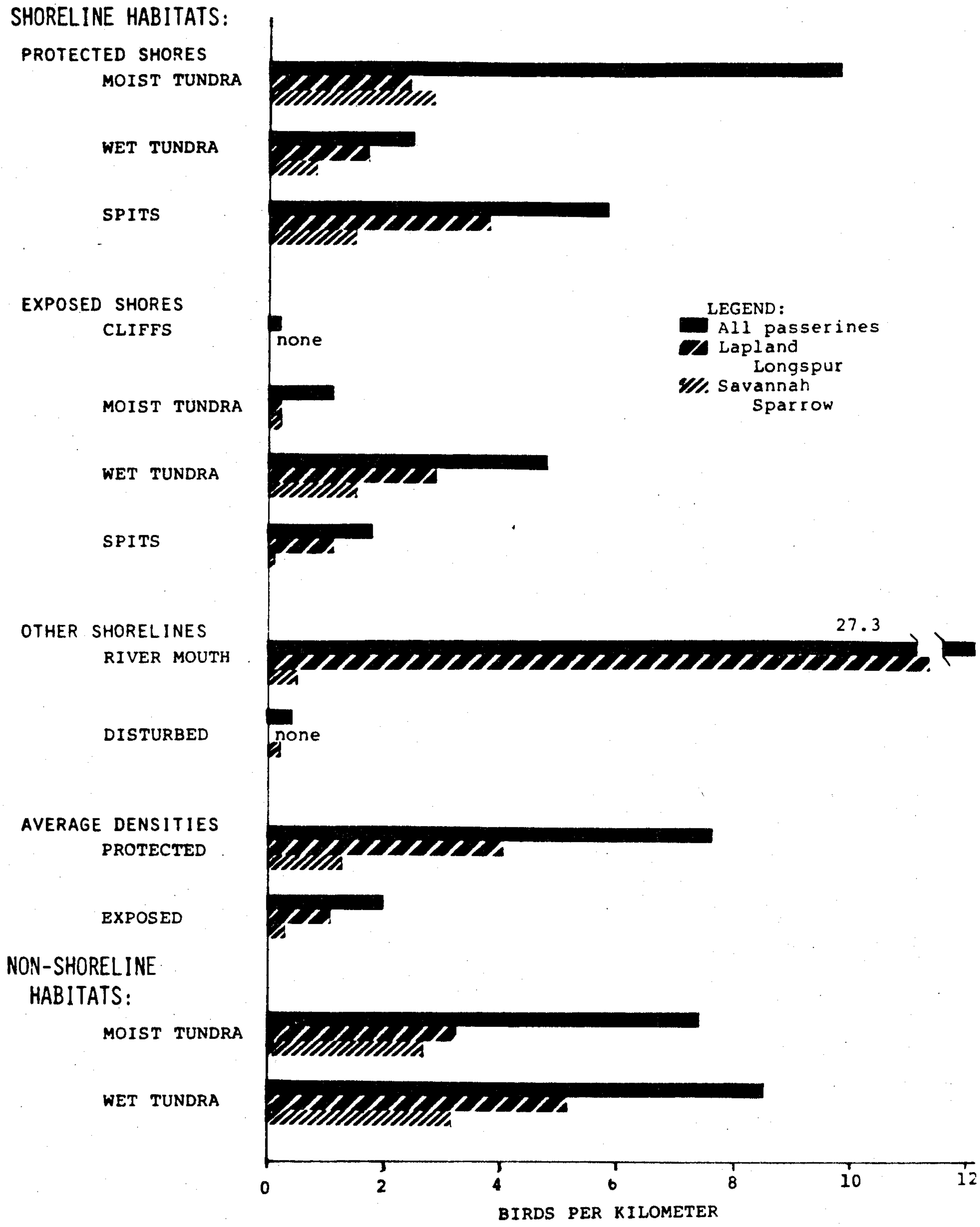


Figure 62. Habitat use by passerines. Data are from 1980 land surveys and apply to habitats in the immediate vicinity of wetlands. High densities along river mouths is almost entirely due to concentrations of longspurs and Yellow Wagtails at Brevig Lagoon in early August. Protected shorelines had more passerines than did exposed shores, and these were mainly in shrubs of moist tundra shores. On the tundra (non-shoreline) habitats both moist and wet tundra had similar densities.

nestling and fledgling Lapland Longspurs on the Y-K Delta consists primarily of cranefly species associated with wet, lowland habitats. This contrasts with Barrow, where longspur diets are composed mainly of craneflies found in mesic and upland habitats (MacLean and Pitelka 1971). The diets of young longspurs in Norton Sound are probably similar to those on the Y-K Delta, since the young appear to feed almost entirely on the wetlands.

Savannah Sparrows nested primarly on grassy wet tundra and also fed there. They occasionally nested on moist tundra also. Most other passerines preferred shrubby moist tundra and uplands for nesting.

Use of shoreline habitats, particularly lagoon shores, was common in all months. Passerines were regularly seen foraging along the drift line on beaches.

2. Seasonal Use

Passerine abundance was marked by two peaks during the season, one in June and another in August (Figure 63). The first peak is due to breeding adults and fledged young, while the later peak represents an influx of juveniles (mostly Lapland Longspurs) from inland and northern nesting areas. June densities of Savannah Sparrows were the highest for this species and they continued to drop every month. By September few of this species remained in Norton Sound. Adult passerines of most species generally left soon after the young fledged, leaving juveniles to follow later.

Like Savannah Sparrows, Lapland Longspur densities dropped in July as adults left the area. An influx of juveniles in August raised August densities to the highest of the season. By early September most Lapland Longspurs had left the area.

Fall migration was much more visible than that of spring. Both longspurs and Savannah Sparrows moved through all of the wetlands that we visited in August in sizeable flocks. Shields and Peyton (1979) report a peak migration date of 8 August for Savannah Sparrows at the Akulik-Inglutalik Delta near Koyuk when approximately 500 birds passed through. They found that Lapland Longspur numbers peaked on 15 August with an estimated 800 birds.

3. Geographic Distribution

Although passerines were common in all the wetlands of Norton Sound, some areas had especially dense concentrations. These area use patterns are illustrated in Figure 64 for Lapland Longspurs, Savannah Sparrows, and for all passerines combined.

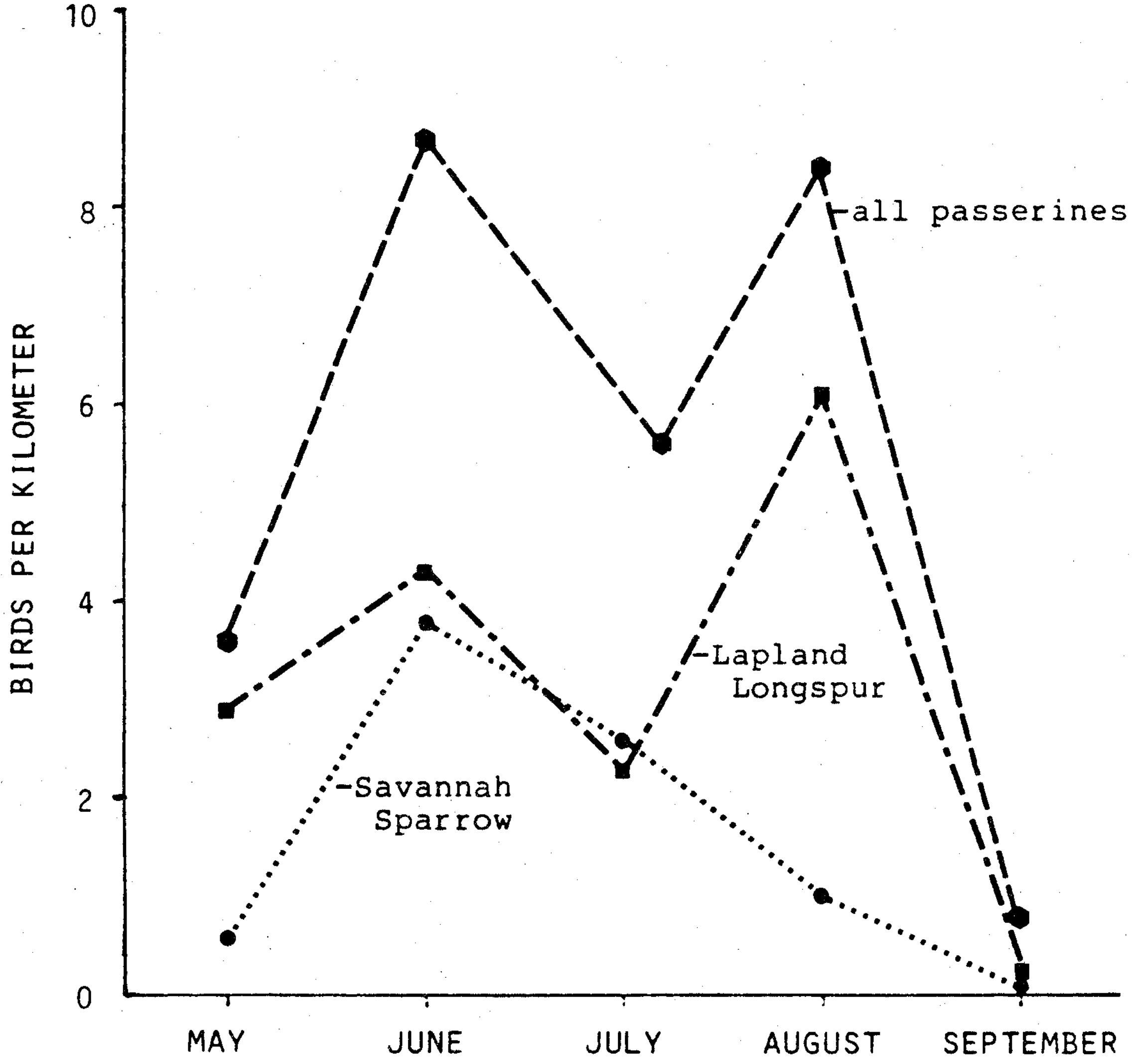


Figure 63. Seasonal abundance of passerines. Data are from 1980 land surveys and apply to the immediate vicinity of wetlands. The June peak is due to breeding birds and their newly fledged young, while the August peak is due to an influx of juveniles, mostly longspurs, from northern and inland areas.

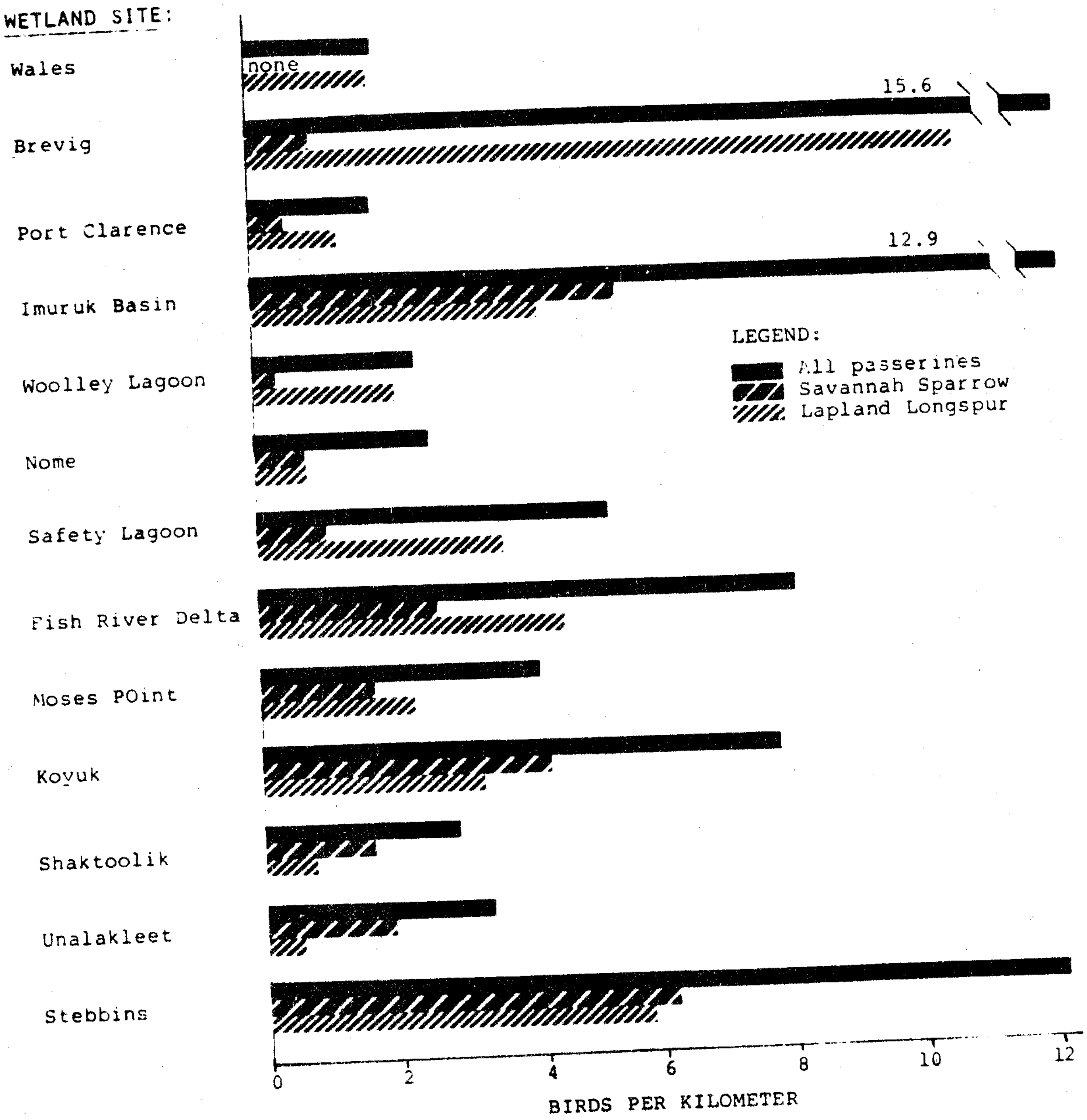


Figure 64. Geographic distribution of passerines on Norton Sound wetlands. Data are from 1980 land surveys. High densities at Brevig represent concentrations on a small wetland area, mostly of juvenile wagtails and longspurs in early August. High densities at Imuruk are for breeding populations in June only, and thus are inflated relative to densities at other wetlands that were censused more often. High densities at Stebbins are coupled with a large wetland area such that Stebbins had a far greater passerine population than the other wetlands.

Brevig Lagoon had the highest densities for all passerines and for longspurs. This was a small area, however, and relatively unimportant in total numbers when compared to large wetland areas such as Stebbins, Imuruk Basin, the Fish River Delta, and Koyuk. The high densities at Brevig were largely due to migratory flocks of Lapland Longspurs and Yellow Wagtails from 2 to 8 August.

Imuruk Basin was censused only in late June, when most passerines were at peak density; therefore, its densities are not as representative as data from areas censused over several months. Imuruk Basin was shrubbier than other wetland areas in Norton Sound. Consequently it had a more diverse passerine population, containing 15 species. In contrast, the passerine population at Stebbins was composed almost entirely of Lapland Longspurs and Savannah Sparrows. Due to its large wetland area, both species were more abundant there than anywhere else in the Sound. Savannah Sparrows were the most common passerine breeder at Stebbins, but had slightly lower overall densities than longspurs because they migrated south sooner. The Fish River Delta, Koyuk, and Safety Lagoon also had relatively high passerine densities and numbers, primarily of Lapland Longspurs and Savannah Sparrows.

4. Nesting Phenologies

By the first week of May in both 1980 and 1981 many passerines, including Lapland Longspurs and Savannah Sparrows, had arrived on the breeding grounds. These two species began setting up territories within a few days of arrival. Nesting began within a week of arrival for most Lapland Longspurs and slightly later for Savannah Sparrows (Figure 65). There was no noticeable migration. Numbers simply increased until breeding densities were reached.

The average clutch size of 13 longspur nests in 1981 was 4.7, and this includes two late nests, probably re-nesting attempts, with three eggs each. Savannah Sparrow nests averaged 5.3 eggs each in 1981 (10 nests).

In late May the young began to hatch, and the high June densities reflect this addition to the population. By the end of June almost all young passerines had fledged.

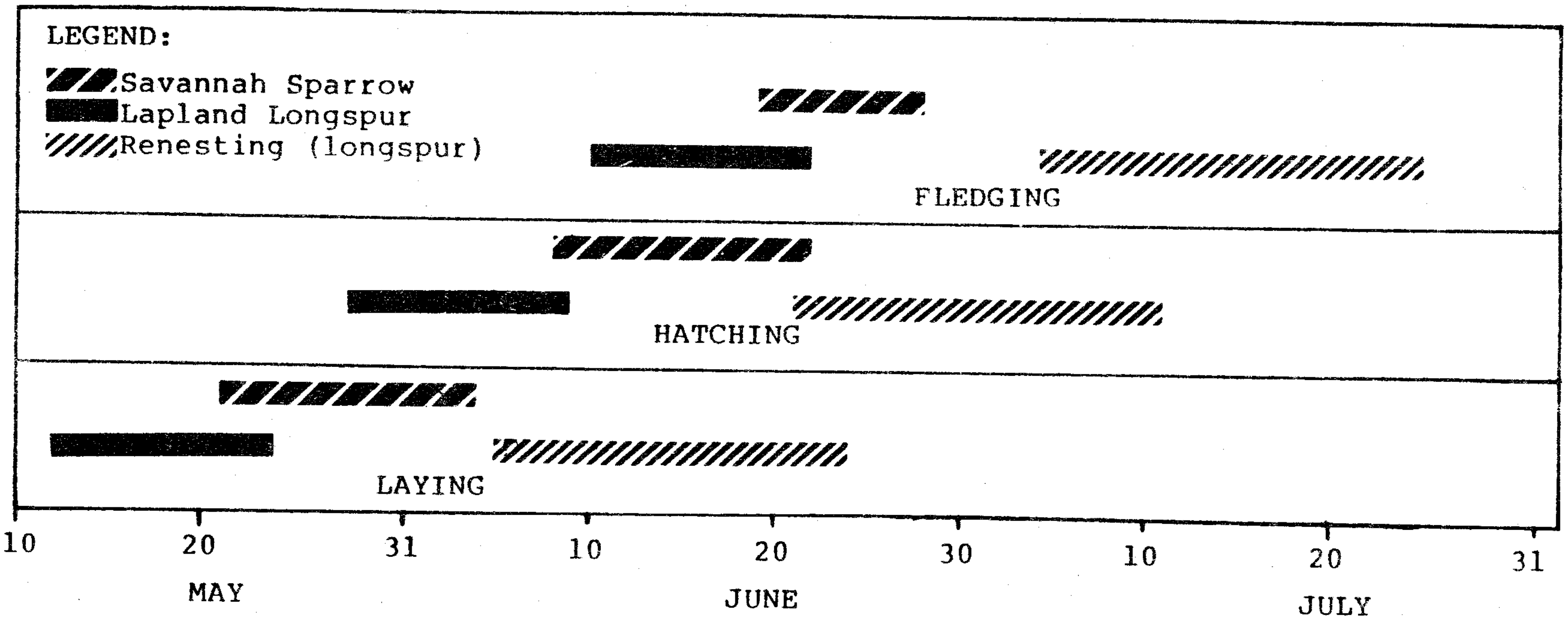


Figure 65. Nesting phenologies of Savannah Sparrows and Lapland Longspurs. Data are combined from 1980 and 1981. Longspurs (n=17 nests) began nesting earlier than Savannah Sparrows (n=8 nests and 6 observations of fledglings) and some attempted renesting (n=2 of the 17 nests).

M. Peregrine Falcons

Peregrine Falcons are rare breeders on the cliffs and rock outcrops around Norton Sound. Known and suspected nest sites are usually on cliffs near seabird colonies, where falcons are protected from mammalian predators and have a reliable supply of food. Our observations of nest sites and individual birds have been reported to the OCSEAP Arctic Project Office in Fairbanks. None are given here, because of the sensitive nature of this species and the potential for disturbance by unlawful taking of eggs or young for falconry.

VI. RESULTS

Part Two. Trophic Systems

Seasonal trends in the primary and secondary productivity of habitats play an important role in patterns of bird habitat selection and migration. This section will discuss productivity of bird foods in habitats of Norton Sound, the seasonal energy cycles of birds using these habitats, and the specific food habits of the common shorebird and duck species.

A. Productivity of Habitats

Nutrients are a driving force of growth, and their availabilitiy limits or promotes primary productivity. Wetlands of river and littoral systems receive periodic and substantial inputs of waterborne nutrients, and for this reason are the prime habitats supporting bird life in Norton Sound. Drainage systems channel spring floods carrying the winter's snowmelt and a surplus of production from the previous year in the form of detritus. This detrital load is composed of tons of plant and animal remains. It is concentrated from large watersheds into relatively narrow valleys and outpourings of rivers, and is deposited over deltas and into lagoon systems, replenishing them with nutrients. Detritus feeds scavenging invertebrates, classed as detritivores, including many of the fly larvae eaten by birds, and the nutrients released from detritivores and from detrital decomposition allow a rich plant growth. This in turn allows a rich fauna.

Wetland flooding each spring is enhanced by snow and ice dams at river mouths and lagoons. Thus, most of the major wetlands of Norton Sound retain floodwaters from the beginning of snowmelt until the end of break-up, a period of about two weeks in mid to late May. Post flood river flow continues the nutrient input from terrestrial sources, though at reduced levels. Further nutrient enhancement is provided by coastal flooding in late summer and fall when storm-churned coastal waters swell onto low-lying wetlands. In this way, these wetlands are part of the intertidal zone.

Lagoon systems at river mouths owe their richness not only to their freshwater nutrient inputs but also to their partially enclosed shallow waters. Barrier beaches reduce the fetch, limiting the extent and strength of wave scouring, and by similar means limit ice scour. In turn, ice is retained later into spring (damming rivers, as above) without the aid of currents and wind drift available offshore; this serves to delay the seasonal production cycle. Nonetheless, rooted aquatics may take hold in the photic zone. Notable among these is Eelgrass (Zostera marina) which approaches its northern limit in Norton Sound (McRoy 1968).

Eelgrass plays an important role in the ecology of shallow waters. It stabilizes bottom sediments, produces oxygen, provides a sheltered habitat for small animals, and captures nutrients, cycling them back into the lagoon when the grass dies (Klug 1980; den Hartog 1977). It is a renowned food of Brant and may nourish Canada Geese and Swans as well. We found extensive Eelgrass beds, particularly in July and August, in Safety Lagoon, and have found thick windrows at Lopp and Golovin Lagoons. It has been reported from St. Michael's Bay, Malikfik Bay, Kwiniuk Inlet (Moses Point), Port Clarence, and Grantley Harbor (McRoy 1968).

B. Energy Demands of Birds

Nesting, molting, and migration place seasonally high energy demands on most birds. Indeed, the seasonal limits on productivity in the north compel migrants to move south to exploit seasonally productive habitats of their winter grounds. While birds are in Norton Sound, their prey selection and choice of habitat reflect their energy demands. Food choices may be further modified by strategies limiting competition between parent birds and their young, as these age classes may select markedly different foods.

Nesting is always an energy-intensive activity for birds, though each species may approach the problem differently. Canada Goose females are known to begin laying and proceed through incubation without feeding, relying on fat reserves and protein stored before arrival at the nesting grounds (Raveling 1979). This allows them to begin nesting well before the tundra is clear of snow and before the summer's plant growth is underway. Most other birds, particularly the smaller ones, cannot develop such large fat deposits and must continually replenish their reserves. This is particularly true during and after the northward migration. Western Sandpipers, for example, must make frequent stops during migration to feed, whereas the larger Dunlin can migrate by long, sustained flight (Senner 1979). The amount of fat they have in reserve upon arrival on the breeding grounds, and how much food is then available, may affect reproductive activity and nesting success (Norton 1973; MacLean 1969).

Egg laying is particularly draining. Small sandpipers lay four eggs in as many days that together may weigh nearly as much as an adult female. Their need for calcium can be great at this time, and MacLean (1974) has shown that they may take in a majority of their calcium from teeth and bones of small mammals and from insect prey prior to laying, and little is stored for the purpose. He further suggests that much of shorebird feeding may not be regulated by the need for fat reserves alone but by the need for minerals and nutrients that are scarce in food.

The hatching of young in late June and July signals another demand on the food supply. Ducklings are noted for their dependence on insect food for rapid body growth (Danell and Sjoberg 1977). A similar dependence by young Lapland Longspurs on craneflies has been found (Custer and Pitelka 1978; Seastedt 1980) while Holmes (1966a, 1972) has demonstrated the need for emergent insects by young arctic and subarctic sandpipers. All of these prey selections serve to build body tissues from protein-rich foods.

Many adult birds molt their flight feathers, and sometimes their body feathers, soon after nesting. Feather development requires a great deal of energy. Following the molt, intense feeding builds up fat reserves for the return flight south. Even species such as Semipalmated Sandpipers, which do not molt after nesting, exhibit a similar pattern, spending about 90 percent of the 24 hour day feeding before migration (Ashkenazie and Safriel 1979).

Thus, the entire period of residence in Norton Sound is one of high energy needs for birds, and this, for the most part, explains why birds concentrate in the food-rich wetlands.

C. Shorebird Food Habits

This section begins with an overview of shorebird foods, lumping the food habits of the four common species: Semipalmated Sandpipers, Western Sandpipers, Dunlin, and Northern Phalaropes (Table 27). This provides a general picture of what foods are important, and is supported by discussions of the major food types in both wet tundra and protected shoreline habitats. Following these, particulars of the food habits of each of the four species are discussed separately (details of the stomach contents are given in Appendices 8 through 15). Food habits of less common shorebird species are discussed earlier in this report in Section VI(1)-H, "Shorebirds."

Collections of shorebird stomachs allow us to comment on the principal foods of adults and juveniles over the course of the spring and summer. We did not secure samples large enough to allow analysis of seasonal trends, and we will rely on published works to discuss these. Identification of food organisms was usually only to familal or higher categories due to lack of faunal descriptions for western Alaska.

As a group the four common shorebird species fed most heavily on fly larvae of the midge family (Chironomidae, Figure 66, Table 27); these were found in 40% of birds collected from both tundra ponds and intertidal areas.

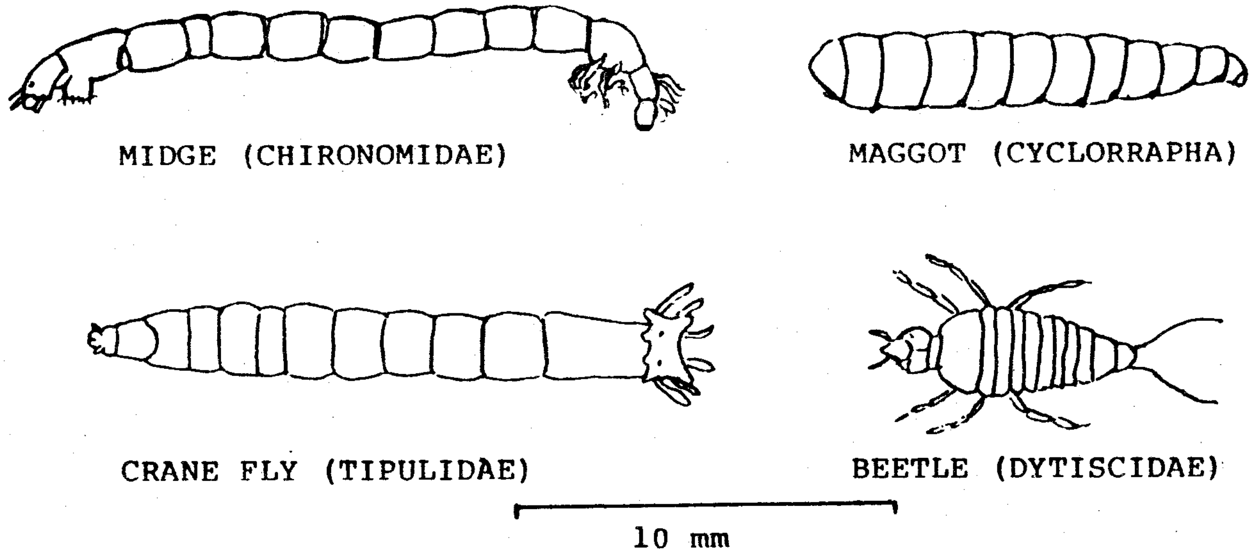
Table 27. **Shorebird food habits summarized for 17 Semipalmated Sandpipers, 22 Western Sandpipers, 27 Dunlin, and 20 Northern Phalaropes collected in Norton Sound, 1981. See Appendices 8 through 15 for details for each species.**

	Wet Tundra					Littoral				
Prey Items	n	%[1]	Freq.[2]	%f[3]	Mean Length (mm)	n	%[1]	Freq.[2]	%f[3]	Mean Length (mm)
Midge Larvae	330	47.8	18	40	9.8	102	57.3	13	42	8.7
Crane Fly Larvae	7	1.0	3	7	19.3	1	0.6	1	3	12
Cyclorrapha Larvae	73	10.6	8	18	11.1	6	3.4	3	10	8.0
Beetle Larvae	208	30.1	18	40	8.8	14	7.9	4	13	9.0
Beetle Adults	7	1.0	5	11	3.9	1	0.6	1	3	6
Hymenoptera	4	0.6	3	7	4.8	1	0.6	1	3	4
Spiders	4	0.6	3	7	5.0					
Isopod						1		1	3	4
Mysids						26	14.6	3	10	9.0
Cladocerans	52	7.5	1	2	2					
Cladoceran Egg Cases	530	--	2	4	1					
Snails	5	0.7	1	2	4	6	3.4	5	16	3
Clams						20	11.2	1	3	2
Seeds	724	--	21	47	1.4	466	--	17	55	1.5
N of Birds			45					41		

[1] Percent of total individuals, not including cladoceran eggs.

[2] Number of stomachs in which the item was found.

[3] Percent of stomachs in which the item was found.



MIDGE (CHIRONOMIDAE)

MAGGOT (CYCLORRAPHA)

CRANE FLY (TIPULIDAE)

BEETLE (DYTISCIDAE)

Figure 66. Common insect larvae eaten by shorebirds in Norton Sound. The scale is approximate.

Beetle larvae were the next most common food from wet tundra, and were also frequently taken from intertidal substrates, as were mysids, small snails, and small clams. Fly larvae of the suborder Cyclorrapha (essentially maggots) were the third most common food taken from wet tundra ponds and were less common from the littoral zone. Approximately half of all shorebirds, regardless of habitat, had seeds in their stomachs, mostly from sedges (*Carex spp.*) and Mare's Tail (*Hippuris tetraphylla*). These seeds may be a neccessary part of the diet and might not be ingested incidentally (see below).

1. Wet Tundra Foods

Fly larvae are the principal component of most shorebird diets in tundra areas. Midge larvae of tundra habitats in Norton Sound are probably limited primarily to pond margins, and this is where we observed most tundra shorebird feeding activity. For similar habitat on the Kolomak River (Y-K Delta), Holmes (1972) asserts that there are virtually no sod-dwelling insect larvae, and that Dunlin find almost all of their food at pond margins. This is in contrast to the more widespread occurrence of insect larvae found by Holmes in the well-developed sod at Barrow. There, crane-fly larvae (Tipulidae) are the preferred food; these are able to respire in air and are well adapted to living in moist soils. In the low-lying wetlands of Norton Sound there is little humus-like soil, and these more barren substrates cannot support the rich larval populations that thrive in moist organic-rich sediments, as are found in ponds and along pond margins. The moisture content of wetland sods in the Sound may also be too low for many midge and other larvae that depend on a water medium for respiration. This paucity of sod-dwelling larvae is caused in part by periodic floods. The details of how this works are not clear to us, yet the result is quite apparent; the most productive wetlands, notably at Stebbins, Koyuk, and the Fish River, have a low-lying, fairly sparse vegetation, and myriads of ponds and channels. Salt burning is partly a cause, as is silt and sand deposition from floods.

We found midge larvae to be the most abundant suitably-sized prey in mud samples from pond margins and the littoral zone (Table 28). They were only slightly more common in these substrates than they were in stomach contents, relative to other organisms, suggesting passive selection by feeding birds. However, the average size was about 40% larger for midges eaten in wet tundra ponds (9.8 mm) relative to those available (6.9 mm). Hence, selection for large size is apparent; Holmes (1966a) has noted a minimum size of 5 millimeters for midge larvae taken by Dunlin.

Table 28. **Prey availability in (A) Pond margin mud on wet tundra and (B) Littoral mud from protected shorelines of the Fish River Delta and from canals at Stebbins.**

Item	May n	May Length (mm)	June n	June Length (mm)	July n	July Length (mm)	August n	August Length (mm)	Sept. n	Sept. Length (mm)	No. per Sample	%[1]	Length
(A) Pond Margins													
Midge Larvae	532	6.7	755	6.8	625	7.2	23	8.4			30.7	58.4	6.9
Crane Fly Larvae	1	14	1	10.0	16	10					0.3	0.5	10.2
Cyclorrapha Larvae	1	8	620	5.6	9	5.8	4	6.3			10.1	19.1	5.6
Beetle Larvae			25	10.4	1	10					0.4	0.8	10.4
Caddis Fly Larvae			1	10.0							<0.1	<0.1	10.0
Nematodes	660	7	17	12.9			13	6			11.0	20.8	7.1
Snails			5	4.8	5	3.5	1	3			0.2	0.3	4.0
Clams													
N of Samples[2]	10		25		14		14		0	Sum =	63		
(B) Littoral													
Midge Larvae	586	7.4	489	7.5	7	4.0	109	6.6	3	8.3	16.4	77.2	7.4
Cyclorrapha Larvae			26	4.2	1	8.0	1	4.0			0.4	1.8	4.3
Isopods					2	9.0					<0.1	0.1	9.0
Amphipods							2	7.5	2	4.0	0.1	0.3	5.8
Nematodes	76	5.6	112	9.0	57	3.2	36	10.1			3.8	18.2	7.0
Snails			4	6.0			20	3.9	2	6.0	0.4	1.7	4.4
Clams			1	3.0	1	4.0	9	2.9			0.2	0.7	3.0
N of Samples[2]	20		23		10		15		5	Sum =	73		

[1] Percent of total numbers from each habitat.

[2] Samples were 20 x 25 cm and 4 cm deep.

Midge larvae are not always readily available to shorebirds, and this is dependent on the midge life cycle (Figure 67) and on weather. A midsummer emergence of adult flies causes a depression in larval populations, though this may be smoothed by the presence of several different species with non-synchronous emergence periods. This emergence is heavily exploited by shorebirds, though we substantiated this only by observations of feeding birds and not a stomach contents examination. Chick hatching is notably synchronous with fly emergence, and chicks feed heavily on adult flies in their first week of life (Holmes 1966 and 1972; Holmes and Pitelka 1968).

We noted drying pond margins in Norton Sound wetlands in August of 1980 and 1981, and suggest that this may be a regular event in the region, exposing more substrate to larvae-hungry birds. Local flooding may quickly change this availability, as Holmes (1966a) found at Barrow where inclement weather may override insect life cycles in controlling food availability. There late-season rains flooded ponds and covered otherwise accessible larvae.

