Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

Volume 45 July 1986

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Oceanography and Marine Assessment
Ocean Assessments Division
Alaska Office

U.S. DEPARTMENT OF THE INTERIOR
Minerals Management Service
OCS Study, MMS 86-0062

"Outer Continental Shelf Environmental Assessment Program Final Reports of Principal Investigators" ("OCSEAP Final Reports") continues the series entitled "Environmental Assessment of the Alaskan Continental Shelf Final Reports of Principal Investigators."

It is suggested that sections of this publication be cited as follows:

Eppley, Z. A., G. L. Hunt, Jr., and N. Butowski. 1982. Pelagic distribution of marine birds of the north Aleutian shelf and analysis of encounter probability. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 45(1986):1-120

Baird, P. A. and P. J. Gould (eds.). 1983. The breeding biology and feeding ecology of marine birds in the Gulf of Alaska. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 45(1986):121-504

Individual sections of the above report may be cited using the following format:

Hatch, S. A. 1983. Northern Fulmar (_Fulmaris glacialis_). _In_: Baird, P. A. and P. J. Gould (eds.). 1983. The breeding biology and feeding ecology of marine birds in the Gulf of Alaska. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 45 (1986):143-170

Krawsnow, L. D. and G. A. Sanger. 1982. Feeding ecology of marine birds in the nearshore waters of Kodiak Island. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 45(1986):505-630

Sanger, G. A. 1983. Diets and food web relationships of seabirds in the Gulf of Alaska and adjacent marine regions. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 45(1986):631-771

OCSEAP Final Reports are published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Oceanography and Marine Assessment, Ocean Assessments Division, Alaska Office, Anchorage, and primarily funded by the Minerals Management Service, U.S. Department of the Interior, through interagency agreement.

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OUTER CONTINENTAL SHELF

ENVIRONMENTAL ASSESSMENT PROGRAM

FINAL REPORTS OF PRINCIPAL INVESTIGATORS

Volume 45

July 1986

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Oceanography and Marine Assessment
Alaska Office

U.S. DEPARTMENT OF THE INTERIOR
Minerals Management Service
Alaska OCS Region
OCS Study, MMS 86-0062

Anchorage, Alaska

The facts, conclusions, and issues appearing in these reports are based on research results of the Outer Continental Shelf Environmental Assessment Program (OCSEAP), which is managed by the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, and funded (wholly or in part) by the Minerals Management Service, U.S. Department of the Interior, through an Interagency Agreement.

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Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

VOLUME 45 JULY 1986

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PELAGIC DISTRIBUTION OF MARINE BIRDS
OF THE NORTH ALEUTIAN SHELF
AND ANALYSIS OF ENCOUNTER PROBABILITY

by

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Nancy Butowski

Department of Ecology and Evolutionary Biology
University of California, Irvine

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 83

1982

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ACKNOWLEDGEMENTS

We thank the people of the Office of Marine Pollution Assessment and other NOAA personnel for their assistence. Dr. H. Curl, Dr. J. Cline and Dr. J. D. Schumacher from the Pacific Marine Environmental Lab, Seattle, Washington gave us valuable discussions. Dr. H. Peterson and the Data Projects Group at the University of Rhode Island provided the computer graphics. Within our own group, Dr. R. G. Ford provided computer programs for analyzing seabird distribution by zones and Dr. J. Kaiwi provided error calculations. B. Braun, N. Harrison and Dr. D. Schneider provided assistence throughout the project. Data collection was supported by NOAA (OCSEAP) contract No. 03-5-002-72 to George Hunt and by NSF grants DPP-79103186 to George Hunt and DP76-23340 to PROBES.

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

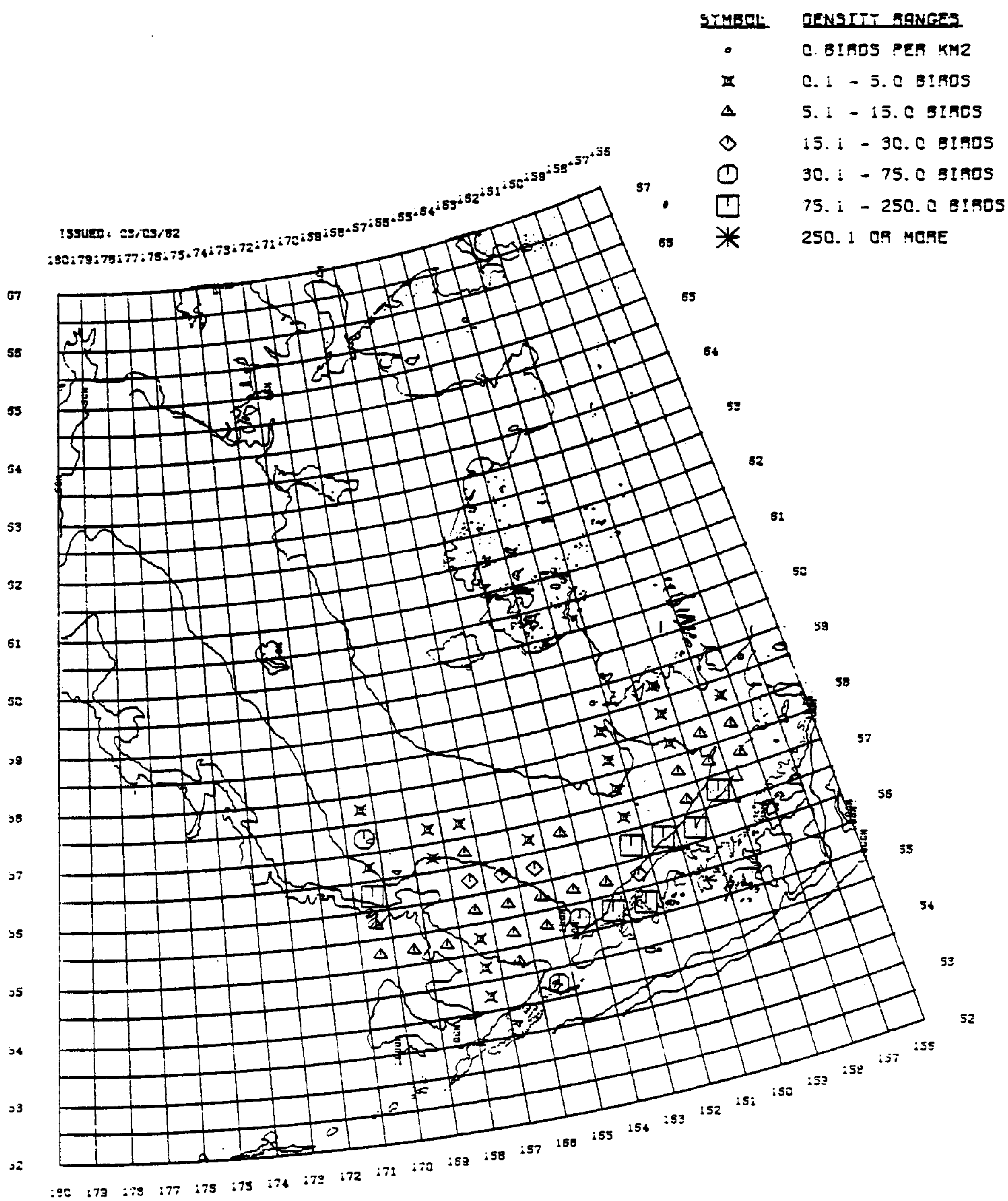
The purpose of this study was to summarize information on avian use of the North Aleutian Shelf (NAS), and to evaluate the relative vulnerability of birds to oil spills in different portions of this region. We participated in three OMPA sponsored cruises over the North Aleutian Shelf in 1980 and 1981 and additionally have drawn upon data of previous OCSEAP and PROBES investigations. By doing so, we cover nearly all regions of Bristol Bay.

Mean bird densities for all species are presented by season in Figures 1-4. From these figures it is clear that the NAS supports high densities of birds in virtually all seasons, but summer densities are highest of all. Resident breeding birds are significant, but extremely high numbers of non-breeding birds are also present. Thus, in contrast to bird concentrations in the St. George Basin (Hunt et al. 1981a), over 90% of the birds in the NAS are migratory species which do not breed in the area. While the colonies at Cape Newenham and Cape Peirce support over 1.85 million birds (Sowls et al. 1978), approximately 9 to 20 million shearwaters occupy the eastern Bering Sea (Hunt et al. 1981b) between spring and autumn and 11.5 million waterfowl pass through the NAS during their migrations in spring and autumn (King and Dau 1981). As a result, any major impact of OCS development on marine birds will not only affect the Bristol Bay ecosystem; it will also affect ecosystems far removed from Bristol Bay.

It is important to have a measure of the frequency that high bird densities are likely to be encountered. We estimate the probability of encountering particular densities of birds using the proportion of transects in an area in which a given mean density was equalled or exceeded (Figures 5-8). The distribution of transects with 100 or more birds/km^2 (Figure 6) is particularly instructive.

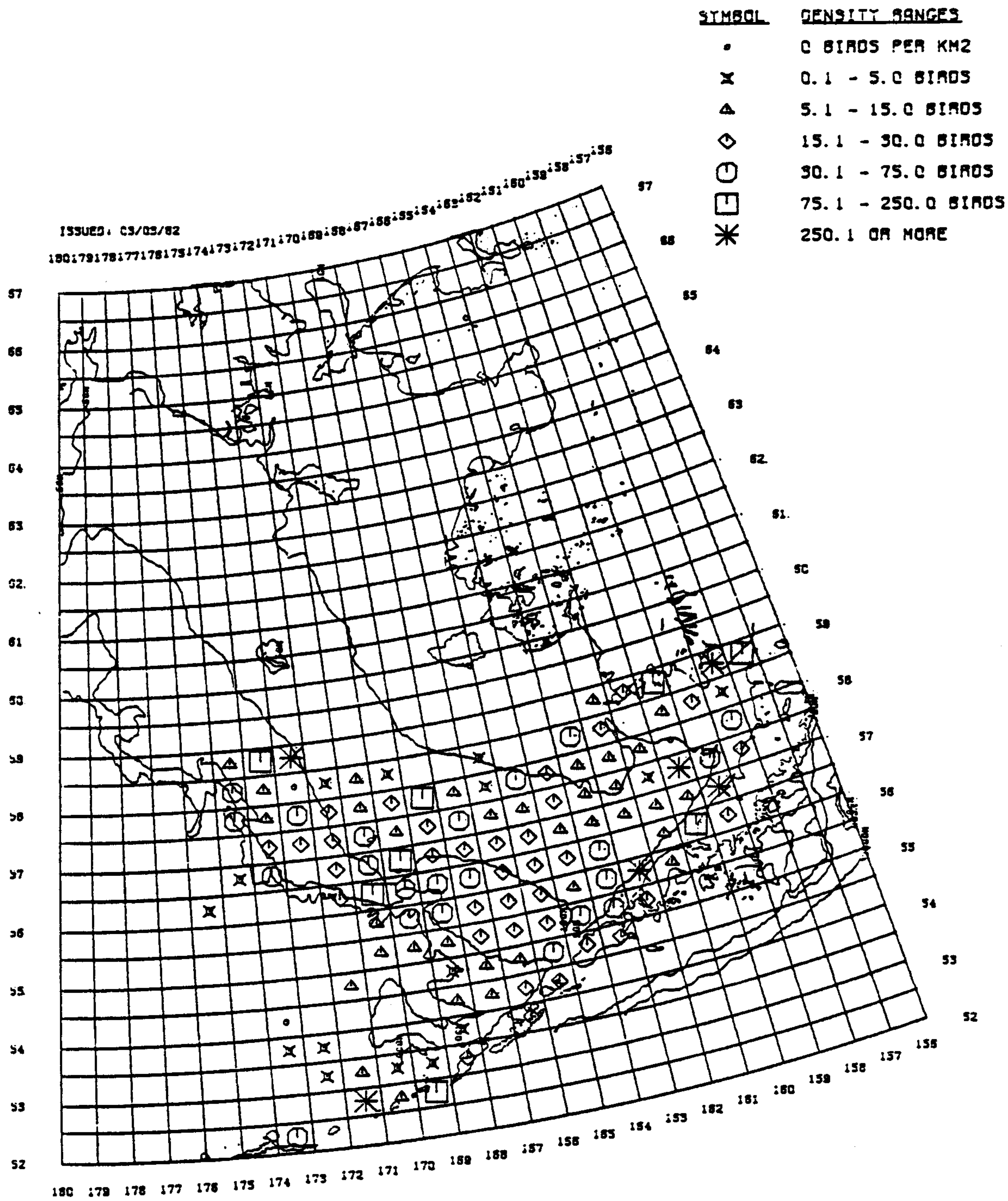
Over all seasons and using all data available, the coastal waters along the Alaska Penninsula and Bristol Bay have bird densities of 100 birds/km^2 in more than 10% of the transects. A large oil spill in these areas would have a high probability of affecting large numbers of birds.

There is need for additional surveys of the coastal regions of Bristol Bay and Unimak Pass. The last six to seven years of pelagic work in the southeastern Bering Sea have tremendously increased our knowledge of avian use of Bristol Bay. However, our conclusions for much of the important coastal waters and Unimak Pass are based on a relatively small number of transects, particularly in winter, spring and autumn (Appendix 1). Therefore, we recommend that additional surveys be conducted in important areas prior to the decision about OCS development in Bristol Bay to fully assess the avian use of important habitats. Until additional work is done, we must assume from our results that the coastal waters of Bristol Bay are critical habitat for extremely large numbers of marine birds.



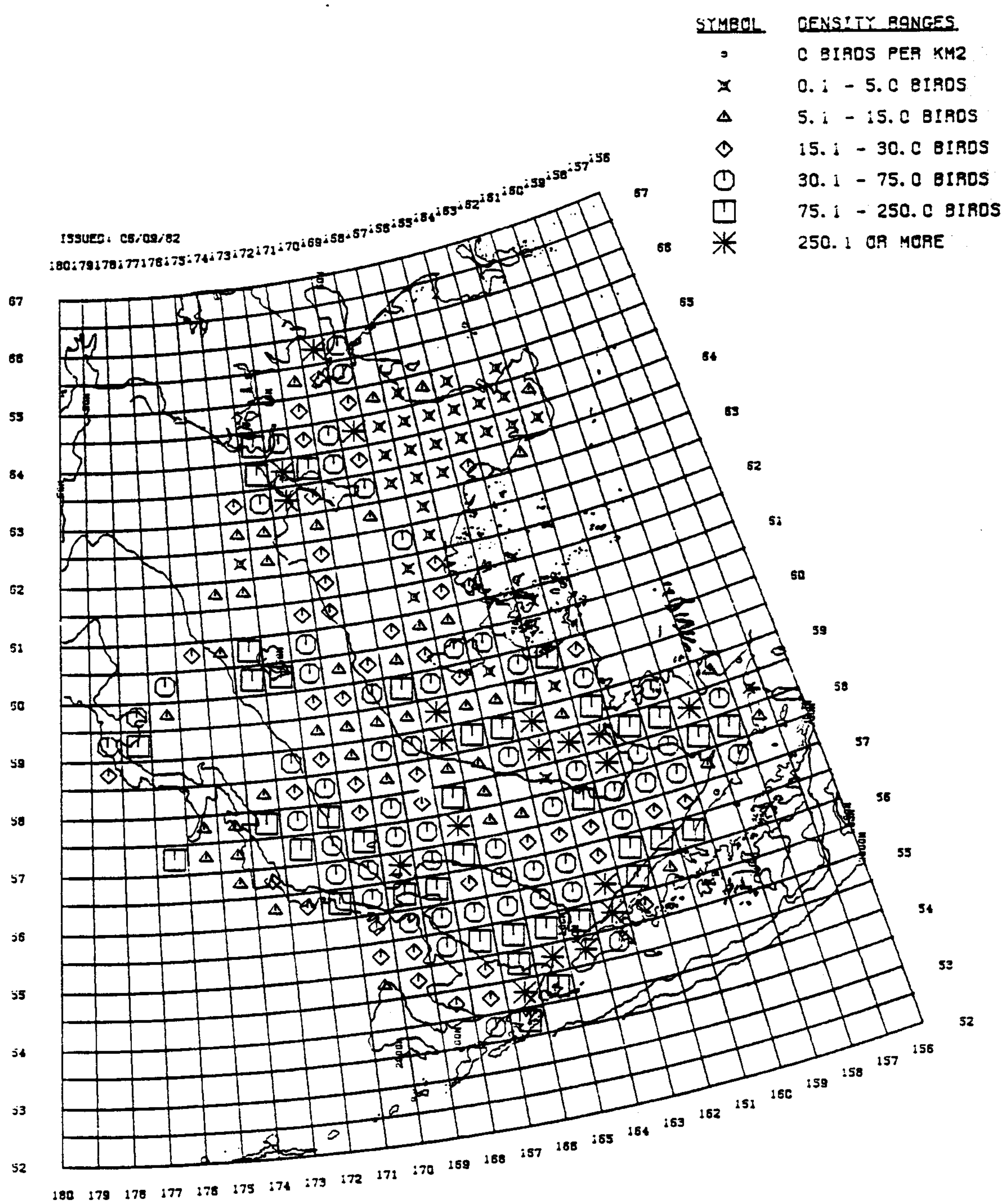
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
ALL BIRDS - WINTER

Figure 1



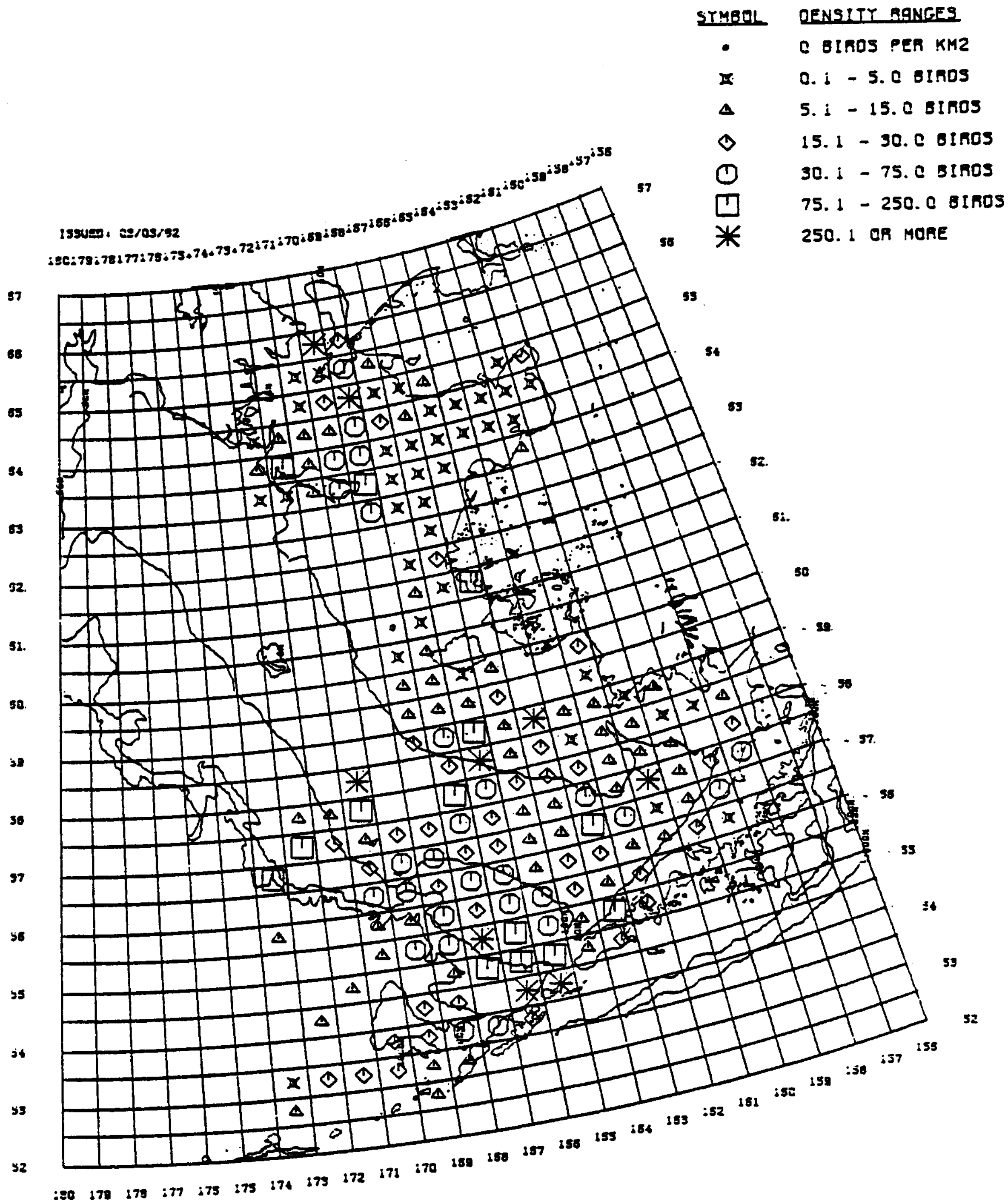
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
ALL BIRDS - SPRING

Figure 2



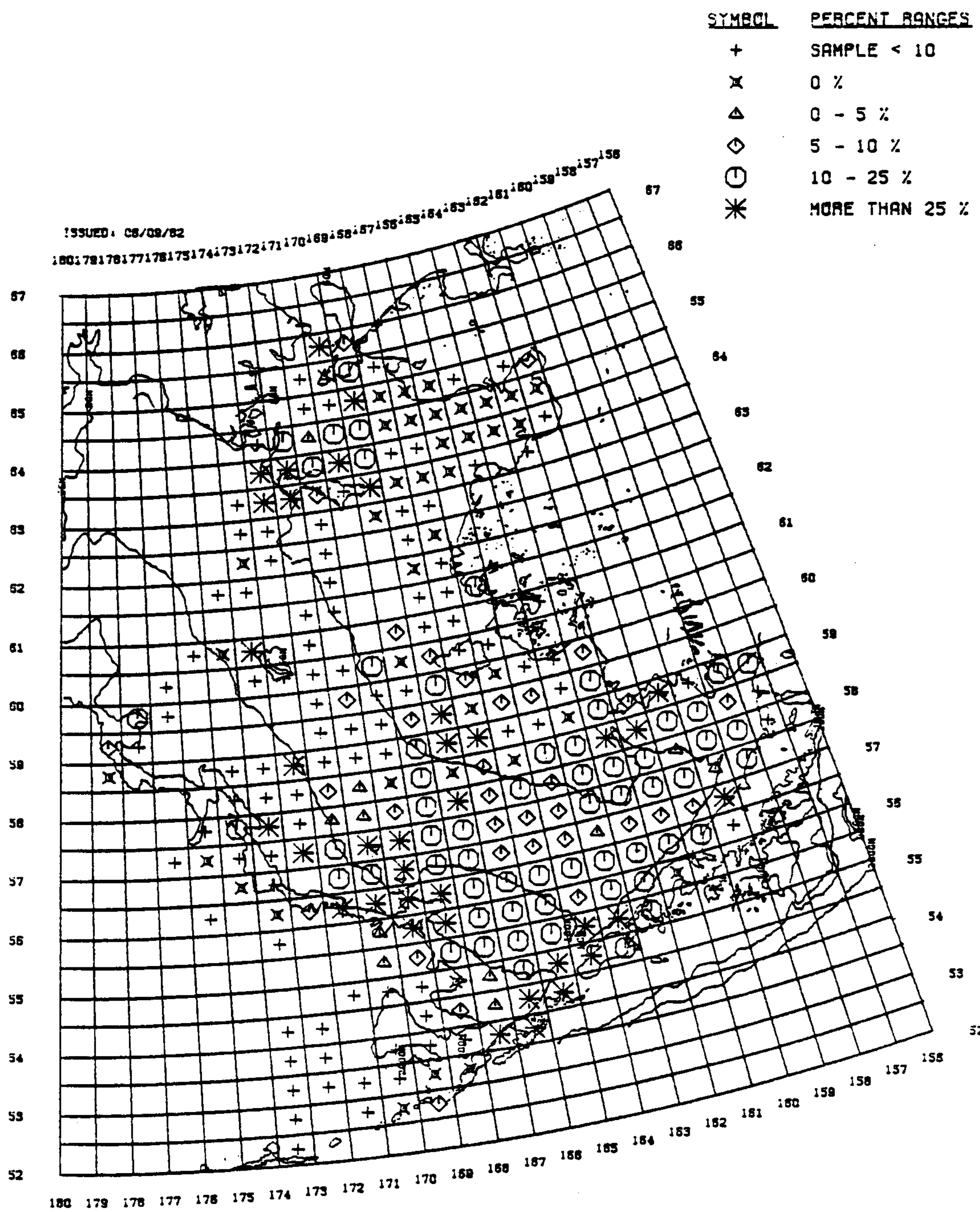
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
ALL BIRDS - SUMMER

Figure 3



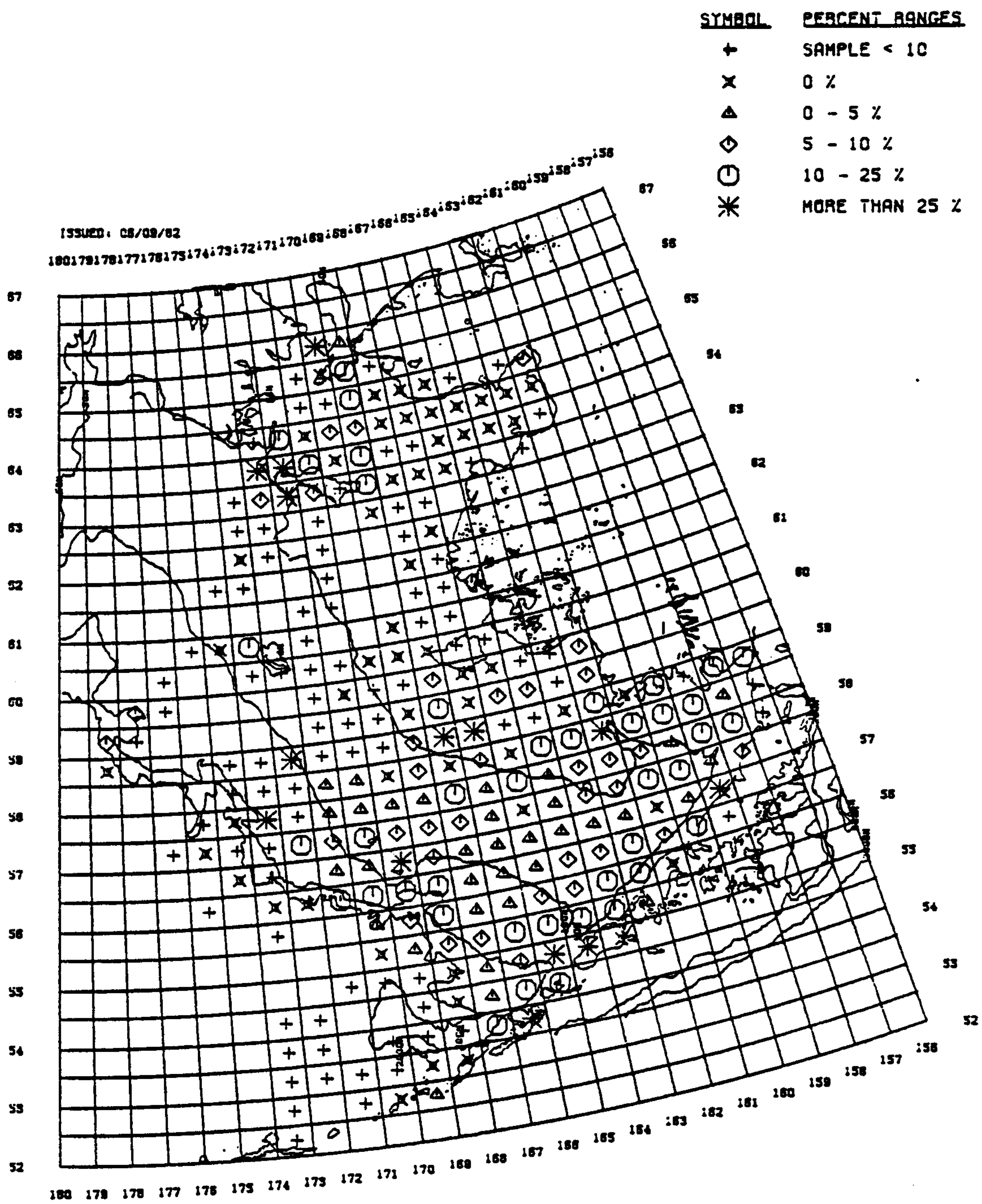
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
ALL BIRDS - AUTUMN

Figure 4



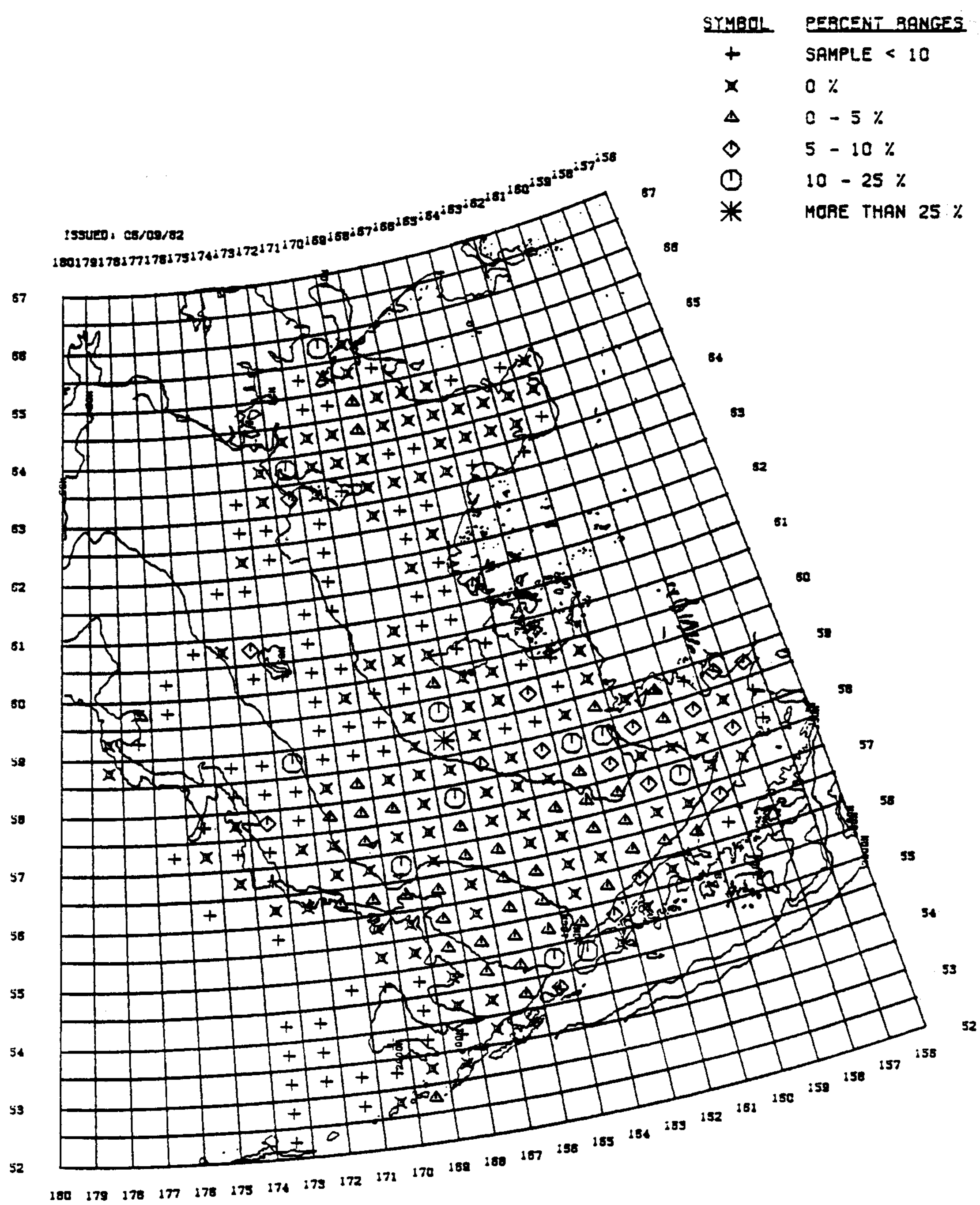
BERING SEA RELATIVE DENSITY PLOT
ALL BIRDS, ALL FIELD OPS, ALL SEASONS
BASE LEVEL: 50 BIRDS PER KM**2

Figure 5



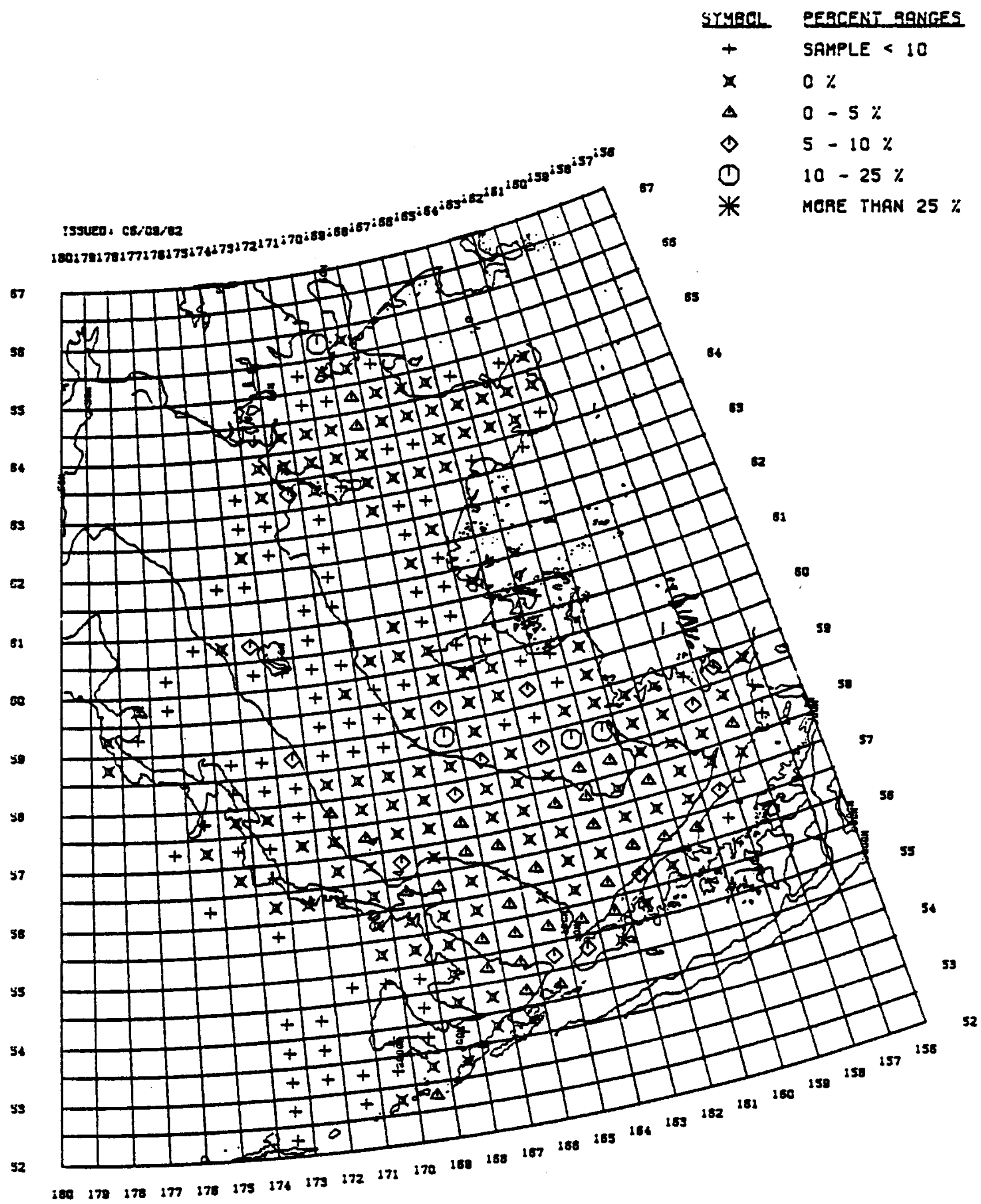
BERING SEA RELATIVE DENSITY PLOT
ALL BIRDS, ALL FIELD OPS, ALL SEASONS
BASE LEVEL: 100 BIRDS PER KM**2

Figure 6



BERING SEA RELATIVE DENSITY PLOT
ALL BIRDS, ALL FIELD OPS, ALL SEASONS
BASE LEVEL: 500 BIRDS PER KM**2

Figure 7



BERING SEA RELATIVE DENSITY PLOT
ALL BIRDS, ALL FIELD OPS, ALL SEASONS
BASE LEVEL: 1000 BIRDS PER KM**2

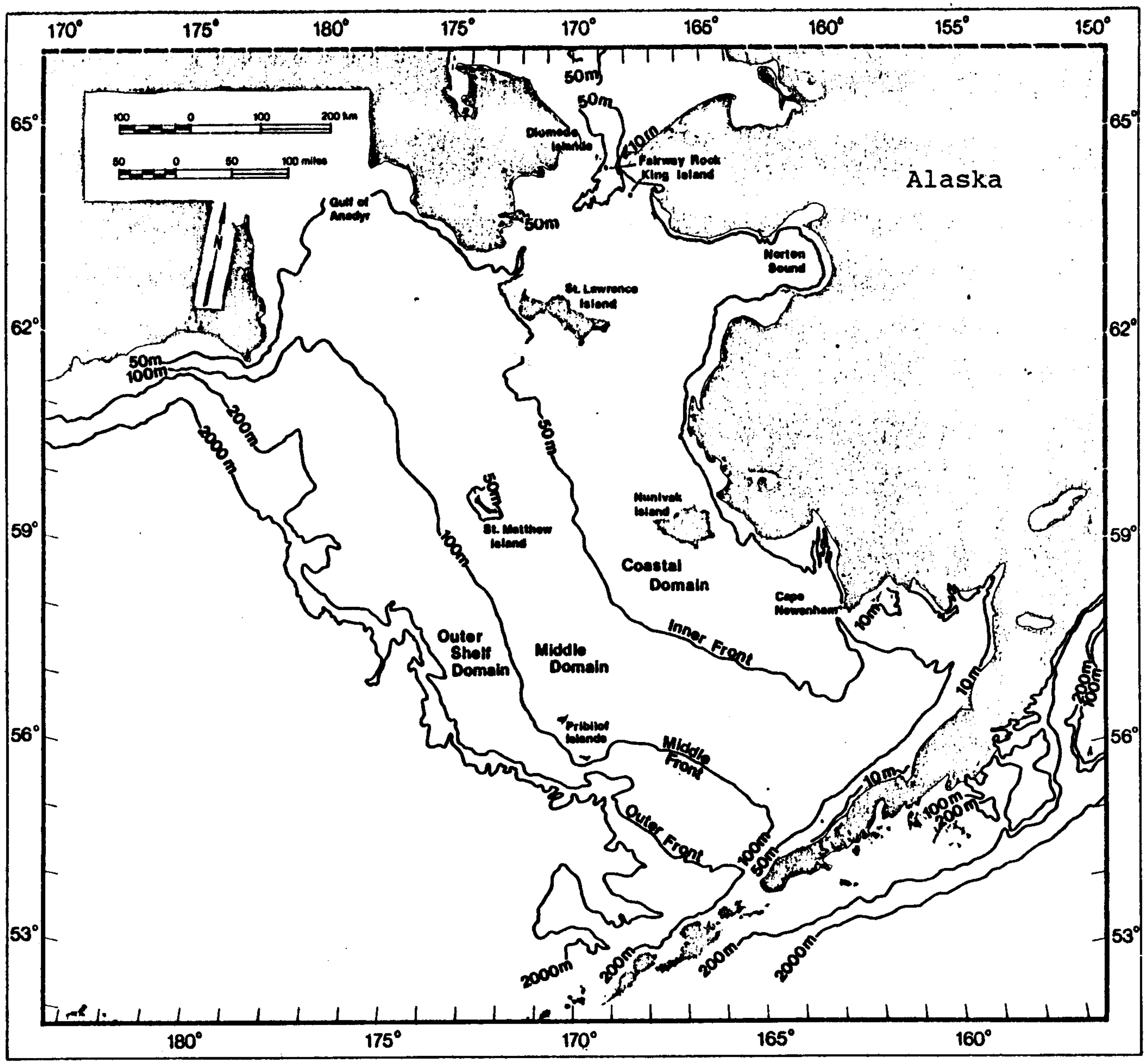
Figure 8

INTRODUCTION

This study examines avian use of the North Aleutian Shelf and Bristol Bay regions, and concentrates on marine-oriented birds. We classify areas within the NAS based on the probability of encountering large concentrations of birds, and specify areas and seasons when bird densities, and therefore risk, are greatest. We discuss the importance of the NAS avifauna within the broader context of the Bering Sea. Within the NAS, we examine the importance to birds of different marine habitats. We identify areas within the NAS which lack adequate censusing and make recommendations for future studies.

Hunt et al. (1981c) analyzed the risk to seabirds in the southeastern Bering Sea, based largely on work around the Pribilof Islands and along the PROBES line (Figure 9). This report updates that report and includes new information from 1981 PROBES cruises in Bristol Bay and the three NAS cruises. These cruises covered previously uncensused areas in the coastal areas of Bristol Bay and the NAS.

Our knowledge of bird densities in the coastal areas of the NAS are based on a relatively small number of transects, compared to the data base available for the St. George Basin. However, even this minimal coverage is sufficient to show the importance of the NAS and Bristol Basin for marine birds. Prior to oil and gas extraction from this region, additional work will be needed to define the most sensitive areas and the seasons of greatest vulnerability.



Hydrographic domains on the southern Bering Sea shelf

Figure 9

CURRENT STATE OF KNOWLEDGE

Study Area

In this study, we examine bird distributions in the North Aleutian Shelf (NAS) and the waters overlying the Bering Sea shelf from the Aleutian Islands north to 59°N latitude, and from Unimak Pass eastward to Kvichak Bay (157°W longitude, see Figure 9). Much of the NAS consists of shallow coastal waters less than 50 m deep which are influenced by tidal mixing and freshwater input. Generally, coastal waters are highly productive due to the abundance of nutrients and light penetration throughout the water column. Shallow water habitat is extensive in northern Bristol Bay, extending 40 km or more from the shore. This region, along with inner Bristol Bay, receives considerable freshwater input from the Kvichak, Nushagak and other rivers. In southern Bristol Bay, shallow water habitat is confined to within about 5 km of the shore. This region is less influenced by freshwater; instead, it is dominated by large lagoon and estuarine systems.

Oceanographic Summary

The three hydrographic domains defined by the PROBES program occur in the NAS region. Figure 9 shows the approximate location of these domains and their frontal boundaries (Iverson et al. 1979). In the Bering Sea, little work has been done on the Coastal domain, the most extensive domain in the NAS. More is known about the food webs of the Middle and Outer domains. In the Middle domain, primary production outstrips consumption, leading to an accumulation of phytoplankton biomass. This settles out to support a vigorous benthic community. Only a small portion of the Outer domain occurs on the NAS. This domain has a complex water column consisting of interleaving layers of shelf and oceanic water (Coachman and Charnell 1979). The Outer Shelf domain has a vigorous pelagic food web in which consumption keeps pace with primary production. In the southwest corner of the NAS, the hydrography becomes complex. Water depth changes rapidly, and the presence of islands and Unimak Pass increases the complexity.

The domains and interdomain fronts partition the NAS region into distinct habitats, and increase its physical diversity. The hydrographic complexity is heightened by weather-induced variation. Ice-cover damps out difference between the Middle and Coastal domains, but the duration and extent of ice-cover is highly variable. In some years, ice may extend to the Alaska Peninsula, while in other years it may barely extend into Bristol Bay. Storms in the NAS may obliterate the inner front or shift it seaward many kilometers. Strong tides or wind patterns may also shift the inner front, occasionally driving it within meters of shore. The impact of this variability of the Coastal and Middle domains on their populations and food webs is unknown.

Biological Summary

Several factors serve to enrich the biological diversity of the North Aleutian Shelf and Bristol Bay areas. The region is heterogeneous both in its topography and oceanography and there is considerable area of productive habitat (estuaries, lagoons and the Coastal domain). To a large degree the biological resources of the North Aleutian Shelf are described in the Draft Environmental Impact Statement for the St. George Basin (BLM 1981). The region has commercial populations of several benthic invertebrates and fishes, including salmon, herring, cod and pollock.

Avian use of the NAS varies seasonally. In spring and fall, the region is dominated by migrating shorebirds and waterfowl (Arneson 1981, Gill et al. 1977, 1978). In the summer, the region is dominated by shearwaters which "winter" in the NAS. Shearwaters are the most numerous bird in the Bering Sea in the summer, and an estimated 9-20 million occur on the Bering Sea shelf (Hunt et al. 1981b). Seabird colonies consisting mainly of Black-legged Kittiwakes, Common Murres and cormorants are located in northern Bristol Bay at Cape Peirce, Cape Newenham and on the Walrus Islands. These colonies support 1.85 million colonial seabirds (Sowls et al. 1978). The NAS region as a whole, has a censused population of 1.89 million colonial seabirds (Sowls et al. 1978). In winter, much of the Bering Sea is ice-covered except portions of the NAS and oceanic regions southwest of the Pribilof Islands. Although quantitative data are few, Shuntov (1972) has suggested that the NAS may be an important wintering area for Bering Sea bird populations.

Previous studies of the pelagic distribution of seabirds in the southeastern Bering Sea have shown large concentrations of birds in the Coastal domain of the NAS, particularly near Cape Peirce (Hunt et al. 1981c). Shearwaters have been associated with the Coastal domain (Schneider and Hunt 1982, Hunt et al. 1981b) and aggregations of murres have been associated with a front between well-mixed coastal waters and the Middle domain near the Pribilof Islands (Kinder et al. MS) and near the Alaska Peninsula (Hunt et al. 1981c). Densities of surface-feeding seabirds are high in the Outer domain while densities of sub-surface foragers are higher in the Middle domain (Schneider and Hunt 1982). Northern Fulmars, Black-legged Kittiwakes, Storm Petrels, Sooty Shearwaters, Red-legged Kittiwakes and Thick-billed Murres have been associated with the Outer domain (Schneider and Hunt 1982), at least near the large Pribilof Islands' colonies. The distribution of seabirds in relation to the Coastal domain has not been investigated. Schneider (1982) and Schneider et al. (MS) have found seabirds concentrated at the interdomain fronts, but only sporadically.

The coastal regions along the north shore of the Alaska Penninsula, particularly the lagoon systems at Port Moller, Port Heiden and Izembek Lagoon, are important areas for waterfowl (Arneson 1981) and shorebirds (Gill et al. 1977, 1978). These lagoons are used as staging, stopover or wintering areas for large proportions of the Pacific Flyway populations of Black Brant (100%), Lesser Canada Goose (60-75%) and Black Scoter (60-80%) and for North American populations of Steller's Eider (100%), King Eider (75%) and Emperor Goose (BLM 1981). The prey populations in these lagoons are extremely important to migrating birds which depend on them to replenish their reserves before molting, breeding, or resuming their migrations.

The NAS supports numerous marine mammals; common cetaceans are the Beluga, Killer, Minke and Gray Whales and Harbor Porpoise, while common pinnipeds are the Steller's Sea lion, Sea Otter, Walrus, and Harbor Seal (AEDIC 1974). Two ice-associated seals are relatively common in the region, the Ribbon Seal and the Spotted Seal. The coastal regions of Bristol Bay are used as a migration route by Gray Whales (BLM 1981). Fur Seals make extensive use of the Outer Shelf portion of the NAS both as a foraging area and as a migration corridor (BLM 1981). Sea Otters are present along much of the northern coast of the Alaska Peninsula and are abundant near Izembek Lagoon (BLM 1981). The lagoons of the Alaska Peninsula are heavily used by Harbor Seals as haulout areas.

METHODS

Data Collection

The data presented in this report were obtained on three cruises we made in the NAS during 1981, and on other cruises in the area made my ourselves (including PROBES cruises) and other OCSEAP investigators. We used U. S. Fish and Wildlife Service data, along with data from John Wiens' group and from

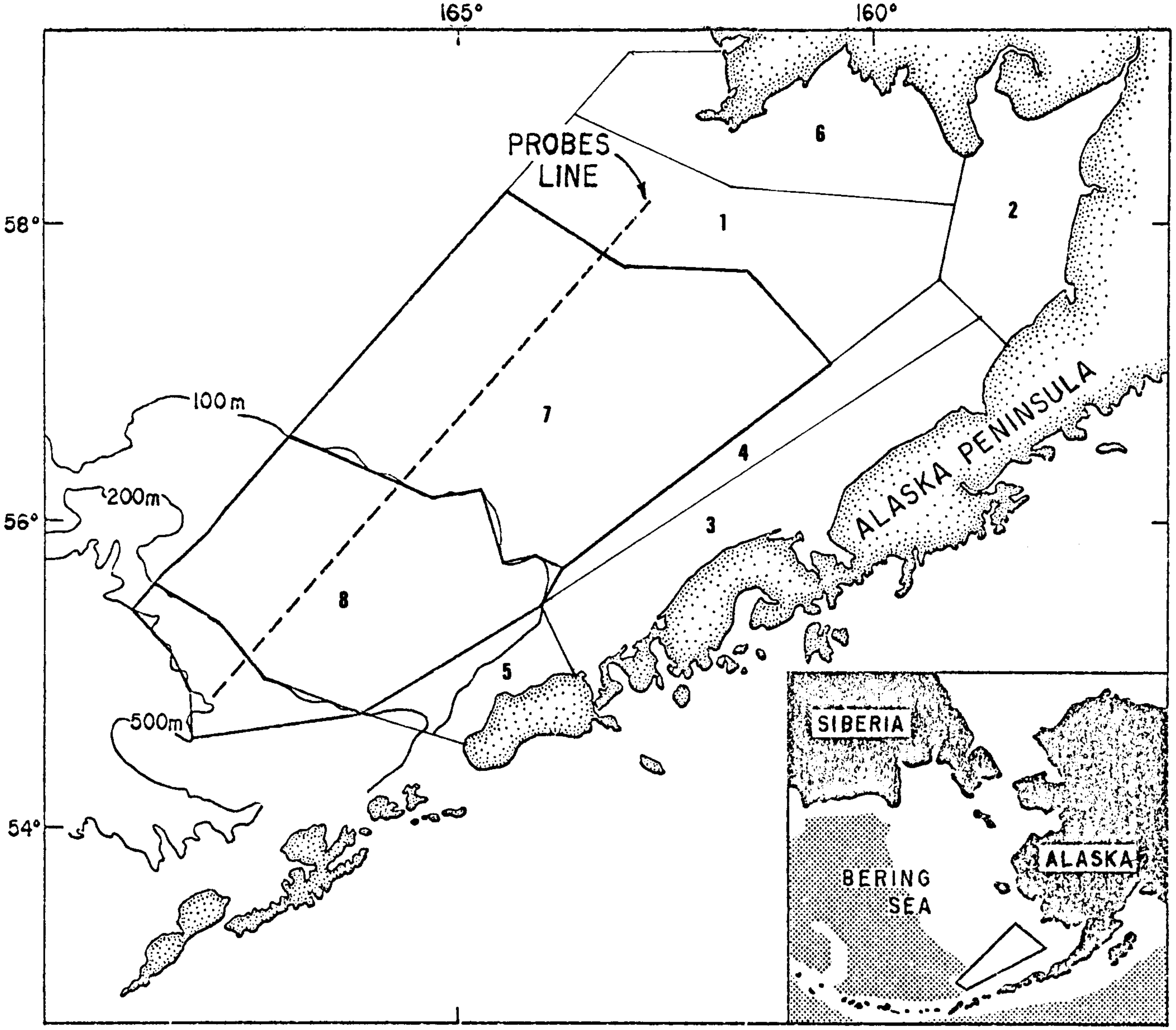
Juan Guzman. Bird densities were estimated using a line transect method and modified for use at sea (Hunt et al. 1981c). Counts were made from ships, using a 90° sector extending 300 m abeam and forward. Counts were made while the ship was underway at speeds ranging from 10 to 20 km/hr. Ship following birds were noted and were thereafter excluded from counts. Ship's position to the nearest tenth of a minute was recorded at the start and end of each 10 minute count. Identifications were made to the lowest possible taxonomic level. Bird densities were computed for each 10 minute transect, based on the area scanned (calculated by multiplying distance traveled by the transect width). Three of our surveys and several of the Fish and Wildlife surveys were made from helicopters or fixed-wing aircraft. Bird densities were computed in a similair fashion as for the ship transects and both types of transects were included in the data base. The number of transects within each 30' latitude by 60' longitude block by season are given in Appendix 1.

Analysis

An analysis of the environmental risk associated with oil spills and the potential for bird losses due such an event must be based on judgements of the population densities of birds. A preliminary identification of high risk areas was made by computing the densities of birds encountered over the NAS and Bristol Bay regions, using 30' latitude by 60' longitude blocks. Average densities were computed in each of the four seasons for ALL BIRDS, BIRDS ON WATER, and for abundant species. Mean densities, without an indication of their variability, can be misleading. Therefore, we present companion maps for ALL BIRDS and BIRDS ON WATER showing the frequency with which high densities were encountered.

We have also analyzed the environmental risk to birds in different marine habitats. We constructed zones encompassing different marine habitats in the NAS, corresponding to the hydrographic domains of the region, foraging areas near large colonies and adjacent areas presumably too distant to be used by breeding birds (Figure 10). To avoid the problems involved with applying parametric techniques to this density data, we modeled the frequency distributions of density categories using discrete probability fuctions as described in Hunt et al. (1981c). This method greatly reduces the number of assumptions required for estimating the probability of encountering large numbers of birds. For each sampling area, mean density estimates for several species were placed in the following mutually exclusive categories: 1) 0 birds/km^2; 2) 0.1-5; 3) 5.1-15; 4) 15.1-30; 5) 30.1-75; 6) 75.1-250; 7) over 250. Confidence limits for the proportions observed in each category were computed (Appendix 2; Hunt et al. 1981c). The zonal analysis used only RU83 shipboard cruises.

We attempted to correlate bird densities with particular features of the environment during each of the three NAS cruises. We were particularly interested in the association of birds with fronts. However, because our work was done on a not-to-interfere basis and because of weather problems, we were not able to investigate the association of birds with the inner front as planned.



Zones in the NAS area

Figure 10

RESULTS

The NAS and Bristol Bay stand out among the other regions of the Bering Sea as areas with high average bird densities. The densities seen here are as high as those recorded anywhere else in the Bering Sea. Additionally, these high densities are found over a large area and for a greater portion of the year than other regions of the Bering Sea for which we have comparative data (Figures 1-4). Thus, the NAS and Bristol Bay regions are of major importance to marine birds.

The coastal regions of Bristol Bay receive the heaviest avian use, and have bird densities greater than 30 birds/km^2. Within this region there are areas with particularly high densities. The Alaska Penninsula coastal zone (zone 3) and the Unimak zone (zone 5) (Table 1) support the greatest number of birds through all seasons. Other areas receiving high seasonal use are the coastal regions of northern Bristol Bay (zones 1 and 6).

Despite the similarity of bird densities in portions of the NAS and other heavily used areas of the southeastern Bering Sea, the patterns of use and the species involved differ. The high densities of birds recorded in the St. George Basin are primarily due to birds associated with the large colonies on the Pribilof Islands. In the NAS, the pattern is of seasonal use by non-resident and generally, non-breeding birds. Resident seabirds contribute relatively little to bird densities in the NAS, even though 1.85 million birds use the colonies at Cape Newenham, Cape Peirce and Walrus Island (Sowls et al. 1978).

The composition of the NAS avifauna changes radically among seasons. In the winter, waterfowl are the numerically dominant group in the NAS, while shearwaters dominate in spring, summer and autumn. Waterfowl overwinter in the NAS in large numbers. They also use the NAS in spring and fall to recover from their migrations and to prepare for breeding, though mostly they breed to

Table 1. Mean densities of all birds in the NAS by Zone [x ± s (n)].

Zone	WINTER	SPRING	SUMMER	AUTUMN
1	(0)	12 ± 35 (77)	368 ± 1025 (112)	5 ± 5 (25)
2	4 ± 2 (13)	(0)	8 ± 10 (20)	(0)
3	116 ± 388 (96)	236 ± 1492 (120)	87 ± 312 (127)	9 ± 11 (39)
4	5 ± 4 (26)	16 ± 38 (89)	63 ± 175 (138)	7 ± 7 (26)
5	3 ± 4 (2)	52 ± 167 (43)	164 ± 677 (81)	186 ± 244 (10)
6	(0)	28 ± 55 (8)	514 ± 827 (23)	(0)
7	6 ± 5 (13)	11 ± 21 (617)	46 ± 213 (598)	35 ± 160 (127)
8	9 ± 12 (91)	19 ± 77 (687)	56 ± 194 (700)	48 ± 76 (74)

Zones: 1) Coastal domain zone, 2) Inner Bristol Bay zone, 3) Alaska Peninsula coastal zone, 4) Alaska Peninsula offshore zone, 5) Unimak zone, 6) Cape Newenham coastal zone, 7) Middle domain zone, 8) Outer domain zone (see Figure 10, p. 19).

the north in the Yukon and Kuskokwim River Deltas (Arneson 1981). In contrast, shearwaters (Table 2) arrive in the NAS in late spring and spend the summer feeding, primarily over the shallow waters of the NAS and Bristol Bay, before migrating south in the autumn to breed. We found shearwater densities as high as 498 birds/km^2 in portions of Bristol Bay in summer. Arneson (1981) found shearwater densities of over 1000 birds/km^2 in a smaller set of samples elsewhere in Bristol Bay in summer.

Among seasons, the importance of habitats as well as the avifaunal composition of the NAS changes. In winter, the NAS is used as a refuging area for Bering Sea bird populations. The ice-free waters along the north shore of the Alaska Peninsula and its lagoons support wintering populations of waterfowl and shorebirds (Gill and Handel 1981). Our surveys of the coastal waters of the Alaska Peninsula (zone 3) showed high bird densities (116 birds/km^2, 80% waterfowl). This area also had the highest spring bird densities in the NAS (235 birds/km^2, 91% shearwaters). In the summer, the highest bird densities were found near Cape Newenham (514 birds/km^2, 97% shearwaters). In the autumn, the Unimak zone (zone 5) supported the greatest densities of birds (186 birds/km^2, 55% shearwaters).

In the NAS, we have found associations of species with particular habitats. Northern Fulmar (Figures 29-32 in Appendix 3) and Storm Petrel (Figures 36-39 in Appendix 3) densities were highest in the Outer Shelf domain in all seasons. Shearwaters were associated with the Coastal domain except during their autumn migration when they were concentrated near Unimak Pass (Figures 33-35 in Appendix 3). Murres were concentrated close to their colonies at Cape Newenham, Cape Peirce and Amak Island. Black-legged Kittiwakes were associated with the Coastal domain and ranged farther from the large colonies at Cape Newenham than the murres. The seasonal distribution of other species are given in Appendix 3.

Table 2. Mean densities of Shearwaters in the NAS by Zone [x ± s (n)].

Zone	WINTER	SPRING	SUMMER	AUTUMN
1	(0)	1 ± 5 (77)	361 ± 1025 (112)	0 ± 0 (25)
2	0 ± 0 (13)	(0)	0.1 ± 0.3 (20)	(0)
3	0 ± 0 (96)	215 ± 1490 (120)	72 ± 313 (127)	3 ± 9 (39)
4	0 ± 0 (26)	11 ± 37 (89)	54 ± 175 (138)	3 ± 7 (26)
5	0 ± 0 (2)	40 ± 165 (43)	137 ± 667 (81)	102 ± 158 (10)
6	(0)	0 ± 0 (8)	498 ± 821 (23)	(0)
7	0 ± 0 (13)	5 ± 20 (617)	32 ± 213 (598)	25 ± 160 (127)
8	0 ± 0 (91)	8 ± 76 (687)	9 ± 45 (700)	17 ± 53 (74)

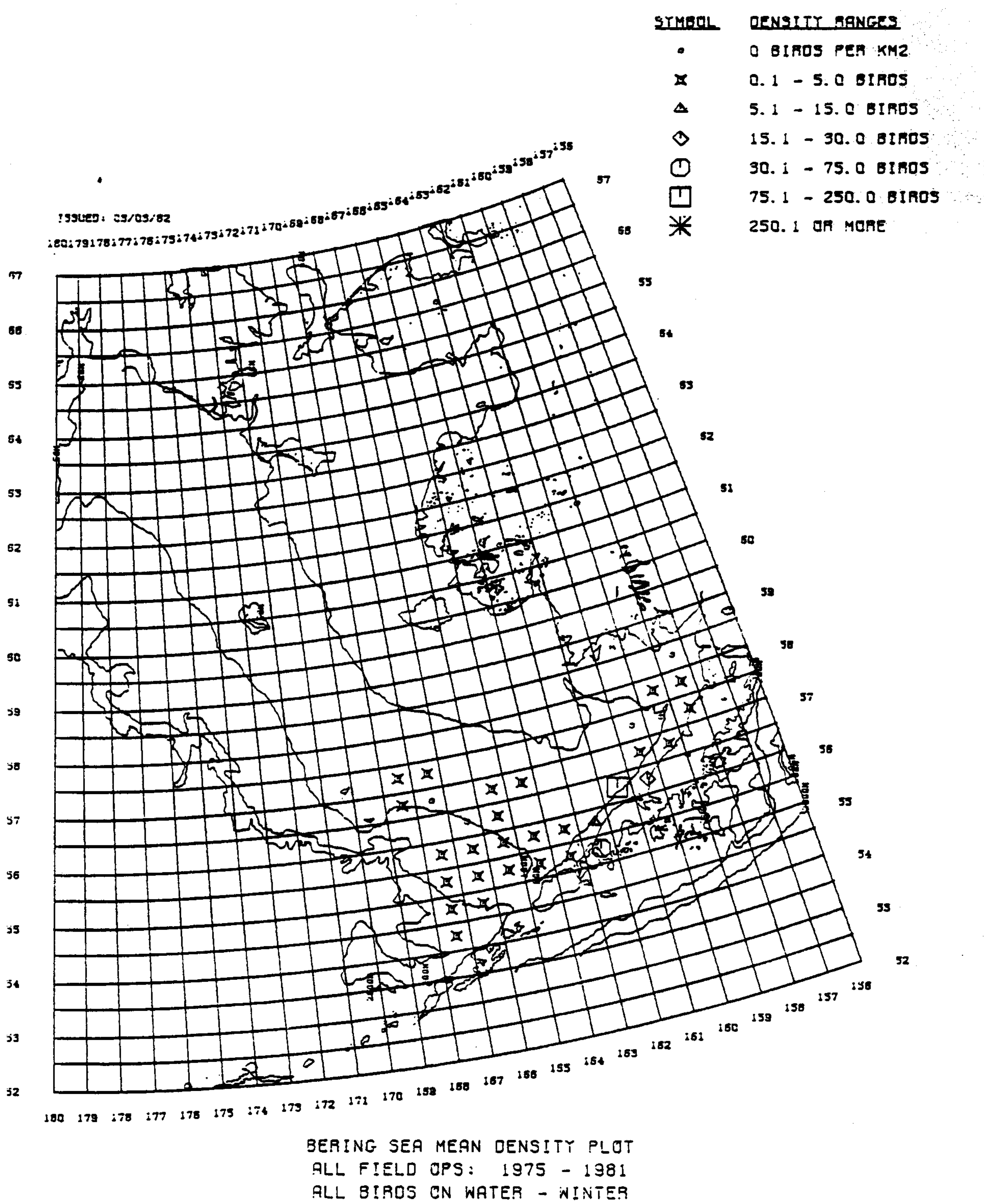
Zones: 1) Coastal domain zone, 2) Inner Bristol Bay zone, 3) Alaska Peninsula coastal zone, 4) Alaska Peninsula offshore zone, 5) Unimak zone, 6) Cape Newenham coastal zone, 7) Middle domain zone, 8) Outer domain zone (see Figure 10, p. 19).

Results particularly Relevant to Risk Assessment

Birds resting or foraging on the water are particularly vulnerable to floating oil. Therefore, it is important to identify areas where consistently large numbers of birds are found on the water. Large flocks of birds on the water were consistently seen in the NAS, but the locations of these flocks varied among seasons. Isolated high densities of birds on the water were found along the north coast of the Alaska Peninsula in both winter and spring (Figures 11 and 12). In summer, the coastal region of northern Bristol Bay off Cape Newenham and Cape Peirce had consistently high densities of birds on the water (Figure 13). In autumn, we found essentially no areas in the NAS with high densities of birds on the water (Figure 14). However, Arneson (1981) found densities of 453 birds/km^2 along the north shore of the Alaska Peninsula and its lagoons. His surveys, mostly aerial observations, were much closer to the shore than our shipboard surveys. Our density estimates for the Alaska Peninsula may be low in all seasons, because we were not able to census lagoons or estuaries. These areas have been found to support large numbers of waterfowl and shorebirds in the spring, summer and autumn (Arneson 1981, Gill et al. 1977, 1978).

The relative density plots (Figures 5-8 and Figures 15-18) give some indication of the probability of encountering high bird densities. Averaged across all seasons, there is a greater than 10% chance of encountering bird densities of 100 birds/km^2 virtually anywhere in the coastal region of the NAS (Figure 6). Near Cape Newenham and Cape Peirce, there is a greater than 10% chance of encountering bird densities of 1000 birds/km^2 (Figure 8), and, there is also a greater than 10% chance of encountering large numbers of birds on the water (p 0.10 for densities 500 birds/km^2, Figure 15).

The probability of encountering high bird densities increased for all zones from winter, when the probability was 5% only in the Alaska Peninsula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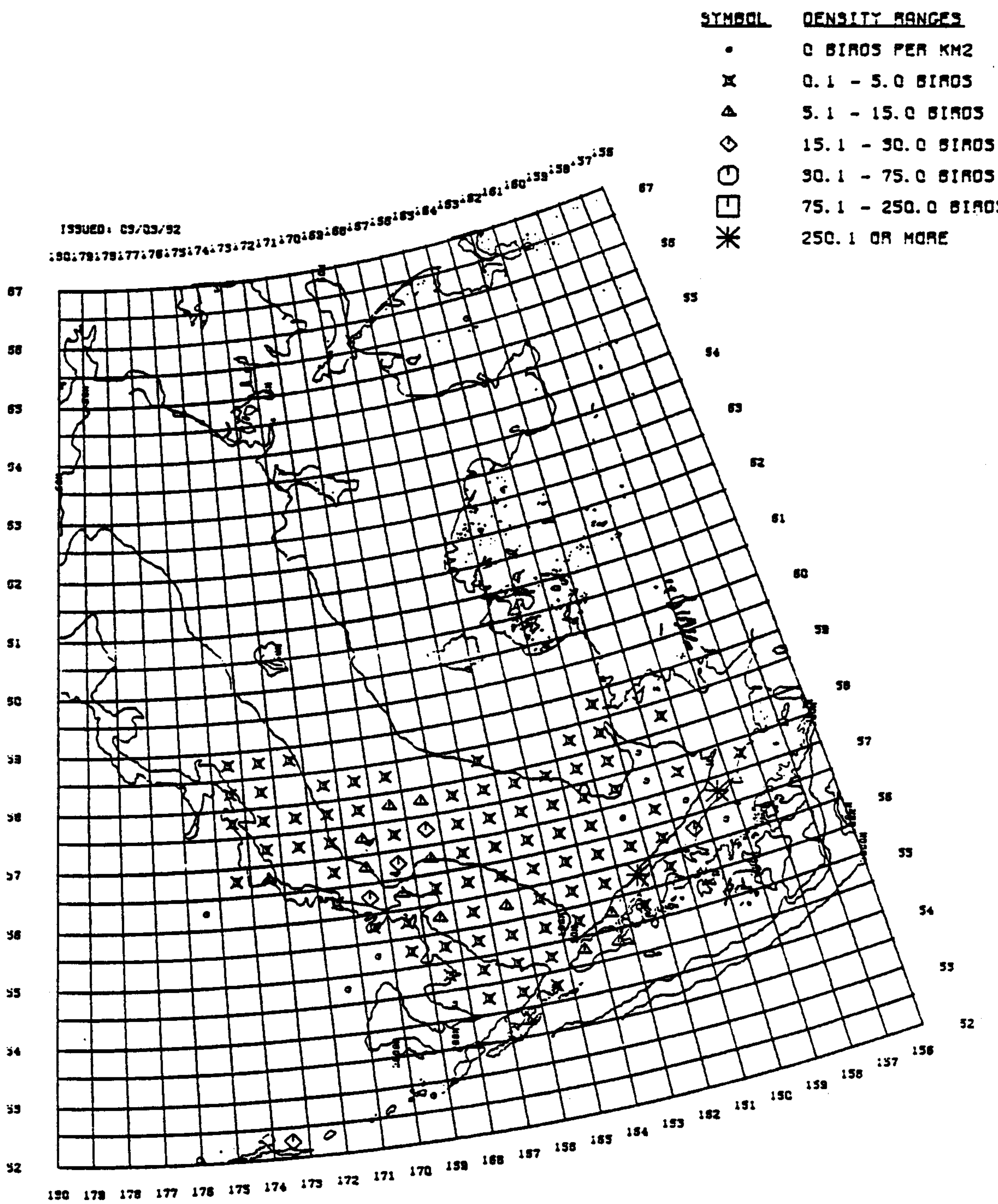
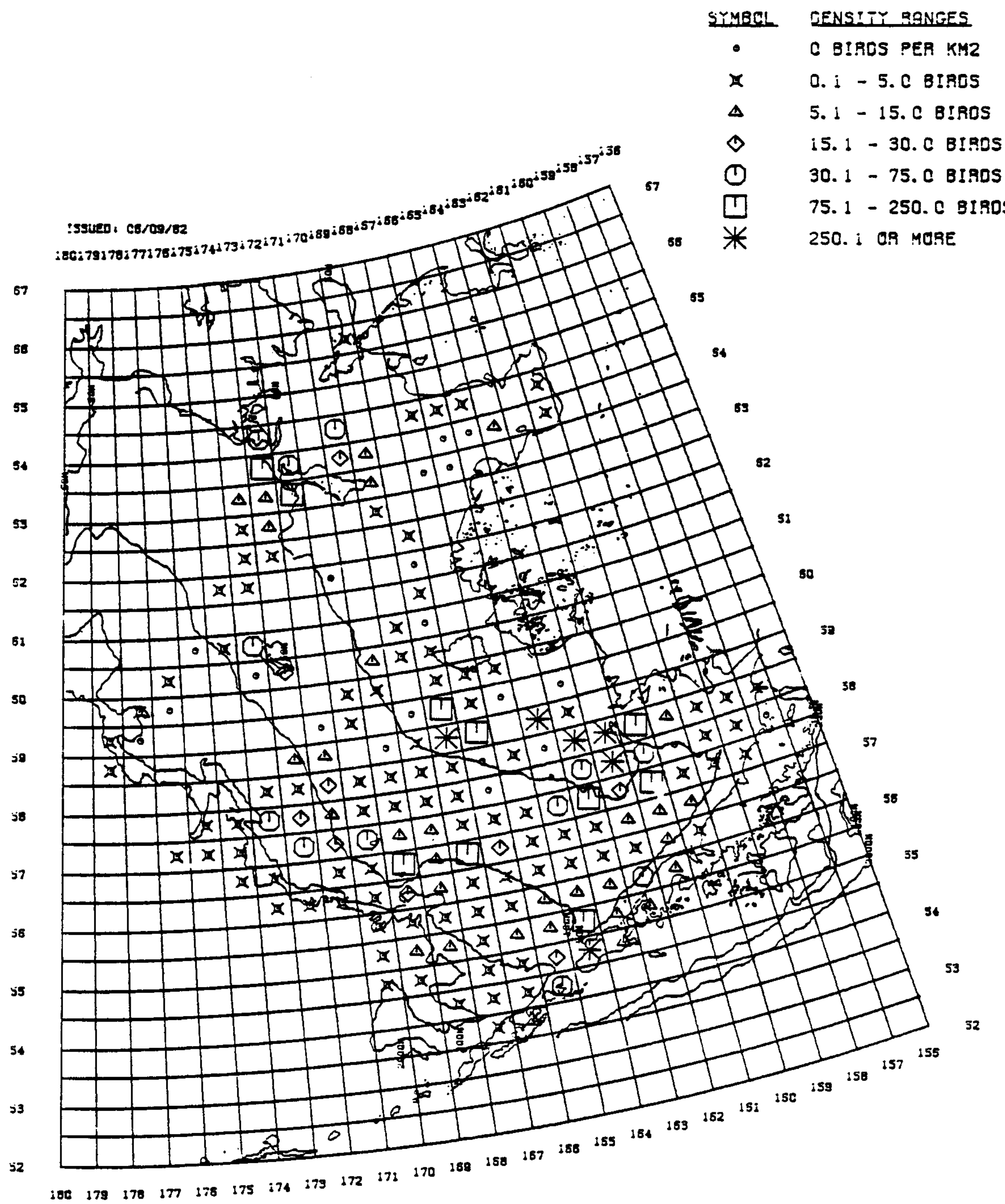
0.1 - 5.0 BIRDS
5.1 - 15.0 BIRDS
15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
ISSUED: 03/03/82
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
ALL BIRDS ON WATER - WINTER

Figure 11



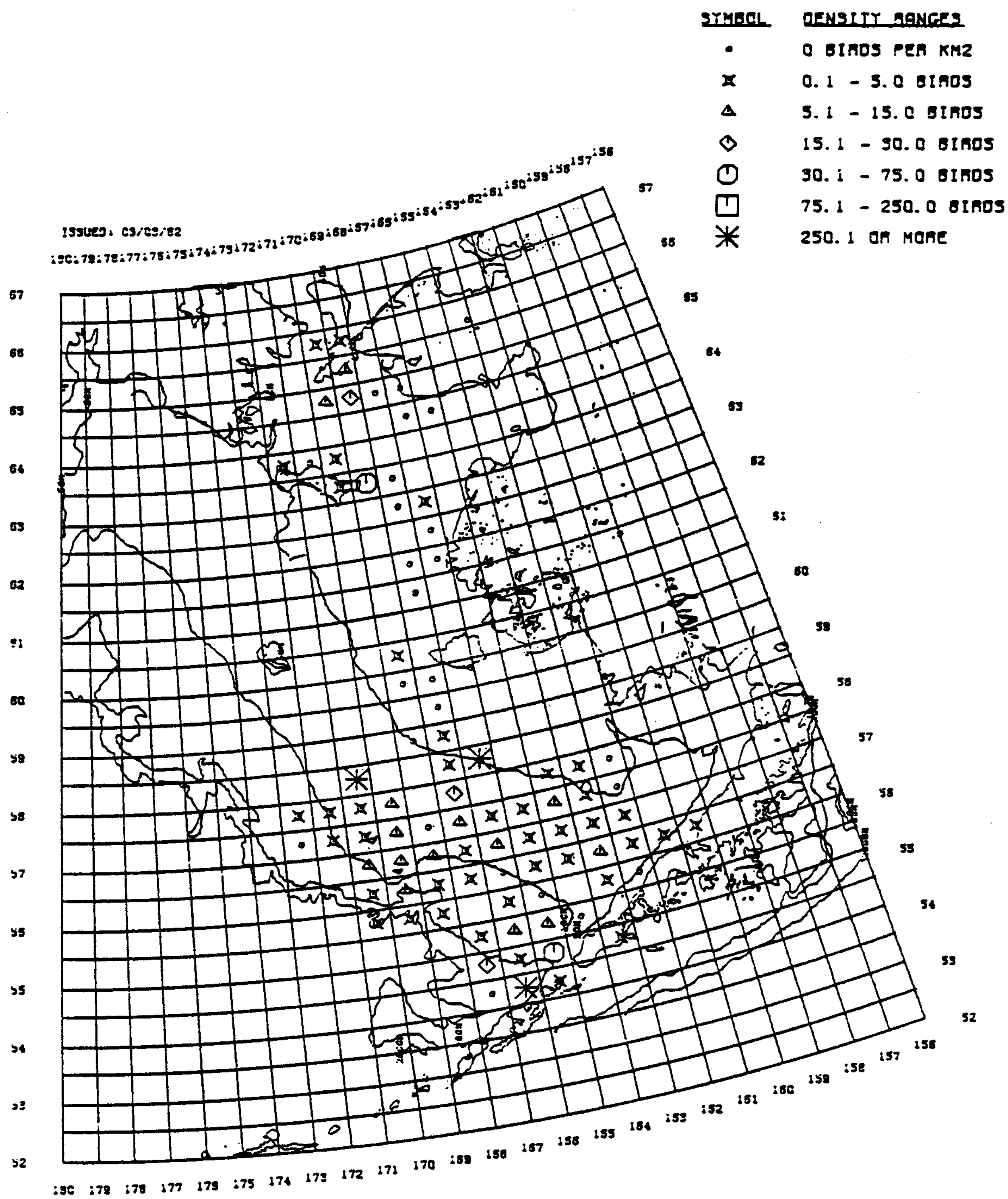
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
ALL BIRDS ON WATER - SPRING

Figure 12



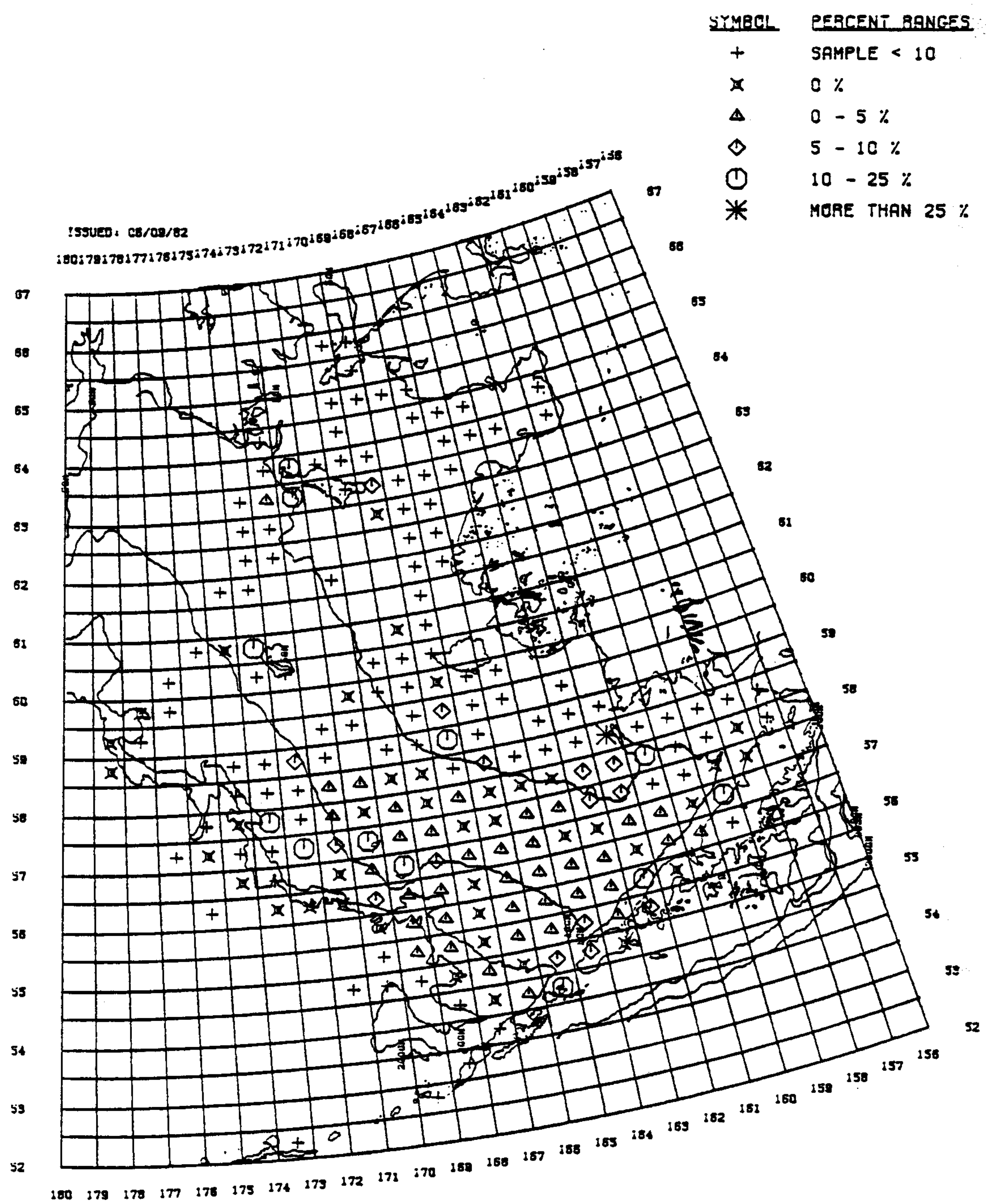
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
ALL BIRDS ON WATER - SUMMER

Figure 13



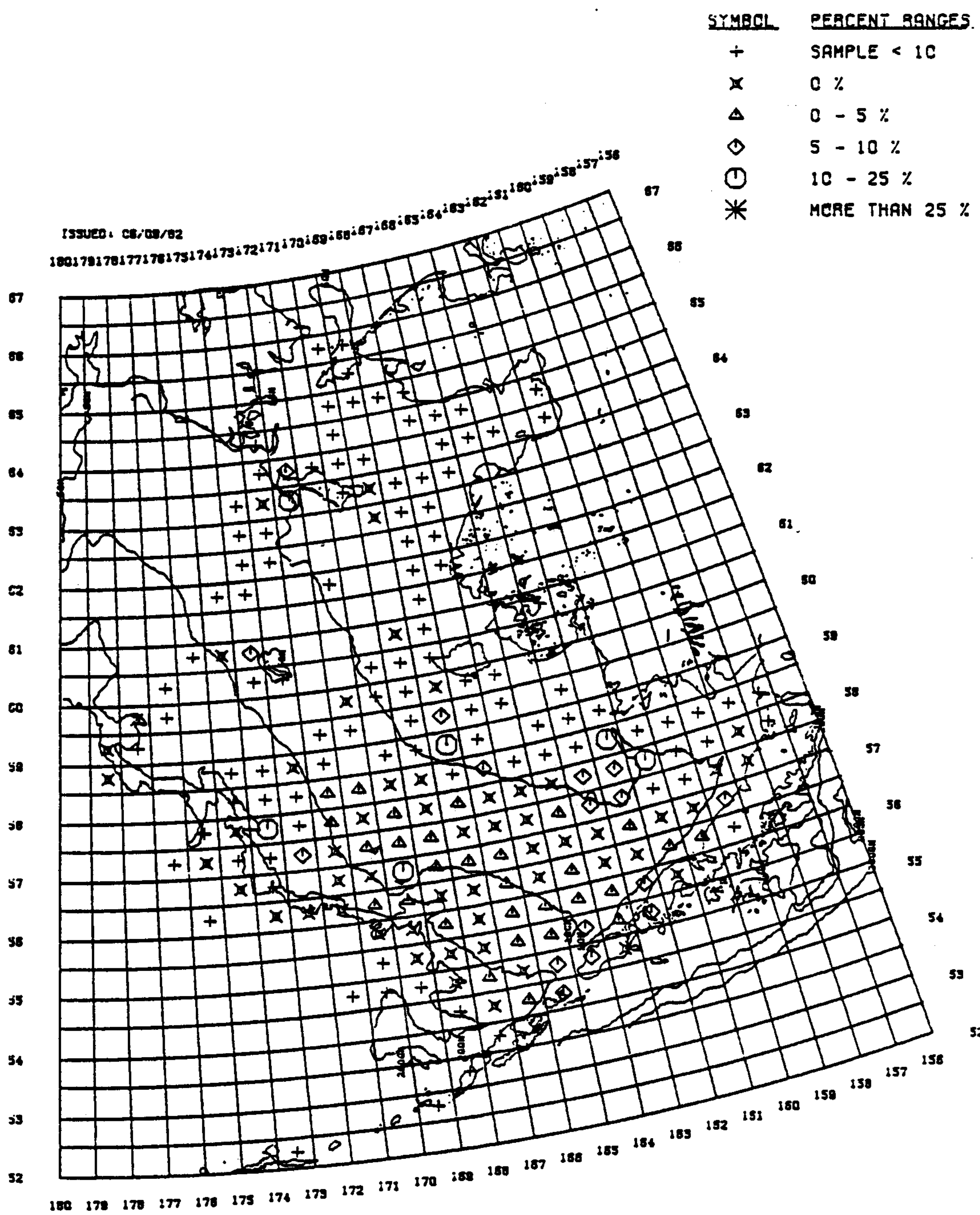
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
ALL BIRDS ON WATER - AUTUMN

Figure 14



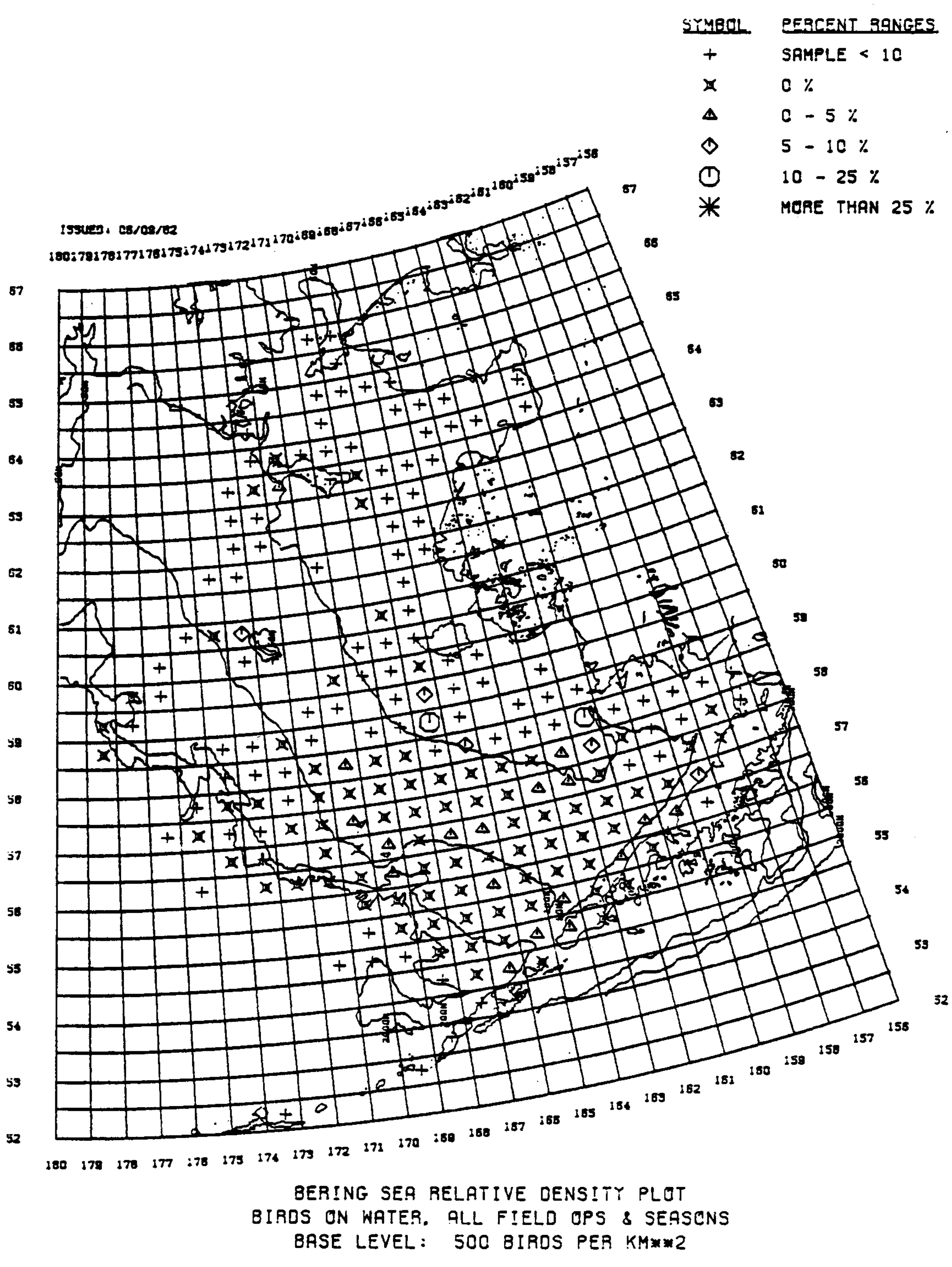
BERING SEA RELATIVE DENSITY PLOT
BIRDS ON WATER. ALL FIELD OPS & SEASONS
BASE LEVEL: 50 BIRDS PER KM**2

Figure 15



BERING SEA RELATIVE DENSITY PLOT
BIRDS ON WATER, ALL FIELD OPS & SEASONS
BASE LEVEL: 100 BIRDS PER KM**2

Figure 16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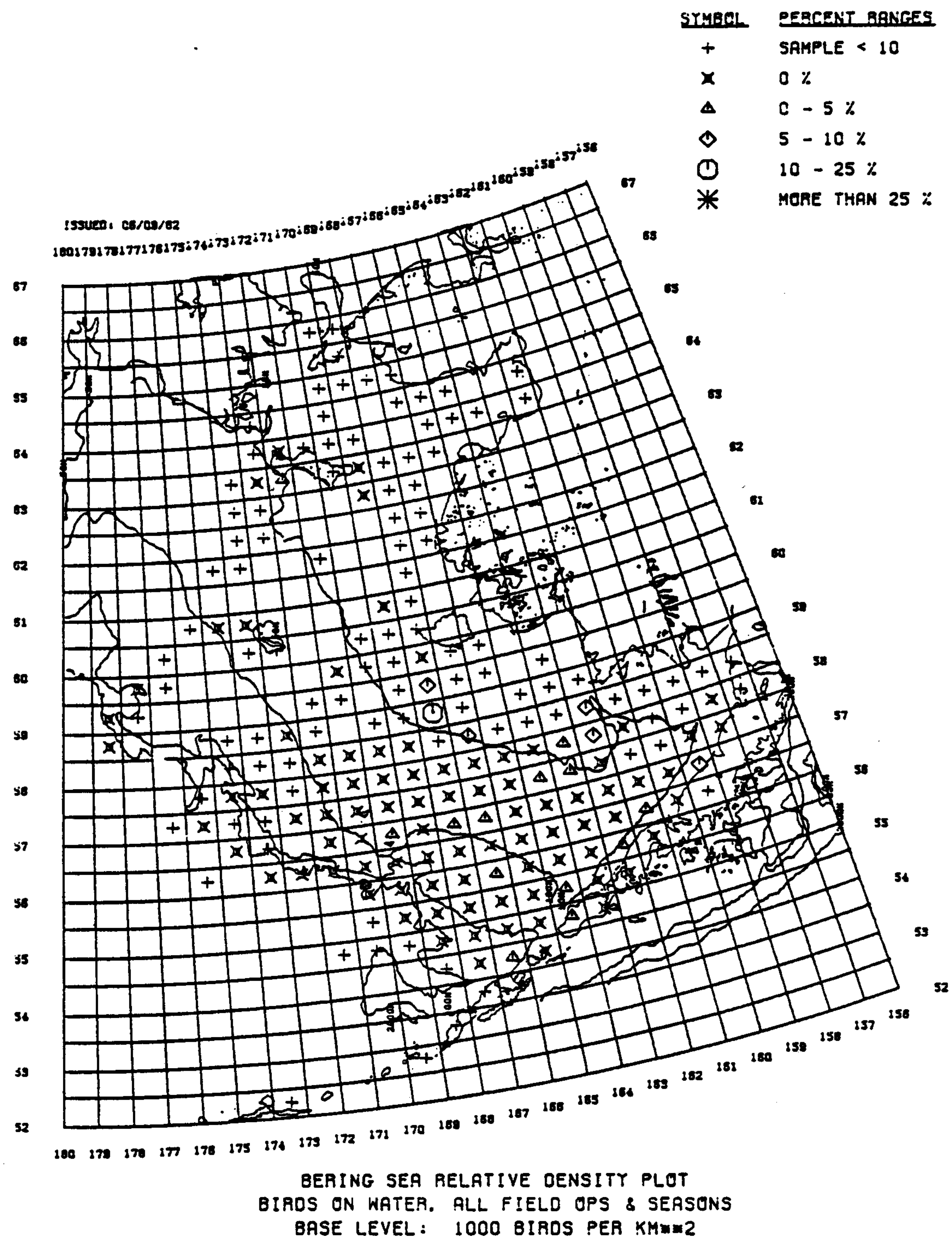
0 %
0 - 5 %
5 - 10 %
10 - 25 %
MORE THAN 25 %
ISSUED: 08/09/82
BERING SEA RELATIVE DENSITY PLOT
BIRDS ON WATER, ALL FIELD OPS & SEASONS
BASE LEVEL: 500 BIRDS PER KM**2

Figure 17



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ISSUED: 08/09/82
BERING SEA RELATIVE DENSITY PLOT
BIRDS ON WATER, ALL FIELD OPS & SEASONS
BASE LEVEL: 1000 BIRDS PER KM**2

Figure 18

coastal zone (zone 3, Table 3). Through spring, probabilities of encounter increased (Table 4). Maximum probabilities were reached in summer, when the probabilities were greater than 5% for all zones (Table 5). In the autumn, probabilities were ≥5% for most zones, except the Outer domain (zone 8) and the Unimak zone (zone 5), where the encounter rates for densities >250 birds/km^2 was estimated to be near 30% (Table 6). Table 7 summarizes the encounter rate for high bird densities (≥30 birds/km^2). Confidence intervals for the encounter rates are given in Appendix 2.

Table 3. Percentages of transects in various density intervals: ALL BIRDS, ALL ZONES, WINTER

Zone	N	Empty	0.1-5.0	5.1-15.0	15.1-30.0	30.1-75.0	75.1-250.0	>250
1	0							
2	13	15.4	53.8	30.8	0	0	0	0
3	96	1.0	15.6	18.8	22.9	17.7	14.6	9.4
4	26	19.2	50.0	50.0	0	0	0	0
5	2	0	50.0	50.0	0	0	0	0
6	0							
7	13	0	53.8	38.5	7.7	0	0	0
8	91	2.2	35.2	46.2	14.3	1.1	1.1	0

Zones: 1) Coastal domain zone, 2) Inner Bristol Bay zone, 3) Alaska Peninsula coastal zone, 4) Alaska Peninsula offshore zone, 5) Unimak zone, 6) Cape Newenham coastal zone, 7) Middle domain zone, 8) Outer domain zone (see Figure 10, p. 19).

Table 4. Percentages of transects in various density intervals: ALL BIRDS, ALL ZONES, SPRING

Zone	N	Empty	0.1-5.0	5.1-15.0	15.1-30.0	30.1-75.0	75.1-250.0	>250
1	77	6.5	59.7	20.8	7.8	1.3	3.9	0
2	0							
3	120	5.8	22.5	32.5	15.0	13.3	5.8	5.0
4	89	9.0	48.3	22.5	11.2	3.4	5.6	0
5	43	4.7	23.3	32.6	9.3	20.9	7.0	2.3
6	8	12.5	25.0	25.0	12.5	12.5	12.5	0
7	617	8.8	38.9	35.0	10.4	4.2	2.8	0
8	687	1.5	26.8	44.1	18.6	7.1	1.0	0.9

Zones: 1) Coastal domain zone, 2) Inner Bristol Bay zone, 3) Alaska Peninsula coastal zone, 4) Alaska Peninsula offshore zone, 5) Unimak zone, 6) Cape Newenham coastal zone, 7) Middle domain zone, 8) Outer domain zone (see Figure 10, p. 19).

Table 5. Percentages of transects in various density intervals: ALL BIRDS, ALL ZONES, SUMMER

Zone	N	Empty	0.1-5.0	5.1-15.0	15.1-30.0	30.1-75.0	75.1-250.0	>250
1	112	10.7	25.9	18.8	8.9	7.1	12.5	16.1
2	20	10.0	45.0	30.0	5.0	10.0	0	0
3	127	0.8	18.9	35.4	18.9	13.4	6.3	6.3
4	138	2.2	13.8	32.6	23.3	16.7	5.8	5.8
5	81	0	11.1	12.3	17.3	35.8	16.0	7.4
6	23	4.3	17.4	26.1	0	8.7	13.0	30.4
7	598	3.7	23.2	29.9	20.2	13.9	6.5	2.5
8	697	0.4	9.4	25.9	24.4	24.4	12.3	3.1

Zones: 1) Coastal domain zone, 2) Inner Bristol Bay zone, 3) Alaska Peninsula coastal zone, 4) Alaska Peninsula offshore zone, 5) Unimak zone, 6) Cape Newenham coastal zone, 7) Middle domain zone, 8) Outer domain zone (see Figure 10, p. 19).

Table 6. Percentages of transects in various density intervals: ALL BIRDS, ALL ZONES, AUTUMN

Zone	N	Empty	0.1-5.0	5.1-15.0	15.1-30.0	30.1-75.0	75.1-250.0	>250
1	25	12.0	52.0	32.0	4.0	0	0	0
2	0							
3	39	7.7	41.0	35.9	5.1	10.3	0	0
4	26	0	46.2	38.5	15.4	0	0	0
5	10	0	10.0	20.0	0	10.0	30.0	30.0
6	0							
7	127	0.8	28.3	45.7	15.0	3.9	3.9	2.4
8	74	2.7	21.6	13.5	13.5	33.8	12.2	2.7

Zones: 1) Coastal domain zone, 2) Inner Bristol Bay zone, 3) Alaska Peninsula coastal zone, 4) Alaska Peninsula offshore zone, 5) Unimak zone, 6) Cape Newenham coastal zone, 7) Middle domain zone, 8) Outer domain zone (see Figure 10, p. 19).

Table 7. Summary of percentages of transections with 30 birds/km^2 (n).

Zone	WINTER	SPRING	SUMMER	AUTUMN
1	(0)	5.2 (77)	35.7 (112)	0 (25)
2	0 (13)	(0)	10.0 (20)	(0)
3	41.7 (96)	24.1 (120)	26.0 (127)	10.3 (39)
4	0 (26)	9.0 (89)	28.3 (138)	0 (26)
5	0 (2)	30.2 (43)	59.2 (81)	70.0 (10)
6	(0)	25.0 (8)	52.1 (23)	(0)
7	0 (13)	7.0 (617)	22.9 (598)	10.2 (127)
8	2.2 (91)	9.0 (687)	39.8 (700)	48.7 (74)

Zones: 1) Coastal domain zone, 2) Inner Bristol Bay zone, 3) Alaska Peninsula coastal zone, 4) Alaska Peninsula offshore zone, 5) Unimak zone, 6) Cape Newenham coastal zone, 7) Middle domain zone, 8) Outer domain zone (see Figure 10, p. 19).

DISCUSSION

Patterns of Use

High bird densities (≳30 birds/km^2) are encountered regularly (≳10%) in the NAS in every season (Table 7). In winter and autumn, high bird densities are restricted to specific habitats, but in spring and summer, high densities are found throughout the NAS. In summer, densities of 30 birds/km^2 or more are encountered 20 to 60% of the time throughout the NAS area, and for all but one of the zones, densities over 75 birds/km^2 are encountered more than 5% of time (Table 8).

In all seasons, the coastal areas of Bristol Bay emerge as critical habitat for marine and coastal birds. In autumn and winter, large numbers of waterfowl use the coastal lagoons along the Alaska Peninsula. The lagoons have not been censused in winter to our knowledge, however, autumn densities over 1000 birds/km^2 have been reported (Arneson 1981). In the spring, large numbers of birds are concentrated in the narrow strip of coastal water (about 5 km wide) along the Alaska Peninsula. Large numbers of shorebirds and waterfowl occupy the lagoons and huge flocks of shearwaters funnel through this narrow coastal strip. In summer, all coastal areas of the NAS support large concentrations of birds. In southern Bristol Bay, bird densities are concentrated within a few kilometers of shore. High densities are found throughout the shallow water habitat of the northern Bristol Bay, extending out 40 km or more from the coast. Large concentrations of birds are also found in Unimak Pass and the Outer Shelf domain, extending north from Unimak.

The preference of birds for the coastal waters means that birds are restricted to a relatively small area, increasing the potential vulnerabilty to an oil spill there. Particularly at risk are the huge flocks of shearwaters which move through the narrow coastal strip along the Alaska Peninsula. In contrast to the heavily used coastal regions of Bristol Bay, the Middle domain (waters 50-100 m deep) supports fewer birds, although high densities (≥30 birds/km^2) are encountered with similiar frequency.

Densities in the coastal region are large, and the encounter rates for high densities appear to be as great as we previously found around the Pribilof Islands (Hunt et al. 1981c). Bird densities of over 30 birds/km^2 were observed over half of the time around the Pribilof Islands in summer; rates this high were also found in the Cape Newenham coastal zone (zone 5) and the Unimak zone (zone 6). Summer densities greater than 250 birds/km^2 were observed over 6% of the time for all the coastal zones in the NAS, except the Inner Bristol Bay zone (zone 2). Encounter rates for densities >250 birds/km^2 were 16% for the Coastal domain (zone 1) and 30% for the Cape Newenham coastal zone (zone 6), both in northern Bristol Bay. Despite our limited samples for the coastal regions of Bristol Bay in seasons other than summer, encounter rates for bird densities of 30 birds/km^2 appear to be 10% in all seasons. A moderate oil spill of 100 km^2, occurring anywhere in the coastal regions could reasonably place 30,000 birds at risk, even if no transport occurred.

Variance

The probability of encountering densities of 30 birds/km^2 are greater than 10% in 19 of 27 zone-season combinations for which we have any data. This indicates that the high mean densities found in these regions are not due to rare encounters with large flocks, but rather that high densities can be expected on a regular basis in these areas. This implies that any oil spill in these regions will encounter large numbers of birds. Sub-surface foragers make up the majority of birds in the Middle and Coastal domains (Schneider and Hunt 1982), and since they are more vulnerable to oil (King and Sanger 1979), oil spills in the NAS could have greater impact than an equivalent spill in the Outer Shelf domain, even if bird densities are similiar. Also, since the NAS is dominated by migrant species, oil spills in this area will indirectly affect other ecosystems.

In this report, we have not dealt with the distribution of individual species in the NAS. Waterfowl, shearwaters and shorebirds together account for more than 90% of the birds in the NAS. Although there are almost 2 million colonial seabirds in the NAS, they are totally overwhelmed by the many millions of migrants in the region. The populations of colonial seabirds in tha NAS are large for the Bering Sea and significant in terms of their world populations; for instance, the Kittiwake colonies near Cape Newenham and Cape Peirce are the largest known for this species. We have included maps of the distribution of individual species in Appendix 3.

Error rates and the need for further study

Hunt et al. (1981c) have calculated that for an observed encounter rate to be within 10% of the true encounter rate (90% confidence level), a minimum sample size of 250 transects per zone (Figures 23, 24, Appendix 2) is required. For the heavily used coastal areas of the NAS, our largest sample size is 127 transects in the summer. Sample sizes for other seasons are even smaller, and some of the coastal zones have not been surveyed in certain seasons. We have no information on bird densities in the Coastal domain (zone 1) in autumn, in the Inner Bristol Bay zone (zone 2) in autumn and winter, and in the Cape Newenham coastal zone (zone 6) in autumn and winter. For a confidence level of 75%, a minimum sample size of 100 is needed for observed encounter rates to be within 10% of the true rate. We have sample sizes less than 100 for 23 of 32 zone-season combinations. Zone-seasons with adequate sampling are: Spring-zones 3 (Alaska Peninsula coastal domain), 7 (Middle domain) and 8 (Outer domain); Summer-zones 1 (Coastal domain), 3 (Alaska Peninsula coastal), 4 (Alaska Peninsula offshore), 7 (Middle domain), 8 (Outer domain); and Autumn-zone 7 (Middle domain). Winter coverage is not adequate for any of the zones. Even within the Alaska Peninsula coastal (3) and offshore (4) zones, most of the samples within a season come from a single cruise. The high encounter rates we found for large densities, despite the relatively small sample sizes suggest that high densities may be even more common. We conclude that additional surveys are required in the coastal regions before any decisions about OCS oil development in the NAS are made.

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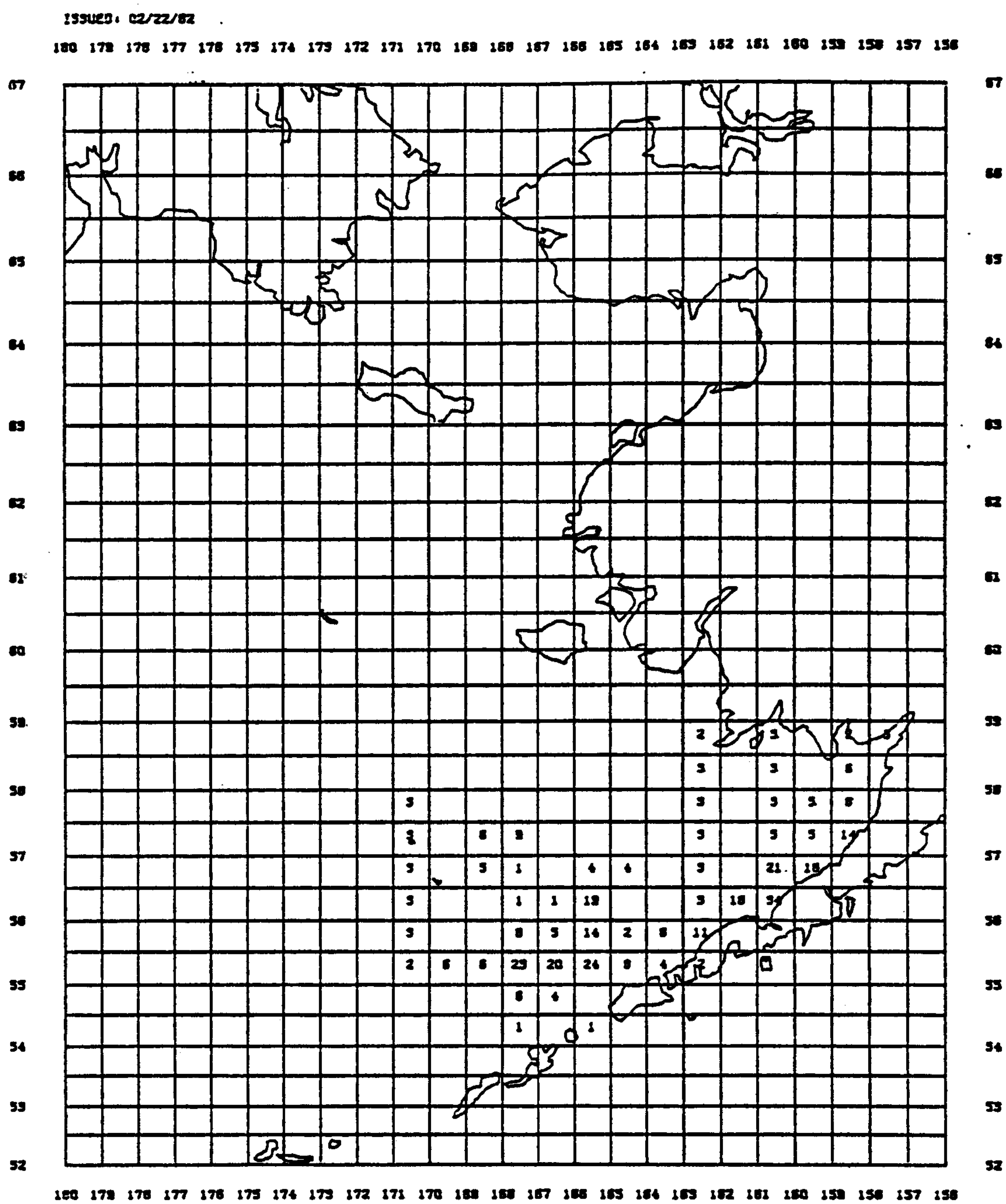
APPENDIX 1: NUMBER OF TRANSECTS IN 30' LATITUDE BY 60' LONGITUDE BLOCKS



BERING SEA EFFORT PLOT: WINTER
ALL FIELD OPS: 1975 - 1981

Figure 19

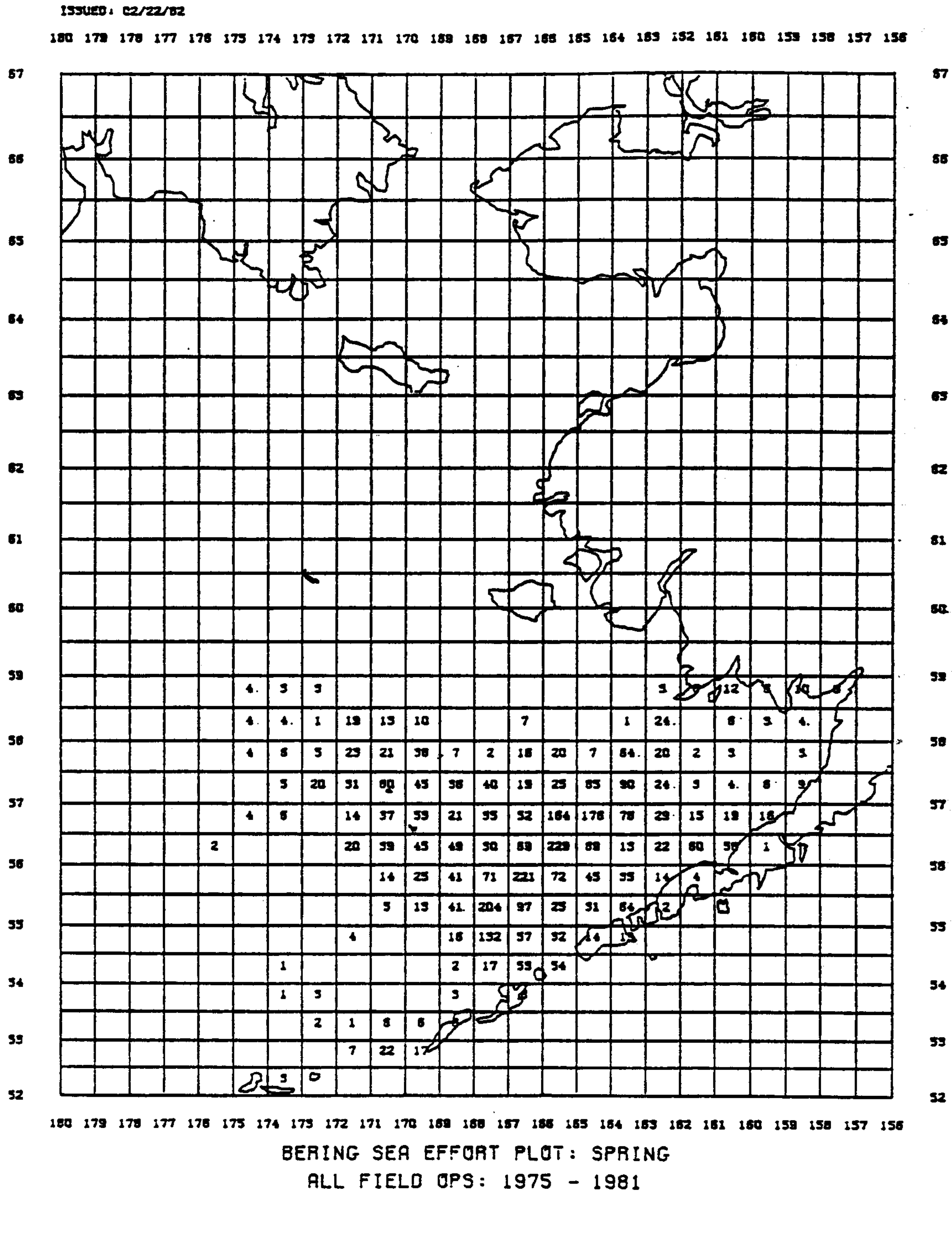
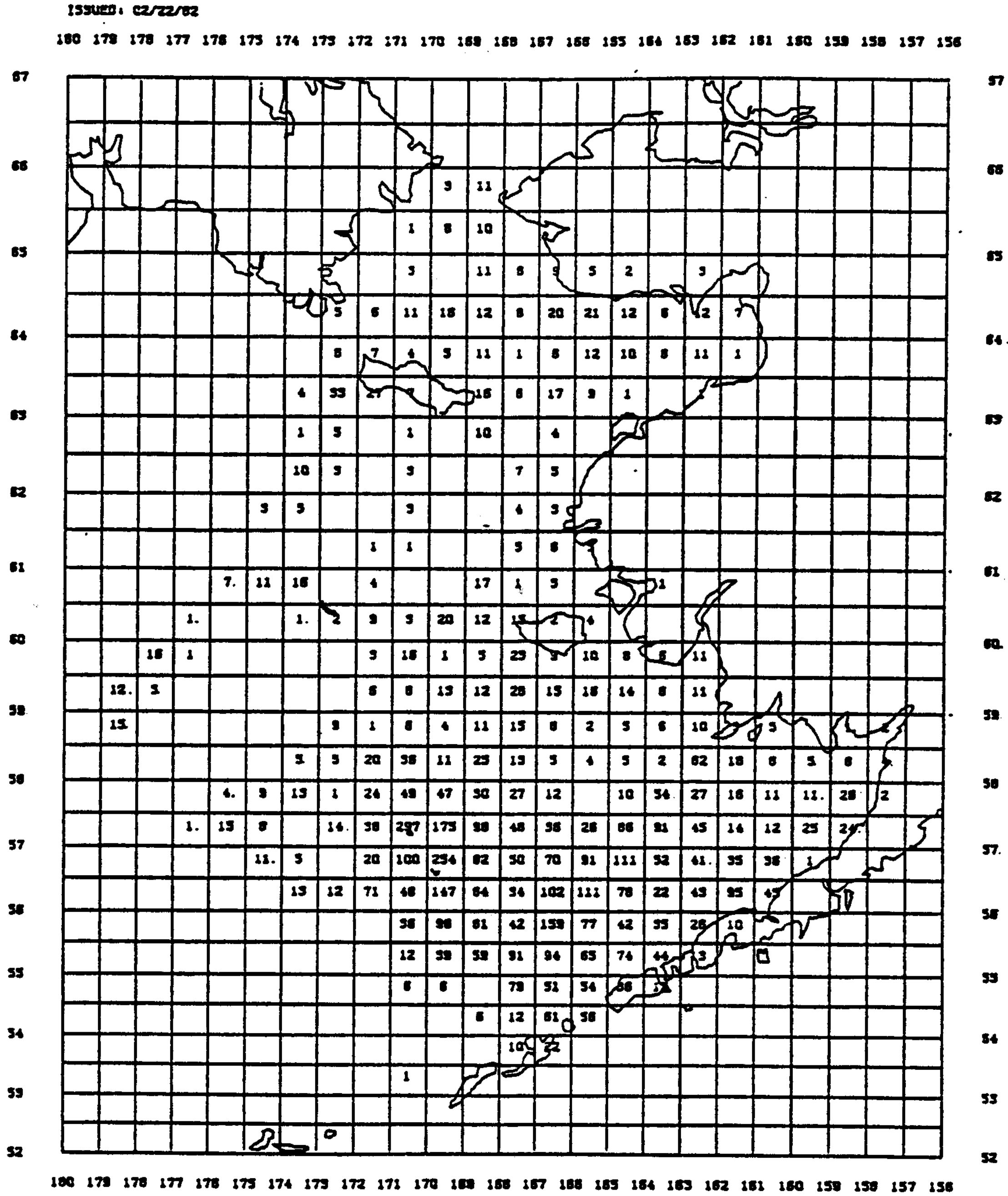
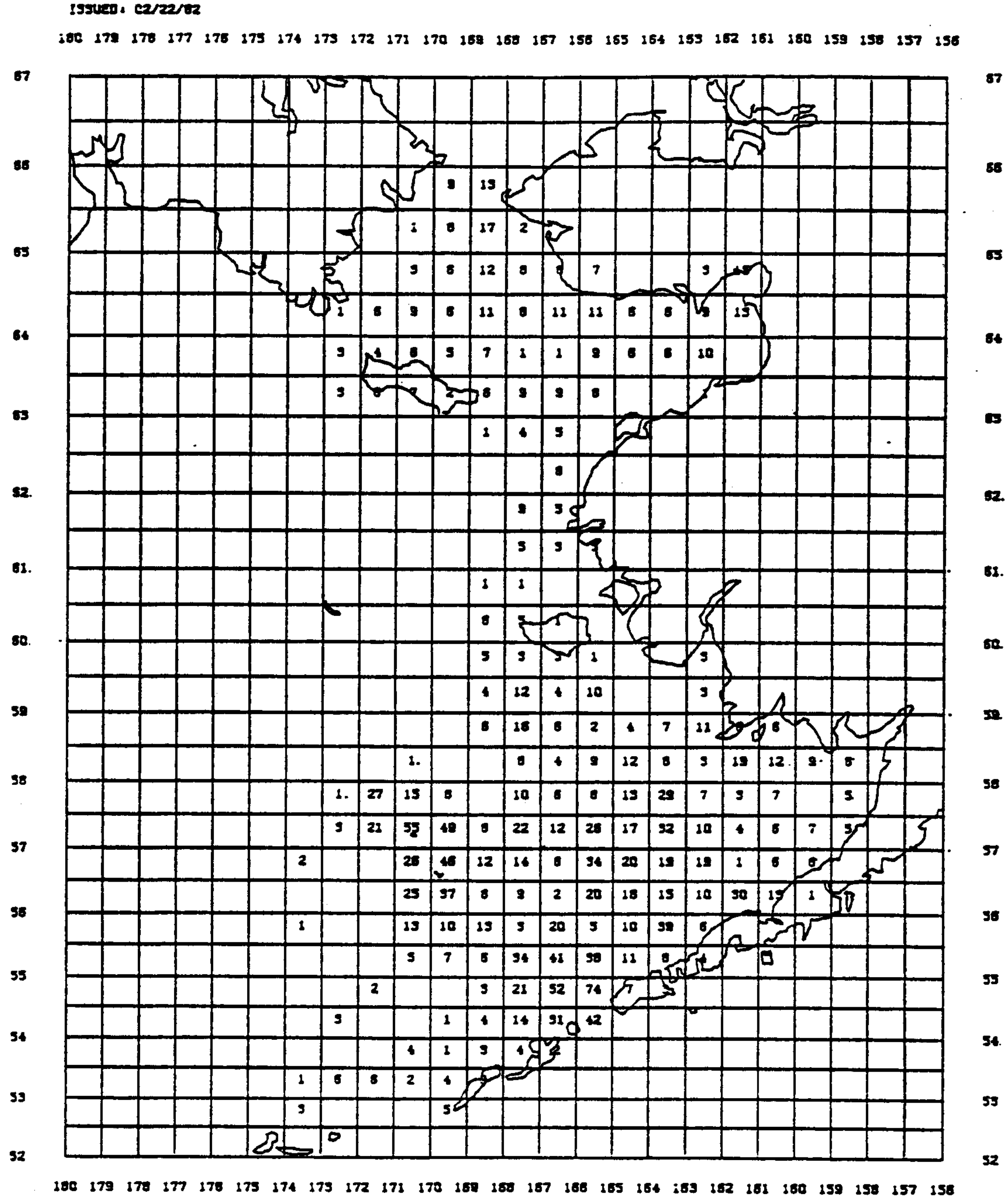

ISSUED: 02/22/82
BERING SEA EFFORT PLOT: SPRING
ALL FIELD OPS: 1975 - 1981

Figure 20



BERING SEA EFFORT PLOT: SUMMER
ALL FIELD OPS: 1975 - 1981

Figure 21



BERING SEA EFFORT PLOT: AUTUMN
ALL FIELD OPS: 1975 - 1981

Figure 22

APPENDIX 2: ERROR RATES AND CONFIDENCE INTERVALS FOR BIRD DENSITIES BY ZONE

		d	
		.1	.25
α	.99	2500	400
	.95	500	80
	.90	250	40
	.75	100	16

$$N = \frac{1}{4} d^2 (1-\alpha)$$

Sample size (N) required for a given confidence level (α) and error rate (d)

Figure 23

α \ d	.1	.25	k
.99	665	166	2.58
.95	384	96	1.96
.90	272	68	1.65
.75	135	34	1.16

$$N = \frac{1}{4} (k/d)^2$$

Sample size (N) required for a given confidence level (α) and error rate (d) with the normal approximation

Figure 24

ALL BIRDS

confidence interval = encounter rate $\pm$ d%

ZONE	1	2	3	4	5	6	7	8
N	0	13	96	26	2	0	13	91
d*	---	62%	10*%	44%	-	-	62%	10*%

*If N 50, with the normal approximation $d = \left[\frac{1.96^2}{4N}\right]^{1/2}$

otherwise $d = \frac{1}{2[N(1-\alpha)]^{1/2}}$

Error rates for zones in the NAS: WINTER

Figure 25

Note: Before publication of this volume, figures 25-28 had the equation $d = \frac{1}{2[N(1-\alpha)]^{1/2}}$ incorrectly shown as $d = 1/2[N(1-\alpha)]^{1/2}$. Citations of this article before it was published in this volume might reflect this typographical error.

ALL BIRDS

confidence interval = encounter rate ± d%

ZONE	1	2	3	4	5	6	7	8
N	77	0	120	89	43	8	617	687
d*	11*%	-	9*%	10*%	34%	79%	4*%	4*%

*If N 50, with the normal approximation $d = \left[\frac{1.96^2}{4N}\right]^{1/2}$

otherwise $d = \frac{1}{2[N(1-\alpha)]^{1/2}}$

Error rates for zones in the NAS: SPRING

Figure 26

Note: Before publication of this volume, figures 25-28 had the equation $d = \frac{1}{2[N(1-\alpha)]^{1/2}}$ incorrectly shown as $d = 1/2[N(1-\alpha)]^{1/2}$. Citations of this article before it was published in this volume might reflect this typographical error.

ALL BIRDS

confidence interval = encounter rate $\pm$ d%

ZONE	1	2	3	4	5	6	7	8
N	112	20	127	138	81	23	598	700
d*	9*%	50%	9*%	8*%	11*%	47%	4*%	4*%

*If N 50, with the normal approximation $d = \left[\frac{1.96^2}{4N}\right]^{1/2}$

otherwise $d = \frac{1}{2[N(1-\alpha)]^{1/2}}$

Error rates for zones in the NAS: SUMMER

Figure 27

Note: Before publication of this volume, figures 25-28 had the equation $d = \frac{1}{2[N(1-\alpha)]^{1/2}}$ incorrectly shown as $d = 1/2[N(1-\alpha)]^{1/2}$. Citations of this article before it was published in this volume might reflect this typographical error.

ALL BIRDS

confidence interval = encounter rate $\pm$ d%

ZONE	1	2	3	4	5	6	7	8
N	25	0	39	26	10	0	127	74
d*	45%	-	36%	44%	71%	-	9*%	11*%

*If N 50, with the normal approximation $d = \left[\frac{1.96^2}{4N}\right]^{1/2}$

otherwise $d = \frac{1}{2[N(1-\alpha)]^{1/2}}$

Error rates for zones in the NAS: AUTUMN

Figure 28

Note: Before publication of this volume, figures 25-28 had the equation $d = \frac{1}{2[N(1-\alpha)]^{1/2}}$ incorrectly shown as $d = 1/2[N(1-\alpha)]^{1/2}$. Citations of this article before it was published in this volume might reflect this typographical error.

APPENDIX 3: DISTRIBUTION MAPS FOR INDIVIDUAL SPECIES IN THE NAS AND SOUTHEASTERN BERING SEA

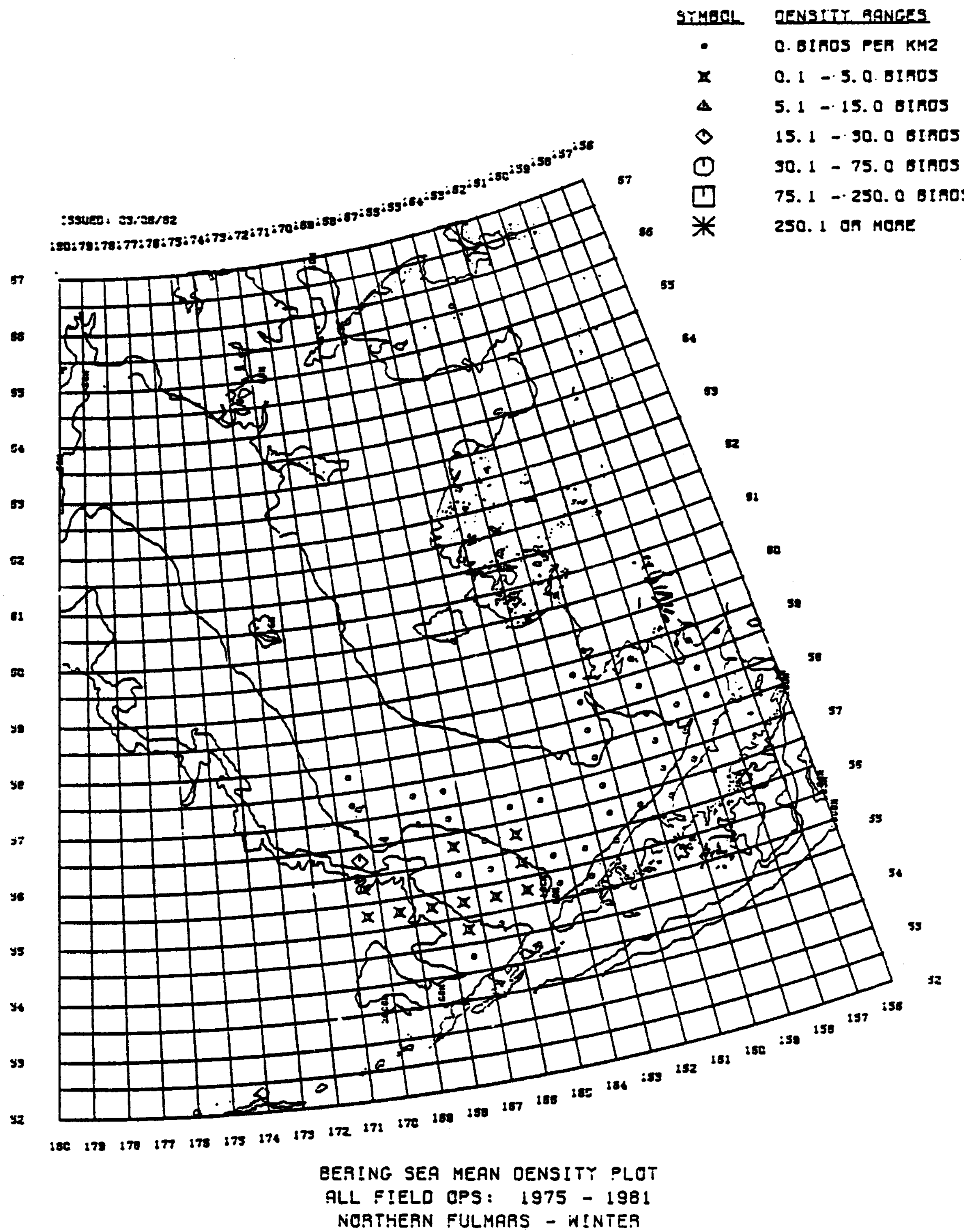
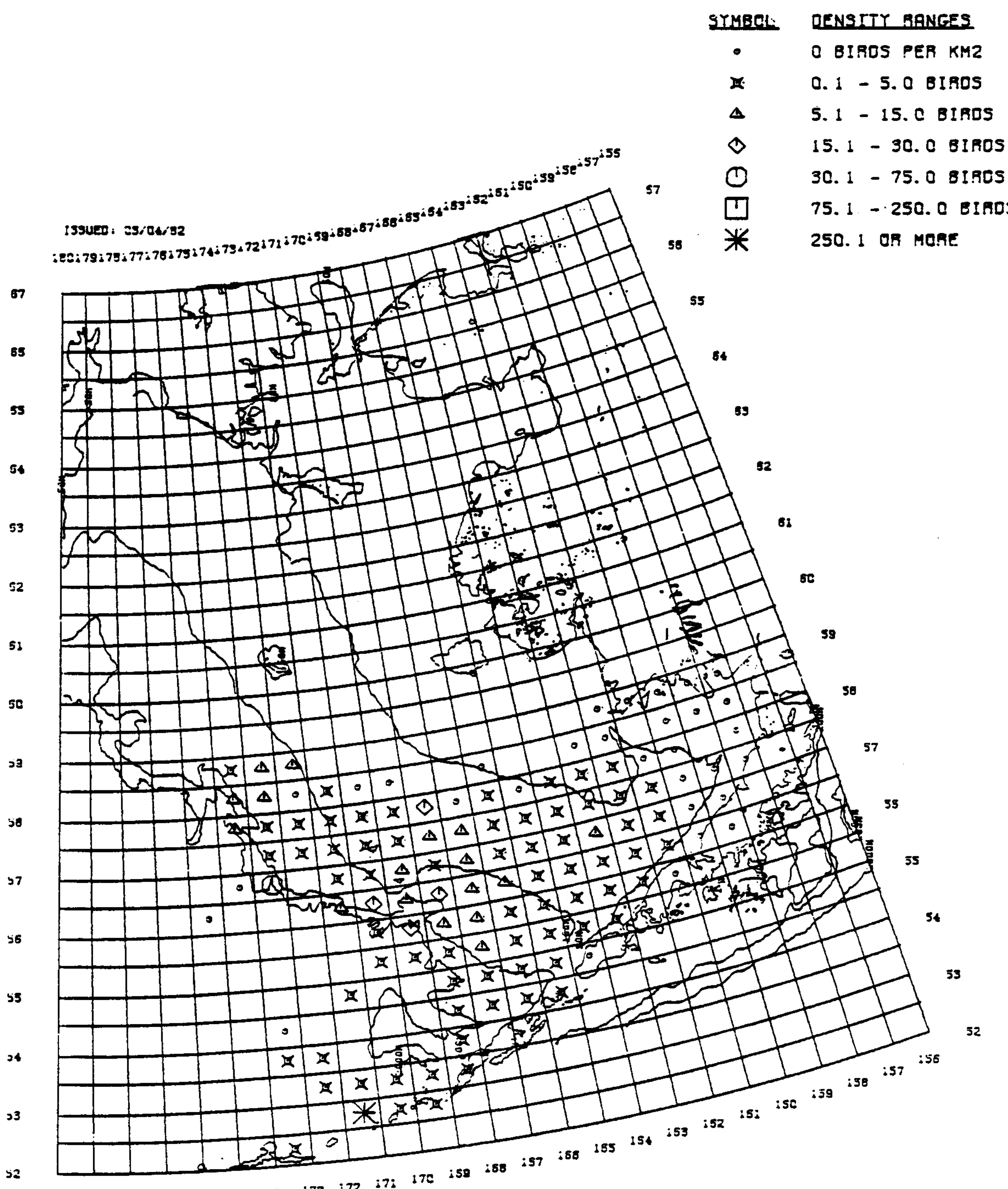
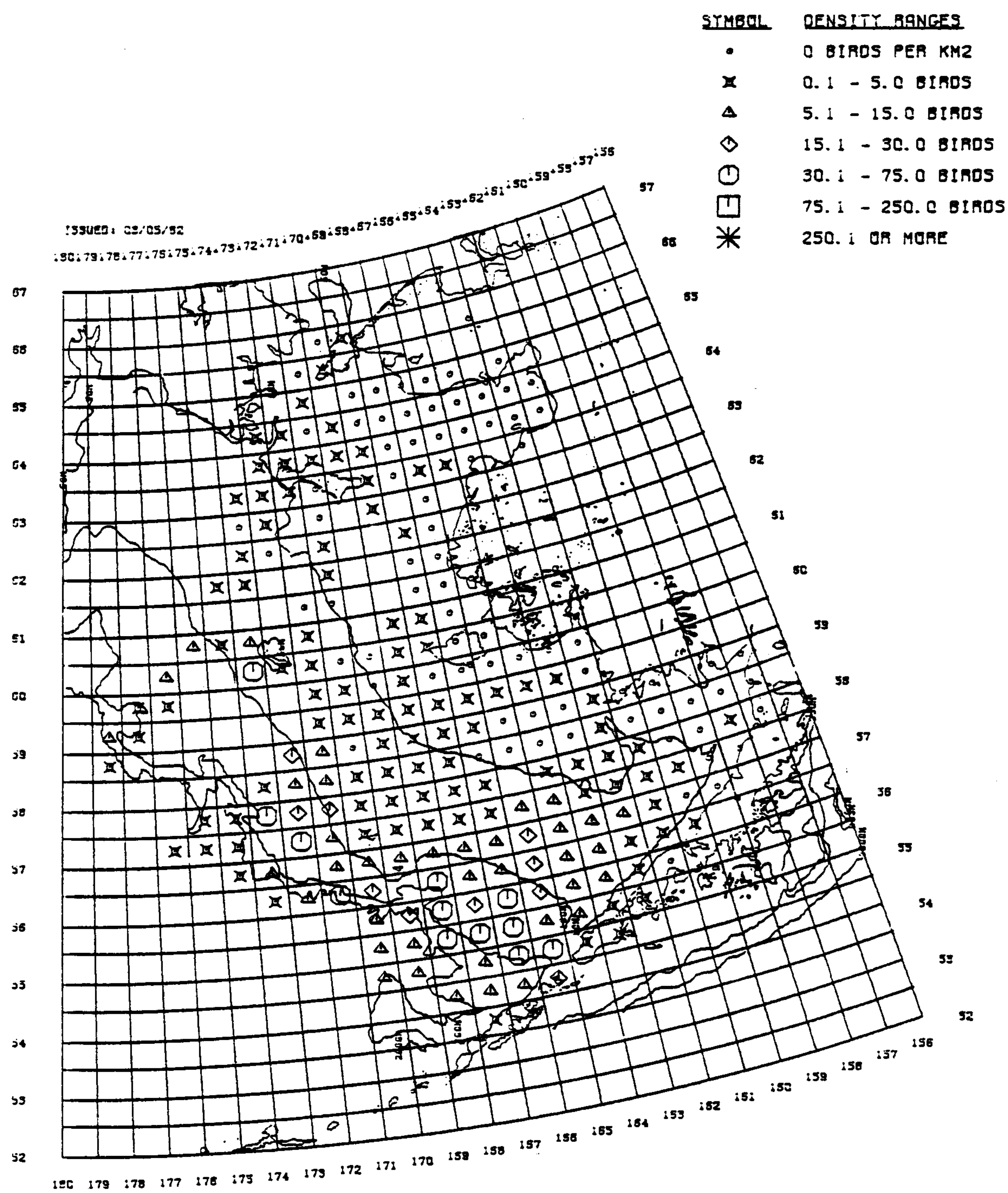

SYMBOL DENSITY RANGES
0. BIRDS PER KM2
0.1 - 5.0 BIRDS
5.1 - 15.0 BIRDS
15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
NORTHERN FULMARS - WINTER

Figure 29



BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
NORTHERN FULMARS - SPRING

Figure 30



BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
NORTHERN FULMARS - SUMMER

Figure 31

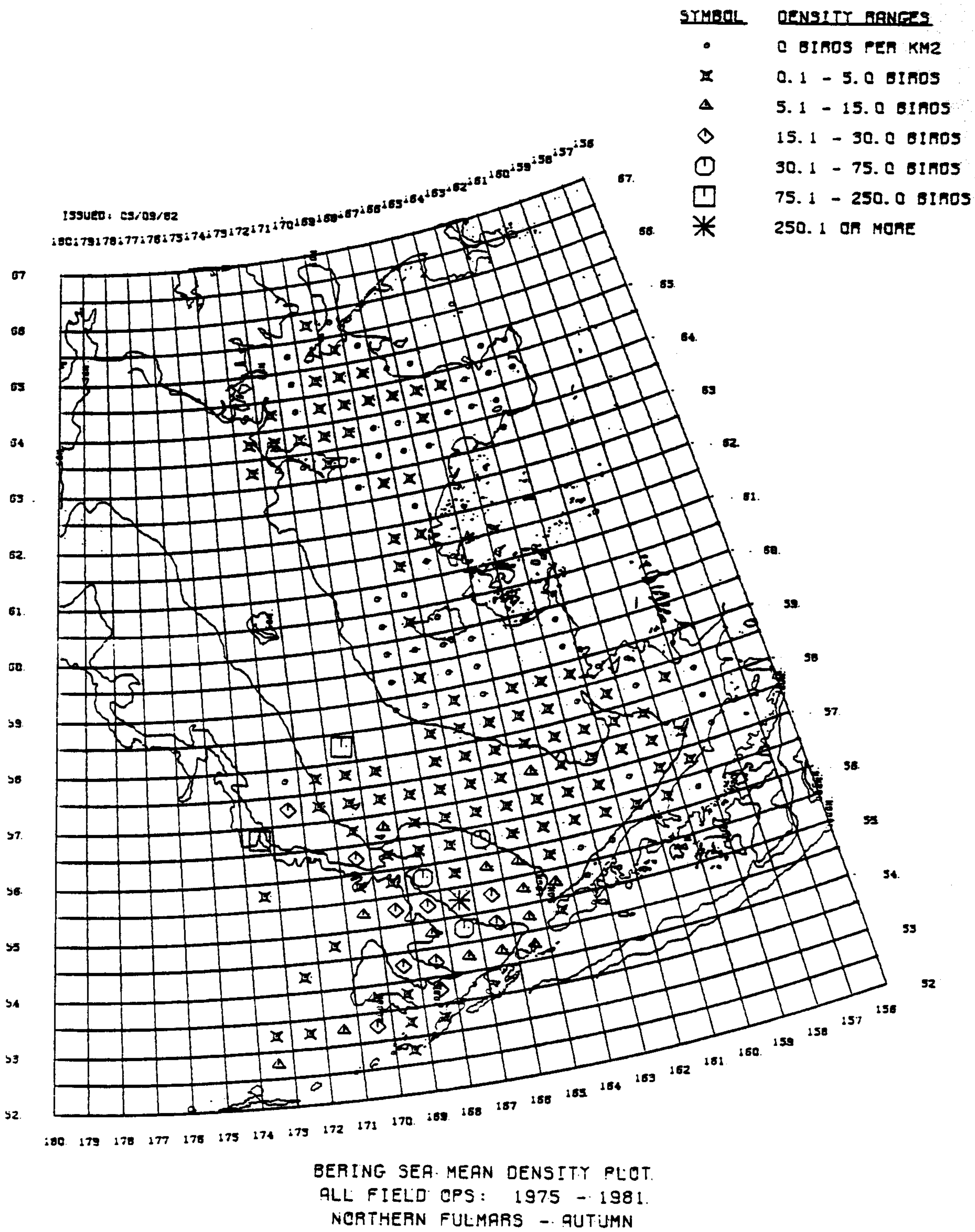

SYMBOL DENSITY RANGES
0 BIRDS PER KM2
0.1 - 5.0 BIRDS
5.1 - 15.0 BIRDS
15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
ISSUED: 03/09/82
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
NORTHERN FULMARS - AUTUMN

Figure 32

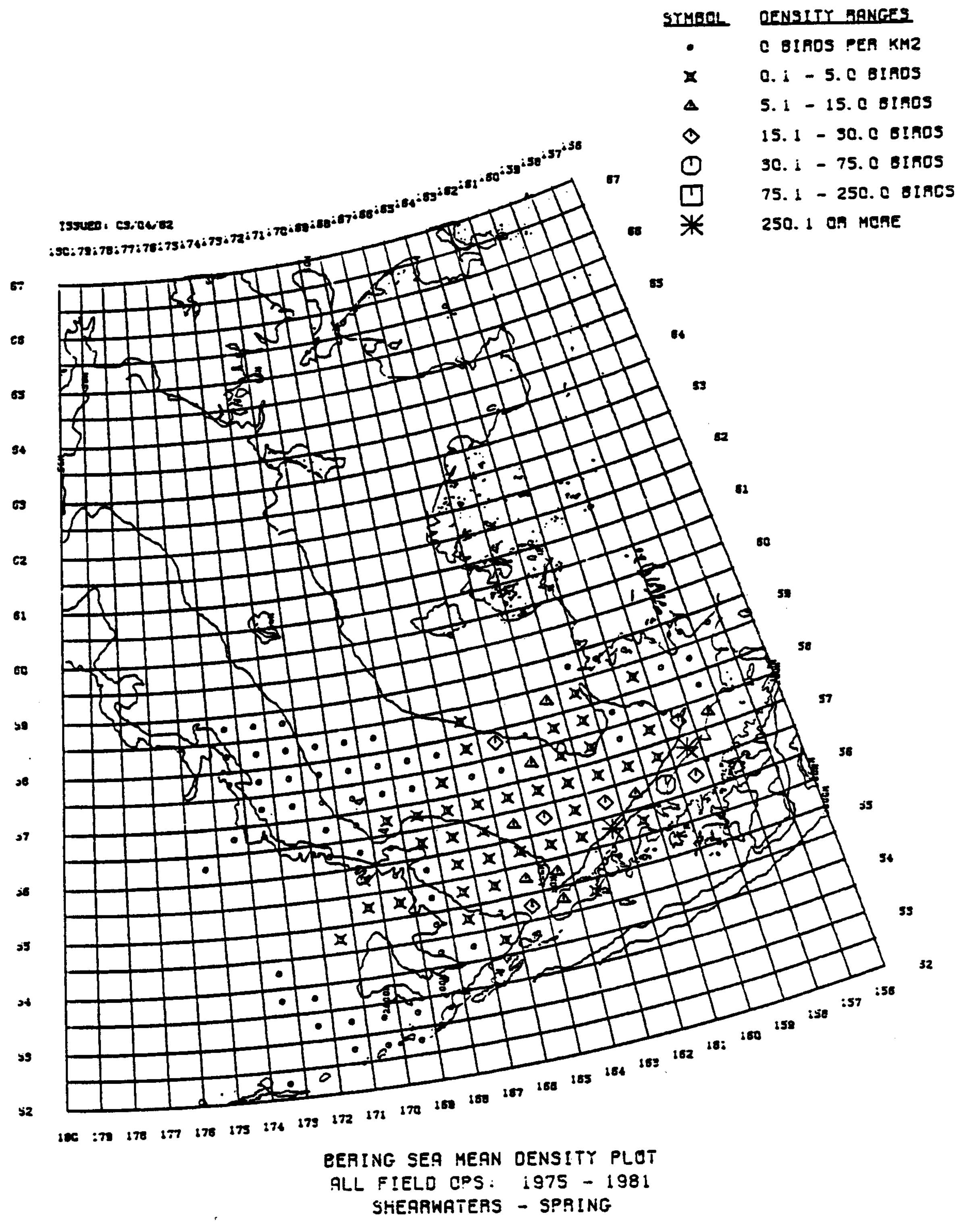

SYMBOL DENSITY RANGES
0 BIRDS PER KM2
0.1 - 5.0 BIRDS
5.1 - 15.0 BIRDS
15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
ISSUED: 03/04/82
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
SHEARWATERS - SPRING

Figure 33

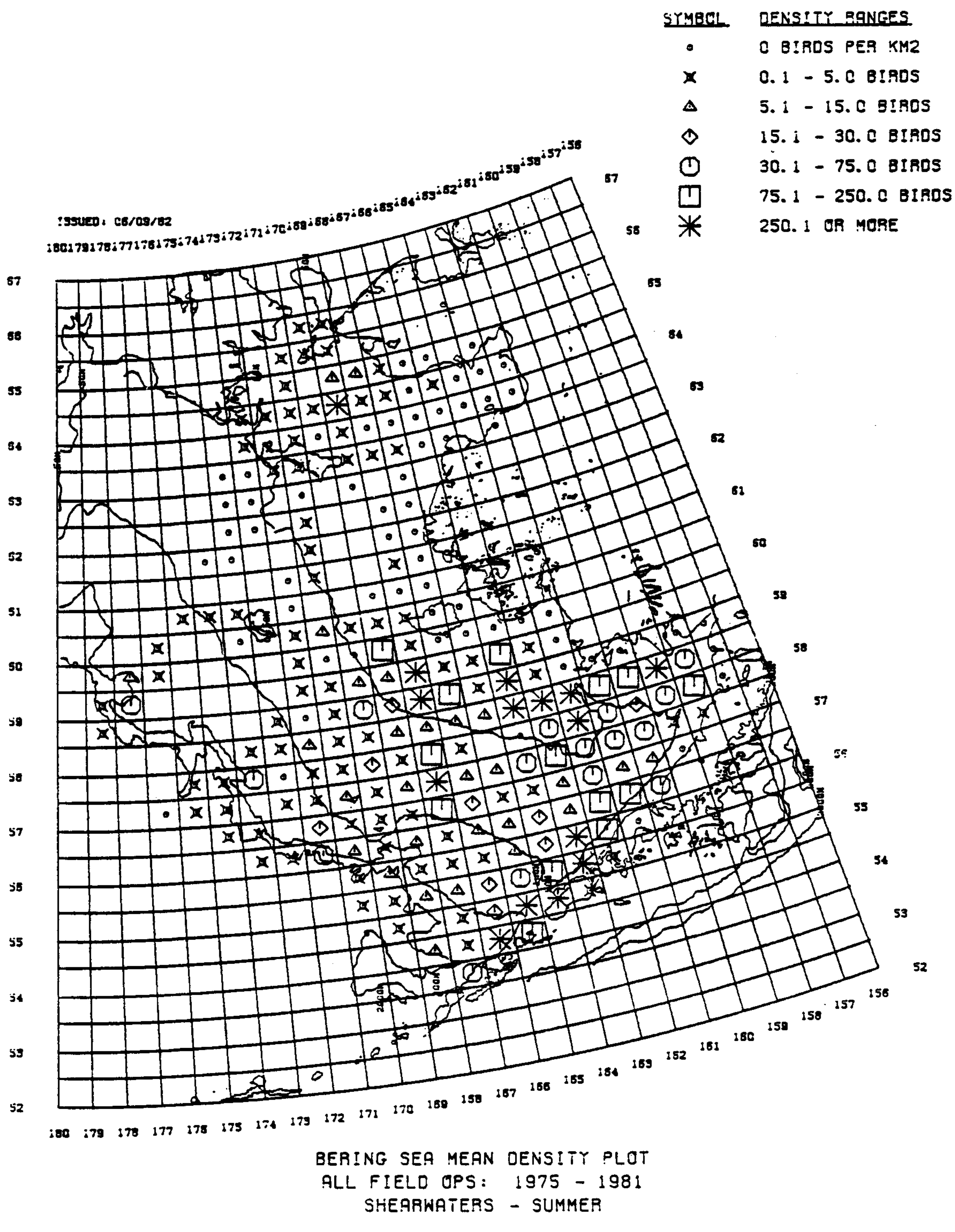
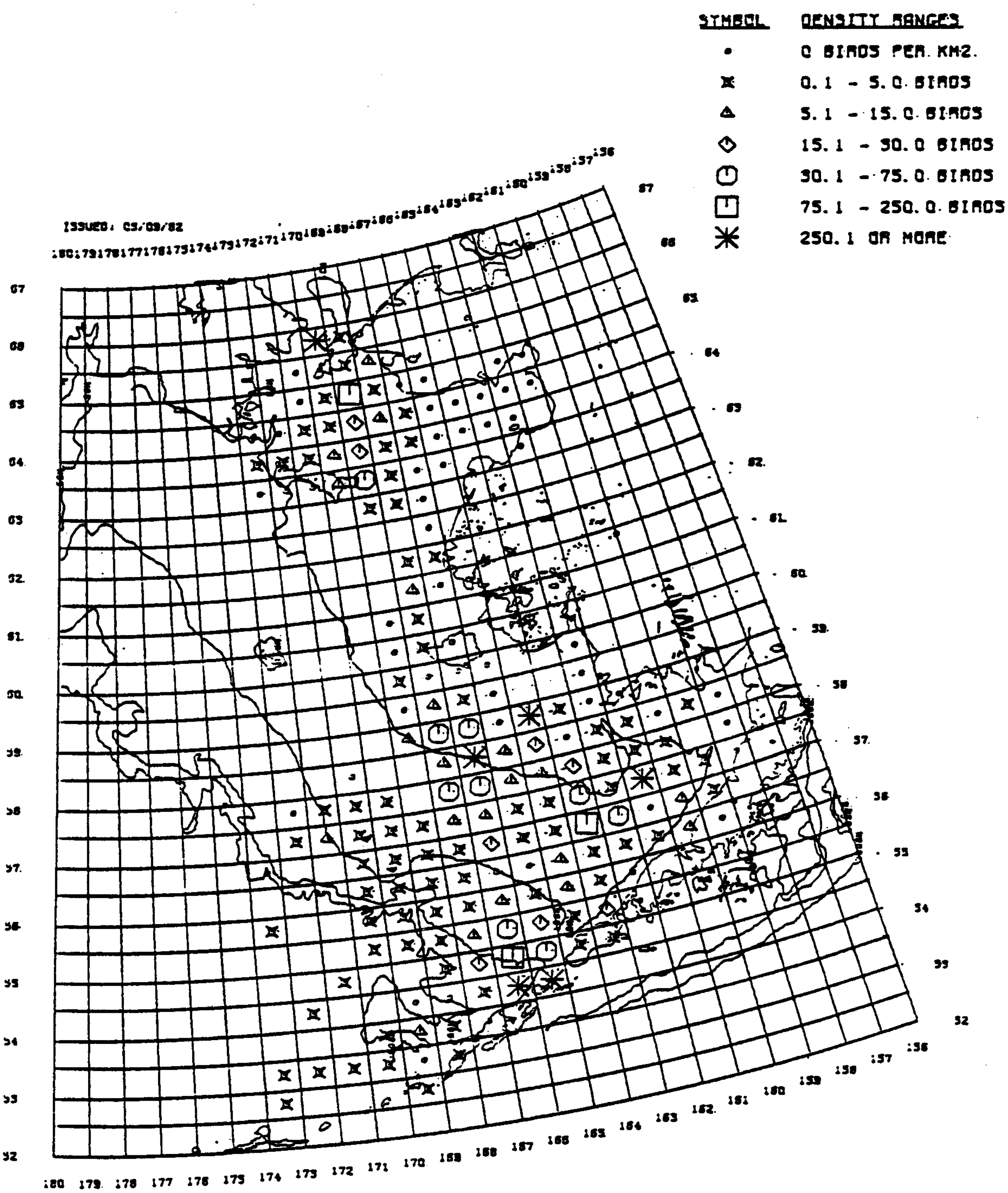
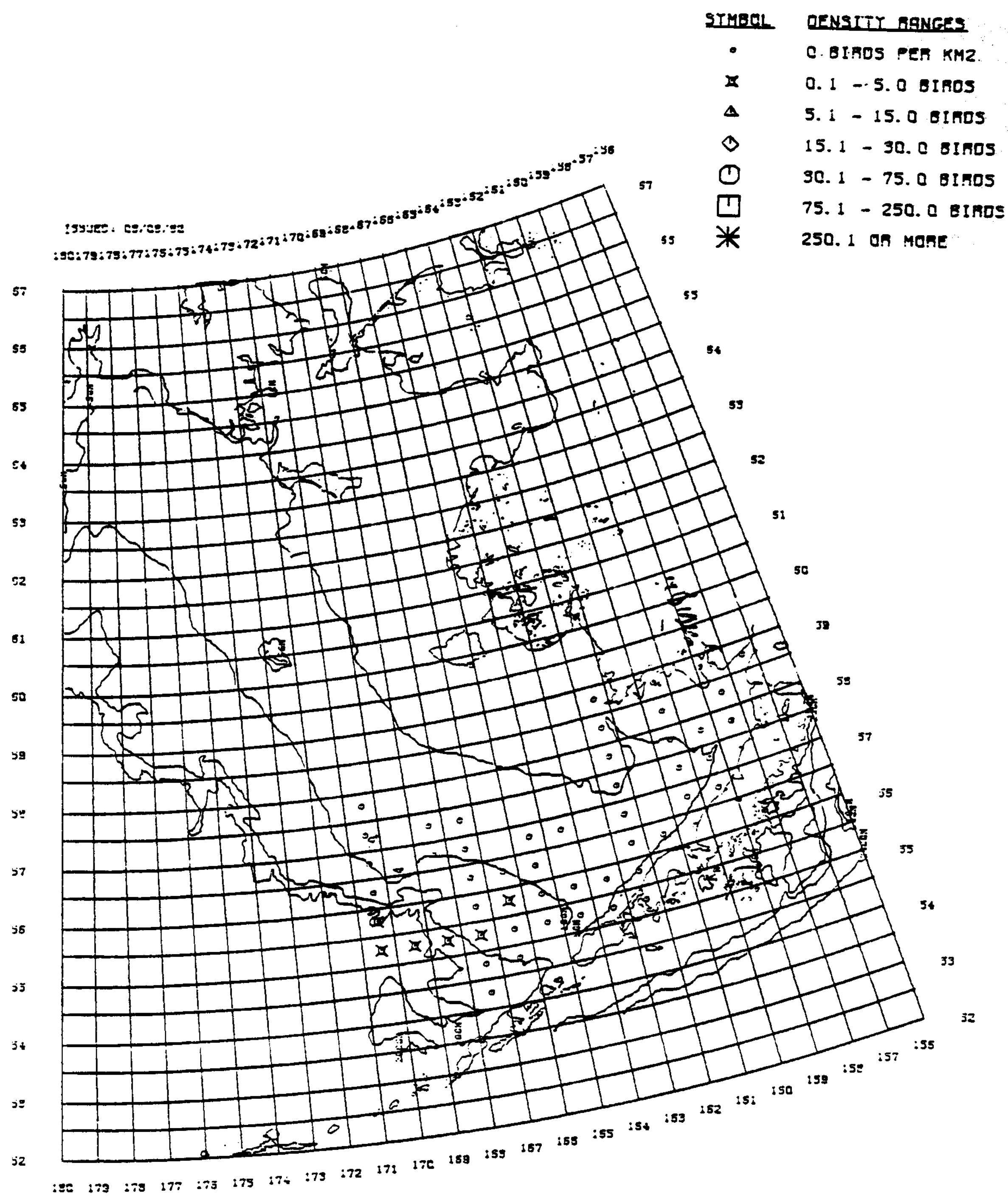

SYMBOL DENSITY RANGES
0 BIRDS PER KM2
0.1 - 5.0 BIRDS
5.1 - 15.0 BIRDS
15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
ISSUED: 06/09/82
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
SHEARWATERS - SUMMER