Other factors must surely affect midge larvae availability, as we noted a steep decline from July to August in tundra pond samples (Figure 68). Holmes (1970 and 1972) noted the same for his study area on the Y-K Delta, and suggests that this decline induces Western Sandpipers to depart early and Dunlin to shift to riverbanks and intertidal feeding sites. Our habitat use information supports this. There were a variety of shorebirds feeding along tundra ponds in August, yet there were far less than in either June or July, and we noted a shift to intertidal areas in July and August (see Figures 48 and 49).

Cyclorrapha fly larvae were taken principally from wet tundra ponds; few were available or taken in the littoral zone. They are true maggots (Figure 66). They have a soft body and usually no head capsule, and are considered to be the most highly evolved flies, including in their ranks houseflies, fruit flies, and a host of parasitic flies (Oldroyd 1966). Larval forms are particularly difficult to identify, and we can only say that those eaten by shorebirds were mostly detritus and plant feeders. A few may have been leaf miners, though these types were more commonly eaten by ducks (see below). Maggots were very important as food for Western Sandpipers on the Y-K Delta (Holmes 1972) where they were of minor importance for Dunlin (Holmes 1970). On arctic tundra near Barrow, maggots were infrequent foods of the four calidridines nesting there (Holmes and Pitelka 1968). Their frequency in the stomachs of Norton Sound shorebirds is probably related to their availability (11% of tundra foods, 19% of prey in mud samples).

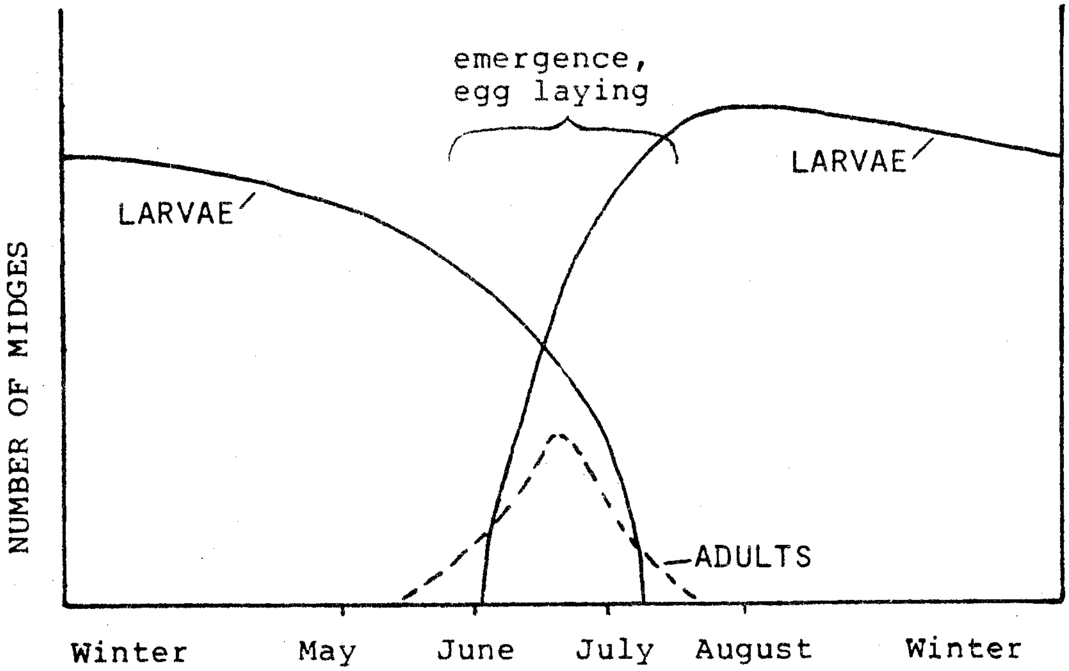


Figure 67. Life cycle of midges in Norton Sound. Adapted from Holmes (1966a). Dates are approximate. A decrease in the abundance of larvae may occur during adult emergence.

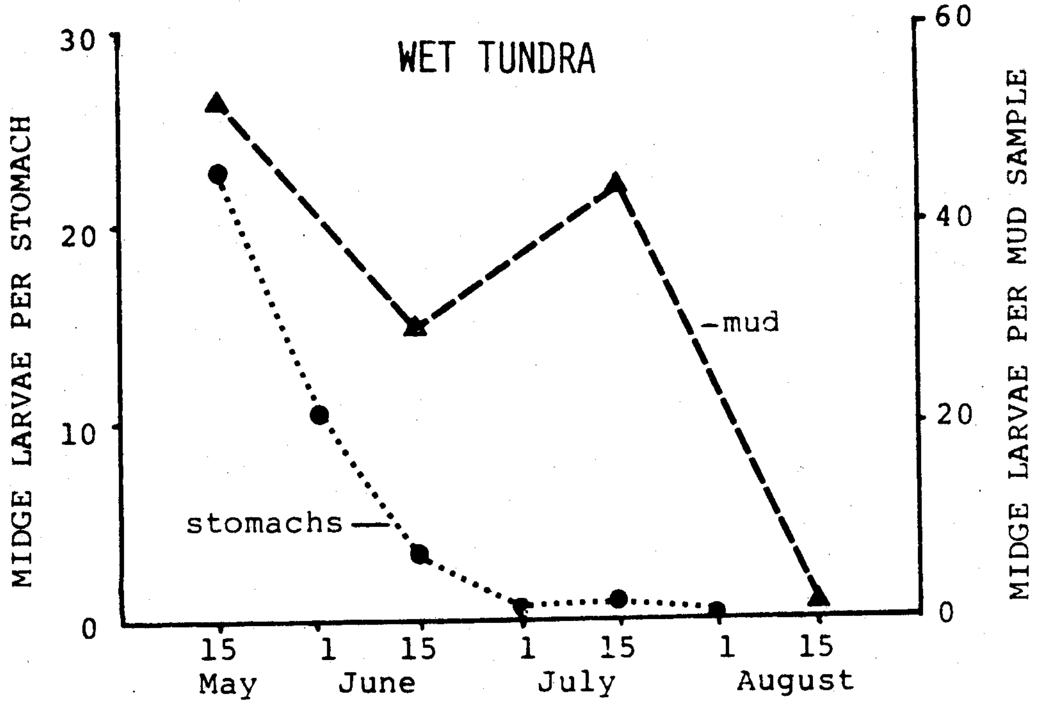


Figure 68. Seasonal abundance of midges and consumption of midges by shorebirds on wet tundra ponds. Data are from the Fish River Delta and Stebbins.
Midge numbers dropped steeply in spring in both mud and stomach samples. This was followed by an increase in midge numbers in the mud in mid-July that was not paralleled in the stomach samples.

Beetle larvae were also mostly found in tundra ponds rather than in the littoral zone, and many of those eaten by shorebirds were carnivorous dytiscids. Their low frequency in mud samples is surely due to their mobility, as they are more likely to be caught by deft shorebirds than by us. These larvae were far more important in the tundra diet of Norton Sound shorebirds than as recorded for Dunlin and Western Sandpipers on the Y-K Delta (Holmes 1970 and 1972) or for the common calidridines at Barrow (Holmes and Pitelka 1968). As with fly larvae, this is probably a result of their availability, and beetle larvae may also be easy to capture, being active on top of the mud substrate.

Seeds appear to be a common food, although their nutritional use is not clear. Ruddy Turnstones nesting in the high arctic may feed on seeds almost exclusively before insects become available in spring (Nettleship 1973) and seeds are common in diets of numerous other shorebirds reported by Bent (1927). Seeds are definitely over-represented in stomach contents analysis because they do not break down readily, and they may be regurgitated (in snipe) without having been digested (Whitehead and Harris 1966; Tuck 1972).

Three-quarters of all seeds taken in tundra ponds were eaten by Northern Phalaropes, and nearly all of these were in July when phalaropes were surface feeding on ponds. These seeds were probably floating and had recently been released by parent plants. Holmes (1970, 1972) suspects that seeds ingested by Dunlin and Western Sandpipers were incidentally eaten with caddis-fly larvae (Trichoptera) that use seeds in their case building. We noted too many seeds in their stomachs and too few caddis-fly cases in ponds to support this.

2. Littoral Foods

Shoreline littoral habitats offer mostly midge larvae and nematodes as animal prey (Table 28), though nematodes were very rare in shorebird stomachs. Excluding nematodes, midge larvae comprised 94 percent of the macroscopic animals in the mud. The lower percentage of midge larvae in shorebird stomachs (56 percent) and their slightly larger size (mean = 8.7 mm) relative to those in the mud (mean = 7.4 mm) suggests that shorebirds mostly detected, or mostly selected, the larger ones. Midge larvae were most available in May and June, and their abundance in shorebird diets roughly follows this seasonality (Figure 69). The low in July is probably due to the emergence of adults.

Few other insects occured in the littoral zone. All littoral zone feeding shorebirds whose stomachs contained beetle larvae were collected near river channel banks on the vegetational edge of the Fish River Delta. These larvae were surely not living within the mud substrate, as midge

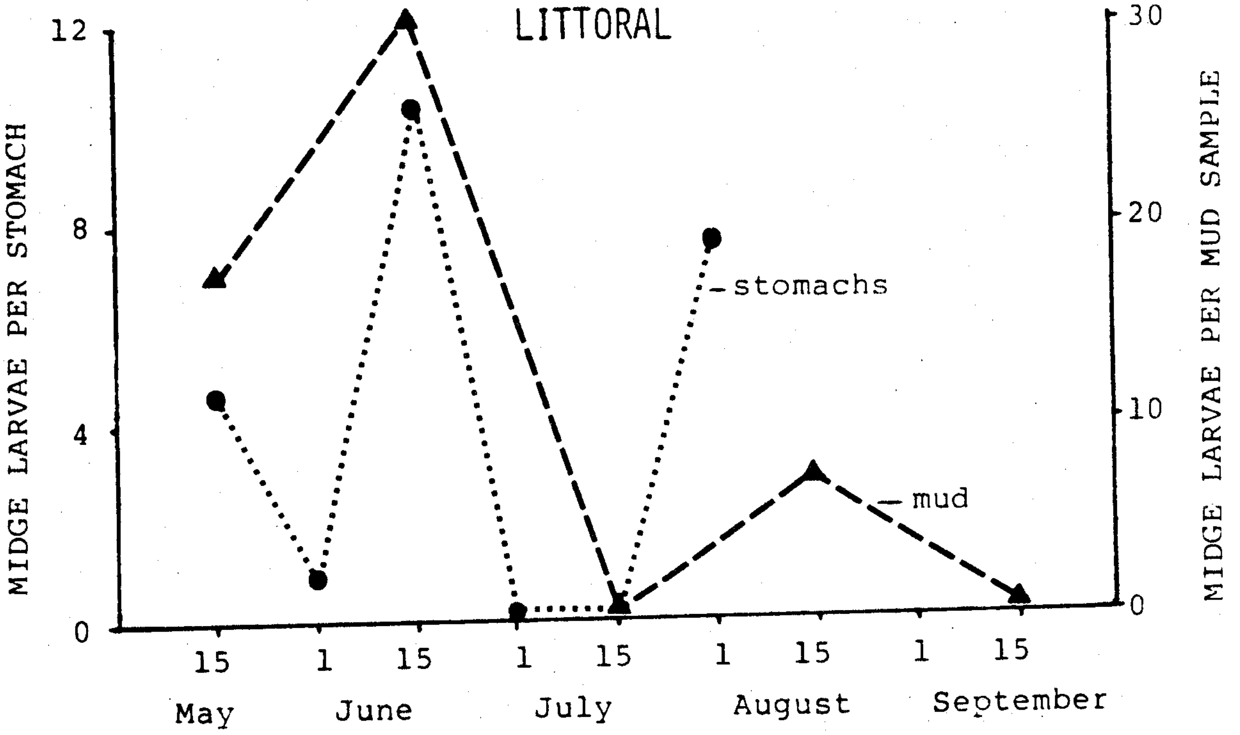


Figure 69. Seasonal abundance of midges and consumption of midges by shorebirds in littoral habitats. Data are from protected shores of the Fish River Delta and the canal shores of the Stebbins wetlands. Occurrence of midge larvae in shorebird stomachs roughly parallels their availability in the littoral mud.

larvae do. We found none in our mud sampling (Table 28) and suspect that they were gleaned as surface-active carnivores. The cyclorrapha larvae were uncommon in both mud and stomachs.

Clams were prey of Northern Phalaropes alone as was true of all but one of the mysids eaten.

The littoral zone is not always available for shorebird feeding, and is covered periodically by what Drury (1980) considers "capricious tides." Though generally exposed at night, mud and sand flats reach their greatest exposure late in summer. Riverine delta flats are prominent at Woolley, Safety, and Golovin Lagoons near the mouths of the Kwik, Koyuk, Inglutalik, and Unalakleet Rivers, and at the mouth of Malikfik Bay. Moderately steep canal banks are tidally exposed in the Stebbins/St. Michael's and Koyuk wetlands. Of these, the littoral zone at Safety and Golovin Lagoons, at Koyuk, and the canal banks on the wetlands near Stebbins were the most intensively used by feeding shorebirds.

3. Wet Tundra and Littoral Habitats Compared

The comparisons presented here apply only to mud substrate and stomach samples, taken principally at the Fish River Delta and near Stebbins. We suspect that similar sites in Norton Sound have similar properties, though more samples are needed to discuss them.

As a group, shorebirds usually fed more successfully at tundra ponds, having an average of over twice as many prey animals per stomach than did birds collected in the littoral zone (Table 29), and this difference was significant. The number of midge larvae per stomach was greater in tundra feeders, though not significantly different from littoral feeders. This implies that the variety of other tundra invertebrates complimented larval midges in the richness of tundra diets.

Wet tundra mud samples held over twice as many suitably sized animals on average than did littoral samples, and this is also true when comparing numbers of midge larvae alone (Table 30). These differences are not significant because of the high variability between samples, especially of midge larvae. About one-fifth of the samples in each habitat were devoid of macroscopic animals, many had few animals, some had numerous animals, and a minority, particularly from wet tundra ponds, had a great many animals (Figure 70). Excluding counts of nematodes (these were rare as bird food) the number of animals per littoral sample decreases to the point of being significantly different, but marginally so, from that of tundra pond samples. Hence, we found a high degree of variability in our samples, with generally higher counts of potential prey in the mud of tundra ponds. As discovered with stomach contents (see the preceeding paragraph), numbers of midge larvae were dominant, but not all-important. Rather, the numbers of other

Table 29. Stomach contents of wet tundra pond edge and littoral feeding shorebirds compared.[1]

	Wet Tundra Ponds	Littoral	p^2
Total Animals[3]			
Mean	16.1	7.4	0.02
Standard Error	2.9	1.7	(Significant)
n	40	25	
Midge Larvae[4]			
Mean	18.3	7.8	0.12
Standard Error	4.9	2.4	(Not
n	18	13	significant)

[1] Data for Semipalmated Sandpipers (16), Western Sandpipers (18), Dunlin (15), and Northern Phalaropes(16).

[2] Mann-Whitney U test; used instead of t-test because of unequal variances.

[3] Does not include cladocerans taken by phalaropes, which were taken only on tundra ponds. These are much smaller than the other prey and would grossly inflate the total numbers data.

[4] Does not include data for stomachs without midge larvae (22 stomachs from tundra ponds without midge larvae, and 12 from the littoral zone); inclusion of this "zero" data would have reduced the difference between means and made it less significant.

Table 30. Faunal comparison of mud substrates from wet tundra ponds and littoral shores.

	Wet Tundra Ponds	Littoral	p[1]
Total Animals[2]			
Mean	54.2	21.8	0.29
Standard Error	11.8	4.0	(Not
n	63	73	significant)
No. of Empty Samples	11	15	
Total without Nematodes			
Mean	53.7	17.9	0.057
Standard Error	11.8	3.7	(Marginally
n	63	73	significant)
Midge Larvae			
Mean	32.0	16.4	0.51
Standard Error	9.0	3.8	(Not
n	63	73	significant)

[1] Mann-Whitney U test; used instead of t-test because of unequal variances.

[2] Does not include animals less than two millimeters. Samples were 20 x 25 cm and 4 cm deep.

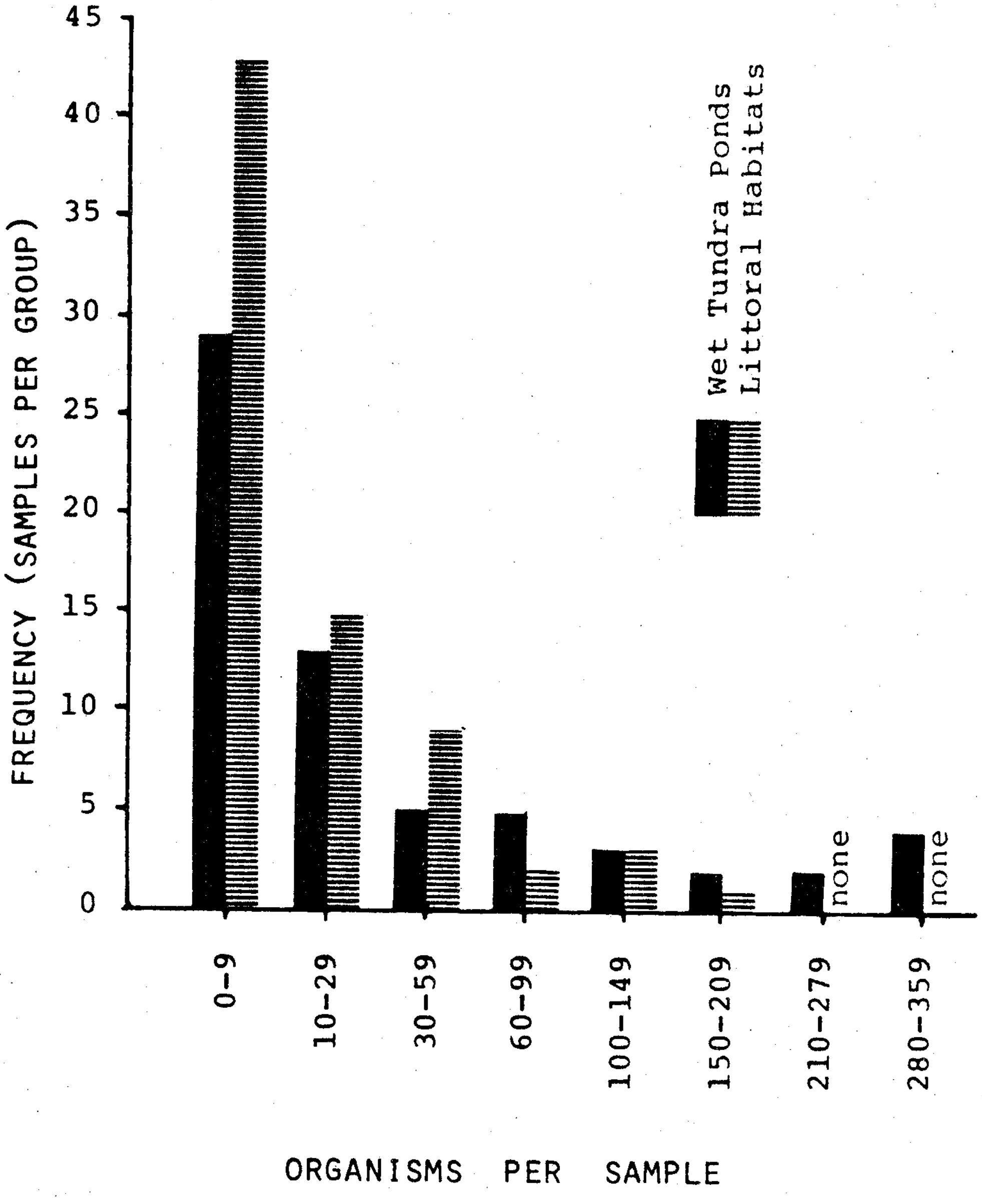


Figure 70. Frequency distribution of invertebrate densities in mud samples from wet tundra ponds and littoral habitats. Data were collected between 24 May and 8 September 1981, principally at the Fish River Delta and at Stebbins. Samples from both habitats usually had few (less than 60) organisms each. There were more samples with high numbers of organisms from wet tundra than from littoral habitats.

foods available in tundra ponds enhanced prey abundance.

It seems obvious that shorebirds were better fed at tundra ponds because these sites offered more food. This may be enhanced by the concentrating effect of a narrow pond edge relative to the width of a mud flat, and shorebirds may have to spend more time searching for food in the littoral zone. Both habitats had a high degree of patchiness in food abundance as was implied by the high variability we found in animal numbers per mud sample. This was found despite our efforts to sample mud only where shorebirds appeared to be feeding. In both habitats this patchiness can be partly attributed to the egg-laying patterns of gravid insects, as well as to physical properties. Substrate qualities may enhance faunal richness, and on tundra this may be furthered by a pond's tendency to dry up periodically. Littoral substrates may be scoured by ice, or may have their top layers continually suffocated or replenished by sedimentation. These processes can vary in time and space depending on currents, wave action, and tidal flow, and thus contribute to patchiness. We do not know their direction and magnitude, and as a result, we do not know the effects of these actions on patchiness.

4. Stomach Contents

(a) Semipalmated Sandpipers. Adult Semipalmated Sandpipers near Barrow were found to feed most heavily (70%) on midge larvae (Figure 71). At Barrow they were found to switch momentarily to adult flies when they were available in early July (Holmes and Pitelka 1968). Our collections were too few to document a switch to adult flies if this occurred. Our sample of 4 littorally feeding adults showed small amounts of larvae of midges, craneflies, maggots, and beetles, as well as 2 small snails.

Of the 6 fledged juveniles collected on tundra, 3 had eaten fly maggots and 4 had ingested beetle larvae. Notably, none had eaten midge larvae, in strong contrast to the diet of juveniles at Barrow that relied mostly on midge larvae after their initial diet of adult flies (Holmes and Pitelka 1968). Midge larvae were common in tundra ponds in July in Norton Sound (Figure 68) and it appears that maggots and beetle larvae may be preferred foods during their short post-fledging period when they fatten before departure by the end of July.

(b) Western Sandpipers. Adult Western Sandpipers feeding on tundra were not as partial to midge larvae as were Semipalmated Sandpipers, consuming fairly equal numbers of midge larvae, fly maggots, and beetle larvae (Figure 72). This dietary range resembles that for Westerns nesting further south on the Y-K Delta (Holmes 1972), though beetle larvae were considerably more common as food in our study.

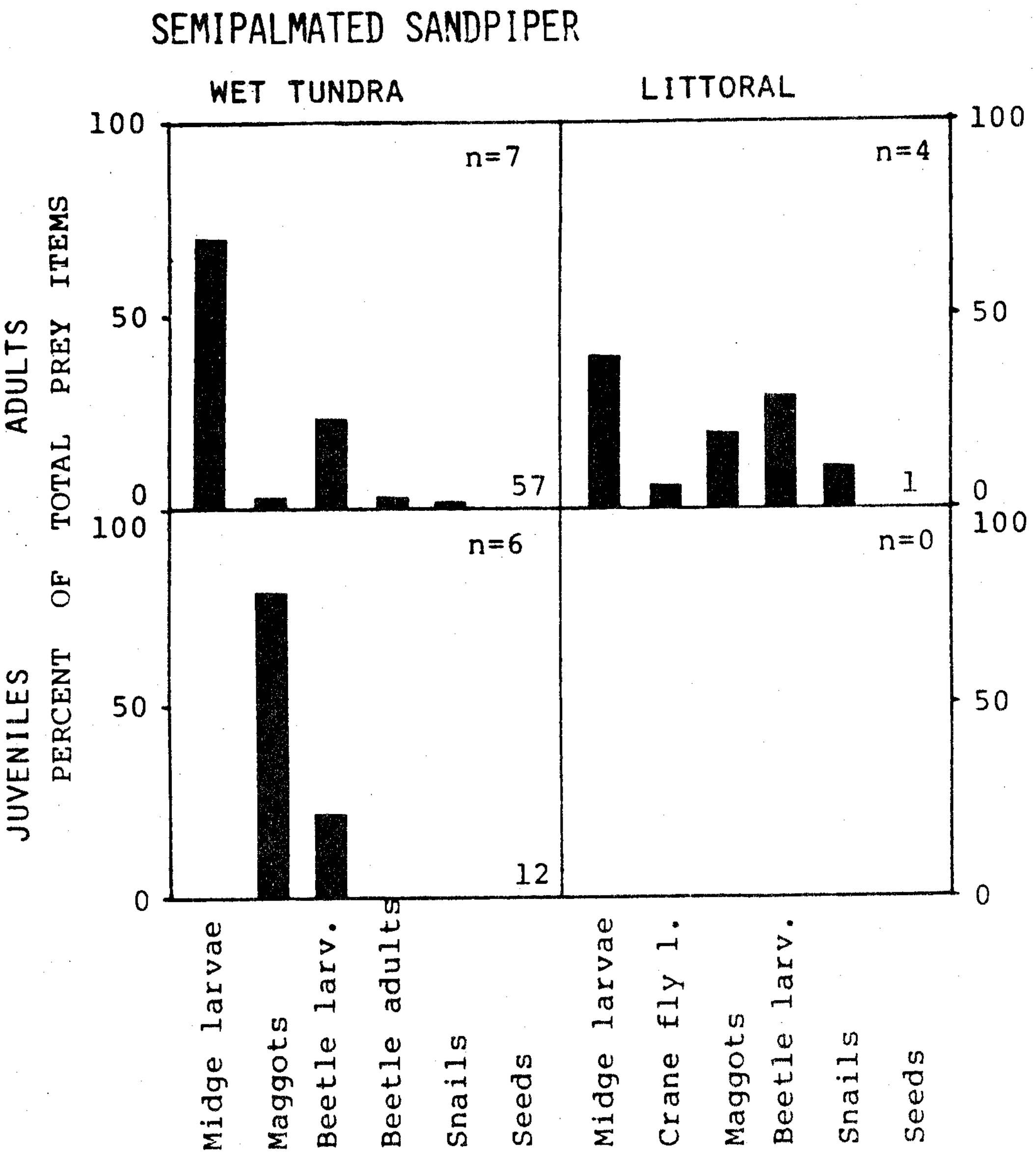


Figure 71. Stomach contents of Semipalmated Sandpipers from wet tundra and littoral habitats. Midge larvae were the common food of adults in both habitats. Juveniles fed mostly on maggots on tundra and none were collected in the littoral habitats.

Figures 71-74: n= number of birds in each age and habitat group; the number in the lower right= number of seeds. See Appendix 7 for dates and locations of collections, and see Appendices 8-15 for details of stomach contents.

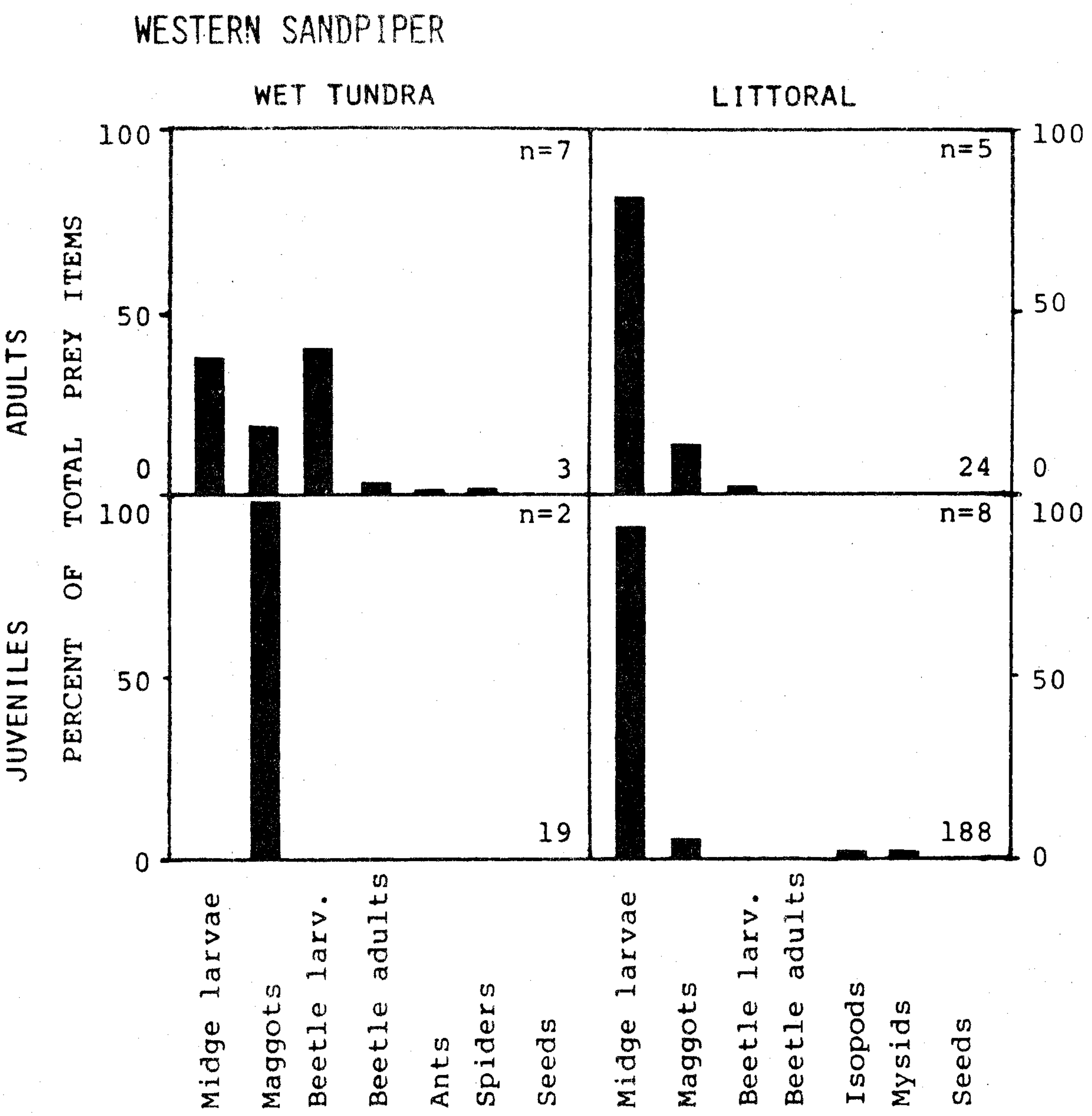


Figure 72. Stomach contents of Western Sandpipers from wet tundra and littoral habitats. Tundra foods were not at all similar for adults and juveniles, although the latter sample was small. Adults were generally taken earlier in the season. Littoral foods were nearly identical for the two age groups; these were usually feeding together at the same time.

Figures 71-74: n= number of birds in each age and habitat group; the number in the lower right= number of seeds. See Appendix 7 for dates and locations of collections, and see Appendices 8-15 for details of stomach contents.

Because Westerns nest mostly on raised moist tundra, their early season foods, ants, spiders, and adult beetles, are principally those of their territories, before wetlands are fully free of snow and spring floods (Holmes 1972). In Norton Sound by the end of May they feed regularly in wetlands away from their territories, and larval flies and beetles become the mainstay of the diet for the duration of the season (Figure 72).

Western juveniles first feed on surface-active flies, beetles, and also maggots shortly after hatching, switching, once they have fledged, to a diet resembling that of adult Westerns (Holmes 1972). Our negligible sample (N = 2) of post-fledging juveniles roughly supports this, especially those in the littoral zone.

Littoral feeding was common in Norton Sound for Western adults and juveniles, though Holmes (1972) found this to be infrequent on the Y-K Delta. In this habitat in Norton Sound midge larvae were the predominant food (Table 27).

(c) Dunlin. The tundra food habits of Dunlin in Norton Sound (Figure 73) are those of strictly wetland feeders since on wet tundra they were rarely seen feeding away from ponds and pond margins. Of the 8 adults collected, half had been eating beetle larvae while cranefly larvae and midge larvae were each found in 2 stomachs. Numerically, larvae of both beetles and midges were each somewhat less than half the animal diet. Though a small sample, this dietary array resembles the results of a more complete analysis of foods on the Y-K Delta (Holmes 1970), where midge larvae were by far the most common prey. With the exception of our preponderance of beetle larvae, this diet is similar to that of Dunlin near Barrow, where cranefly and midge larvae were predominant in a diet gleaned from tundra sod (Holmes 1966a). There, midge larvae were most frequently taken in July and August. Biomass analysis of that diet showed cranefly larvae to be the most important food by far due to their large size.

In the littoral zone, midge larvae were the only prey of adult Dunlin, save for a single snail, while the number of seeds dwarfed the small amount of animal prey in juveniles.

(d) Northern Phalarope. Adult phalaropes took mostly midge larvae and some beetle larvae from tundra ponds (Figure 74), and they gleaned these mostly from pond edges. Seeds were common in half of those collected near ponds, while 2 of the 3 adults collected in the littoral zone had seeds. Few phalaropes in the littoral zone were swimming and pecking at the water, as is typical for phalaropes; instead, most were pecking at the mud surface. This was the usual feeding mode of adults at tundra ponds, notably males, prior to chick fledging. Only one adult female was taken, and she had eaten 3 midge larvae and a snail in the littoral zone.

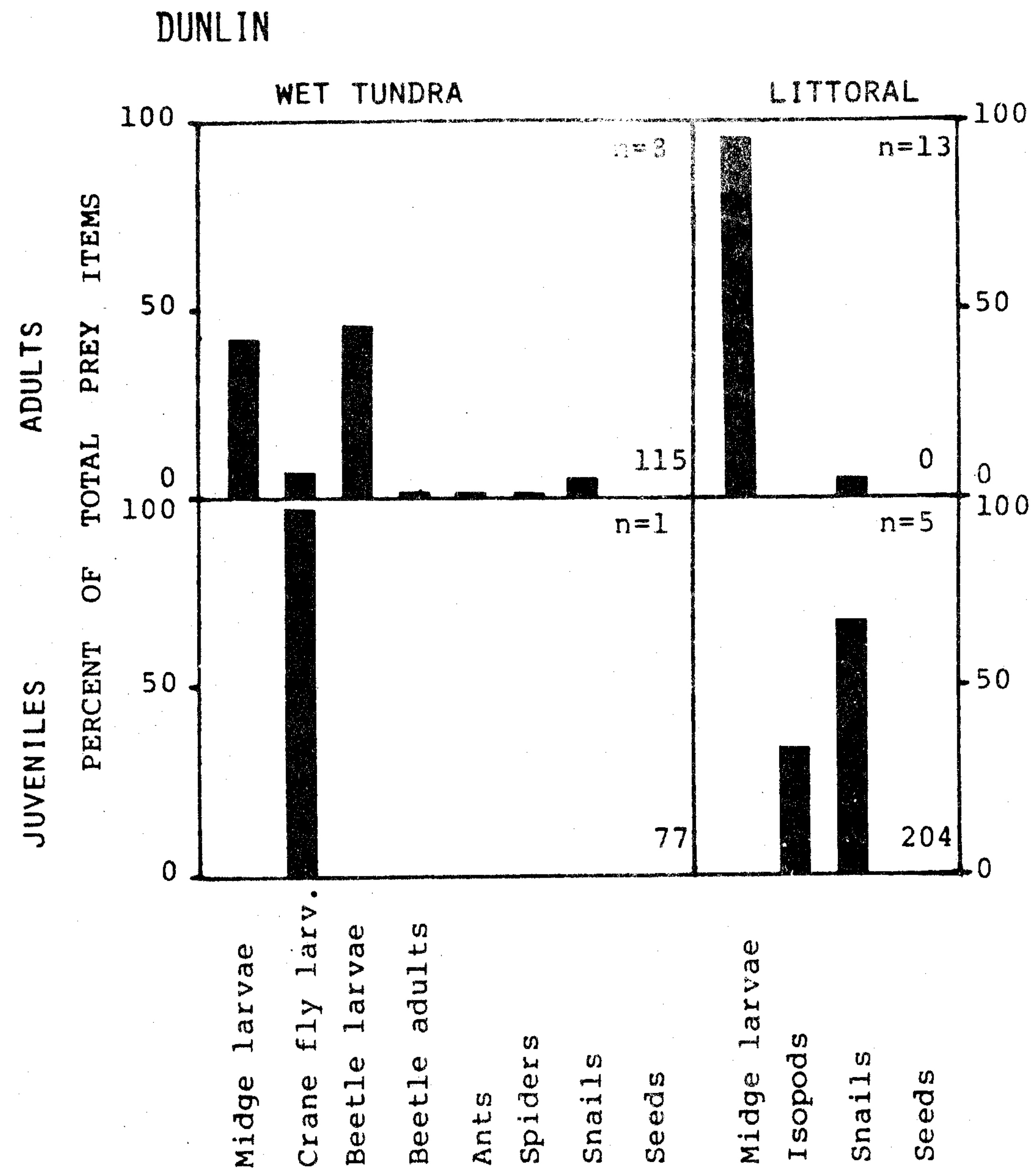


Figure 73. Stomach contents of Dunlin from wet tundra and littoral habitats. Tundra foods are not readily compared between the age groups due to the small sample of juveniles collected there. Littoral foods of adults and juveniles are very different from each other; note the great number of seeds taken by juveniles.

Figures 71-74: n= number of birds in each age and habitat group; the number in the lower right= number of seeds. See Appendix 7 for dates and locations of collections, and see Appendices 8-15 for details of stomach contents.

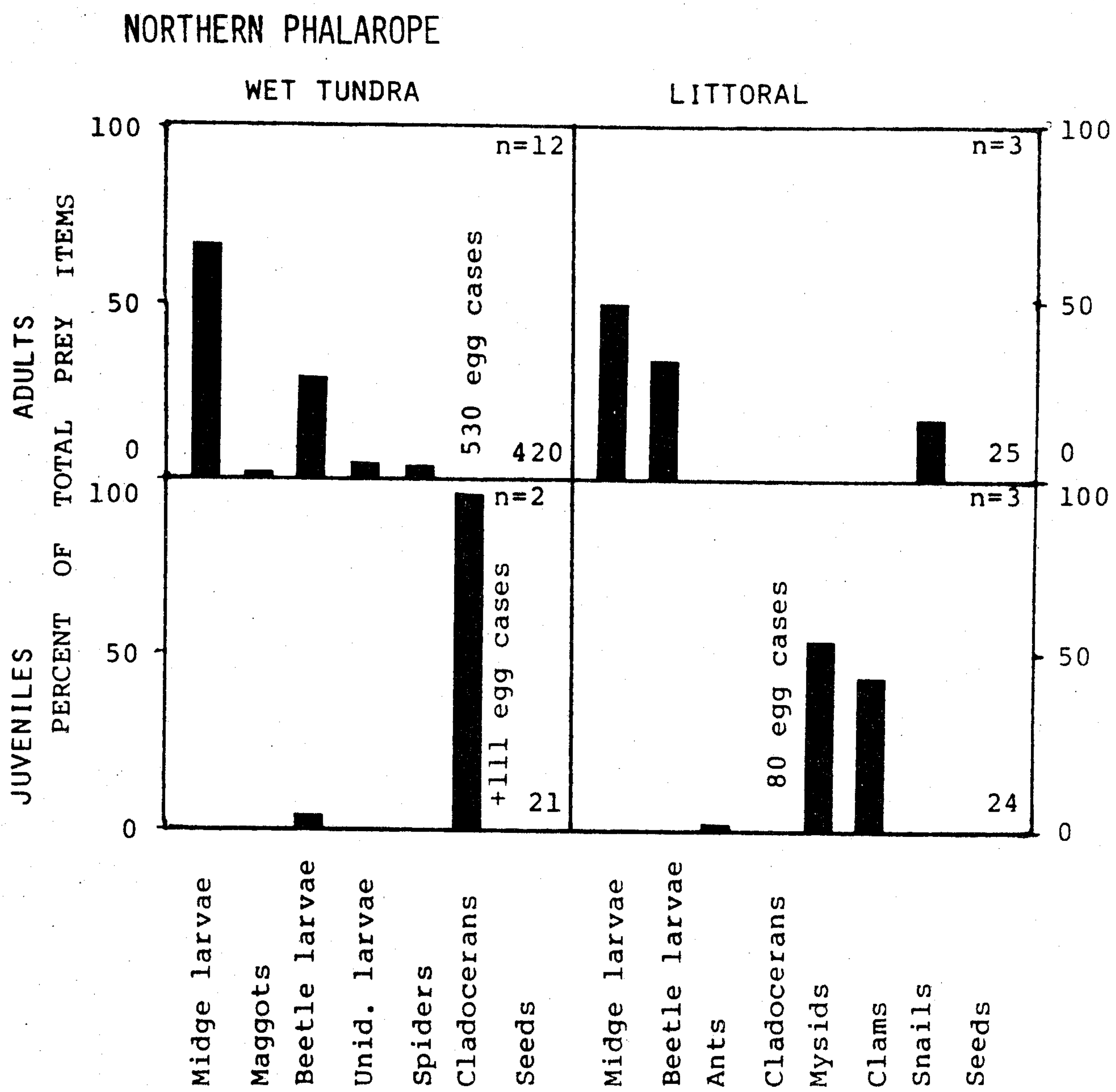


Figure 74. Stomach contents of Northern Phalaropes from wet tundra and littoral habitats. Juveniles (note the small sample sizes) had quite different foods than adults in both habitats.

Figures 71-74: n= number of birds in each age and habitat group; the number in the lower right= number of seeds. See Appendix 7 for dates and locations of collections, and see Appendices 8-15 for details of stomach contents.

Females massed on tundra ponds in late June, prior to departure, and fed by surface seizing.

After fledging, juveniles feeding on the tundra were mostly on ponds. One of the 2 we collected had eaten many cladocerans, while the other had taken 2 beetle larvae. In the littoral zone feeding juveniles were pecking at the water's edge or the mud surface, finding mysids and clams. The cladoceran egg cases may have come from this habitat, though they may be resistant to digestion and could have come from nearby pond feeding sites. Seeds were eaten by 3 of the 5 juveniles.

D. Duck Food Habits

We are best able to describe the food habits of dabbling ducks, as they were much more common than divers and considerably easier to collect. Dabblers are also more characteristic of the wet tundra areas stressed in this report. The sample size of duck stomachs is about half that of shorebirds; and, as with shorebirds, stomach contents data from the five most common dabblers are lumped to give a general picture of dabbler foods. Details of stomach contents for each species are given in Appendices 16 through 20.

All dabblers were collected on wet tundra, and the food habits reported here pertain to this habitat alone. Identification of food types is mostly limited to familial or higher categories, as with shorebird foods, because invertebrate faunal descriptions are lacking for western Alaska.

1. Tundra Foods

Dabblers are typically vegetarians except in spring and summer when animal prey provides additional protein needed for females to lay eggs, adults to molt, and young to grow quickly to flight stage.

Ninety percent of adult dabblers (N = 25) had plant remains (largely unidentifiable) in their stomachs, and 76% had animal items (Table 31). Plant shoots were mainly sedges (Carex spp.), and the chyme was mostly remains of shoots from earlier meals. Seeds were also of sedges as well as Mare's Tail (Figure 75), an abundant emergent plant common in mid to late summer. The most frequent animal prey were midge larvae, occurring in over 40% of adult stomachs. Cyclorrapha larvae were fairly frequent, at 24%, and many of these were probably plant miners (see below). Beetle larvae, beetle adults, cranefly larvae, mites, and mysids were all of lesser importance.

Table 31. Stomach contents of adult and juvenile dabbling ducks collected on wet tundra from 18 May to 8 September 1981. Data are for 4 Mallards, 17 Pintails, 14 Northern Shovelers, 8 Green-winged Teal, and 3 American Wigeon (see Appendices 16 through 20 for details).

	Adults					**Juveniles**				
Prey Items	n	%[1]	Freq.	%f	Mean Length (mm)	n	%[1]	Freq.	%f	Mean Length (mm)
Midge Larvae	617	69.2	9	43	9.6	160	66.9	2	8	7.8
Crane Fly Larvae	3	0.3	2	10	20					
Cyclorrapha Larvae	209	23.4	5	24	9.9					
Adult Diptera						37	15.5	2	8	3
Beetle Larvae	7	0.8	2	10	7.7					
Beetle Adults	7	0.8	2	10	10.7	13	5.4	2	8	5.3
Hymenoptera Adults						8	3.3	1	4	3
Mites	31	3.5	1	5	1					
Mysids	3	0.3	1	5	7					
Copepods	150	—	1	5	1					
Snails	14	1.6	2	10	5	21	8.8	2	8	5
Nematodes	1	0.1	1	5	7					
Animal Items	1,042	100.0	16	76	8.1	239	99.9	5	20	6.5
Shoots	323	—	6	29	13.1	75	—	1	4	15
Vegetation (Chyme)	—	36[2]	12	57		—	41[2]	18	72	
Seeds	1,379	—	16	76	2.0	1,896	—	20	80	1.8
Plant Items			19	90				23	92	
N of Birds			21[3]					25		

[1] Percent of animal matter, not including copepods.

[2] Percent volume for those birds with chyme in stomach.

[3] 16 of the 21 dabbler adults were males.

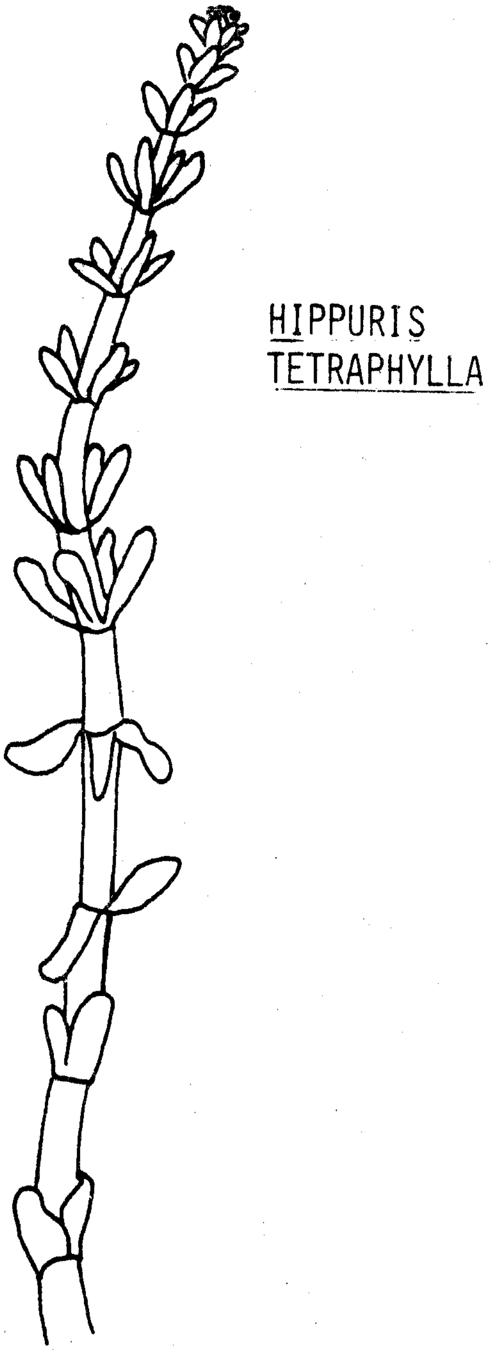


Figure 75. Mare's Tail (Hippuris tetraphylla), a common emergent pond plant in Norton Sound wetlands. It serves as a substrate for micro fauna, thus enriching pond life.

Only one pre-laying female was collected; its stomach and esophagus were full of shoots and shoot-mining maggots. The larvae are probably a fine protein source for egg formation and prey; laying females are known to frequently consume midge or other larvae (Dirschl 1969; Swanson et al. 1974; Krapu 1974; Serie and Swanson 1976; Schroeder's 1973 review article). Heavy reliance on midge larvae has been demonstrated by Bengston (1971), where a reduction in these larvae prior to egg formation was coupled with a 20 to 30% drop in body weight of females in 4 duck species. Clutch size was significantly lowered in 5 of the 8 species he studied.

Adults are also highly dependent on invertebrates when molting, as feather replacement requires a rich protein supply that plants alone may not provide (Krull 1970, Hawkins 1964). We did not collect flightless ducks and cannot describe their food habits during wing molt.

Many of the cyclorrapha larvae (maggots) were probably picked up by ducks eating shoots of sedges and other wetland grasses, as certain of these larvae are known to develop within plants. Called stem (or leaf) miners, these maggots feed on nutrients procured by the plant, and they provide what might be considered incidental protein to ducks. Brant feed on shallow water shoots in spring on Golovin Lagoon, and their stomachs often contain many of these larvae (Stanley Amarok, pers. comm.). Not all cyclorappha are ingested with plants, as we found them living free in mud samples (Table 28), and ducks may procure them by dabbling.

Dabbler ducklings are particularly dependent on insects in the first few weeks of life (Chura 1961, Bartonek 1972, Bengsten 1975, Street 1978). We made numerous observations of young ducklings feeding on the surface and at the edges of ponds, and conclude that they glean their much-needed insects principally from these sites. It is quite likely that the ducklings of each of the dabbling duck species in Norton Sound have their own unique foraging methods, and subsequently their own unique preferred prey base, as this result was found for numerous duckling species in Manitoba (Collias and Collias 1963).

As ducklings age, their dependence on animal food wanes. Chura (1961) reports that Mallard ducklings steadily decrease their intake of animal foods from almost 100% in the first 6 days of life to nearly none at 46 to 55 days, when they are close to fledging.

Foods of juvenile ducks (N = 21) in Table 31 are of post-fledging young. The stomach contents show an infrequency of animal prey (20%) and a preponderance of seeds (80%). Seeds are more resistant to digestion than insects, and thus will remain longer in duck stomachs (Swanson and Bartonek 1970). This fact, plus the low frequency of animal prey, suggests that young birds were not feeding as much as adults, and they were not consuming much invertebrate food.

The richness of ponds and pond margins in insect life has been discussed earlier in the section on shorebird food habits. In the context of ducks, we must also discuss the abundance of macrophytes, as the abundance of invertebrates undoubtedly relies on the richness of aquatic plants (Krull 1970). Plants themselves occasionally nourish invertebrates (e.g. plant miners), yet the prime nourishment comes from the periphyton, i.e., the film of microorganisms covering submerged plant surfaces (Schroeder 1973). These are principally bacteria, protozoa, and algae. The more dissected the plant (greater surface area), the greater the insect fauna (Krecker 1939, Andrews and Hasler 1943). Mare's Tail (Figure 75) is probably the most abundant and well-dissected aquatic plant of ponds in Norton Sound, providing abundant surface area for invertebrates. The fauna supported by these plants, coupled with the larval fauna of pond substrates, provide the richness supporting Norton Sound's ducks.

2. Littoral Foods

We know little of the littoral feeding of dabblers, though we can surmise it is mainly limited to shallow zones where dabblers congregate from late July through September. We have observed many ducks drawn to flooded shallows along canals at Stebbins, immediately following storm conditions with onshore winds. These were probably rooting up shoots in the wet, loosened soil.

VII. DISCUSSION OF RESULTS AND IMPACTS

A. Distribution of Habitats

Discussed here is the distribution of the eleven shoreline habitats in Norton Sound from Wales on the Bering Strait to Apoon Mouth in Pastol Bay, the easternmost mouth of the Yukon River. The detailed division of the entire coastline into 15 sections is simplified here into a three-region scheme (Figure 76):

Northwestern — Wales to Cape Nome (Sections 1-6)
Northeastern — Cape Nome to Tolstoi Point (Sections 7-12)
Southern — Tolstoi Point to Apoon Mouth (Sections 13-15)

These regional divisions are distinguished by their proportions of habitats (Table 32) and by bird use (see below).

1. Northwest Coast

This region has nearly three-fourths of the total surface area of protected waters in Norton Sound (Table 33). Less than a tenth of this is in true lagoons, the bulk being in the extended chain of embayments from Port Clarence east through Grantley Harbor, Tuksuk Channel, and Imuruk Basin. Over one-half of all shorelines are backed by moist tundra and uplands, and these predominate in Grantley Harbor, Tuksuk Channel, and Imuruk Basin. Exposed shore cliffs are found from Wales to Tin City and in a few locations between Tin City and Brevig Lagoon. The only cliffs along protected shores in Norton Sound are found in Port Clarence and Grantley Harbor. Wetland shores (wet tundra and river delta shorelines) are most extensive on Imuruk Basin, with a lesser amount on Woolley Lagoon and a little on Brevig Lagoon. Spits are extensive at Port Clarence and both Woolley and Brevig Lagoons.

2. Northeast Coast

This region is unique because of its extensive wetland shores (23% of the region's shorelines) and productive lagoons, notably Safety and Taylor Lagoons, Golovin Lagoon, and Kwiniuk Inlet inside of the Moses Point spit. Coastal cliffs are much more extensive here (and more heavily used by seabirds) than in the other two regions, and there is relatively less shoreline backed by moist tundra and uplands. This is the only region with spruce forests. Spits are extensive and comprise approximately one-fourth of all shorelines. Mud flats in Norton Sound are essentially confined to this region, and they occur on Safety Lagoon on Golovin Lagoon at the mouth of the Fish River Delta, adjacent to the Kwik River mouth near Moses Point, south of the Koyuk River mouth, and near Shaktoolik and Malikfik

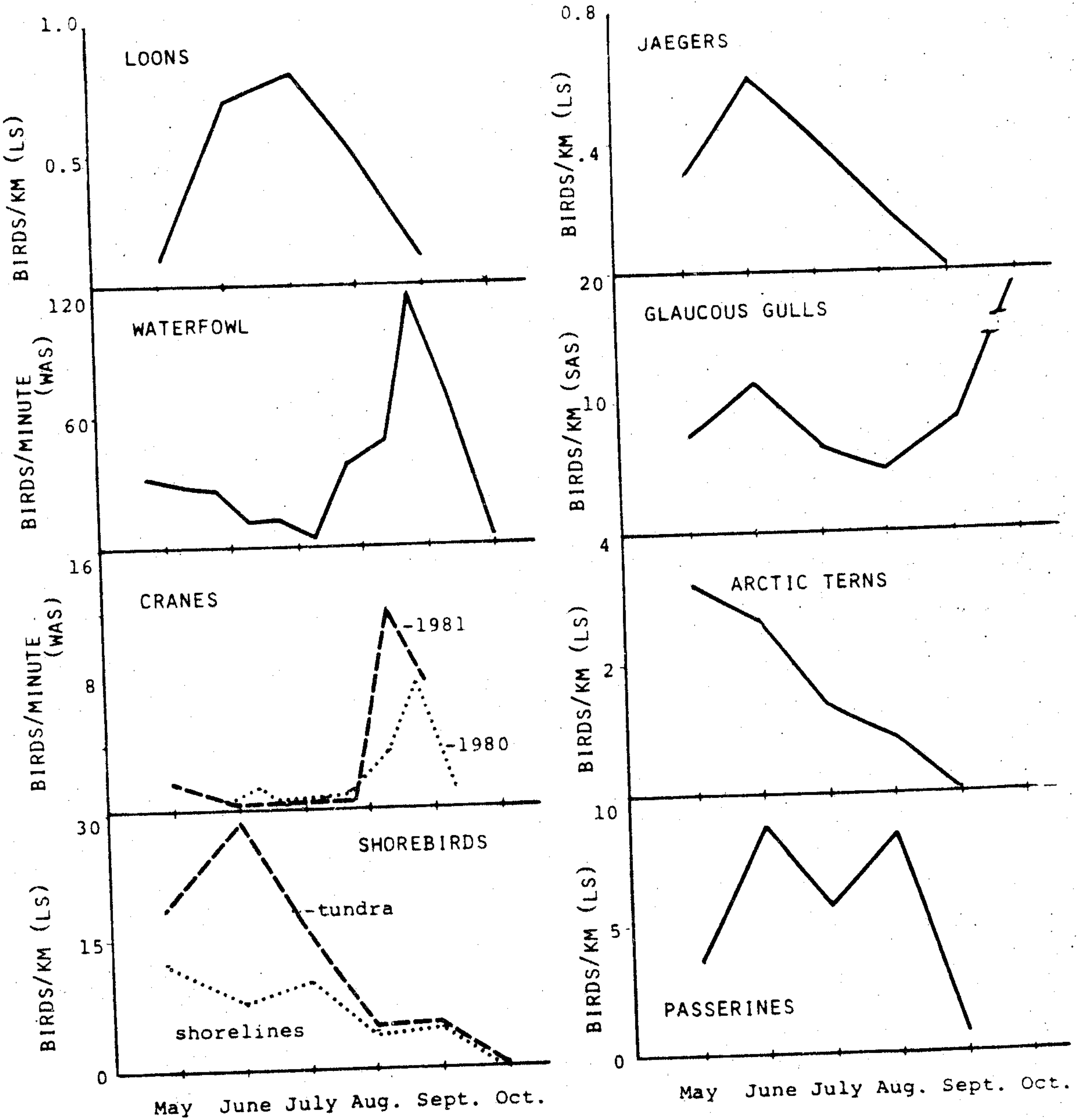


Figure 76. Seasonal abundance of loons, waterfowl, cranes, shorebirds, jaegers, Glaucous Gulls, Arctic Terns, and passerines in Norton Sound. Data are from three methods: shoreline aerial surveys (SAS), wetland aerial surveys (WAS), and land surveys (LS); these are indicated in each chart. Some birds are at peak numbers from May to June (loons, shorebirds, jaegers, terns), in August and September (waterfowl and cranes), and others are bimodal being most abundant in June (gulls and passerines) and then again in August (passerines) or October (gulls).

Table 32. Summary of shoreline habitat lengths (km) in northwestern, northeastern, and southern regions of Norton Sound.

Region of Norton Sound	Exposed Shores				Protected Shores				Other					
	Cliffs	Moist Tundra/ Uplands	Wet Tundra	Spits	Cliffs	Moist Tundra/ Uplands	Wet Tundra	Spits	River Delta	River Mouth	Disturbed	Total of Wetland Shores[1]	Percent of Total	Total
Northwestern (Sections 1-6)	16.8	144.2	3.2	70.6	4.8	183.6	37.3	81.2	26.9	7.0	1.3	67.4	(38)	576.9
Percent in section	(3)	(25)	(1)	(12)	(1)	(32)	(6)	(14)	(5)	(1)	(<1)	(12)		
Northeastern (Sections 7-12)	104.8	202.1	59.6	77.5	0	62.1	41.6	88.3	61.9	7.0	1.4	163.1	(46)	706.3
Percent in section	(15)	(28)	(8)	(11)		(9)	(6)	(13)	(9)	(1)	(<1)	(23)		
Southern (Sections 13-15)	11.8	193.0	40.4	0	0	0	0	0	0	7.8	0	40.4	(16)	253.0
Percent in section	(5)	(76)	(16)							(3)		(16)		
Total	133.4	539.3	103.2	148.1	4.8	245.7	78.9	169.5	88.8	21.8	2.7	270.4		1536.2
(Percent of Total)	(9)	(35)	(7)	(10)	(1)	(16)	(5)	(11)	(6)	(1)	(<1)	(18)		

[1] Wetland shores include exposed and protected shorelines with wet tundra, and river delta shorelines.

Table 33. Surface areas (km sq.) of lagoons and other protected marine waters in the northwest, northeast and south coastal regions of Norton Sound.

	Northwest Region (sections 1-6)		Northeast Region (sections 7-12)		South Region (sections 13-15)
Lagoons and Embayments	Brevig Lagoon	38	Safety and Taylor Lagoons	54	-NONE-
	Port Clarence	441	Golovin Lagoon	133	
	Grantley Hbr.	73	Kwiniuk Inlet (Moses Point)	19	
	Tuksuk Channel	5	Kwik R. Basin	9	
	Imuruk Basin	119	Shaktoolik and Malikfik Bays	9	
	Woolley Lagoon	14	Beeson Slough	7	
TOTAL (% of total)		690 km sq. (75)		231 km sq. (25)	0 km sq. (0)

Bays.

3. South Coast

This region is considerably less diverse in habitats than the two northern regions. Over three-fourths of the shorelines are along moist tundra uplands with low basalt bluffs and numerous tiny bays. There are no enclosed waters, though St. Michael Bay is protected on the northwest and south. Wet tundra shores extend most of the distance from Stebbins to Apoon mouth; these are peat banks, and unlike the wetland shores in other regions, they are poor for birds. As will be discussed below, the wet tundra behind the shore is highly productive bird habitat. There is no spit habitat in the region.

B. Habitat Use, Seasonal Abundance, and Geographic Distribution of Birds

The high mobility of birds allows them to exploit seasonally productive habitats for nesting and feeding. In Norton Sound we have identified several patterns of seasonal habitat use distinguished by breeding habitat, by when populations peak (breeding versus post-breeding periods), and by where most of the peak population feeds (Table 34). Most migratory birds arrive in Norton Sound from mid to late May. Their primary nesting habitat (excepting cliff-nesting species) is wet tundra, usually adjacent to lagoons, river mouths, or river deltas. Much lower densities of nesting birds occur in upland moist tundra, shrub, or forested habitats in Coastal Norton Sound. Birds are generally mot abundant in coastal areas after the breeding season, when they gather to build fat reserves and prepare for the flight south. There is a seasonal trend of increased littoral feeding as the season progresses from spring through fall. Overall, populations are generally highest in the northeastern region of Norton Sound (from Cape Nome to Tolstoi Point, 32 km south of Unalakleet), followed by the southern region (Tolstoi Point to Apoon Mouth, Yukon River), with the lowest populations in the northwestern Sound (Cape Prince of Wales to Cape Nome; see Table 39 below). Departures of most migratory birds from coastal Norton Sound peak from mid-August through mid-September. These patterns do not necessarily apply to all bird groups; the details for each of the eight common groups in Norton Sound are given next. Appendix 26 gives further information on habitat use and seasonal abundance in checklist form for all species we observed in Norton Sound.

Table 34. Patterns of habitat use and seasonal abundance for eight bird groups in coastal Norton Sound.
M = most individuals. S = some individuals.

	Loons	Waterfowl	Cranes	Shorebirds	Jaegers	Gulls	Terns	Passerines
1. Wetland breeders with								
a) peak numbers in breeding period feeding in:								
(1) littoral	M			S			M	
(2) tundra	S			S		S	S	S
b) peak numbers after breeding feeding in:								
(1) littoral		M		M		M		S
(2) tundra		S	M	S				S
2. Upland breeders with								
a) peak numbers in breeding period feeding in uplands				S	M		S[1]	M
b) peak numbers after breeding period feeding in:								
(1) littoral		S		S				S
(2) tundra				S				S

[1] Some Aleutian Terns nest on uplands and feed in marine waters.

1. Loons

Loons breed primarily on wet tundra and are most common during the nesting season (Table 34). A slightly higher density in July than in June represents the production of young (Figure 76); both young and adults depart Norton Sound soon after nesting is completed. Of the two species common in Norton Sound, the Red-throated Loon feeds more in littoral areas, usually exposed shores (Table 35) than does the Arctic Loon, which often feeds in tundra ponds (Bergman and Derksen 1977), as well as along exposed littoral shores.

Estimates of loon populations on Norton Sound wetlands were in the low hundreds or less at each site (Table 36). Well over half of these were in the northeastern region (see Table 39 below), although the Stebbins wetlands, in the south, had the high population of Arctic Loons (200) and the Imuruk Basin, in the northwest, had the high estimate of Red-throated Loons (120).

2. Waterfowl

Swans, geese, and ducks are treated separately here due to their differing patterns of habitat use and abundance. Generally, they are wetland nesters and after nesting are most abundant in wetlands and along protected shores near wetlands when they gather to feed (Table 34, Figure 76).

(a) Swans. Whistling swans are most prevalent in coastal Norton Sound after nesting (Figure 76) and at that time are found in lagoonal (protected shoreline) as well as wet tundra habitats (Table 35). Post-breeding populations are greatest in the northeastern region (see Table 39 below) and these occur primarily at the Fish River Delta (Golovin Lagoon) and at Koyuk (Table 37). The origin of these birds is uncertain, though they may come from nesting areas on St. Lawrence Island as well as the Seward Peninsula. As many as 1,000 swans were counted at the Stebbins wetlands, and these probably came from nesting sites on the nearby Y-K Delta.

Nesting populations on wetlands were usually less than ten swans each, though a few hundred non-breeders were present in spring at the Fish River Delta (Table 36). Widely scattered nesting pairs were also observed along large inland lakes in upland tundra areas.

(b) Geese. Very few geese nest in Norton Sound (Table 36) and those that occur there are primarily migrants. Canada Geese are the most abundant and these concentrate (after nesting to the north of Norton Sound) along protected shores, on wetlands, and on uplands (Table 35) where they feed on berries. Numbers peak in September and most of these can be found in the northeastern region (Table 37); our estimates for total popu-

Table 35. Habitat use and activities [1] of Norton Sound birds during spring migration, breeding, and post-breeding periods. This list includes the common species discussed in Chapter VI-Results; see Appendix 26 for other species.

	Shorelines		Non-shorelines	
Species	Exposed Littoral	Protected Littoral(lagoons)	Wet tundra (Wetlands)	Moist tundra (Uplands)
LOONS				
Arctic Loon	br,pb		BR,pb	
Red-throated Loon	sm,br,pb		BR,pb	
WATERFOWL				
Swans				
Whistling Swan		sm,PB,br	sm,br,PB	br
Geese				
Canada Goose		PB	sm,br,PB	PB
Brant		SM,pb	SM,pb	
Emperor Goose	PB[2]		sm,br,pb	
Snow Goose			sm,pb	PB[2]
Dabbling Ducks				
Mallard		sm,pb	sm,br,pb	
Pintail	sm,pb	SM,BR,PB	SM,BR,PB	br
Green-winged Teal			sm,BR,PB	
Northern Shoveler			sm,BR,pb	
American Wigeon		sm,PB	sm,br,pb	
Diving Ducks				
Greater Scaup	sm	PB	sm,BR	
Oldsquaw	sm,br,pb	sm,br,pb	BR	
Common Eider	sm,br,pb	pb	br	
Black Scoter	SM,pb			br
Red-breasted Merganser	sm	sm,br,pb		br
CRANES				
Sandhill Crane			SM,br,PB	sm,PB
SHOREBIRDS				
American Golden Plover		pb	pb	sm,BR,pb
Bar-tailed Godwit	pb	pb	sm,br,pb	BR
Whimbrel		br,pb	br,PB	sm,BR,PB
Black Turnstone	sm,pb	sm,pb	BR	
Northern Phalarope	sm	sm	BR,PB	
Red Phalarope	SM,pb		br	
Common Snipe			br,pb	br
Long-billed Dowitcher		sm,PB	sm,br,PB	
Semipalmated Sandpiper	BR,pb	sm,BR,PB	SM,BR	br
Western Sandpiper	PB	br,PB	SM,br,pb	BR

Table 35 cont.

	Shorelines		Non-shorelines	
Species	Exposed Littoral	Protected Littoral(lagoons)	Wet tundra (Wetlands)	Moist tundra (Uplands)
SHOREBIRDS cont.				
Pectoral Sandpiper		pb	SM,br,PB	
Sharp-tailed Sandpiper			PB	
Dunlin	pb	sm,PB	sm,BR,PB	
JAEGERS				
Parasitic Jaeger	pb	pb	sm,br,pb	sm,BR
Long-tailed Jaeger	pb	pb	sm,br,pb	sm,BR
GULLS				
Glaucous Gull	SM,BR,PB	sm,br,pb	sm,BR,pb	
Glaucous-winged Gull	pb	pb		
Mew Gull	sm,pb	sm,pb	sm,BR	
Black-legged Kittiwake	SM,BR,pb			
Sabine's Gull	pb	pb	br	
TERNS				
Arctic Tern	sm,BR,PB	sm,BR,PB	BR	
Aleutian Tern	sm,BR,pb	sm,BR,pb		br
PASSERINES				
Common Raven[3]	br,pb	br,pb	br,pb	br,pb
Yellow Wagtail		br,pb		BR
Savannah Sparrow		br,pb	BR,PB	br
Lapland Longspur		br,pb	SM,br,PB	BR

[1] Key to activities - SM = spring migration, BR = breeding (not necessarily nesting habitat), PB = postbreeding feeding and migration. Upper case denotes major use of the habitat, lower case indicates minor use.

[2] St. Lawrence Island habitat use seen on 18 September 1980.

[3] Year round resident.

Table 36. Spring migration and breeding populations of the common birds on Norton Sound wetlands, 1980 and 1981. See Chapter 4 for area of each wetland.

Species	Data Source[1]	Estimation Technique[2]	Northwest Wetlands				Northeast Wetlands						South Wetlands	TOTAL[4]
			Brevig Lagoon	Imuruk Basin	Port Clarence	Woolley Lagoon	Safety and Taylor Lagoons[3]	Fish River Delta	Moses Point	Koyuk	Shaktoolik	Unalakleet	Stebbins and Stuart Island	
LOONS														
Arctic Loon	LS	PV	<10	40	15	<10	30	60	80	80	60	15	200	562
Red-throated Loon	LS	PV	15	120	30	15	30	60	60	100	60	10	30	470
WATERFOWL														
Swans														
Whistling Swan	LW	TC	-[5]	10's	<10	<10	100's[6]	100's	<10	<10	10's[6]	<10	10's	100's
Geese														
Canada Goose	LS	RE	-	<10	-	-	<10	10's	-	10's	-	-	10's	10's
Brant[6]	LW	RE	40	-	100's	10's	100's	1000's	100's	1000's	-	-	10's	m1000's
Emperor Goose[6]	LS	RE	-	-	10's	-	-	-	-	-	-	-	10's	10's
Snow Goose[6]	LW	RE	<10	-	10's	-	<10	10's	100	100's	-	10's	100's	100's
Dabbling Ducks														
Mallard	LS	RE	-	<10	-	-	10's	100's	-	10's	-	-	<10	f100's
Pintail	LW	RE	100's	10's	100's	100's	100's	1000's	100's	100's	10's	100's	1000's	f1000's
Green-winged Teal	LS	RE	10's	100's	10's	10's	10's	100's	100's	100's	10's	<10	100's	f1000's
Northern Shoveler	LS	RE	10's	100's	10's	10's	10's	100's	10's	100's	<10	-	100's	f1000's
American Wigeon	LS	RE	-	100's	<10	10's	10's	10's	10's	<10	<10	<10	10's	f100's
Diving Ducks														
Greater Scaup	LS	RE	10's	100's	<10	<10	10's	100's	10's	100's	10's	10's	1000's	f1000's
Oldsquaw	LS	RE	100's	100's	100's	10's	10's	10's	100's	10's	10's	10's	100's	f1000's
Common Eider	LS	RE	100's	<10	10's	10's	10's	10's	10's	<10	<10	-	10's	f100's
Black Scoter	LS	RE	-	100's	100's[6]	<10	-	10's	10's	<10	10's	10's	10's	f100's
Red-breasted Merganser	LS	RE	<10	10's	10's	10's	10's	10's	10's	<10	10's	10's	10's	f100's
CRANES														
Sandhill Crane[7]	LS	RE	<10	10's	10's	<10	<10	10's	<10	<10	<10	-	10's	f100's
SHOREBIRDS														
American Golden Plover	LS	PV	<10	200	10	20	<10	<10	<10	<10	<10	<10	50	300+
Bar-tailed Godwit	LS	PV	25	40	25	<10	20	<10	40	230	-	-	30	410+
Whimbrel	LS	PV	20	100	<10	<10	<10	<10	45	20	10	<10	20	215+
Black Turnstone	LS	PV	10	100	-	<10	<10	-	<10	<10	<10[6]	<10[6]	1000	1110+
Northern Phalarope	LS	PV	90	4180	510	120	2040	3700	7430	8230	1030	100	25520	51950
Red Phalarope	LS	RE	<10	-	<10	-	500[6]	-	-	-	<10	-	<10	500+

Table 36, continued.