Figure 34



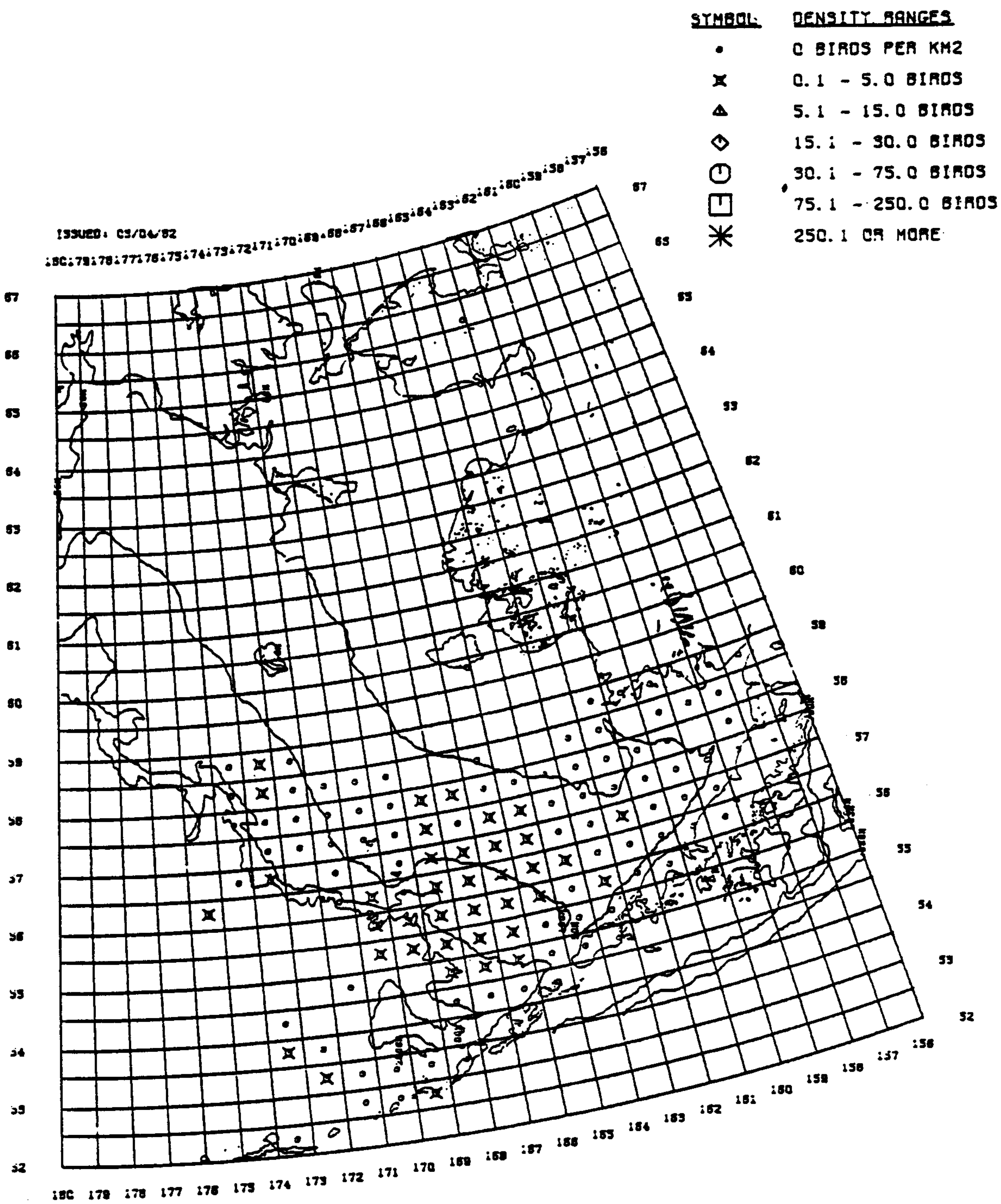
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
SHEARWATERS - AUTUMN

Figure 35



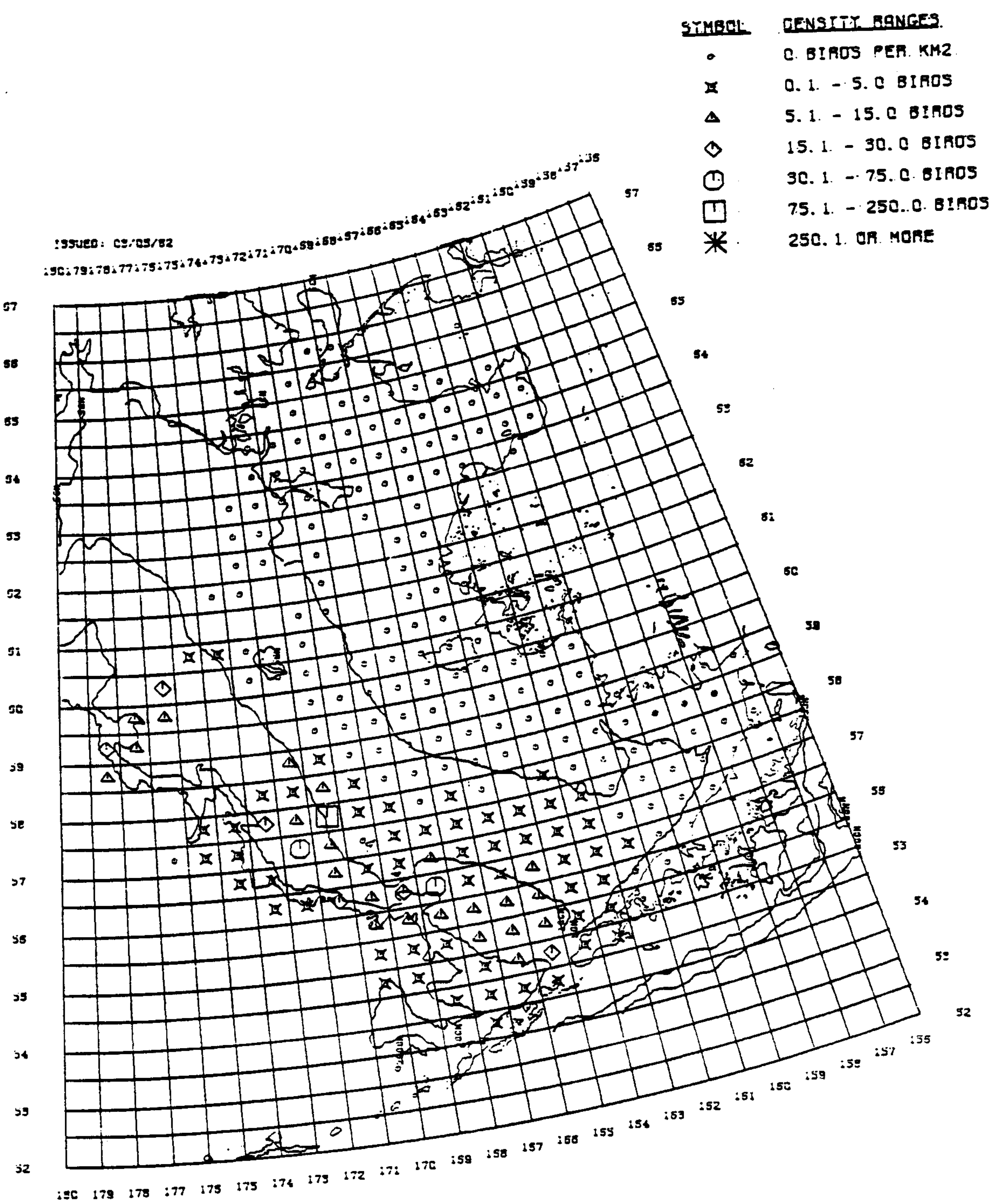
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
FORK-TAILED STORM PETRELS - WINTER

Figure 36



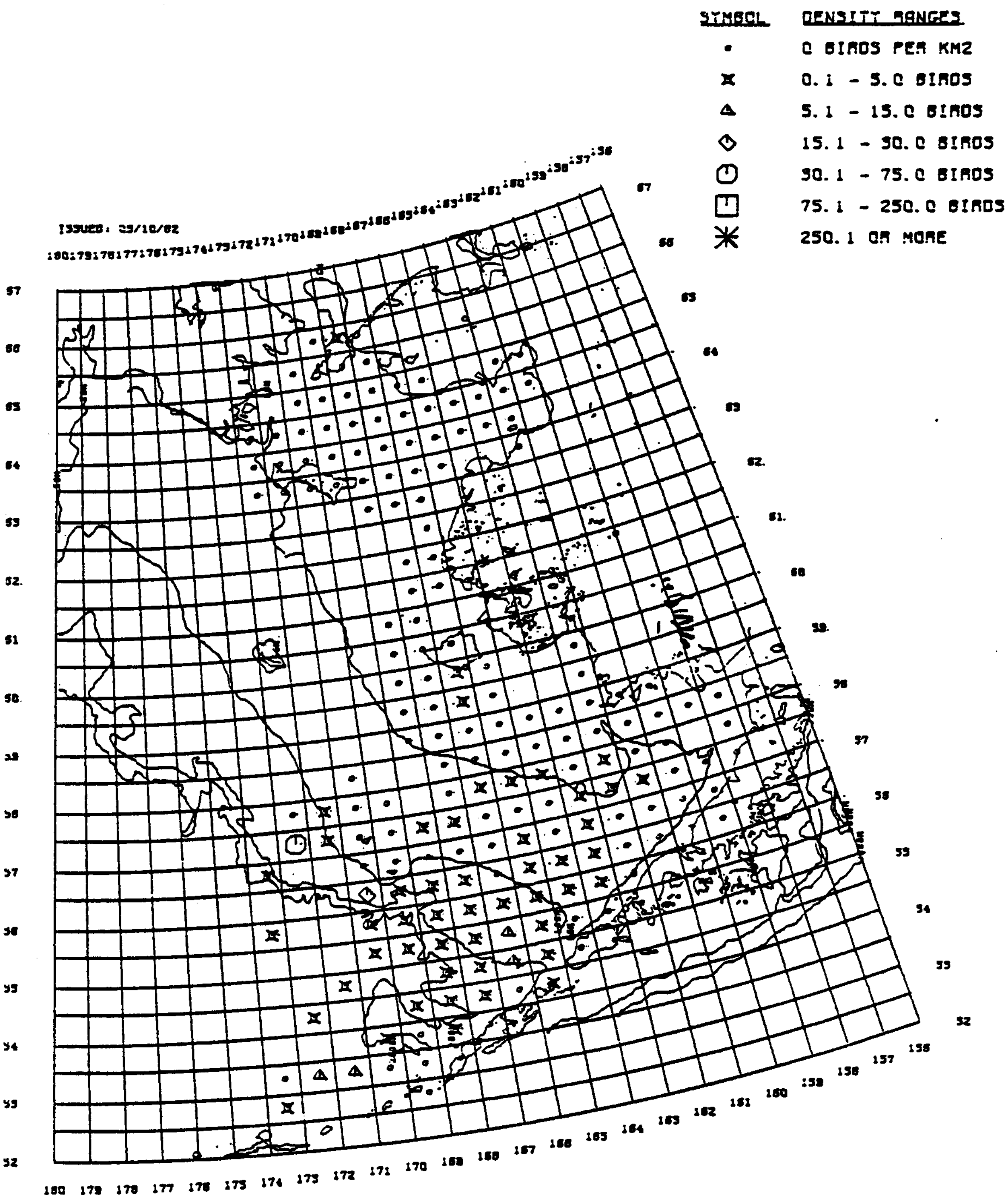
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
FORK-TAILED STORM PETRELS - SPRING

Figure 37



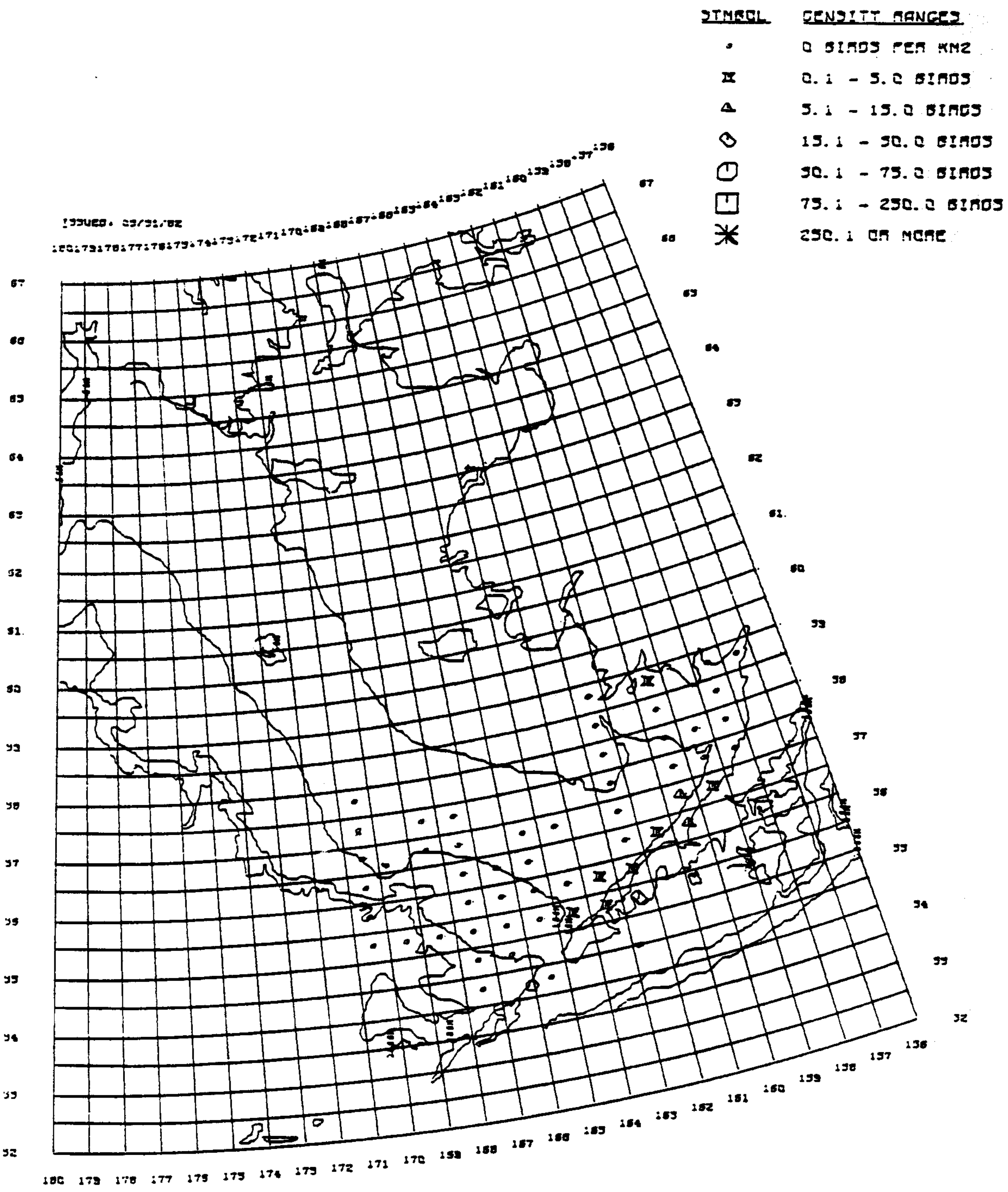
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
FORK-TAILED STORM PETRELS - SUMMER

Figure 38



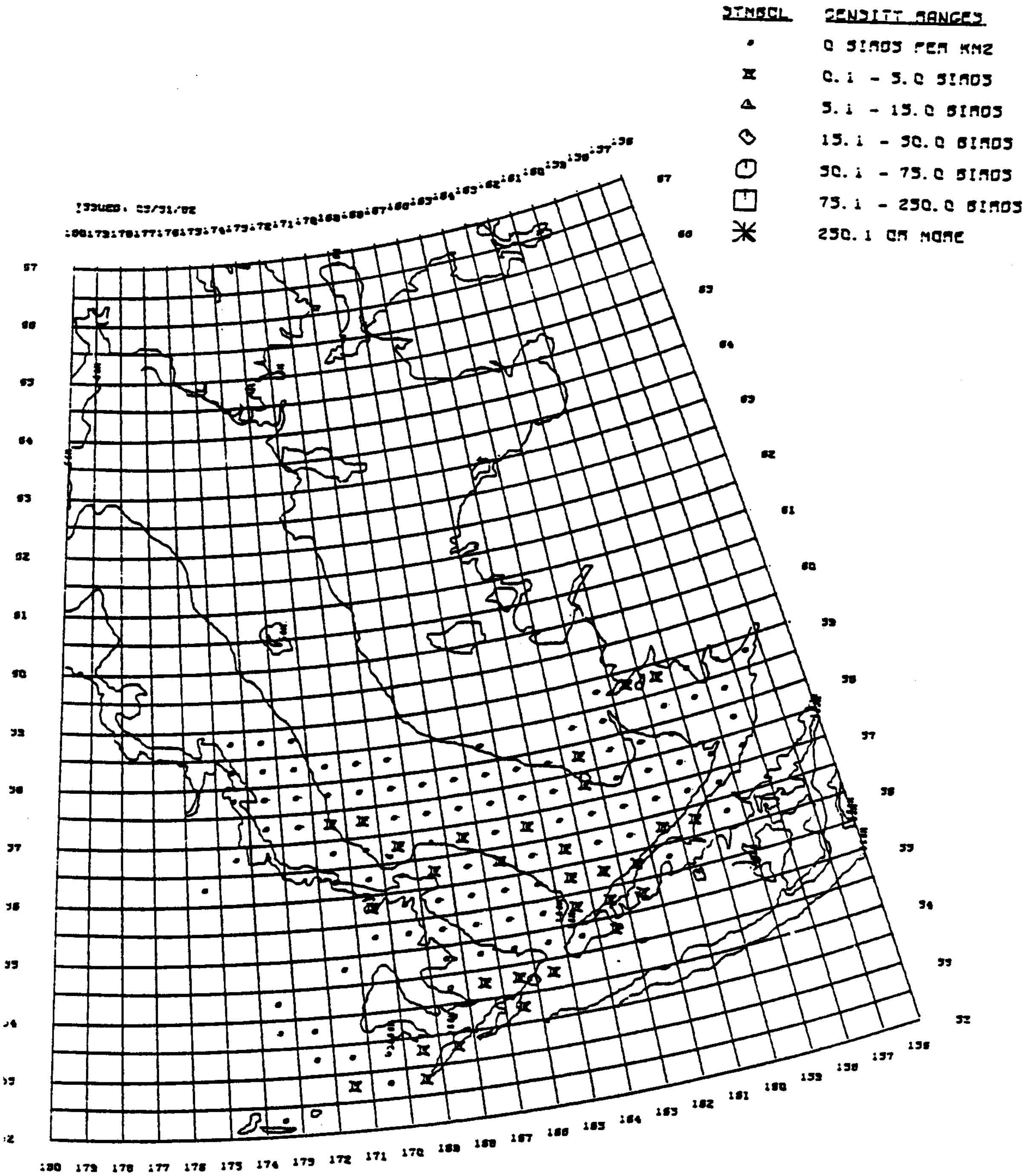
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
FORK-TAILED STORM PETRELS - AUTUMN

Figure 39



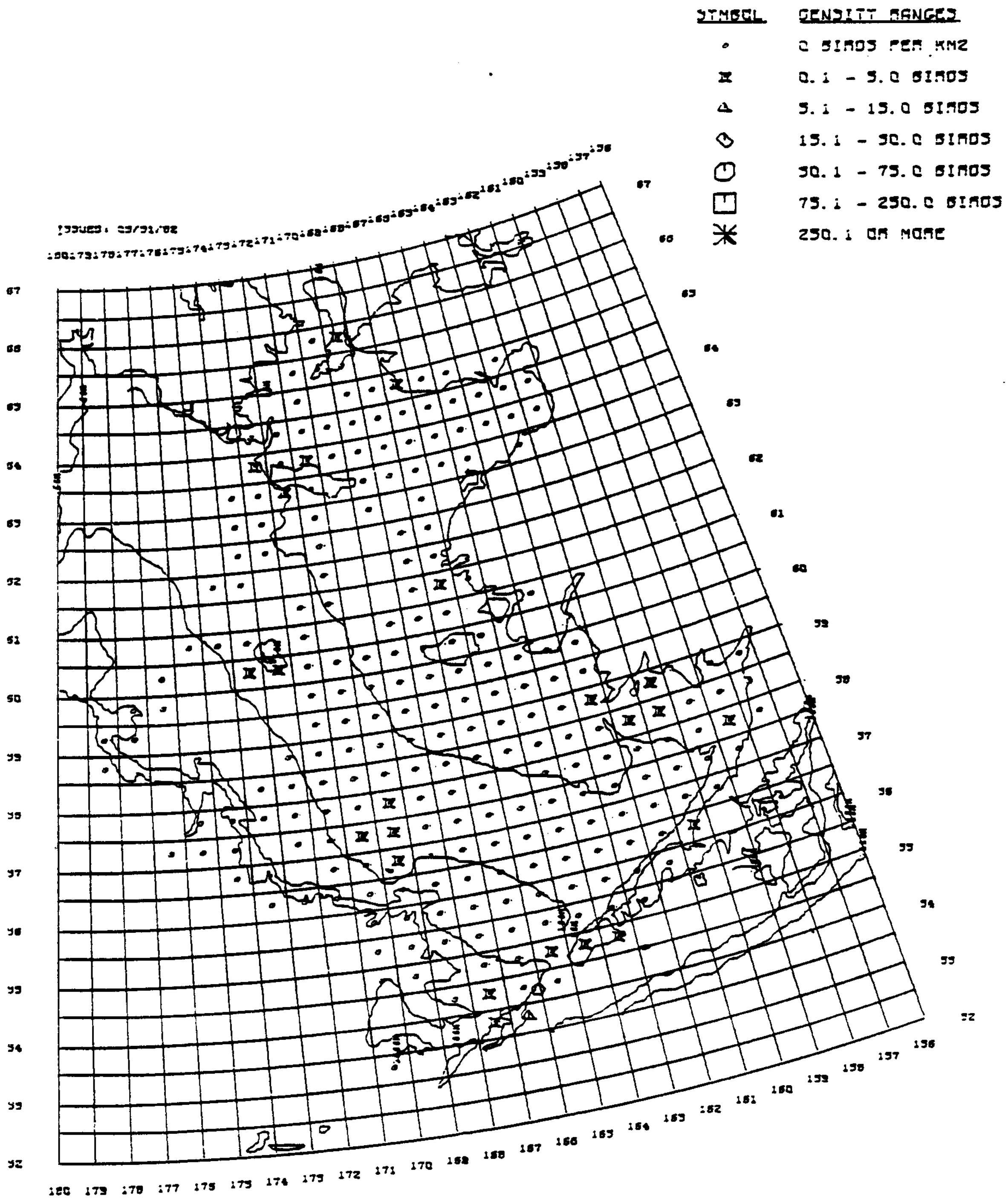
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
CORMORANTS - WINTER

Figure 40



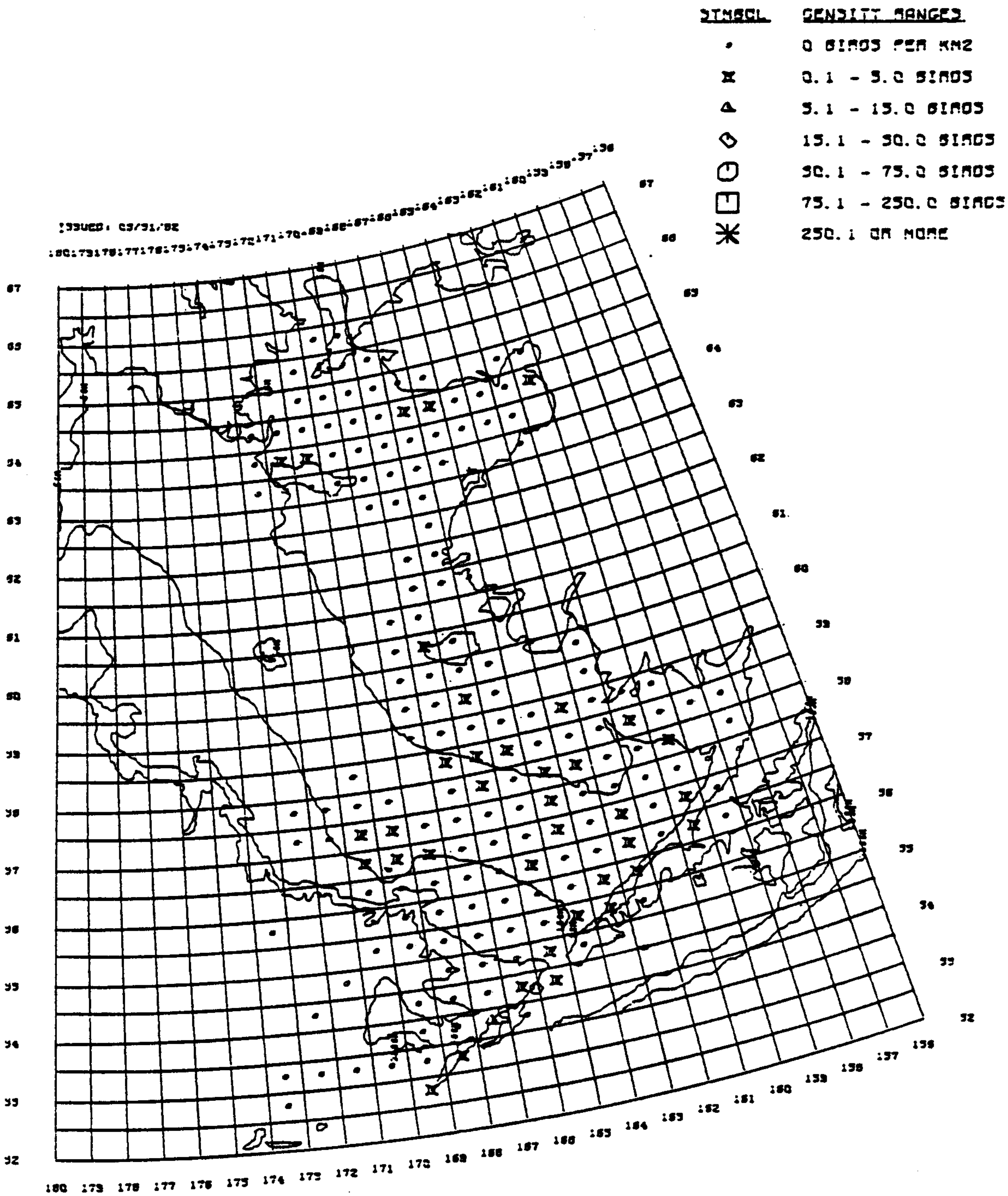
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
CORMORANTS - SPRING

Figure 41



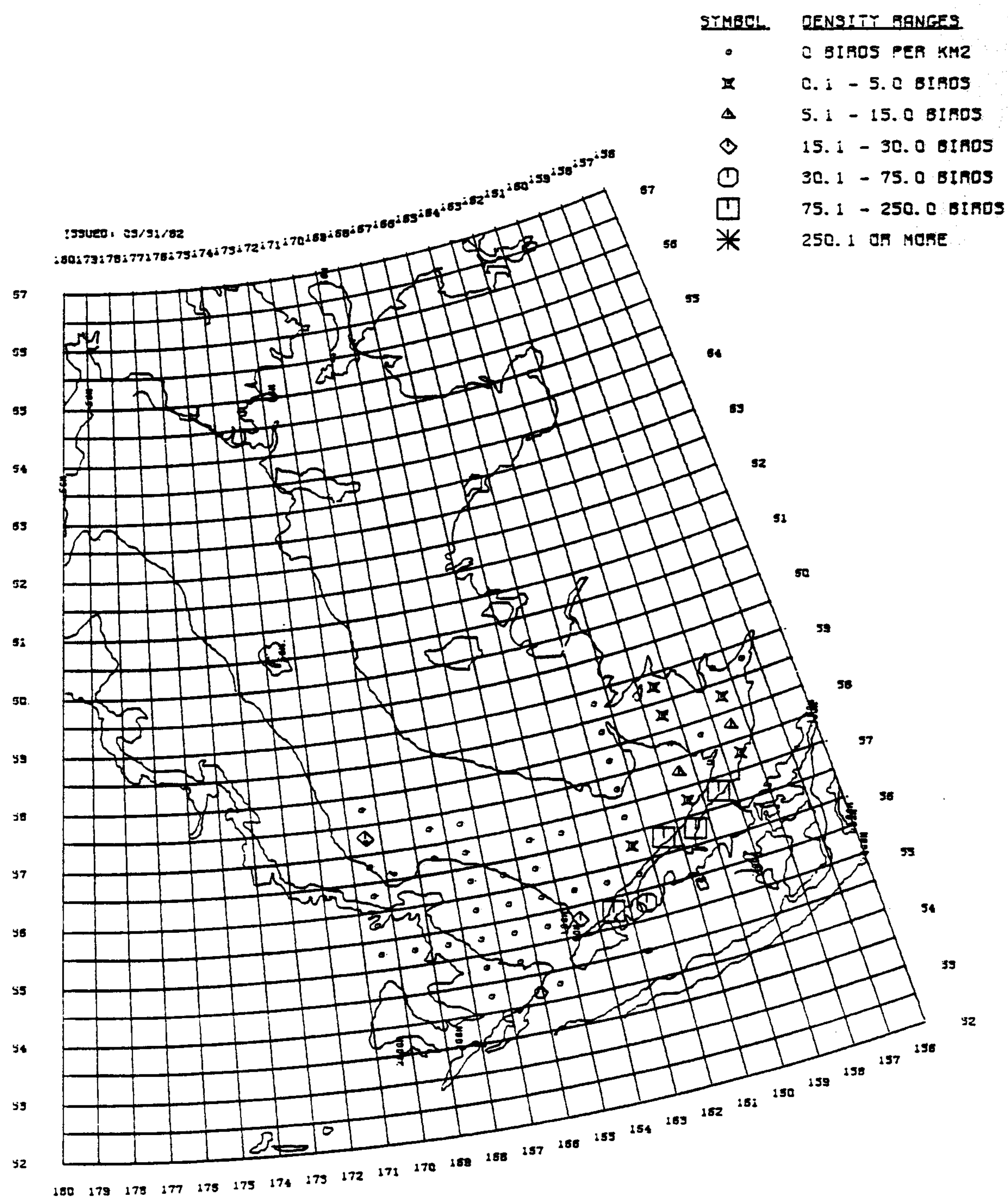
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
CORMORANTS - SUMMER

Figure 42



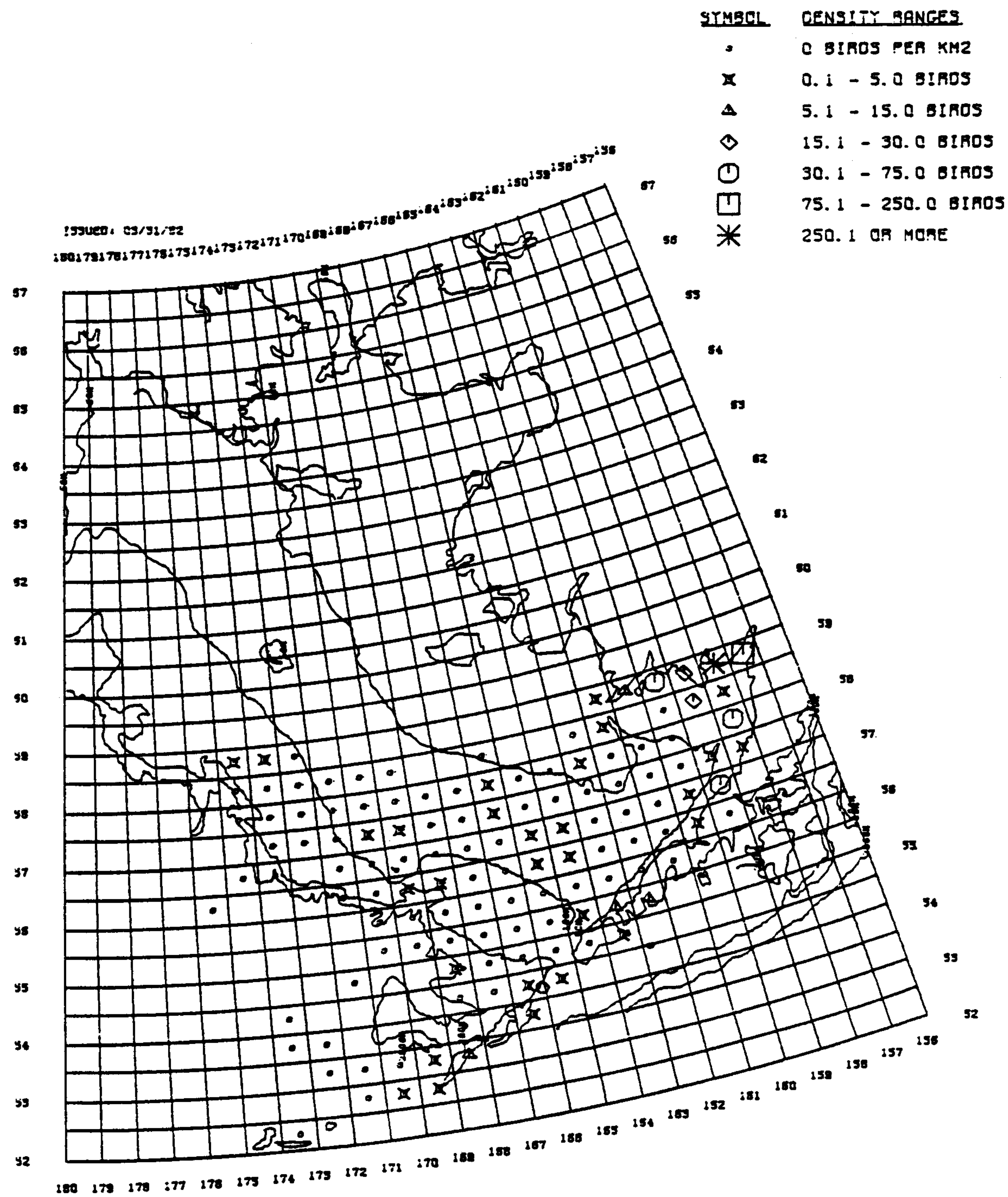
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
CORMORANTS - AUTUMN

Figure 43



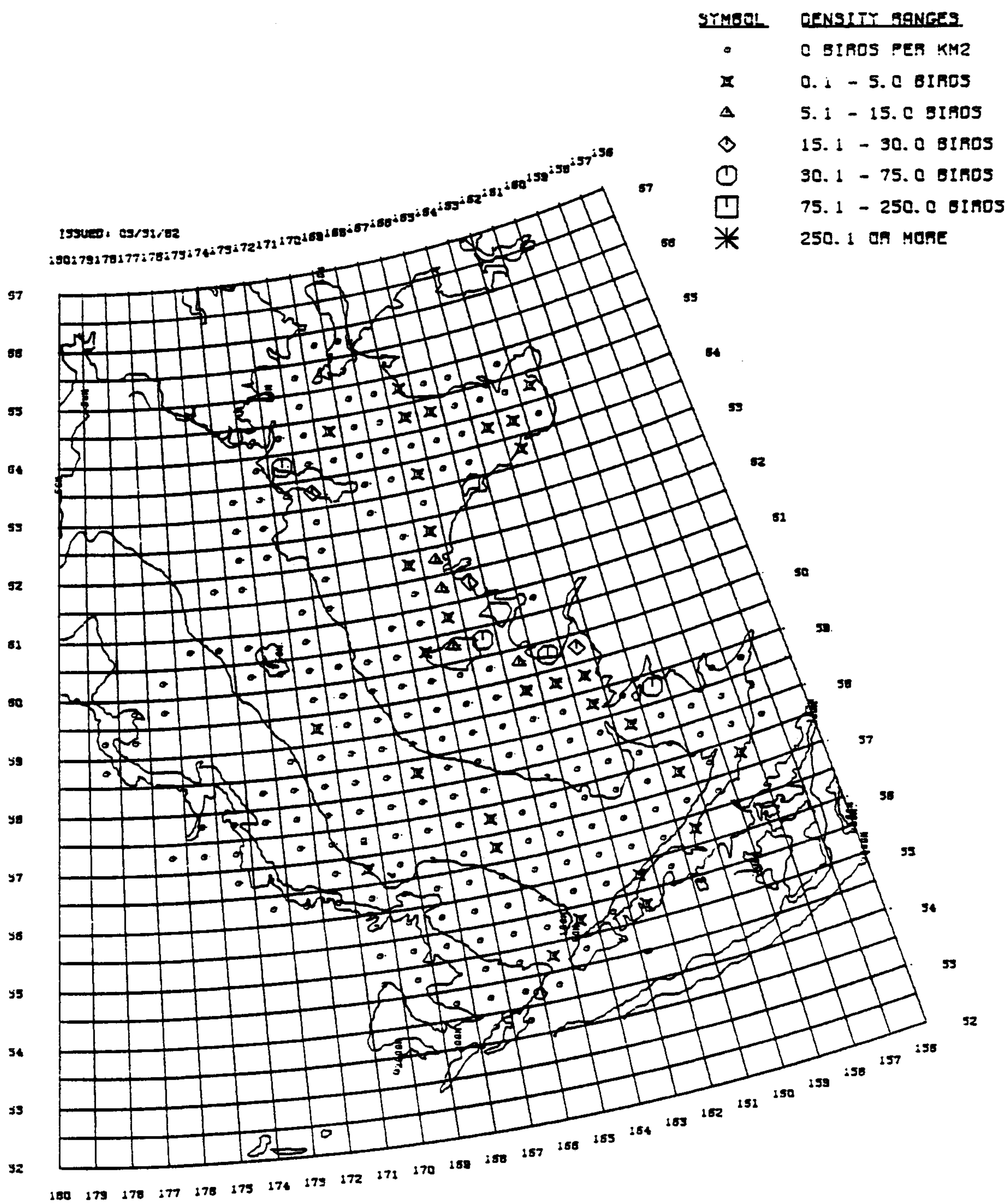
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
DUCKS, GEESE, AND SWANS - WINTER

Figure 44



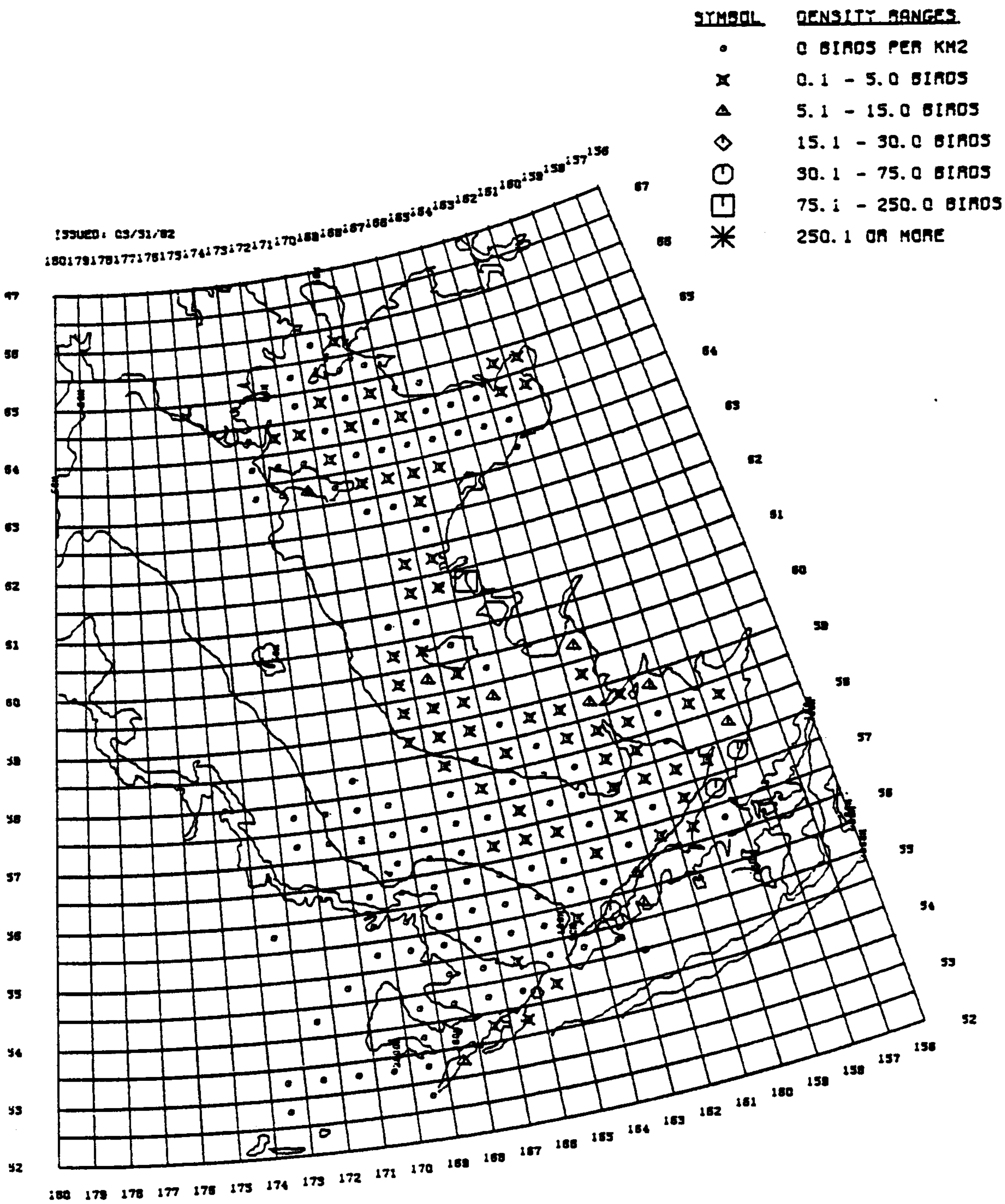
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
DUCKS, GEESE, AND SWANS - SPRING

Figure 45



BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
DUCKS, GEESE, AND SWANS - SUMMER

Figure 46



BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
DUCKS, GEESE, AND SWANS - AUTUMN

Figure 47

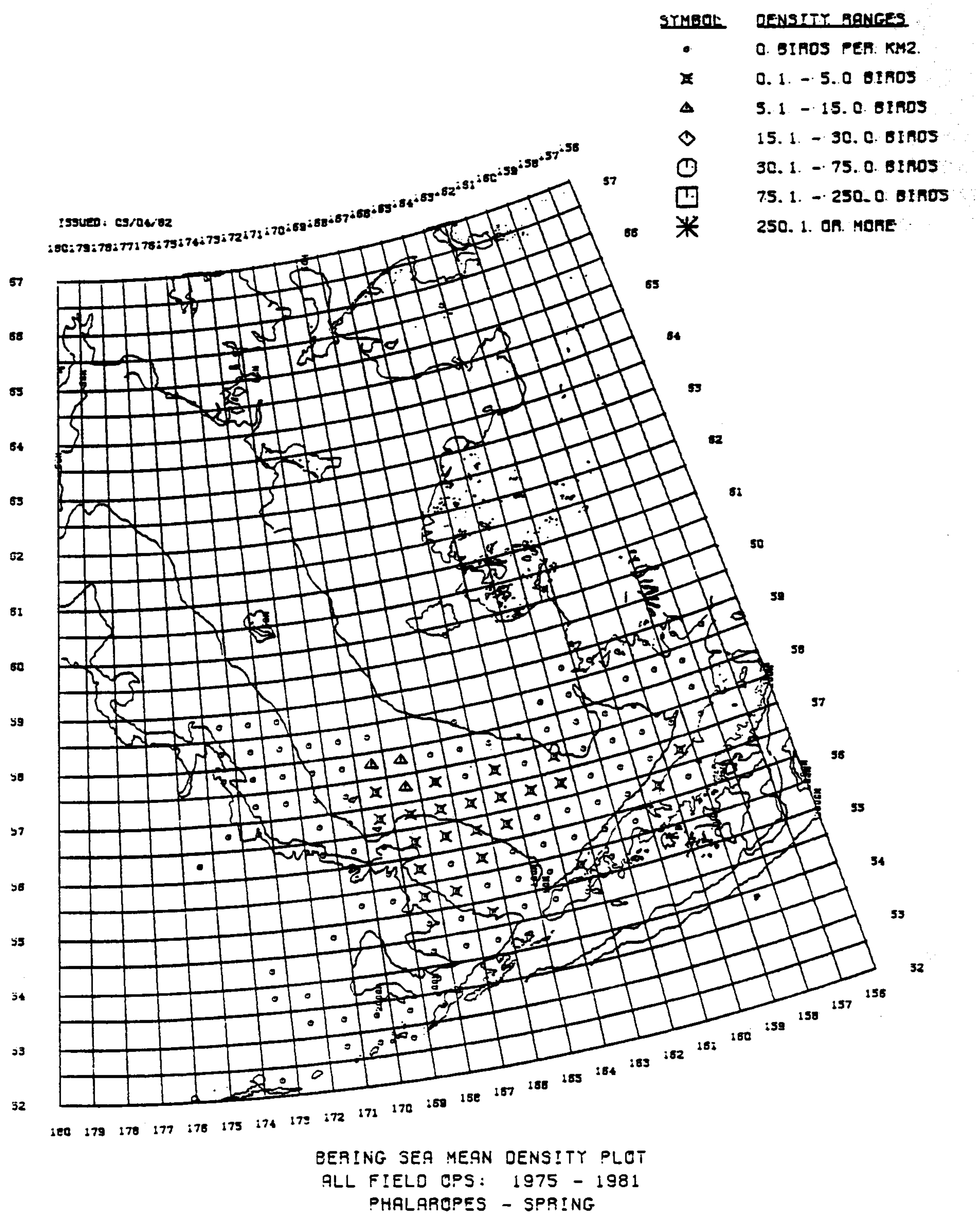

SYMBOL
DENSITY RANGES
0. BIRDS PER KM2.
0.1 - 5.0 BIRDS
5.1 - 15.0 BIRDS
15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
ISSUED: 03/04/82
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
PHALAROPES - SPRING

Figure 48

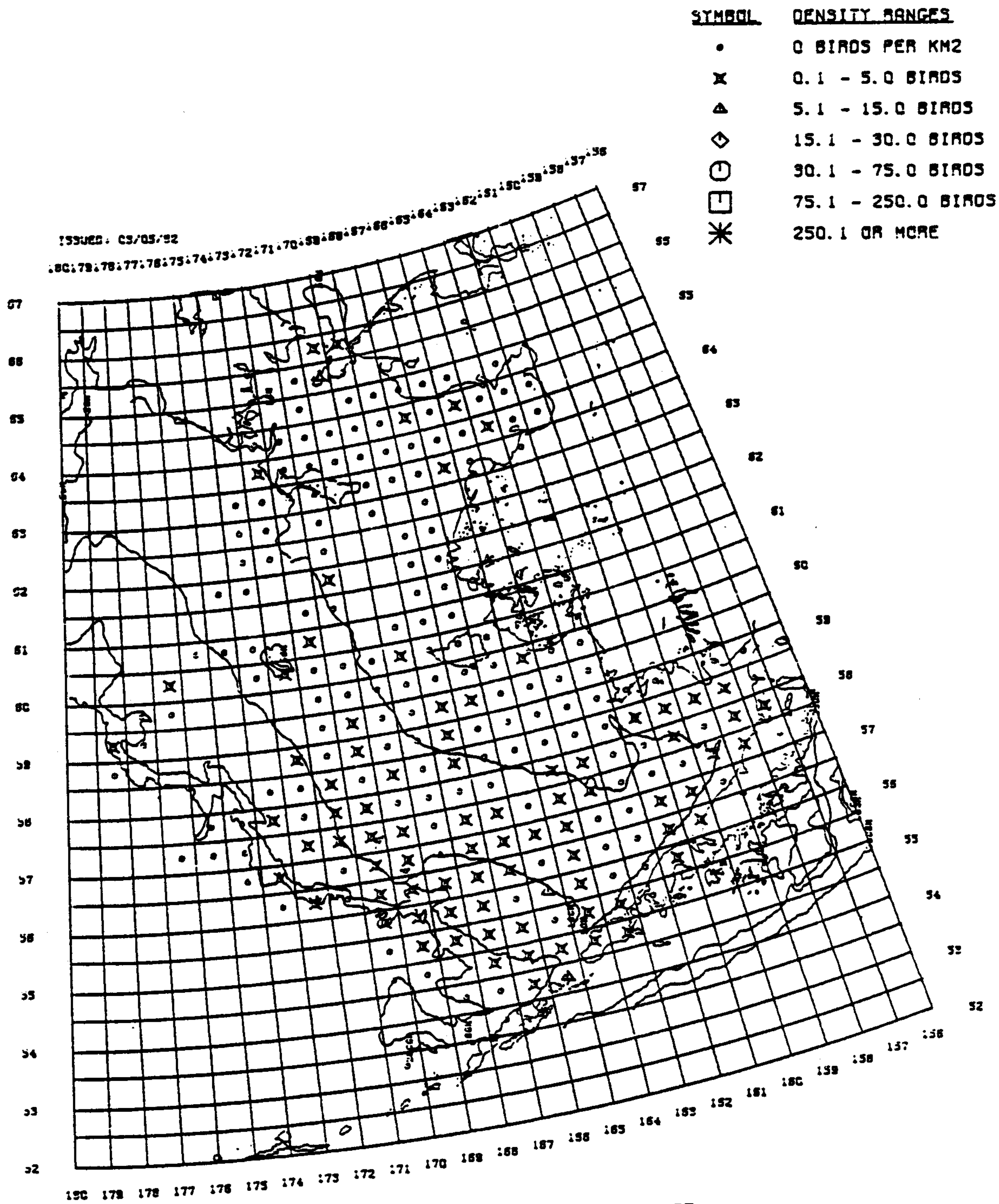
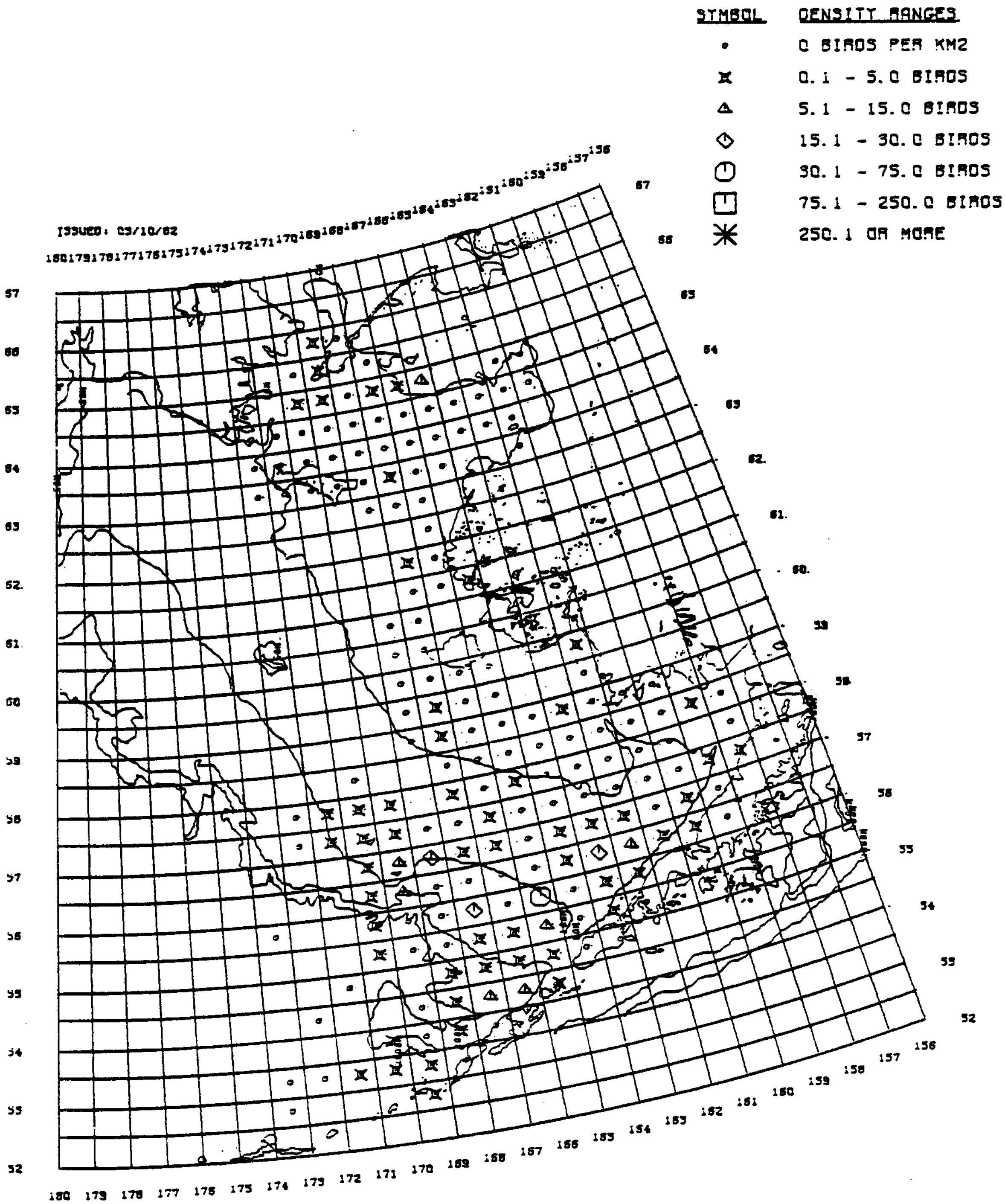

SYMBOL DENSITY RANGES
0 BIRDS PER KM2
0.1 - 5.0 BIRDS
5.1 - 15.0 BIRDS
15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
PHALAROPES - SUMMER

Figure 49



BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
PHALAROPES - AUTUMN

Figure 50

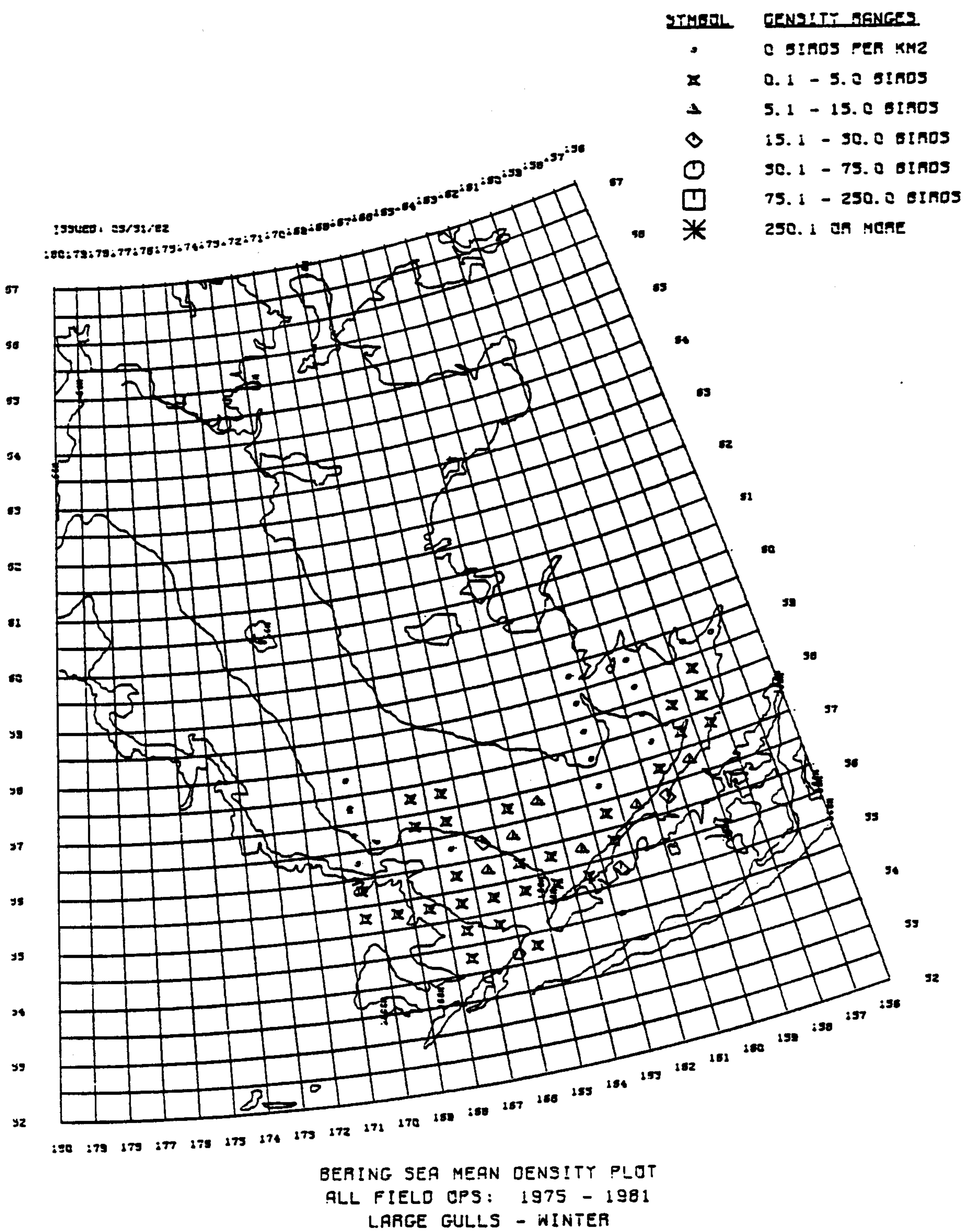
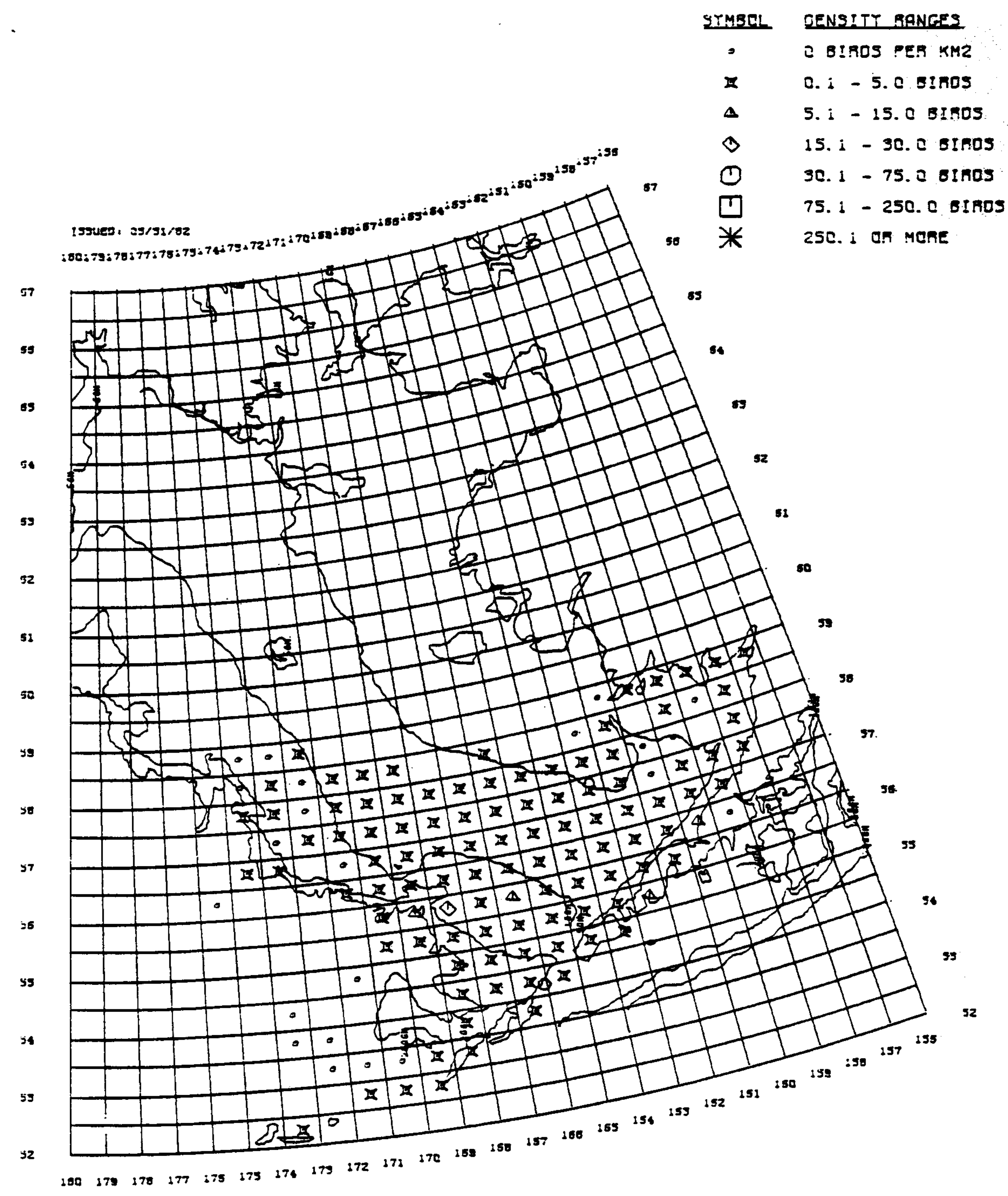
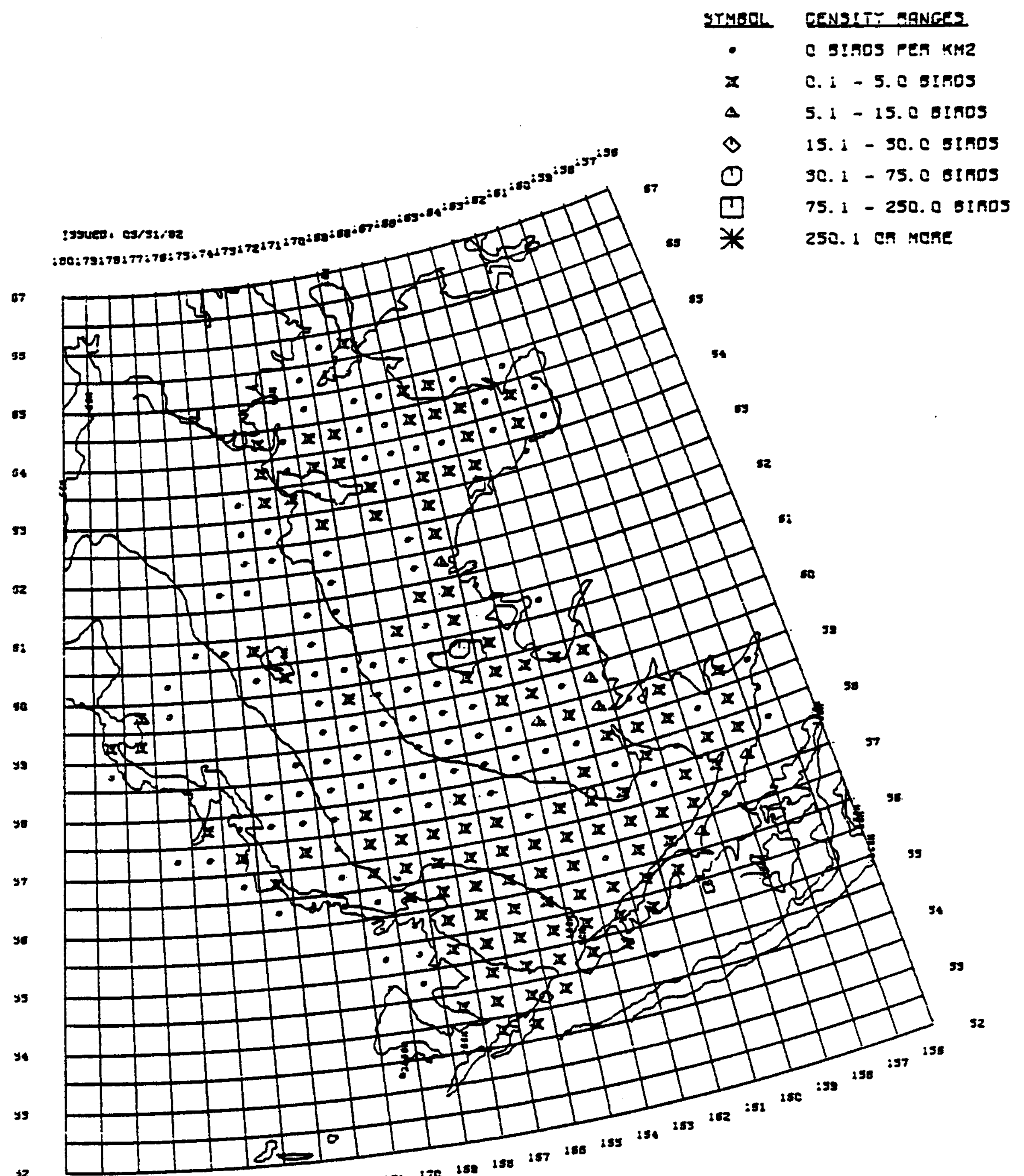

SYMBOL DENSITY RANGES
0 BIRDS PER KM2
0.1 - 5.0 BIRDS
5.1 - 15.0 BIRDS
15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
LARGE GULLS - WINTER

Figure 51



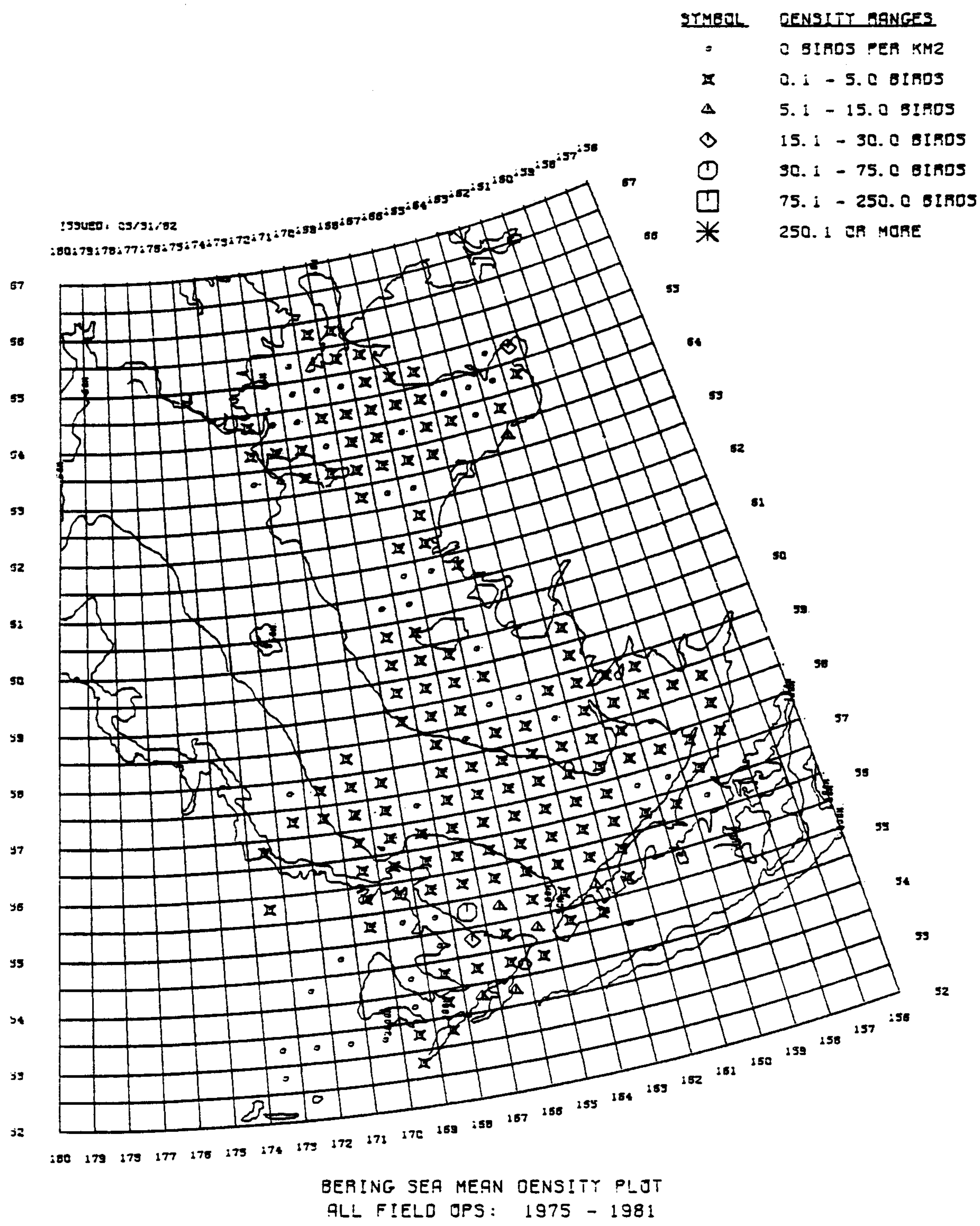
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
LARGE GULLS - SPRING

Figure 52



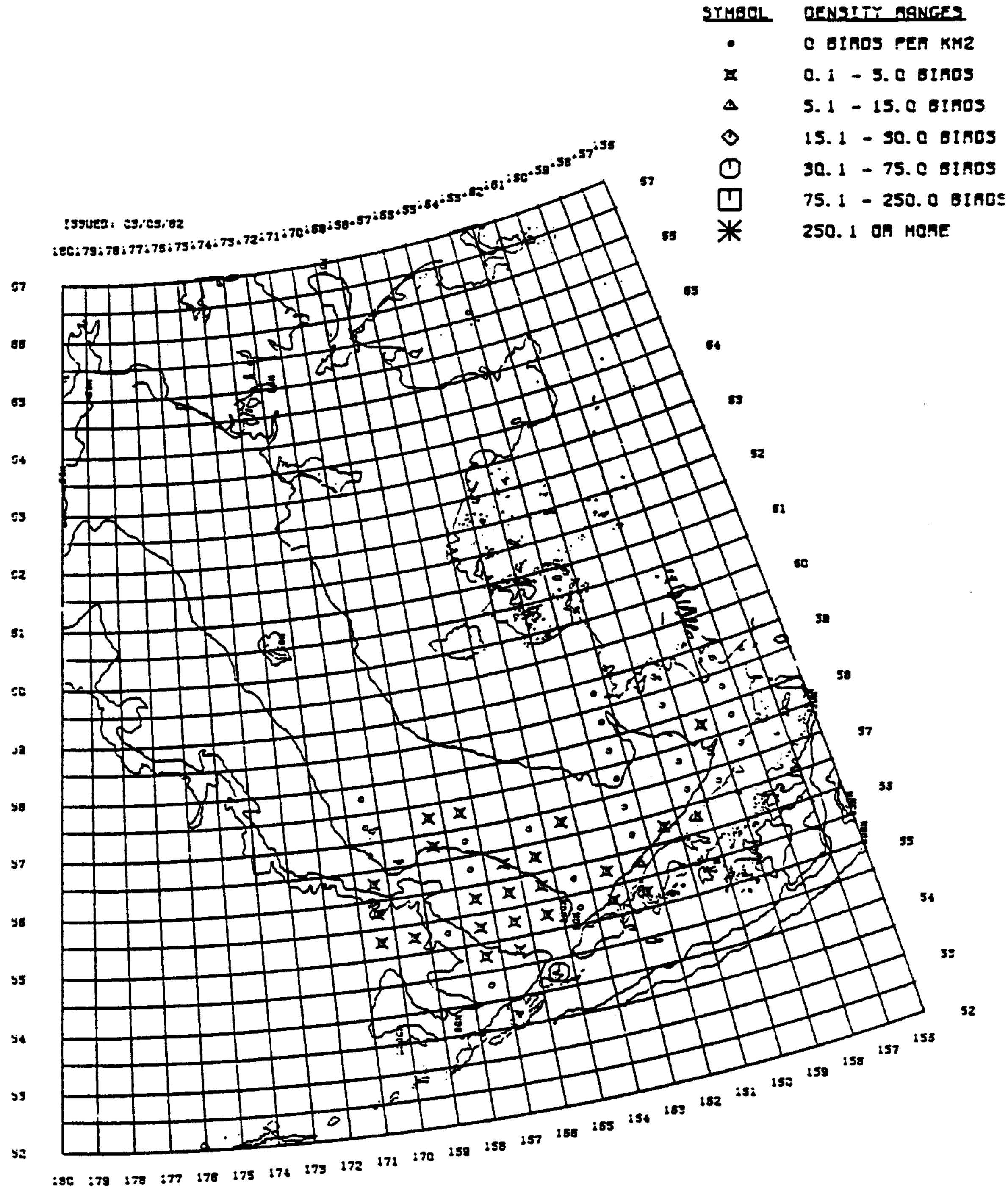
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
LARGE GULLS - SUMMER

Figure 53



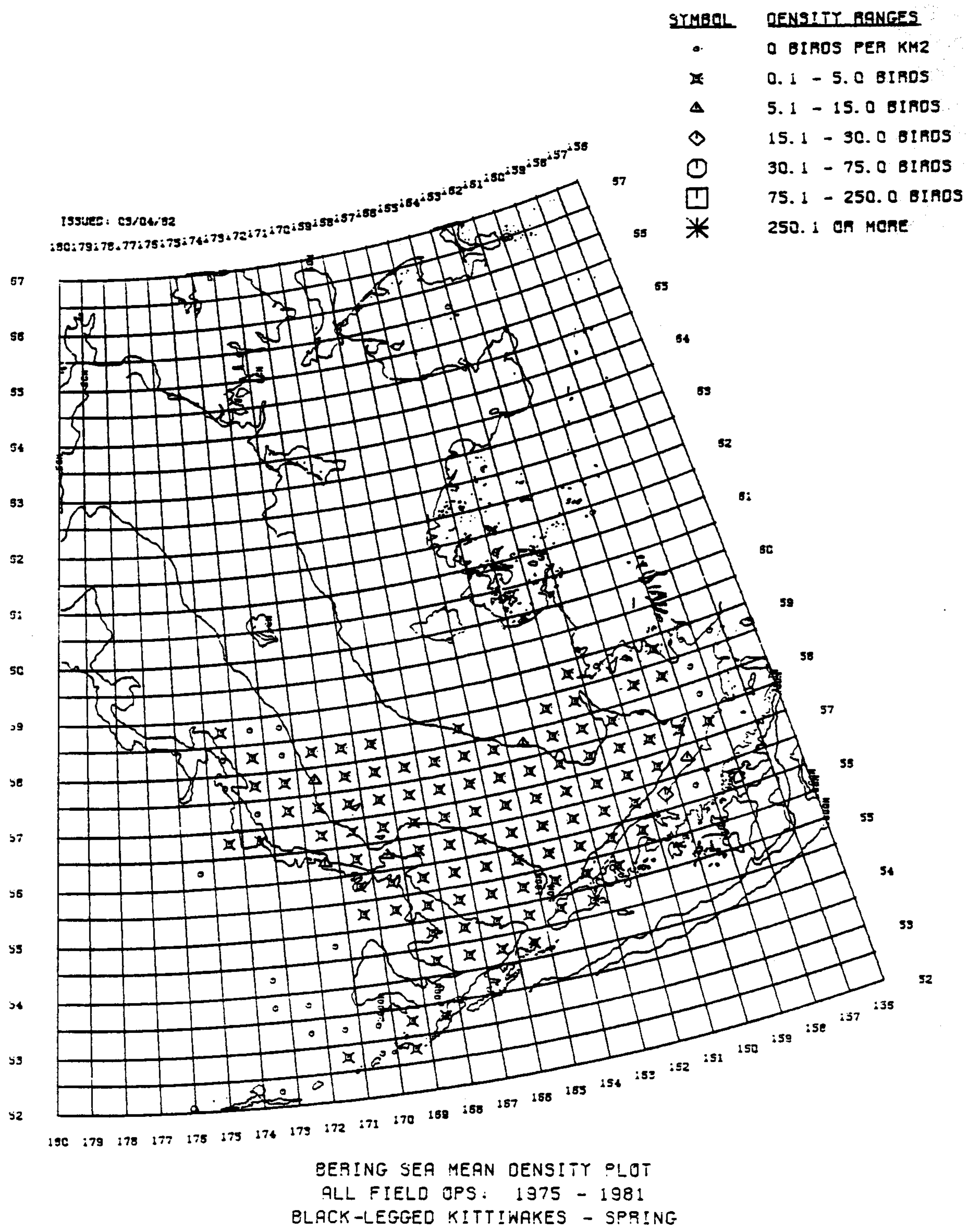
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
LARGE GULLS - AUTUMN