Species	Data Source[1]	Estimation Technique[2]	Northwest Wetlands: Brevig Lagoon	Northwest Wetlands: Imuruk Basin	Northwest Wetlands: Port Clarence	Northwest Wetlands: Woolley Lagoon	Northeast Wetlands: Safety and Taylor Lagoons[3]	Northeast Wetlands: Fish River Delta	Northeast Wetlands: Moses Point	Northeast Wetlands: Koyuk	Northeast Wetlands: Shaktoolik	Northeast Wetlands: Unalakleet	South Wetlands: Stebbins and Stuart Island	TOTAL[4]
Common Snipe	LS	PV	20	40	-	<10	30	20	20	30	10	-	40	210+
Long-billed Dowitcher	LS	PV	40	30	40	-	<10	20	-	20	-	150[6]	20	300+
Semipalmated Sandpiper	LS	PV	210	4140	750	460	2160	4660	7390	16460	360	-	43600	80,190
Western Sandpiper	LS	PV	90	370	2430	220	2630	660	50	550	510	-	680	8,190
Pectoral Sandpiper	LS	PV	20	-	20	-	-	200[6]	-	200[6]	-	-	-	440+
Dunlin	LS	PV	130	40	900	330	1000	1390	850	3070	-	-	16220	23,930
JAEGERS														
Parasitic Jaeger	LS	RE	10's	10's	10's	<10	10's	10's	10's	10's	10's	<10	10's	f100's
Long-tailed Jaeger	LS	RE	10's	10's	10's	<10	10's	10's	10's	<10	10's	10's	10's	f100's
GULLS														
Glaucous Gull	WAS	PV	10's	40	250	10's	100's	410	270	870	440	10's	230	3,000
Mew Gull	LS	PV	<10	40	-	-	10's	20	180	170	90	30	250	800
Black-legged Kittiwake	LS	RE	10's		10's	10's	100's	-	<10	-	<10	-	10's	f100's
Sabine's Gull	LS	RE	-	-	<10	-	<10	<10	<10	<10	<10	-	10's	f10's
TERNS														
Arctic Tern	LS	PV	70	230	100's	10's	600	100	100	60	40	10's	500	2,000
Aleutian Tern	LS	TC	21	-	30	-	300+	30[8]	10's	-	-	35	<10	500
PASSERINES														
Common Raven	LS	RE	-	10's	-	10's	10's	10's	10's	40	10's	10's	10's	f100's
Yellow Wagtail	LS	RE	100's	100's	-	-	10's	10's	10's	10's	10's	10's	10's	m100's
Savannah Sparrow	LS	RE	100's	1000's	100's	100's	100's	100's	100's	1000's	100's	100's	1000's	f10,000's
Lapland Longspur	LS	RE	100's	100's	10's	10's	1000's	100's	100's	1000's	100's	100's	1000's	f10,000's

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[1] Data sources: LS = land survey, WAS = wetland aerial survey, LW = both types of surveys.

[2] Estimation technique: TC = total count, PV = projected value using densities, RE = rough estimate.

[3] Includes Flambeau and Eldorado River mouths.

[4] Total estimate key: f = few(1-5), m = many(6-9).

[5] Blank denotes no sightings.

[6] Migrants in spring. None or 10 nesting in wetland indicated.

[7] Abundant as migrants in spring, though spring migrants were not adequately censused. Numbers indicate nesting population.

[8] On Golovin Spit.

Table 37. Post-breeding populations of common birds on Norton Sound wetlands, 1980 and 1981. This only includes species whose post-breeding populations are significantly greater than the breeding populations (Table 35).

			Northwest Wetlands				Northeast Wetlands						South Wetlands	
Species	Data Source	Estimation Technique	Brevig Lagoon	Imuruk Basin	Port Clarence	Woolley Lagoon	Safety and Taylor Lagoons	Fish River Delta	Moses Point	Kayuk	Shaktoolik	Unalakleet	Stebbins and Stuart Island	TOTAL
WATERFOWL														
Swans Whistling Swan	WAS	TC	-[5]	40	42	10	71	1602	63	447	65	< 10	1007	3347
Geese Canada Goose	WAS	TC	40	331	561	112	1030	1935	872	1025	608	-	150	6664
Dabbling Ducks														
Mallard	WAS	PV	10	350	-	-	30	40	570	300	90	-	300	1690
Pintail	WAS	PV	50	1350	200	60	2100	3100	6700	1070	460	100	2200	17390
American Wigeon	WAS	PV	20	1300	-	-	300	800	3100	250	200	< 10	1880	7850+
Diving Ducks Greater Scaup	WAS	PV(TC)	<10	100	25	-	180	1530(TC)	180	200	< 10	-	1340	3555+
CRANES														
Sandhill Crane	WAS	PV	40	6700	600	80	100	1300	300	2900	480	-	8000	20500
SHOREBIRDS														
American Golden Plover	LS	RE	100's	-	10's	100's	10's	10's	10's	10's	10's	-	100's	f100's
Bar-tailed Godwit	LS	RE	10's	-	10's	10's	10's	10's	100's	100's	10's	-	100's	m100's
Whimbrel	LS	RE	10's	-	-	10's	100's	1000's	100's	100's	10's	-	100's	f1000's
Northern Phalarope	LS	PV	110	-	1300	130	1450	2000	2700	2600	270	170	46310	57040
Long-billed Dowitcher	LS	RE	10's	100's	10's	10's	100's	100's	100's	1000's	-	10's	1000's	m1000's
Western Sandpiper	LS	PV	90	-	1270	400	11280	960	200	1220	-	-	340	15760
Pectoral Sandpiper	LS	RE	10's	-	10's	10's	100's	100's	10's	10's	-	10's	100's	f1000's
Sharp-tailed Sandpiper	LS	RE	-	-	-	10's	100's	100's	10's	-	-	-	100's	f1000's
Dunlin[6]	LS	PV	130	-	150	200	2530	850	3390	1790	-	-	4730	13770
PASSERINES														
Yellow Wagtail	LS	RE	600	-	10's	10's	10's	10's	10's	10's	100's	10's	10's	f1000's

[1] Data sources: LS = Land Survey, WAS = Wetland Aerial Survey

[2] Estimation techniques: TC = total count, PV = projected value using densities, RE = rough estimate.

[3] Includes Flambeau and Eldorado River mouths.

[4] f = few(1-4), m = many(5-9); total may involve duplication due to large flocks moving between wetlands, though counts are probably all low.

[5] Blanks denote no sightings.

[6] Dunlin population was greater during breeding season; post-breeding populations are greater for some wetlands.

lations are probably quite low as we do not know the residency period of the large flocks seen, though we suspect that it was short and that far more Canada Geese used the wetlands than were counted.

Brant were present in coastal Norton Sound in greatest numbers in spring, when thousands migrated near Koyuk and Golovin (near the Fish River Delta, Table 36). They congregate along protected shores as well as on wet tundra at that time (Table 35), and feed on vegetation shoots. The first of these migrants (mid to late May) are adults, while later migrants (early to mid June) are mainly immatures; all are bound for the arctic. In August when Brant return south most migrate through the Bering Strait and bypass other coastal areas of Norton Sound.

Only a few Emperor Geese nest in Norton Sound, and these are at Stebbins (Table 36). Populations of this Beringian endemic were probably considerably greater along Norton Sound's shores but have been reduced by hunter harvest (C. Lensink, pers. comm.). Minor coastal concentrations were seen in both spring and late summer, and may have been part of a small population nesting along the Seward Peninsula's north shore. Large molting flocks concentrate along the southern shores of St. Lawrence Island (Fay and Cade 1959).

Snow Geese are migrants in Norton sound, with at least 5,000 passing Koyuk in spring (Shields and Peyton 1979); we noted lesser concentrations elsewhere (see Table 10). These are bound for colony sites on Wrangel Island in the Soviet Chuckchi Sea. Fall migrants pass mostly offshore, stopping to feed on upland moist tundra of St. Lawrence Island; a few hundred stop briefly along Norton Sound's northwestern outer coast.

(c) Dabbling Ducks. These are wetland breeders (Table 35). Pintails were the most abundant of these and were common as spring migrants and nesters, with peak abundance after nesting when pre-migratory flocks gathered along protected shores and on wetlands (Tables 36 and 37). Many of those seen in Norton Sound in 1980 and 1981 were probably refugees from drought conditions in the mid-continental prairies (USFWS and CWS 1981), and populations were thus higher than in normal years. Late summer concentrations were greatest in the northeastern region (13,500, Table 37). Mallards showed the same patterns in habitat use, seasonal abundance, and geographic distribution as Pintails, though their populations were less than one-tenth those of Pintails. Teal followed similar patterns though post-breeding concentrations were not much greater than in spring and are attributable to production of young. Littoral feeding by teal was minimal. Shovelers were most common on wetlands while nesting, with lower post-breeding populations and little use of littoral zones. American Wigeon were uncommon nesters and reached peak abundance following the nesting season, with highest numbers at the Imuruk Basin (1,300), Moses Point (3,100), and

Stebbins (1,880, Table 37). These were immigrants from inland and northern nesting sites.

Dabblers feeding in wetlands eat shoots and seeds all season, and concentrate on fly larvae when nesting. Larval flies are especially important for ducklings, and these are obtained on wet tundra ponds.

(d) Diving Ducks. Species in this group use a greater variety of habitats than all other waterfowl in Norton Sound, and many exploit exposed coasts, notably rocky shores, to feed during and after the nesting season (Table 35). There were nearly three times as many species of divers (n = 17) as dabblers (n = 6), yet divers were only one-third as numerous as dabblers (see Table 13).

Greater Scaup were common divers and were the most common nesting ducks (only slightly more so than Pintails; see Tables 12 and 13). They bred on wetlands and gathered in late summer flocks in protected waters with the largest pre-migratory flocks on Golovin Lagoon at the Fish River Delta (1,500) and on wetlands at Stebbins (1,300, Table 37). Oldsquaw also nested on wetlands. They gathered to molt in lagoonal waters, particularly at Brevig Lagoon, and were otherwise present along exposed and protected shores, mostly in spring. They were nearly as common as scaup but were less common as nesters. Common Eiders nested in wetlands and probably nested on raised tundra along sections of exposed coasts. They moved to exposed littoral areas after the chicks hatched, and became most abundant in fall when they gathered offshore, principally near rocky shores. Common Eiders were most abundant near Cape Nome and Safety Lagoon (coastal sections 6 and 7) and along the low basalt bluffs from Tolstoi Point to Cape Stephens (section 13, Table 38). Black Scoters were the most common diver and their nesting was restricted to inland areas along rivers and on uplands. They were most common in spring along exposed shores with cliffs and rock outcrops in the northeastern region (Table 36), and were uncommon in late summer and fall in coastal Norton Sound. Red-breasted Mergansers were most concentrated near river mouths and presumably nested in nearby moist and wet tundra habitats. They were evenly distributed throughout coastal Norton Sound in low numbers (Table 36) and were most common in June. The remaining 12 species of diving ducks were relatively uncommon in coastal Norton Sound, with the exception of King Eiders. These arctic nesters pass offshore in western Norton Sound in late April and early May and move north through the Bering Strait. Their total population of 1.1 million (Barry 1968) returns south through the strait in mid to late summer and fall, again passing far offshore.

(e) Relative Importance of Norton Sound Waterfowl. Waterfowl populations in Norton Sound are dwarfed by those using the nearby Y-K Delta wetlands and littoral (King and Dau 1981). Relative to eastern

Table 38. Populations of selected bird species which were most abundant in habitats other than wetlands, by coastal section, Norton Sound 1980 and 1981.

			Northwest Region						Northeast Region						South Region		
Species	Data Source[1]	Estimation Technique[2]	Wales to Brevig 1	Port Clarence 2	Grantley Harbor 3	Imuruk Basin 4	C. Douglas to Nome 5	Nome to C. Nome 6	C. Nome to Rocky Point 7	Golovin Bay 8	Golovin Lagoon 9	C. Darby to Kayuk 10	Kayuk to C. Denbeigh 11	C. Denbeigh to Tolstoi Pt. 12	Tolstoi Pt. to C. Stephens 13	C. Stephens to Apoon Mouth 14	TOTAL[3]
WATERFOWL[4]																	
Diving Ducks																	
Common Eider	SAS	TC	20	90	10	-[6]	80	260	480	10	20	20	15	10	230	10	1255
Black Scoter	SAS	TC	50	75	-	130	320	-	260	-	10	10	70	100	90	-	1115
Red-breasted Merganser	SAS	TC	10	20	10	30	20	-	80	-	20	30	30	30	10	-	290
SHOREBIRDS[5]																	
American Golden Plover	LS	RE	-	10's	-	100's	100's	10's	10's	10's	10's	10's	10's	10's	-	10's	m100's
Bar-tailed Godwit	LS	RE	10's	10's	-	10's	10's	10's	10's	-	10's	10's	10's	10's	-	10's	f100's
Whimbrel	LS	RE	10's	10's	-	100's	100's	10's	100's	-	10's	100's	100's	10's	-	10's	m100's
Western Sandpiper	LS	RE	10's	100's	100's	100's	100's	100's	1000's	10's	100's	100's	100's	100's	-	100's	f1000's
JAEGERS																	
Long-tailed Jaeger	LS	RE	10's	10's	10's	100's	10's	10's	10's	-	10's	10's	10's	10's	-	10's	m100's
GULLS[4]																	
Glaucous Gull[7]	SAS	TC	160	150	60	150	1640	980	5920	4770	600	3000	2000	460	220	170	20,280

[1] Data Sources: LS = land surveys, SAS = shoreline aerial surveys.

[2] Estimation technique: TC = total count, RE = rough estimate.

[3] f = few(1-4), m = many(5-9); Totals may involve duplication due to birds moving between coastal sections.

[4] Waterfowl and gull populations are primarily postbreeding counts.

[5] Shorebird and jaegers populations are breeding estimates.

[6] Blanks denote no sightings.

[7] High counts for regions 6 to 10 from October 27, 1980, others in late September.

Bering Sea total populations, diving duck populations are particularly small in Norton Sound, as are Pintails (see Table 40 below), the most abundant duck in our study area. American Wigeon gathering on wetlands of the Sound make up the largest percentage (40%) for any eastern Bering Sea waterfowl species, and Green-winged Teal and Northern Shoveler populations of the Sound are also significant (10% to 20% of the total). Whistling Swans using the Sound are also a fairly significant part of the total (11%) as are Canada Geese (Taverner's race, 13%). Excepting teal and shovelers, these significant populations come to Norton Sound as migrants and only a few remain to nest.

3. Cranes

Sandhill Cranes are primarily migrants in coastal Norton Sound with small populations nesting on wetlands (Table 36). Most gather on wetlands to feed after nesting and we have noted peak populations of 6,700 at Imuruk Basin and 8,000 at Stebbins (Table 37). The majority of these are returning from Siberian nesting grounds, or from the Y-K Delta. The migratory route across the southern Seward Peninsula is also used early and mid May, through spring migrants pass through more quickly and use coastal habitats less than in the fall (late August to mid September). We have also noted extensive use of moist tundra uplands adjacent to wetlands, particularly in fall, when cranes feed on berries there.

4. Shorebirds

The 31 spcies of shorebirds recorded by us show a great diversity in habitat use patterns (Table 34); this discussion will treat the 13 most common species along the coast.

Shorebirds first arrive in early to mid May when ice covers most lagoons and exposed shores, preventing littoral feeding. They occupy tundra sites that are rapidly losing their snow and ice cover. Most feed on tundra until done with nesting, when many shift to littoral areas to feed. The peak littoral use in Figure 76 in May is primarily due to Semipalmated Sandpipers exploiting this newly opened habitat late in the month. Migrant shorebirds stop to feed in coastal wetlands on their way north, and many of these return after nesting to feed in coastal wetlands and in littoral area; these are usually followed by a later immigration of juveniles. The highest populations occur in spring with lower numbers during the post-breeding period from July through September (Figure 76). This is due to early exodus of Semipalmated Sandpipers, Norton Sound's most common shorebird, soon after nesting. Highest populations of most other species occur after nesting, and this is due either to immigration from the north or to the production of young. The northeastern and southern regions support the

Table 39. Regional populations of birds during the breeding and post-breeding periods in coastal Norton Sound in 1980 and 1981. Post-breeding populations are given for groups which were considerably more numerous during that period than during breeding.

	Northwest		Northeast		South	
Group	Breeding Period May/June	Post-Breeding July/Oct.	Breeding Period May/June	Post-Breeding July/Oct.	Breeding Period May/June	Post-Breeding July/Oct.
Loons	240	--	625	--	230	--
Waterfowl						
Swans	[1]f 10's	90	f 100's	2250	f 10's	1010
Geese	[2]f 100's	1040	[2]f 1000's	5470	[2]f 100's	200
Ducks	f 1000's	5500	[3]m 1000's	24000	f 1000's	7000
Cranes	f 10's	7420	f 10's	5080	f 10's	8000
Shorebirds[3]	16000	--	65000	--	71000	--
Jaegers	f 100's	--	f 100's	--	f 10's	--
Gulls	400	3600	2800	18000	500	500
Terns	600	--	1400	--	500	--
Passerines	f 1000's	--	m 1000's	--	f 1000's	--

[1] Abundance key: f=few (1-4), m=many (5-9)

[2] Mostly migrants

[3] Shorebirds were most common in May and June with equal or lower numbers during the post-breeding period due to the early exodus after nesting of Semipalmated Sandpipers, the most common species.

largest shorebird populations (Table 39) in all months, though few feed in the littoral of the southern region after nesting, due to lack of suitable habitat. In the northeast, shorebirds gather from late June through August on littoral areas of lagoons and especially on mud flats south of Koyuk. Shorebird use of littoral habitats after nesting has been summarized for the eastern Bering Sea, including Norton Sound, by Gill and Handel (1981).

Four species dominated wetland and littoral shorebird populations: Semipalmated and Western Sandpipers, Dunlin, and Northern Phalaropes. Foods of these were primarily midge fly larvae and these were found in 40 percent of birds collected at both wetland ponds and littoral areas. Also commonly taken as food were beetle larvae and cyclorrapha larvae (maggots), though these were more commonly taken on wetlands than in the littoral zone.

(a) American Golden Plover. Golden Plovers were fairly common as a nesting species on raised moist tundra in upland areas. Soon after nesting many move to wet tundra areas and lagoon shorelines to feed, though some remain to feed on moist tundra. Local nesters apparently leave in August, and are replaced by arctic-nesting plovers that flock on wetlands and littoral areas. They were most numerous in the northeastern coastal sections, particularly in Imuruk Basin and from Cape Douglas to Nome (Table 38); both areas offer the drier upland tundra most often chosen by these birds as nesting habitat.

(b) Bar-tailed Godwit. These are faily common on moist tundra uplands where they nest. After nesting they abandon the moist tundra and flock in wetlands in littoral zreas, particularly at Moses Point, Koyuk (principally on mudflats) and at Stebbins (along canal banks). Peak populations occur in August except at Koyuk where large concentrations gathered on the mudflats, and we suspect that these were failed or non-breeders. Few Bar-tailed Godwits remained into September.

(c) Whimbrel. These curlews were fairly common when nesting in upland moist tundra. Wetland concentrations during June were not common; a small population of at least 45 were apparently nesting at Moses Point, in a mixed habitat of moist and wet tundra, and in late June flocks of apparently failed breeders as well as a few local nesting Whimbrels were observed along wetland shores of Imuruk Basin. Post-breeding habitat use was fairly evenly distributed between moist and wet tundra areas. Populations peaked in August and many Whimbrels seen on moist tundra at that time were feeding on berries. We observed few Whimbrels in September, though H. Springer (in Gill and Handel 1981) reports roosting flocks of 200 or more on mudflats of Safety Lagoon.

(d) Black Turnstone. These nest on wet tundra, though they were common only at Stebbins (1,000 plus) and at Imuruk Basin (100) in June (Table 36). After nesting they move to littoral areas to feed; adults move first soon after the chicks hatch, and juveniles follow after fledging (Gill and Handel 1981). Most Black Turnstones depart Norton Sound by September.

(e) Northern Phalarope. These were abundant nesters restricted almost entirely to wet tundra areas, particularly in the wetter meadows with many ponds. In years with late springs they often congregate along open ice leads (H. Springer in Gill and Handel 1981) though in the early springs of 1980 and 1981 they proceeded directly to tundra nesting sites. Highest nesting populations were projected for wetlands at Stebbins (25,520) with lesser populations at the smaller wetlands in the northeastern region at Imuruk Basin (Table 36). At least 51,950 nest in wetlands of coastal Norton Sound. Post-breeding populations are somewhat greater for Stebbins, though not at other wetlands visited after June, and this apparently represents pre-migratory flocking at Stebbins that was not witnessed elsewhere. Northern Phalaropes did not often feed in littoral areas and once they departed Norton Sound they may move to nearshore and littoral areas of the Y-K Delta, where Gill and Handel (1981) have observed many adults in mid-July and a peak of juveniles in mid-August through mid-September.

(f) Red Phalarope. These were mostly migrants in Norton Sound, appearing in large rafts nearshore on the northeastern coast as well as at Safety Lagoon in early June. A few remain to nest at Brevig Lagoon and at Wales. They are scarce in late summer and fall in coastal Norton Sound, though a great many must pass south through the Bering Strait after nesting in the arctic.

(g) Common Snipe. These nested at all wetlands as well as in marshy areas of moist tundra. Small groups of juveniles fed in wetlands in mid-July through August and no littoral habitats were used.

(h) Long-billed Dowitchers. Dowitchers nested in wetlands, primarily in the northwestern region (Table 36). They were more common as migrants in spring and especially after nesting with high populations in August and September at Koyuk and Stebbins. Adults first came south in late July and were mostly gone when juveniles arrived in mid-August. Juveniles peaked on approximately 7 September and their migration was of greater magnitude than that of adults. Most migrant dowitchers fed on borders of wet tundra ponds, though littoral feeding was noted on mudflats at Koyuk and on canal margins at Stebbins.

(i) Semipalmated Sandpipers. These were the most abundant nesting shorebird in wetlands, with a projected nesting population of over 80,000 in coastal Norton Sound (Table 36). Over half of these were at Stebbins in the southern Sound, and most of the remaining population was in wetlands in the northeast, excepting somewhat over 4,000 in Imuruk Basin wetlands. Some Semipalmated Sandpipers nested on raised moist tundra near wetlands, though the vast majority were restricted to wet tundra nesting. Littoral zone feeding occurred in late May along protected (lagoonal) shores at Port Clarence, Woolley lagoon, and Safety Lagoon when these areas became free of ice. Most adults departed soon after nesting and did not feed in littoral areas then. Juveniles did congregate along lagoon shores on mudflats at Koyuk and along canal banks at Stebbins. These departed in mid-July, leaving very few by August. We suspect that few immigrations from arctic areas occurred and suggest that once Semipalmated Sandpipers depart their nesting grounds they fly far south of coastal western Alaska.

(j) **Western Sandpiper.** These are the most common nesting shorebird of moist tundra in coastal Norton Sound, and are especially common where moist tundra intermixes with wet tundra, as at Port Clarence and Safety Lagoon. Western Sandpipers nesting near wetlands often traveled to these lower marshy areas to feed during their nesting period. After nesting, broods were often led to these wetlands to exploit rich feeding opportunities along pond margins. Adult females are the first to move to littoral areas after breeding (Gill and Handel 1981) and are soon followed by adult males and juveniles. Large concentrations occurred principally along the protected shores of Safety Lagoon (11,280, Table 37). Western Sandpipers gathering there are probably from more northerly nesting areas as well as from local sites. Most adults had left by late July and few juveniles remained in late August.

(k) **Pectoral Sandpiper.** These arctic nesters are the most common of the migrant shorebirds that do not commonly nest in Norton Sound. In both spring and late summer, 90 percent of the Pectoral Sandpipers seen were on wet tundra and 10 percent were in littoral areas. A few nesting Pectoral Sandpipers were found in the northwestern region at Brevig Lagoon and at Wales on wet tundra. Migrants in spring reached peak abundance in late May, and these were mostly females. The southward migration peaked from 25 August to 9 September and these were apparently juveniles. An inland migration route for adults is possible (Gill and Handel 1981). Late summer migrants were more numerous than spring migrants.

(l) **Sharp-tailed Sandpipers.** Only juveniles of this species visit coastal Norton Sound, and these occur from early August through mid-September. Adults leave their northern Siberian nesting sites and do not migrate through Alaska. All juvenile Sharp-tailed Sandpipers were seen in wet tundra, especially the wettest meadows, and they were most common at Safety lagoon, the Fish River Delta, and at Stebbins (Table 37). They were often near flocks of Pectoral Sandpipers though interspecific flocking was not apparent.

(m) Dunlin. This species is restricted in nesting to the low wet tundra of the coast. It was especially common at Stebbins (16,220) and was considerably less numerous at the other wetland sites (Table 36). In both study years Dunlin made little use of littoral habitats until mid-August. At this time many of the locally nesting adults had left and an influx of apparently arctic Dunlin occurred, and these made more use of littoral habitats. Dunlin were the only common shorebird to remain into September, and many were still feeding on wet tundra. It is sometimes common for adult Dunlin to remain near their nesting grounds to molt (Holmes 1966b). This was not the case in either of your study years, when locally nesting adults apparently departed prior to completing their molt.

5. Jaegers

Parasitic and Long-tailed Jaegers were faily common nesters in moist tundra areas, particularly near wetlands (Table 35). They prey on birds, rodents, and insects, and often steal prey from other birds. Peak abundances occurred in June, with steadily declining numbers thereafter. After completing nesting jaegers were sometimes common over wetlands or patrolling shorelines up until the end of August when most had departed. They winter at sea and presumably head offshore after leaving coastal Norton Sound.

6. Gulls

Three patterns of habitat use are shown by gulls in Norton Sound (see Table 34). The principal pattern is of peak populations along shorelines after July, and this is shown by Glaucous Gulls, which comprised the vast majority of all gulls in Norton Sound (99% on shorelines, 76% on wetlands; see Table 24). Glaucous Gulls are one of the very first birds to arrive in Norton Sound each spring; we found them at the shorefast ice edge at river mouths, near cliff colonies, at townsites, and on mostly frozen wetlands in early May. They nest on cliffs and wetlands, usually in small colonies of several dozen. After nesting many move to exposed shorelines and also up rivers to follow spawning salmon, especially in late summer. Many immatures and some non-breeding adults congregate along shorelines from early summer through fall. These populations are augmented in late September and October when northerly birds descend to Norton Sound and numbers build to over 20,000, with highest concentrations in the northeastern region (Table 38). A high proportion of one and two year old immatures (30%) in Norton Sound in late summer 1980 suggests that the Glaucous Gull populations are expanding, and this is likely as a result of fisheries and other developments by man.

Glaucous-winged Gulls come to coastal Norton Sound in July and August and flock with Glaucous Gulls on shorelines and along salmon-spawning rivers. They come from southern coastal Alaska, where Glaucous-winged Gulls nest, and most are immatures one and two years old.

Mew Gulls nest in wetlands and make limited use of shoreline habitats upon arrival in early May and after nesting. Small gatherings of adults and juveniles were mixed with Glaucous Gulls at river mouths and on river deltas, though Mew Gulls had almost all vacated coastal Norton Sound by 1 September.

Black-legged Kittiwakes are abundant nesters at cliff colonies and frequent exposed shorelines, particularly at Safety Lagoon near the Bluff colonies. This pattern is not included in Table 34.

Sabine's Gulls nest on wet tundra in small numbers on some of Norton Sound's wetlands (Table 36) and fed along shorelines for a few weeks after nesting. None were seen after mid-August in coastal Norton Sound and they apparently moved offshore to feed and migrate south.

7. Terns

Arctic and Aleutian Terns both nest in coastal Norton Sound; Arctics are widespread and common, whereas Aleutian Terns are only common locally in small colonies. Arctic Terns first arrive in mid-May and nest on wetlands as well as on both the exposed and protected shores of spits. They are most abundant while nesting (Figure 76) and feed in littoral areas, especially exposed shores, and on wet tundra ponds. Largest populations were at Safety lagoon (600), where many fed at the main lagoon entrance, and at Stebbins (500, Table 36) where many terns fed along tidal canals. Nearly all Arctic Terns depart Norton Sound by 1 September.

Aleutian Terns arrive in late May to early June and are also at peak abundance in coastal Norton Sound while nesting, though they are considerably less numerous than Arctic Terns. They nest in small colonies on spits, on small islands in lagoons, and sometimes on moist tundra near lagoons or wetlands. Norton Sound's largest colony is at Safety Lagoon (has varied from 80 to 480 adults, H. Spring pers. comm.) and smaller colonies (6 to 40 adults) occur at Brevig Lagoon (two sites), Moses Point, Unalakleet, Golovin, and possibly Port Clarence and the Stebbins area. They occasionally feed on tundra ponds though they usually feed well offshore. Adults and young depart soon after the young fledge in early to mid August and few remain by 1 September.

8. Passerines

This group is comprised of ravens and numerous small songbirds and these show a variety of habitat use patterns (Table 34). Many nest in shrubby or forested uplands and are most numerous during the nesting season. The species most common wetlands and shorelines are ravens, Yellow Wagtails, Savannah Sparrows, and Lapland Longspurs. The latter two reach two peaks in population (Figure 76), one in June when the young fledge and the other in August when the young gather on shorelines and coastal wetlands. Yellow Wagtails are not abundant along the coast as a nesting species, whereas in August the young produced inland, as well as coastally, gather along shorelines.

C. Norton Sound Waterfowl Populations

Norton Sound hosts minor populations of nesting waterfowl relative to nearby areas, notably the Y-K Delta (King and Lensink 1971; King and Dau 1981). This is due in part to the restriction of wetland habitats to low pockets in the raised coastal relief that dominates the Sound. Gatherings of waterfowl in late summer and fall are greater than in spring, and for some species, these post-breeding populations are of significant regional importance. Table 40 lists population estimates for both Norton Sound and the entire eastern Bering. Both sets of figures are error-prone and the following comparisons between them are valid at the level of orders of magnitude, and not percentage points.

Swans using Norton Sound coastal habitats comprise about 10 percent of the eastern Bering Sea populations. Many of these (3,350) come from nesting areas outside the Sound. Canada Geese visiting Norton Sound number at least 6,700 (13% of eastern Bering Sea total for Taverner's race), and there are actually probably many more, since we do not know how quickly flocks leave and are replaced (turnover rates) and this apparently takes place in Norton Sound. Less than 10 percent of the total Pacific race of Brant visit Norton Sound, and these are arctic-bound migrants in spring. Other goose species are of minor importance in Norton Sound.

Relative to regional populations, the Norton Sound Pintail populations were minor, and this is surprising since they were the most abundant species of waterfowl. Mallards, teal, and shovelers are of modest importance in the region; our shoveler totals are from June. Our counts of American Wigeon comprise about 40 percent of the regional total, indicating that coastal Norton Sound is especially important for pre-migratory flocks of this species.

Table 40. A comparison of Norton Sound waterfowl populations to those of the entire eastern Bering Sea. All numbers are estimates of fall populations.

Species	Number[1] using Eastern Bering Sea Habitats	Number[2] using Norton Sound Habitats	Percent of Bering Sea Population in Norton Sound
Whistling Swan	30,000	3,350	11
Canada Goose	50,000	6,700	13
Brant	150,000	m 1000's[3]	<10
Emperor Goose	150,000	f 100's	<01
Snow Goose	150,000	m 100's	<01
White-fronted Goose	67,000	f 10's	<01
Mallard	20,000	1,700	09
Pintail	1,222,000	17,400	01
Green-winged Teal	20,000	f 1000's	10-20
Northern Shoveler	20,000	f 1000's	10-20
American Wigeon	20,000	7,900	40
Greater Scaup	338,000	3,600	<01
Oldsquaw	3,600,000	f 1000's	<01
Common Eider	750,000	f 100's	<01
Black Scoker	489,000	f 100's	<01
Red-breasted Merganser	20,000	f 100's	<01

[1] Data are from King and Dau (1981).

[2] Data are from Tables 36 and 37, this report, though many are unadjusted and thus low relative to actual values (see text).

[3] f = few (1-4), m = many (5-9)

Diving ducks as a whole were of minor importance in Norton Sound relative to regional populations.

D. Major Wetlands

Our visits to the major wetlands in Norton Sound allowed us to rank their importance to birds as measured by shorebird and waterfowl population.

1. Areas with Heavy Bird Use

(a) Stebbins. These wetlands (southwest of the village) are Norton Sound's largest expanse (170 km^2) of prime shorebird and waterfowl nesting habitat. This area is heavily used by ducks in early spring and by ducks, swans, and cranes in August and September. It has the highest population of shorebirds at all wetlands in the Sound. The land is barely above sea level along an exposed northwest-facing shoreline, and is regularly flooded, though rarely in spring. Stebbins is the closest wetland to the proposed lease tracts.

(b) Koyuk. These wetlands, south of town, are prime shorebird nesting habitat, with extensive coastal mud flats attracting thousands of feeding shorebirds. This site is an important stopover for swans, geese, ducks, and crane in later summer and is a Brant flyway in spring. The shorelines are exposed, but far removed from the proposed lease tracts.

(c) Moses Point. This is an important shorebird feeding area, heavily used by waterfowl in late summer, particularly at Kwiniuk Inlet and inside the mouth of the Kwik River. The wetlands are partially protected by the Moses Point spit.

(d) Fish River Delta. On Golovin Lagoon, this delta provides good shorebird and duck nesting habitat, with a heavy migration of Canada Geese from mid-August to late September. Brant pass through each spring. The lagoon receives seaward protection from Golovin Spit and supports beds of Eelgrass.

(e) Imuruk Basin. This wetland has shrubby delta habitat on the north, providing good nesting for shorebirds and ducks. Canada Geese and cranes pass through in large numbers in late summer, and ducks congregate during both the spring and fall migrations. This is the most protected site and the farthest removed from the proposed lease tracts.

(f) Safety Lagoon. This includes the Flambeau and Eldorado River wetlands and Taylor Lagoon, and offers good by limited shorebird nesting habitat. Mud flats inside of the main entrance to the lagoon were often used by feeding shorebirds. Terns concentrate at the entrance. This site is visited by many ducks, geese, and cranes, especially in August and September. Beds of Eelgrass thrive in the brackish waters. Most of the wetlands are protected from the open sea by barrier spits.

2. Areas with Moderate to Little Bird Use

(a) Shaktoolik. These wetlands have fewer ponds than those listed above, and we found low densities of nesting shorebirds and moderate populations of migrating waterfowl. Much of this area is protected by spits.

(b) Port Clarence. These wetlands lie at the base of the Point Spencer spit. The total area is small (13 km^2), but rich with many ponds and high densities of nesting shorebirds. Migrant waterfowl make minimal use of this site. There is little protection from the open sea, and the tundra is occasionally salt-washed.

(c) Stuart Island. These wetlands are confined to the shores along the central canal. Shorebird nesting densities are unknown; waterfowl migrate in moderate densities in late summer. The wetlands are protected by the narrow canal entrances (the northern entrance was closed in 1981), though this site is quite near the proposed lease tracts.

(d) Woolley Lagoon. This area has fair shorebird nesting habitat along its shores, with minor concentrations of migrating waterfowl. Barrier spits provide some protection from the open sea.

(e) Brevig Lagoon. These wetland habitats are dry and rocky, and hence fair to poor for shorebirds. Small flocks of Oldsquaw molt in the lagoon, but waterfowl use is otherwise low. Barrier beaches protect the mainland shore.

(f) Unalakleet. These wetlands are within the Unalakleet River Delta. Minor shorebird and waterfowl populations occur here.

(g) Wales. These wetlands are the margin of our study area. They extend far northeast from the Cape along the barrier tundra strip. These support dense concentrations of nesting shorebirds and moderate numbers of nesting waterfowl.

E. Oil Development Impacts

1. General Remarks

Our general remarks on impacts will be divided into expected (or planned) impacts that will occur as a result of the normal activities associated with oil exploration and exploitation, and unexpected (or unplanned) impacts associated with accidents or mishaps due to human error, mechanical failure, or natural catastrophes. It is important to note that while unexpected impacts receive most of the attention, expected impacts can have overall detrimental effects that are much greater and of longer duration. These general remarks are followed by a discussion of potential impacts for each of the eight bird groups.

(a) Expected Impacts. These include the construction and operation of onshore facilities such as pipelines, construction camps, road systems, and an increase in the amount of human activity. Such impacts usually result in a general degradation of the area surrounding them in terms of suitability for birds. Human disturbance affects most large birds, which are less tolerant of harrassment and will abandon nests and areas where human activity is high. These species include loons, swans, geese, ducks, cranes, jaegers, and terns. Shorebirds, gulls, and passerines are less affected. The building of roads and pipelines usually entails the building of gravel pads. Such structures frequently change drainage patterns, resulting in small but obvious changes in wet tundra areas. A complex road network in an area of wet tundra would almost certainly cause habitat degradation due to these changes. Such changes are multiplied if the onshore facilities take water from streams or lakes.

An expected human impact that will cause disturbance in many coastal areas and not just in close proximity to camps and pipelines is the movement of aircraft along the coast. Because aircraft frequently follow the shoreline much of the air traffic associated with oil development will be over the coastal habitats described in this report. Population changes due to chronic low level disturbance by aircraft is hard to measure and the effects of such disturbance would probably go unnoticed except in areas directly adjacent to airstrips.

Scavengers such as gulls, foxes, and ravens could be expected to increase as human settlements become more common in the Sound. These scavengers also consume eggs and chicks of birds, and any increase in scavengers would probably result in local decreases in nesting success. It is doubtful, however, that scavenging opportunities associated with oil development would equal those already present in the Sound associated with fishing activities. Glaucous Gulls appear to be already on the increase, as described in this report, but it is likely that offal from fishing boats in the Bering Sea in winter is the primary reason for the increase.

Subsistence hunting will be altered as a result of oil development and thus the birds that are taken as part of the subsistence hunt will be impacted. Should oil development cause the native peoples of Norton Sound to depend less on the subsistence hunt, those species that are taken in the Sound could be expected to increase. If, however, the subsistence hunt continues and even becomes larger in scale (due to increased funds to expend on hunting and the building of more roads to provide access to hunting areas) there could well be a large increase in hunting pressure on certain populations and species. Should this occur, the following points deserve consideration:

(1) Subsistence hunting is in transition, as many who claim subsistence rights also hold paying jobs, while others are in truth still trying to subsist. With increasing pressure on wildlife resources these two subgroups will be in sharper conflict.

(2) Additions to the population of hunters will exacerbate the effects of new technologies already in use (e.g. snowmobiles, aircraft, rifles, outboards, etc.). This will make subsistence hunting more difficult for the natives.

(3) Increasing population (mostly of whites) may require refuges to be set aside where waterfowl may rest unhunted. Similar considerations will likely encourage native corporations to closely regulate sport and quasi-subsistence hunting on corporate lands.

(4) Exemption of native hunters from federal control is not reasonable, because:
    (a) Biological forces will not tolerate unneeded harvests, and
    (b) Migratory bird populations "belong" to everyone.

(b) Unexpected Impacts. The major unexpected impact that occurs as a result of oil development is an oil spill. Norton sound is sufficiently different from other coastal areas of Alaska that a spill occurring in the nearshore waters or just offshore would have quite a different impact on bird populations that one in other areas. The paucity of birds in most of the nearshore waters and littoral zone of Norton sound would mean that in many areas the impacts of a spill on birds would be much less than in the more productive coastal waters to the north and south. Large concentrations of birds are present in exposed nearshore waters of Norton Sound only near seabird breeding cliffs and when diving ducks are present near headlands, such as eider in the fall. While Norton Sound would not have large numbers of diving birds becoming oiled in nearshore waters, as is typical of oil spills elsehwere, the effects of a spill would be less direct and result from coastal habitat degradation due to oiling. The wetland areas identified in this report as being of great importance to Norton Sound birds are all susceptible to becoming oiled by spills present in nearshore waters. For many of the areas in regular contact with marine waters the oiling would take place as a result of normal tidal and wind-driven currents. Such areas include lagoons, river deltas, and channels in low-lying wet tundra areas. These habitats have been identified by Hayes and Gundlach (1980) as the most sensitive habitats in Norton Sound since, if oiled, the oil would adhere to the sediments and vegetation for some time, and cleanup of spills in such habitats is not possible. Even wetland areas that are not in regular contact with marine waters are vulnerable to spills in nearshore waters. While the circumstances leading to oiling of these habitats (a major spill followed by a storm surge) are less likely to occur, the frequency of fall storm surges in Norton Sound makes the fouling of these habitats a real possibility. The natural processes that would degrade and disperse the oil in such wet tundra areas could be expected to be much slower than in lagoonal and river delta areas.

Norton Sound wetlands could also be impacted by oil leaked from pipelines on the mainland. Such spills would be especially dangerous since they would follow natural freshwater drainage patterns and foul ponds, streams, and rivers.

While catastrophic oil spills present the worst case scenario, chronic low-level pollution could be more of a problem in areas where drilling and human activities are greatest.

The oiling of habitats described above would impact birds primarily through decreasing prey populations and the access of birds to prey.

2. Potential Impacts on the Common Bird Species

Discussed here are the impacts likely to occur for each of the eight groups of birds common in Norton Sound, and this includes both planned and unplanned impacts. Table 41 gives the relative susceptibility of these birds to disturbances in neashore habitats. These habitats include exposed inland waters, protected waters, shorelines, and wet tundra of wetlands. Susceptibility is based on dependence on each habitat as well as the vulnerability of the habitat. Dependence includes both duration of habitat use and the magnitude of use. Vulnerability is mostly dependent on exposure and likelihood of oiling, such that birds in exposed waters are most vulnerable, while those in protected waters and on shorelines are more vulnerable than those on wet tundra of wetlands. This does not include a consideration of the retention times of oil in habitats as in Hayes and Gundlach (1980).

A summary of the kinds of impacts and their degrees of effect on the common birds of Norton sound is given in Table 42.

(a) Loons. Loons are especially susceptible to oiling, since they feed by diving, spend little time on land, and frequent coastal areas where humans concentrate development. They are less gregarious than waterfowl and many shorebirds, and thus less prone to massive mortality in an oil spill.

(b) Swans. Possibly the greatest threat to swans is disturbance in late summer and early fall. At this time, over a thousand swans gather in coastal wetlands to feed before their trans-continental flight. They are particularly vulnerable to oiling where they flock on salt water, though this is limited to the sheltered waters of Golovin Lagoon, where oil on water is unlikely. At Koyuk and Stebbins swans gather on ponds.

Table 41. Relative susceptibility of common Norton Sound birds to disturbances in nearshore habitats.

Species	High		Moderate		Low	
	Hab.[1]	Mo.[2]	Hab.[1]	Mo.[2]	Hab.[1]	Mo.[2]
LOONS			IW	5-8	WT	5-9
WATERFOWL						
Swans						
Whistling Swan	PW	8,9			WT	5-9
Geese						
Canada Goose	PW	8,9				
Brant					PW,WT	5,6,8
Emperor Goose					IW	5-9
Snow Geese					IW	5-9
Dabbling Ducks						
Mallard			PW	8,9	WT	8,9
Pintail	PW	8,9			WT	5-8
Green-winged Teal					WT	5-8
Northern Shoveler					WT	5-8
American Wigeon	PW	8,9			WT	5-8
Diving Ducks						
Greater Scaup			PW	8,9	WT	5-9
Oldsquaw			IW,PW	5-9	WT	5-9
Common Eider			IW	5-10		
Black Scoter			IW	5,8,9		
Red-breasted Merganser			IW	5-9		
CRANES						
Sandhill Crane			WT	5,8,9		
SHOREBIRDS						
American Golden Plover					SL,WT	7-9
Bar-tailed Godwit					SL,WT	7,8
Whimbrel					SL,WT	7-9
Black Turnstone			WT,SL	5-7		
Northern Phalarope			WT,SL	5-8		
Red Phalarope			IW	5,6	WT	6-8
Common Snipe					WT	5-8
Long-billed Dowitcher			WT,SL	5,7-9		
Semipalmated Sandpiper			WT,SL	5-7		
Western Sandpiper	SL	7-8			WT	5-7
Pectoral Sandpiper					WT,SL	5,8-9
Sharp-tailed Sandpiper					WT	8-9
Dunlin					WT,SL	5-8
JAEGERS					WT,SL	5-8
GULLS						
Glaucous Gull			SL	4-10	WT	5-9
Glaucous-winged Gull					SL	7-10
Mew Gull					WT,SL	5-8
Black-legged Kittiwake	IW	5-9				
Sabine's Gull					WT,SL	5-8
TERNS						
Arctic Tern	IW,PW	5-8			WT	5-7
Aleutian Tern	IW	5-8				
PASSERINES					WT,SL	5-9

[1] Habitat abbreviations: IW = exposed inshore waters, PW = protected (lagoonal) waters, SL = shorelines of both exposed and protected coasts, WT = wet tundra of wetlands.

[2] Months of susceptibility.

Table 42. Expected levels of oil development related impacts on common birds in Norton Sound. Levels are predicted as high (H), medium (M), low (L), or none (N), and population changes are predicted as +, 0, or -.

Species	Loss of Nesting Habitat	Disruption of Nesting	Increased Hunting	Oiling by Contact	Oiling by Prey Base	Expected Population Change
Loons	M	M	L	H	L	-
Waterfowl						
Swans	L	M	L	M	L	-
Geese	L	M	H	M	L	-
Diving Ducks	L	M	L	H	L	-
Dabbling Ducks	M	M	H	M	L	-
Cranes	L	M	M	N	L	-
Jaegers	M	L	L	L[1]	M	-
Gulls	L	M	N	L	L	+[2]
Terns	M	M	L	M	L	-
Passerines	L	L	L	L	L	0[3]

[1] Most shorebirds are unlikely to contact spilled oil directly, although phalaropes sit on water to feed and are more prone to oiling.

[2] Glaucous, Mew, and other large gulls will probably show an increase in population while smaller gulls may remain the same or dwindle. Large gulls thrive on refuse proliferation and similar human activities.

[3] Most passerine populations will probably not be affected, although Ravens may increase due to the proliferation of refuse.

A possible threat is disturbance in the early nesting period from mid May to early June, when noise and human activity could thwart nesting attempts. Swans do not renest because of their prolonged nesting cycle. This problem is most critical on the Y-K Delta where swans are most numerous.

(c) Geese. Canada Geese are most vulnerable to oil impacts in late summer, when as many as 100,000 may pass through Norton Sound. Areas of concentration are Golovin Lagoon and Moses Point, where geese roost on salt water and feed on land, and Koyuk, where geese were seen mostly on land. On the Y-K Delta large nesting populations of several species of geese are susceptible to disturbance throughout the nesting season. Increased hunting pressure is likely.

Brant in Norton Sound have a low risk of impact, except in spring when they rest and feed in shallow salt water. Snow Geese also have a low risk since they pass through Norton Sound quickly. Emperor Geese are prone to suffer from increased hunting, as they are strictly coastal and therefore concentrated where human access is easiest.

(d) Ducks. Diving ducks are more susceptible to oiling than dabblers. Many must dive for food, and they are more common than dabblers on exposed coasts. Cape Woolley, Cape Nome, and the rocky shores from Tolstoi Point to Stebbins are favorite diving duck haunts. Molting flocks of eiders and scoters are highly vulnerable to oiling, as they are unable to fly from a spill area. Our sightings of these flocks are few; they are likely to be common in shallow waters north of the Yukon Delta.

Dabblers are more likely to suffer from an increase in hunting pressure, since they are favored table fare. Spring hunting is most precarious for ducks, when the availability of open wetlands may be limited by ice, and the next nearest opening without guns may be many miles away. Spring came early in both 1980 and 1981, and openings were not limited; in years of late ice we predict the most heavily used openings will be at Stebbins, Shaktoolik, Koyuk, Golovin Lagoon (Kachavik River), the Safety and Taylor Lagoon system, Woolley Lagoon, and the Imuruk Basin.

(e) Cranes. The most ominous scenario for cranes is increased hunting during the spring and fall migrations. This is a real consideration near Nome and Safety Lagoon, where sport hunting for cranes interfaces with subsistence shooting. Cranes have low yearly productivity as do many large birds, and their populations may not be as resilient as other game species. Cranes are not suceptible to oiling, since they feed only on land.

(f) Shorebirds. Sandpipers are most suceptible to oil disturbances when they feed in littoral habitats. In Norton Sound these are most heavily used in July and August, especially at Koyuk and Safety Lagoon. Oil fouling of their invertebrate food base could inhibit adequate buildup of fat for the southward migration. Northern Phalaropes spend little time in littoral areas, except when they first arrive, particularly in years with a late spring.

Shorebird dependence upon wetlands for nesting and on pond edges for feeding makes shorebirds vulnerable to oil washed over wetlands. The most critical wetlands are southwest of Stebbins, where an estimated 86,000 shorebirds nest; this area is quite near and exposed to the proposed lease tracts. Koyuk area wetlands host at least 28,000 nesting shorebirds. Other important breeding sites are at Moses Point, the Fish River Delta, Imuruk Basin, and Safety Lagoon; these are all considerably more protected than the Stebbins coastline.

Shorebirds would suffer from habitat destruction, but they may be more tolerant of minor human intrusions related to development.

(g) Jaegers. Jaegers have a low vulnerability to oil-related disturbances because they nest on moist tundra and when they feed along shorelines or offshore they often take prey from other birds or scavenge. Jaegers may benefit from an increase in sea traffic and the profusion of refuse dumped from vessels.

(h) Gulls. Glaucous as well as Mew Gulls may benefit from oil development via the resulting proliferation of refuse. Glaucous Gulls are predators of duck eggs and chicks, and an increase in gull populations may inhibit waterfowl production. Our estimates of age ratios show a strong contingent of young gulls, suggesting that Glaucous Gulls are on the rise. They are most numerous in northeastern Norton Sound.

(i) Terns. Both Arctic and Aleutian Terns are vulnerable to nearshore oil spills due to their dependence on small saltwater fishes. Human disturbance may affect Aleutian Terns most. They seem much less tolerant of human activities than Arctic Terns and are more susceptible to nest failure. The Safety Lagoon area is the most heavily used by both species.

(j) Passerines. Small songbird populations are unlikely to be affected by offshore petroleum development. Ravens, being scavengers, are likely to increase in numbers, as they already have near Nome. This may cause additional usurpation of hawk and falcon nests, as well as increased predation on bird eggs, chicks, and other foods.

VIII. NEEDS FOR FURTHER STUDY

A. Coastal Censusing

The data presented in this report provide an overview of the kinds, amounts, and uses of coastal bird habitats in Norton Sound. Additional work needs to be done in the following areas:

1. Fall Censusing

Only one October census was conducted during the present study, and it showed large numbers of eiders in certain nearshore areas and large numbers of Glaucous Gulls on the beach. Additional censusing from late September to freeze-up would help to delineate those areas that are important in late fall. October could be especially important, since use of the nearshore waters may be higher then than during the rest of the year.

2. Censusing of Low-Density Areas

Because of time limitations this study directed much effort to those areas in the Sound where birds are most abundant. While we censused habitats and areas with low bird densities, we made little attempt to compare these densities for areas within the Sound or to find out how densities vary within these habitats. More detailed studies of low-density habitats and areas would be especially important if oil development is to occur in them.

3. Small Scale Censusing

The large area to be censused during the present study precluded high-resolution mapping or censusing. Should development be planned for a certain section of coastline, a detailed censusing program of the area being coonsidered would provide information on which specific areas are most important to birds and allow placement of road, buildings, and so on in areas of low bird density.

B. Site-Specific Studies

Having a field camp in an area of high bird use would provide a number of parameters not available from a large-scale censusing program.

1. Turnover Rates of Migrants

The importance of an area to birds cannot fully be judged until an idea of the total number of individuals using the area can be obtained. Daily counts of the waterfowl in an area and observations on movements in and out of the area would provide such information. The areas where such studies would best be done are presented in the species accounts.

2. Breeding Bird Activities

Site-intensive studies at breeding areas provide insights into habitat use and feeding ecology that can only be gained by daily contact with the birds. While we have made minor contributions to breeding biology and feeding ecology of the major species of Norton Sound, more detailed work is needed for all species.

3. Plot Censuses

Yearly censusing of plots during the breeding season is a good way to accurately monitor changes in breeding populations. A series of plots established before development begins would provide data on future impacts.

C. General Studies

1. Offshore Censusing

This study, other parts of RU 196, and work by Drury have shown that the offshore waters of Norton Sound support few birds. In the spring and fall, however, when birds are actively migrating, offshore areas may be important for short periods of time but to large numbers of birds (primarily sea ducks). Well-scheduled censuses with airplanes suitable for long over-water flights would be needed.

2. Monitoring of Subsistence Harvest

As was mentioned in the section on potential impacts of oil development, subsistence harvests of waterfowl may increase as oil development occurs in the Sound. Efforts by native groups and governmental agencies to monitor the waterfowl harvest would allow the impact of these harvests on the total population to be evaluated.

3. Trophics Studies

Most habitats of importance to birds in Norton Sound are important because of their food resources. The trophics of all Norton Sound bird species are poorly known and less has been done on the availability of their foods.

D. Post-Development Studies

Post-development studies should ideally be a continuation of studies begun before development. In addition, specific studies should be done, including beached bird surveys, measuring the effects of disturbances on birds, and so forth.

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Appendix 1. Norton Sound land surveys, 1980. See Figure 2 for locations.

Area	Dates	km of Transects	Observers
Wales	May 17-20	0	Woodby (migrant watch)
	June 21-23	5.9	Hausler, Woodby
	July 25-28	2.9	Woodby
Brevig Lagoon	July 1-7	62.4	Blick, Drury
	August 2-8	68.9	Drury, Warheit
Imuruk Basin	June 26-July 1	52.5	Hausler, Warheit, Woodby
Port Clarence	May 29-June 3	49.2	Blackham, Weisel
	July 3-9	48.4	Blackham, Chance
	August 2-9	50.8	Blick, Chance
Woolley Lagoon	May 29-30	8.5	Chance, Woodby
	June 8	9.8	Blackham, Blick, Chance
	July 9	10.5	Drury, Woodby
	August 2	10.8	Warheit
	September 9	9.5	Blackham, Warheit, Weisel
Nome	Weekly from May 12-September 25	124.7	All personnel
Safety Lagoon	Weekly from May 14 - September 27	273.7	All personnel
Solomon	June 15	3.0	Blackham, Blick
	July 2	3.0	Hausler, Woodby
	July 19	3.0	Blick, Drury
	August 20	3.0	Drury, Warheit
	August 30	3.0	Chance, Warheit
	September 21	3.0	Hausler, Woodby
Flambeau and Eldorado Rivers	June 15	9.3	Drury, Weisel
	July 11	11.3	Weisel, Woodby
	August 12	11.3	Blick, Woodby
	September 4	11.3	Blackham, Blick, Warheit

Appendix 1. Land land surveys, 1980 (Continued).

Area	Dates	km of Transects	Observers
Fish River and Golovin Lagoon	June 7-11	42.5	Drury, Hausler, Woodby
	July 11-16	67.1	Blick, Drury
	August 13-18	45.5	Chance, Drury
	September 6-10	38.4	Hausler, Woodby
Moses Point	June 24-30	35.9	Blick, Chance
	July 23-28	45.3	Blick, Drury
	August 22-26	33.3	Chance, Weisel
	September 10-16	35.8	Blackham, Blick, Weisel
Koyuk	June 14-17	37.3	Hausler, Woodby
	July 16-19	32.0	Chance, Woodby
	August 26-29	19.3	Chance, Weisel
Shaktoolik	June 9-13	52.7	Blackham, Blick, Chance
	July 15-16	20.4	Chance, Woodby
Unalakleet	May 15-22	25.9	Chance, Weisel
	July 3-9	31.9	Warheit, Weisel
	August 6-11	35.4	Weisel, Woodby
Stebbins	June 18-23	45.6	Blackham, Drury, Weisel
	July 15-21	61.6	Blackham, Warheit, Weisel
	August 26-29	44.9	Blackham, Warheit, Woodby

Appendix 2. Land surveys, 1981. See Figure 2 for locations.

Area	Dates	km of Transects	Observers
Safety Lagoon	May 23-25	12.6	J. Blackham
	June 22-24	15.8	Allison, Hausler
Fish River and Golovin Lagoon	May 27-31	31.2	Hausler, Woodby
	June 6-10	28.8	S. Blackham, Hausler
	June 15-19	28.4	Hausler, Woodby
	June 28-July 3	29.9	J. Blackham, Allison
	July 10	3.0	S. Blackham, J. Blackham
	August 3-5	24.8	S. Blackham, J. Blackham
	August 18-21	10.6	J. Blackham, Scoville
	September 8	4.5	S. Blackham, Scoville
Golovin Spit	Almost daily May 8-September 4	110.7	All personnel
Koyuk	May 25-29	22.1	S. Blackham, Allison
Shaktoolik	June 23-25	24.2	S. Blackham, J. Blackham
Stebbins and St. Michael	June 8-15	29.5	J. Blackham, Allison
	July 22-29	32.9	Hausler, Woodby
	August 28-September 2	22.4	J. Blackham, S. Blackham, Scoville

Appendix 3. Aerial surveys, 1980. See Figure 1 for locations of coastal sections.

Date	Coastal Sections 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Observers
May 8						X	X	X		X		X	X		X	Woodby
May 15										X		X				Chance, Weisel
May 22						X	X	X		X	X	X				Chance, Weisel
May 26	X	X	X	X	X											Blackham, Weisel, Woodby
May 31						X	X	X	X	X	X	X	X	X		Chance, Woodby
June 13							X			X	X	X				Blackham, Blick, Chance
June 18												X	X	X	X	Blick, Chance
June 30	X	X	X	X	X											Blackham, Drury, Weisel
July 24						X	X	X	X	X	X	X				Warheit, Weisel, Woodby
July 25	X	X			X											Blackham, Chance, Woodby
August 15						X	X	X	X	X	X	X	X	X		Warheit, Woodby
August 16	X	X	X	X	X											Blackham, Weisel

Appendix 3. Aerial surveys, 1980 (Continued).

	Coastal Sections															
Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Observers
August 23	X						X									Blackham, Warheit, Woodby
September 2	X	X	X	X	X											Chance, Warheit, Woodby
September 6						X	X	X	X	X	X	X	X	X		Blackham, Blick, Weisel
September 10							X									Hausler, Woodby
September 17	X	X			X											Hausler, Woodby
September 23							X	X	X	X	X	X	X	X		Blackham, Hausler, Weisler
October 27						X	X	X		X						Woodby

Appendix 4. Aerial surveys, 1981. See Figure 1 for locations of coastal sections.

	Coastal Sections															
Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Observers
May 1						X	X	X		X	X					Woodby
May 6								X		X	X	X	X	X		S. Blackham, J. Blackham
May 18								X		X						S. Blackham, Hausler
June 3		X			X	X	X	X								S. Blackham, Hausler
June 8								X		X	X	X	X			J. Blackham, Allison
August 6		X		X	X											S. Blackham, Hausler
August 28								X	X	X	X	X	X	X		S. Blackham, J. Blackham
September 5		X		X	X											S. Blackham, J. Blackham
September 10									X	X	X	X	X	X		S. Blackham, J. Blackham

Appendix 5. **Wetland aerial surveys, 1980. See Figure 3 for locations.**

Date	Imuruk Basin	Port Clarence	Cape Woolley	Flambeau River	Safety Lagoon	Fish River Delta	Moses Point	Koyuk	Shaktoolik	Unalakleet	Stebbins	Stuart Island	Yukon Delta	Shishmaref Coast	Observers
May 31					X	X		X	X		X				Chance, Woodby
June 7						X									Drury, Woodby
June 9					X	X	X	X	X						Blackham, Chance
June 11					X	X									Drury, Woodby
June 13					X		X	X							Blick, Chance
June 18									X		X	X	X		Blick, Chance
June 30	X	X													Drury, Weisel
July 19					X	X	X	X							Chance, Woodby
July 24			X	X	X	X	X	X							Warheit, Weisel
July 25				X											Blackham, Chance
July 28					X	X	X								Blick, Drury
August 15				X	X	X	X	X	X		X		X		Warheit, Woodby
August 16	X	X													Blackham, Weisel
August 23		X		X	X	X	X	X						X	Blackham, Woodby

Appendix 5. Wetland aerial surveys, 1980 (Continued).

Date	Imuruk Basin	Port Clarence	Cape Woolley	Flambeau River	Safety Lagoon	Fish River Delta	Moses Point	Koyuk	Shaktoolik	Unalakleet	Stebbins	Stuart Island	Yukon Delta	Shishmaref Coast	Observers
Sept. 2	X	X													Warheit, Woodby
Sept. 3				X	X	X									Blackham, Weisel
Sept. 6							X	X	X	X	X	X	X		Blackham, Blick
Sept. 10				X	X	X									Hausler, Woodby
Sept. 16							X								Blick, Weisel
Sept. 17		X	X												Hausler, Woodby
Sept. 23				X	X	X	X	X	X		X	X	X		Blackham, Weisel
Sept. 29				X	X	X	X	X	X						Hausler, Woodby
October 27				X	X			X							Woodby

Appendix 6. Wetland aerial survey, 1981. See Figure 3 for locations.

Date	Imuruk Basin	Port Clarence	Safety Lagoon	Fish River Delta	Moses Point	Koyuk	Shaktoolik	Stebbins	Stuart Island	Observers
May 6					X		X	X	X	S. Blackham, J. Blackham
May 15		X	X							S. Blackham, J. Blackham, Woodby
May 18				X	X	X				Allison, Blackham
June 8	X	X	X	X						S. Blackham, Hausler
June 22		X	X							Allison, Hausler
July 3				X						Hausler, Woodby
July 7				X						S. Blackham, Hausler
July 13				X						S. Blackham, J. Blackham
Aug. 4				X	X	X				Hausler
August 6	X	X	X	X						S. Blackham, Hausler
August 10				X						J. Blackham, Hausler
August 28					X	X	X	X	X	S. Blackham, J. Blackham
Sept. 5	X	X	X	X						S. Blackham, J. Blackham
Sept. 10				X	X	X	X	X	X	S. Blackham, J. Blackham
Sept. 12			X	X						S. Blackham, J. Blackham, Scoville

APPENDIX 7. BIRDS COLLECTED.

PERMIT # PRT 2-171 AK in 1981

LOCATION CODES:
A - Safety Lagoon, 35 km E of Nome, Alaska
B - Golovin, 115 km E of Nome, Alaska
C - Fish River Delta, 103 km EnE of Nome, Alaska
D - 5 km SSE of Shaktoolik, Alaska
E - 10 km SW of Stebbins, Alaska

Age Codes:
A - adult
J - juvenile

Species	#	Month	Date	Location	Age	Sex	Wt.(gm)
Mallard	1	6	24	D	A	M	--
	2	8	19	C	J	-	1175
	3	8	19	C	J	-	940
	4	8	21	C	J	-	920
Pintail	1	5	18	B	A	F	855
	2	5	20	B	A	M	857
	3	5	25	A	A	M	865
	4	5	27	C	A	M	880
	5	5	28	C	A	M	825
	6	6	11	E	A	M	--
	7	8	4	C	J	F	575
	8	8	4	C	J	-	575
	9	8	4	C	A	M	1080
	10	8	19	C	J	-	700
	11	8	19	C	J	-	700
	12	8	29	E	J	-	725
	13	8	29	E	-	M	1045
	14	8	29	E	J	M	790
	15	8	30	E	J	F	625
	16	9	8	C	J	-	730
	17	9	8	C	J	F	750
American Wigeon	1	5	19	B	A	M	750
	2	6	9	E	A	M	--
	3	8	29	E	-	-	750
Northern Shoveler	1	5	18	B	A	M	510
	2	5	25	A	A	F	450
	3	5	30	C	A	M	418
	4	5	30	C	A	F	595
	5	6	10	E	A	M	--
	6	8	3	C	J	-	450
	7	8	3	C	J	-	--
	8	8	3	C	J	-	450

APPENDIX 7 CONTINUED

Species	#	Month	Date	Location	Age	Sex	Wt.(gm)
Northern Shoveler	9	8	18	C	-	-	550
	10	8	19	C	A	M	575
	11	8	29	E	J	F	450
	12	8	29	E	J	-	530
	13	8	29	E	J	F	550
	14	8	29	E	-	-	440
	15	8	29	E	J	M	475
Green-winged Teal	1	5	25	A	A	M	340
	2	6	14	E	A	M	--
	3	6	17	C	A	M	349
	4	6	19	C	A	F	280
	5	6	19	C	A	M	320
	6	8	30	E	J	F	240
	7	8	30	E	A	F	270
	8	9	8	C	J	-	425
Greater Scaup	1	5	19	B	A	M	900
	2	6	9	E	A	M	--
	3	6	10	E	A	M	--
Oldsquaw	1	8	18	C	J	-	580
Black Scoter	1	7	25	E	A	F	1050
	2	7	25	E	A	F	1050
Red-breasted Merganser	1	5	18	B	A	M	1160
	2	5	18	B	A	F	920
Whimbrel	1	8	18	C	-	M	375
	2	8	18	C	J	-	300
	3	8	18	C	J	-	375
	4	8	18	C	-	M	350
	5	9	8	C	-	-	425
Long-billed Dowitcher	1	5	20	B	A	M	111
	2	7	26	E	A	F	145
	3	7	26	E	A	F	150
	4	7	26	E	A	F	149
	5	7	26	E	A	M	130
	6	7	26	E	A	F	130
	7	7	26	E	A	M	125
	8	9	8	C	-	-	105
	9	9	8	C	-	-	100
Dunlin	1	5	13	B	A	M	46
	2	5	25	A	A	M	50
	3	6	9	C	A	M	56
	4	6	10	E	A	M	
	5	6	14	E	A	M	--

APPENDIX 7 CONTINUED

Species	#	Month	Date	Location	Age	Sex	Wt.(gm)
Dunlin	6	6	18	C	A	M	59
	7	7	3	C	J	M	--
	8	7	3	C	A	F	--
	9	7	10	B	A	M	51
	10	7	10	C	A	M	--
	11	7	22	E	J	-	53
	12	7	22	E	J	M	52
	13	7	22	E	J	M	52
	14	7	23	E	J	F	50
	15	8	5	C	-	F	52
	16	9	8	C	A	M	48
	17	9	8	C	A	F	49
Semipalmated Sandpiper	1	5	16	B	A	F	31
	2	5	25	A	A	M	--
	3	5	30	C	A	F	29
	4	5	30	C	A	F	29
	5	5	30	C	A	F	29
	6	6	8	C	A	F	27
	7	6	9	C	A	F	28
	8	6	9	C	A	F	25
	9	6	14	E	A	F	25
	11	6	18	C	A	M	27
	12	6	18	C	A	M	26
	13	6	18	C	A	F	27
	14	6	19	C	A	M	26
	15	6	23	D	A	M	24
	16	7	3	C	A	F	--
	17	7	9	B	J	M	20
	18	7	10	C	J	M	23
	19	7	10	C	J	M	18
	20	7	10	C	J	M	23
	21	7	10	C	J	M	--
	22	7	10	C	J	F	--
	23	7	10	C	J	M	22
	24	7	10	C	J	M	23
	25	7	14	B	J	M	23
Western Sandpiper	1	5	10	B	A	M	28
	2	5	13	B	A	F	30
	3	5	13	B	A	M	25
	4	5	16	B	A	M	23
	5	5	30	C	A	F	30
	6	5	30	C	A	F	30
	7	5	30	C	A	F	30
	8	6	9	C	A	F	28
	9	6	18	C	A	M	26
	10	6	24	D	A	M	28
	11	6	24	D	A	F	28

APPENDIX 7 CONTINUED

Species	#	Month	Date	Location	Age	Sex	Wt.(cm)
Western Sandpiper	11	6	24	D	A	F	28
	12	7	10	C	A	M	26
	13	7	10	C	A	M	28
	14	7	23	E	J	-	28
	15	7	23	E	J	M	24
	16	7	26	E	J	-	26
	17	7	26	E	J	-	30
	18	8	4	C	J	M	25
	19	8	4	C	J	-	26
	20	8	4	C	J	-	24
	21	8	5	C	J	M	23
	22	8	5	C	J	F	23
	23	8	5	C	J	M	24
	24	8	5	C	J	M	24
Northern Phalarope	1	5	16	B	A	M	33
	2	5	25	A	A	M	32
	3	5	30	C	A	F	36
	4	7	3	C	A	M	--
	5	7	10	C	A	M	28
	6	7	10	C	A	M	30
	7	7	10	C	A	M	30
	8	7	10	C	A	M	32
	9	7	10	C	A	M	81
	10	7	10	C	A	M	35
	11	7	10	C	A	M	33
	12	7	10	C	A	M	34
	13	7	10	C	A	M	--
	14	7	23	E	J	M	32
	15	7	23	E	A	M	36
	16	8	23	E	J	-	36
	17	7	25	E	J	M	35
	18	7	25	E	J	M	29
	19	7	25	E	J	F	32
	20	7	26	E	A	M	37
	21	7	26	E	A	M	35
	22	7	26	E	J	F	38

Appendix 8. Semipalmated Sandpiper stomach contents; adults.