Figure 54



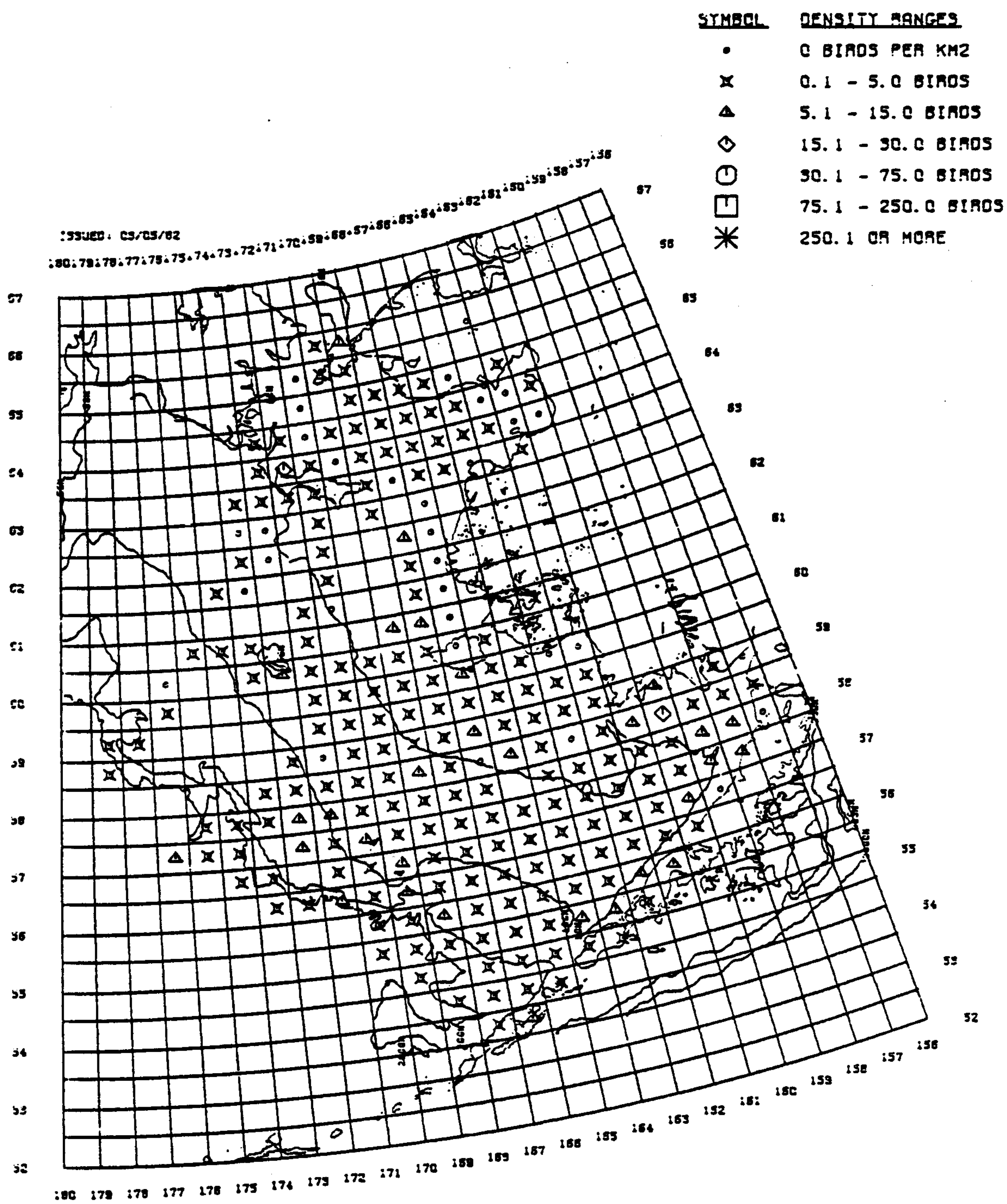
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
BLACK-LEGGED KITTIWAKES - WINTER

Figure 55



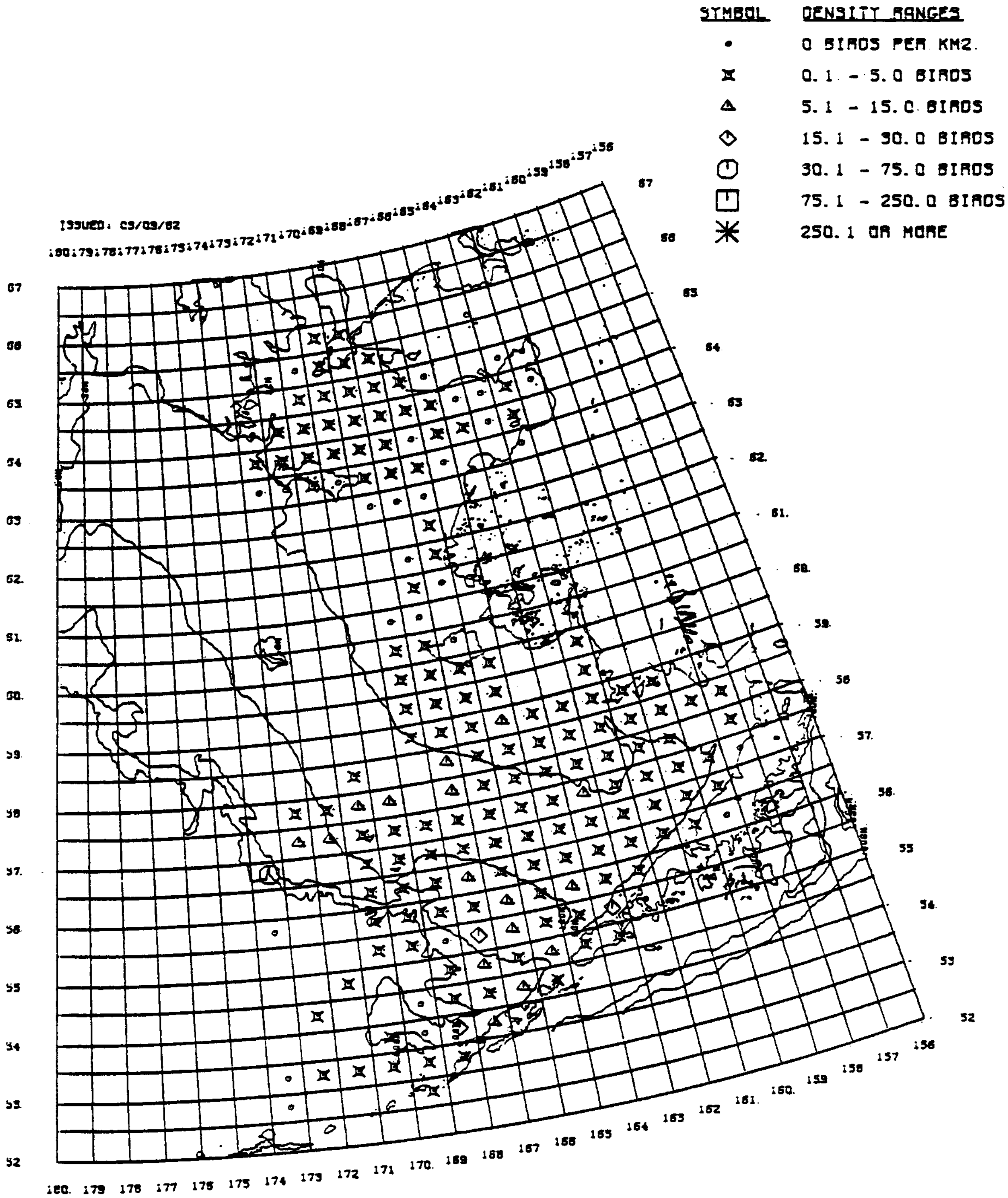
SYMBOL DENSITY RANGES
0 BIRDS PER KM2
0.1 - 5.0 BIRDS
5.1 - 15.0 BIRDS
15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
ISSUED: 03/04/82
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
BLACK-LEGGED KITTIWAKES - SPRING

Figure 56



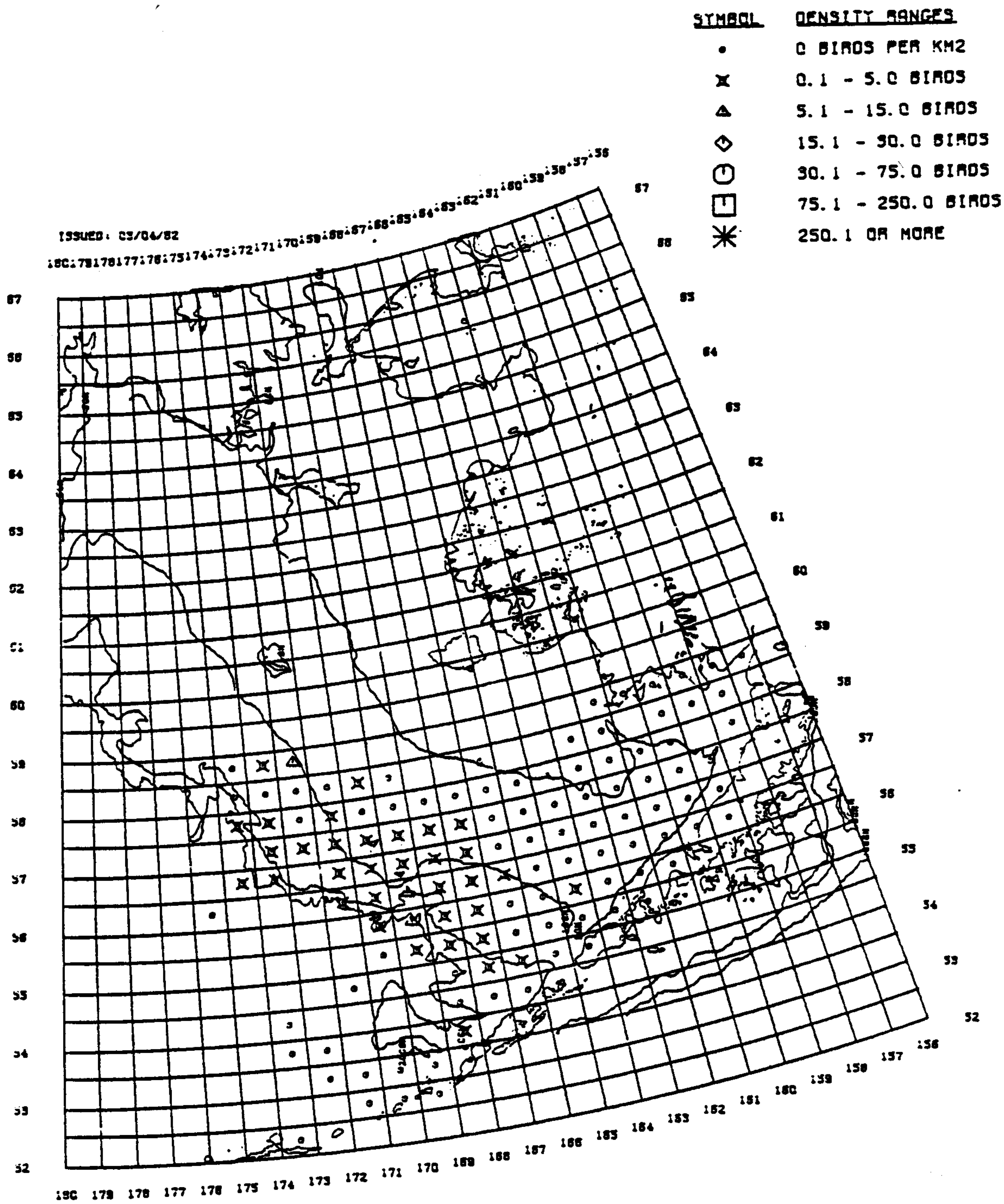
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
BLACK-LEGGED KITTIWAKES - SUMMER

Figure 57



BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
BLACK-LEGGED KITTIWAKES - AUTUMN

Figure 58



BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
RED-LEGGED KITTIWAKES - SPRING

Figure 59

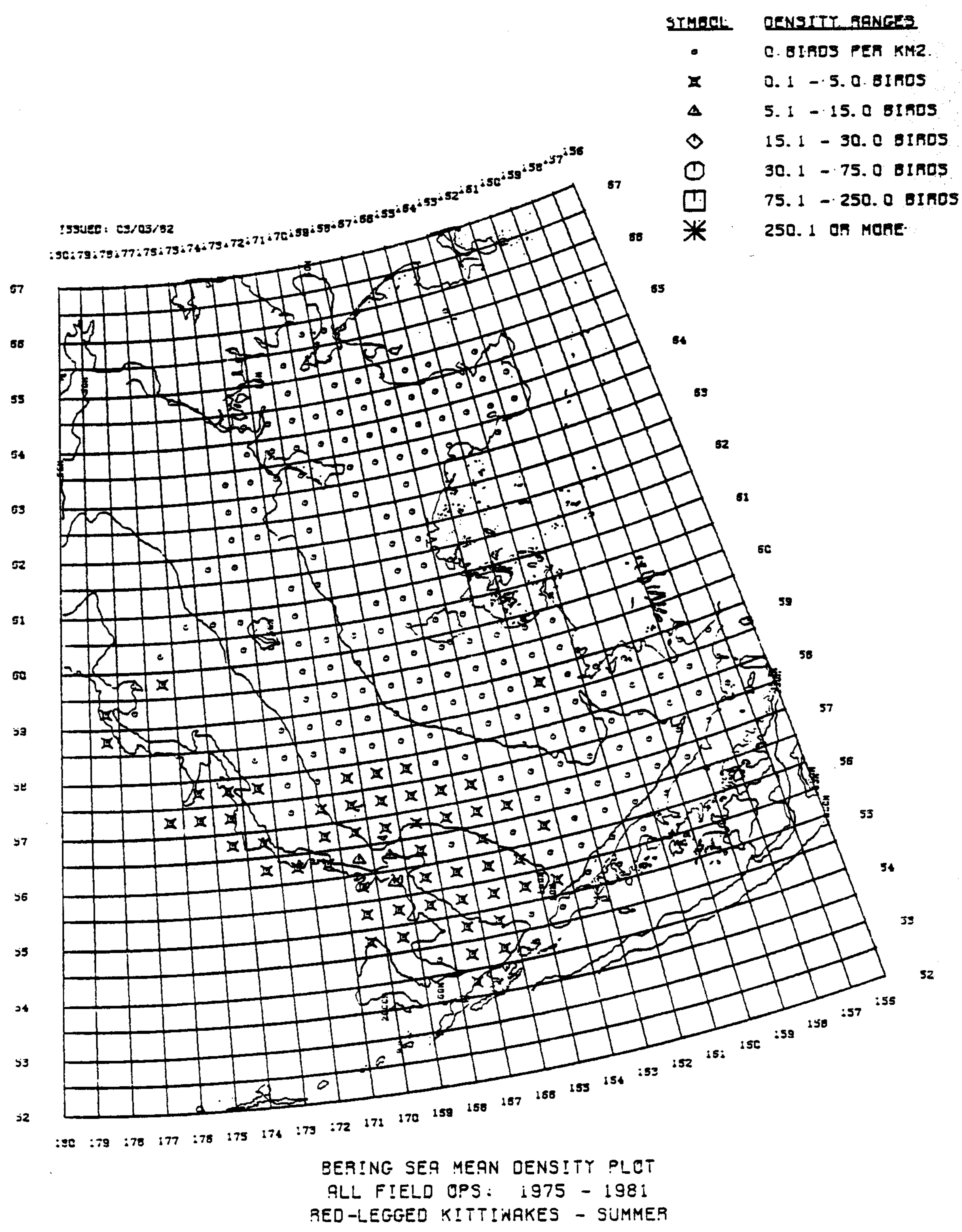
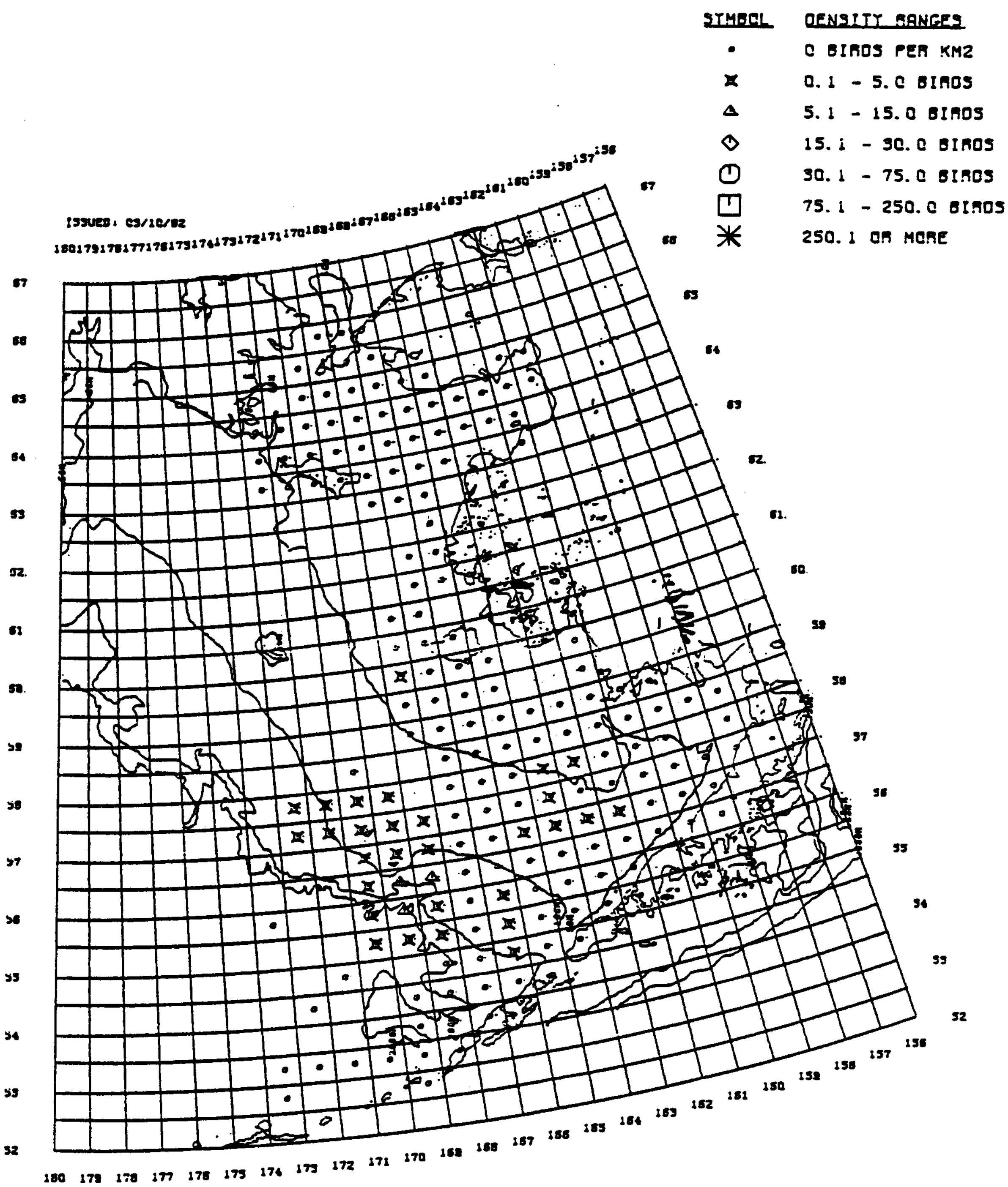

SYMBOL DENSITY RANGES
0 BIRDS PER KM2.
0.1 - 5.0 BIRDS
5.1 - 15.0 BIRDS
15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
ISSUED: 03/03/82
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
RED-LEGGED KITTIWAKES - SUMMER

Figure 60



BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
RED-LEGGED KITTIWAKES - AUTUMN

Figure 61

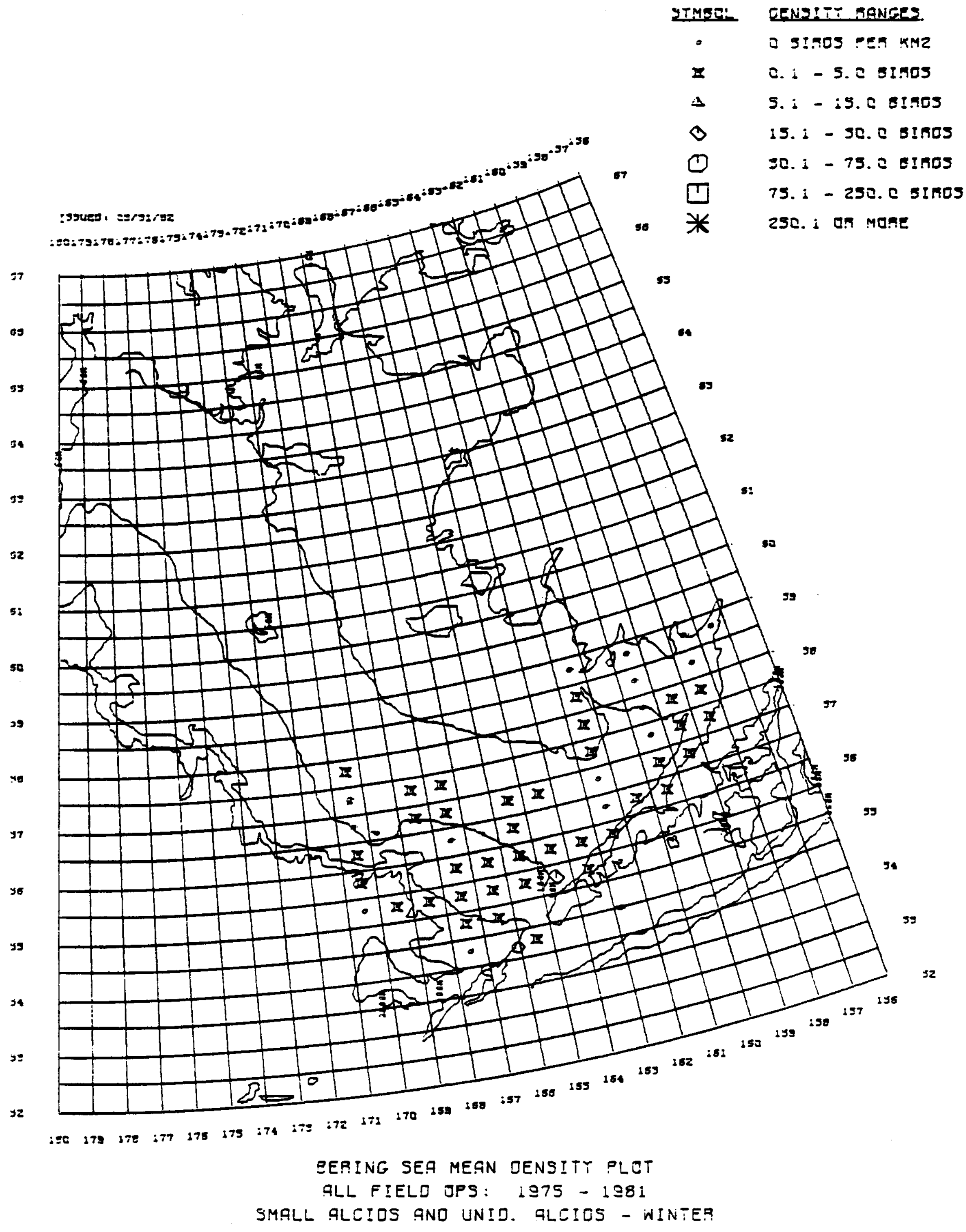
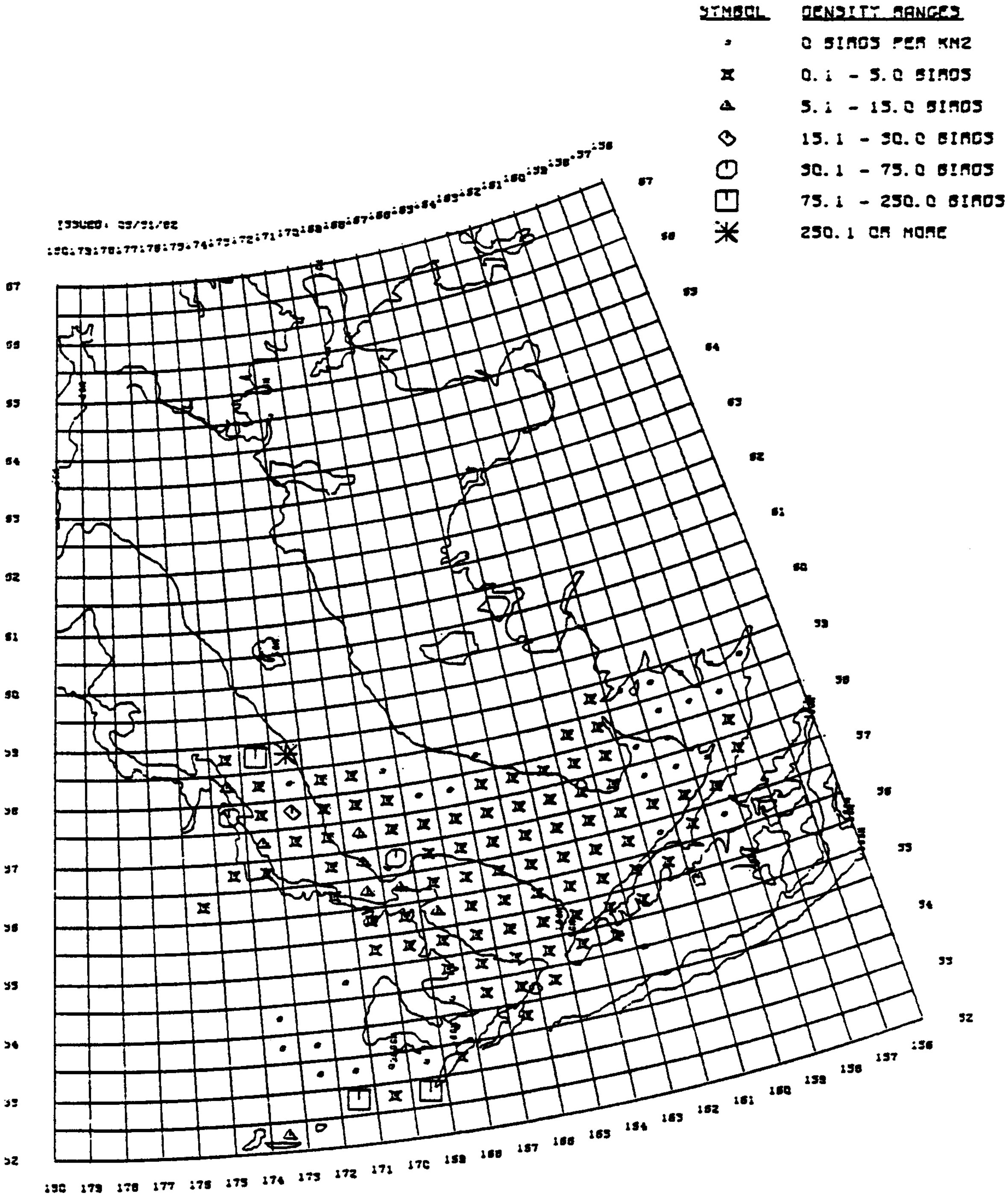
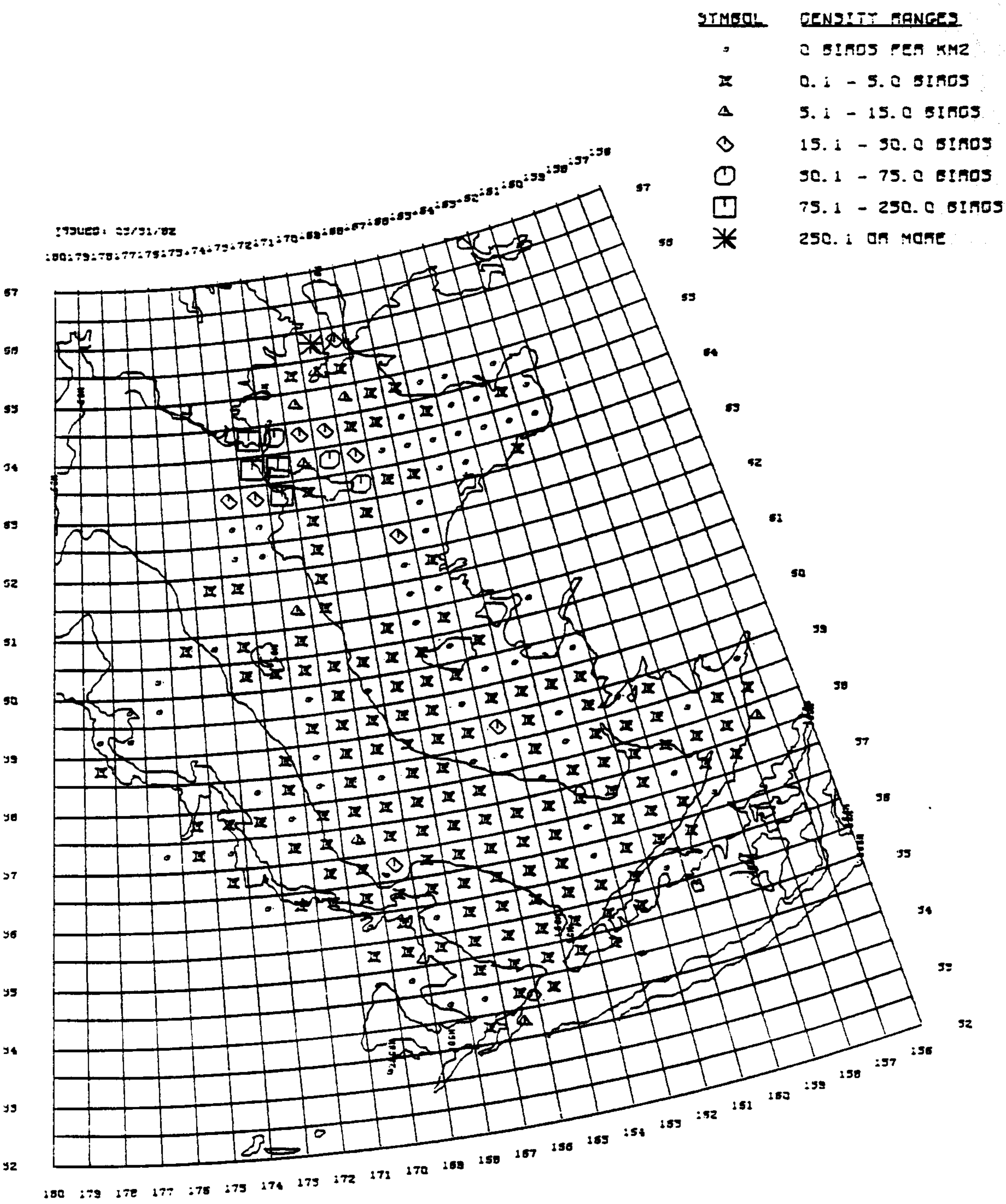

SYMBOL DENSITY RANGES
0 BIRDS PER KM2
0.1 - 5.0 BIRDS
5.1 - 15.0 BIRDS
15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
SMALL ALCIDS AND UNID. ALCIDS - WINTER

Figure 62



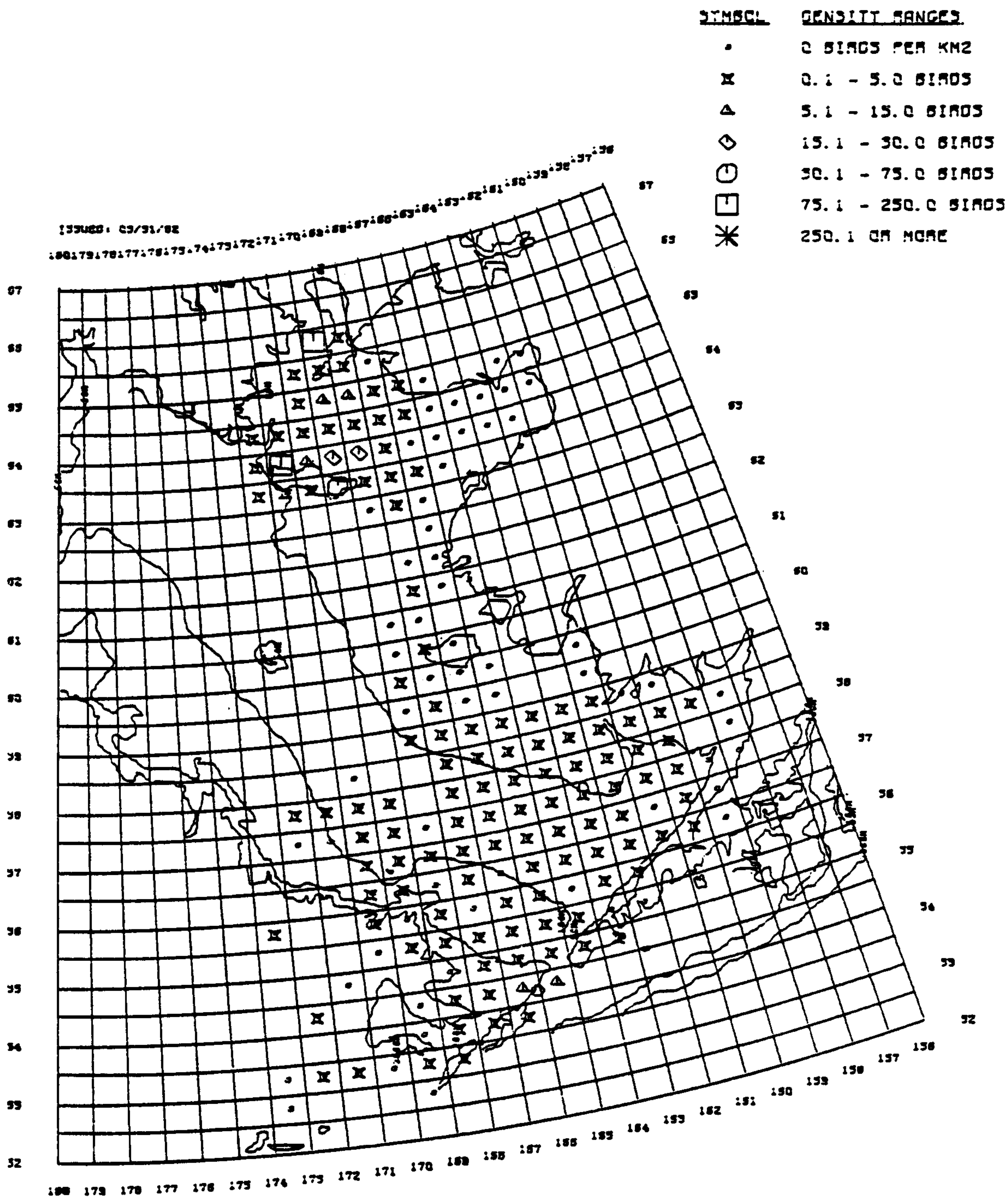
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
SMALL ALCIDS AND UNID. ALCIDS - SPRING

Figure 63



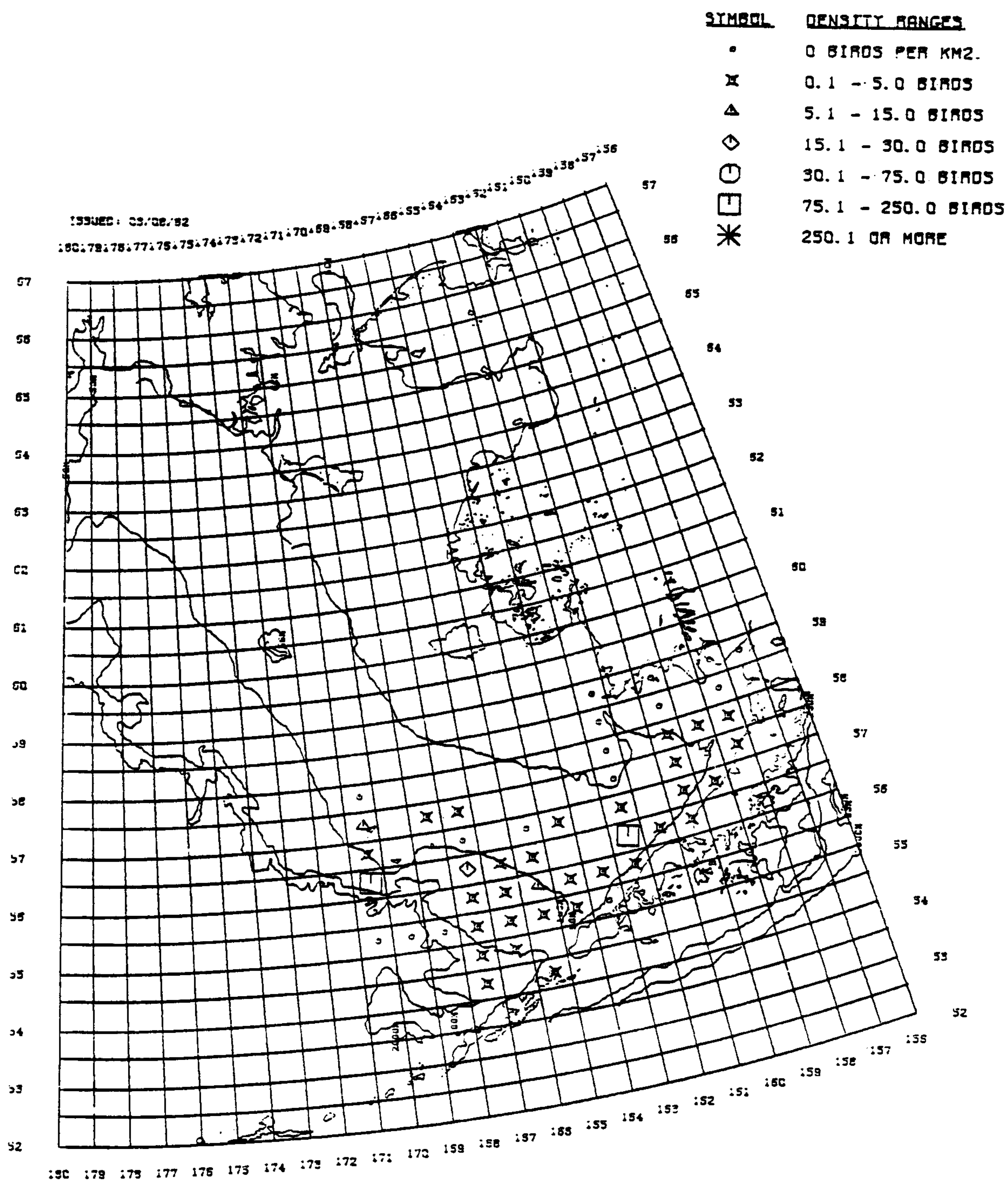
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
SMALL ALCIDS AND UNID. ALCIDS - SUMMER

Figure 64



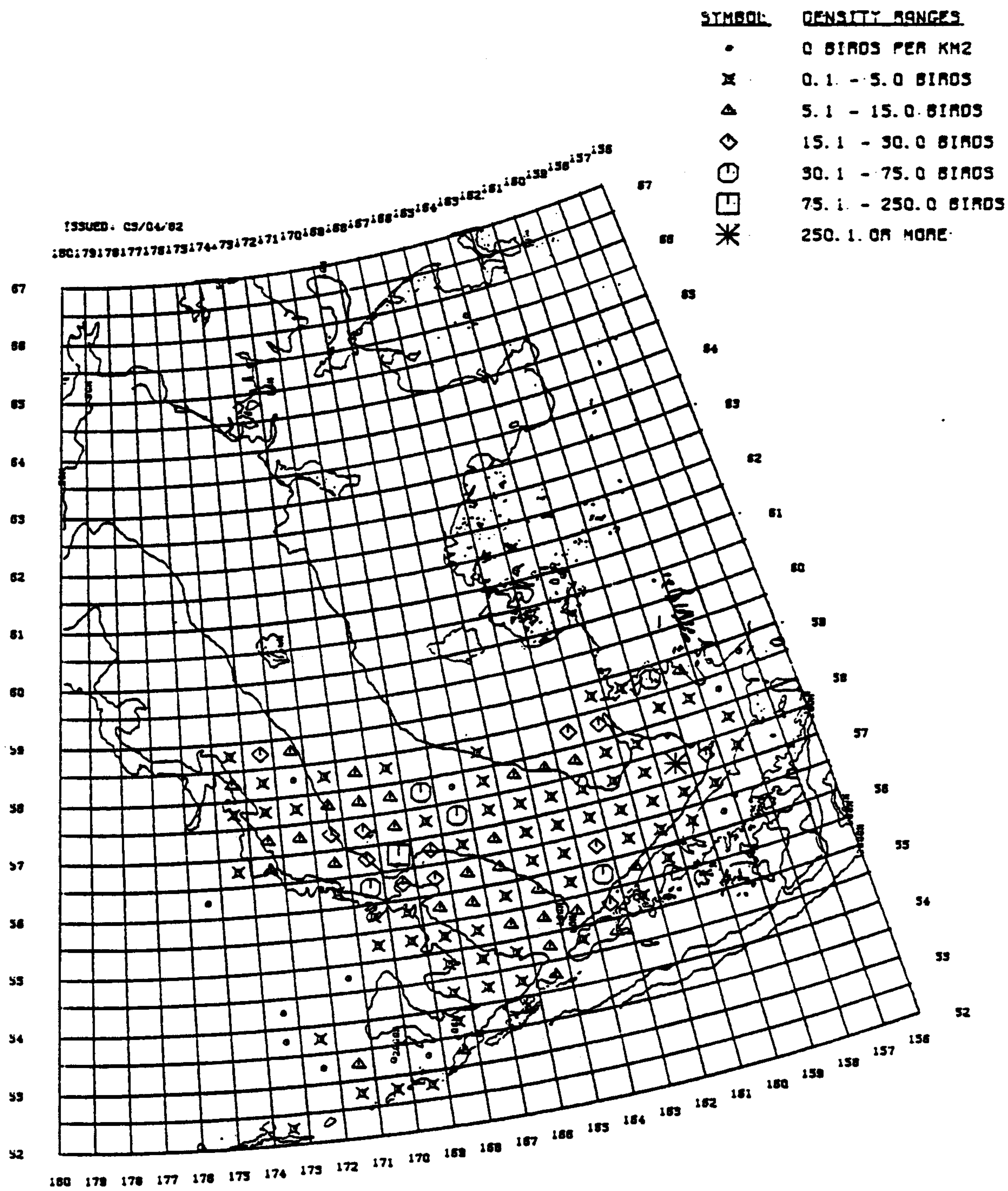
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
SMALL ALCIDS AND UNID. ALCIDS - AUTUMN

Figure 65



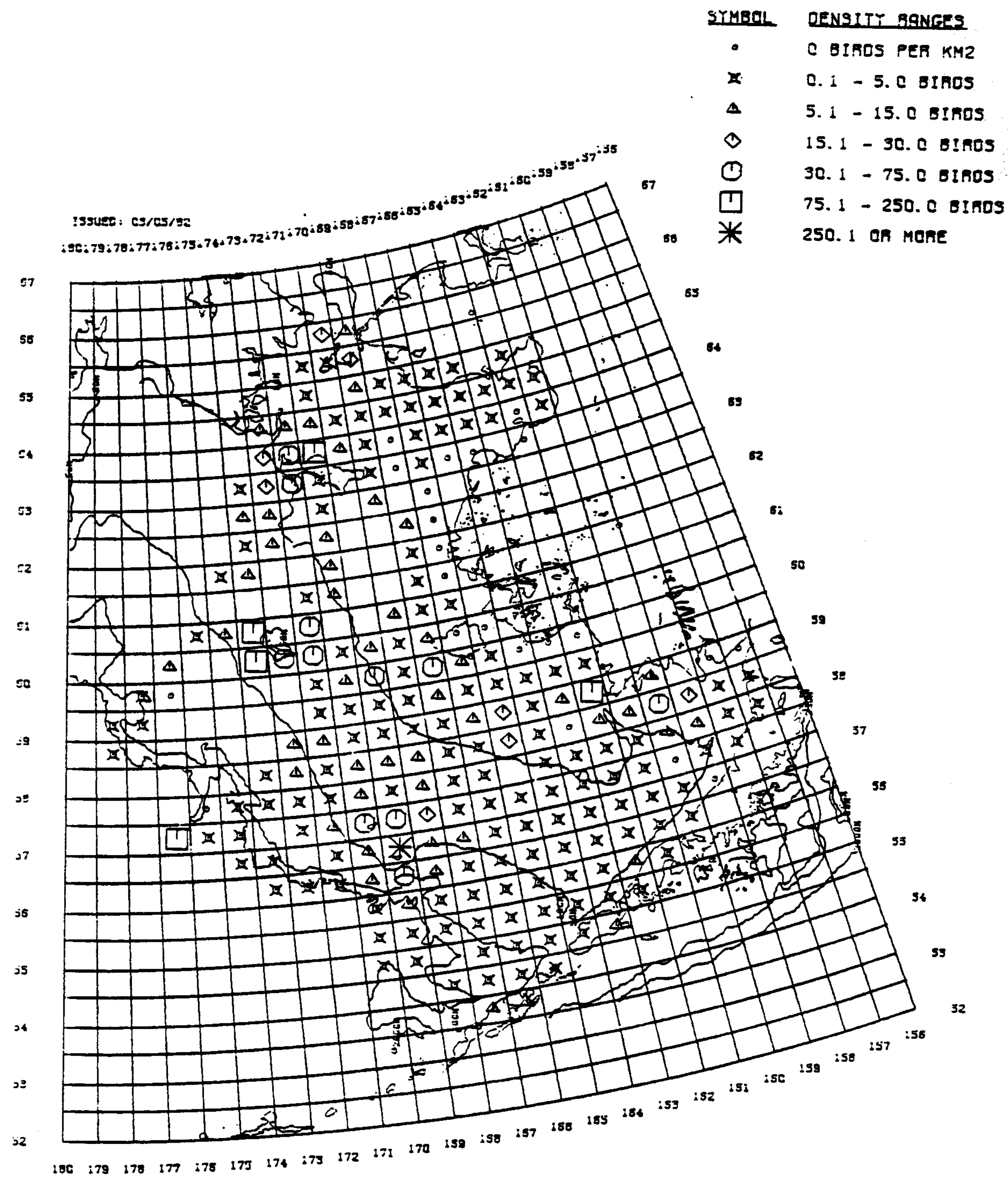
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
MURRES - WINTER

Figure 66



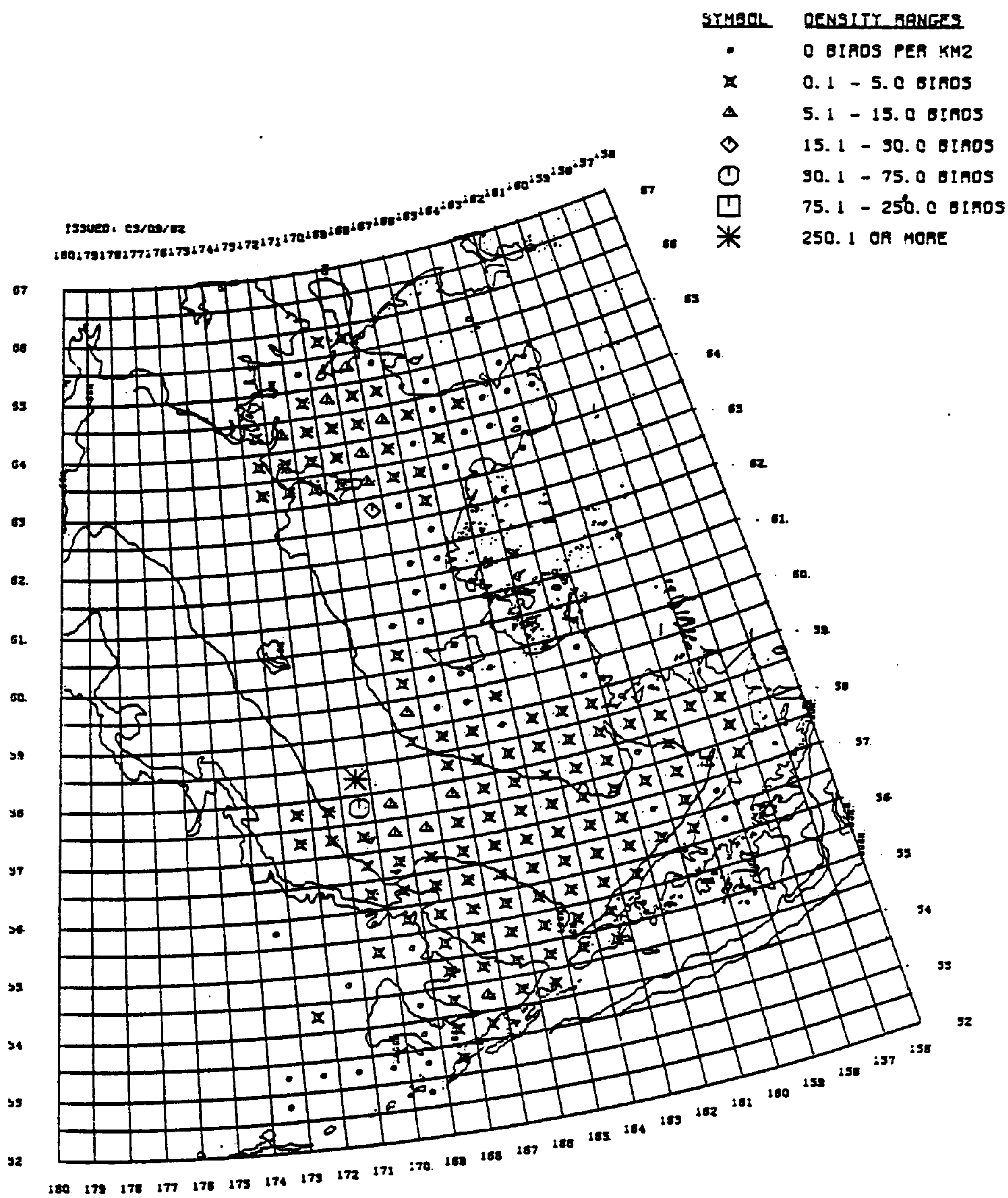
BERING SEA MEAN DENSITY PLOT
ALL FIELD CPS: 1975 - 1981
MURRES - SPRING

Figure 67



BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
MURRES - SUMMER

Figure 68



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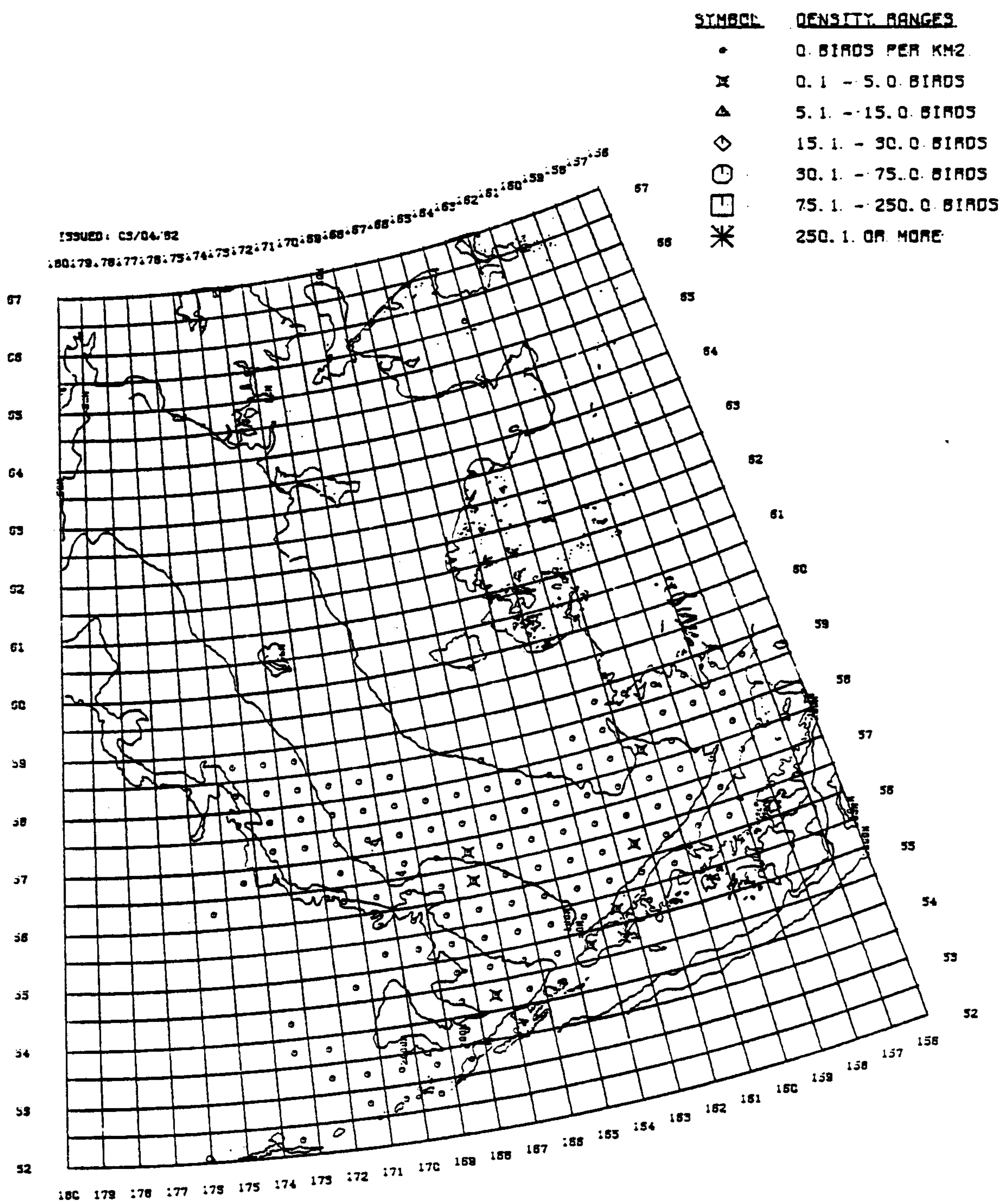
MURRES - AUTUMN

Figure 69



BERING SEA MEAN DENSITY PLOT
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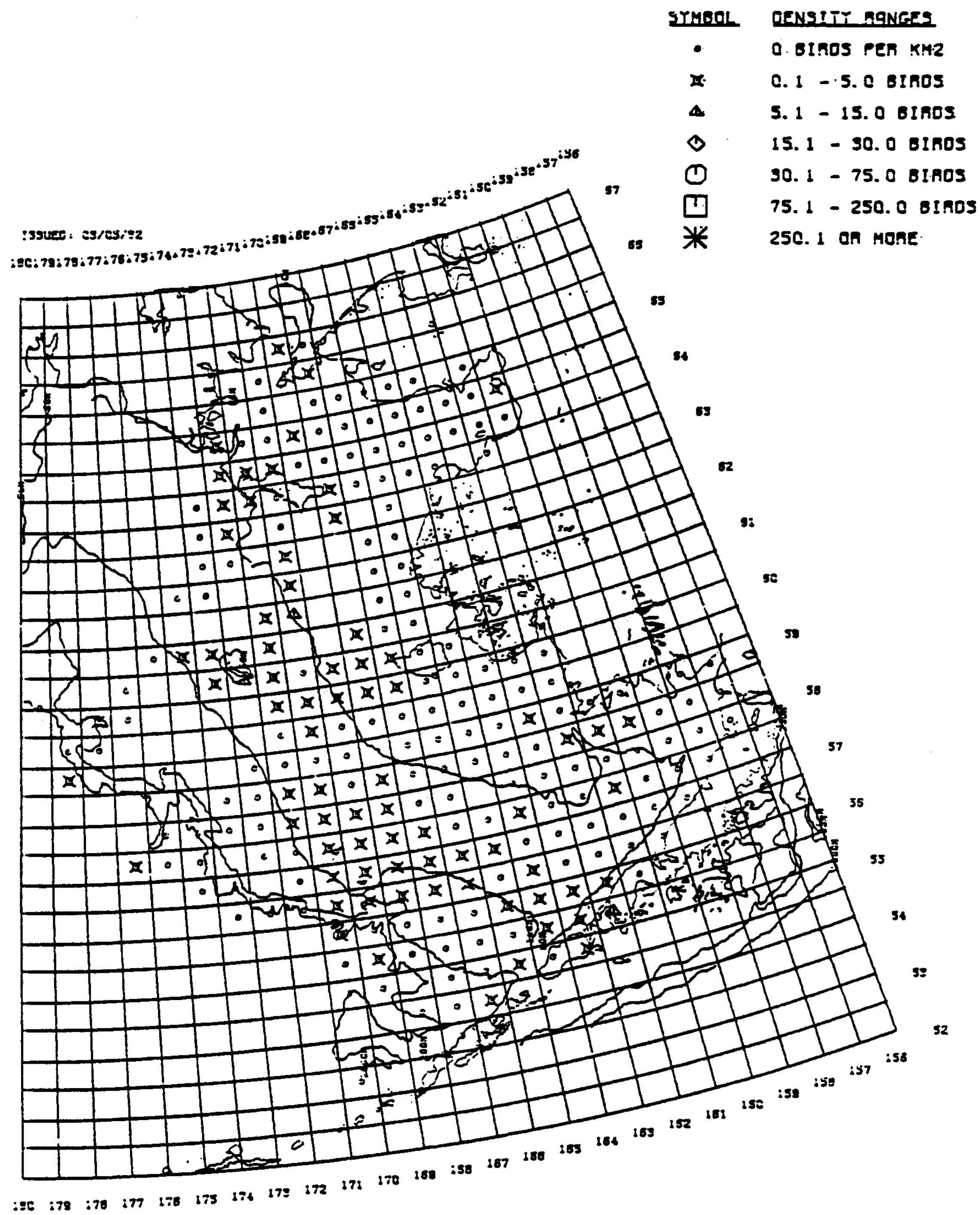
Figure 70



BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
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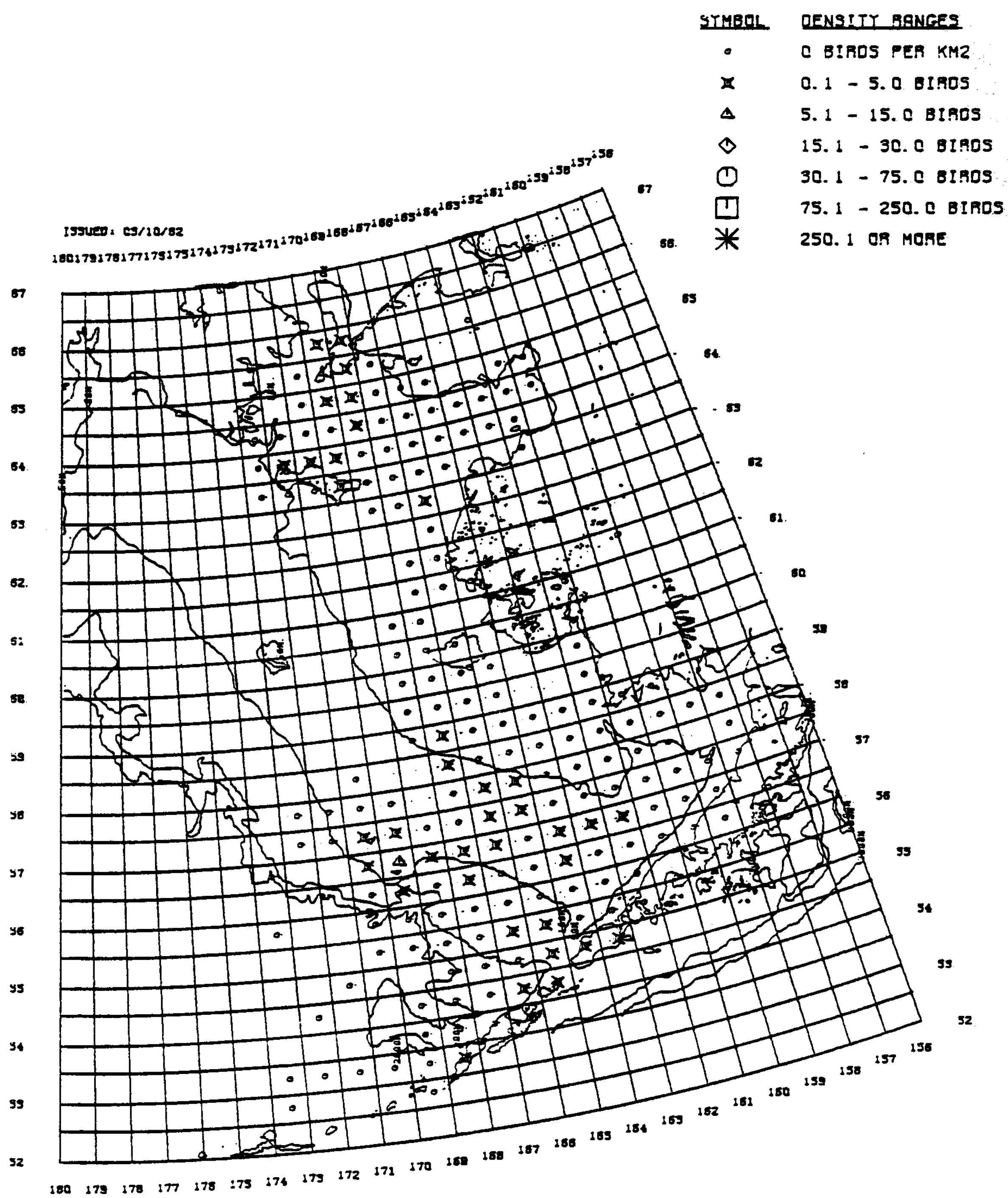
Figure 71



BERING SEA MEAN DENSITY PLOT
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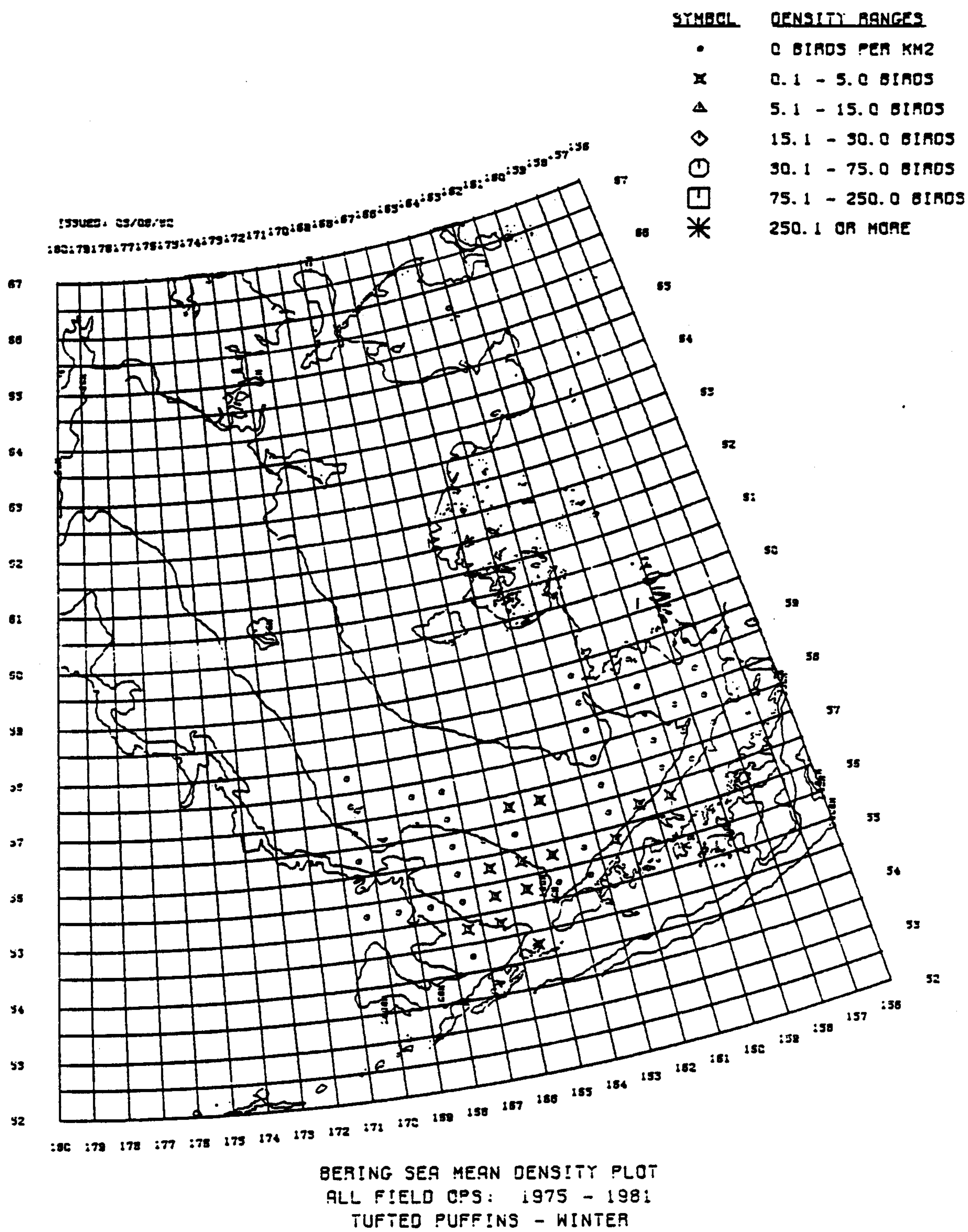
Figure 72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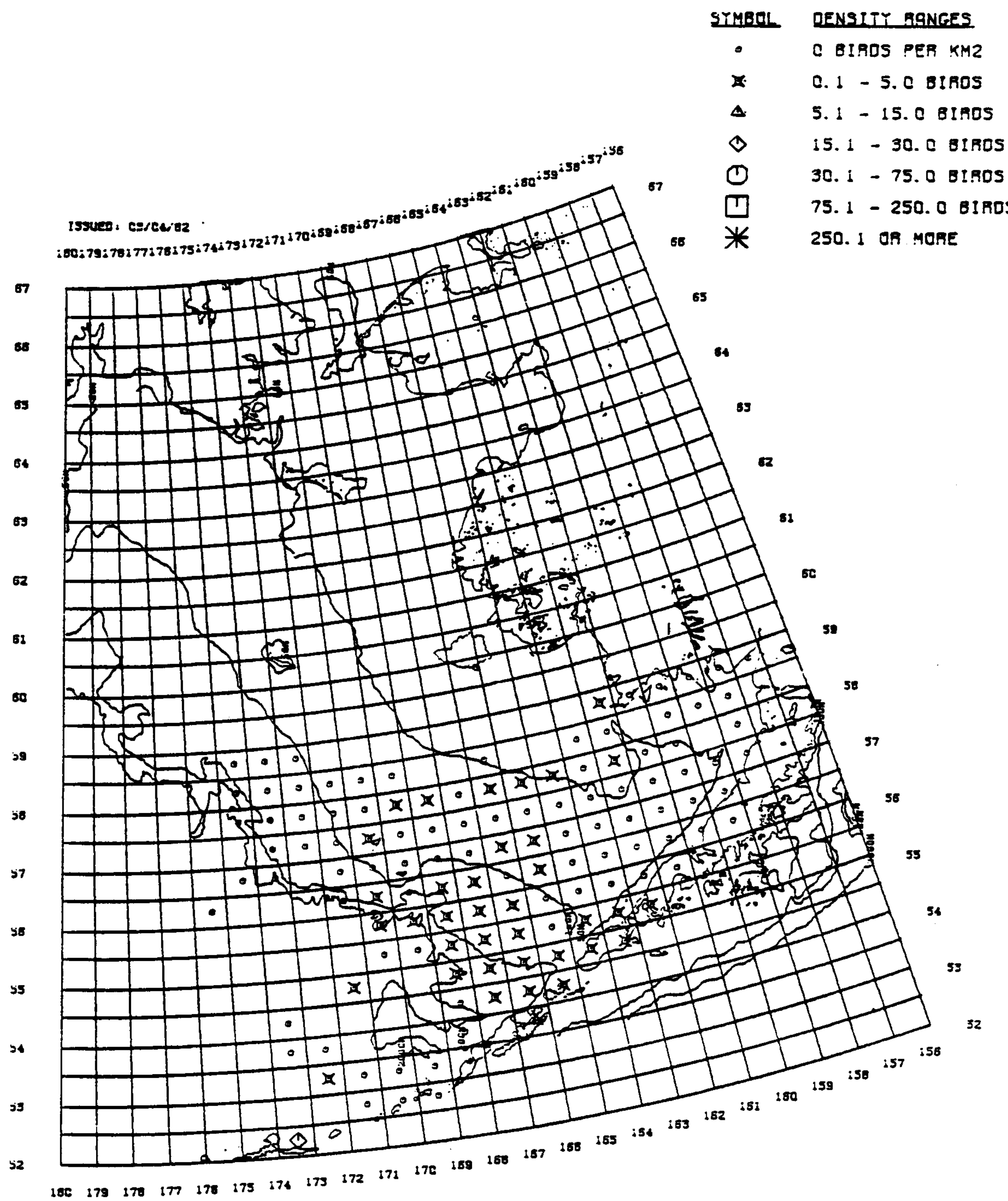
0.1 - 5.0 BIRDS
5.1 - 15.0 BIRDS
15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
TUFTED PUFFINS - WINTER

Figure 73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15.1 - 30.0 BIRDS
30.1 - 75.0 BIRDS
75.1 - 250.0 BIRDS
250.1 OR MORE
BERING SEA MEAN DENSITY PLOT
ALL FIELD OPS: 1975 - 1981
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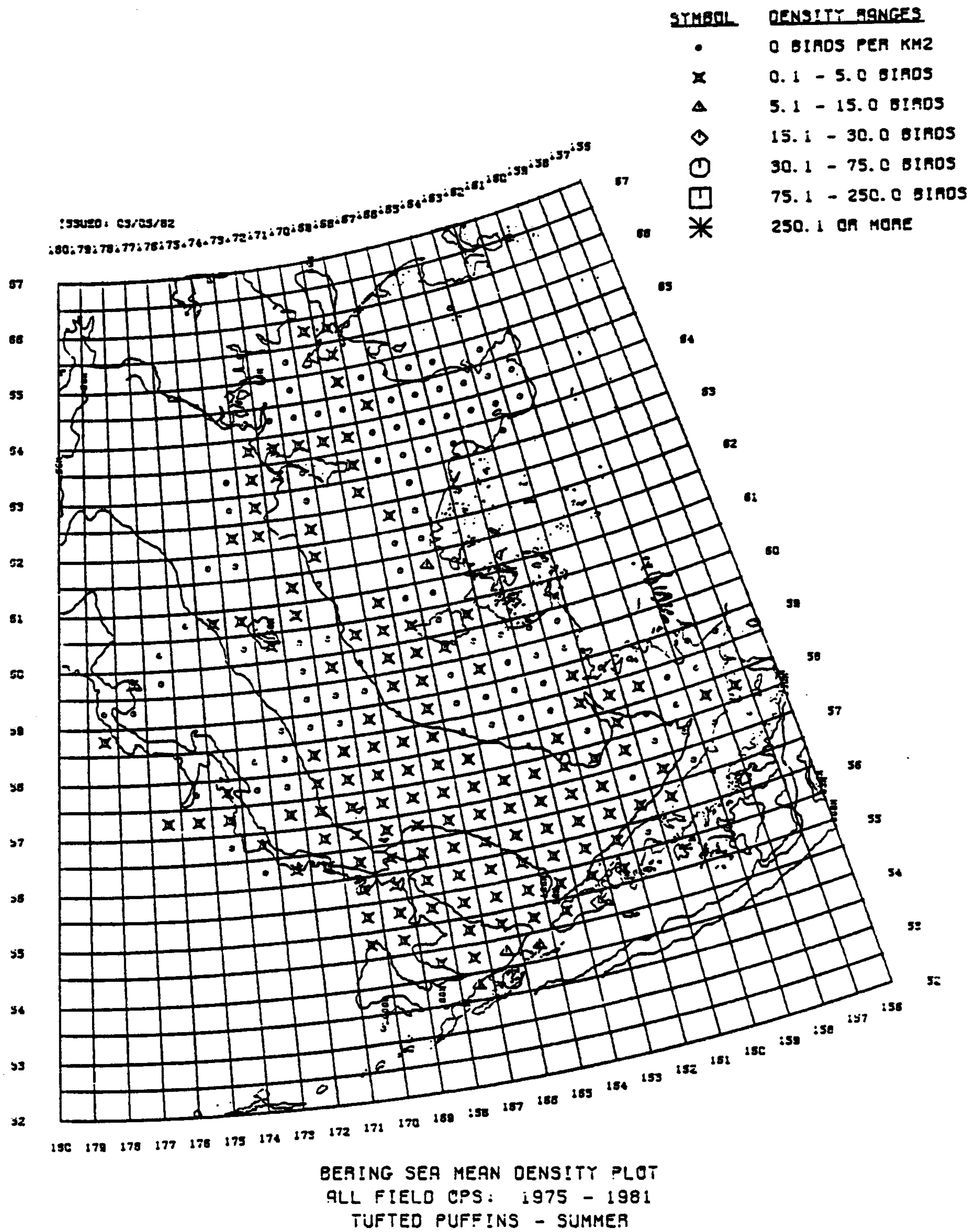
Figure 74


SYMBOL DENSITY RANGES
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250.1 OR MORE
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BERING SEA MEAN DENSITY PLOT
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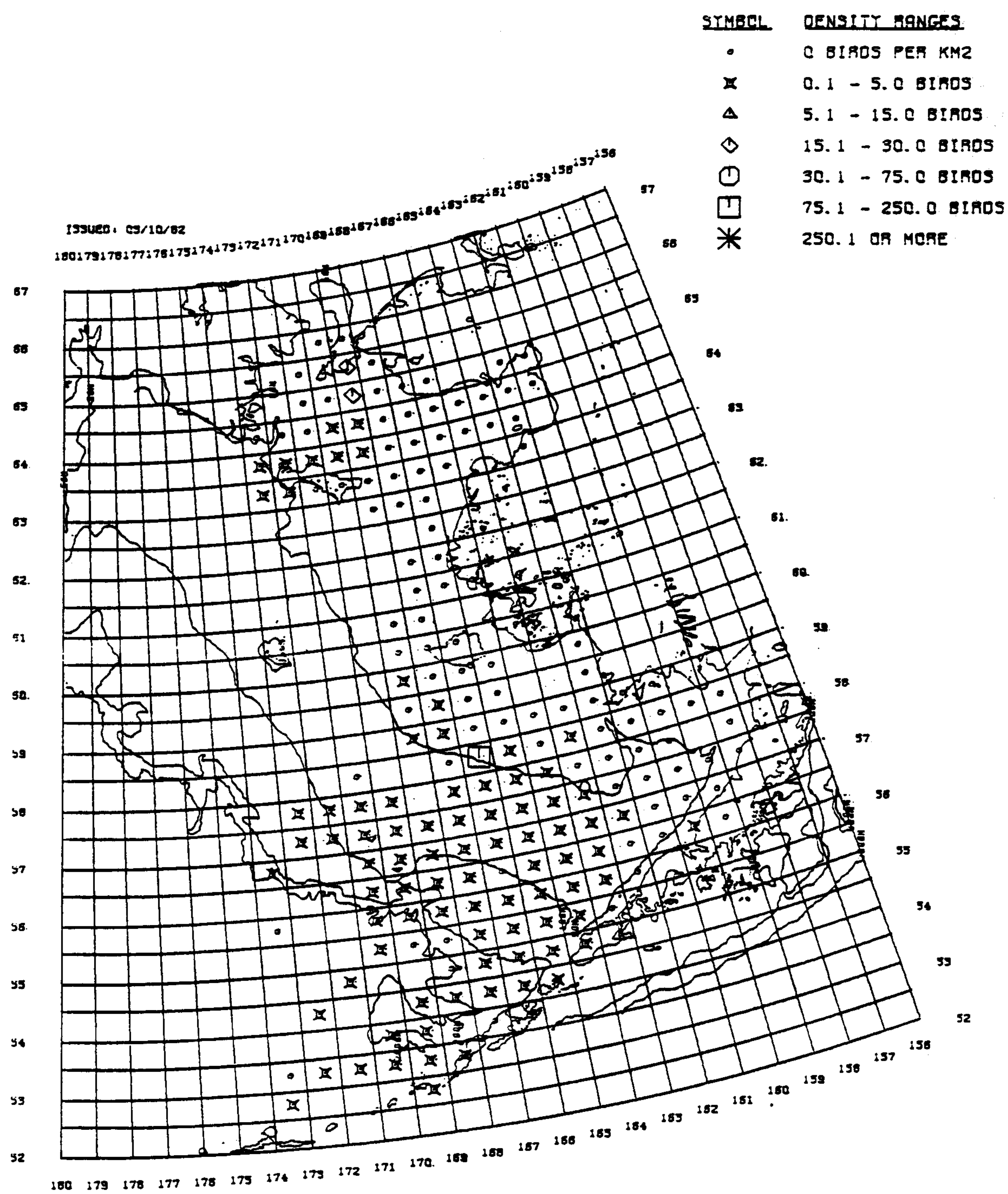
Figure 75



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ALL FIELD OPS: 1975 - 1981
TUFTED PUFFINS - AUTUMN

Figure 76

THE BREEDING BIOLOGY AND FEEDING ECOLOGY OF MARINE BIRDS IN THE GULF OF ALASKA

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Denver Wildlife Research Center
Migratory Bird Project

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 341

August 1983

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ACKNOWLEDGEMENTS

This study was supported by the Bureau of Land Management (BLM) through an interagency agreement with the National Oceanic and Atmospheric Administration (NOAA), under which a multi-year program responding to needs of petroleum development of the Alaskan continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office.

This report would not have been possible without the help of many people. We express our deepest thanks to the following persons who contributed energy and ideas to the manuscript. Laurie Jarvela, Jawed Hameedi, and Francesca Cava of the OCSEAP office contributed greatly to the success of the project. NOAA and the U.S. Coast Guard assisted in logistics. Charlotte I. Adamson, Colleen M. Handel, and Calvin J. Lensink of the U. S. Fish and Wildlife Service contributed to the summary and writing of various sections of the species accounts. Editorial assistants Charlotte I. Adamson, Jan Grielich, and Amy E. Zabloudil lessened a lot of the editing burden, and Stephanie A. Kessler and Charlotte I. Adamson helped in data analysis. Constructive editorial comments were made by James C. Lewis, John L. Trapp, Gerald A. Sanger, Calvin J. Lensink, David R. Nysewander, Colleen M. Handel, P. Dee Boersma, Douglas J. Forsell, and Charlotte I. Adamson. James Lockhart, Charlotte I. Adamson, and Amy E. Zabloudil assisted in graphics. Karleen Boskofsky, Mary L. Hadra, and Donna M. Hoffman devoted long hours to typing the manuscript, and did an excellent job, and Clarence Johnson expertly coordinated the effort.