	Wet Tundra					Littoral				
Prey Items	n	%[1]	f	%f	Mean Length (mm)	n	%[1]	f	%f	Mean Length (mm)
Midge Larvae	83	70	5	71	9	8	38	1	25	8
Crane-fly Larvae					9	1	5	1	25	12
Cyclorrapha Larvae	4	3	2	29	9	4	19	2	50	9
Beetle Larvae	28	24	2	29	12	6	29	2	50	7
Beetle Adults	2	2	1	14	3					
Ants	1	1	1	14	6					
Snails						2	10	1	25	1
Seeds	57	--	2	29	2	1	--	1	25	2
N of Birds			7[2]					4[3]		

[1] Percent of non-seed items.

[2] Three others with only grit and chyme in stomachs.

[3] Two others with only grit and chyme in stomachs.

Appendix 9. **Semipalmated Sandpiper stomach contents; juveniles.**

	Wet Tundra					**Littoral**				
Prey Items	n	%[1]	f	%f	Mean Length (mm)	n	%[1]	f	%f	Mean Length (mm)
Cyclorrapha Larvae	31	78	3	50	10					
Beetle Larvae	9	22	4	67	9					
Seeds	12	--	3	50	2					
N of Birds			6[2]					1[3]		

[1] Percent of non-seed items.

[2] One other with only grit in stomach.

[3] One collected in intertidal habitat had an empty stomach.

Appendix 10. Western Sandpiper stomach contents; adults.

	Wet Tundra					Littoral				
Prey Items	n	%[1]	f	%f	Mean Length (mm)	n	%[1]	f	%f	Mean Length (mm)
Midge Larvae	55	37	4	57	7	34	81	5	100	9
Cyclorrapha Larvae	27	18	1	14	11					
Beetle Larvae	59	40	1	14	6	6	14	1	20	11
Beetle Adults	4	3	3	43	4	1	2	1	20	6
Ants	2	1	1	14	2					
Spiders	2	1	1	14	4					
Unid. Worms						1	2	1	20	5
Seeds	3	--	2	29	2	24	--	2	40	2
N of Birds			7					5[2]		

[1] Percent of non-seed items.

[2] One other with only stones and chyme in stomach.

Appendix 11. Western Sandpiper stomach contents; juveniles.

	Wet Tundra					Littoral				
Prey Items	n	%[1]	f	%f	Mean Length (mm)	n	%[1]	f	%f	Mean Length (mm)
Midge Larvae						39	91	3	38	8
Cyclorrapha Larvae	3	100	1	50	7	2	5	1	13	6
Isopods						1	2	1	13	6
Mysids						1	2	1	13	4
Seeds	19	--	2	100	1	188	--	6	75	1
N of Birds			2[2]					8		

[1] Percent of non-seed items.

[2] One other with only grit and chyme in stomach.

Appendix 12. Dunlin stomach contents; adults.

	Wet Tundra					Littoral				
Prey Items	n	%[1]	f	%f	Mean Length (mm)	n	%[1]	f	%f	Mean Length (mm)
Midge Larvae	44	42	2	25	11	18	95	3	100	10
Crane-fly Larvae	6	6	2	25	21					
Beetle Larvae	47	45	4	50	10					
Beetle Adults	1	1	1	13	5					
Ants	1	1	1	13	9					
Spiders	1	1	1	13	10					
Snails	5	5	1	13	4	1	5	1	33	4
Seeds	115	--	4	50	2					
N of Birds			8					3		

[1] Percent of non-seed items.

Appendix 13. Dunlin stomach contents; juveniles.

	Wet Tundra					Littoral				
Prey Items	n	%[1]	f	%f	Mean Length (mm)	n	%[1]	f	%f	Mean Length (mm)
Crane-fly Larvae	1	100	1	100	9					
Isopods						1	33	1	20	4
Snails						2	67	2	40	4
Seeds	77	--	1	100	2	204	--	4	80	2
N of Birds			1					5		

[1] Percent of non-seed items.

Appendix 14. Northern Phalarope stomach contents, adults.

Prey Items	Wet Tundra n	%[1]	f	%f	Mean Length (mm)	Littoral n	%[1]	f	%f	Mean Length (mm)
Midge Larvae	148	67	7	58	11	3	50	1	33	10
Cyclorrapha Larvae	1	0.5	1	8	10					
Beetle Larvae	63	28	6	50	9	2	33	1	33	9
Unid. Larvae	9	4	2	17	13					
Spiders	1	0.5	1	8	2					
Cladoceran Egg Cases	530	---	2	17	1					
Snails						1	17	1	33	4
Seeds	420	---	6	50	1	25	---	2	67	1
N of Birds			12[2]					3[3]		

[1] Percent of non-seed items.

[2] One other with an empty stomach, all males.

[3] Two males, one female.

Appendix 15. Northern Phalarope stomach contents, juveniles.

	Wet Tundra					Littoral				
Prey Items	n	%[1]	f	%f	Mean Length (mm)	n	%[1]	f	%f	Mean Length (mm)
Beetle Larvae	2	4	1	50	14					
Ants						1	2	1	33	4
Cladocerans	52	96	1	50	2					
Cladoceran Egg Cases	111	--	1	50	1	80	--	1	33	1
Mysids						25	54	2	67	9
Clam						20	43	1	33	2
Seeds	21	--	1	50	2	24	--	2	67	1
N of Birds			2[2]					3		

---

[1] Percent of non-seed items.

[2] One other with an empty stomach.

Appendix 16. Mallard stomach contents.

	Adults					Juveniles				
Prey Items	n	%[1]	f	%f	Mean Length (mm)	n	%[1]	f	%f	Mean Length (mm)
Midge Larvae	11	--	1	100	11					
Snails						21	--	2	67	5
Vegetation (Chyme)		15	1	100			25	3		
Seeds	89	--	1	100	3	35	--	2	67	1
N of Birds			1					3		

[1] Volume.

Appendix 17. Pintail stomach contents.

	Adults					Juveniles				
Prey Items	n	%[1]	f	%f	Mean Length (mm)	n	%[1]	f	%f	Mean Length (mm)
Midge Larvae	253	--	2	29	10					
Crane-fly Larvae	3	--	2	29	20					
Cyclorrapha Larvae	202	--	3	43	10					
Adult Beetles	1	--	1	14	10	6	--	1	10	7.5
Shoots	299	--	4	57	11					
Vegetables (Chyme)	--	30	3	43		--	48	6	60	--
Seeds	691	--	5	71	1.9	736	--	9	90	2.0
N of Birds			7					10		

[1] Volume.

Appendix 18. American Wigeon stomach contents.

	Adults					Juveniles				
Prey Items	n	%^{1}	f	%f	Mean Length (mm)	n	%^{1}	f	%f	Mean Length (mm)
Shoots	22		1	50	40	75	80	1	100	15
Vegetation (Chyme)		45	2	100			10	1	100	
Seeds	105	--	2	100	2	10	5	1	100	2.5
N of Birds			2					1		

---

[1] Volume.

Appendix 19. Northern Shoveler stomach contents.

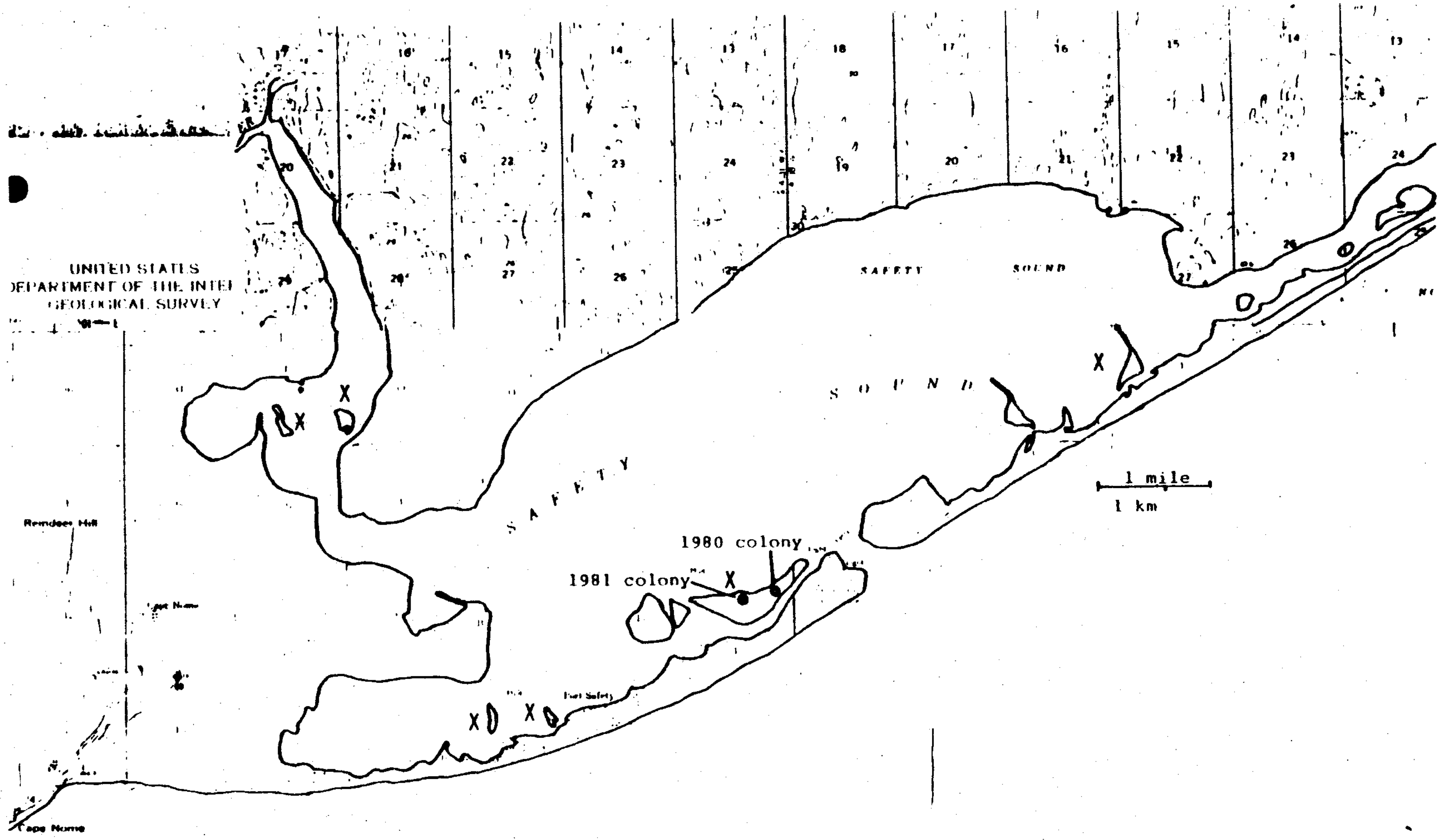
	Adults					Juveniles				
Prey Items	n	%[1]	f	%f	Mean Length (mm)	n	%[1]	f	%f	Mean Length (mm)
Midge Larvae	37		2	40	4.1	160		2	22	7.8
Cyclorrapha Larvae	7		2	40	6.8					
Adult Diptera						37		2	22	3
Adult Hymenoptera						8		1	11	3
Adult Beetles						7		1	11	3.5
Adult Mites	31		1	20	1					
Snails	14		2	40	5					
Vegetation (Chyme)		40	3	60			43	6	67	
Seeds	280	--	3	60	2.2	1,055	--	6	67	1.7
N of Birds			5					9		

[1] Volume.

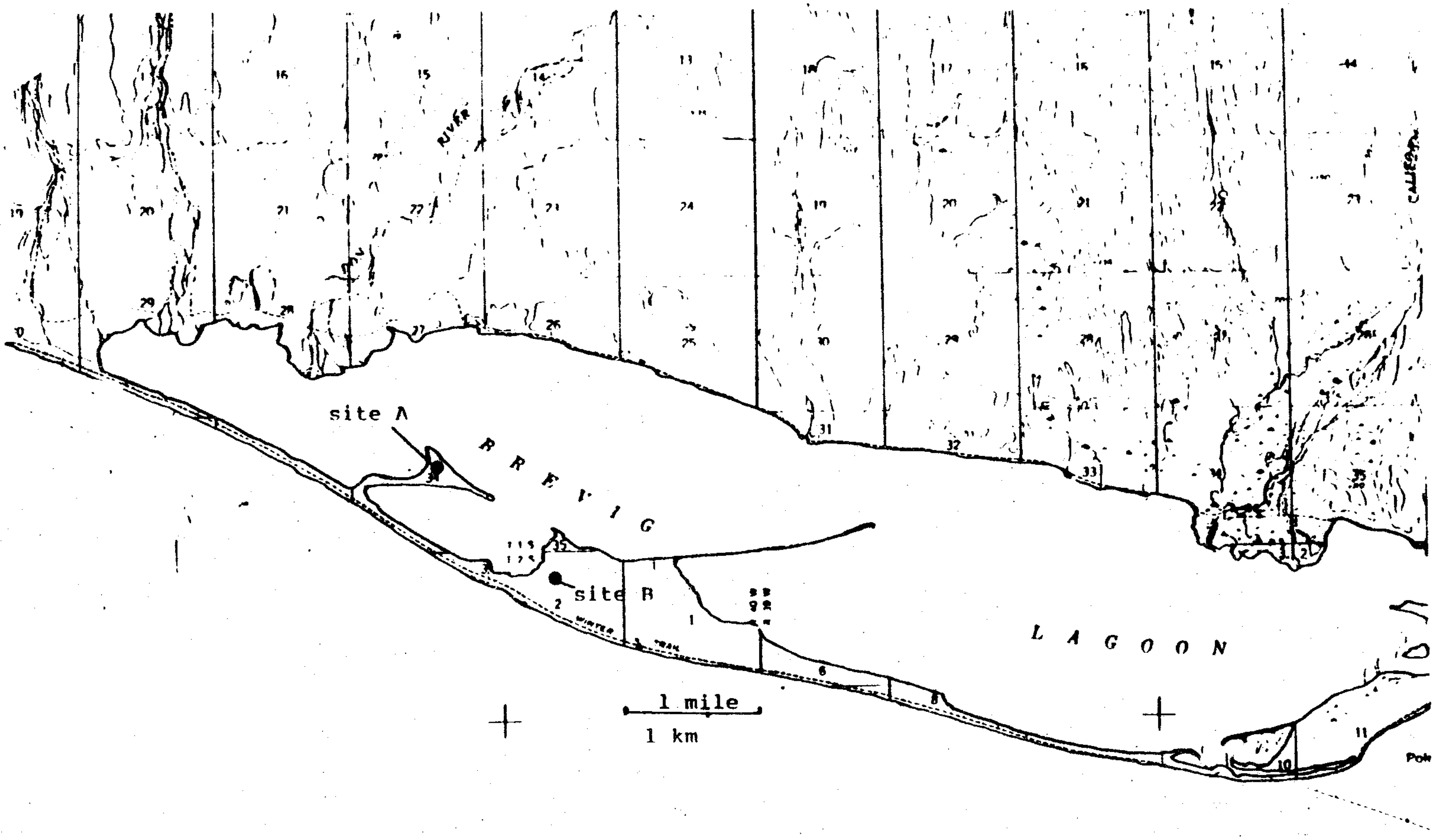
Appendix 20. Green-winged Teal stomach contents.

	Adults					Juveniles				
Prey Items	n	%[1]	f	%f	Mean Length (mm)	n	%[1]	f	%f	Mean Length (mm)
Midge Larvae	316	--	4	67	9.8					
Beetle Larvae	7	--	2	33	7.7					
Beetle Adults	6	--	1	17	10.8					
Copepods	150	--	1	17	1					
Mysids	3	--	1	17	7					
Nematodes	1	--	1	17	7					
Shoots	2	--	1	17	7					
Vegetation (Chyme)	--	38	3	50		--	50	2	100	
Seeds	232	--	5	83	2.2	60	--	2	100	2
N of Birds			6					2		

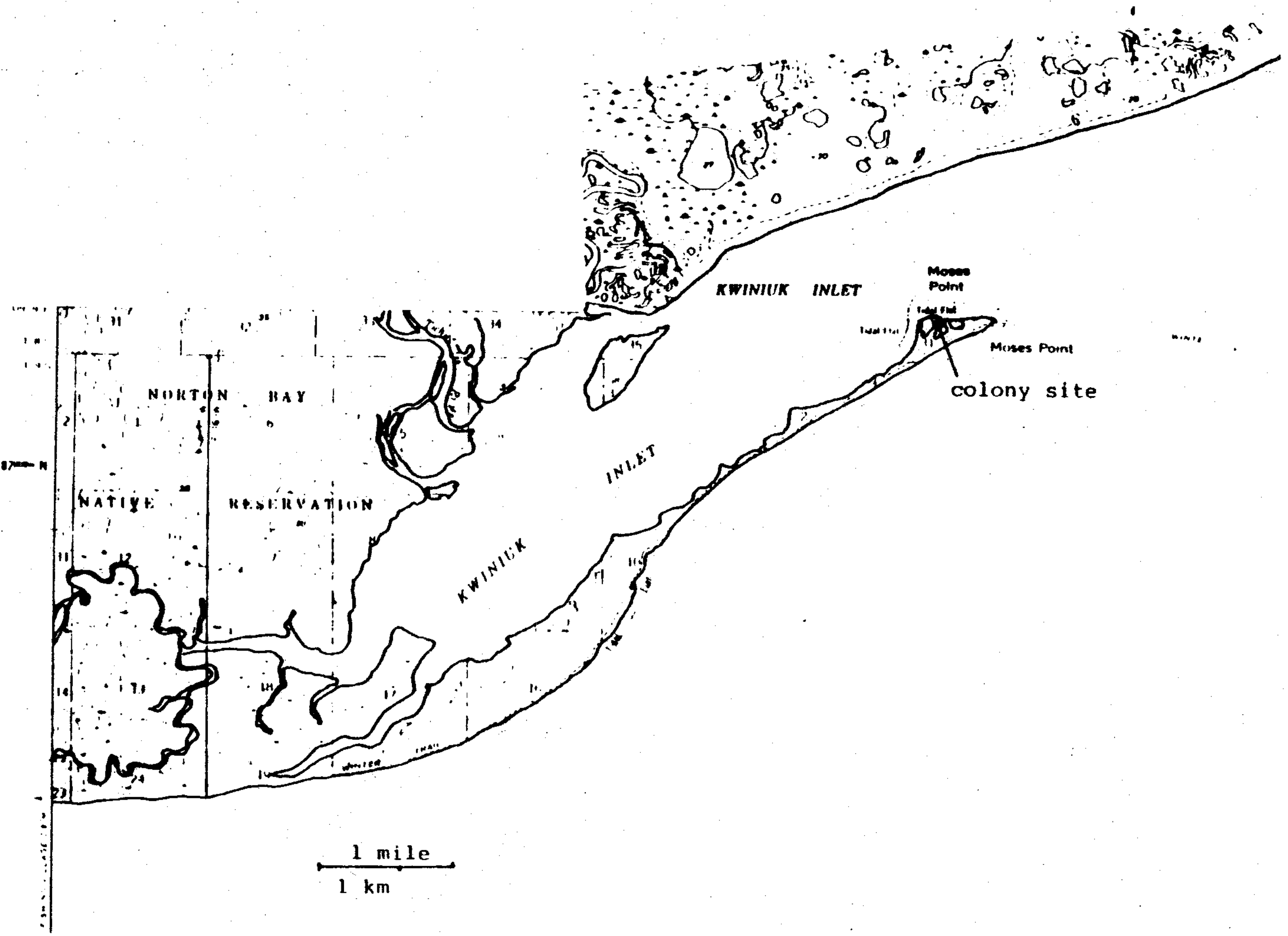
[1] Volume.



Appendix 21. Aleutian Tern colony locations, Safety Lagoon. Islands that have had colonies between 1976 and 1981 are marked with an X; the peak population reached 480 adults in 1979 (H. Springer pers. comm.). Colony locations found by us in 1980 and 1981 are marked with dots; these were on the same island.

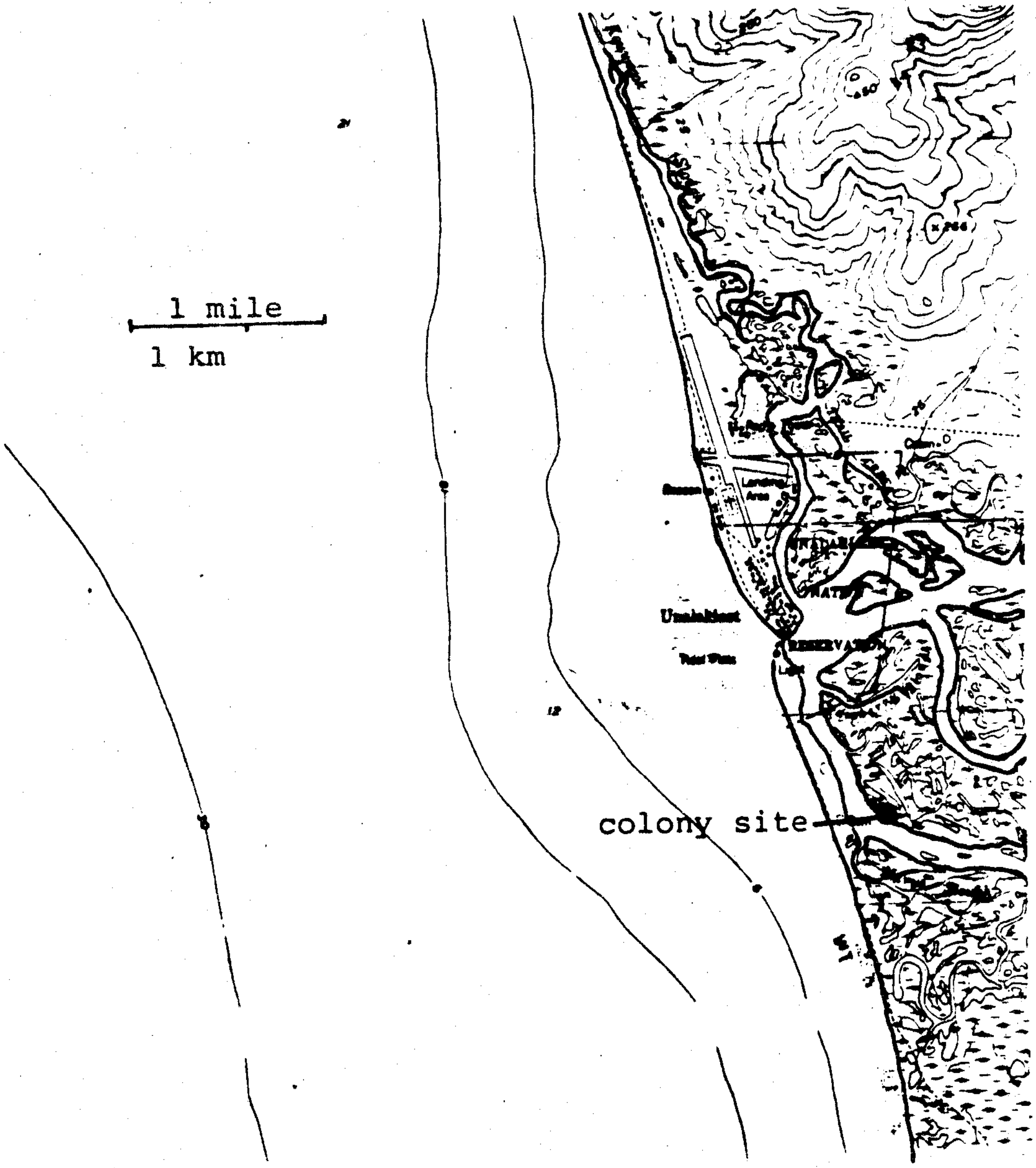


Appendix 22. Aleutian Tern colony locations, Brevig Lagoon. Site A had 6 adults and site B had 12 on 3 July, 1980. No nests or young were found.

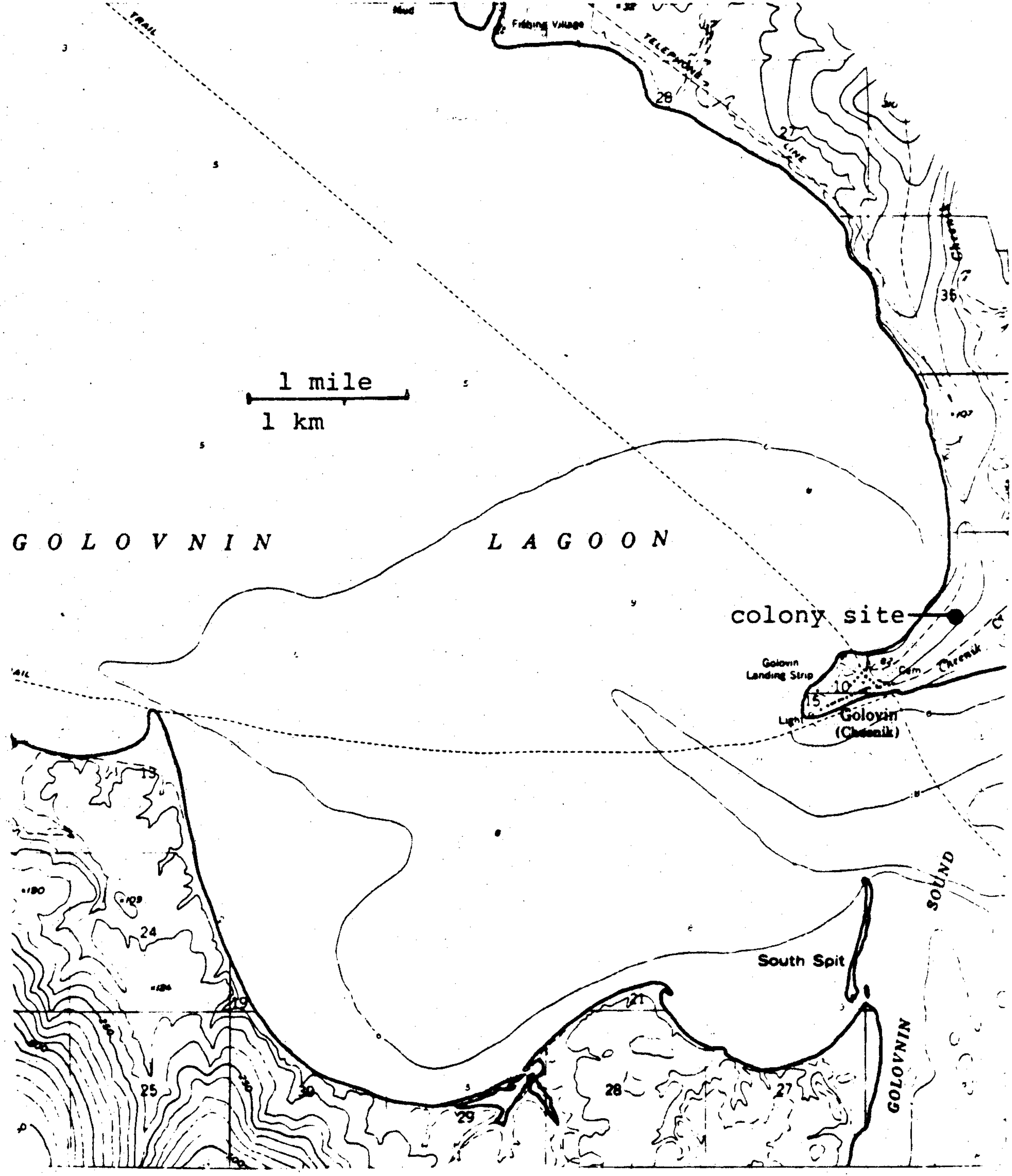


Appendix 23. Aleutian Tern colony location, Moses Point. Colony was at end of spit.

Appendix 24. Aleutian Tern colony location, Unalakleet. Approximatley 35 adults were seen at the site indicated (2 km SSE of town) on 7 August, 1980.



Appendix 25. Aleutian Tern colony location, Golovin. Nests were concentrated 1 km ENE of the town on raised moist tundra. At least 30 adults were at this colony in 1981.



Appendix 26.

Species List; Seasonal Abundance and Habitat Use of Birds in Coastal Norton Sound, 1980 and 1981.

Legend

Codes

***:** Nesting in coastal Norton Sound.
T: Discussed in text.

Abundance Terms

A: Abundant — seen almost always, and in large numbers (1,000's).
C: Common — seen regularly in moderate numbers (100's).
FC: Fairly Common — seen regularly in low numbers (10's).
U: Uncommon — seen occasionally in small numbers.
LC: Locally Common — as with Common, but at limited sites only; not widely distributed.
R: Rare — seen only a few times, within normal range.
RX: Range Extension.
V: Vagrant, far from normal range.

Habitats

OW: Offshore Waters (pelagic).
IW: Inshore Waters (within 1 km of shore).
PW: Protected Waters.
SP: Spits.
SL: Shorelines.
CL: Cliffs.
RM: River Mouths.
RI: Rivers.
WT: Wet Tundra (in wetlands).
MT: Moist Tundra/Uplands.
TR: Trees: spruce forest, muskeg (principally for songbirds).
SH: Shrubs.
DB: Disturbed Beaches.
VL: Villages.

Appendix 26. **Species list; seasonal abudance and habitat use of birds in coastal Norton Sound, 1980 and 1981 (continued).**

	Spring	Migration	Breeding		Post-Breeding	
Species	Status	Habitat	Status	Habitat	Status	Habitat
Common Loon (Govia immer)	R	IW				
Yellow-Billed Loon (G. adamsii)	R	IW	R			
Arctic Loon*T (G. arctica)	U	IW	FC	WT IW	FC	WT IW
Red-throated Loon*T (G. stellata)	FC	IW	FC	WT IW	FC	WT IW
Red-necked Grebe* (Podiceps grisegena)	U	IW	R	WT IW	U	WT IW
Horned Grebe (P. auritus)	U	IW	R	IW	U	IW WT
Short-tailed Shearwater (Puffinus tenuirastris)					A	OW
Pelagic Cormorant* (Phalacrocorax pelagicus)	C	CL IW	C	CL IW	C	CL IW
Whistling Swan*T (Olor columbianus)	UC	IW WT	FC	WT PW	C	WT PW
Canada Goose*T (Branta canadensis)	C	WT	U	MT WT	A	MT WT PW
Brant T (B. bernicla)	A	PW WT	R		FC	IW WT
Emperor Goose*T (Philacte canagica)	U	WT	R	WT	U	IW WT
White-fronted Goose T (Anser albifrans)	U	WT	R		U	WT
Snow Goose T (Chen caerulescens)	C	IW WT MT	V		C	WT MT
Mallard*T (Anas platyrhynchos)	U	PW WT	U	WT	FC	PW WT
Gadwall*T (A. strepera)	RX	WT	RX	WT		
Pintail*T (A. acuta)	A	PW WT IW	A	PW WT MT	A	PW WT IW
Green-winged Teal*T (A. crecca)	FC	WT	C	WT	C	WT
Blue-winged Teal (A. discors)				V		
Northern Shoveler*T (A. clypeata)	FC	WT	C	WT	FC	WT

Appendix 26. **Species list; seasonal abudance and habitat use of birds in coastal Norton Sound, 1980 and 1981 (continued).**

	Spring Migration		Breeding		Post-Breeding	
Species	Status	Habitat	Status	Habitat	Status	Habitat
American Wigeon*T (*A. americana*)	U	PW WT	U	WT	C	PW WT
Canvasback*T (*Agytha valisineria*)	RX		RX		RX	
Redhead*T (*A. americana*)	RX		RX	WT		
Greater Scaup*T (*A. marila*)	FC	IW WT	C	WT	C	PW WT
Lesser Scaup (*A. affinis*)	R		R			
Common Goldeneye (*Bucephala clangula*)	V					
Bufflehead (*B. albeola*)	R		R	RI	R	
Oldsquaw*T (*Clangula hyemalis*)	FC	IW PW	FC	PW IW WT	FC	IW PW
Harlequin Duck* (*Histrionicus histrionicus*)	LC	IW	U	RM	LC	IW
Steller's Eider (*Polysticta stelleri*)	R	IW	R		LC	IW
Common Eider*T (*Somateria mollissima*)	FC	IW	FC	IW WT MT	FC	IW PW
King Eider T (*S. spectabilis*)	A	IW OW	R		R	
Spectacled Eider*T (*S. fischeri*)	R	IW	R		LC	IW
White-winged Scoter (*Melanitta deglandi*)	U	IW	U	IW		
Surf Scoter (*M. perspicillata*)	U	IW	U	IW		
Black Scoter*T (*M. nigra*)	C	IW	U	RI MT	U	IW
Common Merganser (*Mergus merganser*)	R		R			
Red-breasted Merganser*T (*M. serrator*)	FC	IW RM	FC	IW MT RM	FC	IW WT RM
Goshawk (*Accipiter gentilis*)			R			
Rough-legged Hawk* (*Buteo lagopus*)	U	MT	U	CL MT	U	MT

Appendix 26. Species list; seasonal abudance and habitat use of birds in coastal Norton Sound, 1980 and 1981 (continued).

	Spring	Migration	Breeding		Post-Breeding	
Species	Status	Habitat	Status	Habitat	Status	Habitat
Golden Eagle* (_Aquila chrysaetos_)			R	CL		
Marsh Hawk* (_Circus cyaneus_)	U	WT	U	WT	FC	WT
Osprey (_Pandion haliaetus_)			R	RI		
Gyrfalcon* (_Falco rusticolus_)	R		R	CL MT	U	SL
Peregrine Falcon*T (_F. peregrinus_)	R	WT	R	CL WT	R	
Merlin* (_F. columbarius_)	R		R	TR	R	
Willow Ptarmigan (_Lagopus lagopus_)	FC	MT	FC	MT	FC	MT
Sandhill Crane*T (_Grus canadensis_)	C	WT MT	FC	WT	C	WT MT
Semipalmated Plover*T (_Charadrius semipalmatus_)	U		U	SP Gravel		
Killdeer (_C. vociferus_)	V	SP	V	SP		
American Golden Plover*T (_Pluvialis dominica_)	FC	MT	FC	MT	C	WT MT SL
Black-bellied Plover*T (_P. squatarola_)	U	MT	U	MT		
Bar-tailed Godwit*T (_Limosa lapponica_)	U	WT	LC	MT WT	LC	WT SL
Hudsonian Godwit*T (_L. haemastica_)	U	WT	R		U	WT
Whimbrel*T (_Numenius phaeopus_)	FC	MT	FC	MT WT	C	MT WT
Bristle-thighed Curlew T (_N. americanus_)	U	MT WT	R			
Lesser Yellowlegs*T (_Tringa flavipes_)	U		U	TR		
Solitary Sandpiper*T (_T. solitaria_)			U	TR		
Spotted Sandpiper*T (_Actititis macularia_)			FC	RI		
Wandering Tattler T (_Heteroscelos incanus_)					R	SL

Appendix 26. Species list; seasonal abudance and habitat use of birds in coastal Norton Sound, 1980 and 1981 (continued).