SUMMARY AND CONCLUSIONS WITH RESPECT TO OIL AND GAS DEVELOPMENT

Productivity in most species of seabirds in the Gulf of Alaska appears to be within that which is needed to maintain populations. There are, however, many naturally occurring stress factors that limit productivity. Some of these are cyclical (e.g., food availability), others are reasonably constant (e.g., predation), while others are erratic (e.g., weather). Each factor affects individual species differently; some species, for example, appear to have periodic boom and bust productivity cycles (e.g., Black-legged Kittiwake) while others seem to be extremely consistent from year to year (e.g., Tufted Puffin). These differences are related to features of seabird life history, especially to foraging techniques (e.g., surface feeders versus water-column feeders capable of reaching the bottom) and nest types (e.g., open nests versus burrows), interacting with environmental stresses. The seeds of both chronic and episodic "artificial" stresses are contained in the development of the outer continental shelf in Alaska. The impact of these man-related stresses, especially if coincident with naturally occurring cyclical and erratic stresses, could seriously threaten local populations.

Proper management and protection procedures during the development and exploitation of oil and gas reserves on the outer continental shelf, including periodic monitoring of the ecosystem, would considerably reduce potential conflicts between man and seabirds. These procedures must be based on sound biological data including knowledge of habitat preferences, breeding chronologies, reproductive success, adult mortality, growth rates, food and foraging habits, and existing population stresses. Baseline data and preliminary conclusions on various aspects of the breeding biology of a selected group of seabirds in the Gulf of Alaska are presented in this report.

INTRODUCTION

The biology of marine birds in Alaska was poorly understood until the initiation of studies funded by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of the National Oceanic and Atmospheric Administration (NOAA) and the Bureau of Land Management (BLM) in the mid-1970's. Much information was gathered on many species in a very short time. The object of the studies was to gather enough information so that managers could make sound decisions for the development of oil and gas reserves on the outer continental shelf of Alaska.

This summary of the breeding biology and feeding ecology of marine birds synthesizes work conducted by members of the United States Fish and Wildlife Service (USFWS) or subcontractees to the USFWS over the period 1975-1979. The key species targeted for study were: Northern Fulmar, Leach's and Fork-tailed Storm-Petrels, Double-crested, Pelagic and Red-faced Cormorants, Glaucous-winged and Mew Gulls, Black-legged Kittiwakes, Arctic and Aleutian Terns, Common and Thick-billed Murres, and Horned and Tufted Puffins (Table I-1). The islands or island complexes at which we conducted this research were, in order from west to east: Shumagin, Semidi, Ugaiushak, Kodiak/Sitkalidak, Barren, Chisik, Wooded, Hinchinbrook, Middleton and Forrester (Fig. I-1).

The specific objectives of the studies of seabirds at the individual colonies were:

- To determine the numbers and distribution of each species within the study areas;
- To determine the habitats used by the different species of breeding birds;
- To describe the chronology of events in the reproductive cycle of individual species, including changes in numbers from the onset of site occupancy in spring through departure in fall;

Table I-1.
Numbers of Nesting Colonies and Breeding Birds in the Gulf of Alaska.
Adapted From Sowls et al. 1978.

SPECIES	Number of Colonies in:			
	Eastern Gulf		Western Gulf	
	Known Colonies	Estimated Birds	Known Colonies	Estimated Birds
Northern Fulmar	1	few	11	655,000
Fork-tailed Storm-Petrel	3	403,000	36	2,240,000
Leach's Storm-Petrel	3	1,707,000	26	374,000
Double-crested Cormorant	2	few	67	4,000
Brandt's Cormorant	1	few	?	?
Pelagic Cormorant	17	2,000	160	31,000
Red-faced Cormorant	0	0	130	50,000
Glaucous-winged Gull	24	17,000	418	357,000
Herring Gull	5	few	1	few
Mew Gull	3	2,000	39	7,000
Black-legged Kittiwake	5	3,000	162	1,348,000
Arctic Tern	11	3,000	70	17,000
Aleutian Tern	4	1,000	10	2,000
Common & Thick-billed Murres	11	11,000	67	1,994,000
Pigeon Guillemot	15	5,000	253	128,000
Marbled Murrelet	?	Abundant	?	Abundant
Kittlitz's Murrelet	?	Common	?	Abundant
Ancient Murrelet	3	212,000	28	162,000
Cassin's Auklet	3	127,000	16	472,000
Parakeet Auklet	0	0	70	165,000
Crested Auklet	0	0	6	63,000
Least Auklet	0	0	2	few
Rhinoceros Auklet	4	193,000	7	8,000
Horned Puffin	9	2,000	287	1,157,000
Tufted Puffin	11	167,000	350	2,155,000
Total		> 2,855,000		> 11,389,000

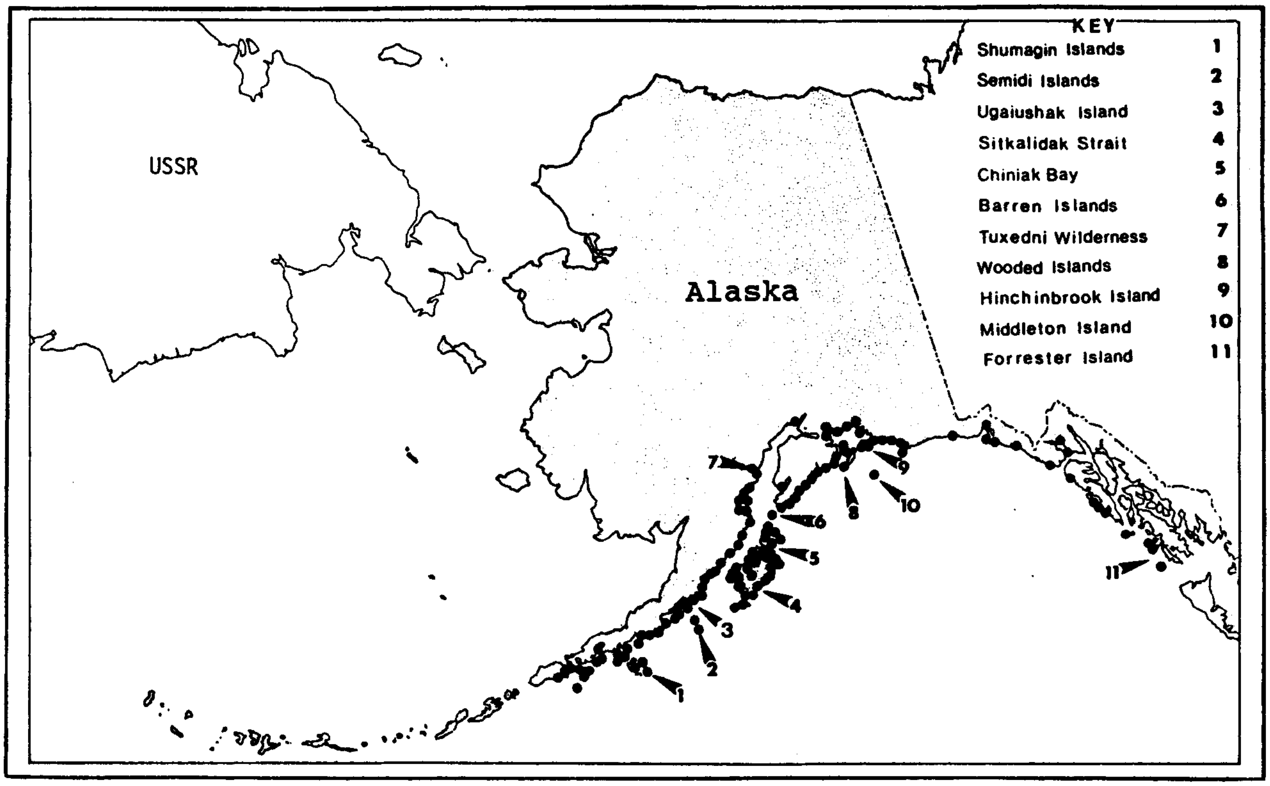
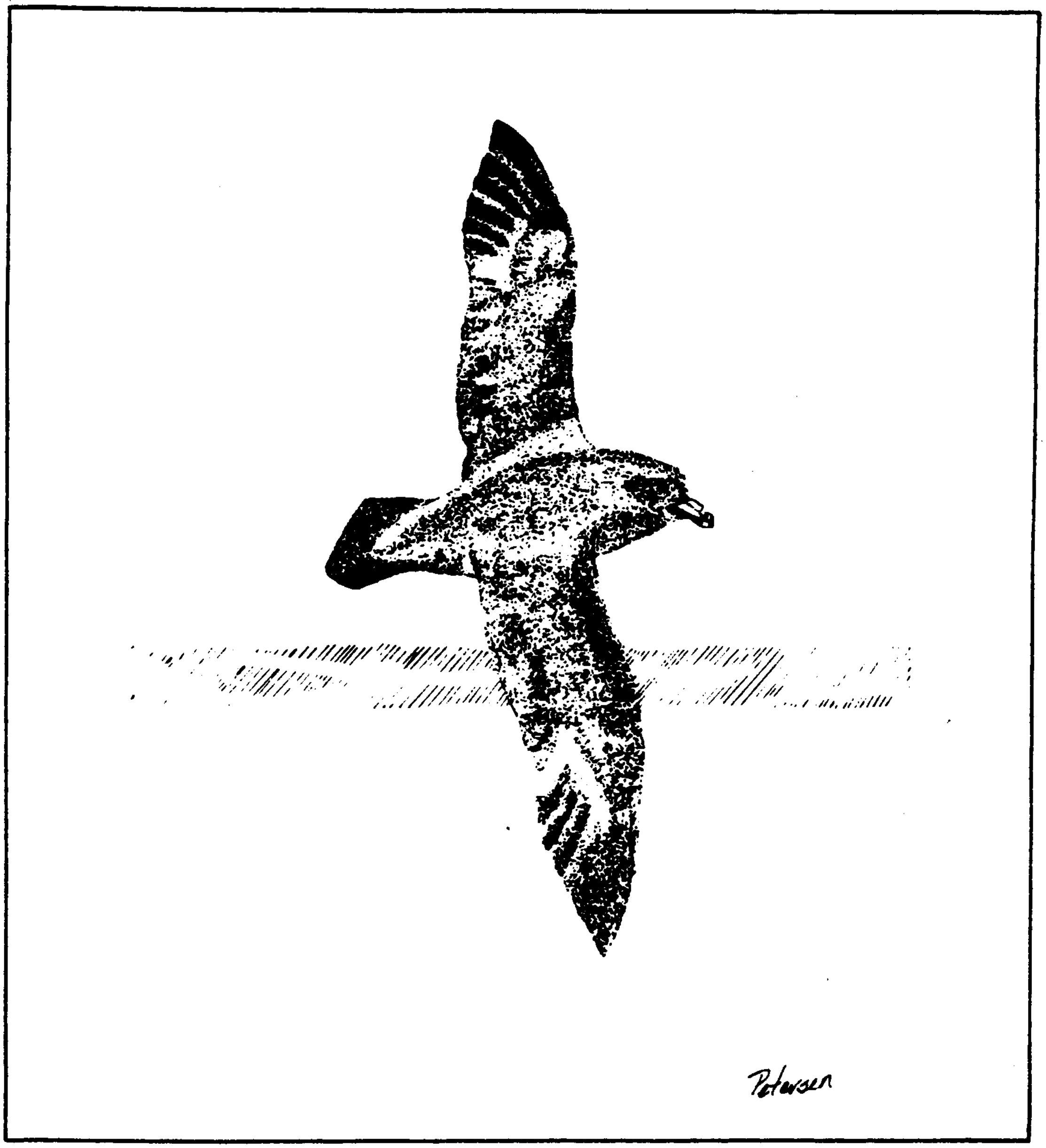


Figure I-1. Distribution of seabird nesting colonies in the Gulf of Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

- To provide estimates of reproductive success including laying, hatching, and fledging success and to suggest possible causes of annual variation;
- To determine average growth of chicks by obtaining measurements of weight, culmen, tarsus and wing;
- To describe food habits and daily and seasonal foraging patterns with particular emphasis on their relationship to growth and survival of chicks; and
- To establish and describe sampling areas or units which may be used in subsequent years or by other investigators for monitoring the status of populations.

Northern Fulmar (*Fulmarus glacialis*)



by

Scott A. Hatch

NORTHERN FULMAR

(*Fulmarus glacialis*)

In Alaska, the Northern Fulmar is the only breeding species of the Procellariidae, a family of tube-nosed birds whose diversity and abundance is greatest in the southern hemisphere. In the North Atlantic, this species is noteworthy because of remarkable expansions in its population size and breeding range over the last 200 years. An extensive literature on the Atlantic subspecies (*F. g. glacialis*) documents this phenomenon and speculates about its probable causes (e.g., Fisher and Waterston 1941; Fisher 1950, 1952a, 1966; Salomonsen 1965; Brown 1970; Cramp et al. 1974). In contrast, literature on the breeding biology of the Pacific subspecies (*F. g. rodgersii*) is virtually non-existent, although there is information on pelagic zoogeography and ecology (Bent 1922; Kuroda 1955, 1960a, b; Gabrielson and Lincoln 1959; Sanger 1970, 1972; Shuntov 1972; Wahl 1975, 1978; Ainley 1976). Thus, it is not known if the size or distribution of the Pacific population has also changed appreciably during the last 200 years.

Among publications on the breeding of fulmars outside of their Pacific range, the monograph by Fisher (1952b) is still a standard reference. However, this work is largely concerned with the range expansion of the Atlantic subspecies, and much information on breeding biology is either lacking or misleading. Other important contributions include those by Dunnet and his co-workers at the University of Aberdeen (Carrick and Dunnet 1954, Dunnet and Anderson 1961, Dunnet et al. 1963, Dunnet 1975, Dunnet and Ollason 1978, Ollason and Dunnet 1978, Dunnet and Anderson 1979), recent banding studies by Macdonald (1977a, b, c), a comparative study of the Atlantic Fulmar and Antarctic Fulmar (*Fulmarus glacialoides*) by Mougin

(1967), and work in progress at Prince Leopold Island in the Canadian Arctic by Nettleship (1977, and pers. comm.). Most of the latter work remains to be published. Recent studies of the breeding biology of Northern Fulmars at the Semidi Islands (Hatch 1977, 1978, 1979; Hatch and Hatch 1979) are the first devoted to this species in its Pacific range.

BREEDING DISTRIBUTION AND ABUNDANCE

Fulmars, with an estimated population of more than 2 million, are among the most common pelagic birds in Alaska. However, they breed at only a small number of sites (Fig. II-1). Of these, four colonies contain more than 99% of the breeding population, and range in size from 70,000 to 475,000 birds (Table II-1) (Sowls et al. 1978). The fifth largest colony, probably the one on Gareloi Island in the west-central Aleutians, is smaller by an order of magnitude than the least of these major breeding areas. Other colonies contain only a few dozen to a few hundred pairs and are insignificant compared to the main production centers. About one out of three fulmars in Alaska is reared at the Semidi Islands, which are thus presumably of major importance to the maintenance of this species' population. No other colonies of any consequence exist in the Gulf of Alaska.

NESTING HABITAT

The Northern Fulmar is a cliff-nesting species, and all known colonies in Alaska are located on islands with rugged and precipitous cliffs. At the Semidi Islands, there is very little overlap in nesting habitat between fulmars and other open cliff-nesting species (i.e., murres (*Uria aalge* and *U. lomvia*) and Black-legged Kittiwakes (*Rissa tridactyla*)). Murres and kittiwakes mainly inhabit ledges of bedrock, whereas fulmars usually dominate the higher, vegetated portions of cliffs.

Northern Fulmar (*Fulmarus glacialis*)

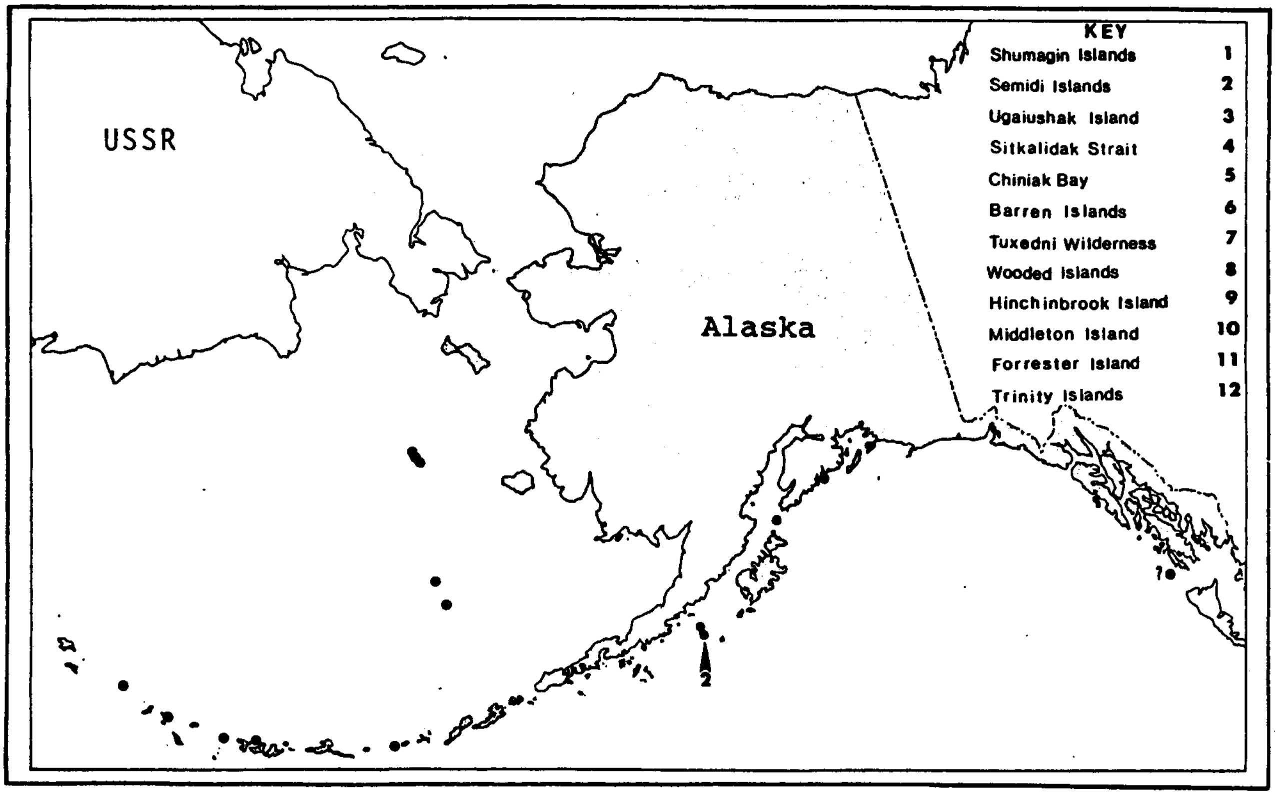


Figure II-1. Distribution of breeding colonies of Northern Fulmars in Alaska. Site where intensive colony studies were conducted is indicated by arrow.

TABLE II-1
Estimated Numbers of Fulmars Nesting at Four Major Colonies in Alaska.

Colony	Location	Number of birds
Semidi Islands	Gulf of Alaska	475,000
Chagulak Island	Central Aleutians	450,000
St. Matthew-Hall Islands	Central Bering Sea	450,000
St. George Is.	Central Bering Sea	70,000

Nest sites are usually established on a soil substrate, but are occasionally placed on bedrock or unconsolidated sand and rubble with no vegetation. On Chowiet Island at the Semidis, a few nests were placed among boulders at the bases of cliffs. By far the most important cover plant on Chowiet is beach rye (*Elymus arenarius*), although a variety of other grasses and forbs generally contribute to the concealment of nests by mid-summer.

Fulmars nest on slopes of as little as 40°, but highest densities of nests occur on cliffs with slopes of 60° to nearly vertical. A slope of at least 50° in the immediate vicinity of a vegetated nest site seems to be necessary for unhampered access to the nest and egress by the birds. However, suitable habitat of any exposure and elevation is used. At the Semidi Islands, the height of the nest sites ranged from about 10 m to 200 m above sea level. Typical densities on Chowiet Island were one nest site per 1 to 4 m^2, but occasionally pairs nested 10 to 15 m from their nearest neighbors. Although most suitable habitat is now occupied at the Semidi Islands, nesting space does not appear to be in short supply.

Nesting areas situated in the numerous canyons indenting the shoreline of Chowiet Island are accessible to Arctic ground squirrels (*Spermophilus parryii*), the only known land mammals inhabiting the Semidi Islands. Cade (1951) noted that ground squirrels are avid scavengers of meat on St. Lawrence Island, and they have been known to prey on living eggs and young of nesting seabirds. However, they were never seen preying on fulmars at Chowiet Island.

BREEDING CHRONOLOGY

Fulmars laid eggs over a span of 20 to 25 days at the Semidi Islands. In 3 years of study at Chowiet Island, the date of the onset of breeding varied only by 7 days, being earliest in 1978 (26 May) and latest in 1977 (2 June) (Table II-2, Fig. II-2). Ninety-five percent of the eggs were laid in a span of 15 to 17 days.

The incubation period, determined to the nearest day in 52 instances, averaged 48.4 days and ranged from 46 to 51 days (SD=1.01). Hatching commenced on about 15 July in 1976 and was all but completed by 4 August. It spanned the period 18 July to 8 August in 1977 and 13 July to 7 August in 1978. Young fulmars had not left the cliffs by the time field work was discontinued each year, consequently fledging dates were estimated using Mougin's (1967) data on the fledging period of Atlantic Fulmars (mean = 53.2 days, range = 49-58 days, SD = 2.01, n = 47). The first young presumably fledged on or about 3 September in 1976, 7 September in 1977, and 1 September in 1978. The last young probably left the cliffs during the first week of October in all years. The duration of a successful breeding attempt (laying to fledging) thus averages about 101 days.

REPRODUCTIVE SUCCESS

Female fulmars lay only one egg each season. The proportion of fulmars that occupied nest sites but did not lay varied little from year to year and averaged about 29% despite wide variation in overall reproductive performance (Table II-3). The percentage of chicks fledged per nest with an egg was more than three times higher in 1977 and 1978 (51.0% and 46.6% respectively) than it was in 1976 (14.9%), when a high rate of egg loss was observed during the first 2 weeks after laying (Fig. II-3). The mortality of chicks in 1977 was similar in both timing and magnitude to that observed in the preceding year. Observations were not made throughout the 1978 season, but the trend established early in incubation suggested a pattern of mortality similar to that in 1977, with losses distributed about evenly

TABLE II-2
Breeding Chronology of Northern Fulmars at the Semidi Islands, 1976-1978.

Year	Laying				Hatching[a]			Fledging[b]		
	N	First	Peak	Last	N	First	Last	N	First	Last
1976	205	29 May	5 June	22 June	46	15 July	4 Aug	46	3 Sept	28 Sept
1977	377	2 June	9 June	21 June	267	18 July	8 Aug	267	7 Sept	28 Sept
1978	399	26 May	3 June	19 June	-	13 July	7 Aug	-	1 Sept	26 Sept

[a] Observed hatching dates for 1976 and 1977; calculated hatching dates for 1978.

[b] Calculated fledging dates for all 3 years.

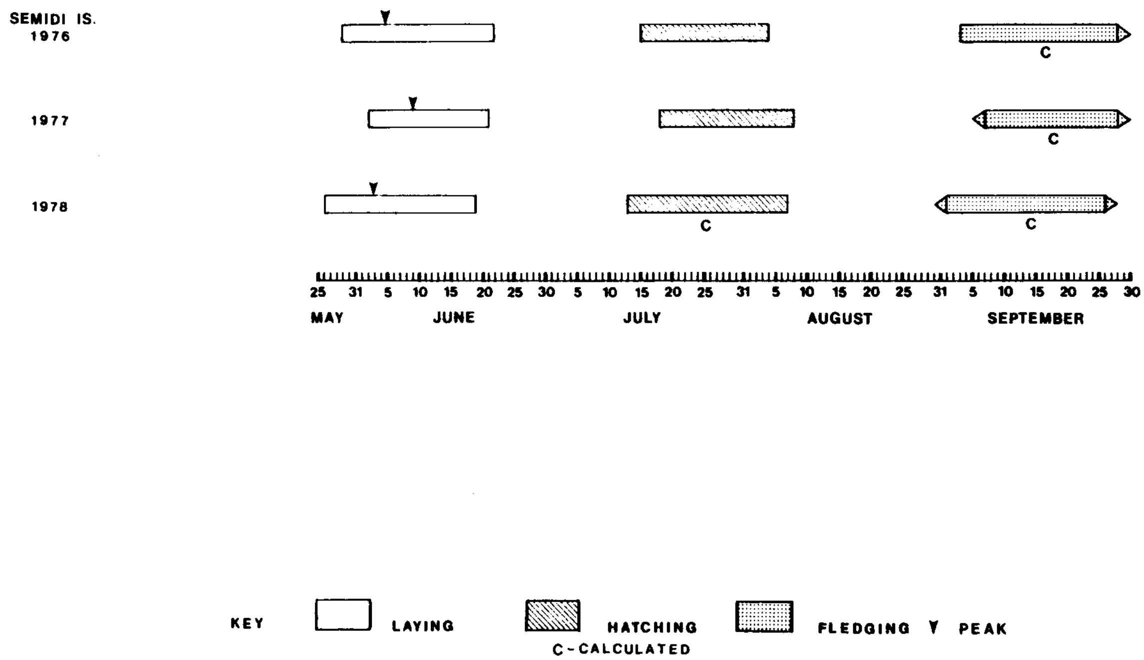


Figure II-2. Chronology of major events in the nesting season of Northern Fulmars at the Semidi Islands in the Gulf of Alaska.

TABLE II-3
Productivity of Northern Fulmars at the Semidi Islands.

	1976	1977	1978
No. of nests built	306	540	540
No. of nests with egg	208	386	397
No. of eggs hatched	46	267	-
No. of chicks fledged	31	197	183
Nests with egg per nest built	0.68	0.71	0.74
Eggs hatched per egg laid (hatching success)	0.22	0.69	-
Chicks fledged per egg hatched (fledging success)	0.67	0.74	-
Chicks fledged per nest with egg (breeding success)	0.15	0.51	0.46
Chicks fledged per nest built	0.10	0.36	0.34

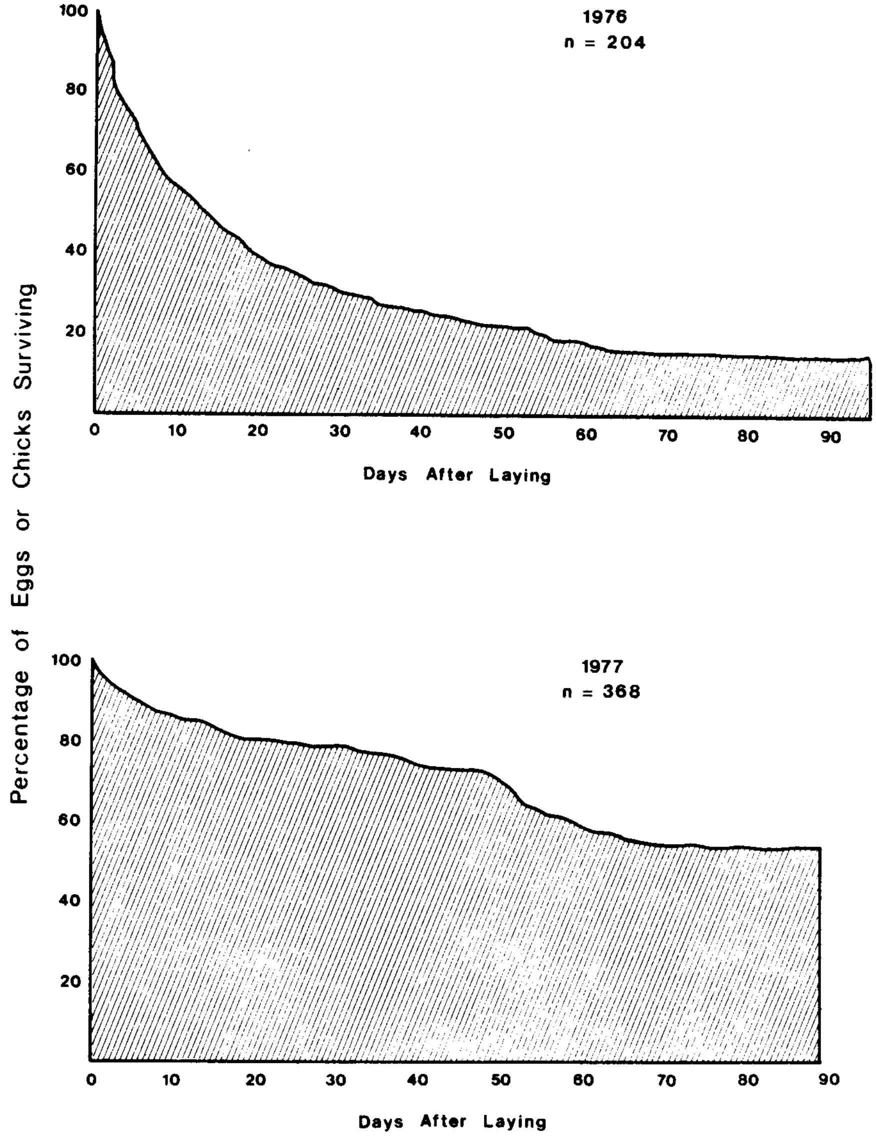


Figure II-3. Survivorship of Northern Fulmar eggs and nestlings at the Semidi Islands in 1976 and 1977.

between egg and chick stages. Infertile eggs made up about 6 percent of the total laid in 1976 and in 1977.

Data on the reproductive success of fulmars available in the literature include those of Mougin (1967) who found that 45.6% of eggs laid produced fledged young at Sands of Forvie, Scotland. Similarly, Macdonald (1977a) indicated a 2-year average reproductive success of fulmars at Sands of Forvie of 52.9%. At Prince Leopold Island, northern Canada, fulmars had 48.5% reproductive success in 1975 (Nettleship 1977). Assuming these data represent the norm for the Pacific fulmar, 1976 was an exceptionally poor year for fulmars at Chowiet Island, while 1977 and 1978 were probably close to the norm.

GROWTH OF CHICKS

Growth rates of nestlings during the 1976 and 1977 seasons were similar; there were no significant differences between years in the mean weights of chicks at any age. Therefore, a generalized account of growth in body weight, wing, tarsus, and culmen is provided in Table II-4 and Fig. II-4 by combining data for 1976 and 1977. Measurements of nine adult females and seven adult males are included for reference.

In the first 4 to 6 weeks of life, chicks accumulated much fat and surpassed the mean adult weight by an average of about 40%. Much of this fat would be before fledging, although measurements were discontinued before most chicks had begun to lose weight. The data suggest an average peak weight of nearly 900 g reached at an average age of about 42 days. During the period of maximum rate of growth (ages 15-30 days), fulmars gained an average of 28 g per day. The similarity of growth patterns in 1976 and 1977 indicates that, although nesting failure occurred at a high rate early in the season in 1976, fulmars had no difficulty finding enough

TABLE II-4
Growth of Northern Fulmar Chicks at the Semidi Islands
(1976 and 1977 Data Combined).

Age	n	Weight (g)		Wing chord(mm)		Total tarsus(mm)		Culmen(mm)	
		$\overline{X}$	SE	X	SE	X	SE	X	SE
0	20	65	0.7	24	0.3	25	0.3	20.0	0.14
1-2	55	82	1.1	25	0.2	26	0.1	20.0	0.09
3-4	54	107	2.1	27	0.2	28	0.2	20.7	0.12
5-6	55	141	3.0	29	0.3	30	0.3	21.6	0.13
7-8	51	171	5.2	32	0.4	33	0.3	22.7	0.15
9-10	51	202	5.2	36	0.6	35	0.3	23.9	0.19
11-12	50	239	6.5	40	0.6	38	0.4	24.9	0.20
13-14	51	285	9.2	45	0.8	40	0.4	25.8	0.21
15-16	50	345	10.5	50	0.9	42	0.5	26.8	0.22
17-18	50	395	11.9	57	1.2	44	0.5	27.8	0.25
19-20	50	450	13.4	67	1.6	47	0.5	28.9	0.24
21-22	50	515	13.3	77	1.8	49	0.5	30.2	0.25
23-24	50	588	14.1	89	2.1	51	0.5	31.1	0.25
25-26	49	643	15.7	102	2.4	53	0.4	32.2	0.26
27-28	49	683	17.1	116	2.5	55	0.4	33.1	0.26
29-30	47	744	15.2	131	2.4	56	0.4	34.0	0.26
31-32	43	785	15.1	144	2.5	57	0.4	34.6	0.28
33-34	35	816	14.9	156	2.9	58	0.4	35.3	0.34
35-36	28	830	20.6	167	3.2	58	0.4	35.9	0.36
37-38	19	823	21.8	175	3.6	58	0.6	35.7	0.43
39-40	10	828	22.8	192	3.4	58	0.8	36.2	0.70
41-42	8	884	24.8	202	4.4	59	0.8	36.7	0.83
43-44	3	907	90.6	223	2.6	59	1.2	36.9	1.40
45-46	2	848	27.5	234	1.5	59	2.0	37.1	2.20
Adult male	7	654	15.7	320	2.7	63	0.5	39.2	0.4
Adult female	9	576	12.4	302	4.9	58	0.3	36.3	0.4

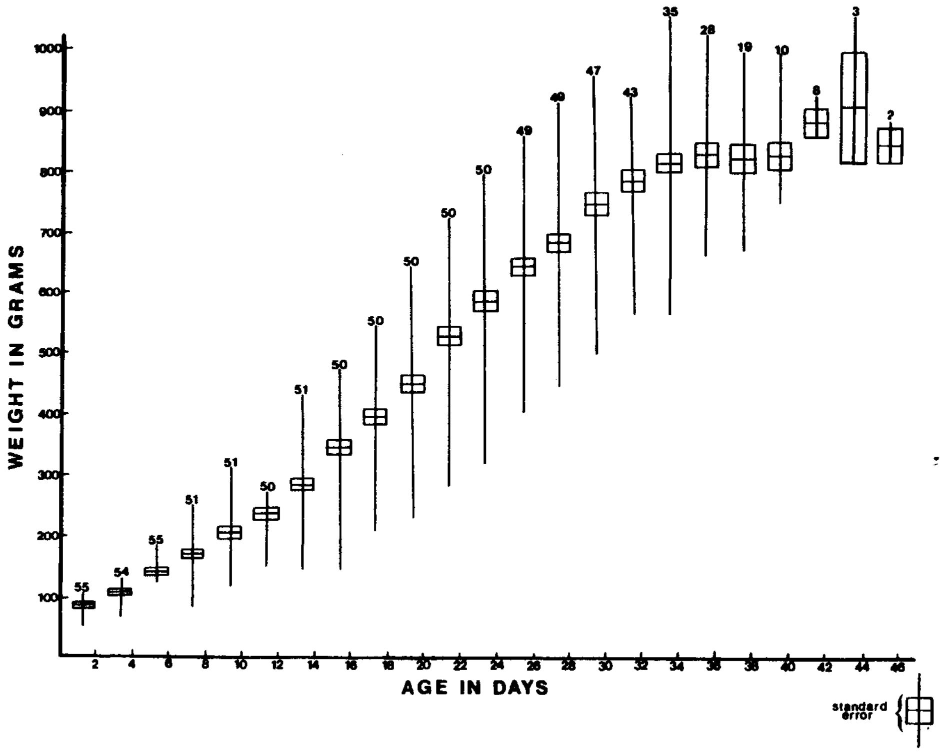


Figure II-4. Growth of Northern Fulmar chicks at the Semidi Islands. Data for 1976 and 1977 combined.

food for normal chick growth in either year.

FOOD HABITS AND FORAGING

Intensive studies of the food habits and feeding rates of fulmars were not conducted at Chowiet Island. The collection of adults (n=16) proved to be an ineffective approach to the study of food habits because the birds' stomachs were invariably empty near the colony. Squid beaks were present in the gizzards of all birds collected, however, indicating that these animals are probably an important component of the diet of adults. Fish, amphipods, and squid were noted incidentally in material regurgitated by chicks or by adults with young.

Fisher (1952b) and Palmer (1962) provide lists of the types of prey identified in the diet of Northern Fulmars. Besides cephalopods, fulmars take a wide variety of crustaceans including amphipods, isopods, schizopods, copepods, decapods, and cumaceans. They occasionally take chaetognaths and pelagic polychaetes, and they are one of the few marine birds known to avidly feed on hydrozoans and ctenophores. They are also avid scavengers of offal, particularly from ships associated with fishing and whaling operations, and carrion. Offal may be an important supplement to the diet of fulmars in the Aleutian Islands and Bering Sea, but probably is not available in quantity to birds breeding at the Semidi Islands and other colonies in the Gulf of Alaska. In short, fulmars are highly opportunistic in their food habits.

COLONY ATTENDANCE

Colony attendance was monitored on Chowiet Island by daily counts of fulmars on study plots, that had a combined total of about 800 nests. Changes in numbers at the colony during the 1976 and 1977 breeding seasons are illustrated in Fig. II-5. Maximum attendance each year occurred in May, before egg-laying. Throughout the prenesting period, attendance fluctuated between 75% occupation and complete evacuation of the colony for periods of several days. Some regular diurnal variations occurred (see below), but these synchronized departures no doubt constituted the main feeding trips. The birds presumably responded en masse to particularly favorable foraging conditions. During the remainder of the breeding season, no more than 40-50% of the population were present on land at one time.

Daily attendance during incubation and chick-rearing exhibited far less variability in 1977 than in 1976. This reflected the fact that birds engaged in incubation and the rearing of chicks made up a much larger segment of the population in 1977. When nonbreeders and failed breeders were a large proportion of the birds at the cliffs, such as in 1976, their irregular, often synchronized, movements masked the more regular attendance of breeders. A census of fulmars on the breeding grounds in late July or August must be interpreted with caution because the number of adults on land at any time may be only a small fraction of the population associated with the breeding grounds earlier in the year.

The date of final departure is unknown at the Semidi Islands, but it probably coincides with the fledging of the last young in early October. The first adults probably begin visiting their nest sites again during early spring, perhaps as early as March in most years, but direct observations of this are also lacking. Presumably, however, Fulmars that breed successfully spend at least 6 months of the year from March through September within a few hundred miles of the Semidi Islands.

In 1976, changes in colony attendance were strongly correlated with changes in weather. Intervals of fair and stormy weather were defined

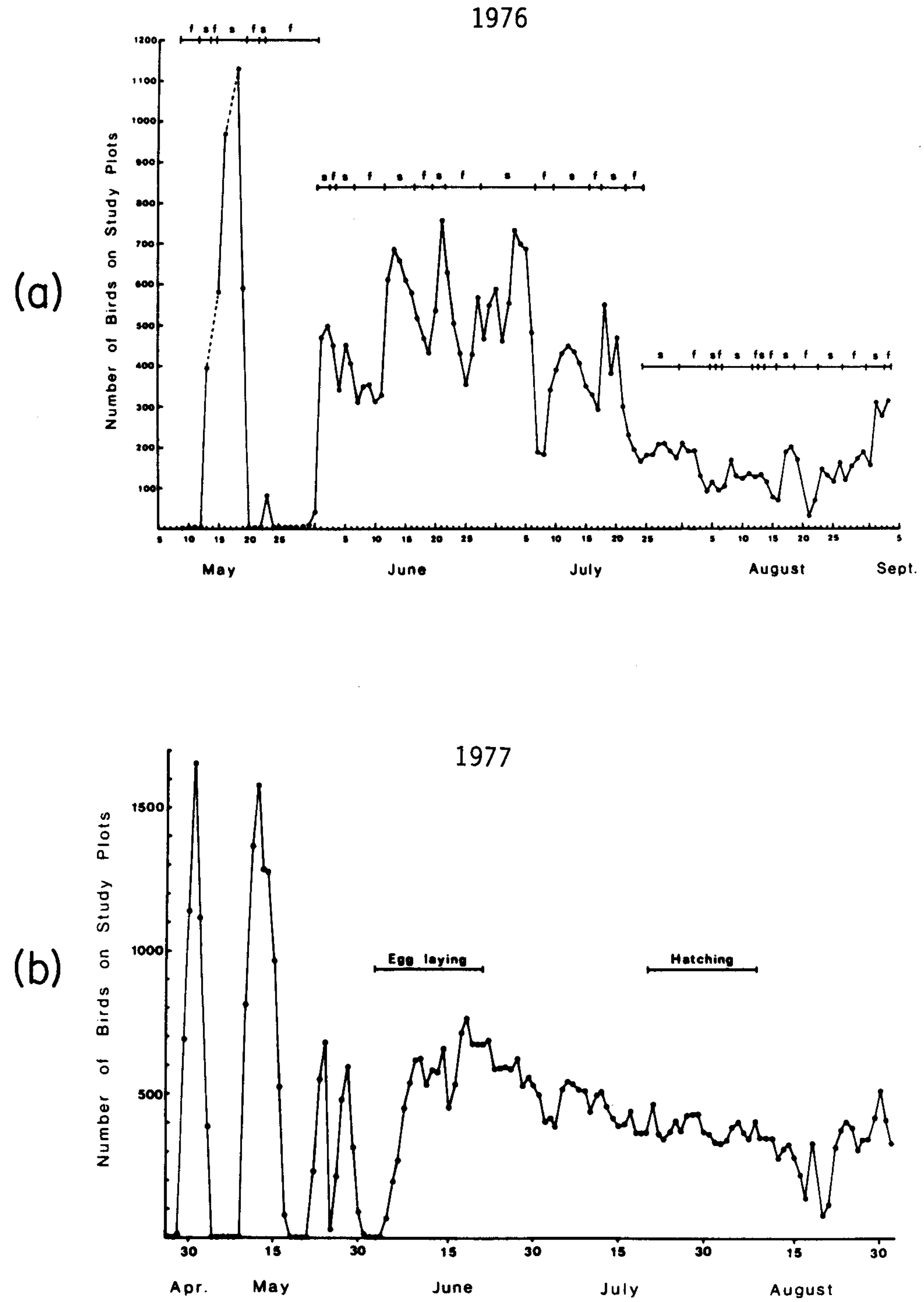
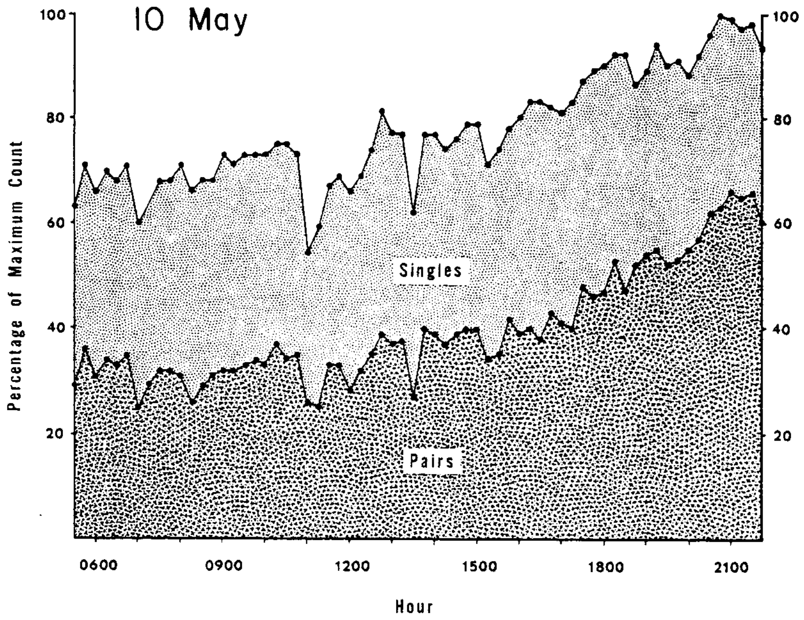


Figure II-5. Seasonal patterns of colony attendance of Northern Fulmars at the Semidi Islands in (a) 1976 and (b) 1977. Periods of fair (f) and stormy (s) weather during 1976 are indicated.

primarily on the basis of cloud cover and rain or fog. Thus calm, rainy days were designated as stormy, while clear days with strong winds were considered fair. With few exceptions, peaks in attendance occurred under stormy conditions and lows under fair conditions (Fig. II-5a). Weather conditions possibly influence the ease with which fulmars travel to and from feeding grounds, as well as the availability of food organisms at the surface.

In contrast to 1976, there was a lack of any evident effect of weather on colony attendance in 1977, probably for two reasons. First, there was a smaller proportion of failed breeders in the population during June and July that were free to leave the colony at will. Second, the weather itself tended to be less cyclic in 1977 with fog, rain, and steady winds persisting over longer periods.

The counts upon which Fig. II-5 is based were generally made between the hours 0900 and 1600. Eight all-day watches were conducted between 10 May and 21 August at a study plot containing about 130 nest sites to determine the extent of diurnal fluctuations in colony attendance. The general trend on all days but 21 August was a gradual increase in numbers over the course of the day with maximum attendance occurring in the evening (Figs. II-6 to II-9). Minimum counts, generally those made soon after dawn, represented 60 to 80% of daily maxima. The wide diurnal range in nest site attendance observed on 21 August reflects, in part, the greater mobility of parents after their chicks are well developed. But this watch was further exceptional in having followed a strong gale on the previous day, during which nearly all the adult population had evacuated the cliffs. In the main, however, these observations showed that diurnal fluctuations in colony attendance were generally minor compared to the variability observed from



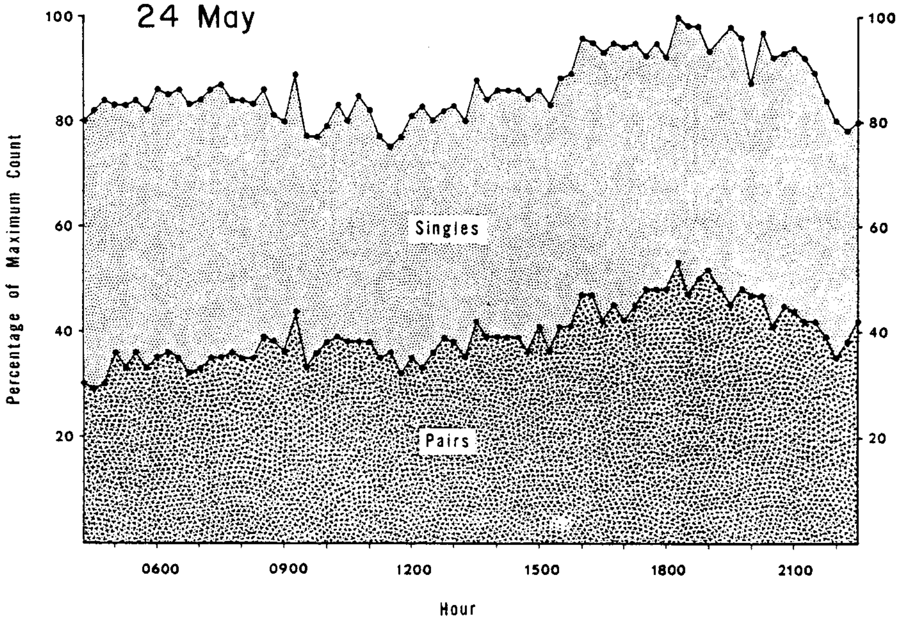
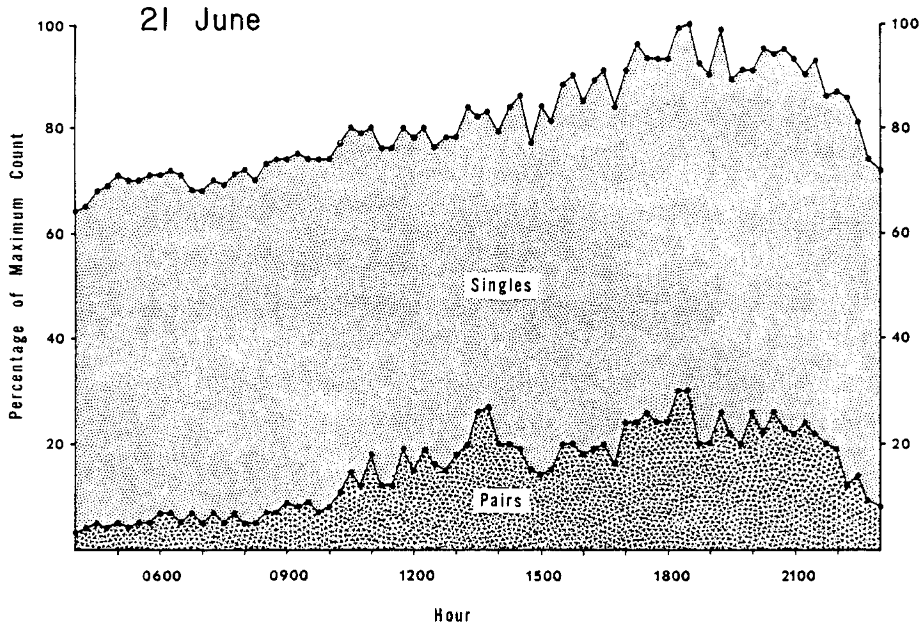


Figure II-6. Diel attendance patterns of Northern Fulmars during the pre-egg stage, Semidi Islands, 1977.



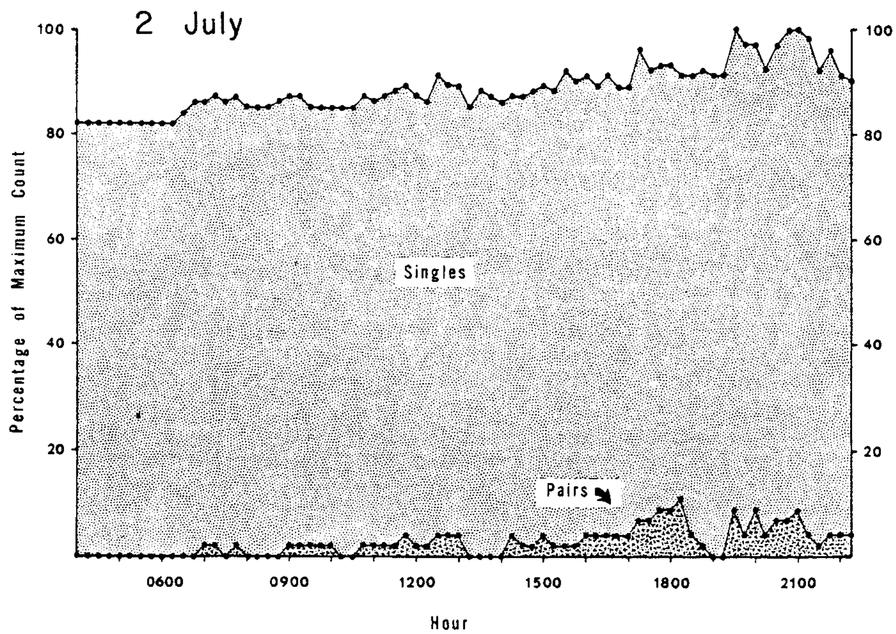
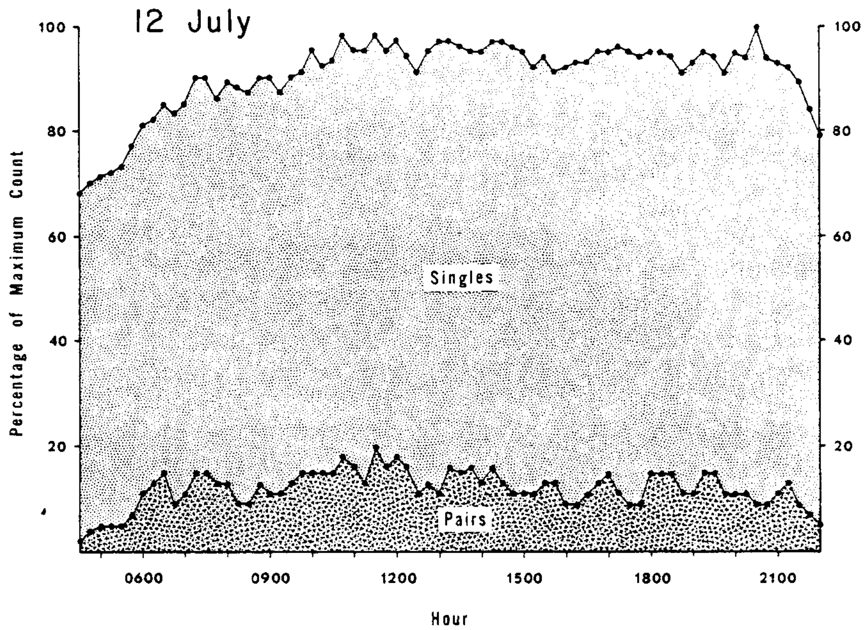


Figure II-7. Diel attendance patterns of Northern Fulmars during incubation, Semidi Islands, 1977.



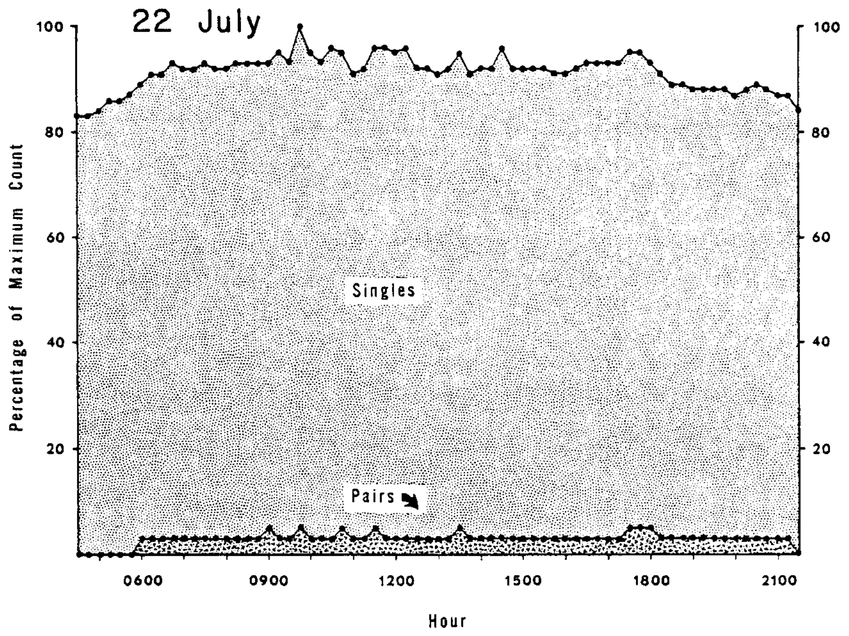


Figure II-8. Diel attendance patterns of Northern Fulmars during late incubation and early nestling stages, Semidi Islands, 1977.

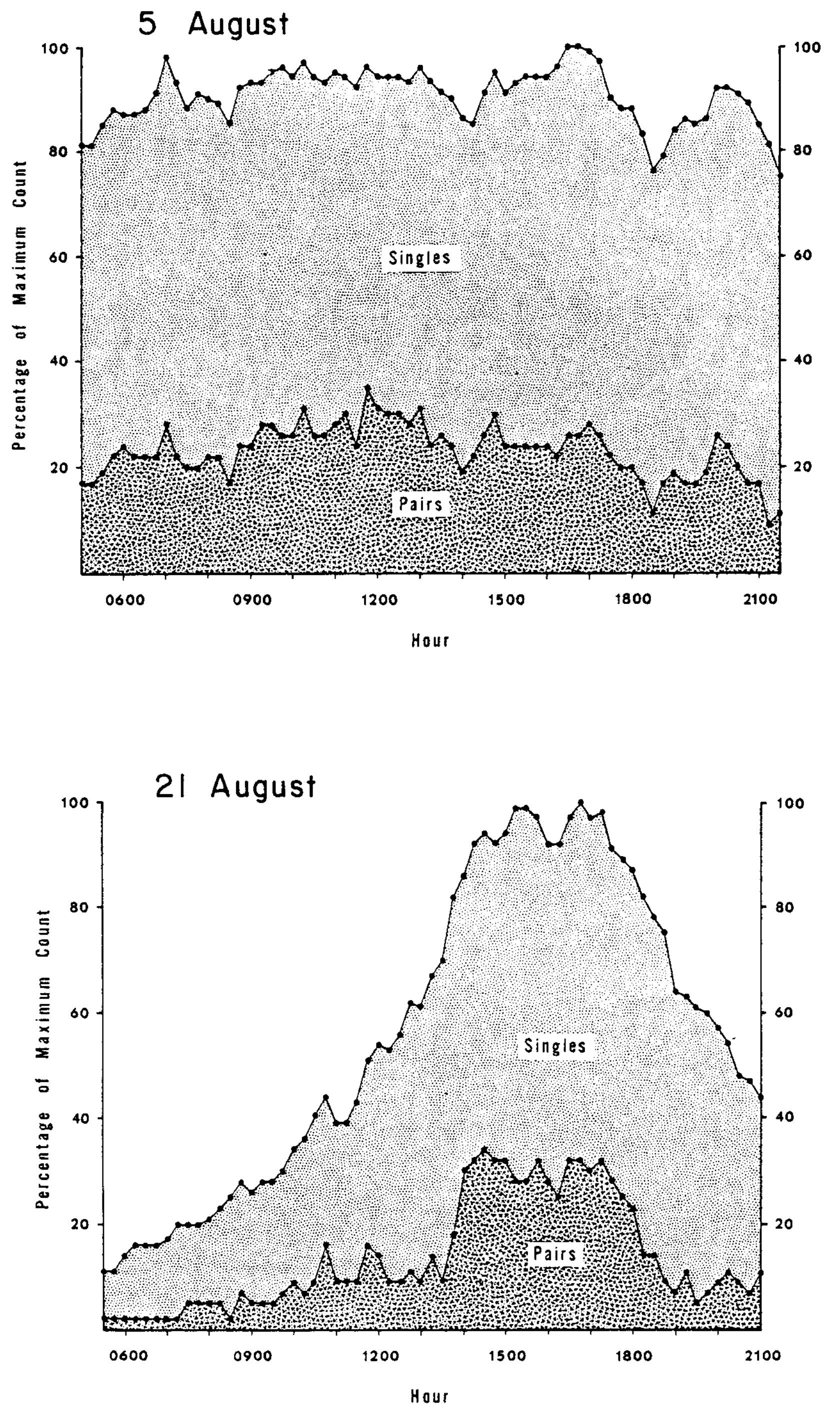


Figure II-9. Diel attendance patterns of Northern Fulmars during the nestling stage, Semidi Islands, 1977.

day to day.

FACTORS AFFECTING REPRODUCTIVE SUCCESS

Six percent of those fulmar eggs that survived the full-term of incubation failed to hatch. Virtually all of the other egg losses were the result of predation by Glaucous-winged Gulls and Common Ravens. Gulls, because of their greater numbers, inflicted far more losses than ravens.

Fulmars first left their chicks unattended after they reached 2 weeks of age. Gulls and ravens may take these unattended chicks on occasion, but this was never observed at Chowiet Island. Some chicks died despite seemingly careful brooding and favorable weather. These were often found dead in their nests within a few days after hatching. Thus, the greater part of total chick mortality was from unknown causes, and occurred within the first few days in the nest. Severe rainstorms, however, appeared to be a significant source of chick mortality in 1977. A few young chicks were found dead in their nests following unusually wet weather that year.

Since mortality during the nestling stage varied little during the 3 years of study, it is essential to understand what caused the wide variation observed in hatching success. Fulmars lost eggs to gulls and ravens only when incubating birds left their nests unattended. The high rate of egg loss in 1976 resulted from a greater tendency for fulmars to leave their eggs exposed, which in turn was probably caused by difficulty in their finding enough food during foraging trips. Supporting this conclusion is the observation that incubation shifts of males and females averaged longer in 1976 than in 1977, suggesting a greater search time for food. Also, failed and nonbreeding birds initiated wing molt earlier in the season in 1977 than in 1976, and unsuccessful breeders showed a greater tendency to linger at the colony after failure. These observations all suggest that food was more abundant or distributed closer to the breeding grounds in 1977 than in 1976. Although predation was the immediate cause of egg loss in all years, there was no apparent difference in predation pressure; i.e., the populations and behavior of gulls and ravens were unchanged.

In summary, food supply appears to exert early control over breeding success by determining the capability of adults to incubate and hatch their eggs, rather than markedly affecting the growth and survival of young. The time of onset and duration of breeding seem to be relatively fixed. Thus, during a critical period for 2 to 3 weeks before and after egg-laying, food supply and the physiological condition of adults may largely determine the outcome of the season's nesting effort.

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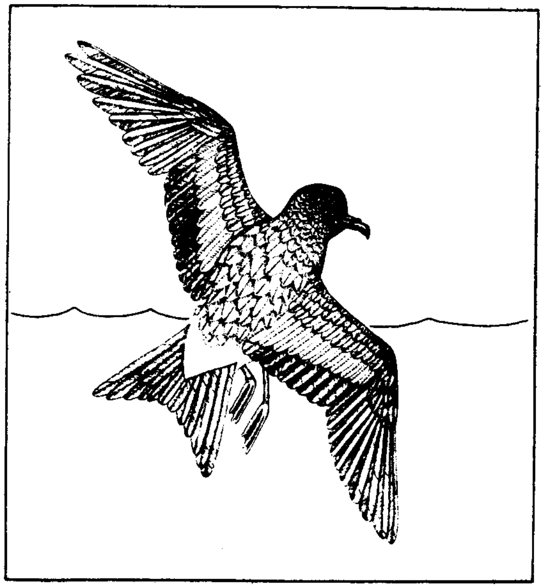
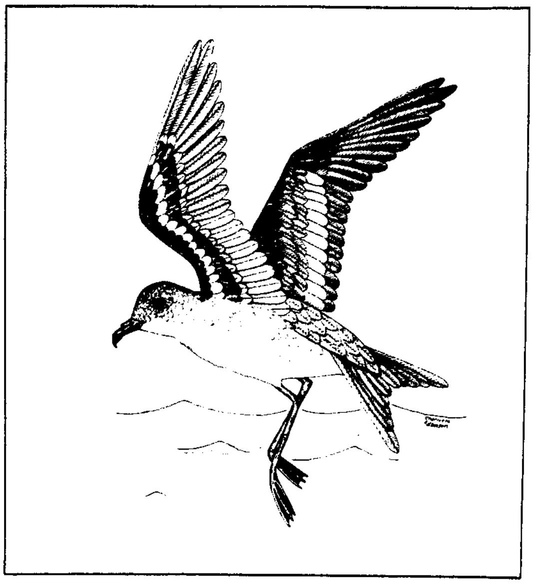
Storm-Petrels (*Oceanodroma* spp.)

Leach's Storm-Petrel (*Oceanodroma leucorhoa*)



Fork-tailed Storm-Petrel (*Oceanodroma furcata*)



by

Scott A. Hatch

FORK-TAILED AND LEACH'S STORM-PETRELS

(*Oceanodroma furcata* and *O. leucorhoa*)

Fork-tailed and Leach's Storm-Petrels are abundant oceanic birds in Alaska but have only recently been the subject of intensive studies at their breeding grounds. Before the studies reviewed here, Fork-tailed Storm-Petrels had not been thoroughly studied in any part of their range. Harris (1974) provided information on their population numbers, nesting chronology, and molt in northern California. The only other published materials are accounts of incidental information collected by early researchers including Grinnell (1897), Willet (1919), Bent (1922), Clay (1925), Grinnell and Test (1938), and Richardson (1960). Leach's Storm-Petrels have been studied more thoroughly than have Fork-tailed Storm-Petrels, although not in Alaska. Gross (1935), Huntington (1963), Wilbur (1969), Harris (1974), and Ainley et al. (1975) provide the most comprehensive studies. This discussion summarizes information from research on the following colonies:

Shumagin Islands:	1976	(Moe and Day 1977)
Barren Islands:	1976-78	(Manuwal and Boersma 1977, Manuwal 1978, Manuwal and Boersma 1978, Boersma and Wheelwright 1979, Wheelwright and Boersma 1979, Boersma et al. 1980)
Wooded Islands:	1976-77	(Mickelson et al. 1977, 1978; Quinlan 1979)
Forrester Island:	1976	(DeGange et al. 1977)

BREEDING DISTRIBUTION AND ABUNDANCE

The distribution and sizes of Leach's and Fork-tailed Storm-Petrel colonies are poorly known because the birds nest in burrows or crevices and enter or leave their colonies only at night. Sowls et al. (1978)

identify 38 colonies of Leach's Storm-Petrels and 60 colonies of Fork-tailed Storm-Petrels in Alaska, with 29 and 39 colonies, respectively, in the Gulf of Alaska. These colonies occur from Petrel Island in the extreme southeast portion of Alaska to Buldir Island at the western end of the Aleutian chain (Fig. III-1). Sowls et al. (1978) estimate populations of about 4 million Leach's and 5 million Fork-tailed Storm-Petrels divided somewhat equally between the Gulf of Alaska and the Aleutian Island areas. Local breeding populations range from a few hundred pairs to colonies of hundreds of thousands of birds.

Studies of the breeding biology of storm-petrels were conducted in 1976 at Castle Rock in the Shumagin Islands; between 1976 and 1978 at East Amatuli in the Barren Islands; in 1976 and 1977 at Fish Island in the Wooded Island Group; and in 1976 at Petrel Island in the Forrester Island Group. Wooded Islands colony is the northernmost known for either species within the Pacific Region. Estimates of the number of breeding birds at these colonies are displayed in Table III-1.

NESTING HABITAT

Storm-petrels nest either in burrows or in natural cavities of suitable proportions. Fork-tailed Storm-Petrels at the Wooded Islands were found in approximately equal numbers in burrows on soil-covered slopes and in crevices in rocky slopes on the periphery of Fish Island. Mean particle diameter on rocky slopes used by petrels ranged from about 30 to 60 cm, and nests were located anywhere from 1 to 50 m from the high tide line. In upland areas, birds used natural cavities under roots, stumps, fallen logs, or partially buried rocks. Ninety percent of all active nests on Fish Island were located within 12 m of the edges of marine cliffs.

Fork-tailed Storm-Petrels at the Barren Islands nested primarily in

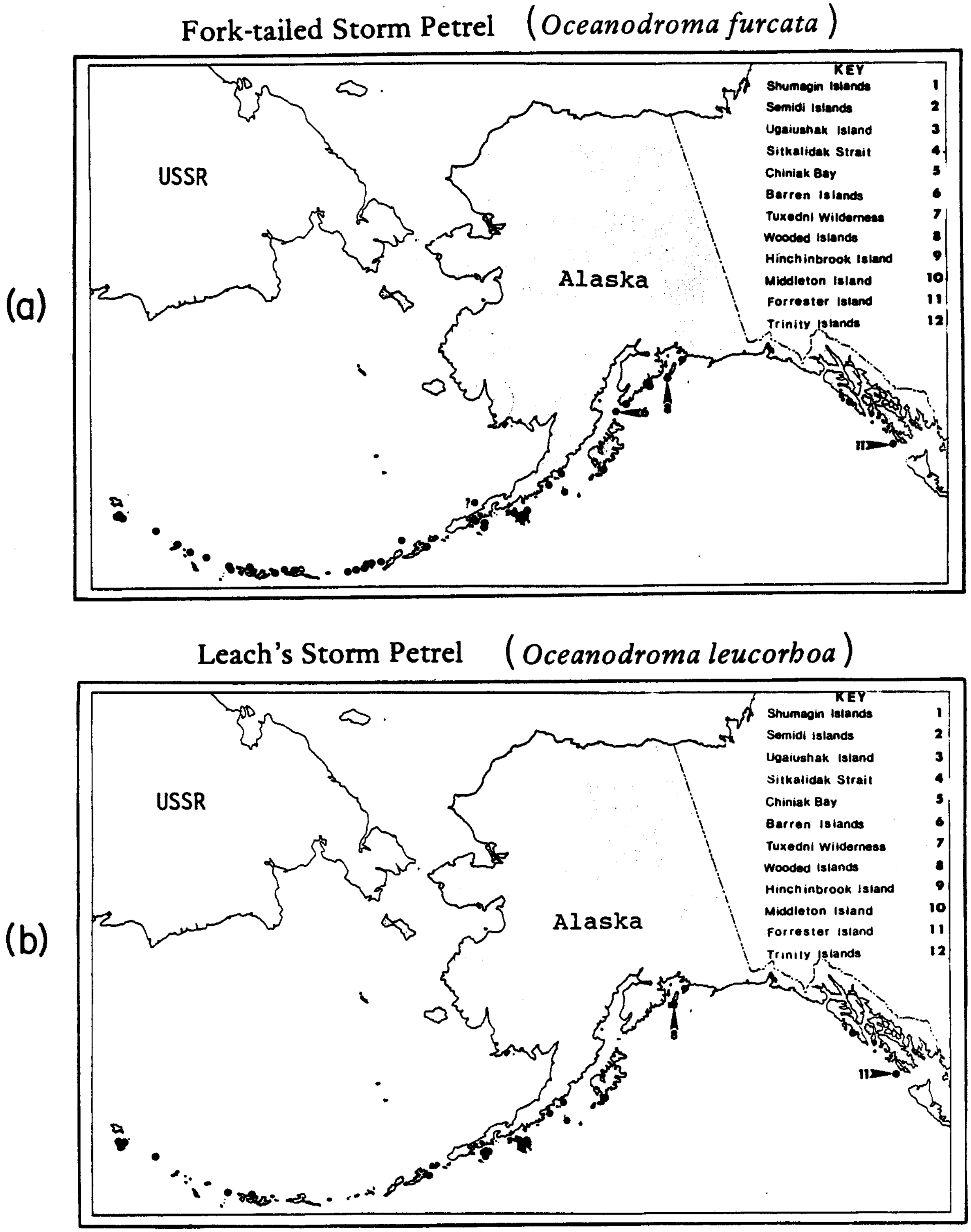


Figure III-1. Distribution of breeding colonies of (a) Fork-tailed Storm-Petrels and (b) Leach's Storm Petrels in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

TABLE III-1
Estimated Numbers of Fork-tailed and Leach's Storm-Petrels Nesting at Study Sites in the Gulf of Alaska

Colony	Year	Number of breeding birds	
		Fork-tailed Storm-Petrels	Leach's Storm-Petrels
Castle Rock (Shumagin Is.)	1976	3,000	6,000
East Amatuli (Barren Is.)	1976-78	150,000	
Fish Island (Wooded Is.)	1976-77	1-2,000	100
Petrel Island (Forrester Is. Grp)	1976	80,000	700,000

natural rock crevices on slopes with Umbelliferae. Nesting densities were found to be highest along the bases of slopes where an accumulation of talus and boulders produced a high level of local relief. Apparently this species readily occupies newly created nesting habitat, as was demonstrated in 1977 when birds nested in the rubble of a mudslide which had occurred in 1976 on East Amatuli Island. Investigators also provided artificial habitat on East Amatuli in 1977 (Manuwal and Boersma 1978). Among the 60 artificial nest boxes installed that year, only 1 was used by a breeding pair. In 1978, however, eight of the nest boxes were occupied by breeding birds. At Castle Rock, Shumagin Islands, both species nested in burrows on grassy slopes and on flat areas dominated by Elymus and various umbels. They were often in association with Ancient Murrelets and Cassin's Auklets.

Leach's Storm-Petrels nested exclusively in soil burrows on the Wooded Islands and at Petrel Island, in the Forrester group. On occasion they also nested in rock crevices but this choice of habitat appeared to be less common in Leach's than in Fork-tailed Storm-Petrels.

Both Leach's and Fork-tailed Storm-Petrels frequently nested in unoccupied burrows of other species, or in side chambers of active burrows. Eight percent of "empty" burrows of Tufted Puffins were occupied by Fork-tailed Storm-Petrels on East Amatuli Island. On some islands, nests of storm-petrels may occur largely or solely in association with those of other burrow-nesting species.

Nesting densities on Petrel Island in 1976 illustrate the extreme crowding that occurs on some heavily populated islands. An average of 4.1 burrows/m^2 (both occupied and unoccupied) was counted in sample plots totaling 62 m^2. Not all nest sites appeared to be used, but estimated densities of active burrows were $2.4/m^2$ and $0.3/m^2$ for Leach's and Fork-tailed Storm-

Petrels, respectively.

BREEDING CHRONOLOGY

Data on the breeding chronology of storm-petrels at four colonies in the Gulf of Alaska between 1976 and 1978 are summarized in Table III-2 and Figs. III-2 and III-3. In all situations, hatching was the most thoroughly documented phase of the nesting cycle. Accordingly, the range of laying and fledging dates was estimated from hatching dates using information on the duration of the incubation and nestling periods. All these data reveal substantial species', geographic, and seasonal differences in breeding chronology in the Gulf of Alaska. Storm-petrels probably begin visiting their nesting sites in the Gulf of Alaska during March or early April. In most years, the last young of both species may not leave the breeding grounds until late October. Thus, storm-petrels may be found on land during at least 7 months of the year at colonies in this region.

A difficulty arises because interrupted incubation is common in the Fork-tailed Storm-Petrel, and this makes the interval between laying and hatching extremely variable. The same phenomenon probably occurs in Leach's Storm-Petrels (P. Dee Boersma, pers. comm). Boersma and Wheelwright (1979) found that embryos of Fork-tailed Storm-Petrels species survive frequent and extended periods of neglect at low temperatures. At the Barren Islands in 1977, the 33 eggs that hatched were left unattended an average of 11.0 days during incubation, and there was one extreme instance of lack of attendance for 31 days. One egg hatched after being left unincubated for 7 consecutive days. Depending on the extent of egg neglect, the interval between laying and hatching ranged from 37 to 68 days ($\bar{x}$ = 49.8 days, n = 33), although the number of days of actual incubation averaged only 38.6 in the same nests.

This phenomenon was closely studied only at the Barren Islands in 1977,

TABLE III-2
Breeding Chronology of Storm-Petrels in the Gulf of Alaska 1976-1978

Species	Location	N	Year	Laying		Hatching			Fledging	
				First	Last	First	Peak	Last	First	Last
Fork-tailed Storm-Petrel	Shumagin Is.	2	1976	24 April	9 June	10 June		27 July	9 Aug	26 Sept
	Wooded Is.	30	1976	22 April	12 May	3 June	20 June	11 July	2 Aug	9 Sept
		85	1977	29 April	8 June	10 June	30 June	15 Aug	9 Aug	14 Aug
	Barren Is.	94	1976	17 May	15 June	28 June	23 July	22 Aug	27 Aug	21 Oct
		40	1977	23 May	21 June	3 July	20 July	26 Aug	1 Sept	25 Oct
		56	1978	30 April	1 June	10 June	25 June	8 Aug	9 Aug	7 Oct
	Forrester Is.	Unk.	1976	26 April	31 May	7 June	20 June	18 July	6 Aug	17 Sept
Leach's Storm-Petrel	Shumagin Is.	6	1976	21 April	26 June	1 June		6 Aug	12 Aug	18 Oct
	Wooded Is.	6	1976	6 June	14 July	18 July		25 Aug	21 Sept	29 Oct
		4	1977	31 May	16 July	13 July		27 Aug	16 Sept	1 Nov
	Forrester Is.	Unk.	1976	17 June		29 July	9 Aug		2 Oct	

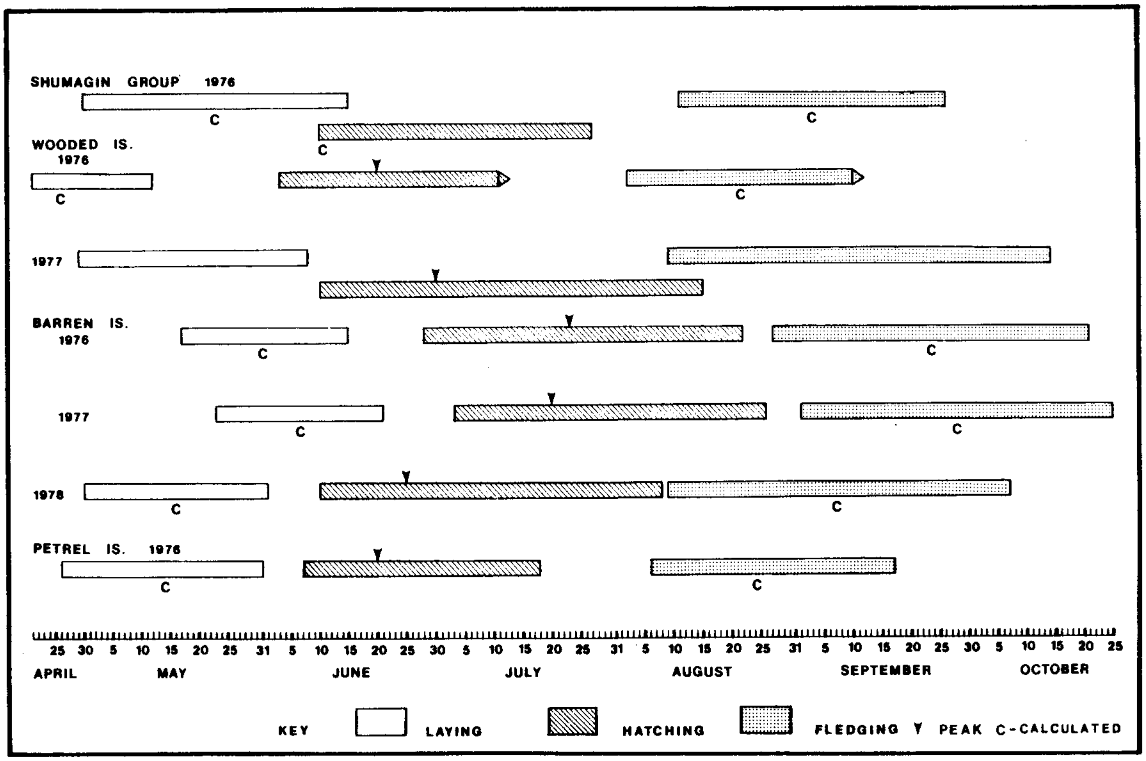


Figure III-2. Chronology of major events in the nesting season of Fork-tailed Storm-Petrels in the Gulf of Alaska.