Species	Spring Migration Status	Spring Migration Habitat	Breeding Status	Breeding Habitat	Post-Breeding Status	Post-Breeding Habitat
Ruddy Turnstone*T (*Arenaria interpres*)	U		LC	SP	U	SL
Black Turnstone*T (*A. melanocephala*)	U	SL	LC	WT	U	SL
Northern Phalarope*T (*Lobipes lobatus*)	C	WT IW	A	WT	C	WT
Red Phalarope*T (*Phalaropus fulicarius*)	LC	IW	LC	WT	U	IW OW?
Common Snipe*T (*Capella gallingo*)			FC	WT MT	FC	WT
Long-billed Dowitcher*T (*Limnodromus scolopaceus*)	FC	WT SL	U	WT	C	WT SL
Surfbird T (*Aphriza virgata*)					U	SP
Red Knot T (*Calidris canutus*)	FC	SL(West)			FC	SL(West)
Sanderling T (*C. alba*)	U	SL			U	SL
Semipalmated Sandpiper*T (*C. pusillus*)	A	WT SL	A	WT	C	WT SL
Western Sandpiper*T (*C. mauri*)	C	WT	C	MT WT	A	SL WT
Rufous-necked Sandpiper T (*C. ruficollis*)			R	WT		
Least Sandpiper*T (*C. minutilla*)			R	WT	R	
Baird's Sandpiper T (*C. bairdii*)	U	SL	R		U	SL
Pectoral Sandpiper*T (*C. melanotos*)	LC	WT	U	WT	C	WT
Sharp-tailed Sandpiper T (*C. acuminata*)					FC	WT
Rock Sandpiper T (*C. ptilocnemis*)	R		U	MT	U	SL
Dunlin*T (*C. alpina*)	FC	WT SL	C	WT	C	WT SL
Buff-breasted Sandpiper T (*Tryngites subruficollis*)	R				R	
Pomarine Jaeger (*Stercorarius pomarinus*)	U					

Appendix 26. **Species list; seasonal abudance and habitat use of birds in coastal Norton Sound, 1980 and 1981 (continued).**

Species	**Spring Migration** Status	 Habitat	**Breeding** Status	 Habitat	**Post-Breeding** Status	 Habitat
Parasitic Jaeger*T (*S. parasiticus*)	FC	MT WT	FC	MT WT	FC	WT SL OW
Long-tailed Jaeger*T (*S. longicaudous*)	FC	MT WT	FC	MT WT	FC	WT SL OW
Glaucous Gull*T (*Laurus hyperboreus*)	A	CL IW WT	A	CL WT SL	A	SL RI WT
Glaucous-winged Gull T (*L. glaucescens*)	U	SL	U	SL	FC	SL RI
Slaty-backed Gull (*L. schistisagus*)	R	SL	R	SL	R	SL
Herring Gull (*L. argentatus*)	R	SL	U	SL	FC	SL RI
Mew Gull*T (*L. canus*)	FC	WT SL	C	WT	FC	SL
Bonaparte's Gull (*L. philadelphia*)			U	TR		
Black-legged Kittiwake*T (*Rissa tridactyla*)	A	SL CL	A	CL	A	IW SL
Sabine's Gull*T (*Xema sabini*)	U	SL	U	WT	U	SL OW
Arctic Tern*T (*Sterna paradisaea*)	FC	SL	C	SP WT SL	C	SL OW
Aleutian Tern*T (*S. aleutica*)	U	SL	LC	SP MT	U	SL OW
Murre *spp.** (*Uria spp.*)	A	CL	A	CL	A	CL
Pigeon Guillemot* (*Cepphus columba*)			FC	CL		
Kittlitz's Murrelet* (*Brachyramphus brevirostis*)			R	MT	U	OW
Parakeet Auklet* (*Cyclorrhynchus psittacula*)			U	CL		
Crested Auklet* (*Aethia cristatella*)			LA	CL		
Least Auklet* (*A. pusilla*)			LA	CL		
Horned Puffin* (*Fratercula corniculata*)			C	CL		
Tufted Puffin* (*Lunda cirrhata*)			FC	CL		

Appendix 26. **Species list; seasonal abudance and habitat use of birds in coastal Norton Sound, 1980 and 1981 (continued).**

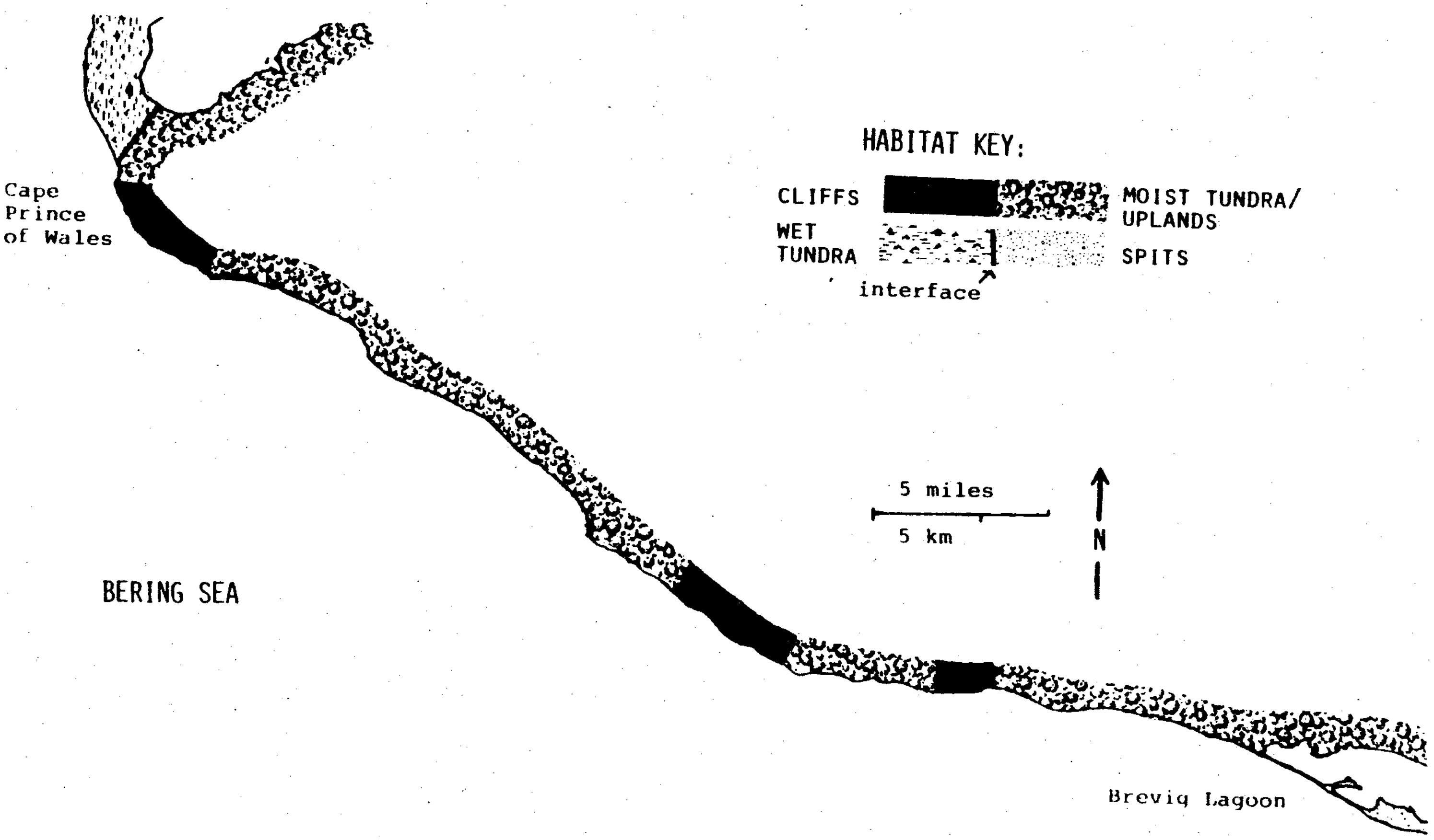
Species	Spring	Migration	Breeding		Post-Breeding	
	Status	Habitat	Status	Habitat	Status	Habitat
Snowy Owl (*Nyctae scandiaca*)	R	WT MT			R	WT MT
Hawk Owl (*Surnia uiulua*)					R	TR
Short-eared Owl* (*Asio flammeus*)	FC	MT WT	FC	MT WT	FC	MT MT
Belted Kingfisher* (*Megaceryle alcyon*)			U	RI		
Say's Phoebe* (*Sayornis saya*)			R	CL MT		
Alder Flycatcher* (*Empidonax alnorum*)			FC	TR		
Horned Lark* (*Eremophila alpestris*)			FC	MT		
Tree Swallow* (*Iridoprocne bicolor*)			LC	DB VL		
Bank Swallow* (*Riparia riparia*)			LC	SL RI VL		
Barn Swallow* (*Hirundo rustica*)			U	DB VL		
Cliff Swallow* (*Petrochelidon pyrrhonota*)			LC	VL		
Gray Jay* (*Perisoreus canadensis*)			U	TR		
Common Raven* (*Corvus corax*)	FC	WT SL VL	FC	CL VL	FC	WT SL VL
Black-capped Chickadee* (*Parus atricapillus*)			U	TR		
Boreal Chickadee* (*P. hudsonicus*)			U	TR		
American Robin* (*Turdus migratorius*)	FC		FC	TR SH		
Varied Thrush* (*Ixoreus naevius*)			FC	TR		
Hermit Thrush* (*Catharus guttatis*)			R	TR		
Gray-cheeked Thrush* (*C. minimus*)	C		C	TR SH		
Wheatear (*Oenanthe oenanthe*)					U	MT

Appendix 26. Species list; seasonal abudance and habitat use of birds in coastal Norton Sound, 1980 and 1981 (continued).

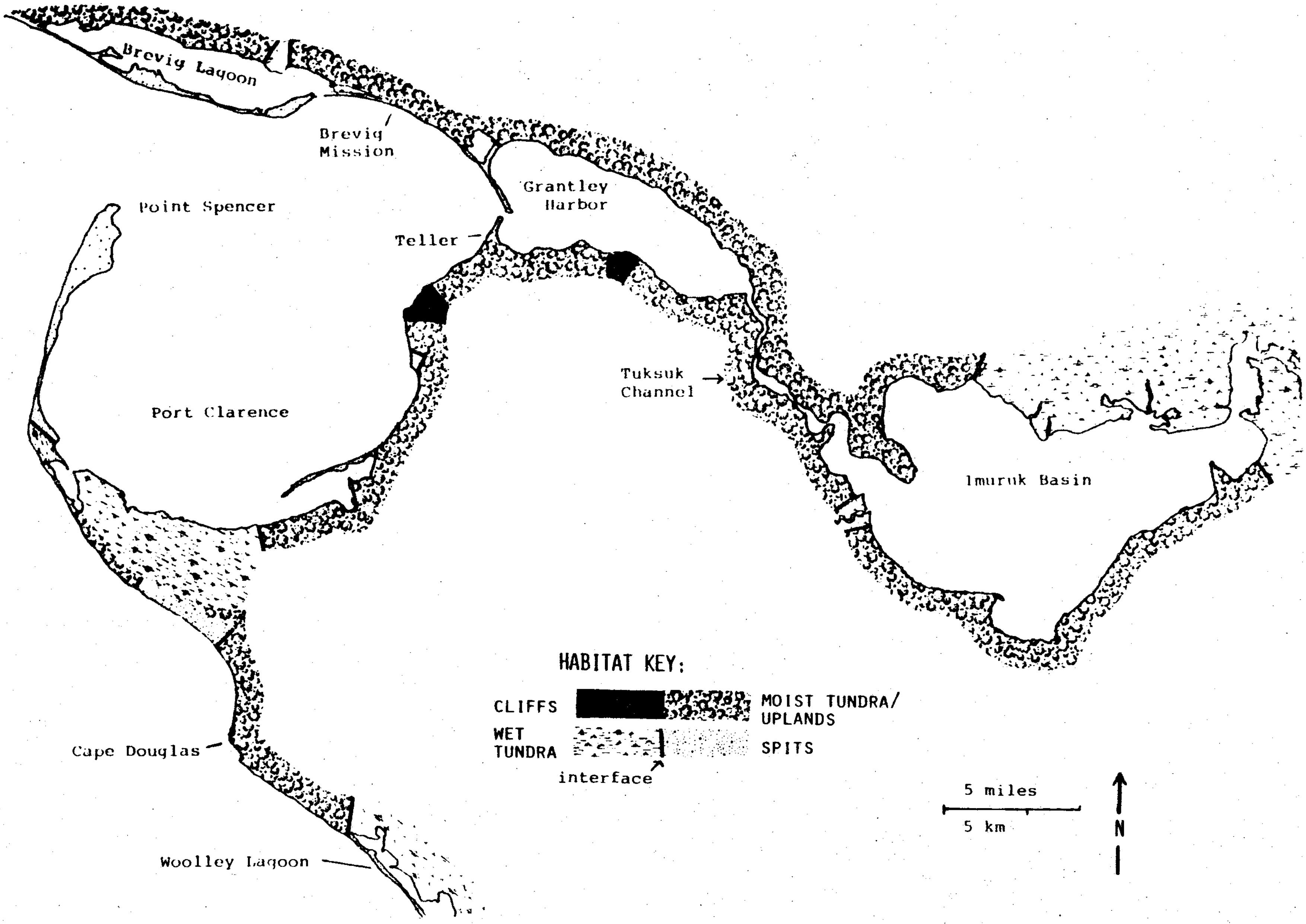
Species	Spring Migration		Breeding		Post-Breeding	
	Status	Habitat	Status	Habitat	Status	Habitat
Bluethroat (*Zuscinia svecica*)	R				R	
Arctic Warbler (*Phylloscopus borealis*)			U	SH		
White Wagtail* (*Motacilla alba*)			U	VL DB		
Yellow Wagtail*T (*M. flava*)			C	SH SL	C	SL
Water Pipit* (*Anthus spinoletta*)			U	MT		
Red-throated Pipit (*A. cervinus*)			R	MT		
Northern Shrike* (*Lanius excubitor*)			U	SH		
Orange-crowned Warbler* (*Vermivora celata*)			C	SH TR		
Yellow Warbler* (*Dendroica petechia*)			C	SH TR		
Yellow-rumped Warbler* (*D. coronata*)			FC	SH		
Blackpoll Warbler* (*D. striata*)			C	TR		
Northern Waterthrush* (*Seiurus noveboracensis*)			FC	SH TR		
Wilson's Warbler* (*Wilsonia pusilla*)			FC	SH		
Rusty Blackbird* (*Euphagus carolinus*)			FC	SH TR		
Pine Grosbeak (*Pinicola enucleator*)			U	TR		
Redpoll* (*Acanthus flammea*)			C	MT SH WT		
Savannah Sparrow*T (*Passerculus sandwichensis*)			A	WT SL	C	WT SL
Dark-eyed Junco* (*Junco hyemalis*)			U	TR		
Tree Sparrow* (*Spizella arborea*)			FC	SH		
White-crowned Sparrow* (*Zonotrichia leucophrys*)			FC	SH		

Appendix 26. **Species list; seasonal abudance and habitat use of birds in coastal Norton Sound, 1980 and 1981 (continued).**

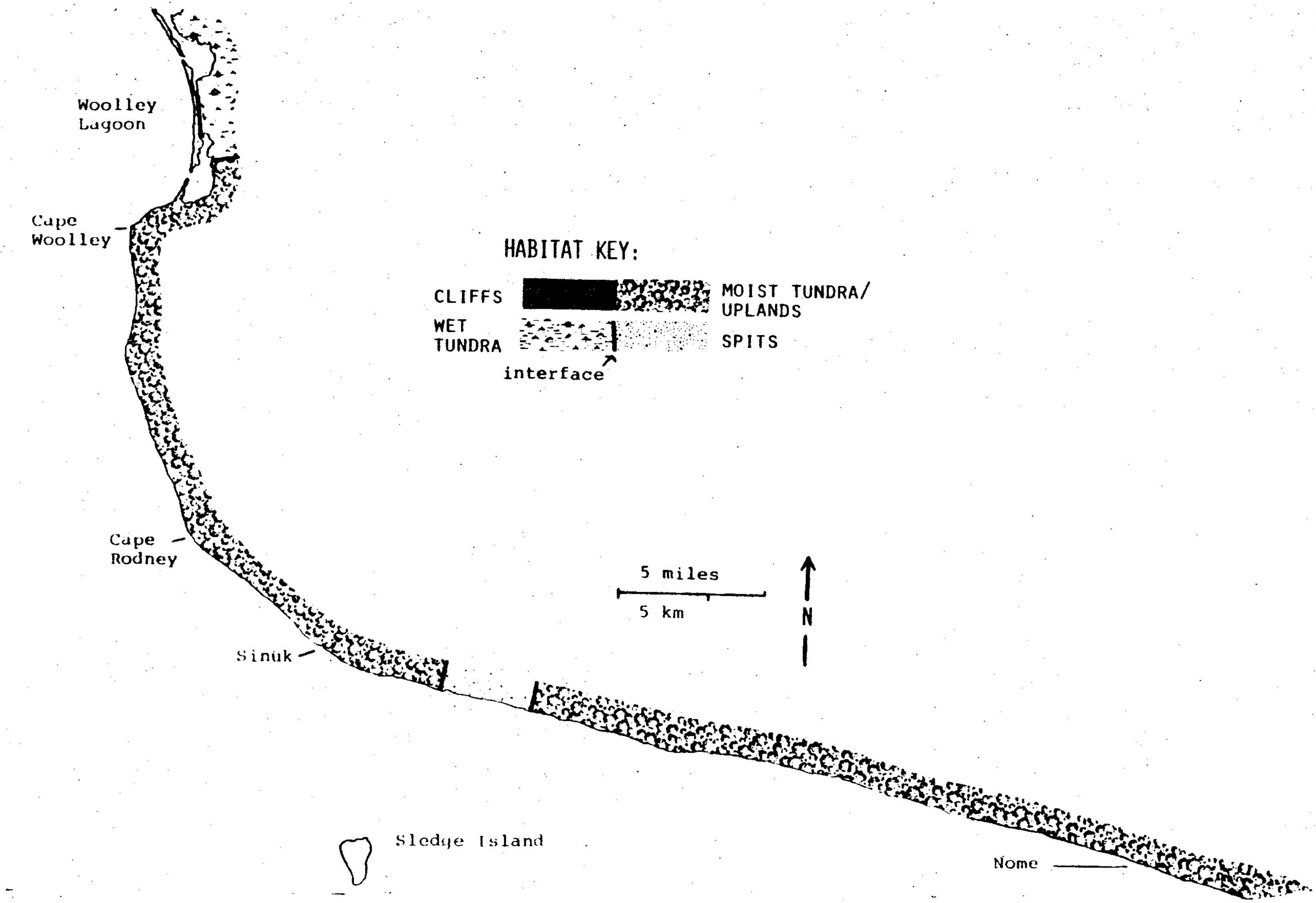
	Spring Migration		**Breeding**		**Post-Breeding**	
Species	Status	Habitat	Status	Habitat	Status	Habitat
Golden-crowned Sparrow* (*Z. atricapilia*)			U	SH		
Fox Sparrow* (*Passorella iliaca*)			C	SH		
Lapland Longspur*T (*Calcarius lapponicus*)	A	WT	A	MT WT	A	WT
Snow Bunting* (*Plectrophenax nivalis*)	C	SL	U	VL MT	C	SL



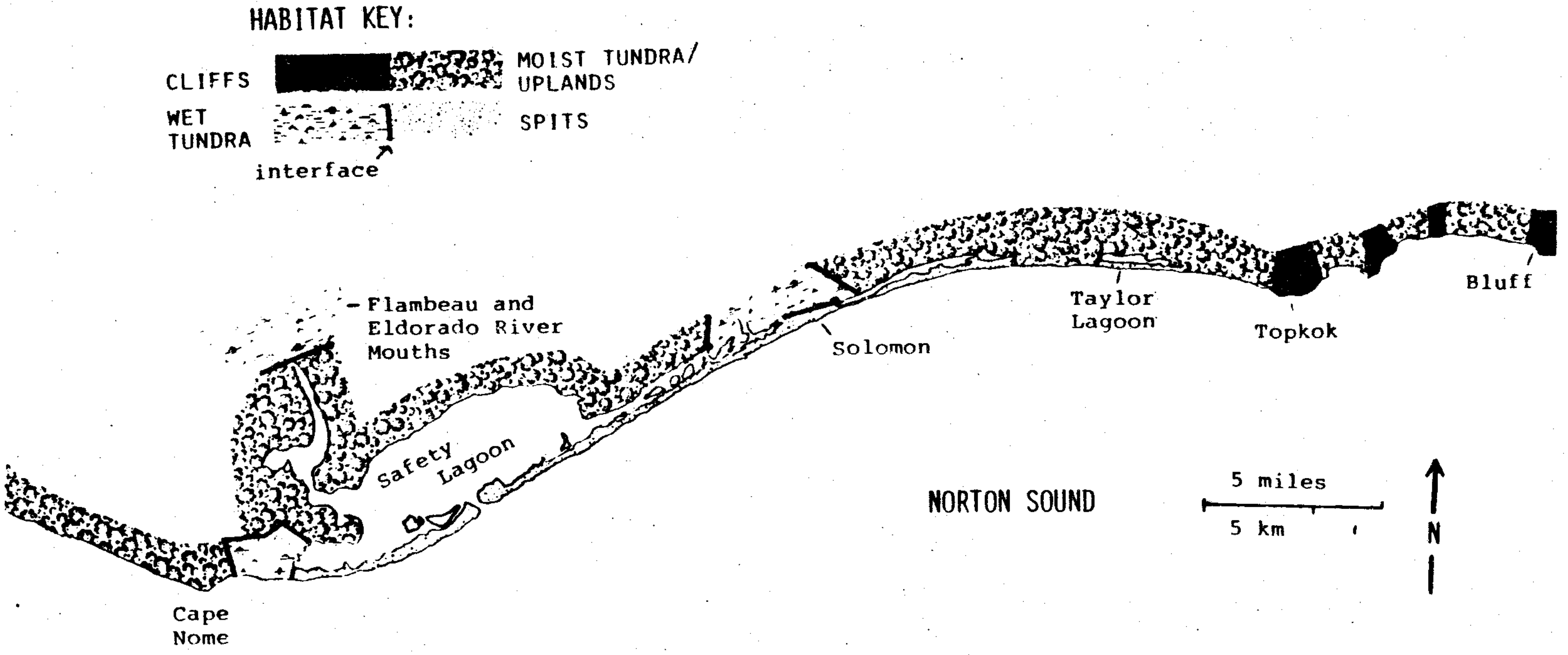
Appendix 27. Map of coastal habitats from Wales to Brevig Lagoon.



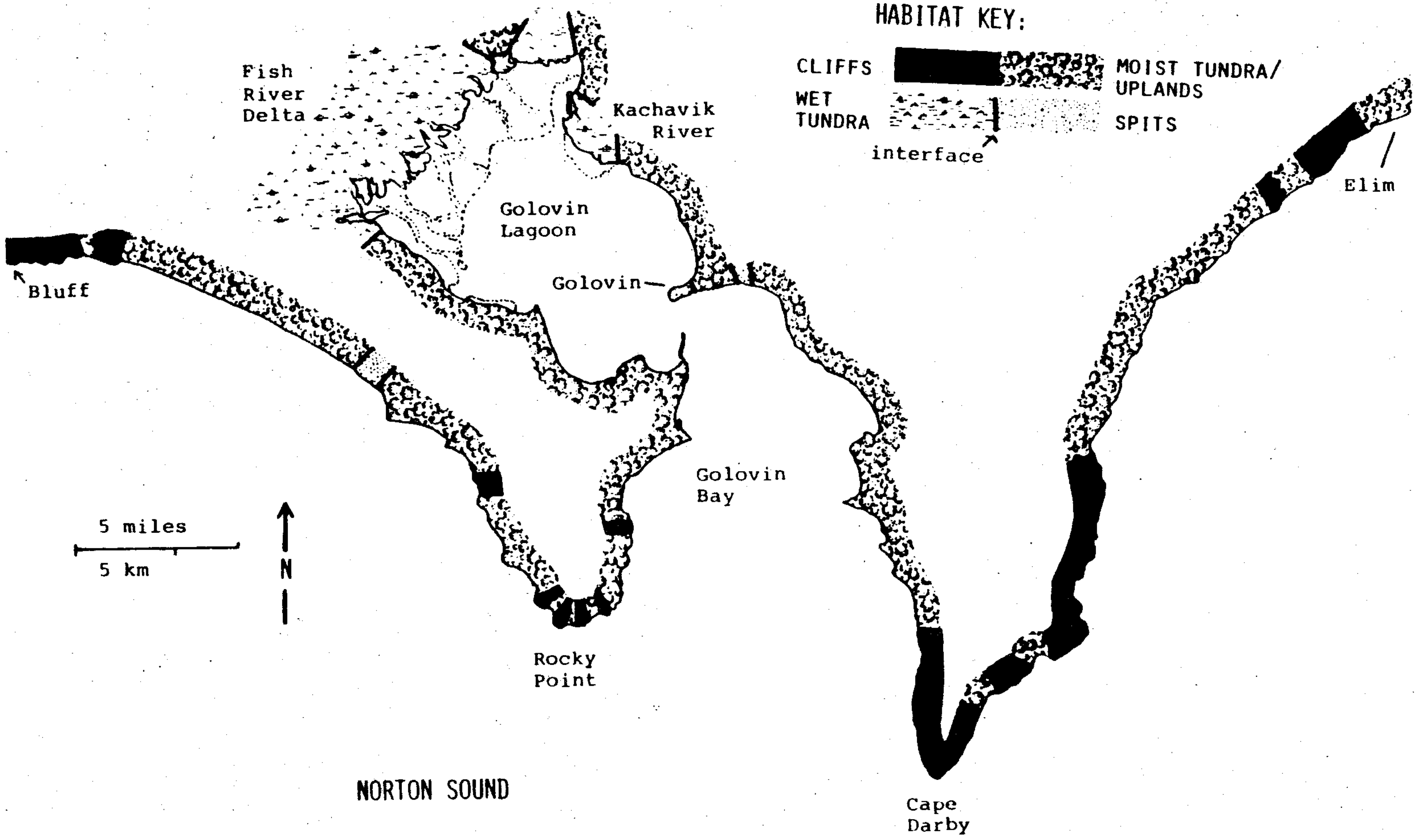
Appendix 28. Map of coastal habitats from Brevig Lagoon to Woolley Lagoon, including Port Clarence, Grantley Harbor, Tuksuk Channel, and Imuruk Basin.



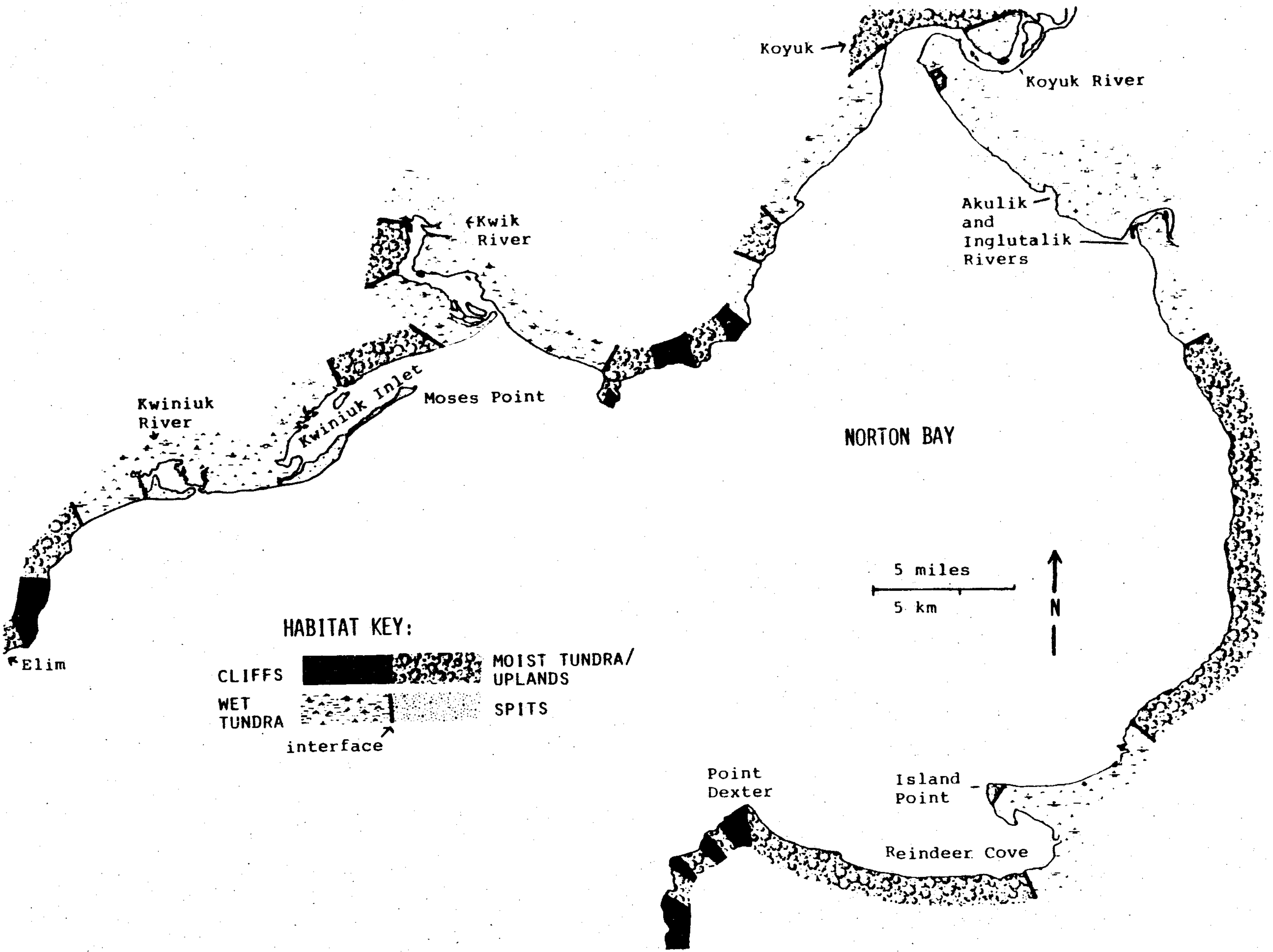
Appendix 29. Map of coastal habitats from Woolley Lagoon to Nome.



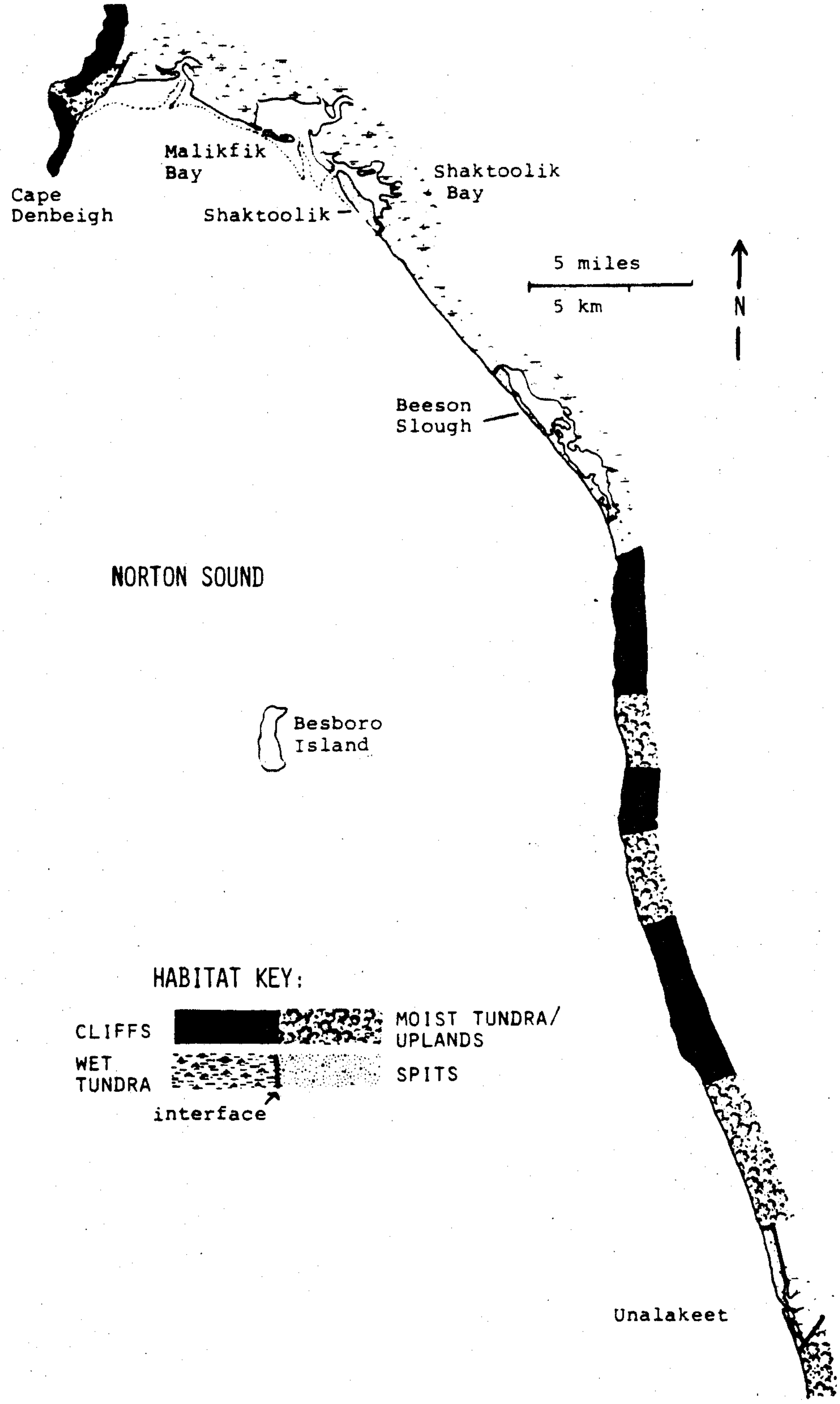
Appendix 30. Map of coastal habitats from Cape Nome to Bluff.