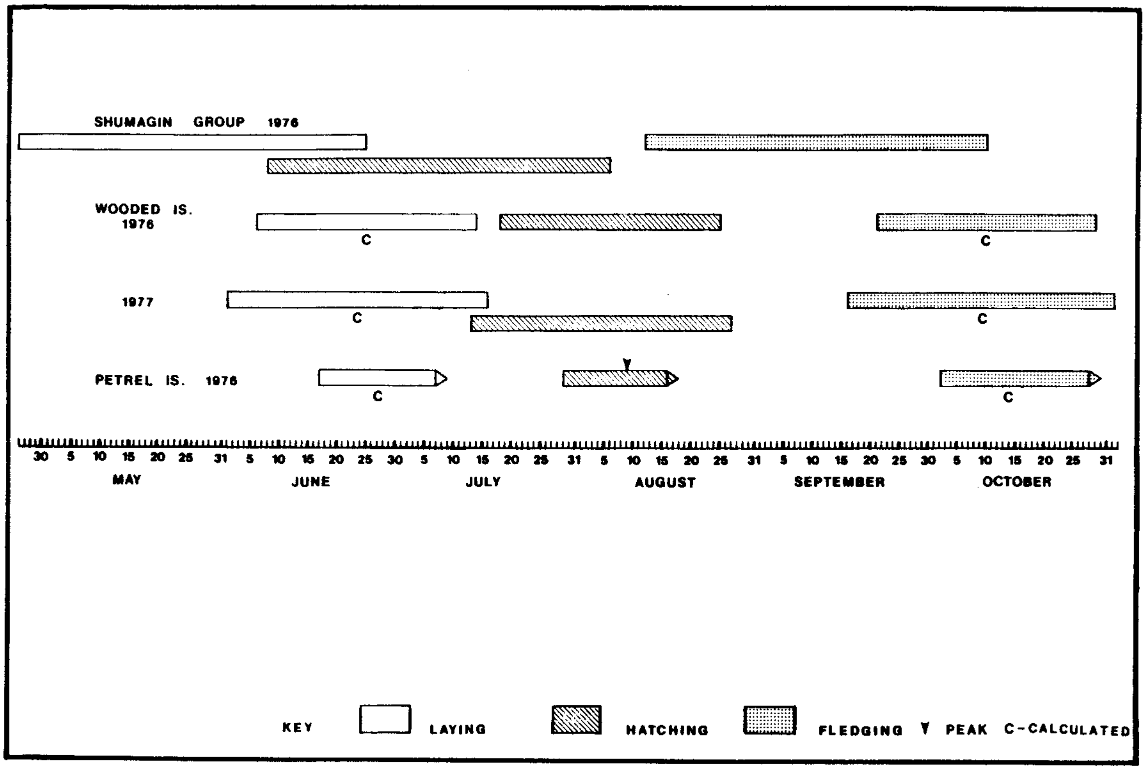


Figure III-3. Chronology of major events in the nesting season of Leach's Storm-Petrels in the Gulf of Alaska.

but egg neglect was also prevalent in 1976. The mean incubation period of Fork-tailed Storm-Petrels at the Wooded Islands in 1977 was 48.4 days, with a range from 42 to 59 days (n = 9). This suggests that egg neglect was also common at the Wooded Islands and is probably a regular feature of incubation in this species. Its occurrence may prove to be a sensitive indicator of foraging conditions during the incubation phase of the nesting cycle (Boersma et al. 1980). Egg-laying dates of Fork-tails (Table III-2) were calculated from observed hatching distributions on the assumption that egg neglect at all study sites was comparable to that documented by Boersma and Wheelwright (1979).

With due allowance for possible errors in estimating the breeding chronology of Fork-tailed Storm-Petrels, the spread of egg laying was about 30 days at the Barren Islands, 35 days at Forrester Island, 40 days at the Wooded Islands, and More than 40 days at Castle Rock (Table III-2). Depending on the incidence of egg neglect, hatching spanned about 40 days at Forrester Island, 55-60 days at the Barren Islands, about 50 days at Castle Rock, and more than 60 days at the Wooded Islands. The earliest eggs laid were in late April at Forrester, the Shumagin, and the Wooded Islands. The onset of laying in the Barren Islands occurred in late April in 1978 but about 3 weeks later in 1976 and 1977. The last eggs were laid as early as 12 May in the Wooded Islands in 1976 and as late as 21 June at the Barrens in 1977.

The nestling period (hatching to fledging) of Fork-tailed Storm-Petrels averaged 59.5 days (range 52-63 days, n = 20) at the Barren Islands in 1978. Similar values (mean 60.1 days, range 51-65 days) were obtained for 33 chicks at the Wooded Islands in 1977. Thus, an interval of 60 days was used to compute the approximate range of fledging dates from observed hatching dates. Onset of hatching ranged from early June to early July, and hatching was completed by mid-July to late August. Fledging occurred from early August till late October.

Although it probably occurs, egg neglect was not documented for Leach's Storm-Petrels. In the absence of better data, an incubation period of 41-42 days (Palmer 1962) was assumed for back-dating the few hatching dates recorded for this species. A nestling period of 65 days (Palmer 1962) was used in calculating probable fledging dates from known hatching dates. Laying dates for Leach's Storm-Petrels ranged from late April to mid-July, and hatching spanned from mid-July to late August. The chicks fledged from mid-August to the first of November.

Breeding chronology of Fork-tailed Storm-Petrels was more than 3 weeks later at the Barren Islands than at Wooded Islands in both 1976 and 1977. Local variations in the timing or availability of food before breeding may affect the onset of breeding even in this wide-ranging species. Chronology of events in the nesting cycle of Fork-tails at the Wooded Islands in 1976 was similar to that observed on Petrel Island (Forrester group) more than 400 km to the southeast. Thus, no consistent latitudinal gradient in breeding chronology is evident in the colonies studied.

Observers at the Barren Islands noted a marked difference in the chronology of birds nesting at high and low elevations on East Amatuli Island. Approximately 2 weeks separated the mean hatching dates of chicks at 450 m from those at 10 m elevations in 1978, with those at 10 m breeding earlier. In this early year, birds at higher elevations may have been prevented from breeding until their nests sites were free from ice and snow.

REPRODUCTIVE SUCCESS

Reproductive success of Fork-tailed Storm-Petrels was studied at the

Wooded Islands in 1976 and 1977 and at the Barren Islands during three breeding seasons from 1976 to 1978 (Table III-3). Too few nests of Leach's Storm-Petrels were studied to permit a meaningful assessment of productivity in species. An average of 77% of the burrows of Fork-tailed Storm-Petrels were active (showed signs of use) each year at the study sites, and eggs were laid in about 68% of active burrows.

Storm-petrels normally lay only one egg each season. To test the capability of storm-petrels to replace their eggs should they be lost, investigators on the Barren Islands in 1977 removed eggs early in incubation from 36 nests of Fork-tailed Storm-Petrels. New eggs appeared in 27 nests (75%) within 3-6 weeks. A small proportion of newly laid eggs were produced by new pairs, but most were true replacement clutches.

Laying success (eggs laid per active burrow) was about 69% for the 2 years it was calculated--one at the Barren and one at the Wooded Islands. Hatching success (eggs hatched per eggs laid) ranged from 53% to more than 80% between 1976 and 1978 at the Barren Islands and from 35% to more than 90% in the different habitats on the Wooded Islands. The survival of chicks showed similar variation, and fledging success ranged from 52% to 94%. Overall breeding success (chicks fledged per burrow with eggs or per breeding pair) ranged from 29% to 68% at the two study sites. It averaged 52% over a 3 year-period at the Barren Islands (excluding data from heavily disturbed study plots).

At the Wooded Islands in 1976, reproductive success was determined accurately only for birds nesting in soil habitat. Productivity was poor due to a high incidence of predation by river otters (Lutra canadensis). In 1977, three estimates of overall breeding success were made at the Wooded Islands. These were based on samples of nests in soil habitat, in rocky

TABLE III-3
Productivity of Fork-tailed Storm-Petrels.

	Barren Islands				Wooded Islands			
	1976	1977		1978	1976	1977		
		Light Disturbance	Heavy Disturbance		Soil	Soil	Rock	Soil Exclosure
Sample size	85		341	100	134			
No. of burrows w/ signs of use (nest attempt)[a]			259		108			
No. of burrows w/ an egg[b]	49[1]	100[2]	176[2]	85[1]	75[3]	204[3]	33[4]	25[4]
No. of eggs hatched	26	84	107	62	44	72	31	21
No. of chicks fledged	14	58	78	58	23	49	21	17
Burrows w/ an egg per nest attempt			0.68		0.69			
Eggs hatched per egg laid (hatching success)	0.53	0.84	0.61	0.73	0.59	0.35	0.94 (0.67)[c]	0.84
Chicks fledged per egg hatched (fledging success)	0.54	0.69	0.73	0.94	0.52	0.68	0.68	0.81
Chicks fledged per burrow with an egg	0.29	0.58	0.44	0.68	0.31	0.24	0.64 (0.46)	0.68
Chicks fledged per nest attempt (reproductive success)			0.30		0.21			

[a] Nest attempt = burrows entered at least once.
[b] Burrows were first checked: 1) Before egg-laying, 2) Late in incubation, 3) At varying stages of incubation 4) Mostly after chicks hatched.
[c] Most nests in rock habitat were found after the chick hatched. Two estimates of hatching and breeding success provided. The first is based on all nests found; the second (in parentheses) incorporates an estimate of hatching success based on six eggs found, four of which hatched.

slope habitat, and in soil habitat protected from otters with a wire screen. Success was nearly three times higher within the exclosure than in similar habitat exposed to predation. In the rocky habitat where petrels were less susceptible to predation by otters, success was intermediate between the experimental and control plots in soil habitat.

To summarize, in the absence of mammalian predators, Fork-tailed Storm-Petrels are probably capable of producing 0.6-0.7 young per breeding pair most years. At the Barren Islands, unduly low success in 1976 was probably due in part to heavy disturbance by observers.

GROWTH OF CHICKS

Data on growth in body weight of Fork-tailed Storm-Petrels were gathered at the Wooded Islands in 1977 and at the Barren Islands from 1976 through 1978 (Table III-4, Fig. III-4). Data obtained at the Wooded Islands in 1977 illustrate patterns of growth in wing, tarsus, and culmen (Table III-5). Limited data are available for Leach's Storm-Petrels. Those gathered at the Wooded Islands in 1976 and 1977 are combined in Table III-6 and Fig. III-5 to provide a generalized picture of growth in this species. Mean weight gained per day over the major portion of the nestling period (hatching to peak weight) was about 1.5 g in Fork-tailed and 1.1 g in Leach's Storm-Petrels.

Growth of Fork-tailed Storm-Petrels was similar in all years and locations except in 1977 at the Barren Islands, when growth rates were reduced (Fig. III-4). Slower growth may have resulted from the same conditions that caused a high incidence of interrupted incubation in that year, but insufficient data are available on growth rates and egg neglect in other years to determine how well the two are correlated. The survival rate of chicks in 1977 was intermediate between the rates observed in 1976 and 1978.

During their last 2 weeks in the nest, Fork-tailed Storm-Petrels reached

TABLE III-4.
Growth of Fork-tailed Storm-Petrel Chicks at the Barren and Wooded Islands.

Age in days	Wooded Islands 1977 and Barren Islands 1976 & 1978 (combined)				Barren Islands 1977			
	N	$\overline{X}$ wt.(g)	SE	Range	N	$\overline{X}$ wt.(g)	SE	Range
0	9	10.3	0.50	7-15	32	9.4	0.2	7-11
1-2	49	12.4	0.46	9-17	13	11.6	0.8	7-16
3-4	62	16.0	0.47	8-26	20	13.9	1.0	7-23
5-6	107	19.3	0.45	10-30	36	16.6	0.6	9-24
7-8	115	23.0	0.52	15-36	12	22.6	1.3	17-32
9-10	140	27.8	0.53	15-47	34	24.5	1.1	12-41
11-12	138	32.3	0.60	13-48	12	34.3	2.1	24-44
13-14	134	37.3	0.62	18-56	10	36.7	1.2	30-43
15-16	133	43.2	0.69	31-59	34	34.8	1.3	17-48
17-18	127	48.4	0.74	33-74	12	44.9	3.6	26-64
19-20	120	53.3	0.92	36-71	31	43.8	1.9	25-70
21-22	122	58.0	0.81	35-78	12	50.0	2.2	36-60
23-24	117	62.9	0.79	40-81	11	53.2	2.9	41-74
25-26	118	67.1	0.83	45-94	29	52.2	2.7	17-78
27-28	105	70.1	0.91	54-88	12	58.1	3.3	59-74
29-30	113	72.4	0.95	55-99	24	59.8	2.5	33.81
31-32	119	74.6	0.83	53-92	8	62.9	3.5	48-74
33-34	122	77.1	0.76	48-97	6	61.7	4.3	46-78
35-36	122	78.1	0.78	45-98	17	64.4	2.1	46-82
37-38	111	78.9	0.90	46-107	6	66.3	2.3	60-76
39-40	107	81.5	0.93	51-103	10	70.8	4.4	55-98
41-42	111	81.8	0.96	51-105	4	62.3	3.7	56-72
43-44	99	82.7	0.95	55-103	4	62.5	3.4	54-69
45-46	103	84.7	1.03	52-107	4	69.3	7.1	55-83
47-48	101	84.0	1.03	51-106	4	73.0	3.9	62-80
49-50	56	85.2	1.05	53-106	3	69.0	12.0	56-93
51-52	91	87.0	1.01	53-104				
53-54	87	87.9	1.08	50-108				
55-56	93	86.2	1.06	52-105				
57-58	84	83.0	0.98	49-101				
59-60	63	80.6	0.96	45-103				
61-62	36	75.9	1.19	44-88				
63-64	14	73.1	1.28	67-81				

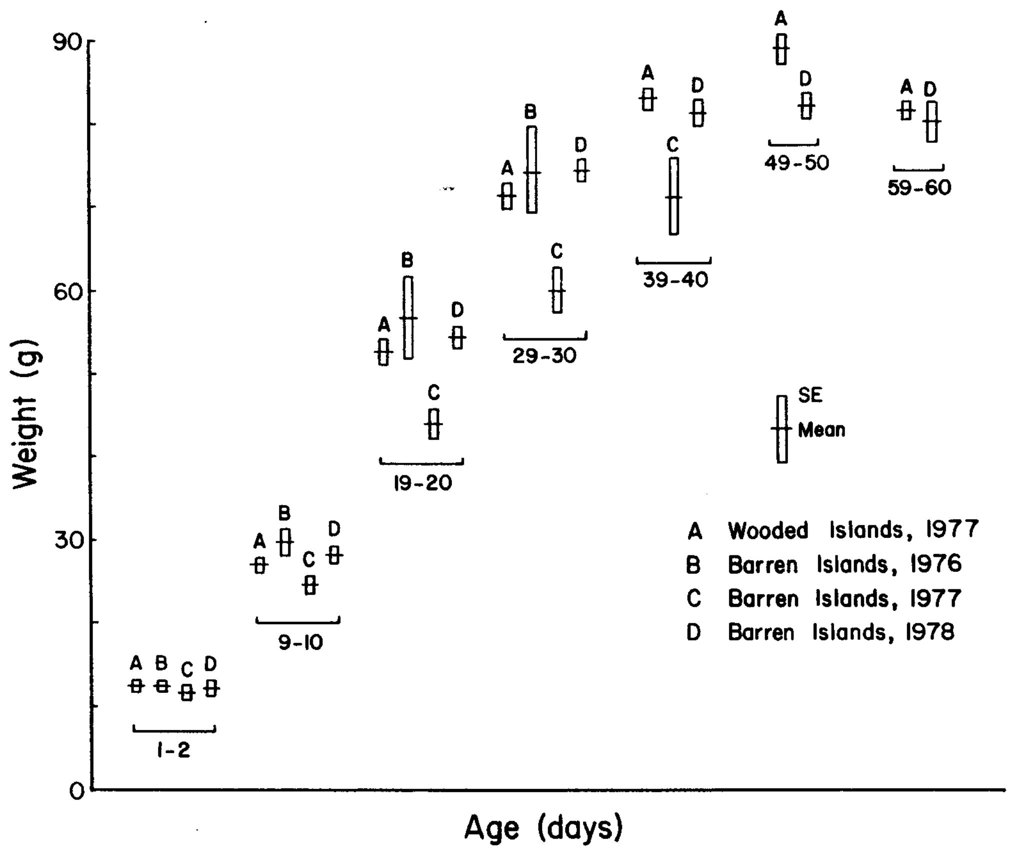


Figure III-4. Comparison of mean weights of Fork-tailed Storm-Petrel nestlings at the Wooded Islands and the Barren Islands between 1976 and 1978.

TABLE III-5

Growth in Culmen, Tarsus, and Wing of Fork-tailed Storm-Petrel Chicks at the Wooded Islands (1976 and 1977 Data Combined).

Age (days)	n	Culmen (mm)			Tarsus (mm)			Wing (mm)		
		X̄	SE	Range	X̄	SE	Range	X̄	SE	Range
1-2	9	9.1	0.1	8.4-9.8	11.7	0.2	10.6-12.8	13.8	0.2	8-15
3-4	19	9.5	0.1	8.7-10.2	12.4	0.2	11.2-14.1	14.5	0.2	13-16
5-6	24	9.9	0.1	9.3-11.4	13.3	0.2	11.8-14.8	15.4	0.2	14-17
7-8	22	10.1	0.1	9.3-11.5	14.0	0.3	11.3-18.2	16.7	0.3	15-21
9-10	28	10.3	0.1	9.4-11.9	15.3	0.2	13.3-19.1	18.3	0.3	16-24
11-12	24	10.6	0.1	9.1-11.6	15.9	0.3	12.9-18.4	19.9	0.4	17-24
13-14	27	11.1	0.1	9.8-11.9	17.3	0.3	13.8-21.8	22.1	0.7	17-30
15-16	23	11.5	0.1	10.2-13.0	19.0	0.4	15.5-23.1	25.0	0.7	19-37
17-18	29	11.9	0.1	10.5-12.8	19.5	0.3	15.2-22.8	27.5	0.7	20-38
19-20	30	12.3	0.1	10.9-13.7	20.8	0.3	16.6-23.9	33.2	1.1	28-49
21-22	26	12.7	0.1	11.7-13.8	22.4	0.3	19.6-24.5	39.3	1.4	30-51
23-24	26	12.9	0.1	11.6-13.7	23.7	0.3	21.1-24.3	43.7	1.4	29-55
25-26	30	13.4	0.1	12.2-14.5	24.0	0.3	21.7-27.0	52.9	1.6	39-77
27-28	22	13.6	0.1	12.9-15.1	24.5	0.3	22.5-27.2	57.7	1.9	40-76
29-30	21	13.7	0.1	12.9-14.6	25.0	0.3	21.5-27.1	65.5	2.0	48-86
31-32	23	14.0	0.1	12.9-15.0	25.6	0.2	22.5-27.2	76.7	2.1	61-96
33-34	22	14.2	0.1	13.2-15.3	26.2	0.2	24.0-27.7	82.3	2.0	58-98
35-36	21	14.3	0.1	13.5-15.4	26.3	0.2	23.9-27.5	89.7	2.1	81-108
37-38	24	14.4	0.1	13.6-15.3	26.0	0.1	24.4-27.4	96.7	2.1	80-111
39-40	22	14.6	0.1	13.3-15.7	26.5	0.2	24.6-27.6	101.5	1.9	80-119
41-42	21	14.7	0.1	13.7-15.6	26.5	0.2	24.7-27.6	111.0	2.1	93-129
43-44	26	14.6	0.1	13.6-15.6	26.3	0.2	24.4-27.6	118.5	2.0	105-137
45-46	27	14.5	0.1	13.9-15.5	26.5	0.2	26.0-27.7	125.5	1.7	102-136
47-48	22	14.7	0.1	13.7-15.7	26.6	0.1	-	132.5	2.0	117-149
49-50	17	14.7	0.1	13.7-15.7	26.2	0.2	-	139.4	1.5	127-156
51-52	25	14.8	0.1	14.1-16.0	26.4	0.1	-	144.4	1.4	123-157
53-54	19	14.7	0.1	14.1-16	26.4	0.2	-	146.5	2.0	133-160
55-56	21	14.7	0.1	13.9-15.8	26.3	0.2	-	152.3	1.1	144-162
57-58	23	14.7	0.1	14.1-15.7	26.4	0.2	-	157.1	0.8	143-160
59-60	17	14.7	0.1	14.0-15.5	26.5	0.2	-	156.8	1.5	146-163
61-62	10	14.4	0.1	14.0-15.5	24.4	0.2	-	159.9	0.6	154-165
63-64	7	14.8	0.2	14.4-15.5	26.0	0.3	-	158.3	1.9	155-161

TABLE III-6
Growth of Leach's Storm-Petrel Chicks at the Wooded Islands
(1976 and 1977 Data Combined).

Age (days)		Weight (g)			Culmen (mm)			Tarsus (mm)				Wing (mm)		
	n	$\bar{X}$	SE	Range	$\bar{X}$	SE	Range	$\bar{X}$	SE	Range	n	$\bar{X}$	SE	Ran
1-5	0	-	-		-	-		-	-		0	-	-	
6-10	2	15.5	1.5	14.17	9.5	0.1	9.3-9.6	11.6	0.1	11.4-11.7	2	14.0	2.1	-
11-15	14	15.3	1.0	11-25	9.6	0.2	9.0-10.0	12.5	0.3	11.5-15.5	7	14.0	1.1	9-17
16-20	14	29.0	2.0	20-43	10.6	0.2	9.4-11.1	14.7	0.3	13.2-15	9	18.5	1.0	15-24
21-25	18	44.1	2.1	31-64	11.3	0.2	10.5-12.2	17.4	0.4	15.9-18.9	6	23.7	1.5	17-29
26-30	11	50.8	1.6	39-58	12.2	0.2	11.7-12.6	20.4	0.6	18.7-22	7	30.8	1.1	28-34
31-35	9	57.7	1.1	52-63	13.0	0.2	12.5-14.0	21.9	0.2	20.4-22.2	6	48.5	2.8	37-55
36-40	10	68.7	1.7	63-78	13.7	0.1	13.6-14.0	23.2	0.2	22.0-23.7	4	68.8	3.8	61-69
41-45	10	65.8	2.5	66-79	14.5	0.2	13.9-15.5	23.2	0.2	22.5-23.9	6	76.8	4.0	78-89
46-50	10	58.1	1.5	55-64	14.8	0.2	14.3-14.9	23.3	0.3	23.2-23.8	4	102.7	3.4	97-110
51-55	10	64.9	1.8	57-75	14.8	0.2	14.3-15.2	23.3	0.3	22.4-23.8	4	119.3	2.8	114-125
56-60	10	68.2	1.6	60-77	14.8	0.4	14.4-15.0	22.8	0.4	22.0-28.8	4	137.5	2.5	133-143
61-65	10	74.1	4.3	56-96	14.7	0.1	14.6-14.8	23.2	0.6	22.4-24.0	3	149.4	0.9	148-151
66-70	7	66.1	3.1	58-81	14.6	0.1	14.4-14.9	23.3	0.4		3	156.4	1.2	154-158

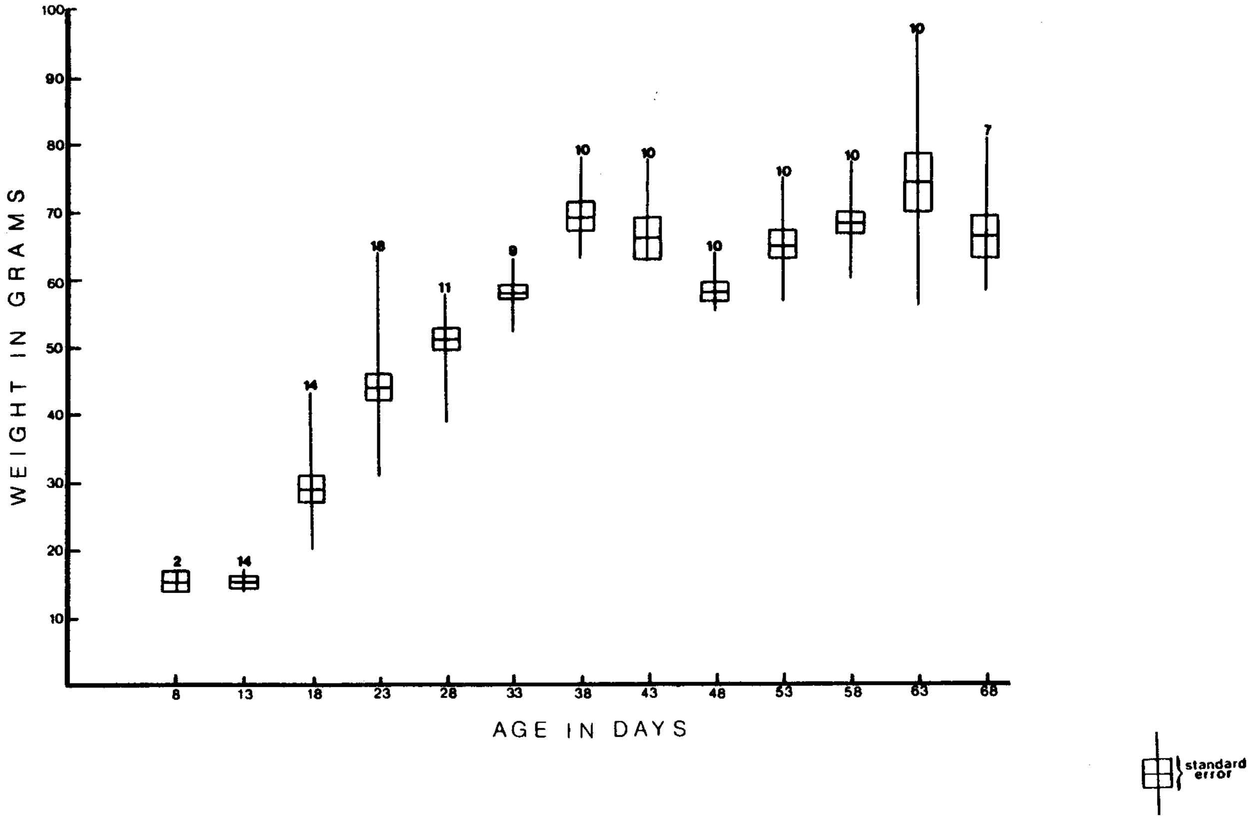


Figure III-5. Weight gain in Leach's Storm-Petrels at the Wooded Islands. Data for 1976 and 1977 combined.

a maximum weight ranging from 92 to 99 g which is 35 to 90% above adult weight (mean 60%), then declined to about 20% above adult weight before fledging (Table III-7). Fledging weights were 64.8 to 74.0 g. Average peak weight attained by nestlings at Wooded Islands was 91.8 to 98.7 g, and this was significantly higher in 1977 than in 1976 ($P<0.05$). Fledglings were significantly heavier upon going to sea in 1977, and the mean duration of the nestling period was shorter ($P<0.05$). Comparable data gathered at Barren Islands in 1978 agree most closely with values obtained at Wooded Islands in 1977 and are probably close to the norm for this species. Leach's Storm-Petrels had a peak weight of 74 g and a fledging weight of 66 g.

Peak nestling weight, the age at which this peak occurs, weight at fledging, and the duration of the nestling period are four well-defined, biologically meaningful variables that convey more information about patterns of development in many species than growth rates per se. Further studies of growth in storm-petrels should focus on these aspects of nestling development. Fledging weight alone would likely prove to be the best single predictor of post-fledging survival.

FOOD HABITS AND FORAGING

Fork-tailed and Leach's Storm-Petrels appear to have different foraging strategies. Leach's Storm-Petrels use the oceanic feeding grounds beyond the continental shelf, while Fork-tailed Storm-Petrels make more intensive use of shelf and perhaps nearshore waters (Harris 1974, Ainley et al. 1975).

Regurgitated food samples were collected from adult Fork-tailed Storm-Petrels mist-netted at Wooded Islands during two breeding seasons. Collections were made on 10 nights in 1976 and 12 nights in 1977. Each of the 22 samples obtained comprised the combined regurgitations of 15-20 birds. Because of variations in the amount of material recovered, its state of decomposition,

TABLE III-7
Characteristics of Nestling Development in Fork-tailed Storm-Petrels at Two Sites in the Gulf of Alaska Between 1976 and 1978.

	Wooded Islands		Barren Islands		
	1976	1977	1976	1977	1978
Adult weight (g)					
$\overline{X}$	-	59.7	57.8	59.5	-
SE	-	0.2	0.2	0.2	-
n	-	353	299	337	-
Range	-	48-74	-	-	-
Peak nestling weight (g)					
$\overline{X}$	91.8	98.7	-	-	96.0
SE	1.6	0.9	-	-	1.3
n	10	47	-	-	24
Range	81-102	84-115	-	-	84-107
Age at peak weight (days)					
$\overline{X}$	50.4	49.3	-	-	47.0
SE	3.0	0.8	-	-	1.4
n	10	47	-	-	24
Range	32-57	34-60	-	-	32-60
Fledging weight (g)					
$\overline{X}$	64.8	72.4	-	-	74.0
SE	1.6	1.0	-	-	2.3
n	5	46	-	-	13
Range	59-70	57-87	-	-	61-90
Nestling period (days)					
$\overline{X}$	64.4	61.0	-	-	59.5
SE	1.0	0.5	-	-	0.3
n	7	47	-	-	20
Range	61-68	50-65	-	-	52-63

and its high oil content, little quantitative analysis was possible. The percent occurrence and numbers of individuals of identifiable prey species are summarized in Table III-8.

The amphipod Paracallisoma alberti, the copepod Calanus cristatus, and the euphausiid Thysanoessa spinifera made up the majority of invertebrates identified in the diet. Paracallisoma alberti was not identified in 1976 but was present in at least 80% of the samples collected in 1977. The occurrence of Calanus cristatus decreased from 90% to 17% between years. These changes suggest marked annual variations in the diet, but they may also reflect differences in the time of sampling if various prey species are abundant at the surface for only a short period during the breeding season of petrels (Quinlan 1979). Fish were present in all samples collected both years but were rarely identifiable. Most samples collected in 1977 contained plastic particles. There was one collection of food on Castle Rock at the Shumagin Islands in 1976. This sample, collected on 9 August at the entrance to a burrow occupied by Leach's Storm-Petrels, contained only the euphausiid Thysanoessa inermis.

Data on the feeding rates of Fork-tailed and Leach's Storm-Petrel nestlings are summarized in Table III-9. At the Wooded Islands in 1977, the feeding rates of the two species appeared to be similar, with chicks between the ages of 6 and 30 days receiving food on about 80% of nights. Deliveries were slightly less frequent during the latter half of the nestling period, and a substantial decrease in feeding rate in the last week or 10 days of the nestling period was evident in both species.

At the Barren Islands in 1977, Fork-tailed Storm-Petrels were fed by one or both parents on about 68% of nights during the first half of the nestling period. The use of specially designed event recorders permitted

TABLE III-8
Percent Numbers and Frequency of Occurrence of Prey From Regurgitations of Adult Fork-Tailed Storm-Petrels at the Wooded Islands, 1976 and 1977.

Identifiable contents	Percent number of prey				Frequency of occurrence			
	1976 (n=83)		1977(n=70)		1976 (n=10)		1977(n=12)	
	n	%	n	%	n	%	n	%
Invertebrates								
Copepoda *Calanus cristatus*	47	57	3	4	9	90	2	17
Gammaridea (Amphipod) *Paracallisoma alberti*	0		27	39	0	0	9	75
Euphausiaceae *Thysanoessa spinifera*	35	42	21	30	7	70	6	50
Decapoda *Hymenodora frontalis*	0		3	4	0	0	2	17
Cephalapoda Unidentified	0		3	4	0	0	2	17
Vertebrates[a]								
Cottidae	-		1	1		-	1	8
Gadidae (Cod)	-		2	3		-	2	17
Myctophidae (Lanternfish)	-		1	1		-	1	8
Scorpaeniformes	-		1	1		-	1	8
Unidentified fish					10	100	12	100
Other								
Fat	-		-		7	70	6	50
Plastic particles	1	1	8	11	10	100	8	67

[a] Fish parts were found in all samples during both 1976 and 1977; most pieces were unidentifiable, but a few could be identified to family in 1977.

TABLE III-9
Feeding Rates of Fork-tailed and Leach's Storm-Petrel Nestlings at the Wooded Islands and Barren Islands in 1977.

	Wooded Island 1979[a]						Barren Island 1977[b]					TOTAL		
	Fork-tailed Storm Petrel			Leach's Storm Petrel			Fork-tailed Storm Petrel					Fork-tailed Storm-Petrel		
								% days fed		No. feedings/chick/day				
Age (days)	No. chick-days	No. days fed	% days fed	No. chick-days	No. days fed	% days fed	No. chicks	$\bar{X}$	SE	$\bar{X}$	SE	No. chick-days	No. days fed	% days fed
6-10	120	101	84.1	-	-	-	5	76.0	9.80	0.92	0.162	145	120	82.8
11-20	241	198	82.2	23	20	87.0	4	57.5	7.50	0.65	0.087	281	221	78.6
21-30	233	179	76.8	26	20	76.9	3	66.7	12.02	0.77	0.067	269	203	75.5
1st half summary:														
6-30	594	478	80.5	49	40	81.6	12	67.5	5.65	0.79	0.078	695	544	78.3
31-40	214	162	75.7	18	12	66.7						226	169	
41-50	226	169	74.8	20	11	55.0								
51-60	207	100	48.3	21	15	71.4								
Total summary (to age 60 days):														
6-60	1241	909	73.2	59	38	64.4								
61-70	-	-	-	16	7	43.7								

[a] Any chick gaining weight overnight or losing 3 g or less was assumed fed.
[b] Feeding rates determined from weight changes and a continuous record of parental visits.

continuous observations on parental attendance and on the feeding rates of chicks in five nests during the entire nestling period. Chicks were fed by both parents on about 12% of all nights during the nestling period, or 20% of all nights fed. The number of feedings per day averaged 0.79.

The average weight of 18 feedings to nestling Fork-tailed Storm-Petrels was 11.6 g (range 4-24 g, SD=5.6 g) at the Wooded Islands in 1977. This average was determined by weighing chicks just before adults arrived and immediately after they left. At the Barren Islands, deliveries of food to one chick averaged 8.7 g per feeding (n=6) during a 1-week interval near the beginning of the nestling period, and 13.7 g (n=6) near the end. An average feeding weighed 11.2 grams, which agrees closely with the value determined at the Wooded Islands.

These data permit a rough calculation of the food requirement of a Fork-tailed Storm-Petrel during its nestling period. Chicks are fed on about 45 of 60 days spent in the nest (75%). Both parents deliver food on about 7 days, so the total number of feedings averages 52. Assuming 11.4 g is the mean quantity of food per load, about 593 g are consumed per chick over the nestling period. During years with normal productivity (say, 60% nesting success), Fork-tailed Storm-Petrels on East Amatuli Island alone (est. 75,000 breeding pairs) gather about 26.7 metric tons of food for their young. Applying these same figures to the population of Fork-tailed Storm-Petrels at the Barren Islands, the annual food requirement of nestling Fork-tailed Storm-Petrels is probably upwards of 50 metric tons there.

COLONY ATTENDANCE

Storm-Petrels are strictly nocturnal on their breeding grounds. Arrivals, departures, and all above-ground activities take place only under cover of darkness. Counts of the number of Fork-tailed Storm-Petrels flying over a prescribed portion of the colony on East Amatuli Island were made on five nights in 1976 (Fig. III-6). The data show that during June and July, all activity is confined to a 3-hour period of maximum darkness (about 2330 to 0230 hours).

Observations in the Wooded Islands and Tatoosh Island in Washington (P. Dee Boersma, pers. comm.) indicated that Leach's Storm-Petrels arrived at the colony later after sunset than did Fork-tailed Storm-Petrels. This difference may be related to the greater distance between breeding grounds and feeding areas of Leach's Storm-Petrels. Both species arrive later and are less active on clear or moonlit nights than on cloudy nights.

Seasonal changes in the number of petrels visiting land are illustrated by data collected on East Amatuli Island in 1976. Seventy-five burrows were checked daily throughout the breeding season for displacement of toothpicks placed across their entrances. The number of burrows entered each night showed a steady decline from June to September (Fig. III-7). Activity was greatly curtailed during gales; no petrels visited their burrows during one severe storm in August.

Further observations on the nocturnal activity of Fork-tailed Storm-Petrels at Barren Islands in 1977 indicated that peak numbers of birds at the colony occurred during the pre-egg stage, followed by a consistent decline throughout the remainder of the season. By mid-August, the number of birds had dropped to less than 5% of the peak population. The evidence suggests that the population in attendance during the pre-egg stage may include up to 50% nonbreeders. Occupation of breeding birds with incubation and feeding, and the departure of failed and nonbreeding birds account for the decline in population as the season progresses.

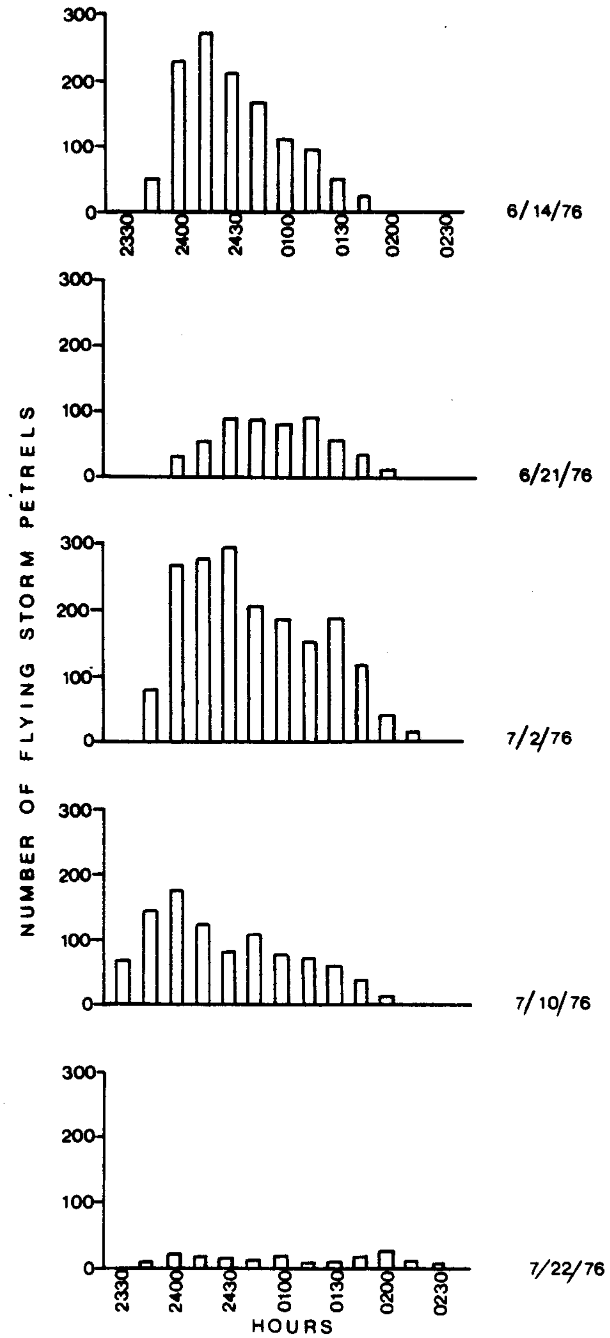


Figure III-6. Counts of numbers of Fork-tailed Storm-Petrels flying over the colony on East Amatuli Island on five nights.

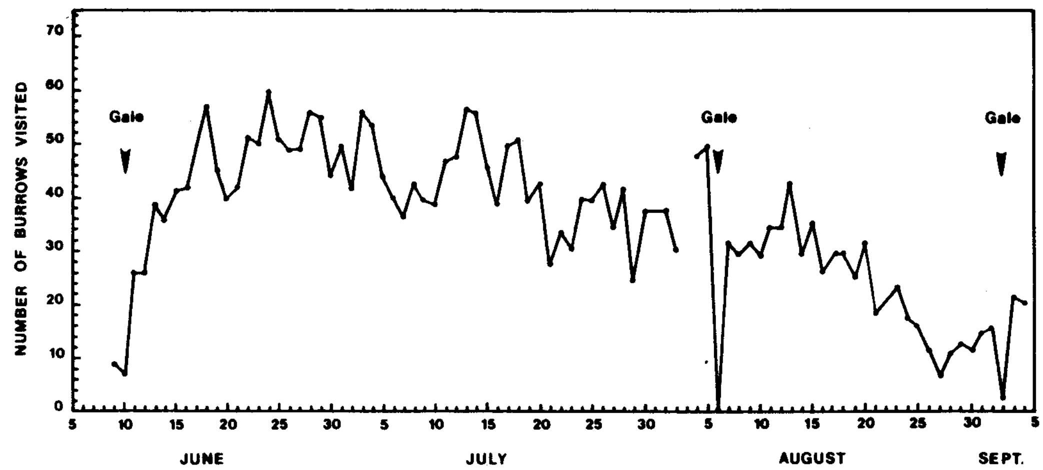


Figure III-7. Numbers of burrows visited by Fork-tailed Storm-Petrels on East Amatuli Island, Alaska in 1976.

FACTORS AFFECTING REPRODUCTIVE SUCCESS

Factors identified as having an important influence on reproductive success of storm-petrels include predation, weather, and food supply. Human disturbance is also important when it occurs because storm-petrels are especially intolerant of intrusions at their nests. Human disturbance is a troublesome factor in research studies, but is not yet a serious problem at most colonies of storm-petrels in Alaska. Islands used for breeding are generally remote and infrequently visited by man.

Predation by river otters was the major cause of breeding failure in storm-petrels at Wooded Islands (Table III-10). Otters were ineffective in reaching nests located in rocky habitat, and reproductive success in such areas approached the level observed on a protected study plot in soil habitat. Otters prey directly upon adult birds, so the effects of losses incurred in any 1 year persist for a number of years. From the number of remains of adult petrels found outside burrows, it was estimated that otters took about 23% of the breeding population of Fork-tailed Storm-Petrels using soil habitat in 1977. Clearly, the presence of this or a similar predator during several consecutive years could severely reduce or eliminate a small colony of storm-petrels such as occurs at the Wooded Islands. Predation by river otters was also known to occur at Barren Islands, but the effect of a small number of otters on this large population was comparatively minor. The contents of 36 regurgitated pellets of Glaucous-winged Gulls from the Shumagin Islands were studied in 1976. Eleven percent of these contained storm-petrel remains, indicating a fairly high rate of predation. Fungus beetles (Leiodidae) were responsible for deaths of some chicks at the Barren Islands. If chicks are not fed regularly, they undergo torpor and become too weak to remove the beetles from their bodies. Beetles tunnel into the head and body of the

TABLE III-10

Mortality of Fork-tailed Storm-Petrel Eggs and Chicks in Different Habitats at Wooded Islands.

Cause of mortality	1976 Soil%	(n=75)	1977 Soil%	(n=204)	Rock%	(n=33)	Exclosure%	(n=25)	Total%	(n=310)
Egg Stage										
Lost to predators	25.3	(19)	48.5	(99)	0		0		38.1	(118)
Egg deserted[a]	17.3	(13)	14.2	(29)	6.1	(2)	16.0	(4)	15.5	(48)
Egg disappeared	0	(0)	1.0	(2)	0		0		0.7	(2)
TOTAL EGGS	42.7	(32)	63.7	(130)	6.1	(2)	16.0	(4)	54.2	(168)
Chick Stage										
Lost to predators	20.0	(15)	7.8	(16)	6.1	(2)	4.0	(1[b])	11.0	(34)
Number died before 5 days old	4.0	(3)	2.0	(4)	6.1	(2)	12.0	(3)	3.9	(12)
Wandered out of burrow			1.0	(1)	3.0	(1)	0		0.7	(2)
Pecked on head	2.7	(2)	1.0	(1)	3.0	(1)	0		1.3	(4)
Starved	1.3	(1)	0		3.0	(1)	0		0.7	(2)
Disappeared		0	1.0	(1)	9.1	(3)	0		1.3	(4)
TOTAL CHICKS	28.0	(21)	11.3	(23)	30.3	(10)	16.0	(4)	18.7	(58)
TOTAL MORTALITY (EGGS + CHICKS)	70.7	(53)	75.0	(153)	36.4	(12)	32.0	(8)	72.9	(226)

[a] Some egg desertions may have been caused by human disturbance.
[b] Within the river otter exclosure, one chick was killed by a raven.

chick and kill it (Wheelwright and Boersma 1979).

Flooding of nest sites during heavy rains was the principal cause of breeding failure at Barren Islands in 1977. The presence of an impermeable covering such as a rock ceiling or overhang protecting nestlings from direct exposure to rain was thus a decisive factor in breeding success. Total rainfall in 1978 was similar to that of the preceding year, but was more evenly distributed throughout the season. Less flooding occurred and the survival rate of nestlings was much higher.

Only indirect measures of the effects of food supply on reproductive performance are possible. The growth of chicks will require further study to determine whether storm-petrels are sometimes unable to provide enough food for their young. The first 5 to 10 days after hatching appear to be the most critical time in the life of the nestling. In the studies reviewed here, almost all mortality of chicks occurred during this period. Chicks apparently require constant brooding and frequent feedings during the first several days of life. A significant increase in mortality can be expected if poor foraging conditions prevent parents from providing for these needs. Slow growth and development that occur later in the nestling period are less likely to have a strong bearing on survival until after fledging, when their effects may become very important. Studies of breeding ecology generally do not provide information on postfledging survival.

The incidence of egg neglect is probably a sensitive indicator of foraging conditions during incubation. Storm-petrels are able to compensate partially for adverse conditions at that time because their eggs remain viable even after they are left cold for several consecutive days. But the advantages of interrupted incubation are not without cost. Boersma and Wheelwright (1979) found that increased egg neglect was correlated with an increased risk of hatching failure, increased weight loss in eggs (probably indicating more complete metabolism of the yolk), and higher chick mortality. Chicks hatching from eggs after a long period of intermittent incubation probably have lower survival because of poor brooding and their smaller size at hatching. Thus, although its effects are less readily documented than those of predation or weather, food availability is probably the factor of greatest long-term importance in regulating populations of storm-petrels in the Gulf of Alaska.

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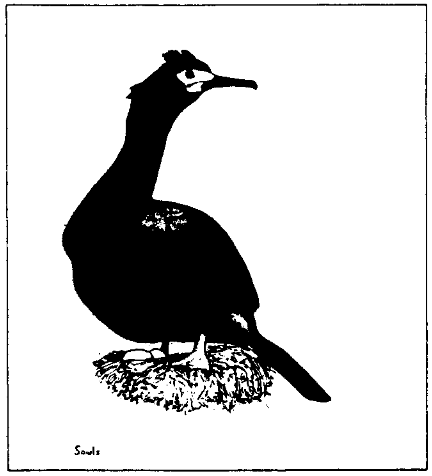
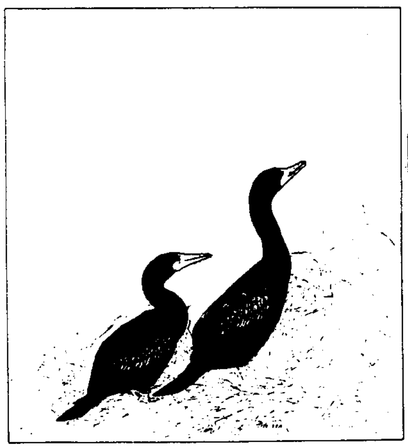
Cormorants (*Phalacrocorax* spp.)

Pelagic Cormorant
Phalacrocorax pelagicus



Red-faced Cormorant
Phalacrocorax urile



Double-crested Cormorant
Phalacrocorax auritus

by

David R. Nysewander

CORMORANTS

(*Phalacrocorax* spp.)

Among the four species which occur in Alaska, the Red-faced Cormorant (*Phalacrocorax urile*) is apparently endemic with breeding colonies also in the Commander Islands. Brandt's Cormorant (*P. penicillatus*), however, is uncommon in Alaska; it is known to breed along the northwest Pacific coast from southern British Columbia to Baja California. The Pelagic Cormorant (*P. pelagicus*) is abundant in Alaska and breeds from the Chukchi Sea south to Japan and Baja California. The Double-crested Cormorant (*P. auritus*) is widely distributed in interior North America as well as on the Pacific and Atlantic coasts of the continent. Mixed colonies of two or three species of cormorants are common. Cormorants are not highly pelagic and are commonly observed only in nearshore waters.

The world family of cormorants can readily be separated into three groups: cormorants, shags, and guanays (van Tets 1959). The Double-crested Cormorant is a member of the cormorant group. All members of this group use sticks in their nest structure, nest either on the ground or in trees, and inhabit either inland or marine areas. They are able to perch in trees and prefer to fish in shallow bays and estuaries. The shag group includes the Red-faced and Pelagic Cormorants. Members of this group never perch in trees and are only found inland as a result of storms or fog. This group rarely, if ever, uses sticks in its nests. Instead they form their nests from grass and algae cemented together with guano. The shags prefer to feed along exposed rocky shorelines and nest underneath rock overhangs, on narrow ledges, and in the cavities of perpendicular cliffs. Brandt's Cormorant belongs to the guanay group whose members prefer to nest on wide cliff ledges and on flat tops of small islands or rocks. These strictly marine species usually feed in open water in large flocks on dense schools of fish. For the purpose of this discussion, we refer to all of the species as cormorants.

Van Tets (1959) summarizes many of the studies conducted on some of the 28 species of *Phalacrocorax* found in the world. Relatively few of these were intensive breeding studies and those that have been conducted were on species that breed overseas; e.g., Kortlandt (1942) on the cormorant and Snow (1960) on the shag. Less intensive studies were those by Lewis (1929), Mendall (1936), Bailie (1947), and McLeod and Bondar (1953), and all treated only the breeding biology of the Double-crested Cormorant. There were no breeding studies on the Pacific coast of the North American continent until those at Mandarte Island, British Columbia (van Tets 1959, 1965; Drent et al. 1964; Robertson 1971). All of these Mandarte Island studies dealt with the Double-crested Cormorant, Brandt's Cormorant, and the southern subspecies of the Pelagic Cormorant (*P. p. resplendens*). Detailed work on breeding biology was not conducted on either of the two most important species found in Alaska, the Red-faced Cormorant and the northern subspecies of Pelagic Cormorant (*P. p. pelagicus*), until studies by Swartz (1966) at Cape Thompson, and Dick (1975) and Petersen and Sigman (1977) at Cape Peirce.

This account summarizes data gathered since 1975 in the Gulf of Alaska from seven sites:

Shumagin Islands	1976	(Moe and Day 1977)
Semidi Islands	1976	(Leschner and Burrell 1977)
	1977	(Hatch 1978)
Ugaiushak Island	1976	(Wehle et al. 1977)
	1977	(Wehle 1978)
Chiniak Bay, Kodiak Island	1977	(Nysewander and Hoberg 1978)
	1978	(Nysewander and Barbour 1979)

Barren Islands	1977	(Manuwal and Boersma 1978)
	1978	(Manuwal 1979)
Wooded Islands	1976	(Mickelson et al. 1977)
	1977	(Mickelson et al. 1978)
Middleton Island	1978	(Hatch et al. 1979)

BREEDING DISTRIBUTION AND ABUNDANCE

The Double-crested Cormorant (P. auritus) breeds in Alaska from Forrester Island, through Prince William Sound, west to near the Unimak Pass region and north along the Alaska Peninsula into Bristol Bay (Fig. IV-1a). Colonies of more than 100 birds are exceptional, but have been reported at Chisik Island in Lower Cook Inlet and Shaiak Island near Cape Peirce, northern Bristol Bay. This species also nests in a few freshwater habitats in Alaska. The total breeding population censused in coastal Alaska is 4,701 birds with estimates of up to 7,000 birds (Sowls et al. 1978). There are 67 known coastal colonies in the western Gulf of Alaska (82% of all known Alaskan sites), which when censused included 2,842 birds (60% of the Alaskan total).

In Alaska, the Pelagic Cormorant (P. pelagicus) has been found breeding from Forrester Island in southeastern Alaska north along the coast to Cape Thompson in the Chukchi Sea and throughout the Aleutian Islands (Fig. IV-1b). Generally, colonies are small, having less than 100 pairs. The total breeding population censused in Alaska is 40,888 birds with an estimate of 90,000 (Sowls et al. 1978). In the western Gulf of Alaska there are 160 recognized colonies at this time (56% of all Alaska cormorant colonies) with 14,285 birds censused (35% of the Alaskan population).

The Red-faced Cormorant (P. urile) is not as widely distributed as the Pelagic, but it is the most common breeding cormorant in the Aleutian and Pribilof Islands as well as in the western portions of the Alaska Peninsula (Fig. IV-1c). Except for a small population on the Commander (Komandorski)

(a)

(b)

(c)

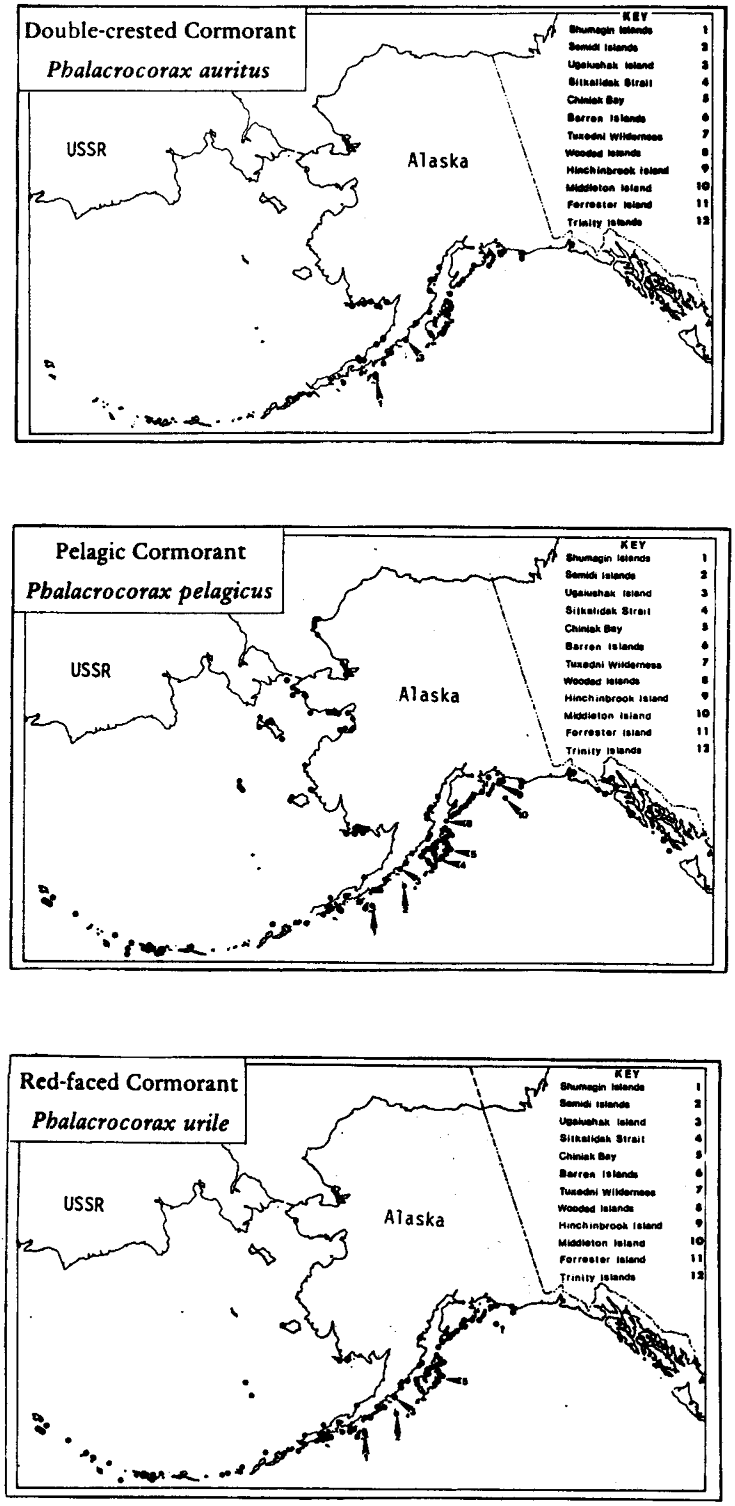


Figure IV-1. Distribution of breeding colonies of (a) Double-crested, (b) Pelagic, and (c) Red-faced Cormorants in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

Islands, the Red-faced Cormorant is an Alaskan species. This species has expanded its breeding range eastward within the last 100 years as colonies have only recently been found in Prince William Sound. The total breeding population censused in Alaska is 51,613 with an estimate of possibly 130,000 individuals (Sowls et al. 1978). In the western Gulf of Alaska there are 130 known colony sites (73% of all Alaskan cormorant colonies) with 19,878 birds censused (39% of the Alaskan population).

Brandt's Cormorant bred in very low numbers on Seal Rock near Hinchinbrook Island in 1972 (M.E. Isleib, pers. comm.) but since then this species has not been positively identified breeding at this site or anywhere else in Alaska (Nysewander and Knudtson 1977). Individuals are seen with some regularity, however, in the region of Prince William Sound, and small colonies may have been overlooked, especially in southeast Alaska. Cormorants of all species in Alaska are commonly observed only in nearshore waters (Gould et al. 1978). Table IV-1 displays the estimated numbers of breeding cormorants at each FWS study site.

Cormorants are not highly philopatric because they often move their nest sites, and even whole colonies, from year to year. In 1977 at Ugaiushak and Chowiet Island all species of cormorants increased up to 400% over the numbers seen breeding there in 1976 and numbers of active nests of both Pelagic and Red-faced Cormorants also showed considerable annual variation at any one site over 3 years in Chiniak Bay on Kodiak Island (Tables IV-2 and IV-3). This variation in numbers at any one site may be the result of (1) recruitment or loss of breeding adults, (2) better or worse breeding conditions affecting the number of pairs which attempt to breed, or (3) a tendency for cormorants to change individual colony sites from year to year. The Chiniak Bay studies support the last explanation for several reasons. The overall

TABLE IV-1
Estimated Numbers of Cormorants Nesting at Eight Colony Sites in the Gulf of Alaska, 1976-1978.

Colony	Numbers of breeding birds		
	Double-crested Cormorant	Pelagic Cormorant	Red-faced Cormorant
Big Koniuji (Shumagin Islands)	14	90	80
Chowiet Island (Semidi Islands)		60	1300
Ugaiushak Island	70	280	1200
Sitkalidak Strait (Kodiak Island)	2	230	260
Inner Chiniak Bay (Kodiak Island)	0	780	280
East Amatuli (Barren Islands)	0	150	0
Wooded Islands	0	190	4
Middleton Island	0	4700	0

TABLE IV-2
Variability in Number of Pelagic Cormorants Nesting at Chiniak Bay, Kodiak Island, 1975-78.

Island colonies	Number of breeding pairs		
	1975	1977	1978
Inner Chiniak Bay			
Bird Is.	112	200	242
Blodgett Is.	0	64	6
Cliff Is.	0	10	48
Gibson Cove	0	100	126
Holiday Is.	86	116	20
Kulichkof Is.	50	142	126
Mary Is.	0	0	28
Puffin Is.	78	62	72
Viesoki Is.	44	8	16
Zaimka Is.	34	50	60
Subtotal of inner bay	404	782	744
Outer Chiniak Bay (excluding Cape Chiniak)			
Jug Is.	12	-	8
Kalsin Is.	72	-	78
Kekur Is.	50	-	0
Long Is.	354	-	262
Middle Is.	4	-	96
Queer Is.	16	-	0
Switlak Is.	92	-	0
Utesistoi Is.	2	-	0
Subtotal of outer bay	602	-	444

TABLE IV-3
Variability in Numbers of Red-Faced Cormorants Nesting in Chiniak Bay, Kodiak Island, 1975-1978.

Island colonies	Number of breeding pairs		
	1975	1977	1978
Inner Chiniak Bay			
Bird Is.	6	62	34
Blodgett Is.	0	14	0
Cliff Is.	4	4	46
Gibson Cove	0	20	48
Holiday Is.	0	46	0
Kulichkof Is.	10	0	0
Mary Is.	0	0	0
Puffin Is.	34	66	40
Viesoki Is.	206	28	52
Zaimka Is.	44	42	62
Subtotal of inner bay	304	282	282
Outer Chiniak Bay (excluding Cape Chiniak)			
Jug Is.	8	-	6
Kalsin Is.	116	-	104
Kekur Is.	90	-	0
Long Is.	110	-	130
Middle Is.	-	-	60
Queer Is.	4	-	0
Switlak Is.	2	-	52
Utesistoi Is.	2	-	10
Subtotal of outer bay	332	-	362

bay totals of breeding pairs were not that different between years. No sizeable population of nonbreeding adults was ever associated with the bay or its colonies, and old colony sites were often completely abandoned even though new colonies occurred on the same island.

NESTING HABITAT

Drent et al. (1964) found that Double-crested Cormorants nested on the rounded shoulders and broad ledges of cliffs, in contrast to Pelagic Cormorants, which preferred more precipitous terrain. Alaskan studies confirmed this. The Red-faced Cormorant also nested on the steeper cliffs, but Gabrielson and Lincoln (1959) suggested that this species occupied broader ledges than did the Pelagic Cormorant.

At Ugaiushak Island, Wehle et al. (1977) noted that when three species of cormorants nested on the same cliff face, Double-crested Cormorants always nested on the top ledges, Red-faced Cormorants usually nested in the middle areas, and Pelagic Cormorants usually nested on the lower ledges, although there was some overlap between the last two species. The spatial distribution of cormorants on Ugaiushak may have resulted at least partially from interspecific competition for nesting sites.

Middleton Island has one of the largest concentrations of breeding Pelagic Cormorants in Alaska (2300 pairs). The cormorants in this colony usually nested in a linear formation on a narrow ledge just below the top of the dirt cliffs. A few nests were built farther down the slope, however, and at least 35 pairs occupied ledges on a shipwrecked boat (Hatch et al. 1979).

BREEDING CHRONOLOGY

All three species were present at all study sites before the arrival of field parties (mid-April). Egg-laying of Double-crested Cormorants at Ugaiushak Island ranged from 26 May to at least 10 June, and hatching ranged from 22 June to 20 July (Table IV-4 and Fig. IV-2a). The first chicks fledged on 17 August in 1976 and 27 August in 1977. Some hatching dates at Big Koniuji Island suggested a similar chronology there. The incubation period in this species averages about 28 days, and fledging takes place at 40 to 50 days of age (van Tets 1959).

The onset of egg laying of Pelagic Cormorants in the Gulf of Alaska generally occurred between 23 May and 3 June (Table IV-5, Fig. IV-2b). The only exception was at Middleton Island in 1978, when eggs were first noted on 3 May. Egg laying was completed by 13 to 30 June except at the Barren Islands in 1977, where birds were still laying on 15 July. At individual sites, egg laying spanned a period of 21 to 45 days. Hatching ranged from 4 June to 15 August at the five sites and the first chicks fledged between 21 July and 1 September (Table IV-5). The large span of time involved in each phase of the breeding cycle as well as the variation in annual hatching and fledging dates appear to result from varying degrees of nest loss and frequent renesting. The incubation period of Pelagic Cormorants averages about 31 days (range: 28 to 32) and the nestling period ranges widely from 40 to 60 days (van Tets 1959; Drent et al. 1964).

Egg laying of Red-faced Cormorants ranged from 16 May to 24 June at Ugaiushak Island (Table IV-6, Fig. IV-2c). Hatching at this site extended from 19 June to 31 July with fledging beginning about 10 August. This chronology (especially egg laying) was essentially a week earlier than that of Pelagic Cormorants at the same site. At Chiniak Bay (Kodiak) in 1978 Red-faced Cormorants began laying at least 5 days before Pelagic Cormorants. Both of these examples suggest that Red-faced Cormorants may occupy the cliffs before the Pelagic Cormorants arrive. Perhaps this excludes Pelagic

TABLE IV-4
Breeding Chronology of Double-Crested Cormorants at Two Sites in the Gulf of Alaska 1976-77.

Colony	Year	Laying	Hatching	Fledging
Big Koniuji Is., Shumagin Is.	1976	5 June >[a,b]	3 July >[a,b]	17 Aug >[a,b]
Ugaiushak Is.	1976	28 May-17 June[a]	22 June-15 July	17-30 Aug
	1977	26 May-10 June	8 July-20 July	27 Aug-3 Sept[a]

[a] Date calculated.
[b] Ending (>) date not determined.

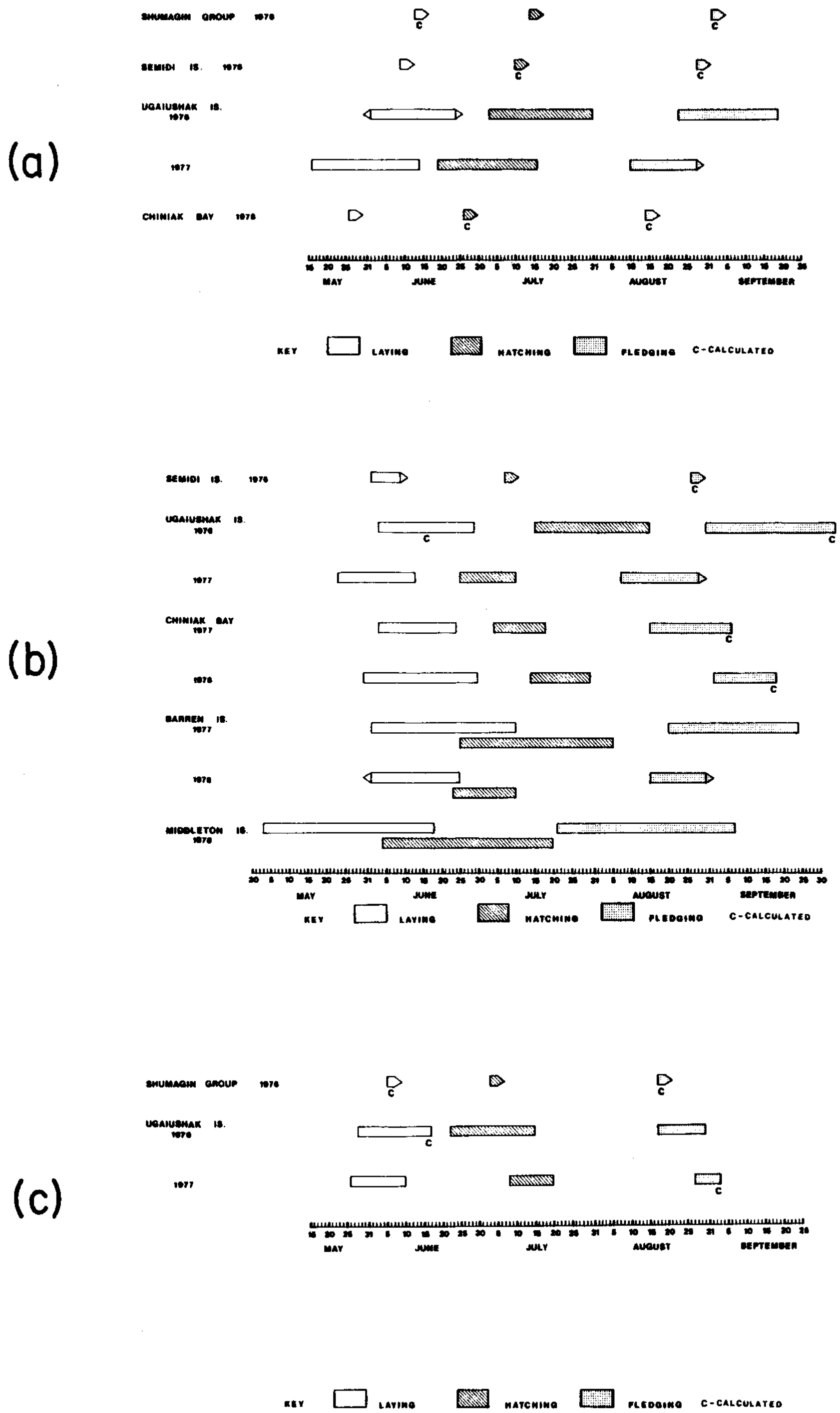


Figure IV-2. Chronology of major events in the nesting seasons of (a) Double-crested, (b) Pelagic, and (c) Red-faced Cormorants in the Gulf of Alaska.

TABLE IV-5
Breeding Chronology of Pelagic Cormorants at Five Sites in the Gulf of Alaska, 1976-78.

Colony	Year	Laying	Hatching	Fledging
Semidi Is.	1976	1 June >[b]	7 July >[b]	26 Aug >[a,b]
Ugauishak Is.	1976	3-29 June	15 July-15 Aug	30 Aug-4 Oct[a]
	1977	23 May-13 June	25 June-10 July	< 7-28 Aug >[b]
Chiniak Bay	1977	3-24 June	4-18 July	15 Aug-6 Sept[a]
	1978	30 May-30 June	14-30 July	1-18[a] Sept
Barren Is.	1977	< 1 June-15 July[b]	25 June-5 Aug	20 Aug-24 Sept[a]
	1978	< 1-25 June[b]	23 June-10 July	15-30 Aug >[b]
Middleton Is.	1978	3 May-18 June	4 June-20 July	21 July-7 Sept

[a] Date calculated.
[b] Exact beginning (<) or ending (>) date not determined.

TABLE IV-6
Breeding Chronology of Red-Faced Cormorants at Four Sites in the Gulf of Alaska 1976-78.

Colony	Year	Laying	Hatching	Fledging
Big Koniuji Is., Shumagin Is.	1976	13 June >[b]	14 July [b]	1 Sept >[a,b]
Semidi Is	1976	9 June >[b]	10 July >[a,b]	28 Aug >[a,b]
Ugauishak Is.	1976	< 1-24 June >[b]	3-31 July	23 Aug[a]-19 Sept[a]
	1977	16 May-14 June	19 June-16 July	10 Aug-28 Aug >[b]
Chiniak Bay	1978	26 May >[b]	26[a] June >[b]	14 Aug >[a,b]

[a] Date calculated.
[b] Exact beginning (<) or ending (>) date not determined.

Cormorants from their choice of nest sites and they must make do with whatever habitat remains. This theory is supported by the fact that Red-faced Cormorants are often found nesting in definite subgroups while the other species is more or less scattered around them. There are no published records of incubation and fledging periods for Red-faced Cormorants, but comparisons of the initiation of egg laying and hatching at Ugaiushak Island suggest that incubation probably lasts from about 32 to 34 days. Chicks of this species typically remained in the nest for 49-50 days at Ugaiushak Island.

REPRODUCTIVE SUCCESS

Double-crested Cormorants were studied in depth only at Ugaiushak Island. They had a mean clutch size of 3.67 in 1976 and 2.67 in 1977. There were 1.67 chicks fledged per nest with eggs in 1976 whereas in 1977 this fell to 0.95 chicks including renesters (Table IV-7). Some birds renested after failure of their first attempt. These renesters fledged an average of 1.43 chicks per second nest with eggs. Lower productivity in 1977 resulted from smaller clutch sizes and lower hatching success.

The mean clutch size of Pelagic Cormorants varied from 2.17 to 3.64 with an overall average of 3.1 (Table IV-8). Average productivity at the seven study sites ranged from 0 to 1.95 chicks fledged per nest built with an overall average of 0.77. At any one site where there were two or more years of data available, the highest productivities occurred during 1977 with success being much less in both 1976 and 1978. This pattern corresponds with that observed for kittiwakes during the same 3-year period in the same area. With one exception (Pelagic Cormorants in Chiniak Bay, 1977), cormorant egg losses were higher than cormorant chick losses, usually by more than 25%. This was most pronounced for Double-crested and Red-faced Cormorants. Productivity can be separated for Pelagic Cormorants into three classes:

TABLE IV-7
Productivity of Double-Crested Cormorants
at Ugaiushak Island, Alaska, 1976-1978.

	Ugaiushak	
	1976	1977
Number of nests built	-	26
Number of nests with eggs	15	21
Number of eggs laid	55	56
Number of eggs hatched	27	-
Number of chicks fledged	25	20
Mean clutch size	3.67	2.67
Range of clutch sizes	-	1-5
Mean brood size	3.0	-
Mean number of fledglings per nest	2.78	2.20
Eggs hatched/eggs laid (hatching success)	0.49	-
Chicks fledged/eggs hatched (fledging success)	0.93	1.00
Chicks fledged/nest with eggs	1.67	0.95
Chicks fledged/nest built	-	0.77

TABLE IV-8
Productivity of Pelagic Cormorants in the Gulf of Alaska, 1976-1978.

	Big Koniuji	Semidi Is.		Ugaiushak		Chiniak Bay		Barren Is.		Wooded Is.		Middleton Is.
	1976	1976	1977	1976	1977	1977	1978	1977	1978	1976	1977	1978
Number of nests built	9	13	6	-	44	26 (127)[a]	28 (135)[a]	-	67	27	19	
Number of nests with eggs				36	42	25	21	63	61			102
Number of eggs laid				115	145	88	46	179	222			290
Number eggs hatched				72	94	60	15	115	65			
Number of chicks fledged	0	3	4	67	86	37	7	102	43	0	5	65
Mean clutch size				3.19	3.45	3.52	2.17	2.84	3.64			2.84
Range of clutch sizes				-	1-5	1-6	1-5	-	-			1-4
Mean brood size				2.88	-	2.81	2.09	2.61	-			
Mean number of fledglings per nest				2.68	-	2.18	1.40	-	-		2.5	
Egg hatched/egg laid (hatching success)				0.63	0.65	0.69	0.32	0.64	0.29			
Chicks fledged/eggs hatched (fledging success)				0.93	0.91	0.62	0.44	0.89	0.66			
Chicks fledged/nest with eggs				1.86	2.05	1.48	0.33	1.62	0.70			0.64
Chicks fledged/nest built	0	0.23	0.67	-	1.95	1.42 (1.35)[a]	0.25 (0.60)[a]	-	0.64	0	0.26	

[a] Numbers in parentheses are the overall bay average and the other data are from one disturbed study area.

good (1.30-2.00 chicks fledged per nest built) at Chiniak Bay (1977), and Barren Islands (1977); intermediate (0.5-0.7 chicks) at the Semidi Islands (1977), Chiniak Bay (1978), Barren Islands (1978), and Middleton Island (1978); and poor (<0.3 chicks fledged per nest built) at the Shumagin Islands (1976), Semidi Islands (1976), and the Wooded Islands (1976 and 1977).

The mean clutch size of Red-faced Cormorants varied from 2.12 to 3.08. Average breeding success at five sites ranged from 0 to 1.91 chicks fledged per nest built (Table IV-9). Reproductive success for this species was good at Chiniak Bay (1977 and 1978) and Ugaiushak Island (1977) while it was poor at the Shumagin Islands (1976), the Semidi Islands (1976 and 1977), and the Wooded Islands (1976). It was poor to moderate at Ugaiushak Island in 1976. Again at the two most intensive study sites at Chiniak Bay and Ugaiushak Island, the best productivity for this species occurred during 1977 with lower success in both 1976 and 1978.

Success varied tremendously in Chiniak Bay from island to island for Pelagic and Red-faced Cormorants (Table IV-10). Red-faced Cormorants in Chiniak Bay had higher overall success in both years than did the Pelagic Cormorants while the reverse was true for Ugaiushak Island.

Nysewander and Hoberg (1978) found that crows destroyed all cormorant eggs on Zaimka Island at Chiniak Bay. Avian predators were few, however, in the vicinity of other islands, causing the cormorant colonies on these to be less affected by predation, even when eggs or young were left vulnerable by human disturbance. This usual lack of predation on Alaskan cormorant colonies contrasts greatly with that found on the colonies in Washington (Nysewander, unpubl. data). In 1978 the cormorant colonies in Chiniak Bay suffered from increased gull predation. The factors which precipitated an increase in predation by gulls are not fully understood. There was no

TABLE IV-9

Productivity of Red-faced Cormorants in the Gulf of Alaska, 1976-78.

	Big Koniuji	Semidi Is.		Ugaiushak		Chiniak Bay		Wooded Is.
	1976	1976	1977	1976	1977	1977	1978	1976
Number of nests built	28	37	116	-	51	57	30	2
Number of nests with eggs				32	49			
Number of eggs laid				68	151			
Number of eggs hatched				16	73			
Number of chicks fledged	0	7	11	13	66	109	40	0
Mean clutch size		2.5		2.12	3.08			
Range of clutch sizes				-	1-5	1-4	1-4	
Mean brood size				2.29	2.71			
Mean number of fledglings per nest	0	2.33		1.86	2.54			
Eggs hatched per egg laid (hatching success)				0.24	0.48			
Chicks fledged per eggs hatched (fledging success)				0.81	0.90			
Chicks fledged per nest with eggs				0.41	1.35			
Chicks fledged per nest built	0	0.19	0.03		1.29	1.91	1.33	0

TABLE IV-10
Variability in Productivity of Pelagic and Red-faced Cormorants in Chiniak Bay, 1977-1978.