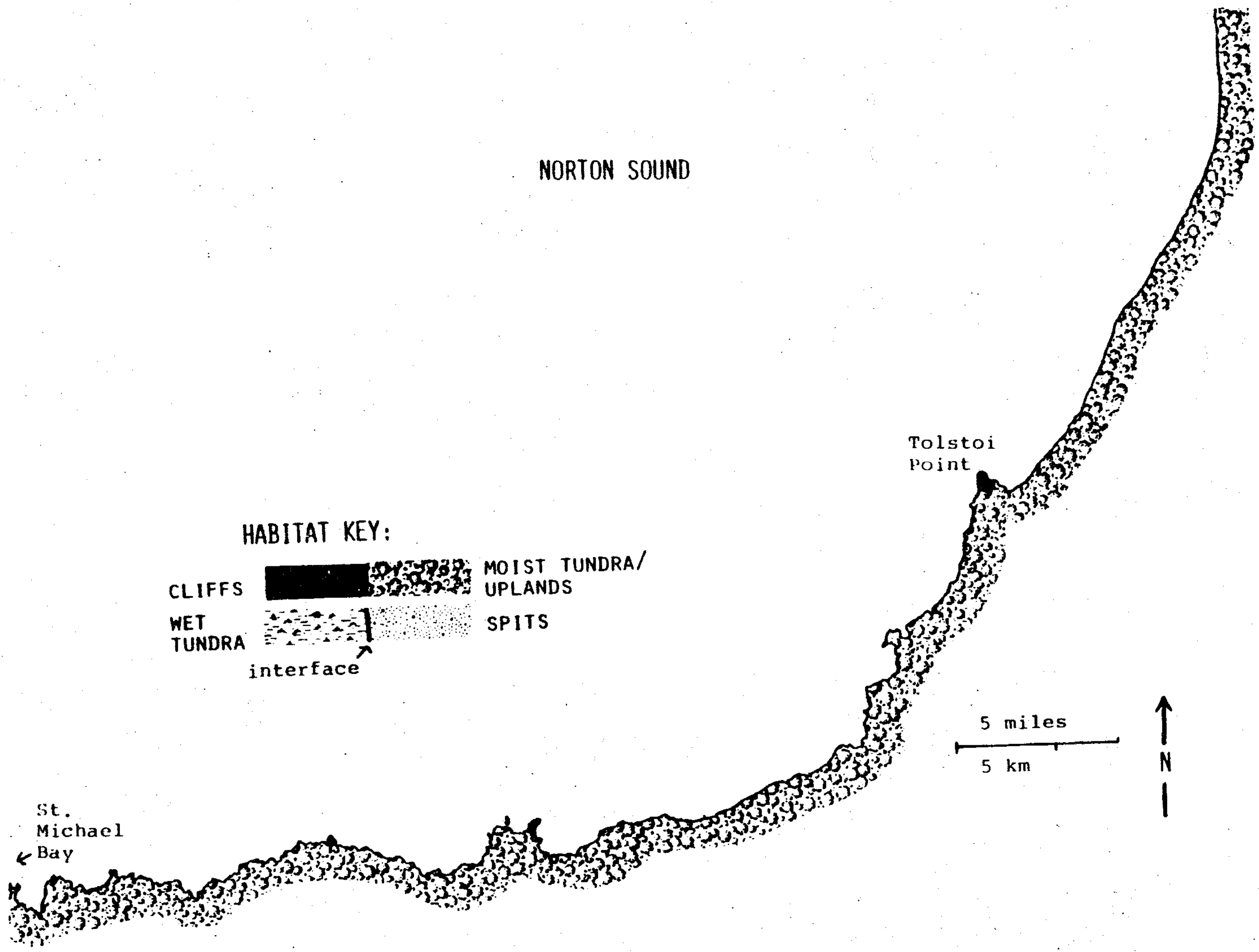
Appendix 31. Map of coastal habitats from Bluff to Elim.



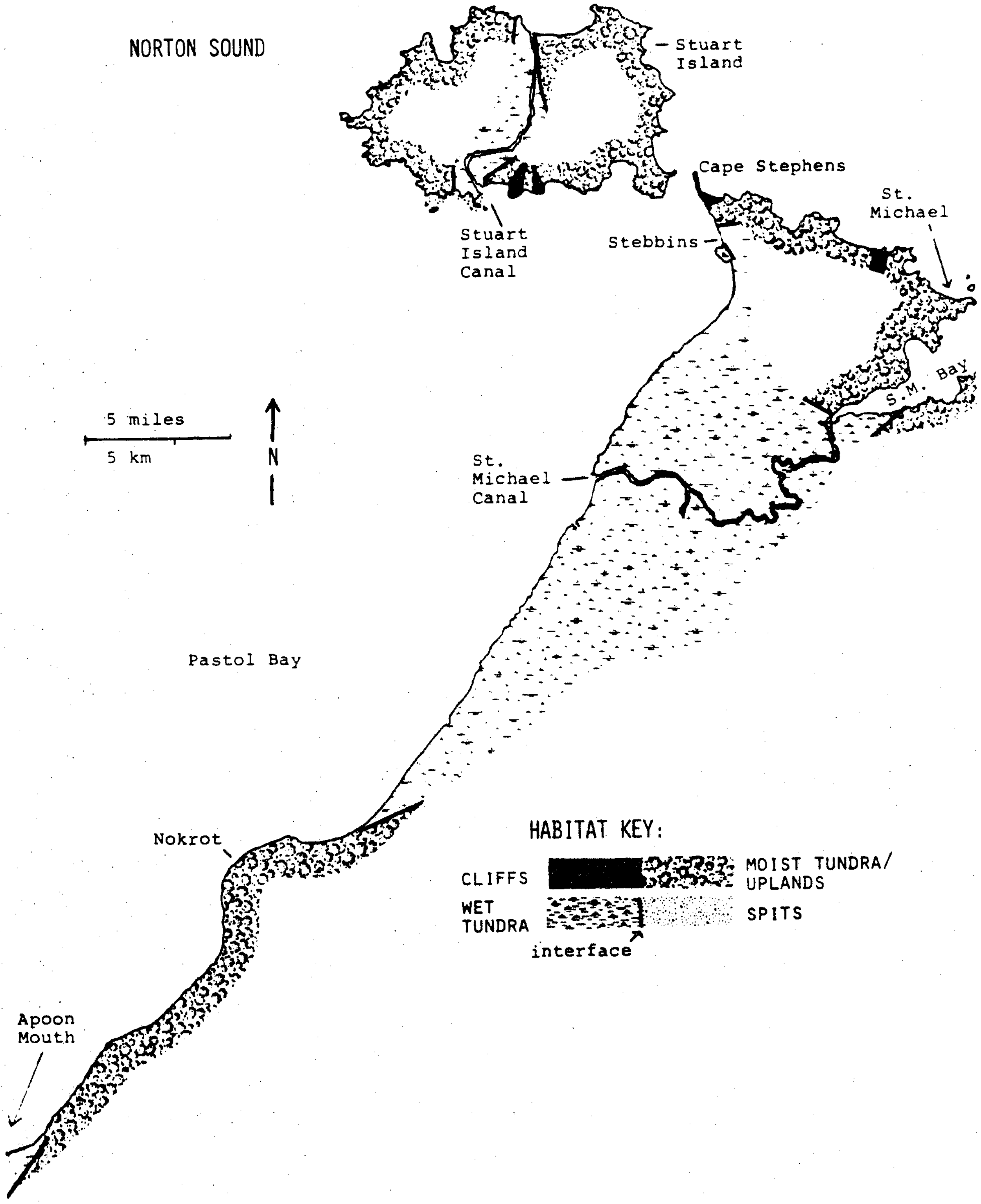
Appendix 32. Map of coastal habitats from Elim to Point Dexter, including Norton Bay.



Appendix 33. Map of coastal habitats from Cape Denbeigh to Unalakleet.



Appendix 34. Map of coastal habitats from Unalakleet to St. Michael Bay.



Appendix 35. Map of coastal habitats from St. Michael Bay to Apoon Mouth of the Yukon River, including Stuart Island.

APPENDIX 36

PELAGIC BIRD OBSERVATIONS IN NORTON SOUND AND THE ADJACENT BERING SEA, JULY 1975 AND SEPTEMBER 1976.

I. Summary of objectives and results.

Limited censusing of Norton Sound and the adjacent Bering Sea was conducted in order to determine species distribution patterns and their relation to water masses. The data are presented here because they complement the information presented on bird use of coastal habitats in Norton Sound. The low densities encountered by Drury et al. (1981) were corroborated by our transects in late July and mid September. In September the Alaskan Coastal Water of Norton Sound was found to support low densities (usually less than 2 birds per km sq.) with the piscivorous cliff nesting species that breed in the sound, Black-legged Kittiwakes (Rissa tridactyla), Glaucous Gulls (Larus hyperboreus) and murres (Uria spp.)being the most common. While one feeding flock 12 km southwest of Cape Darby was encountered in September, no east-west density gradient was present in the Alaskan Coastal Water. The number of tundra-nesting migrants crossing the Sound was found to be low when compared with adjacent areas of the Bering Sea.

The oceanic waters outside of the Sound were found to support over 35 birds per km sq., primarily shearwaters (Puffinus spp.). Auklets were absent from the Sound but regular in the Bering Sea water. These species occurred west of the 7.4°C isotherm and shearwaters were most abundant in waters less than 6.6°C.

This limited pelagic censusing complements the data presented for coastal habitats that show low numbers of birds in the littoral zone of Norton Sound. Low densities are found in both pelagic and littoral zones indicating the low productivity associated with the stratified water of the Sound. Species which occupy the littoral zone in other areas move south across the mouth during fall migration.

II. Introduction.

This report presents data gathered by R.U. 196 in the pelagic waters of Norton Sound. R.U. 196 has as its primary mission the study of birds in and next to the pack ice. Observations in Norton Sound were made from ships going from Nome to the Chukchi Sea where pack ice is present and Norton Sound observations were incidental to our primary objectives. Because Drury et al. (1981) pointed out a lack of data on seabirds in the offshore waters of the Sound and because R.U. 196 is completing a final report of coastal bird habitats in the Sound, it was decided to present this data as an appendix to that report. The data discussed is from late July, 1975 and early September, 1976. Observations made in the region of the Bering Strait adjacent to Norton Sound in May and June will be presented in a final report on seabirds and pack ice in the Bering Sea.

III. Study area.

Norton Sound is a shallow embayment of the Bering Sea with depths averaging less than 20m. The physical oceanography of the area has been studied by Muench et al. (1981). The Sound differs from the adjacent Bering Sea both in its shallow depths and by having warm,low salinity waters as a result of fresh water input from rivers, primarily the Yukon. The extreme eastern Sound (east of Cape Darby) has a weak gyre with a highly stratified two-layered system. A stronger gyre is present in the western Sound with more vertical mixing taking place. Between Norton Sound and St. Lawrence Island Bering Sea pelagic waters move north to the Bering Strait. The oceanographic boundary between Norton Sound's warm and low salinity Alaskan coastal waters and the colder and more saline oceanic waters of the Bering Sea is variable and depends on the intensity of winds and ocean currents. During our 1975 observations warm water (8°C) extended out to as far west as the east end of St. Lawrence Island.

In September 1976 a very different situation was found with cold oceanic waters being present at the mouth of the Sound (Figure 1).

The 7°C isotherm was between 167° and 168° N. Neimark (1979) found Bering Sea water further east in June and July 1977 when the 7°C surface isotherm was between 164° and 165° W and 2°C water was at the surface between 165° and 166° W. At the same time Neimark found 12° to 14°C sea surface temperatures in the eastern Sound where we encountered 8° to 10°C temperatures. The location of the transition from Norton Sound to Bering Sea water is thus extremely variable.

The biological systems associated with the two major water masses are quite different. Norton Sound receives major freshwater input from the Yukon and other rivers and the resulting marine environment is most similar to an estuary. Zooplankton species present are neritic and littoral forms. Much of Norton Sound appears to have a detritus-based system with major organic input from the Yukon and other rivers. The Bering Sea water to the west however, has a pelagic system with an oceanic fauna. Few studies have been conducted on the two ecosystems with regard to primary and secondary productivity and trophic relations, so few meaningful comparisons can be made. Motoda and Minoda (1972) studied zooplankton throughout the Bering Sea and found a gradation of copepod species across the mouth of the Sound with neritic forms in the Sound and oceanic forms over deeper water. Neimark (1979) did a study of Norton Sound zooplankton ecology and documented the neritic nature of the Sound.

IV. Methods and Sources of Data.

Observations were made from the flying bridge of vessels 15m above sea level in 15-minute observation periods (transects). All birds out to 300m of one side of the ship were counted and information gathered on activity, direction of flight, sex, age and plumage. The distance traveled for each transect was obtained and the birds per km sq. were computed for each transect for each species. Ship followers were not included in density calculations.

In 1975 sea surface temperature was taken every three hours. In 1976 sea surface temperature and depth were recorded for each transect.

Data was gathered on 30 and 31 July 1976 when 27 15-minute transects were obtained on a line running from Nome southwest to 63°50' N, 167°54' W (Figure 2). A more extensive cruise from 11 to 14 September 1976 provided 98 15-minute transects with coverage of all parts of the Sound (Figure 3). The July cruise took place at a time when most birds are still involved in breeding activities. By mid-September most species have completed their breeding activities and many have already left arctic and sub-arctic areas.

V. Results.

A. September 1976.

Our September data will be discussed first because the larger area censused in the Sound and more complete oceanographic data give a better overview of the factors affecting seabird distribution. Our observations fall into three subsets corresponding to three marine zones. These zones are based on conditions found on the cruise and their location and characteristics could be expected to be different at other times and in other years. For purposes of discussion, the zones will be called the inner Sound, outer Sound and Bering Sea. The zones are shown on Figure 3, and the characteristics of the zones are as follows (see also Table 1):

Inner Sound

The inner Sound is the shallowest portion of the Sound with depths on transects averaging 17.4m. An area south of Cape Darby has depths as great as 25m but the remainder of the inner Sound is less than 20m. The zone includes the weak gyre east of Cape Darby and the eastern part of the gyre in western Norton Sound. Sea surface temperatures recorded on transects averaged 9.2°C.

Outer Sound

The outer Sound had depths on transects averaging 20.2m and sea surface temperatures averaging 7.8°C. All sea surface temperatures greater than 8°C in this zone were encountered on the most southerly transects near the Yukon River Delta and were presumably due to river discharge.

Bering Sea

This zone contains all observations west of 166°W and the 7.4°C isotherm out to 168°30' W. It includes the eastern portion of the cold Bering Sea waters moving north to the Bering Strait. Depths average 24.2m and are as much as 39m. Sea surface temperatures on transects averaged 6.6°C and were as low as 5°C.

1. Bird densities

Densities presented in Table 1 show the inner Sound to have over 4 birds per km sq. while the outer Sound has less than 2 birds per km sq. Both of these zones have far fewer birds than the Bering Sea zone which has over 35 birds per km sq. due primarily to large flocks of shearwaters. Specific aspects of distribution will be discussed by zone.

The inner Sound was characterized by low densities for most areas with a few areas of moderate to high densities. The area east of Cape Darby had the lowest densities with 1.2 birds per km sq. (n=12) composed primarily of murres, Glaucous Gulls and Black-legged Kittiwakes. One large flock of Spectacled Eider (Somateria fischeri), 420 at 64°22' N 162°16' W had a density of 237 birds per km sq. While this sighting is of importance, it is omitted from the total density given on Table 1 and other totals since it would mask the major differences between the three zones. When this flock is included, the total average density for the inner Sound is 9.4 birds per km sq. The extreme eastern Sound (east of Cape Darby) had twelve transects with an average of 1.2 birds per km sq. and a maximum of 3 birds per km sq. The western portion of the inner Sound (west of Cape Darby and east of 165°W) had 34 transects averaging 5.4 birds per km sq. All densities over ten birds per km sq. were in an area approximately 12 km southwest of Cape Darby where four transects with a range of 17.5 to 43.2 birds per km sq. averaged 33.3 birds per km sq. The average density for the western inner Sound without these four transects is 1.7 birds per km sq. Thus, when the one area of high density is removed, the birds per km sq. is similar for the western and eastern inner Sound (1.7 vs. 1.2). It is likely that high density areas are present east of Cape Darby also, but that we failed to encounter them.

The area where the high densities were encountered south of Cape Darby is of some interest since it indicates an area where prey is apparently more abundant. On 11 and 12 September the ship encountered a diverse assemblage of birds at $64^{o}19'$ N, $163^{o}18'$ W approximately 12 km southwest of Cape Darby. The flocks were associated with the edge of the 25m trench found southwest of Cape Darby. Depth increased from 25m to 18m as recorded on the ship's fathometer. The location is also one where the gyres in the eastern and western inner Sound may come into contact and create mixing that could increase productivity. Black-legged Kittiwakes were the most common birds in the area averaging 23.5 birds per km sq. Glaucous Gulls, murres, Pelagic Cormorants (_Phalacrocorax pelagicus_) and Arctic Loons (_Gavia arctica_) were also present. No feeding observations were made and the prey concentrating the birds is not known although it was almost certainly fish.

In the middle of the inner Sound (south of 64^{o}N) bird densities were low (.7 birds per km sq., n=18) and consisted almost entirely of Glaucous Gulls and Kittiwakes.

The outer Sound had an average density for all birds that was similar to the values for the inner Sound away from the area of Cape Darby (1.6 per km sq., n=32). The zone was characterized by low densities throughout with a maximum of 7 birds per km sq. and only three densities greater than

4 birds per km sq. No feeding flocks were encountered in this zone but Drury et al. (1982) mentions an area south of Cape Nome where seabirds regularly gather and feed.

The Bering Sea adjacent to Norton Sound had a total density of over 35 birds per km sq. due mainly to the presence of shearwaters. Both Sooty (P. griseus) and Short-tailed (P. tenuirostris) Shearwaters may have been present but identification to species was not possible. The boundary between this zone and the outer Sound was crossed twice, at 63°30' N and 64°30' N, with sea surface temperatures dropping from 7.7°C to 7.2°C within 15 minutes and then decreasing rapidly to at least 5.2°C. As soon as the zone was entered shearwaters were present but they did not become abundant until sea surface temperatures dropped to 6.6°C and below. The eight transects with temperatures below 6.6°C had an average of 66 shearwaters per km sq. while the twelve with higher temperatures averaged 5 per km sq. Incidental observations in poor light made as the ship steamed west on 63°30' N showed that directly west of our furthest west transects sea surface temperature dropped from 6°C to 4°C in 15 minutes and at that point, a flock of approximately 10,000 shearwaters was encountered with an average density of 1700 per km sq.

Unidentified small alcids were common in the Bering Sea zone. They appeared at the same time as shearwaters though they were nowhere near as abundant (maximum density 23.5 birds per km sq.) nor were the highest densities associated with the coldest water. The alcids appeared to be primarily Parakeet Auklets (Cyclorrhynchus psittacula).

B. July 1975

Our July 1976 cruise was on a straight line from Nome towards St. Lawrence Island (Figure 2). Sea surface temperatures showed that the boundary between Norton Sound waters and the Bering Sea was either poorly defined or west of 168° W since sea surface temperatures during the transects were not less than 8°C. Total densities (Table 2) were rather constant with an average of 6.8 birds per km sq. and no densities over 20 birds per km sq. The last nine transects showed some of the influence of Bering Sea water although this was not reflected in sea surface temperatures. These transects averaged 9 birds per km sq. compared to 5.7 for the previous 18 transects. In addition, Northern Fulmars (*Fulmarus glacialis*) a true pelagic species, was common on the last nine transects ($\bar{x}$=1.2, percent freq.=66%). Murres and Black-legged Kittiwakes, the two most common species, both showed a slight increase in abundance and occurrence in the same area. Little can be said of this data set except that it represents data for the period prior to migration.

VI. Discussion.

A. Species distributions.

The birds encountered in September 1976 can be divided into three groups based on distributions: species relatively common in all three zones, oceanic plankton-feeding species associated with Bering Sea water at the mouth of the Sound, and tundra migrants moving south at the mouth of the Sound.

Species relatively common in all three zones included Black-legged Kittiwakes, murres and Glaucous Gulls. All three were more abundant in the inner Sound than the outer Sound because of the large feeding flock southwest of Cape Darby. When this flock is not included in the inner Sound data their average densities are similar in the two parts of the Sound. Overall, Glaucous Gulls and Black-legged Kittiwakes were most numerous in the inner Sound while murres were most abundant in the adjacent Bering Sea.

Oceanic species common near the mouth of the Sound but essentially absent from the Sound itself included the Northern Fulmar, shearwaters and small alcids. The alcids are probably primarily Parakeet Auklets but Least (*Aethia pusilla*) and Crested Auklets (*A. cristatella*) may have also been present.

All species associated with the Bering Sea water are primarily plankton feeders and their absence from the Sound is indicative of low zooplankton densities.

A number of tundra nesting species were more common in the outer Sound and Bering Sea than in the inner Sound. These included loons, eider (Somateria spp.), phalaropes (Phalaropus spp.) and jaegers (Stercorarius spp.). This is apparently due to birds moving down from the Arctic and heading south across the mouth of the Sound rather than following the coast into the Sound. In addition to being a shorter route, productivity of the Bering Sea water would provide more prey for individuals feeding in migration. Other species that follow this route earlier in the southward migration could be expected to include Arctic Terns (Sterna paradisaea) and Sabine's Gulls (Xema sabini).

B. General comments.

While the sample size is small and our observations were gathered on a total of five days, some generalities about seabird distribution in and adjacent to Norton Sound can be made. While we censused in a range of sea surface temperatures in the Sound of 7.2°C to 9.0°C and a range of depth of 14m to 30m no east-west gradient in densities was found nor a change in species composition. The offshore waters of the Sound had, with the exception of one area, uniformly low densities of primarily fish eating species that breed in the Sound and small numbers of tundra migrants. This is essentially what Drury et al. (1981) found in their offshore transects of the Sound. Neimark (1979) found that the extreme eastern Sound (approximately east of a line from Cape Darby to Stuart Island) differed from the rest of the Sound in having the copepod (Arcartia clausi) be the dominant zooplankton species while Pseudocalanus spp. was dominant to the west. Our limited sampling in the easternmost Sound showed that bird species and densities in that area are similar to the rest of the Sound. The Bering Sea waters immediately outside the Sound are an area of high productivity as evidenced by the numbers of shearwaters encountered there and the association of auklets with this water mass. Red Phalaropes, which feed in both pelagic and littoral waters in the first part of their southward migration, feed in the littoral zone at Wales on the Bering Strait (Connors 1978) but south of that point move offshore, apparently due to the higher zooplankton densities present in the Bering Sea. This may also, however, be an indication of the low productivity of the littoral zone in Norton Sound. A number of arctic species occupy the littoral zone in their southward migration until they reach the Bering Strait and they then move offshore to pelagic habitats. The main report on coastal habitats documents the paucity of migrants in the littoral zone in Norton Sound.

C. Future Studies.

More thorough studies of offshore seabird distribution in Norton Sound would allow delineation of areas of concentration for seabirds but the number of seabirds in the Sound is so small that it is unlikely that any given area would support a numerically important concentration of birds. The 90 thousand seabirds that nest in Norton Sound colonies can be expected to be associated with those colonies and adjacent waters while involved in breeding activities. It is unlikely that future pelagic studies in the Sound would produce data that would influence decisions on offshore leasing.

The Bering Sea water that flows north past the Sound does warrant further study however, especially since Neimark (1979) found it much closer to the Sound (further east) than we did. The numbers and kinds of seabirds associated with the Bering Sea water when it is east of 166° W are not known. A series of transects crossing the convergence between Norton Sound and Bering Sea water when Bering Sea water is closer to the Sound would provide such data. The pelagic waters of the northern Bering Sea have received little pelagic censusing when compared to other Alaskan waters and, hopefully, initiatives to fill this data gap will be undertaken since the pelagic waters north of St. Lawrence Island and south of Kotzebue Sound are known to support high densities of seabirds.

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	INNER SOUND		OUTER SOUND		BERING SEA	
No. of 15-minute observation periods	n=46		n=32		n=20	
Sea surface temp. (0^{o}C)	$\bar{x}$=9.2 range=8.4-10		$\bar{x}$=7.8 range=7.2-8.5		$\bar{x}$=6.6 range=5.2-7.4	
Bottom depth (m)	$\bar{x}$=17.4 range=14-25		$\bar{x}$=24.5 range=20-30		$\bar{x}$=30.2 range=26-39	
Bird densities (birds/km sq.)	$\bar{x}$	%freq.	$\bar{x}$	%freq.	$\bar{x}$	%freq.
TOTAL (all birds)	4.3	76	1.6*	81	35.8	100
Loons	.1	07	.1	19	.4	40
Northern Fulmar	.0	--	.0	--	<.1	05
Shearwaters	.0	--	.1	03	29.4	100
Cormorants	.1	15	<.1	03	.0	--
Eider*	.1	06	.2	15	.6	10
Sandpipers	.1	02	.3	06	.0	--
Phalaropes	<.1	02	.3	06	.5	05
Jaegers	<.1	02	<.1	03	.1	20
Glaucous Gulls	.5	22	.1	16	.1	10
Glaucous-winged Gulls	<.1	04	.0	--	.0	--
Larus sp.	.1	15	.4	16	<.1	05
Black-legged Kittiwake	2.6	43	.1	16	.4	40
Murres	.4	17	<.1	03	.6	60
Unid. Auklet	<.1	02	<.1	03	3.0	75
Parakeet Auklet	.0	--	.0	--	.2	10
Horned Puffin	<.1	04	.0	--	.0	--
Tufted Puffin	<.1	02	.0	--	.2	10

* Does not include flock of 420 Spectacled Eider equaling 237 birds per km sq.

Table 1. Densities and frequency of occurence of birds in three zones of Norton Sound, 11-14 September 1976. See Figure 3 for location of zones and transects.

Number of 15-minute observation periods		27
Sea surface temperature (0°C)	range=	9.8 - 12
Bottom depth (m)	range=	23 - 35
Bird densities (birds/km^2)	$\bar{x}$	%freq.
TOTAL	6.8	100
Northern Fulmar	.4	22
Jaegers	.5	07
Glaucous Gull	<.1	04
<u>Larus</u> sp.	<.1	04
Black-legged Kittiwakes	1.6	63
Murres	4.0	96
Unidentified Auklets	.2	15

Table 2. Densities and frequency of occurence of birds southwest of Nome in Norton Sound, 30 and 31 July 1975. See Figure 2 for location of transects.

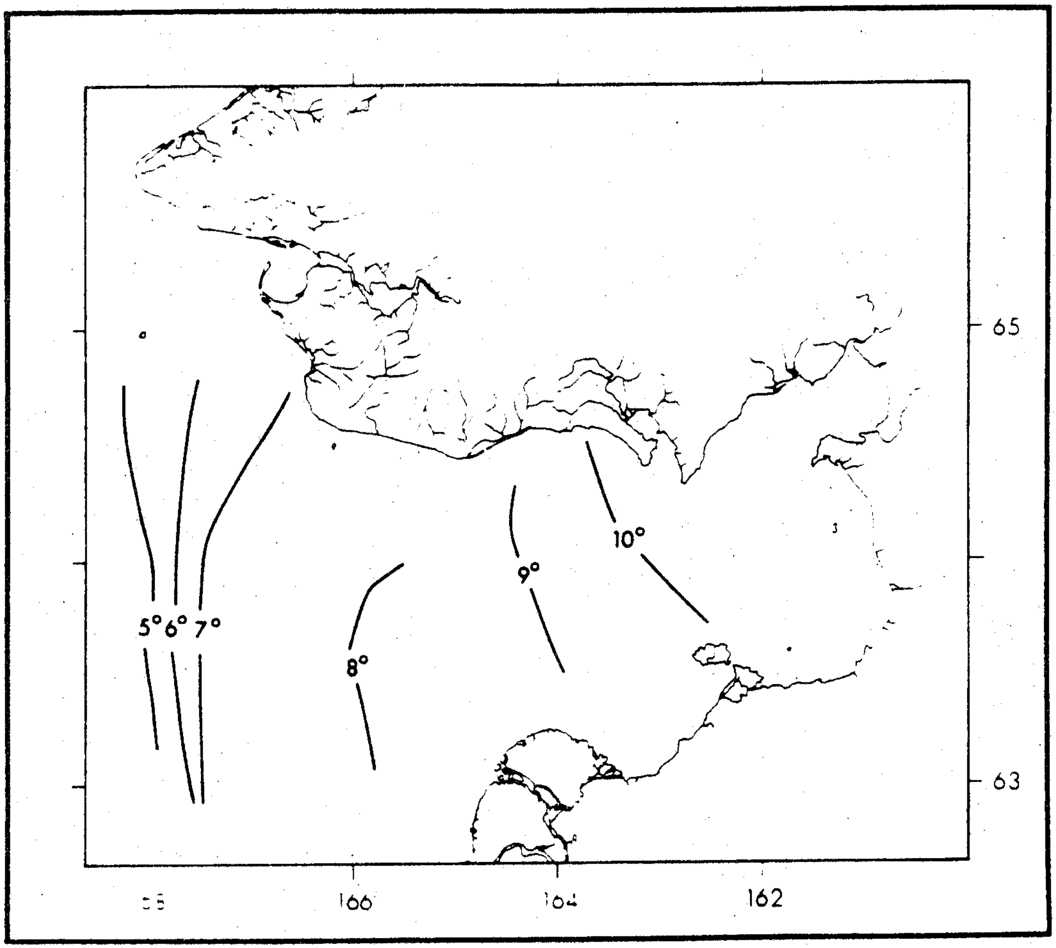

Figure 1. Sea surface temperatures (°C) encountered in Norton Sound and adjacent Bering Sea on 11 - 14 September 1976.

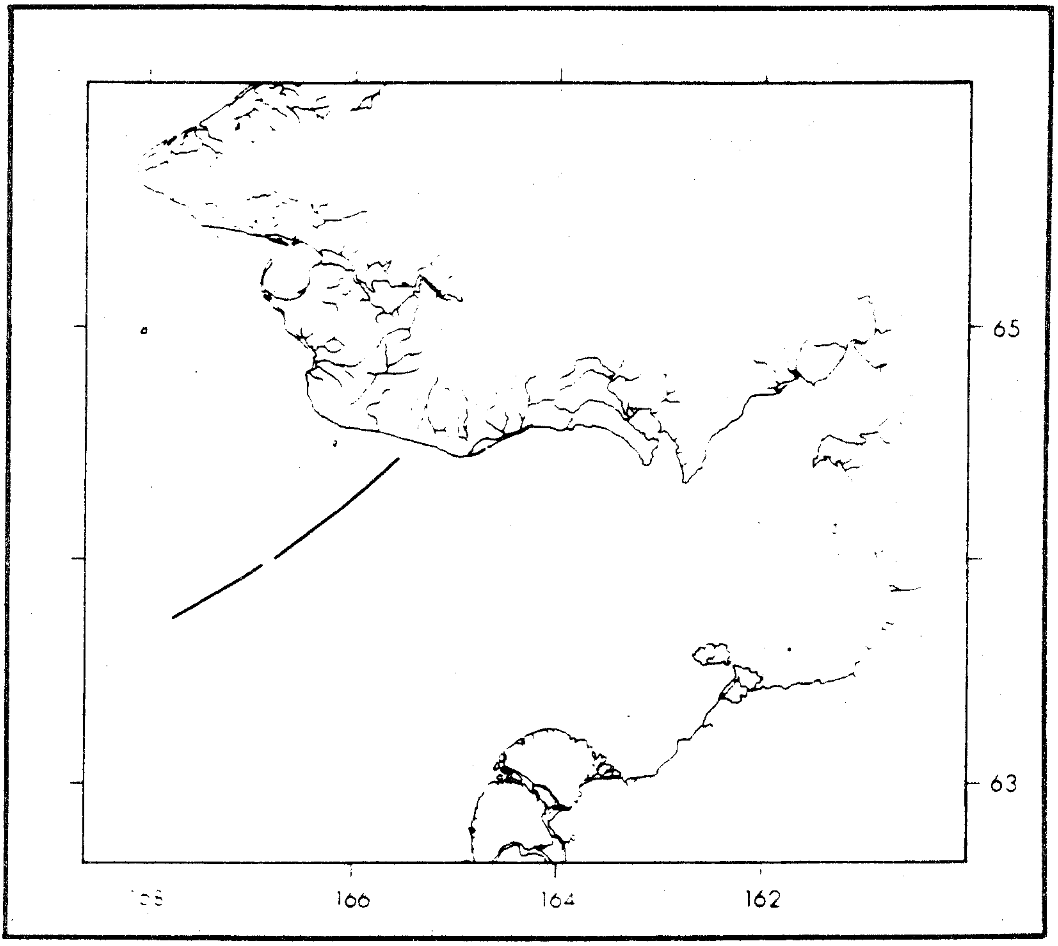

Figure 2. Cruise track where 27 15-minute pelagic bird observation periods were conducted on 30 and 31 July 1975.

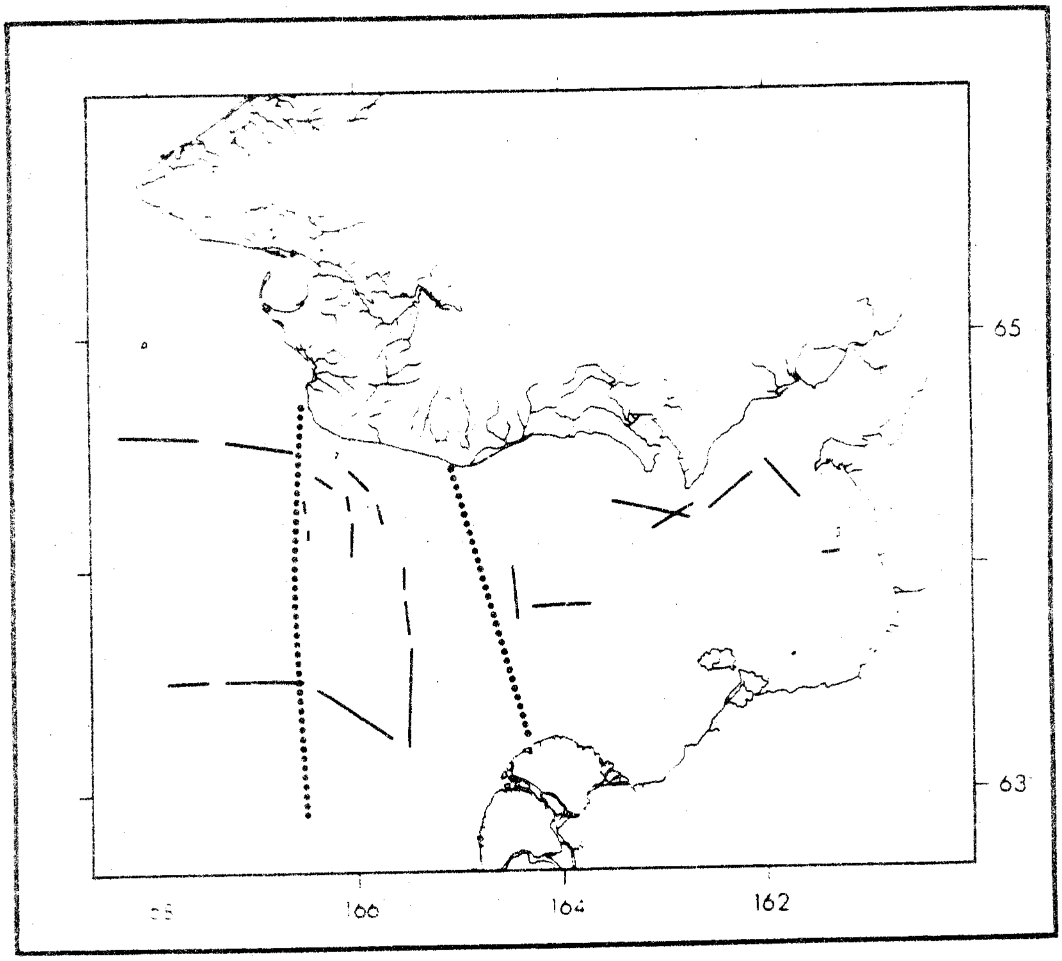

Figure 3. Cruise track (solid lines) where 98 15-minute pelagic bird observation periods were conducted on 11 - 14 September 1976. Dotted lines indicate boundaries between inner Sound, outer Sound and Bering Sea. See text and Table 1 for characteristics of each zone.

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