	Kulichkof Disturbed Plot	Kulichkof Undisturbed Plot	Bird Is.	Puffin Is.	Gibson Cove	Cliff Is.	Zaimka Is.	Mary Is.
Red-faced Cormorant								
1977								
Sample size	0	0	17	33	2	2	3	0
Chicks fledged per nest built	0	0	1.82	2.15	2.50	1.00	0.00	0
1978								
Sample size	0	0	a	12	a	18	a	0
Chicks fledged per nest built	0	0	a	0	a	2.22	a	a
Pelagic Cormorant								
1977								
Sample size	26	42	16	25	16	5	23	0
Chicks fledged per nest built	1.48	2.14	1.94	0.65	1.50	1.20	0.13	0
1978								
Sample size	28	35	a	36	25	24	a	14
Chicks fledged per nest built	0.25	0.89	a	0.19	0.20	1.58	a	0

a Unchecked even though nests were present.

concurrent increase in gull numbers or disturbance to cormorant colonies. There was, however, a noticeable reduction in the numbers of capelin, an important prey species for gulls, and we present the hypothesis that reduced availability of normal food items forced gulls to rely more heavily on bird eggs and chicks as a food source.

FOOD HABITS AND FORAGING

The feeding habits of cormorants have been a source of much controversy (Taverner 1915, Mattingley 1927, Munro 1927, Lewis 1929, Steven 1933 *in* van Tets 1959, Mendall 1936, Dobben 1952, McLeod and Bondar 1953). Many fishermen claim that the diet of cormorants consists chiefly of fish and that the cormorants therefore reduce the fishermen's catch. Consequently, in many parts of the world, fishermen have destroyed breeding colonies, and have persuaded their governments to institute control programs. The persecution and, in some areas, extermination of cormorants did not result in a corresponding increase in the harvest of fish. Sometimes a decline in the abundance of commercial and sport fish was noticed. As a result, several studies on the food habits of cormorants were instituted in various parts of the world. The results of these studies showed that cormorants feed predominantly on bottom-dwelling coarse fish, which are considered a menace to the eggs of food fish. In open water, all three groups of cormorants feed on dense schools of small fishes like smelt and anchovies. The conclusion of most authors is that cormorants are not detrimental to the fishing industry. Indeed, they could actually be beneficial.

At Mandarte Island, van Tets (1959) found Double-crested and Pelagic Cormorants eating the three-spined stickleback (*Gasterosteus aculeatus*), four species of blennies (*Xiphisteridae*), cabezon (*Leptocottus armatus*), and shrimp (*Pandalus* spp.). Each species had its own preferred feeding method and habitat.

Cormorants in Alaska forage almost entirely in nearshore waters. Studies on Ugaiushak Island indicate a maximum foraging distance of 3 km from the island. The Double-crested Cormorant prefers to feed in mud-bottomed bays and estuaries either feeding singly or in flocks, being especially attracted to narrow channels during out-going tides. Sometimes it joins flocks of gulls and other cormorants feeding on schools of fish in open water. The Brandt's Cormorant normally feeds on surfacing schools of fish while in large flocks in the open water. Van Tets (1959) found that this species was often guided to the schools by Glaucous-winged Gulls hovering over fish, which frequently were driven to the surface by Common Murres. Sometimes a flock of Brandt's Cormorants feeds in a long line at right angles to the shoreline. Pelagic and Red-faced Cormorants usually feed singly in the intertidal zone of rocky shorelines or in the surf beside cliffs which drop steeply into deeper water. Small numbers are sometimes found in mixed feeding flocks in bays and estuaries.

The Alaskan studies mentioned in this report made no intensive investigations of prey items of cormorants, but incidental notes and records indicate that capelin (*Mallotus villosus*) and sand lance (*Ammodytes hexapterus*) are probably two of the important prey species in the northern Gulf of Alaska. A small sample of regurgitations from chicks of Pelagic Cormorants on Middleton Island in 1978 was composed almost entirely of a hexagrammid, probably kelp greenling (*Hexagrammos decagrammus*).

FACTORS AFFECTING REPRODUCTIVE SUCCESS

The presence or absence of avian predators (gulls, ravens, and crows) often determines the degree of cormorant egg loss. Likewise, the presence of eagles, humans, or river otters often drives cormorants from their nests, increasing exposure of the eggs to predation. All of the cormorants, however, have relatively large ranges in clutch sizes (up to 6 or 7 for Double-crested Cormorants and 5-6 for Pelagic Cormorants) and are usually capable of relaying. In 1977, all of the cormorants on the colonies in Chiniak Bay had good success except for two that were next to crow colonies and also subject to frequent visits by eagles. In 1977 at Chiniak, heavy rains during the latter part of the summer caused widespread chick mortality and destruction of nests. Heavy rains, predation by gulls and river otters, and starvation of chicks were principal causes of mortality at the Barren Islands.

At Chiniak Bay, where causes of mortality were best documented, the overall decrease in reproductive success from 1977 to 1978 was due to five factors listed here in decreasing order of importance: (1) egg and chick predation by large gulls; (2) increased visitation to nesting areas by river otters which subsequently drove cormorants from their nests; (3) predation by crows and disturbance by eagles at certain colonies; (4) human disturbance on certain islands frequently forcing cormorants away from their nests; and (5) egg and chick loss due to storms. Glaucous-winged Gulls preyed more heavily on eggs in 1978 than in any other year at Chiniak Bay, and cormorants appeared hardest hit by this increased predation.

Table IV-11 compares reproductive success of Pelagic Cormorants nesting at three sites (Ugaiushak Island, Chiniak Bay, and Barren Islands) in the northern Gulf of Alaska with those on Mandarte Island, British Columbia, (Drent et al. 1964) and with those at Cape Peirce (Dick 1975) in the Bering Sea. It appears that the birds breeding in the northern Gulf of Alaska tend to be intermediate in most categories. Although cormorants at the British Columbia site had higher overall productivity and clutch size, there was an inverse relationship between hatching and fledging success of cormorants in the

TABLE IV-11
Comparison of Productivity of Pelagic Cormorants at Three Areas in the North Pacific Ocean.

Study Sites	Cape Peirce 1970[a]	Ugaiushak Island, Chiniak Bay, Barren Islands 1976-78	Mandarte Island (British Columbia) 1957-59[a]
Clutch Size Range	1-5	1-6	1-6
Mean Clutch Size	3.1-3.2	3.3	3.8
% hatching success (chicks hatched per egg laid)	78	54	50
% fledging success (chicks fledged per egg hatched)	56	74	76
Breeding success[b]	1.33	1.32-1.39	1.97

[a] Data sources are Dick (1975) and Drent et al. (1964).

[b] It is unclear whether productivities of Cape Peirce and Mandarte Island are chicks fledged per nest attempt or nests with eggs. Hence, both figures are presented for the sites in the Northern Gulf of Alaska, with the lower number that of chicks fledged per nest attempt.

Bering Sea versus those in the British Columbia colonies. Those in the Bering Sea colonies appear to have greater hatching success and lower fledging success than those on the southern colonies. Although this might simply be due to annual variation, it may possibly indicate that gulls and crows are more important causes of mortality in the south (during the egg stage) while food cycles and weather affect survival of chicks more greatly in the north.

There is some evidence that Black-legged Kittiwakes and cormorants compete for nest sites (Dick 1975) and this may lower productivity, because the cormorants are forced to nest in a more dispersed fashion. Likewise, human disturbance flushes cormorants off their nests and they often do not return for a long time, thus leaving the nests exposed to predators and to the elements. At Chiniak Bay, Kodiak Island, the cormorants which nested closer to kittiwakes than to congeners, and which were often disturbed by humans, produced 1.42 young per nest built (n=26) in 1977 and 0.25 (n=28) in 1978 while the more dense, less disturbed, single-species colony of cormorants on the same island produced 2.14 young per nest built (n=45) in 1977 and 0.89 young (n=35) in 1978. Differences between the plots were significant in both 1977 ($X^2 = 4.43$, 1 df, $p<0.05$) and 1978 ($X^2 = 10.42$, 1 df, $p<0.01$). It is not certain which, if any, of these factors contributed to the difference in young fledged per nest built. More intensive studies need to be undertaken in order to answer many of these questions.

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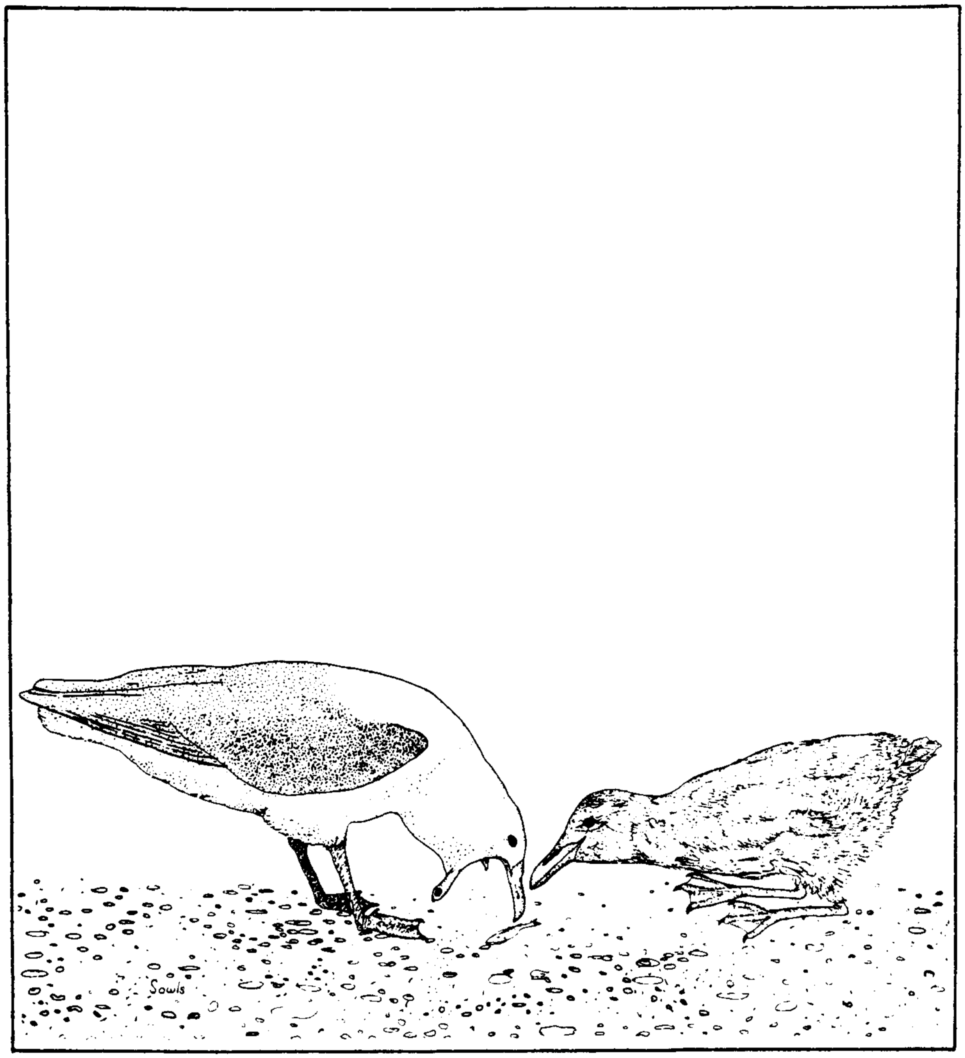
Glaucous-winged Gull (*Larus glaucescens*)



by

Patricia A. Baird

GLAUCOUS-WINGED GULL

(*Larus glaucescens*)

Gulls are one of the most commonly studied groups of birds. However, only a relatively few of these studies, Vermeer (1963) and Patten (1974) among others, had focused on the breeding biology of the Glaucous-winged Gull before 1976, when the Fish and Wildlife Service (FWS) began intensive investigations at several sites in the Gulf of Alaska. The breeding biology of the closely-related Herring Gull (*Larus argentatus*), with which they interbreed, is well-known (e.g., Paynter 1949, Paludan 1951, Tinbergen 1952, Brown 1967, Kadlec and Drury 1968, Kadlec et al. 1969, Spaans 1971, Hunt 1972, Parsons et al. 1975). Glaucous-winged Gulls are the most common coastal gull in Alaska. They were found at every colony studied by FWS personnel. This report summarizes research from the following:

Shumagin Island Group: 1976	(Moe and Day 1979)
Semidi Island Group: 1976-77	(Leschner and Burrell 1977; Hatch 1977, 1978)
Ugaiushak Island: 1976-77	(Wehle et al. 1977, Wehle 1978)
Sitkalidak Strait: 1977-78	(Baird and Moe 1978, Baird and Hatch 1979)
Chiniak Bay: 1977-78	(Nysewander and Hoberg 1978, Nysewander and Barbour 1979)
Chisik Island (Tuxedni Wilderness): 1978	(Jones and Petersen 1979)
Wooded Islands: 1976-77	(Mickelson et al. 1977, 1978)
Barren Islands: 1976-77	(Manuwal and Boersma 1977, 1978)
Hinchinbrook Island: 1976-77	(Nysewander and Knudtson 1977, Sangster et al. 1978)
Middleton Island: 1976, 1978	(Frazer and Howe 1977, Hatch et al. 1979)
Forrester Island Group: 1976	(DeGange et al. 1977)

BREEDING DISTRIBUTION AND ABUNDANCE

Glaucous-winged Gulls (*Larus glaucescens*) are ubiquitous but nowhere as abundant as other seabirds throughout the Gulf of Alaska (Fig. V-1, Table V-1). Their breeding range is restricted to marine coastal habitats and extends north to Cape Denbigh and St. Lawrence Island in the Bering Sea, west to the Aleutian and Komandorskie Islands, and south and east to southeastern Alaska, western British Columbia and northwest Washington. In winter, many of the birds from the Gulf migrate to central California (band recoveries from Berkeley and Oakland). Some Glaucous-winged Gulls remain year-round along the coast in ice-free areas, but it is not known if these birds are from populations which breed in the Bering Sea or in the Gulf of Alaska. Hybridization with Herring Gulls occurs in southcentral and southeastern Alaska (Williamson and Peyton 1963, Patten 1980).

The number of breeding Glaucous-winged Gulls in the Gulf of Alaska is approximately 171,000 birds on 442 colony sites. This makes up 75% of the total numbers and 81% of all the surveyed sites in Alaska, and is probably an underestimate (Sowls et al. 1978). This population figure does not include nonbreeders, which also occupy Alaskan waters during the breeding season; therefore the actual number of gulls present in the Gulf in the summer is a great deal higher. The size of the population wintering in the Gulf is unknown but we suspect that it is much lower than in summer because part moves south to warmer climes at that time.

Most colonies of Glaucous-winged Gulls are small (< 1,000 birds). Although loosely colonial, Glaucous-winged Gulls will often nest solitarily where the distance to the nearest neighbor may be greater than 50 m. Sowls et al. (1978), in considering all gull colonies in Alaska, state that 40% of the colonies surveyed have less than 100 birds, 40% have 100-1,000, 11%

Glaucous-winged Gull (*Larus glaucescens*)

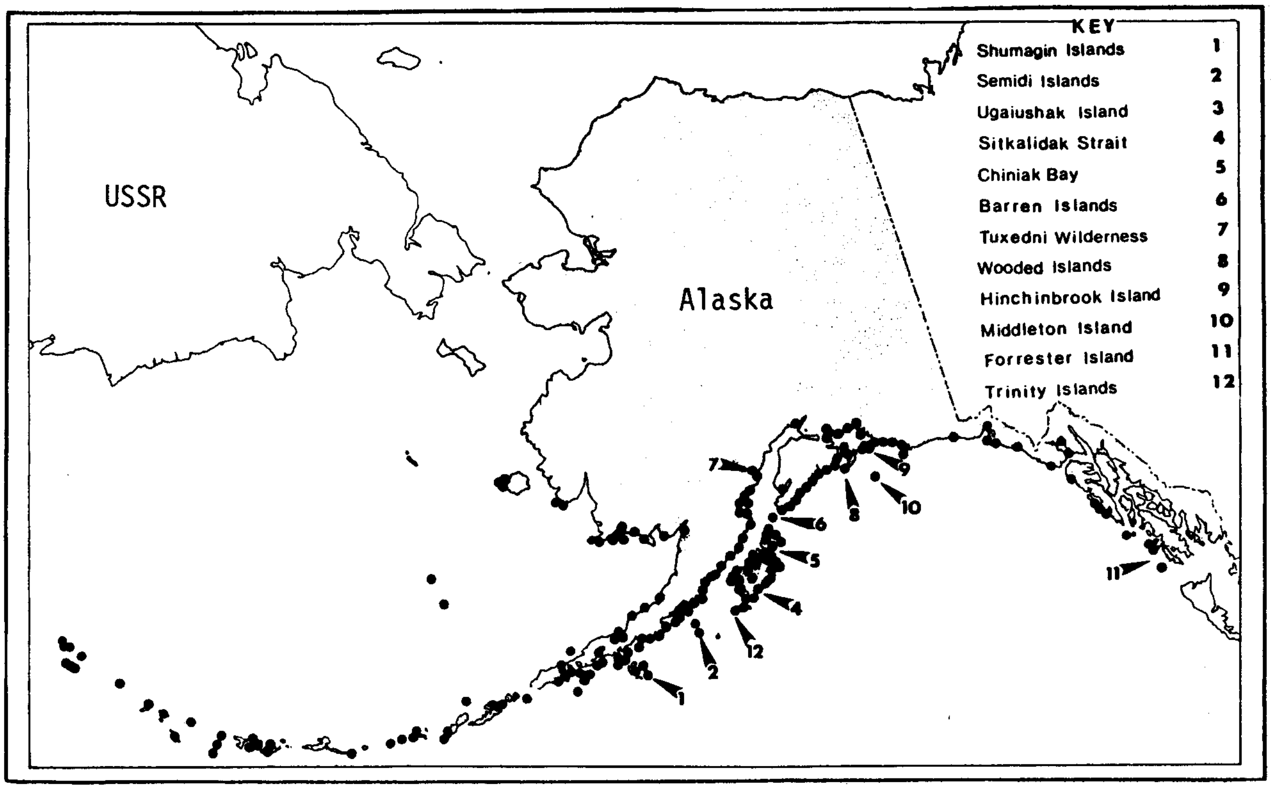


Figure V-1. Distribution of breeding colonies of Glaucous-winged Gulls in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

TABLE V-1
Estimated Numbers of Glaucous-winged Gulls Nesting at Study Sites in the Gulf of Alaska.

Colony	1975	1976	1977	1978
Big Koniuji (Shumagin Group)		2370		
Chowiet Island (Semidi Group)		708	950	
Ugaiushak Island		1680	1272	
Trinity Islands			530	
Sitkalidak Strait (Kodiak Island)			940	482
Chiniak Bay (Kodiak Island)	2144			
Chisilk Island (Tuxedni Wilderness)				2000
Wooded Islands		150	200	
East Amatuli (Barren Islands)			302	
Middleton Island		1140		1400
Hinchinbrook Island		120	250	
Forrester Group		800		

have 1,000-10,000, and 0.37% have greater than 10,000 birds, with 8% of the documented colonies being of unknown size. Among the 12 sites studied, all had breeding gull populations of < 3,000 birds (Table V-1). None of the studies was conducted for more than 2 years, so we cannot reach a conclusion about population trends of the breeders at each colony site.

In many parts of the United States, gulls of all species are increasing in numbers due mainly to their adaptation to the effects of civilization and to the disturbance that civilization brings (Hunt 1972). Of particular importance in recent years is the increased survival of fledglings over their first winter due to artificial food supplies. We may speculate that increased human population and expansion of some industries have enabled more fledglings to survive their first winter in Alaska and there may have been a general increase in Alaskan gull populations over the years; however these expansions are quite local (Patten 1978).

Because of the sparser human population in Alaska, there are not as many dumps or other artificial food sources as in other parts of the United States that have enabled the gull populations there to increase so rapidly. However, the fishing industry probably allows populations to increase beyond the normal carrying capacity of the environment in particular areas. Gulls are often seen following vessels of all sizes in the Gulf, regularly feeding on offal or garbage discarded from ships. Likewise the salmon, especially in areas where there are large concentrations as in Kodiak, attract enormous numbers of Glaucous-winged Gulls during the months of August and September. Patrick J. Gould (pers. comm.) has suggested that increased pressure on the salmon populations by commercial fishermen may cause a reduction in this food source and perhaps lower gull populations. The gulls feeding on salmon are a mixture of all age classes.

In Alaska, Gabrielson and Lincoln (1959) note that one colony on Bogoslof had increased from 100-200 pairs in 1911 to several thousand pairs in 1944, and increased twice again by 1946. However, in that same time period, a colony on Walrus Island decreased tremendously. Thus, at least in Alaska, individual colony sites may have widely varying population sizes in various years, and the gull population as a whole may not be skyrocketing as it is elsewhere in the United States.

We do not have all the data that are necessary for determining the age structure of the population and ultimately from this for predicting long-term predictions of population trends of Glaucous-winged Gulls in the Gulf. We need to know the rates of winter mortality of adults and immatures and also the ratio of breeders to nonbreeders.

NESTING HABITAT

Glaucous-winged Gull colonies are usually situated on islands; these range from very large islands (e.g., Chowiet, Big Koniuji) to very small unnamed sea stacks less than 50 m wide (e.g., Amee Rock off of Kodiak). The nesting gulls may be arranged in what is normally considered a colony or they may be more scattered and almost solitary with nests over 50 m apart. In our studies the average density of nests ranged from 0.1-0.8 nests/m^2; one dense concentration of 17 nests/30 m^2 was noted on the Barren Islands (Table V-2). High density and low density pockets of nesting gulls may reflect preferred and less preferred habitats for nesting.

Distance to nearest neighbor averaged 3.3 m at Chiniak Bay and 5.3 m at Sitkalidak Strait on Kodiak Island, and ranged from 2.0-20.0 m in colonies on the Barren Islands (Table V-2). It is interesting to note that on the colonies in Chiniak Bay the mean distance of the nearest neighbor was not significantly different between the low (3.77 m $\pm$ 0.23 SE) and high (3.07 $\pm$

TABLE V-2
Parameters of the Nesting Habitat of Glaucous-winged Gulls.

Colony	$\bar{X}$ density (nests/m^2)	$\bar{X}$ nearest neighbor(m)	Type of habitat
Semidi Island Group			Among boulders and on exposed bedrock along edge of cliffs, vegetated with beach rye (*Elymus arenarius*) and cow parsnip (*Heracleum lanatum*).
Sitkalidak Strait	0.83 (high)[a] 0.18 (low)	5.3 $\pm$ 0.6	Highest densities on steep (17° slope), unvegetated cliffs of Little Kittiwake Rock and on Amee Rock, a gently sloping (4°) sea stack densely vegetated with umbelliferous meadow. Lower densities on both steep and gentle, vegetated and unvegetated slopes of other islands.
Chiniak Bay	0.51 (high)[a] 0.25 (low)	3.3$\pm$ 0.2	Higher densities in the *Elymus* zone along the periphery of low, well-vegetated islands. Usually lower densities in inland meadows of islands, vegetated with *Calamagrostis* and Umbelliferae.
Tuxedni Wilderness			On sparsely vegetated cliffs of Chisik Island. In dense umbelliferous vegetation underneath alders (*Alnus crispa*) on slopes of Duck Island.
Wooded Islands	0.48 (high)[a]		Scattered around Black-legged Kittiwake nesting area on Wooded Island; most on ledges of grassy slopes vegetated with *Elymus* and the umbels *Heracleum* and *Angelica*; some on narrow unvegetated rock ledges. On South Island on both unvegetated and densely vegetated rocky slopes.
Barren Islands	5.67 (high)[b]	3.5-10.6[c] 2.0-10.2 2.0-20.0	Dense colonies on slopes and ledges of East Amatuli and Sud Islands densely vegetated with grasses (*Festuca*) and umbels (*Angelica*); up to 450 m in elevation. One colony in talus slopes on Sugarloaf Island.
Middleton Island			Most in loose colonies among driftwood and boulders in flat meadows on periphery of island; some along edge of bluff under *Heracleum* and and *Calamagrostis*; fewer on mounds in grass-covered, hummocky uplands.

[a] Mean densities on study plots in high and low nesting concentrations.
[b] Total of 17 nests in 30 m^2 area in dense part of colony on Sud Is. in 1976.
[c] Range of distances found between neighbors within densest part of colony on E. Amatuli Is. in 1976, within entire colony on Sud Is. in 1976, and within the entire colony on E. Amatuli in 1977, respectively.

0.29 SE) density plots (P>0.01). This may mean that the behavioral needs of the gulls require a certain amount of clumping even in less desirable (low density) habitat. Such clumping is very typical for conspicuous ground-nesters like Glaucous-winged Gulls.

Throughout Alaska Glaucous-winged Gulls nest in a variety of habitats. In the Aleutian Islands gulls nest on high ledges or cliffs, on high grassy slopes on islands, on low rocky islets, on beachs among the Elymus, or on sandy shores; the most important requirement appears to be protection from predators (Murie 1959). If blue (Arctic) foxes (Alopex lagopus) are present on an island, the gulls, like the other sea birds, then nest on offshore rocks.

At colonies studied in the Gulf of Alaska, habitats used by Glaucous-winged Gulls also varied widely, in substrate, slope, and degree of vegetation (Table V-2). Generally they preferred areas within 10 m of a cliff edge that were vegetated with umbelliferous plants and grasses. Nests located in more interior parts of larger islands were often on high points or rock outcroppings. Some gulls nested on steep cliffs with little surrounding vegetation. Mean vegetation height around 89 nests at Sitkalidak Strait in 1977 was 18.3 cm during laying and 103.3 cm at hatching. The more clumped the colony, especially if on the small sea stacks, the sparser and lower was the vegetation. The gulls themselves probably helped to modify the habitat in which they nested since they trampled down vegetation. Nests in larger and more clumped colonies often had much less vegetation around them than did those which were solitary. If the gulls did not nest in umbel vegetation, they usually chose a vantage point like the tops of tussocks (Barren Is.) or the tops of the sea stacks (Kodiak). On Middleton Island, where gulls also nested among boulders and driftwood on flat areas, Frazer and Howe (1977) surmised that it was the height above sea level and the drier ground more than anything else that determined where the gulls nested.

BREEDING CHRONOLOGY

At each colony, the onset of laying by Glaucous-winged Gulls usually occurred within a week of the same date from year to year (Table V-3, Fig. V-2). For all areas studied except Middleton Island, laying began between 18 May and 7 June--a period of only 3 weeks--and ended between 1 June and 25 July. In 1978 the laying period at Middleton Island began in late April and spanned 47 days, not including second laying attempts. That year all species of seabirds at Middleton Island had a protracted breeding period, which could have been due to a more abundant food supply than at other areas. Hatching of first clutches throughout colonies in the Gulf occurred generally from mid-June to mid-July and peaked the first 2 weeks of July. Hatching of second clutches extended until the second week in August. The mean incubation period for Glaucous-winged Gulls varied little among colony sites and overall averaged 28.7 days.

Fledging occurred between the last week in July and early September but peaked during the first half of August. The late fledging dates were usually for chicks from a second clutch. The nestling stage lasted an average of 39.5 days (range:31-59 days). Large numbers of fledglings were observed rafting off colonies by mid-August.

REPRODUCTIVE SUCCESS

Reproductive success can be defined as the number of chicks fledging per nest attempt. A comparison, however, of all the various stages of reproduction yields valuable information on what forces may be influencing this overall reproductive success. During the laying stage, some reproductive "failures" occur; that is, some adults simply fail to lay. At all colonies studied

TABLE V-3
Breeding Chronology of Glaucous-Winged Gulls in the Gulf of Alaska 1976-1978.

Colony	Year	N	Laying	Hatching	Fledging
Semidi Group	76	90	24 May-28 June (peak 9-17 June)	17 June-17 July (peak 3-12 July)	28 July>[a]
	77		23 May-15 June (peak 4 June)		
Ugaiushak	76		6 June>[a] (peak 15-20 June)	(peak 8-15 July)	
	77		4 June>[a]		
Trinities	77		25 May>[a]		
Sitkalidak St.	77	89	7 June-14 July (peak 20 June)	7 July-14 Aug	7 Aug-15 Sept>[a]
	78	117	5 June-19 July (peak 5-7 June)	28 June-4 Aug (peak 11 July)	12 Aug-7 Sept>[a] (peak 16-20 Aug)
Chiniak Bay	75			18 June>[a] (peak 30 June)	
	77	36	28 May-25 July[b] (peak 4 June)	25 June-11 July (peak 2 July) 15-25 July relay	25 July-1 Aug>[a]
	78	35	28 May-25 June (peak 6 June) 25-29 June relay	26 June-25 July (peak 3 July) 20-24 July relay	26 July-1 Aug>[a]
Tuxedni	78		18 May-1 June		28 July-27 Aug
Forrester	76		1 June>[a] (peak 1-14 June)	1 July>[a] (peak 8 July)	29 Aug>[a]
Barrens	77		27 May-19 June		
	78		2-22 June	1-17 July	8-17 Aug
Wooded Is.	76		7 June>[a]	6 July>[a]	7-21 Aug
	77		28 May>[a]		1-15 Aug
Hinchinbrook	76		1-30 June (peak 14-21 June)		
Hinchinbrook (continued)	77		25 May-30 June[b] (peak 29 May-6 June)	25 June>[a] (peak 28 June-5 July)	3-25 Aug>[a]
	78		28 May-30 June	28 June-15 July (peak 29 June-10 July)	3 Aug>[a]
Middleton	76		17 May>[a]	14 June>[a] (peak 25-31 June)	
	78		27 April-12 June	24 May-8 July	3 July-17 Aug[b]

[a] Ending date (>) not exactly determined.
[b] Calculated.

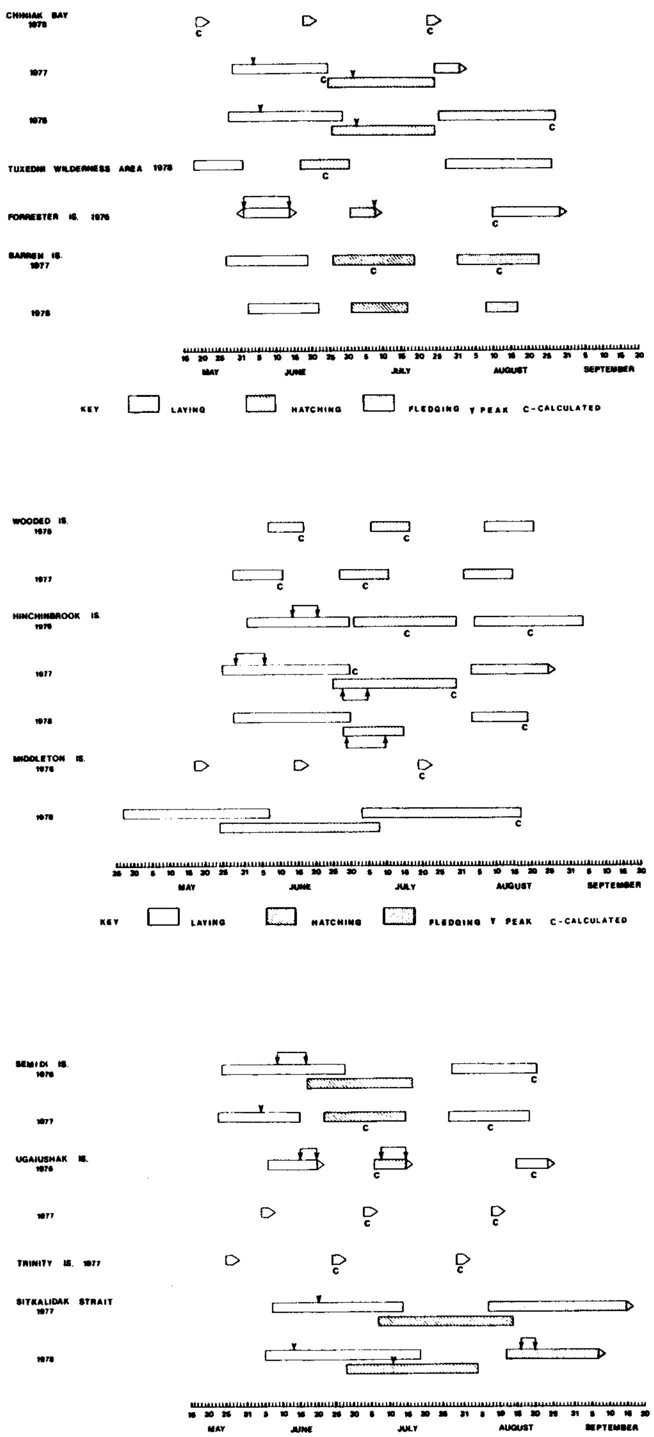


Figure V-2. Chronology of major events in the nesting season of Glaucous-winged Gulls in the Gulf of Alaska.

there was always a certain proportion of adults that did not lay, but it varied widely among colonies and between years. The proportion of nests with eggs ranged from 45% to 92%, and averaged 70% (Table V-4).

Clutch sizes ranged from 1-3 eggs; one nest with 5 eggs on Middleton Island in 1978 was possibly the result of laying by two females. Three-egg clutches were most frequent although two-egg clutches occasionally predominated as on Ugaiushak Island in 1976 (Table V-5). Mean clutch sizes among years and study sites were fairly uniform (Table V-4) and the combined mean for all of our studies was 2.40. The extreme low mean of 1.98 at Ugaiushak Island in 1976 and the extreme high mean of 2.89 at Middleton Island in 1978, however, were significantly different from the means of all of our other studies. Mean clutch sizes were similar to those reported for Herring and Western Gulls (Paynter 1949, Paludan 1951, Harris 1965, Brown 1967, Schreiber 1970, Harper 1971).

Hatching success varied tremendously. The year-to-year variation of hatching success at each site was greater than the variation between sites within each year. The number of chicks hatching per egg laid varied from 0.35 to 0.92, and the overall means were 0.76 (n=2 studies) for 1976, 0.71 for 1977 (n=6 studies), and 0.55 for 1978 (n=3 studies).

Fledging data are sometimes hard to obtain because Glaucous-winged Gulls often nest in heavily vegetated areas and the chicks are adept at concealing themselves. There are usually large numbers of chicks that once hatched are never located again. Thus at times one can only obtain a minimum and a potential maximum range of fledging rates. Minimum assumes all chicks not found had died before fledging; maximum assumes all chicks not found survived to fledge. These data are presented for Sitkalidak, 1977 (Table V-6). The actual fledging rates of Glaucous-winged Gulls were determined at Sitkalidak

TABLE V-4
Productivity of Glaucous-winged Gulls.

	Shumagin Island	Semidi Island		Ugaiushak Island		Sitkalidak Strait		Chiniak Bay			Barren Island		Hinchinbrook		Wooded Island		Middleton	Forrester
	1976	1976	1977	1976	1977	1977	1978	1975	1977	1978	1977	1978	1976	1977	1978	1977	1978	1976
Number of nests built			90[a]			84	117	62	40	38						43		
Number of nests w/eggs	100	117	63	128	126	57	53	41	33	35	32	25	35	68	37	27	70 (52)[b]	27
Number of eggs laid	242	295	160 (18)[b]	254	274	134	124	84	87	87	79	63	88	172	92	72	202 (150)[b]	
Number of eggs hatched	196		143 (15)[b]		168	101	59		75	47	48	22		96			(123)[b]	
Number of chicks fledged			(7)[b]			90[d]	44		46	28	29	4		62		37		
X̄ clutch size	2.42	2.52	2.54	1.98	2.17	2.35	2.34	2.05	2.64	2.49	2.47	2.52	2.51	2.53	2.49	2.67	2.89	2.50
X̄ brood size @ hatching			2.38 (2.50)[b]			1.87	2.10		2.50	1.96				1.4			(2.62)[b]	
X̄ brood size @ fledging			(2.33)[b]			1.67[d]	1.91											
Nests w/eggs per nest built (laying success)			0.70			0.68	0.45	0.66	0.83	0.92								
Eggs hatched/eggs laid (hatching success)	0.81		0.89 (0.83)[b]		0.61	0.75	0.48		0.86 (0.92)[c]	0.54	0.61	0.35	0.70	0.56			(0.82)[b]	
Chicks fledged/chicks hatched (fledging success)			(0.47)[b]			0.89[d]	0.75		0.61	0.60	0.60	0.18		0.65				
Chicks fledged per nest w/eggs			(1.17)[b]			1.58[d]	0.83		1.39	0.80	0.91	0.16	1.8[d]	1.0		1.37		
Chicks fledged/nest built (reproductive success)						1.07[d]	0.38		1.15	0.74								
% nests w/one or more eggs hatching			66.7				54.7										(90.4)[b]	

[a] Nests in main sample area marked during pre-egg stage but not rechecked until just before hatching; thus some eggs until just before hatching; thus some eggs may have been laid and lost.
[b] Based on a subsample.
[c] From lower density plots.
[d] Maximum number.

TABLE V-5
Frequency Distribution of Clutch Sizes
of Glaucous-Winged Gulls.

Colony	Year	Number of nests and (% of total nests) 1 egg	2 eggs	3 eggs
Semidi Islands	1976	8 (6.8)	40 (34.2)	69 (59.0)
Ugaiushak Island	1976	38 (29.7)	54 (42.2)	36 (28.1)
Sitkalidak Strait	1977	10 (18.2)	17 (30.9)	30 (54.5)
	1978	13 (24.5)	9 (16.9)	31 (58.5)

TABLE V-6

Estimates of Minimum and Maximum Number of Glaucous-Winged Gull Chicks Fledged at Sitkalidak Strait, 1977.

Number of nests with eggs	54
Number of eggs	134
Number of chicks hatched	101
Minimum number of chicks fledged	49
Maximum number of chicks fledged	90
Minimum fledging success	48.5%
Maximum fledging success	89.1%

in 1978 by using a dog to locate the chicks in the vegetation. Except for unusually low success in the Barren Islands in 1978 (0.18 chicks minimum fledged per chick hatched), the minimum fledging success ranged from 0.18-0.89 over all years and all colonies. At each study area fledging success was very similar from year to year.

The overall reproductive success, which was defined as number of chicks fledging per nest built, ranged from 1.07-1.15 at two sites in 1977, and varied from 0.38-0.74 at the same two sites in 1978 (Table V-4). Thus, greater variation was found in the breeding success between years in one colony rather than between colonies in one year. For both colonies, 1977 was far more productive with respect to number of chicks fledging per nest built and per nest with eggs. The wide annual variations during all phases of reproduction may be characteristic of northern latitudes, where the size of prey populations may vary more between years than in other latitudes.

GROWTH OF CHICKS

There were few studies of growth of young Glaucous-winged Gulls because chicks were difficult to locate after they were about a week old. One of the few places where chicks were followed to fledging was at Sitkalidak Strait in 1978, where a dog helped locate chicks with almost 100% recapture rate (Tables V-7 and V-8). Figure V-3 shows the growth in weight for chicks at Sitkalidak Strait (1977 and 1978 data combined). Growth rate data from Ugaiushak Island (1977) were obtained from Duff Whele (pers. comm.). The growth rates at Sitkalidak Strait and Ugaiushak in 1977 were compared with those at Sitkalidak in 1978 and no difference was found; the growth rate from the combined data approximated a sigmoid curve (Fig. V-4). Mean weight gain per day for the period of greatest growth differed little among the populations studied in the Gulf. At Sitkalidak, the gulls gained 38 g per day (n=8)

TABLE V-7
Growth of Glaucous-Winged Gull Chicks, Sitkalidak Strait (1977 and 1978 Data Combined).

Age in Days	N	Weight in grams $\overline{X}$	Weight in grams SE
0- 1	22	73.31	4.23
2- 3	9	109.67	6.92
4- 5	14	163.14	12.66
6- 7	7	185.00	18.14
8- 9	13	296.46	8.26[a]
10-11	12	377.75	20.74
12-13	14	477.21	16.15
14-15	10	515.60	28.34
16-17	11	658.36	12.78
18-19	8	732.75	32.26
20-21	11	800.00	34.58
22-23	12	855.75	25.81
24-25	10	930.30	29.77
26-27	8	945.00	27.12
28-29	8	1,077.87	33.13
30-31	6	1,127.83	57.09
32-33	8	1,120.87	31.00
34-35	6	1,148.33	63.80
36-37	1	1,180.00	0

[a] One chick was starving.

TABLE V-8
Growth of Glaucous-Winged Gull Chicks at Sitkalidak Strait, 1978.

Age in Days		Weight (g)	Culmen (mm)	Tarsus (mm)	Wing (mm)
0-1,	$\overline{X}$	80.31	18.49	28.89	2.60
	SE	4.42	0.47	.59	0.05
	N	16	13	13	17
2-3,	$\overline{X}$	133	20.85	33.25	3.18
	SE	14.25	1.22	1.37	0.17
	N	4	4	4	4
4-5,	$\overline{X}$	188.4	22.98	35.07	3.68
	SE	32.01	1.38	3.10	0.28
	N	5	6	6	6
6-7,	$\overline{X}$	186.83	23.13	37.68	3.87
	SE	23.35	1.01	1.43	0.15
	N	6	6	6	6
8-9,	$\overline{X}$	337.89	28.72	47.11	5.54
	SE	25.77	0.97	1.41	0.53
	N	9	9	9	9
10-11,	$\overline{X}$	402.17	30.40	49.78	6.20
	SE	27.35	1.00	1.75	0.56
	N	12	13	12	12
12-13,	$\overline{X}$	476.56	32.49	52.14	6.33
	SE	26.79	1.15	1.63	0.40
	N	9	7	7	9
14-15,	$\overline{X}$	562.11	34.53	58.46	9.47
	SE	39.83	1.33	1.64	0.84
	N	9	10	10	10
16-17,	$\overline{X}$	658.27	37.29	61.33	10.95
	SE	12.13	0.98	0.86	0.53
	N	11	11	11	11
18-19,	$\overline{X}$	815	39.93	66.98	14.34
	SE	25.88	1.42	1.99	1.72
	N	5	5	5	5
20-21,	$\overline{X}$	812.29	39.91	66.16	14.19
	SE	41.69	0.65	1.03	0.65
	N				
22-23,	$\overline{X}$	880.57	43.21	69.51	18.02
	SE	35.10	0.84	1.21	11.01
	N	7	7	7	7

TABLE V-8
Continued.

Age in Days		Weight (g)	Culmen (mm)	Tarsus (mm)	Wing (mm)
24-25,	$\overline{X}$	942.57	42.57	70.14	19.30
	SE	32.09	11.20	0.83	0.78
	N	7	6	7	7
26-27,	$\overline{X}$	1012	45.99	70.28	21.62
	SE	33.16	0.85	1.46	0.58
	N	9	9	9	9
28-29,	$\overline{X}$	1140	47.37	74.47	24.00
	SE	100.67	3.82	3.38	0.51
	N	3	3	3	3
30-31,	$\overline{X}$	1182.33	48.57	74.97	24.43
	SE	63.89	0.84	.50	1.39
	N	3	3	3	3
32-33,	$\overline{X}$	1110.83	49.44	74.82	26.22
	SE	51.64	1.44	1.53	0.42
	N	6	5	5	6
34-35,	$\overline{X}$	1236.67	49.60	71.25	28.53
	SE	76.23	2.80	5.75	0.92
	N	3	2	2	3

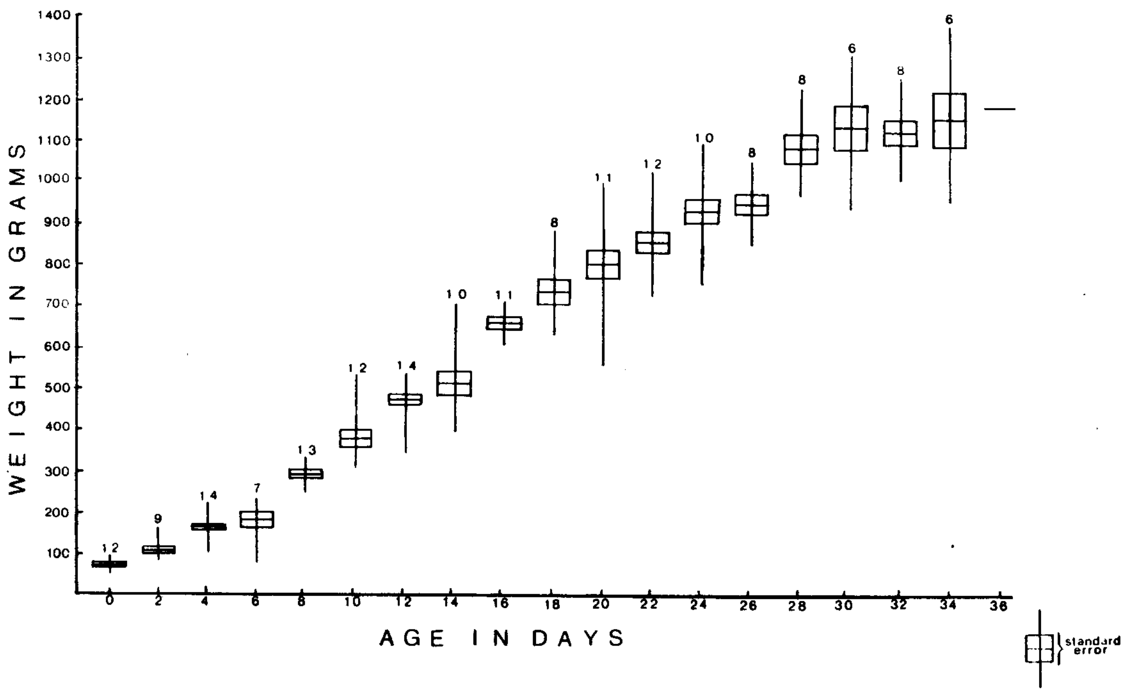


Figure V-3. Weight gain in Glaucous-winged Gull chicks at Sitkalidak Strait (1977 and 1978 data combined).

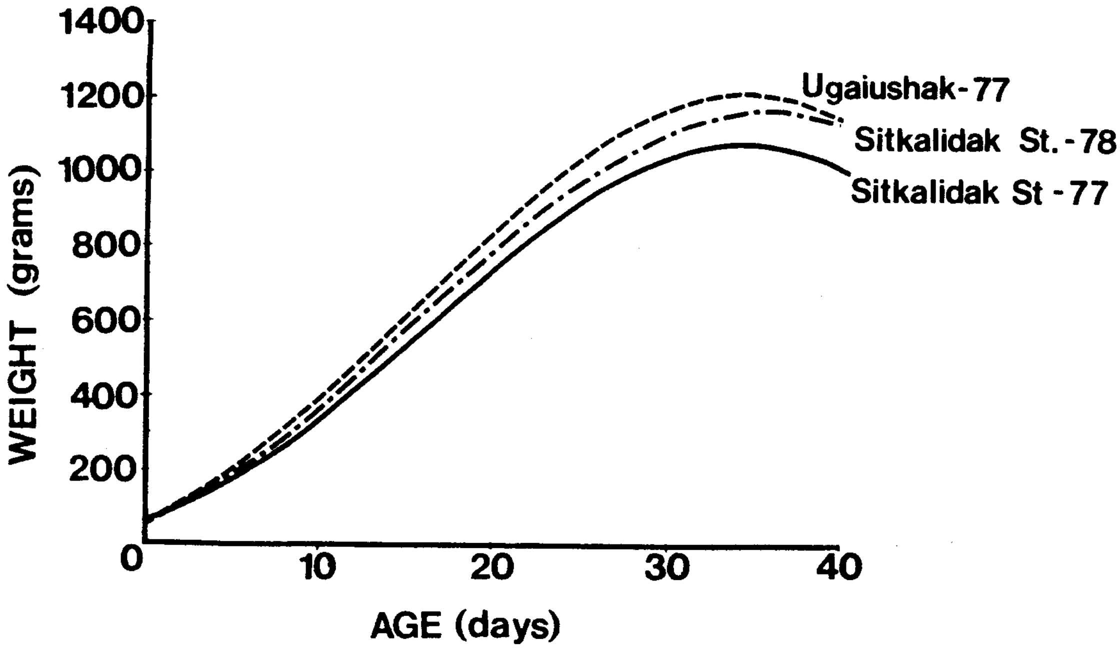


Figure V-4. Comparison of regression curves for growth of Glaucous-winged Gull chicks in the Gulf of Alaska, 1977-1978.

between 4 and 30 days (Baird and Moe 1978, Baird and Hatch 1979); at the Semidis, between 6 and 16 days they gained 37 g per day (n=5, Hatch 1978); and at Hinchinbrook (Sangster et al. 1978) between 9 and 27 days the mean gain was 34 g per day (n=39). These gains are somewhat greater than what Vermeer (1963) found for Glaucous-winged Gulls off of British Columbia ($\bar{X}$=28 g/day).

Fledging weights were often less than maximum weights as was suggested for Western Gulls by Schreiber (1970). Mean age for peak weight was 39.9 days at Hinchinbrook Island (Sangster et al. 1978). Chicks fledged at as early as 30 days of age and the mean fledging weight was 1155.5 g (n=10) at Sitkalidak and 979 g at Hinchinbrook (n=39).

Sangster et al. (1978) compared growth of chicks from clutches of various sizes and found no significant difference in growth rates. Wehle (1978) also compared growth rates of chicks from different-sized clutches in 1977. He experimented with supernormal clutch sizes to see if the adults could indeed raise a greater number of chicks to fledging. His hypothesis was that if they could not, then food was most likely the limiting factor for the breeding success of the gulls. He placed one to two extra eggs in selected nests during the first days of laying. He found (Duff Wehle, pers. comm.) that the chicks hatched from supernormal clutches grew 37 g per day between 5 and 35 days of age, which was similar to growth of chicks from normal clutches. He was not able to obtain fledging weights because the older chicks entered the water when he tried to capture them.

The growth of culmen, tarsus, and wing is less influenced by lack of food than is weight. These body parts keep growing even if a chick is not gaining weight. Growth of chicks at both Sitkalidak (1977, 1978) and Hinchinbrook (1977) was measured and the average daily growth over the straight line portion of the growth curve was calculated. Growth of culmen averaged 0.9 mm per day at both sites, growth of tarsus averaged 1.5 mm at Sitkalidak and 1.9 mm at Hinchinbrook; growth of the wing after eruption of primaries averaged 8.8 mm per day at Sitkalidak (wing chord, Sitkalidak) and 7 mm per day at Hinchinbrook (flattened wing). The data for Sitkalidak Strait are presented in Table V-8. The length of these body parts can be used to age chicks. The culmen is the best measure for aging young chicks (Ricklefs 1968) since it grows steadily until the chicks are about 4 weeks old but then growth begins to slow. The mean culmen length at fledging is about 90% of the adult length (55 mm). Similarly there is rapid tarsus growth the first 3 weeks of life; adult size (74 mm) is reached at about the end of the fourth week. Growth of the wing is very slow at first and is therefore a poor measurement by which to judge age of young chicks. After the primaries have erupted, however, the length of the wing becomes an excellent means by which to age chicks. But it is important to know whether the comparative measurements are for wing chord or for flattened wing. At fledging, the wing chord averages 285 mm and the flattened wing averages 318 mm, 75% of the mean wing length of adult Glaucous-winged Gulls.

FOOD HABITS AND FORAGING

Food

Among all the seabirds studied, Glaucous-winged Gulls were the most eclectic in their food habits. Although a wide variety of prey was found around nest sites and in regurgitations from chicks at every colony studied, fish predominated in the diets of the chicks (Tables V-9 to V-11). At Hinchinbrook Island, Pacific herring (*Clupea harengus*) were delivered most frequently to chicks whereas Pacific sand lance (*Ammodytes hexapterus*) and capelin (*Mallotus villosus*) were most important at Sitkalidak Strait (Table

TABLE V-9
Frequency of Occurrence of Prey of Glaucous-Winged Gull Chicks, 1976-1978.

Prey item	% frequency of occurrence			
	Koniuji Group	Sitkalidak Strait		Hinchinbrook Is.
	1976 (N=16)	1977 (N=79)	1978 (N=36)	1977 (N=27)
Capelin		43.0	22.2	37.0
Sand lance	12.5	20.2	33.3	12.9
Pacific Herring				69.9
Salmonidae				11.1
Gadidae (Cod)		1.3	2.8	
Pacific Sandfish		1.3	8.3	
Stichaeidae (Prickleback)				3.7
Scorpaenidae (Rockfish)				3.7
Other Fish	56.3	5.1	8.3	14.8
Fish Eggs		6.3		
Unidentified Crab	12.5			
Limpet (*Acmaea* sp.)	12.5	26.5	22.2	3.7
Sea Star (*Evasterius troschelii*)				
Plants		2.5	0	

TABLE V-10
Percent Numbers of Prey Items of Glaucous-Winged Gull Chicks at Sitkalidak Strait, 1977-1978.

Prey item	1977 (N=267)	1978 (N=91)
Capelin	63.8	19.7
Sand lance	22.8	56.0
Pacific sandfish	0.4	14.3
Gadidae	0.7	1.1
Other fish	4.0	3.3
Invertebrates	7.6	7.7
Plants	Unknown	0

TABLE V-11
Qualitative List of Types of Prey Found in Regurgitations of Glaucous-Winged Gull Chicks or at the Nest Site.

Semidi Islands 1976	Chiniak Bay 1975	Forrester Group 1976	Wooded Island 1976
Limpets (*Collisella* spp.)	Chitons (*Katharina tunicata*)	Ancient Murrelet chicks	Blue mussel (*Mytilus edulis*)
Chitons (*Katharina tunicata*)	Sea urchins		
Mussels (*Mytilus*)	Sea cucumbers (*Cucumaria*)		
Unidentified fish species			
Fulmar eggs			
Murre eggs			
Black-legged Kittiwake eggs			
Decomposed sea lion pups			

V-9). Limpets were also important at these study sites. The types of prey taken at Sitkalidak Strait were similar during the two years studied, but the percent frequency of occurrence, percent numbers, prey weights, and lengths differed between years. The most common prey in the chicks' regurgitations was capelin in 1977 and sand lance in 1978. This may reflect a change in preference or a change in food availability.

Sand lance in their second year of life are about 66-116 mm in length (Blackburn 1978) and capelin in their second year of life are about 50-110 mm in length (Jangaard 1974). At Sitkalidak Strait in 1977, 76.5% of the capelin fed to kittiwake chicks were less than 110 mm in length and 81.4% of the sand lance were less than 120 mm in length (Fig. V-5). In 1978, fish less than 120 mm in length were comparatively scarce in chick diets; 50.1% of the sand lance brought to chicks were longer than 131 mm and 70% of the capelin exceeded 120 mm in length. In particular, the scarcity of capelin in their second year in 1978 was associated with the fact that capelin comprised a significantly smaller portion of the diets of kittiwake chicks in 1978 than they did in 1977 (Table V-10). The average length of fish the adults brought to their chicks in both 1977 and 1978 did not change markedly as the season progressed ($P>0.5$). This excludes, of course, the adult salmon the gulls brought back in pieces to their chicks.

The selections of prey at various colonies and in different years reflected how different environmental conditions around each colony affected different assemblages of prey species. To understand the trophics of Glaucous-winged Gulls and other seabirds, then, it is important to identify the key prey species around each colony and to determine how each changes in abundance and average length year to year.

Wehle's (1978) studies of experimental clutch sizes suggest that food was not a limiting factor for Glaucous-winged Gulls at Ugaiushak Island in

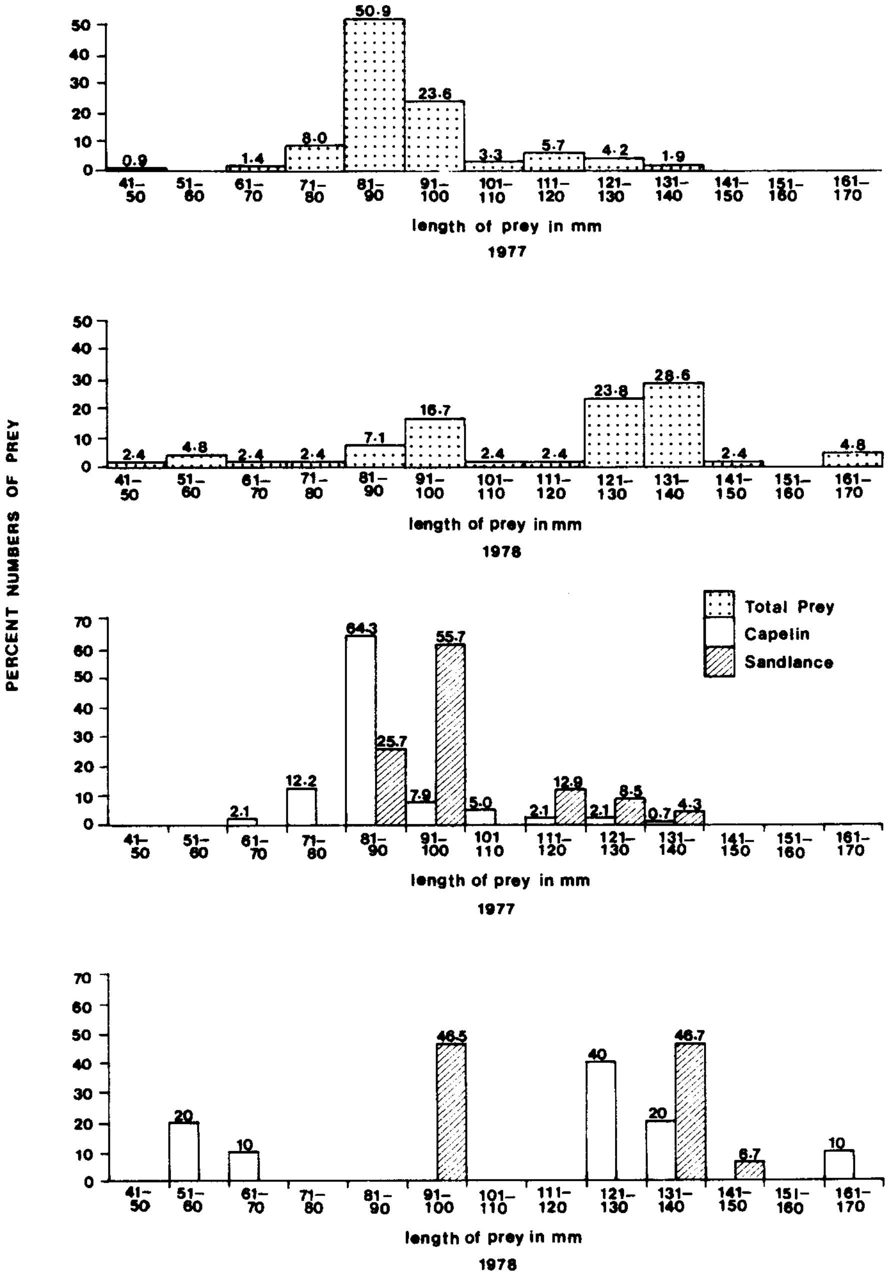


Figure V-5. Distribution of lengths of prey of Glaucous-winged Gull chicks, Sitkalidak Strait, 1977-1978.

1977, because 70% (n=10) of the experimental breeding pairs raised the supernormal clutches to fledging, and the chicks grew as well as those from normal clutches.

At Sitkalidak Strait, the weight of individual regurgitations was measured to estimate the average amount of food needed to raise chicks to fledging. The mean weight of each regurgitation was 27.3 g in 1977 (n=19) and 19.1 g in 1978 (n=29). Assuming that a Glaucous-winged Gull chick was fed at least as often as a Black-legged Kittiwake chick (a mean of 3.8 times per day; see Black-legged Kittiwake section in this volume), the average weight a gull chick would have eaten during the nestling stage was approximately 2,800 g during the poor year (1978) and 4,100 g during the good year (1977). Applying means of 0.83 and 1.67 fledglings per breeding pair (for the poor and the good year) to the population size at Sitkalidak of 480 and 940 birds in 1978 and 1977, respectively, the biomass used per breeding season for chicks alone ranged from 0.6 to 3.2 mt with a mean of about 1.9 mt of food per season. Thus, with a range of success rates similar to those we found at Sitkalidak Strait, Glaucous-winged Gulls nesting at colonies throughout the Gulf of Alaska would require 200-590 mt of food each year in order to raise chicks.

Foraging

Glaucous-winged Gulls foraged near the colonies at which they bred. At Ugaiushak, they foraged within 3 km of the colony (Wehle 1978), at Middleton they foraged in the intertidal and nearshore area (Frazer and Howe 1977), and at the Semidis they foraged in tide rips (Hatch 1978). At Sitkalidak Strait, they foraged up to 10 km from the colony, usually along convergence lines and tide rips within 2 km of the colonies. During pelagic surveys around Kodiak Island, Gould et al. (1978) found a decrease in the number of gulls in water >100 m deep from June through August. This suggests that gulls that had been pelagic in winter concentrated in the waters near the colonies during the breeding season. At some colonies there was occasionally an influx of subadult birds at the end of the breeding season. Wehle (1978) recorded an influx of 2,000 subadult birds the last 2 weeks in August in 1977 at Ugaiushak. This may have have been due to a short-term abundance of some prey species.

Gulls often loafed near the colonies when they were not foraging, brooding, or incubating. Groups of up to several thousand, including nonbreeding individuals, congregated on beaches and offshore rocks.

FACTORS AFFECTING REPRODUCTIVE SUCCESS

The overall production of young at a colony in any year is based on a number of life history events: the number of breeding adults returning to the colony, the proportion of returning adults that lay eggs, the mean clutch size, the proportion of eggs that hatch, and finally, the proportion of chicks that fledge. Any number of environmental factors could influence these parameters and thereby contribute to the variation in productivity typically observed among colonies and in different years.

At the colonies we studied there was variation in the number of birds returning to the colony, in the proportion of birds that built nests but did not lay eggs, and in the clutch size at 2 colonies. Although slight discrepancies in the number of birds breeding at a colony in different years were usually artifacts of methods and timing of censusing, the 49% decline in numbers at Sitkalidak Strait between 1977 and 1978 and the doubling of the population nesting at Hinchinbrook Island between 1976 and 1977 (Table V-1) were deemed real. That the greater number of birds bred at both colonies in 1977, when food resources seemed to be more abundant at Sitkalidak Strait compared with 1978, suggests that a great proportion of Glaucous-winged Gulls may nest when food is plentiful.

The proportion of birds that built nests and subsequently laid eggs varied from 45-92% (Table V-4). Although no clear pattern relating to years or geographical location emerged, the percentage at Sitkalidak Strait decreased from 68% in 1977 to 45% in 1978. Clutch sizes varied little either among years or among colonies, suggesting that, if birds choose to lay, the number of eggs produced is not greatly influenced by abundance of food resources.

Mortality of eggs influenced reproductive output more than any other factor. The greatest mortality at any colony occurred during the egg stage. However, a realistic assessment of differences among colonies in mortality is difficult because the timing and amount of disturbance by investigators varied among the studies and undoubtedly influenced greatly the amount of predation. In most instances of egg loss, the eggs simply disappeared (Table V-12); such losses can probably be attributed primarily to avian predation, much of it by the gulls themselves. Other avian predators included Common Ravens and Northwestern Crows, although Bald Eagles also preyed on nesting adults and indirectly caused some egg loss. Shell damage, which resulted in death of some embryos, may also have been caused by avian predators.

At Sitkalidak Strait, egging by humans was an important cause of mortality. Collecting eggs from bird nests is a Native tradition and those of Glaucous-winged Gulls are preferred in the Kodiak area. Many eggs that disappeared may thus have been taken by Natives. At the Barren and Wooded Islands river otters (<u>Lutra canadensis</u>) were active predators and may have taken many gull eggs.

Mortality from desertion, exposure, and unknown causes during hatching

TABLE V-12
Mortality of Glaucous-Winged Gull Eggs and Chicks.

Cause of Mortality	Numbers (%) of eggs or chicks									
	Barren Is.		Semidi Is.				Sitkalidak Strait			
	1976		1976		1977[a]		1977		1978	
Total number eggs	242	(100)	295	(100)	160	(100)	134	(100)	123	(100)
Egg Stage										
Avian predation	4	(2)	50	(17)			8	(6)	30	(24)
Desertion					1	(<1)				
Collected							2	(2)		
Shell damage	2	(<1)	3	(1)						
Infertile	9	(4)			5	(3)				
Exposure									7	(6)
Died hatching					2	(1)				
Disappeared	31	(13)	8	(3)	9	(6)	23	(17)	27	(22)
Total eggs	46	(19)	61	(21)	17	(11)	33	(25)	64	(52)
Chick Stage										
Exposure									3	(2)
Disappeared							11	(8)	12	(10)
Fate unknown							41	(31)		
Total chicks							11-52	(8-39)	15	(12)
Total Mortality							44-85	(33-64)	79	(64)

[a] Nests checked just before and just after hatching.

was also reported in our studies, but such mortality was minor compared with that from predation. Only 14 (1.9%) of 742 eggs monitored throughout their expected incubation periods were found to be infertile (Table V-12).

Although survival of chicks was difficult to determine at most study sites, avian predation was again the most probable cause of disappearance of most chicks. Some chicks also died from exposure (Table V-12). At the Barren Islands a river otter was observed drowning a fledging gull and otter scats contained bones and down from gull chicks.

Evidence from Sitkalidak Strait suggests that, in a year of abundant food, Glaucous-winged Gulls are able to raise successfully more than the average number of young. The amount of food regurgitated by chicks (which should be directly proportional to the amount fed to chicks) averaged 30% lower in 1978 than in 1977 (19.1 g vs. 27.3 g), suggesting that food was less available to adults in 1978. Whether the annual change in food availability was more than a local phenomenon is difficult to assess, but parallel effects on productivity at most colonies studied suggest that it may have been widespread. At the three colonies studied both years (Sitkalidak Strait, Chiniak Bay, Barren Islands) there was a marked drop in hatching success in 1978 (Table V-4). Interestingly, though, fledging success did not differ markedly between years at either Sitkalidak Strait or Chiniak Bay. Only at the Barren Islands, where river otters were so prevalent, was there a large decline in 1978 (Table V-4). In addition, although there was a decline in the amount of food fed to chicks and a change in prey species and age class taken by gulls at Sitkalidak Strait in 1978, the growth rates of chicks were not affected. These findings suggest that availability of food primarily affects reproductive success during the incubation phase. Mortality of eggs may be augmented if adults have to leave them unattended for greater periods of time during an extended search for suitable prey.

Variations in the production of young by Glaucous-winged Gulls thus appear to be influenced primarily by the number of adults returning to breed, the proportion of adults that lay eggs after building a nest, and the proportion of young that hatch and subsequently fledge. The number of adults that breed and hatching success appear to be correlated with the availability of food. Thus, the reproductive strategy of Glaucous-winged Gulls may, in any given year, be tailored to the amount of energy required to successfully raise young in relation to the amount of time and effort needed to obtain that energy.

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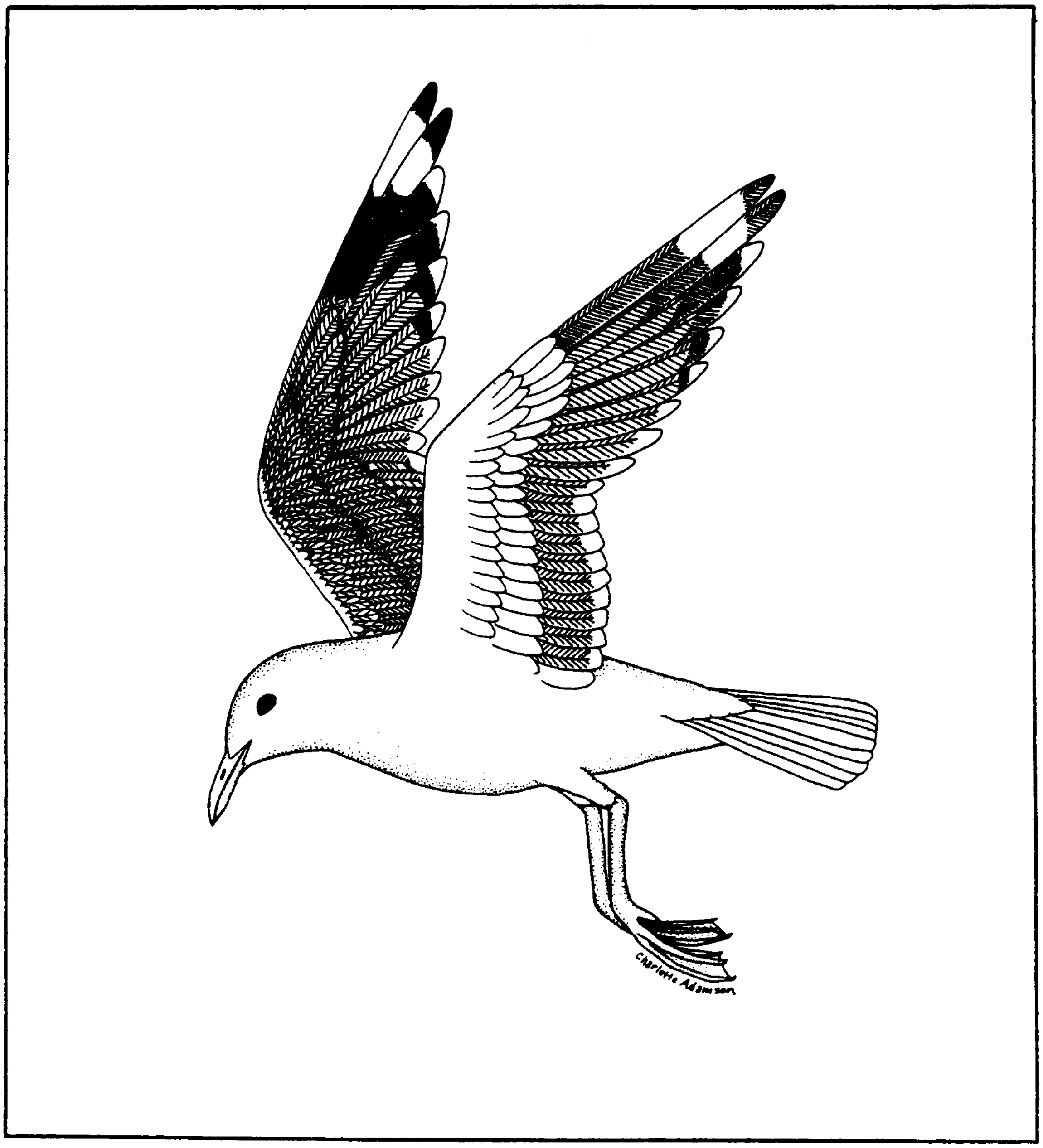
Mew Gull (*Larus canus*)



by

David R. Nysewander

MEW GULL

(*Larus canus*)

The Mew Gull is widely distributed across northern Europe and Asia. The North American breeding populations occur only in northwestern Canada and Alaska, and winter along the Pacific Coast from the northern Gulf of Alaska to southern California. Mew Gulls are not highly pelagic and are commonly observed only in nearshore waters in both winter and summer, and in Alaska's interior in the summer.

Despite the wide distribution of this species, there has been relatively little study of its breeding biology. This information is available primarily from studies conducted in Europe (Barth 1955, Weidmann 1955) and the Soviet Union (Bianki 1967). An unpublished report of a study conducted on the Yukon Delta National Wildlife Refuge (Strang and Strang 1974) provided the most comprehensive account of the breeding biology of Mew Gulls in Alaska prior to the OCSEA Program.

This account summarizes information gathered from 1977-1980 at Chiniak Bay on Kodiak Island (Nysewander and Hoberg 1978, Nysewander and Barbour 1979), at Nelson Lagoon (M. R. Petersen, pers. comm.), and in Anchorage (Patricia A. Baird and Charlotte I. Adamson, pers. comm.).

BREEDING DISTRIBUTION AND ABUNDANCE

In Alaska, Mew Gulls have been found breeding along the coast from the vicinity of Juneau west to Unimak Island and north to the Chukchi Sea. This species also breeds in interior Alaska and is common on inland lakes and rivers throughout the Interior north to the northern slopes of the Brooks Range. Mew Gulls rarely nest colonially on the Yukon River delta, in interior Alaska, or on the northern slopes of the Brooks Range. Small colonies (usually 25-50 breeding pairs), however, do occur along the coast of Alaska (Fig. VI-1). Four larger colonies or associations (100-300 pairs) have been observed in the Gulf of Alaska. They are: Belkofski near King Cove on the Alaska Peninsula, Bendel Island in the Shumagin Islands, Mary Island in Chiniak Bay on Kodiak Island, and the islands at the mouth of the Alsek River (Table VI-1). A colony of 75-100 pairs had been previously reported at Amee Island near Old Harbor, Kodiak Island (Gerald A. Sanger and local residents, pers. comm.). In 1977 and 1978 only 25-30 pairs were noted there and the decrease is thought to be related to the frequent egging activities of local residents.

There are 44 reported coastal breeding sites in Alaska with a total of 3,442 birds, but the actual coastal breeding population is estimated at about 10,000 birds (Sowls et al. 1978). Because of the small size of most colonies of Mew Gulls and their scattered distribution, much of the breeding population probably goes unnoticed or unreported.

NESTING HABITAT

Bianki (1967) found that Mew Gulls in the Soviet Union had a strong nesting preference for maritime meadows with soil substrate. Nesting areas that had lower densities of birds and probably were less preferred were found in crowberry habitat. Densities ranged from 0.03 to 0.06 nests per square dekameter in all habitats in Bianki's study.

In Alaska, Strang and Strang (1974) found that all Mew Gull nests on the Yukon-Kuskokwim River Delta were on islands in ponds and that each pair, with one exception, nested at least 200 m from the nearest neighboring pair, or on a different pond. Nysewander and Hoberg (1978) found that Mew Gulls on Mary Island in Chiniak Bay nested on low, moist maritime meadows dominated by _Calamagrostis_. The mean number of nests per square dekameter on the nine

Mew Gull (*Larus canus*)

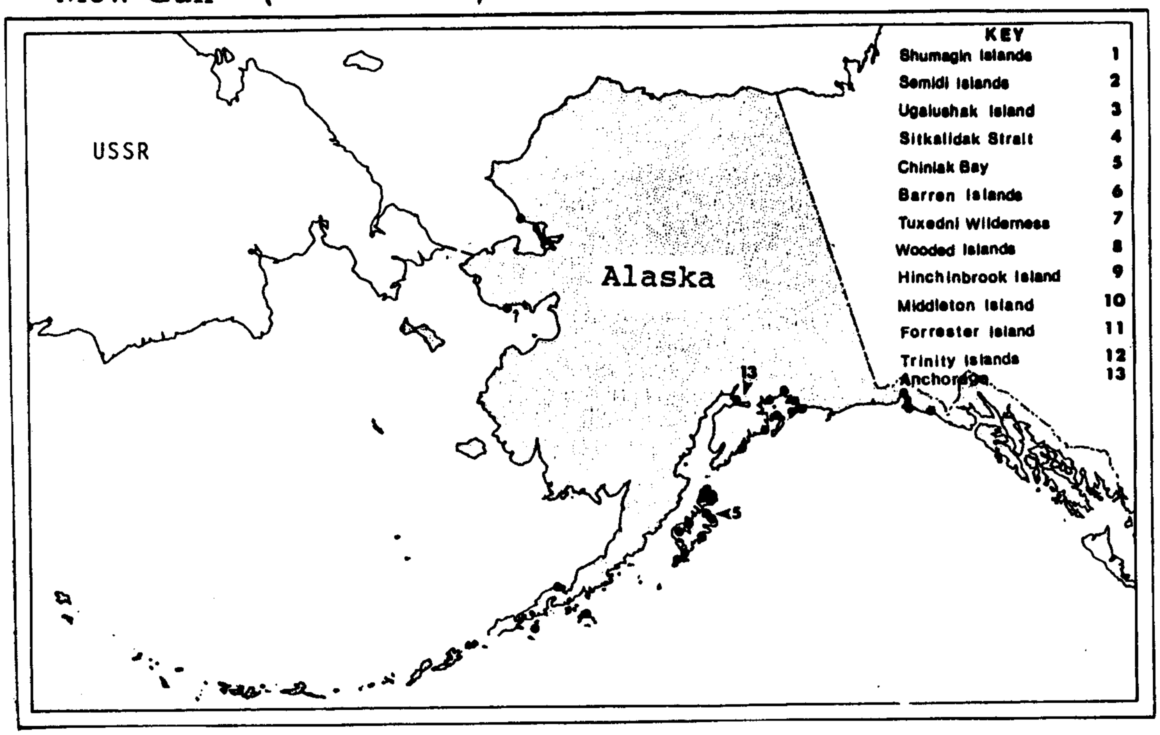


Figure VI-1. Distribution of breeding colonies of Mew Gulls in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

TABLE VI-1
Estimated Numbers of Mew Gulls Nesting at Five Major Sites in the Gulf of Alaska.

Colony	Number of Birds		Source
Belkofski, King Cove	400		Murie 1959
Bendel Is., Shumagin Is.	600		E. Bailey, pers. comm.
Mary Is., Chiniak Bay (Kodiak)	400		Nysewander and Hoberg (1978)
Alsek River mouth	600		S. Patten, pers. comm.
Amee Is., Kodiak	200	1976	G. Sanger, pers. comm.
	60	1977-78	P. A. Baird, pers. comm.

$100\text{-}m^2$ plots was 4.4 (range = 1-7) in both 1977 and 1978 while the mean distance of the nearest nest of the same species was 3.3 m (n = 60, S.E. = 0.22) in 1977.

Mary Island in Chiniak Bay has two exceptionally dense colonies. In other places in Alaska the colony size may be larger but the densities are much lower. Samuel M. Patten (pers. comm.) found Mew Gulls scattered in greater numbers than on Mary Island but with lower densities on several islands at the mouth of the Alsek River. Richard MacIntosh (pers. comm.) in June of 1978 found Mew Gulls nesting on Tugidak Island in low densities over crowberry tundra, which was the same kind of habitat with low densities of nests noted by Bianki (1967) in the Soviet Union. Charlotte A. Adamson (pers. comm.) found Mew Gulls nesting in the shipyards and waterfront industrial area of Anchorage. Although most Mew Gull nests are on the ground, Dick et al. (1976) found a few in trees on Kodiak Island and Patricia A. Baird & Charlotte I. Adamson (pers. comm.) found some on truck trailers, industrial debris, old stoves, and oil pipelines in the waterfront industrial area of Anchorage.

In summary, during the breeding season, Mew Gulls disperse inland and along the coast. For their nest sites they occasionally use bay or lake islands, shorelines of coastal lakes and streams, or upland habitat near coastal regions. However, great variation can occur in both nesting density and choice of nesting habitat.

BREEDING CHRONOLOGY

Mew Gulls arrived at Nelson Lagoon on 19 April in 1977 and had established territories by 25 April (M. Petersen, pers. comm.). Up to 2,000 Mew Gulls have been noted wintering in Chiniak Bay (Dick 1977), but the majority of these birds depart by mid-April. At the beginning of May, the 250-300 pairs breeding in or near Chiniak Bay set up territories on two distinct colonies on Mary Island and as single pairs scattered elsewhere throughout the coastal areas of Chiniak and Ugak Bays.

In 1978 egg laying on Mary Island began on 24 May and peaked on 31 May, with the mode (middle two-thirds) occurring between 27 May and 3 June (Figs. VI-2 & VI-3, Table VI-2). Relaying took place between 7 and 26 June. In Anchorage in 1979, egg laying began 9 May and lasted till 2 June with the mode from 11-25 May and the peak at 17 May.

Using the assumption that incubation begins at the laying of the last egg and that hatching usually occurs one day after pipping, on Mary Island there was a mean of 24.6 days (n = 32, S.E. = 0.21) for incubation. This differs somewhat from the 26 days reported by Barth (1955) and Bianki (1967).

Hatching started 15 June in 1977 and 21 June in 1978 at Chiniak Bay, but the peaks were more similar: 24 June in 1977 and 26 June in 1978 (Table VI-2, Fig. VI-4). The hatching modes were 19-29 June in 1977 and 23-28 June in 1978. The second attempt eggs hatched 10-14 July in 1977 and on 5 July in 1978. In Anchorage, hatching commenced on 3 June and lasted till 27 June with the mode occurring from 7-23 June and the peak at 18 June.

Thirty-five days is the usual fledging period (Barth 1955, Bianki 1967). The first young fledged at Nelson Lagoon on 16 July in 1977 and at Chiniak Bay on 5 August in 1977 and on 27 July in 1978. In Anchorage, young fledged between 8 July and 1 August in 1979. The mode there was 10-28 July and the peak was on 19 July.

REPRODUCTIVE SUCCESS

Mean clutch size of Mew Gulls in Chiniak Bay was not significantly different in the 2 years studied: 2.67 (n = 38, S.E. = 0.11) in 1977 and 2.51 (n = 39, S.E. = 0.12) in 1978. These figures probably reflect some egg loss since nests were not rechecked daily during laying. Particularly

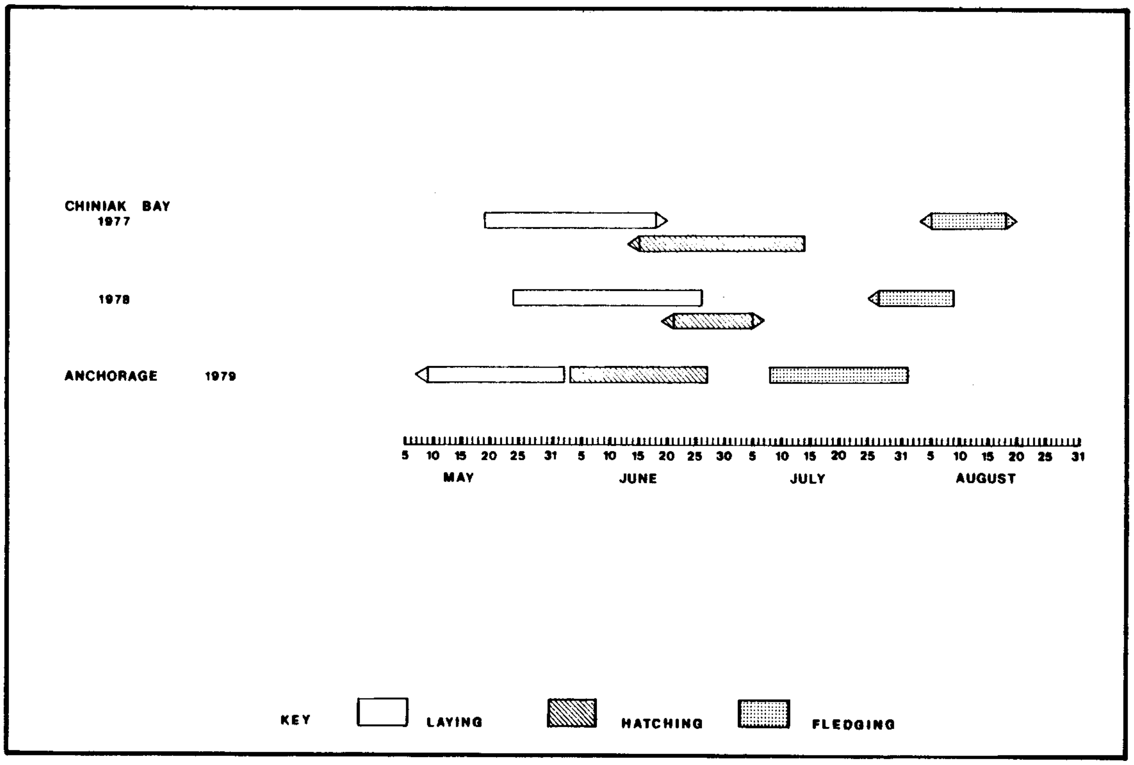


Figure VI-2. Chronolgy of major events in the nesting season of Mew Gulls in the Gulf of Alaska.

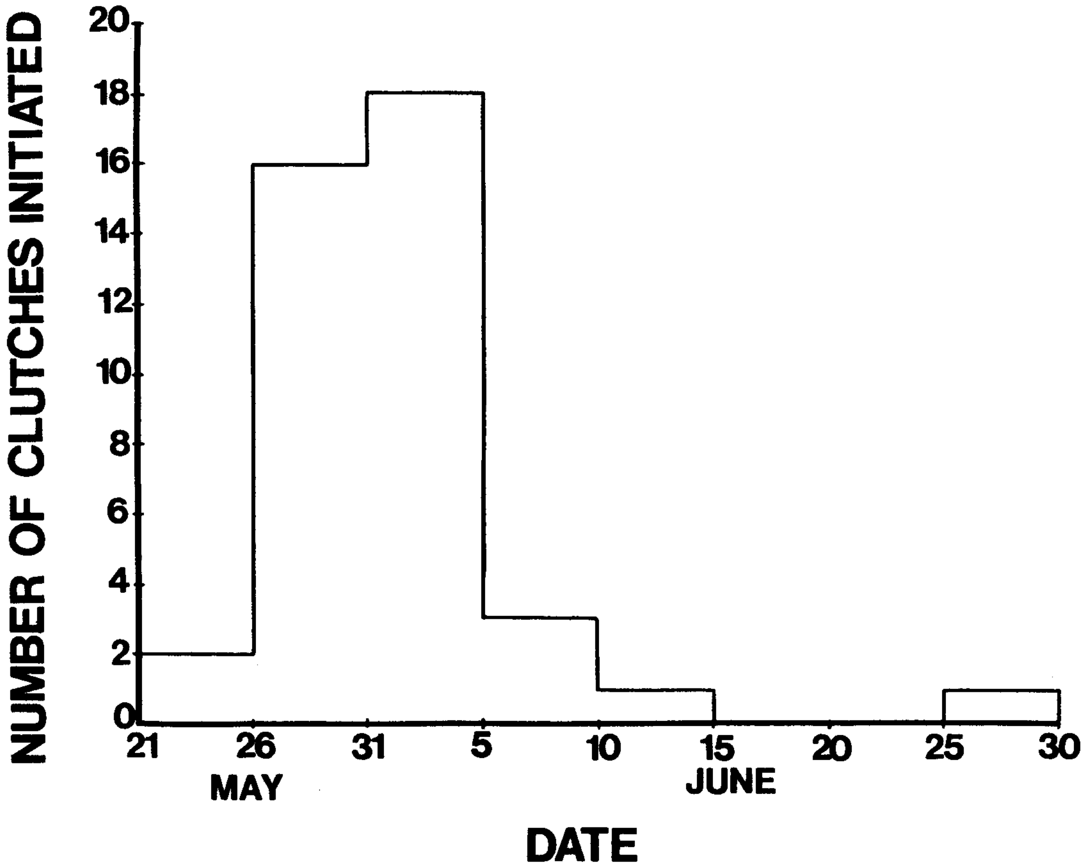


Figure VI-3. Laying chronology of Mew Gulls on south colony of Mary Island in Chiniak Bay, 1978.

TABLE VI-2
Nesting Chronology of Mew Gulls.

Colony	Year	N	Laying	Hatching	Fledging
Nelson Lagoon	1977	7	15 May>[a,b]	11 June>[a,b]	16 July>[b]
Mary Island[c] (Chiniak Bay)	1977	66	19 May - 13 June[a] (relay 14-18 June[a])	15 June - 9 July (peak 24 June) (mode 19-29 June)	5 August>[b]
Renests			14-18 June[a]	10 - 14 July	
	1978	40	24 May - 14 June (peak 31 May) (mode 27 May-3 June)	21 June - 30 June (peak 26 June) (mode 23-28 June)	27 July>[b]
Renests			7-26 June	5 July	
Anchorage	1979	27	9 May - 2 June (peak 17 May) (mode 11-25 May)	3 - 27 June (peak 18 June) (mode 7-23 June)	8 July - 1 August (peak 19 July) (mode 10-28 July)

[a] Calculated.
[b] End date (>) not determined.
[c] Note that 1977 data are from both north and south colonies but 1978 data are from only the south colony.

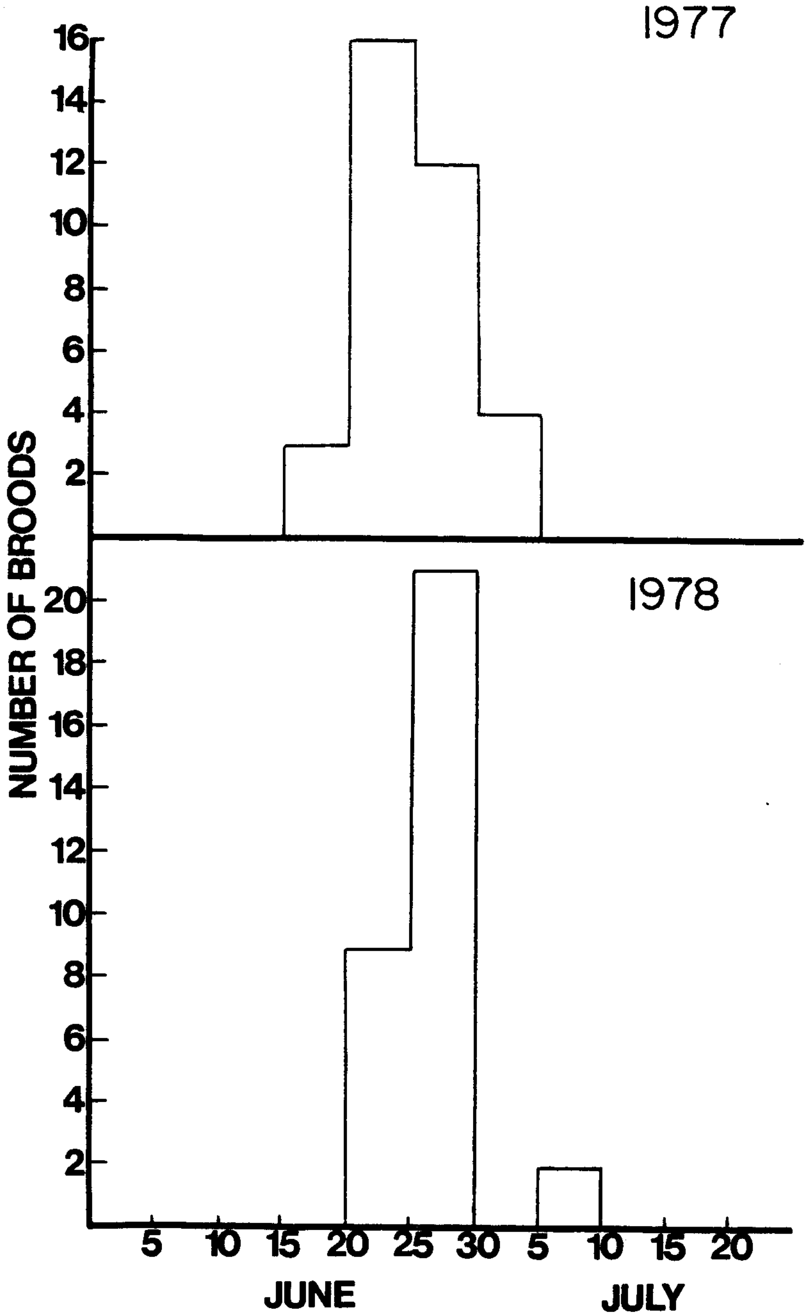


Figure VI-4. Hatching chronology of Mew Gulls on south colony of Mary Island, 1977-1978.

in 1978, broken egg shells were noted in the sample plots during egg laying. In Anchorage, the mean clutch size was 2.88 (n = 22, S.E. = 0.39). At Chiniak Bay, the number of chicks produced per nest built declined from 0.96 to 0.69 between 1977 and 1978 on the intensively studied south colony on Mary Island (Table VI-3). Since hatching success was identical the two years, the lower reproductive success in 1978 was caused primarily by an increase in the number of chick deaths.

Both years fledging success was low at Mary Island, but the mortality occurred in two different ways. In 1977 during the week before the first chicks fledged, the mean brood size was more than two chicks per nest attempt. During a subsequent 3-week period of severe storms many chicks died and productivity at the south colony was reduced to a maximum of 0.90 chicks fledged per nest attempt. In contrast, in 1978 mortality occurred throughout the entire nestling period with the final productivity being 0.70 chicks fledged per nest attempt at the south colony. At the north colony productivity appeared to be even lower than at the south colony because of predation by a river otter (Lutra canadensis), but quantitative estimates of fledging success were not obtained. In Anchorage, arctic ground squirrels (Citellus undulatus) preyed on both eggs and chicks, but fledging success was not deteremined.

In comparison with colonial nesters at Chiniak Bay, Mew Gulls nesting in low densities in the Soviet Union raised an average of 1.5 fledglings per pair (Bianki 1967). However, productivity of those nesting solitarily on the Yukon-Kuskokwim Delta, was at least 0.6 young per pair, and this was similar to that found at Chiniak Bay even though hatching success was much lower among the solitary nesters on the delta (58% vs. 87%)(Strang and Strang 1974). Bianki (1967) stated that Mew Gulls have been noted to have relatively high fledgling mortality at times and our studies have confirmed this. Apparently

TABLE VI-3
Reproductive Success of Mew Gulls.

	Chiniak Bay		Anchorage
	1977	1978	1979
Number of nests built	42	40	27
Number nests with eggs	39	40	25
Number of eggs laid	104	100	72
Number of eggs hatched	90	86	52
Number of chicks fledged	38[a]	28[a]	20[a]
Mean clutch size	2.67	2.51	2.88
Mean brood size at hatching	2.31	2.49	2.74
Nests with eggs per nest built (laying success)	0.93	1.00	0.93
Eggs hatched per eggs laid (hatching success)	0.87	0.86	0.72
Chicks fledged per eggs hatched (fledging success)	0.41[b]	0.32[b]	
Chicks fledged per nests with eggs	0.97[b]	0.70[b]	
Chicks fledged per nest built	0.90[b]	0.70[b]	

[a] Calculated from sample plot data using fledging success determined by above formula.

[b] Figures based on sample plot data from south colony. Fledging success was estimated by the following formula: $F = T/(ACH)$, where F = fledging success, T = total number of chicks on island perimeter near south colony just before fledging, A = number of nest attempts on entire south colony, C = mean clutch size on sample plot, and H = hatching success on sample plot.

Mew Gulls have several different reproductive strategies, ranging from being distinctly colonial to being solitary in their nesting habits, but productivity can be relatively low in either case, with a recorded range of 0.5 to 1.5 chicks fledged per nest attempt.

FOOD HABITS AND FORAGING

Fish and marine invertebrates seemed to be of greatest importance as food for Mew Gulls over the summer on the Yukon-Kuskokwim River Delta (Strang and Strang 1974). Saffron cod (Eleginus gracilis) was most often found in both stomach contents and pellet remains, although flounder (Pleuronectes) and nine-spined stickleback (Pungitius pungitius) were present too. Of the marine invertebrates, two species of small clams (unidentified) appeared to be the dominant food species, with isopods and shrimp next in importance. The diet of the coastal-dwelling Mew Gulls we studied included small surface-shoaling fishes like capelin (Mallotus villosus); Mew Gulls were not usually observed in the offshore mixed feeding flocks of seabirds as were most other gulls, although they were sometimes found in nearshore flocks. Mew Gulls foraged on beaches and mudflats for a wide variety of intertidal marine life. The gulls at the colony on Mary Island in Chiniak Bay ate capelin and similar schooling fishes and in 1978 they also ate small clams (Macoma balthica), rock louse (Idotea wosnesenskii), and three-spined sticklebacks (Gasterosteus aculeatus). The Mew Gulls around Anchorage ingested three-spined sticklebacks, grasshoppers, sparrows and garbage (C. A. Adamson, pers. comm.). Mew Gulls, like most gulls, were attracted in large numbers to garbage dumps, canneries, and salmon spawning streams.

In the Soviet Union, Bianki (1967) found Mew Gulls eating plants, berries, worms, crustaceans, insects, molluscs, starfish, fish, and amphibians. Although fish and invertebrates seem the most preferred food at all sites, Mew Gulls obviously can be quite opportunistic if necessary.

FACTORS AFFECTING REPRODUCTIVE SUCCESS

At Chiniak Bay the two factors responsible for most egg loss were gathering of eggs by Natives and damage or piracy of eggs by unidentified predators. The major reproductive loss, however, occurred during the chick stage in both 1977 and 1978. Both years low fledging success seemed linked with food supply, although predation by other gulls and a river otter did occur. Chicks were often found dead, untouched by predators, suggesting the young gulls may have starved.

The continuous, severe storms in 1977 may have directly caused death of chicks by exposure, but may also have driven the forage fish out of the shallow or surface waters where Mew Gulls fed. In 1978 more of the food found on the colony or regurgitated by chicks was from intertidal and estuarine sources than noted the previous year. This suggests that a decrease in availability of forage fish like capelin may have forced Mew Gulls to look for other food in 1978.

It is important to note that the Mew Gulls were not able to scavenge either enough food or the right type of food from canneries and dumps in Kodiak to prevent the numerous losses of chicks that occurred in both years. Adult Mew Gulls may be opportunistic in their selection of prey, but growing chicks may require food of a particular quality in order to survive. Although most seabirds nesting at Chiniak Bay had a lower reproductive success in 1978 than in 1977, no species was as severely affected by the storms in 1977 as the Mew Gulls. At Sitkalidak Strait in southeastern Kodiak Island, however, Arctic and Aleutian Terns were both severely affected by the storms (Baird and Moe 1978). Mew Gulls also seem to be highly susceptible to displacement from their nesting grounds by humans and by other species of birds. At Sitkalidak Strait, a colony of 300 Mew Gulls was virtually eliminated in 1976 by the egging activities of the Natives from a nearby village. Likewise, another large colony of Mew Gulls in the same area was displaced by Arctic and Aleutian Terns, perhaps with the aid of egging by the Natives in the early 1960's (Baird and Moe 1978).

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Black-legged Kittiwake (*Rissa tridactyla*)

by

David R. Nysewander

BLACK-LEGGED KITTIWAKE

(*Rissa tridactyla*)

The Black-legged Kittiwake is an abundant oceanic bird in both the northern Pacific and Atlantic Oceans. Until recently, only the Atlantic subspecies (*R. t. tridactyla*) had been studied in substantial detail, with most effort focusing on populations in the British Isles: Coulson and White (1956, 1958a, 1958b, 1959, 1960, 1961), Coulson (1963, 1966, 1968), and Coulson and Wooller (1976, 1977). Information from the western Atlantic is based on one intensive study of breeding biology in Newfoundland by Maunder and Threlfall (1972). Prior to the OCSEAP research in Alaska (1975-78) the only intensive work on breeding biology of the northern Pacific subspecies (*R. t. pollicaris*) was that of Swartz (1966) at Cape Thompson in the Chukchi Sea region of Alaska.

This account primarily summarizes information gathered at 10 sites in the Gulf of Alaska from 1975-1978 as listed below:

Shumagin Islands	1976	Moe and Day (1979)
Semidi Islands	1976	Leschner and Burrell (1977)
	1977	Hatch (1978)
	1978	Hatch and Hatch (1979)
Ugaiushak Island	1976	Wehle et al. (1977)
	1977	Wehle (1978)
Sitkalidak Strait	1977	Baird and Moe (1978)
(Kodiak Island)	1978	Baird and Hatch (1979)
Chiniak Bay	1977	Nysewander and Hoberg (1978)
(Kodiak Island)	1978	Nysewander and Barbour (1979)
Barren Islands	1977	Manuwal and Boersma (1978a)
	1978	Manuwal and Boersma (1978b)
Chisik Island	1978	Jones and Petersen (1979)
Wooded Islands	1976-77	Mickelson et al. (1977, 1978)

Hinchinbrook Island	1976	Nysewander and Knudtson (1977)
	1977	Sangster et al. (1978)
	1978	Kane and Boyd (1979)
Middleton Island	1978	Hatch et al. (1979)

BREEDING DISTRIBUTION AND ABUNDANCE

Black-legged Kittiwakes in Alaska nest from Glacier Bay in the southeast panhandle, north to Cape Lisburne in the Chukchi Sea and west through the Aleutian Islands to Buldir Island (Figure VII-1). Most breed along the southern coast of Alaska from Prince William Sound to the tip of the Alaska Peninsula and also along the coast of the southern Bering Sea. The total breeding population of kittiwakes in Alaska is at present estimated at 2.5 million birds with 54% in the Gulf of Alaska. There are 263 recognized colonies at this time in all of Alaska and of these, 63% are in the Gulf of Alaska (Sowls et al. 1978). These colonies range in size from a few pairs to more than 100,000 birds such as those found on Middleton and the Semidi Islands. The number of breeding birds found at the 10 sites studied by Fish and Wildlife personnel are displayed in Table VII-1.

Colonies of kittiwakes are essentially permanent although small colonies in suboptimal habitat may be temporary. The occupation of these established permanent colonies, however, may vary considerably from year to year especially with respect to the use of peripheral areas, the numbers of birds involved and the percent of the population which actually breeds. The number of active nests in kittiwake colonies varies from year to year. Kittiwake nesting sites, unlike those of cormorants, are rarely if ever, completely abandoned during the breeding season and even if there is not a nest, a pair may occupy a nesting site during the entire season.

There were intensive censuses at 6 colony sites or groups of colonies over several years and these clearly show the variations in numbers of

Black-legged Kittiwake (*Rissa tridactyla*)

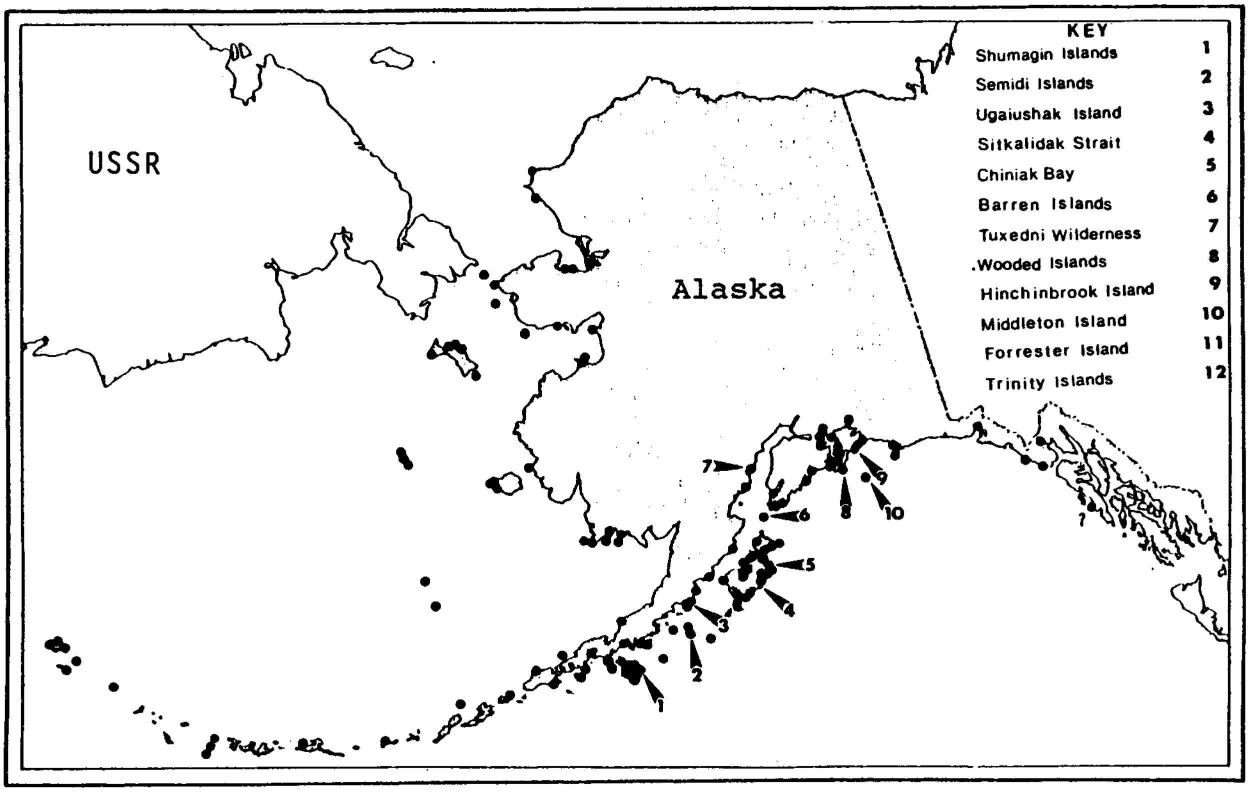


Figure VII-1. Distribution of breeding colonies of Black-legged Kittiwakes in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

TABLE VII-1
Estimated Numbers of Black-legged Kittiwakes Nesting at 10 Study Sites in the Gulf of Alaska.

Colony site	Year	Numbers of birds
Shumagin Island Group		
Big Koniuji	1976	27,700
Semidi Island Group		
Chowiet	1976	15,600
Ugaiushak Island	1976	9,000
Sitkalidak Strait		
(Kodiak Island)	1977	4,800
	1978	5,000
Chiniak Bay		
(Kodiak Island)	1975	3,100
	1977	3,000
	1978	3,100
Barren Islands	1975	12,000
	1977	19,300
	1978	11,400
Chisik Island		
(Tuxedni Refuge)	1978	30,000
Wooded Islands	1972	1,600
	1975	3,400
	1976	2,400
	1977	2,500
Porpoise Rocks		
(Hinchinbrook Island)	1972	2,000
	1976	2,000
	1977	2,700
	1978	2,100
Middleton Island	1956	10-14,000
	1974	145,000
	1976	84,900
	1978	144,500

active nests (Table VII-2). Fluctuations did occur but the total number of kittiwakes nesting in any one area usually did not vary much from year to year, with the exception of the colonies at Middleton Island and at Boulder Bay on Kodiak Island.

On Middleton Island the low number recorded in 1976 was an artifact caused by a late census period and a different definition of active nests. However, there was a dramatic and clear increase in number of nests between 1956 (5-7,000) and 1974 (72,471). There were areas occupied in 1974 (M. E. Isleib, pers. comm.) and 1978 (Hatch et al. 1979) that did not have kittiwakes in 1956. New habitat was created by a major earthquake, but this does not sufficiently explain the increase. The amount of new nesting habitat created by the earthquake cannot account for the magnitude of the total population increase but it may be responsible for a small part of it. Also, new foraging habitat may have been created (larger shelf area) and this may have increased the "carrying capacity" of the area or contributed to higher productivity by increasing the availability of food. Habitat which was available but unoccupied in 1956 has since been colonized, and nests are more densely clumped on the cliffs now than they were in 1956 (Hatch et al. 1979). The increase in numbers at Middleton Island may be due to the abandonment of the fox farms there in the early part of the twentieth century, yet it is unclear if this is the critical factor affecting the increase in numbers because the population was still relatively low in 1956. It is also unclear to what degree the increase on Middleton Island was caused by intrinsic growth or by immigration of birds reared at other colonies. Coulson (in Cramp et al. 1974) documented a similar increase in the British Isles, which he thought was related to decreased predation by men in the twentieth century.

TABLE VII-2
Variations in Numbers of Black-legged Kittiwakes
Nesting at Study Sites in the Gulf of Alaska.

Colony site	Numbers of breeding kittiwakes					
	1956[a]	1972	1974-75[b]	1976	1977	1978
Sitkalidak Strait/ Kiliuda Bay						
Sitkalidak St.					4,766	5,032
Boulder Bay					40,000	7,000
Duck Island					828	1,400
Nest Island					380	360
Ladder Island					200	250
TOTAL					46,174	14,042
Inner Chiniak Bay						
Viesoki Island			2,612		2,192	1,992
Gibson Cove			228		398	508
Holiday Island			10		10	66
Kulichkof Island			208		336	518
Zaimka Island			40		0	0
TOTAL			3,098		3,036	3,084
East Amatuli, Barren Islands[c]			12,000		19,300	11,400
Wooded Islands		1,560	3,360	2,350	2,522	
Hinchinbrook Island						
Porpoise Rocks		1,950		1,984	2,682	2,092
Boswell Rocks		9,872		8,076	7,840	
TOTAL		11,822		10,060	10,522	2,092
Middleton Island[c]	10-14,000		144,942	84,916		144,494

[a] See R. Rausch (pers. comm.) in Hatch et al. (1979).

[b] Data collected by M. E. Isleib, M. Dick, or E. Bailey; available from Catalog of Alaskan Seabird Colonies-Archives maintained by Wildlife Operations, U.S. Fish & Wildlife Service, Anchorage, AK.

[c] Variations found on Barren (1974-77 and 1977-78) and Middleton Islands (1974-76 and 1976-78) are due to differences in census techniques and definitions of nests.

The Boulder Bay colony on Kodiak Island, which was censused briefly during 1977 and 1978, dropped from 40,000 birds attending the colony in 1977 to 7,000 in 1978 (Baird and Hatch 1979). This decrease coincided with a breeding failure. Hatch and Hatch (1979) found a decrease from 426 nests in 1977 to 288 nests in 1978 on one sample plot at the Semidi Islands, although the same number of birds occupied the entire colony site during the egg stage in both years. All of these examples point out that continuing studies will be required in order to fully understand long-term fluctuations in colony numbers.

NESTING HABITAT

Black-legged Kittiwakes usually nest on ledges and in crevices on precipitous rock cliffs with most colonies found either on offshore islands and rocks or on mainland cliffs. However, there is a large population of kittiwakes that nests on comparatively gradual and soil-covered slopes at Middleton Island. Here also, kittiwakes have colonized unlikely sites such as boulders protruding above extensive wet meadows near sea level and the decks and rigging of an aging shipwreck. In Britain, where their population is expanding, kittiwakes nest successfully on window ledges (Coulson and Macdonald 1962).

Habitat selection was examined in detail at Sitkalidak Strait in 1977 and 1978 (Table VII-3). Nest sites were generally 5-7 m above the water while the mean distance to the tops of the cliffs was nearly 2 m. Slopes averaged 70-80° at the nest sites. Nest width averaged 22-23 cm and the ledges used for nest sites were usually about the size of the nest or smaller. In five plots, the mean distance to the nearest nest ranged from 52 to 69 cm. No one component appeared to guarantee reproductive success.

Other birds that may compete with kittiwakes for nest sites include

TABLE VII-3

Parameters of the Nesting Habitat of Black-legged Kittiwakes at Cathedral Island, Sitkalidak Strait, 1977-1978.

Habitat parameters	1977(n=136) Mean	1977(n=136) S.E.	1978(n=93) Mean	1978(n=93) S.E.
Nearest neighbor distance (cm)	57.0	2.90	51.4	4.56
Nest width (cm)	23.7	0.48	22.0	0.69
Slope (degrees)	70.1	0.69	80.6	1.17
Height above water (m)	5.43	0.15	6.93	0.39
Distance from cliff top (m)	--	--	1.94	0.15

cormorants and murres, which often nest in habitat similar to that chosen by Black-legged Kittiwakes. Dick (1975) has recorded evidence of competition between kittiwakes and Pelagic Cormorants at colonies in the Bering Sea and Aleutian Islands. In Britain, murres may compete with kittiwakes (Coulson 1963) but at colonies studied in the Gulf of Alaska, no murre-kittiwake interactions at the nest site have been recorded.

BREEDING CHRONOLOGY

Small numbers of kittiwakes winter in Chiniak Bay (Dick 1979). The first sightings of adult kittiwakes on colony sites in the Bay were from 15 March through 6 April (Dick 1979, Richard MacIntosh pers. comm.). This indicates kittiwakes occupied the colonies 65 to 80 days preceding egg laying in 1977-1978. The first kittiwakes arrived at Chisik Island in Tuxedni Bay on 13 March 1978, about 89 days prior to egg laying. Adult kittiwakes returned to Middleton Island the first week of March in 1978, but did not occupy their nest sites until late March to early April (FAA, pers. comm., in Hatch et al. 1979). By 3 April, about 20 days prior to egg laying, the colony sites there appeared to be fully occupied. Unfortunately, information on the first occupation of colonies is not available from other studies in the Gulf of Alaska, but should be included as part of future studies.

Kittiwakes nesting at Middleton Island in 1978 had the earliest breeding noted in the Gulf of Alaska. Laying of first clutches at other colonies commenced between 28 May and 20 June while that at Middleton Island began on 23 April (Table VII-4 and Fig. VII-2). More recent studies found that such early laying does not always occur at Middleton (Baird and Shields 1981, Gould and Zabloudil 1981). Throughout the Gulf of Alaska replacement clutches were occasionally reported and these were

TABLE VII-4
Breeding Chronology of Black-legged Kittiwakes in the Gulf of Alaska, 1976-1978.

Sites/Year	Egg Laying	Hatching	Fledging
Shumagin Group			
1976	16 June-8 July	14 July-5 August	16 August-17 September
Semidi Island			
1976	14 June-8 July	7 July-4 August	20 August>[a]
1977	10 June-29 June	6 July-24 July	15 August-3 September
1978	6 June-27 June	3 July-26 July	12 August-4 September
Ugaiushak Is.			
1976	20 June-20 July	—	—
1977	11 June-28 June	14 July-25 July	22 August-31 August>
Sitkalidak Strait			
1977	12 June-1 July	8 July-9 August	13 August-10 September
1978	12 June-3 August	14 July-11 August	18 August-7 September>
Chiniak Bay			
1977	—	2 July-26 July	12 August-20 August>
1978	4 June-30 June	4 July-3 August	8 August>
Barren Island			
1977	—	2 July-8 July>	21 August>
1978	10 June-5 July	10 July-31 July	15 August-30 August>
Tuxedni Bay (Chisik Island)			
1978	10 June-30 June	6 July-25 July	23 August>
Wooded Island			
1976	6 June>	3 July>	4 August>
1977	4 June-23 June	—	<17 August>
Hinchinbrook Island (Porpoise Rocks)			
1976	2 June-25 June	30 June>	—
1977	28 May-15 June	26 June-12 July	1 August-20 August
1978	28 May-20 June>	25 June>	11 August>
Middleton Island			
1978	23 April-24 June	21 May-21 July	2 July-20 August

[a] Beginning (<) or ending (>) date not determined.

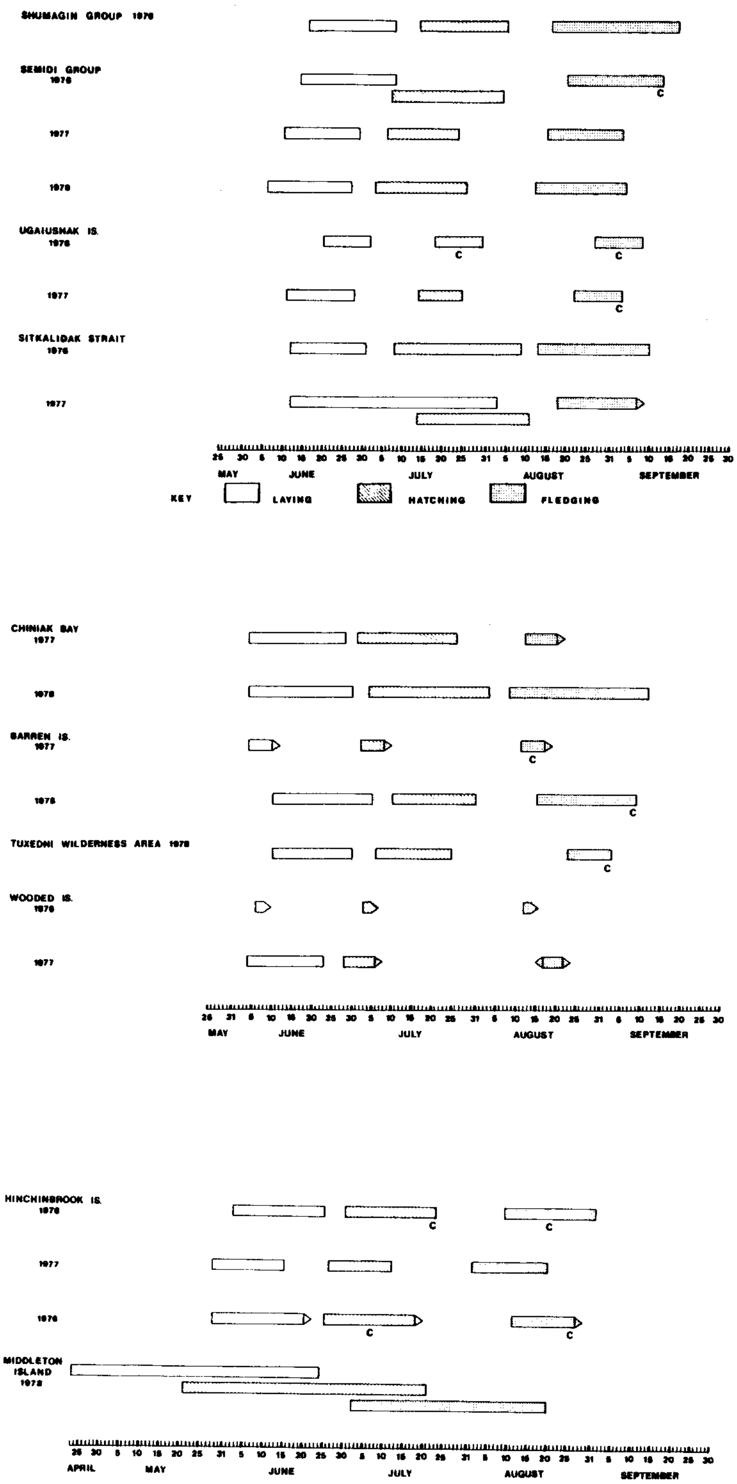


Figure VII-2. Chronology of major events in the nesting season of Black-legged Kittiwakes in the Gulf of Alaska.

initiated as late as 3 August at Sitkalidak Strait (Baird and Hatch 1979).

Year-to-year variation in the onset of laying at individual colonies ranged from 0 to 9 days and averaged 3 days between successive years. Variations in the timing of laying of first clutches have been shown to correlate with breeding success in waterfowl (Raveling and Lumsden 1977). Although the data base for the Gulf of Alaska is small, several points along these lines are worth mentioning. At four sites studied in both 1976 and 1977, clutch initiation was 2-9 days earlier and breeding success (chicks fledged per nest built) was 48-71% higher in 1977. At three sites studied in both 1977 and 1978, however, egg laying dates were identical but breeding success dropped in 1978 by 46-57%. Data in this report are not sufficient to establish a correlation between time of laying and breeding success in kittiwakes, but do indicate the need for and value of long-range studies at individual sites.

At Chisik Island in 1979 the incubation period of kittiwakes averaged 27.4 days (N=37, SE=0.23), which agrees with what other researchers have found (Coulson and White 1958b, Swartz 1966). Hatching at most sites studied in the Gulf of Alaska occurred between 25 June and 11 August (Table VII-4). Swartz (1966) found an average of 44 days for the nestling period of kittiwake chicks at Cape Thompson while Coulson and White (1958b) found it to be 43 days in Great Britain. At the Semidi Islands in 1977 the nestling period of 35 chicks averaged 40.4 days but ranged from 32 to 50 days; at Chisik Island in 1979 the nestling period averaged 43.5 days (N=26, SE=1.1). Most investigators left their study areas before all chicks had fledged, but in general all chicks were due to fledge by mid-September. Most adult birds had also left the breeding islands by this time.

Chronology at Middleton Island in 1978 was quite distinctive and deserves further comment. It provides the earliest known breeding record for kittiwakes in Alaska (23 April), which precedes, by several weeks to more than a month, the onset of egg laying at all other colonies studied in Alaska. Hatch et al. (1979) found that even among three study plots on Middleton Island in 1978 initiation of egg laying differed by as much as 16 days, but laying was completed on the same day on all three study plots (Fig. VII-3).

REPRODUCTIVE SUCCESS

Average overall reproductive success at the ten study sites in the Gulf of Alaska ranged from 0.01 to 1.23 chicks fledged per nest attempt (Table VII-5). The highest reproductive success at any one colony occurred on plots where kittiwakes laid the earliest. At any one site where two or more years were compared, the highest overall reproductive success occurred during 1977 (range: 0.62-1.23) with much lower success recorded in both 1976 (range: 0.03-0.60) and 1978 (range: 0.01-0.77). This type of high-low pattern contrasts with that found in the Bering Sea at the Pribilof Islands (Hunt 1978). In the Pribilofs, the overall reproductive success from 1975 through 1977 was consistent each year (0.42-0.66 chicks fledged per nest attempt).

Clutch size in Black-legged Kittiwakes normally ranges from one to three. In years of high productivity, there are more clutches of two and three while in years of low productivity there are more clutches of one. Mean clutch sizes at different sites ranged from 1.26 to 1.98 (Table VII-5). At five of the six sites where two or more years could be compared, the mean clutch size was higher in 1977 (average of 1.81 for 6 sites) than in either 1976 (average of 1.66 for 3 sites) or 1978 (average of 1.57 for 5

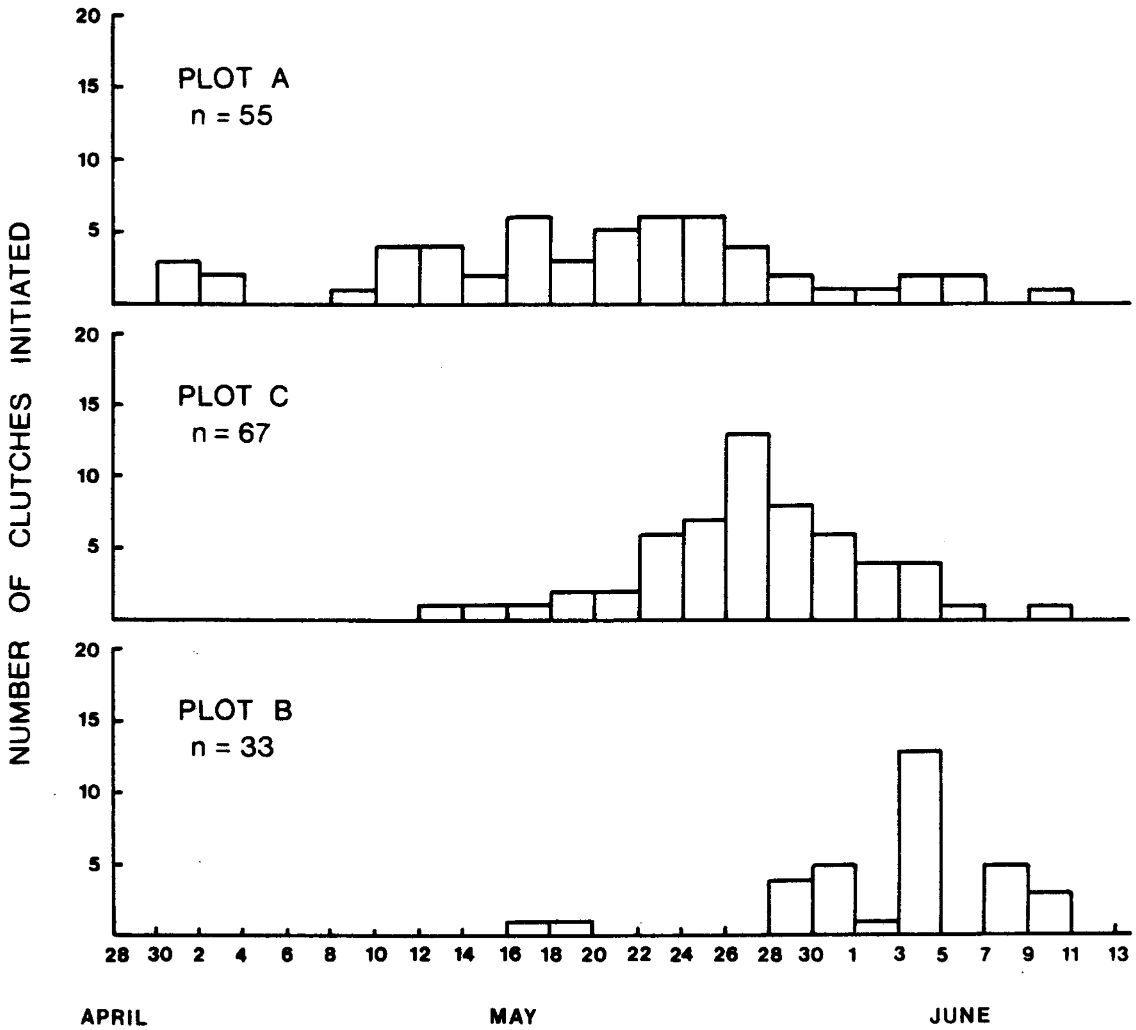


Figure VII-3. Number of clutches initiated by Black-legged Kittiwakes at Middleton Island in 1978.

TABLE VII-5
Productivity of Black-legged Kittiwakes in the Gulf of Alaska, 1976-1978.[a]

	Big Koniuji Island	Semidi Islands			Ugaiushak Island		Sitkalidak Strait		Chiniak Bay	
	1976	1976	1977	1978	1976	1977	1977	1978	1977	1978
No. of nests built	182	65	61	66	60	57	136	121	210	259
No. of nests w/eggs	156	27	54	46	45	52	114	65	177	171
No. of eggs laid	267	49	88	78	62	97	191	78	338	294
No. of eggs hatched	--	--	64	--	14	71	132	28	287	207
No. of chicks fledged	110	9	38	--	4	44	101	20	258	157
$\bar{X}$ clutch size	1.71	1.81	1.63	1.70	1.38	1.89	1.68	1.26	1.91	1.72
$\bar{X}$ brood size @ hatching	--	--	1.19	--	1.40	1.51	1.54	1.25	1.67	1.50
$\bar{X}$ brood size @ fledgling	1.47	--	0.97	--	2.00	1.38	1.34	1.15	1.60	1.45
Nests w/eggs per nests built (laying success)	0.86	0.42	0.89	0.70	0.75	0.91	0.84	0.54	0.84	0.66
Eggs hatched per eggs laid (hatching success)	--	--	0.73	--	0.23	0.73	0.69	0.36	0.84	0.72
Chicks fledged per eggs hatched (fledging success)	--	--	0.60	--	0.29	0.62	0.77	0.53	0.90	0.93
Chicks fledged per nest w/eggs	0.71	0.33	0.70	--	0.08	0.85	0.89	0.31	1.46	1.16
Chicks fledged per nest built (reproductive success)	0.60	0.14	0.62	--	0.06	0.77	0.74	0.17	1.23	0.77

a Based on sample plots.

TABLE VII-5
Continued.

	Barren Islands 1977	Barren Islands 1978	Chisik Island 1978	Wooded Island 1976	Wooded Island 1977	Porpoise Rocks 1976	Porpoise Rocks 1977	Porpoise Rocks 1978	Middleton Island 1978
No. of nests built	—	52	183	417	435	—	--	--	180
No. of nests w/eggs	49	46	137	345	312	210	114	126	145
No. of eggs laid	86	65	214	—	505	376	225	223	281
No. of eggs hatched	71	18	30	--	—	--	83	10	175
No. of chicks fledged	4	7	2	136	275	6	58	5	25
$\bar{X}$ clutch size	1.76	1.41	1.56	—	1.62	1.79	1.98	1.77	1.94
$\bar{X}$ brood size @ hatching	--	—	1.15	—	--	—	--	--	1.72
$\bar{X}$ brood size @ fledgling	—	--	1.0	1.41	1.46	—	—	—	1.00
Nest w/eggs per nests built (laying success)	--	0.88	0.75	0.83	0.72	—	—	--	0.81
Eggs hatched per eggs laid (hatching success)	0.83	0.28	0.14	—	--	--	0.37	0.05	0.63
Chicks fledged per eggs hatched (fledging success)	0.62	0.39	0.13	--	--	--	0.70	0.50	0.14
Chicks fledged per nest w/eggs	0.90	0.15	0.01	0.39	0.88	0.03	0.51	0.04	0.17
Chicks fledged per nest built (reproductive success)	--	0.13	0.01	0.33	0.63	0.03	0.51	0.04	0.15

sites). Even the lowest of these overall means recorded in the Gulf of Alaska was higher than any recorded in the Pribilof Islands between 1975 and 1977 (1.36-1.46). Studies by Belopol'skii (1957) indicated that the number of eggs per clutch was positively correlated with the availability of food. He believed that this was due to intraspecific competition for food. If the colonies in the Gulf of Alaska do have relatively more food available than those in the Bering Sea, this would also help explain why kittiwakes at the Pribilof Islands rarely raised more than one chick per nest attempt, while those in the Gulf of Alaska often raised two and sometimes three chicks.

The kittiwakes at colonies in the Gulf of Alaska had some of the highest reproductive success recorded for this species in Alaska but they also occasionally had complete breeding failures. Most loss occurred at the egg stage. In these poor years, kittiwakes often laid only one egg per clutch, which thus lowered the potential total production of chicks. Much of the loss was due proximately to predation but ultimately to lack of attentiveness by the adults. This lack of attentiveness probably resulted from a lack of food which required adults to forage more. At Sitkalidak Strait and Chiniak Bay on Kodiak Island the large colonies (900+ nests) had low reproductive success but the smaller colonies (<900 nests) seemed to be more successful during the poor year of 1978. If a lack of food was the sole factor behind these failures, then the smaller colonies that were close to the larger ones should also have failed completely. The fact that some of these smaller colonies still produced fledglings suggests that some other variable was in operation or that some individual birds (older, healthier, not so dependent on social mechanisms) were better able to exploit a poor food supply. Food shortages may force kittiwakes to spend more time away from nests for foraging thus increasing the vulnerability of the eggs or chicks to predators. Larger colonies could possibly be more attractive to predators than the small colonies, resulting in increased loss of eggs and chicks.

A comparison of kittiwakes nesting in the center and on the periphery of the colony at Chiniak Bay in 1978 revealed that the nests in the center had a slightly larger clutch size on the average and higher hatching success, and as a result more young fledged per pair (Table VII-6). This agrees with what Coulson (1968) found in Great Britain.

GROWTH OF CHICKS

Data on growth in body weight of chicks were gathered at Sitkalidak Strait in 1977 and at Chisik Island, Middleton Island, Chiniak Bay, and Sitkalidak Strait in 1978 (Table VII-7). Weight at hatching averaged 35.6 g and ranged from 30-44 g (n=26, SE=0.71). After 28-34 days kittiwake chicks reached peak weights which averaged 370-448 g at the 5 study areas; they then lost weight until fledging, which occurred between 34 and 48 days of age. In Newfoundland (Maunder and Threlfall 1972) and Great Britain (Coulson and White 1958b), chick weights decreased prior to fledging to levels that were 77% and 94%, respectively, of the peak weights. This meant that fledging weights ranged from 300-350 g in the North Atlantic while fledging weights in the North Pacific ranged from 300-470 g and averaged 350-440 g at the 5 study areas (Table VII-7). For all 5 studies, the growth of kittiwake chicks followed the typical sigmoid pattern and the polynomial regression best describing the growth was a third order polynomial with an r^2 value of 0.94 or higher (Figs. VII-4 and VII-5, Table VII-8).

We compared growth of chicks at the different sites in two ways: first

TABLE VII-6
Comparison of the Reproductive Success of Black-legged Kittiwakes Breeding on the Edge and in the Center of a Colony.[a]

	Colony center	Colony periphery	Significance
Nests with eggs	110	61	
Mean clutch size	1.77	1.62	$P < 0.10$[b]
Standard error	0.05	0.06	
Chicks hatched/eggs laid	0.77	0.64	$P < 0.05$[c]
Chicks fledged/chicks hatched	0.95	0.91	$P < 0.10$[d]
Chicks fledged/nest with eggs	1.29	0.93	$P < 0.05$[e]

[a] Kulichkof Island, Kodiak, 1978.

[b] Students $t = 1.87$, df = 169

[c] $x^2 = 5.80$, df = 1

[d] $x^2 = 1.82$, df = 1

[e] $x^2 = 4.29$, df = 1

Table VII-7
Growth of Black-legged Kittiwake Chicks in the Gulf of Alaska, 1977-1978

Age (days)	Weight (in grams) Middleton Island 1978				Chisik Island 1978				Chiniak Bay 1978				Sitkalidak Strait 1978				Sitkalidak Strait 1977			
	n	$\overline{X}$	S.E.	Range	n	$\overline{X}$	S.E.	Range	n	$\overline{X}$	S.E.	Range	n	$\overline{X}$	S.E.	Range	n	$\overline{X}$	S.E.	Range
0	14	34	0.53	30-37					5	36	1.21	33-39	3	35	2.85	29-38	4	42	0.85	40-44
1-3	25	47	1.37	38-61	8	37	2.67	31-52	27	54	1.76	40-75	13	51	2.47	43-65	32	51	1.92	36-75
4-6	25	74	2.83	50-98	9	52	4.11	34-72	18	90	3.84	65-119	12	96	7.34	54-142	22	94	4.56	51-140
7-9	25	117	4.35	77-166	4	79	12.45	46-103	28	140	3.46	98-175	9	150	9.62	104-205	27	129	4.59	72-165
10-12	27	178	5.20	136-234	6	118	9.37	89-149	23	202	5.68	138-253	11	218	10.42	160-281	32	190	4.91	129-238
13-15	27	235	5.38	176-285	5	132	15.67	93-174	24	248	4.94	197-282	6	282	7.64	260-306	27	248	10.42	142-440
16-18	36	270	5.60	165-320	7	187	13.72	121-226	27	292	5.34	250-360	8	321	16.55	258-390	17	304	5.09	263-342
19-21	33	299	6.67	240-410	1	271			23	338	5.03	291-386	7	359	17.39	304-427	25	338	7.21	259-408
22-24	36	330	5.64	270-395	0				26	357	6.56	263-421	8	413	12.72	366-460	22	366	8.62	277-412
25-27	25	372	6.11	320-425	4	315	8.42	305-340	22	375	5.44	362-413	3	409	43.98	330-482	23	388	6.21	322-440
28-30	25	380	8.93	275-430	1	325			17	389	7.38	350-465	6	448	17.98	380-501	27	385	5.94	308-438
31-33	28	400	5.69	315-440	3	370	30.00	310-400	11	365	9.82	299-425	5	439	11.10	410-470	16	400	7.67	350-458
34-36	14	411	6.65	365-455	1	380											15	387	8.78	321-448
37-39	11	401	8.50	355-435													8	390	9.37	332-415
40-42	6	390	11.18	350-420													2	358	4.50	353-362

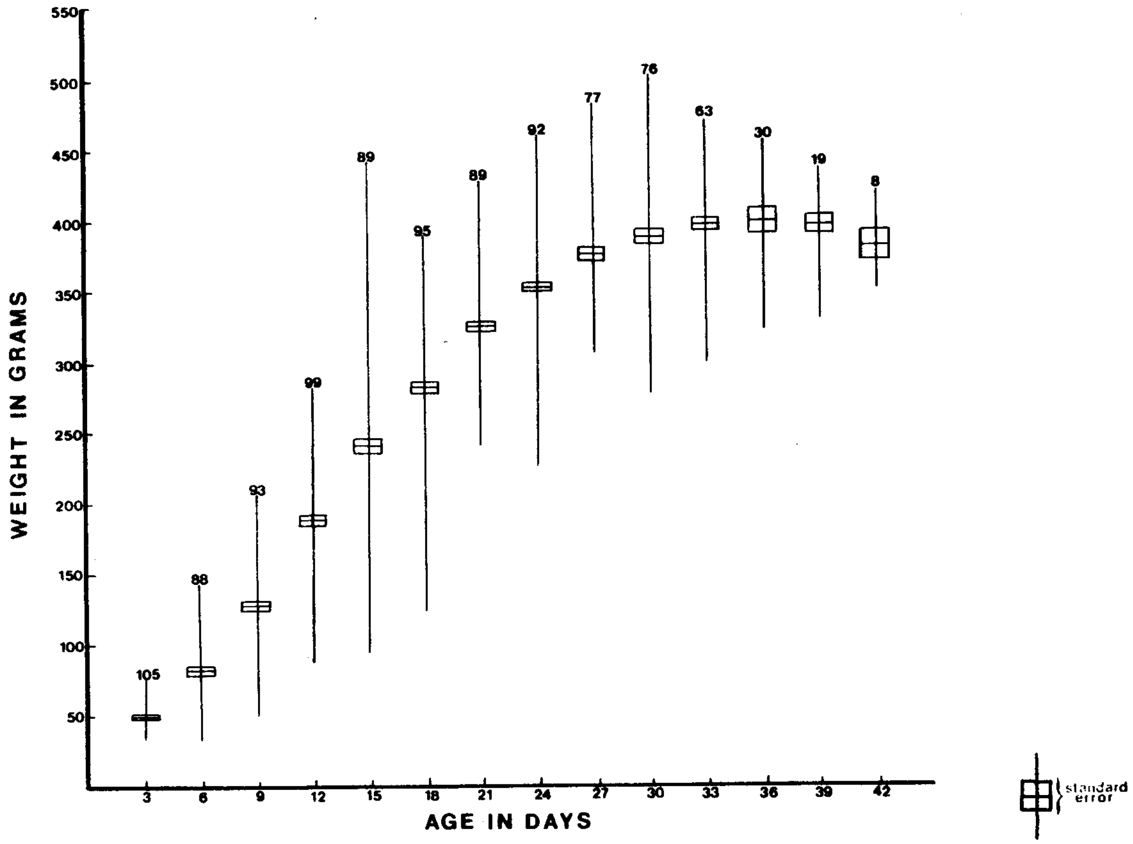


Figure VII-4. Weight gain in Black-legged Kittiwake chicks in the Gulf of Alaska, 1978.

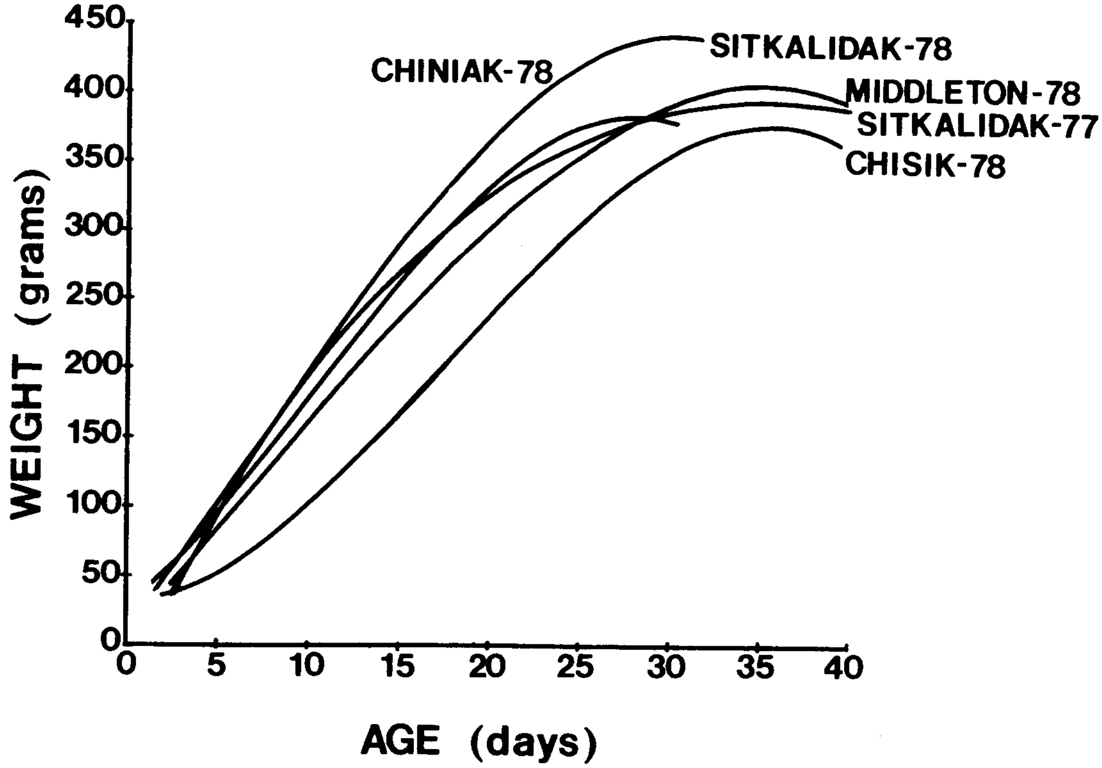


Figure VII-5. Comparison of regression curves of kittiwake chick growth at four sites in the northern Gulf of Alaska, 1977-1978.

TABLE VII-8

Polynomial Regression Equations Describing Growth of Kittiwake Chicks in the Gulf of Alaska, 1977-1978.

Area & Year	Equation[a]	r^2 value
Chisik Island 1978	$Y = -0.02X^3 + 0.76X^2 + 0.93X + 32.09$	0.95
Middleton Island 1978	$Y = -0.01X^3 + 0.12X^2 + 14.79X + 7.51$	0.96
Chiniak Bay 1978	$Y = -0.02X^3 + 0.54X^2 + 11.83X + 23.99$	0.96
Sitkalidak Strait 1978	$Y = -0.02X^3 + 0.73X^2 + 10.76X + 30.13$	0.95
Sitkalidak Strait 1977	$Y = -0.01X^3 + 0.28X^2 + 14.05X + 26.19$	0.94

[a] Y = weight in grams, X = age in days.

we examined the slopes of the straight line portions of the growth curves, which encompassed measurements of chicks aged 4-20 days (Fig. VII-6). We then compared the mean asymptotic or peak weight of chicks at each site. During the period of most rapid growth (4-20 days), the growth rate of chicks (i.e., the slope of the linear regression) was significantly lower at Chisik Island and Middleton Island than at Chiniak Bay or Sitkalidak Strait ($p<0.001$), and lower at Chisik Island than at Middleton Island ($p<0.001$, Table VII-9). The average growth rate during this period varied from 12.0-18.8 g per day. Data from Hinchinbrook Island in 1977 (Sangster et al. 1978) also fell within this range (average weight gain during same period: 17.0 g per day). Corresponding figures from studies of Atlantic Black-legged Kittiwakes are 15.6 g per day (Coulson and White 1958b) and 16.0 g per day (Maunder and Threlfall 1972) and also fall within this range. There were significant differences in the average peak weight reached at different colonies in the North Pacific (Table VII-10), with that at Sitkalidak Strait in 1978 being significantly higher than that reached by chicks in other studies ($p<0.05$). Peak weights of chicks were reached at an earlier age (28-30 days) at Sitkalidak Strait and Chiniak Bay in 1978 than at other areas. At Chisik and Middleton Islands, where growth rates were lower than at the other areas, the survival of chicks after hatching was also much lower (0.13-0.14 vs. 0.53-0.93 fledging success, Table VII-5). This suggests that growth of chicks during this period may be closely linked with their ability to survive to fledging.

Growth of both wings and tarsi showed much less variation than did the increase in weight of chicks. At two study sites, Chiniak Bay and Chisik Island, wing growth was measured using flattened wing length while at two other study sites, Middleton Island and Sitkalidak Strait, wing growth

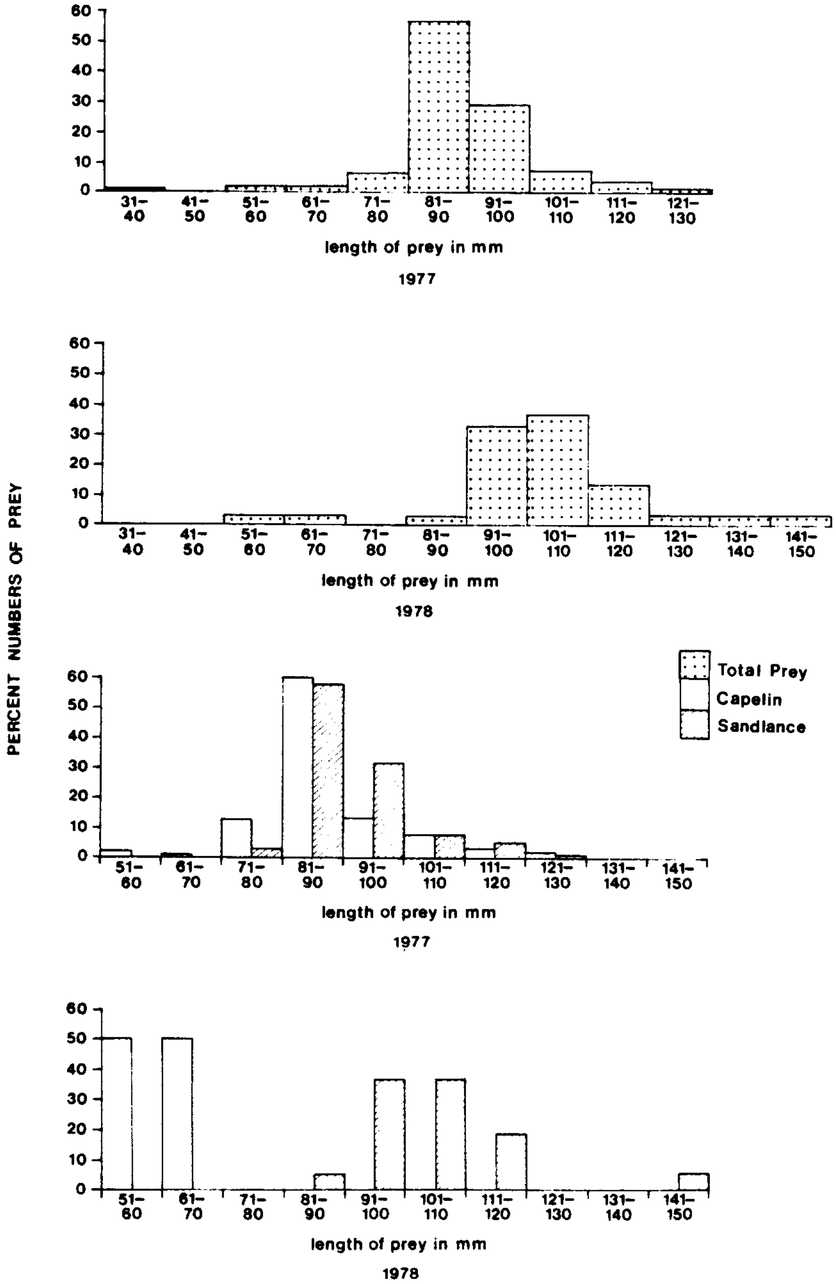


Figure VII-6. Distribution of lengths of prey delivered to Black-legged Kittiwake chicks in Sitkalidak Strait, 1977-1978.

TABLE VII-9
Average Daily Weight Gain of Black-legged Kittiwake Chicks Aged 4-20 Days.

Study Site	Average Daily Weight gain (g)	Number of Measurements
1977		
Sitkalidak Strait	17.0	139
Porpoise Rocks[a]	17.0	-
1978		
Chisik Island	12.0[b]	32
Middleton Island	15.7[b]	161
Chiniak Bay	17.0	136
Sitkalidak Strait	18.8	52

[a] From data in Sangster et al. (1978).

[b] Significantly lower than growth rates at other sites ($P < 0.001$). (Test for equality of slopes, Sokal and Rohlf 1969:450 ff.

TABLE VII-10
Comparison of Asymptote or Peak Weight of Kittiwake Chicks at Four Sites in the Gulf of Alaska, 1977-1978.

Study Site	Average Peak Weight (g)	3-Day Interval of Peak Weight	Sample Size	S.E.
1977				
Sitkalidak Strait	399.7	31-33	16	7.67
1978				
Sitkalidak Strait	448.0[a]	28-30	6	17.98
Chiniak Bay	389.1	28-30	17	7.38
Chisik Island	370.0	31-33	3	30.00
Middleton Island	410.7	34-36	14	6.65

[a] Significantly higher than peak weights in other studies ($P < 0.05$).

was recorded using wing chord (Table VII-11). The growth of wing and tarsus each had curvilinear patterns. Tarsus length increased rapidly from hatching until the age of 15 days, with a daily average growth rate of over 1 mm (Table VII-12). At 15 days, the tarsus was approximately 98% of the adult length. Wing growth, however, was slow the first 5 days after hatching, but then proceeded rapidly. Using a combination of wing and tarsus measurements would be the most precise method of aging chicks when hatching dates were not known.

FOOD

Adult kittiwakes fed their chicks mostly fish, but the composition of their prey varied among study sites. Capelin (Mallotus villosus) and Pacific sand lance (Ammodytes hexapterus) were the two most important species in chick regurgitations at Sitkalidak Strait in the Kodiak region in 1977 and 1978 (Tables VII-13 and VII-14). In 1977 both species were taken although sand lance predominated, but in 1978, the amount of capelin fed to chicks decreased markedly while occurrence of sand lance increased. Pacific sandfish (Trichodon trichodon) and walleye pollock (Theragra chalcogramma) were also a small portion of their diet. The chicks at Chisik Island in lower Cook Inlet were fed almost exclusively fish, with sand lance being by far the most common. In contrast, the chicks in Prince William Sound at Porpoise Rocks were fed mostly Pacific herring (Clupea harengus pallasi), with smaller amounts of capelin and Pacific sand lance. Fish in the chicks' regurgitations on Middleton Island (again primarily Pacific sand lance) comprised approximately 70% of both the frequency of occurrence and the total aggregate weight of food whereas at other sites fish comprised at least 90% in both categories.

Euphausiids formed a small percentage of kittiwake diets at three

Table VII-11
Growth by Two Types of Measurement of Wing Length of Black-legged Kittiwake Chicks in the Gulf of Alaska, 1977-1978.

	Flattened Wing (mm)								Wing Chord (mm)											
	Chisik Island 1978				Chiniak Bay 1978				Middleton Island 1978				Sitkalidak Strait 1978				Sitkalidak Strait 1977			
Age (days)	n	$\overline{X}$	S.E.	Range	n	$\overline{X}$	S.E.	Range	n	$\overline{X}$	S.E.	Range	n	$\overline{X}$	S.E.	Range	n	$\overline{X}$	S.E.	Range
0					5	26	0.77	24-27	14	19	0.21	18-20	6	21	0.76	18-23	10	21	1.58	15-30
1-3					27	28	0.41	25-32	25	21	0.29	18-24	10	22	0.75	18-26	50	27	0.67	18-38
4-6					18	36	1.02	29-46	25	26	0.45	21-30	12	31	1.02	24-35	42	34	0.94	21-45
7-9					28	50	1.54	32-71	25	33	0.78	23-41	10	41	2.48	31-57	48	45	1.16	25-62
10-12					23	76	1.95	51-89	27	50	1.23	39-65	14	62	3.67	27-77	53	63	1.60	41-100
13-15	2	55	2.50	52-57	24	100	1.96	82-111	27	72	1.39	57-90	7	97	5.17	78-122	47	87	2.24	50-137
16-18	6	67	5.97	50-87	27	123	2.28	102-151	36	95	1.59	75-119	7	111	6.77	92-139	36	112	2.10	90-143
19-21	1	112			23	151	1.31	135-162	33	120	1.50	106-142	9	140	2.82	129-155	43	136	3.08	85-179
22-24	0				26	177	1.99	159-194	36	141	1.57	121-165	10	172	2.97	155-190	44	158	2.86	81-187
25-27	4	138	11.24	104-152	22	201	1.82	184-219	25	166	1.41	153-179	6	192	5.84	173-205	35	180	2.55	136-203
28-30	1	198			17	218	2.12	203-229	25	185	1.74	162-200	4	201	5.26	186-210	43	200	2.87	105-230
31-33	3	197	4.91	188-205	11	234	1.38	226-240	28	207	1.28	194-221	5	229	6.54	207-244	29	221	1.60	207-242
34-36	1	240							14	228	1.79	214-236	1	250			25	230	4.03	156-251
37-39									11	241	1.56	230-249					8	240	7.91	190-264
40-42									6	258	2.96	249-265					3	254	8.76	238-268

TABLE VII-12
Growth of Tarsus of Black-legged Kittiwake
Chicks in the Gulf of Alaska, 1977-78.

Age (days)	Chisik Island 1978				Middleton Island 1978				Sitkalidak Strait 1978				Sitkalidak Strait 1977			
	n	$\bar{X}$	S.E.	Range	n	$\bar{X}$	S.E.	Range	n	$\bar{X}$	S.E.	Range	n	$\bar{X}$	S.E.	Range
0					14	18	0.15	17-19	6	19	0.31	18-20	12	19	0.38	16-21
1-3	8	20	0.45	18-22	25	20	0.19	18-22	10	21	0.56	18-25	56	21	0.21	18-24
4-6	9	22	0.40	20-23	25	23	0.26	20-25	12	25	0.47	22-28	42	24	0.33	18-29
7-9	4	24	1.39	21-28	25	26	0.29	23-29	10	29	0.61	26-31	46	28	0.28	23-31
10-12	6	25	0.67	23-27	27	29	0.23	27-32	14	32	0.87	22-35	53	31	0.29	23-34
13-15	5	26	1.56	22-31	27	31	0.23	29-33	6	35	0.48	33-36	46	32	0.28	27-37
16-18	7	30	1.05	26-32	36	32	0.23	30-35	6	36	0.65	33-38	34	33	0.37	24-36
19-21	1	34			33	33	0.21	30-35	9	36	0.52	34-38	39	34	0.24	29-37
22-24	0				36	33	0.20	30-36	9	37	0.55	35-40	37	35	0.20	31-37
25-27	4	34	1.23	30-36	25	34	0.17	32-36	4	39	1.65	35-43	25	35	0.32	31-37
28-30	1	35			25	34	0.27	31-37	3	39	1.67	36-41	35	35	0.21	31-37
31-33	3	35	0.61	34-36	28	35	0.21	33-37	4	38	0.85	36-40	18	35	0.30	33-37
34-36	1	35			14	35	0.26	33-37	1	40			19	35	0.23	32-37
37-39					11	35	0.22	34-36					4	36	0.65	34-37
40-42					6	35	0.20	34-36								

TABLE VII-13

Frequency of Occurrence of Prey of Black-legged Kittiwake Chicks in the Gulf of Alaska, 1977-78.

Species of prey	Sitkalidak Strait 1977 n=138	Sitkalidak Strait 1978 n=33	Chisik Island 1978 n=14	Middleton Island 1978 n=40	Porpoise Rocks 1977 n=9
Capelin (*Mallotus villosus*)	55.8	6.1	14.3	-	11.1
Pacific sand lance (*Ammodytes hexapterus*)	47.8	63.6	71.4	17.5	11.1
Pacific herring (*Clupea harengus pallasi*)	-	-	-	-	55.5
Pacific sandfish (*Trichodon trichodon*)	2.9	9.1	-	2.5	-
Walleye pollock (*Theragra chalcogramma*)	8.0	-	7.1	-	-
Unidentified smelt (Osmeridae)	-	-	-	-	11.1
Unidentified fish	8.7	27.3	21.4	52.5	-
Salmonid eggs and parts	2.9	-	-	2.5	-
Euphausiids:					
Thysanoessa spinifera	-	-	-	20.0	-
Thysanoessa inermis	-	-	7.1	-	-
Euphausia pacifica	-	-	-	-	11.1
Gammarid amphipod (*Paracallisoma alberti*)	-	-	-	10.0	-
Shrimp (*Pandalopsis* sp.)	8.7	-	-	-	-
Unidentified Decapoda	-	-	-	2.5	-
Unidentified Crustacea	-	-	7.1	-	-
Octopus	-	-	-	5.0	-
Squid	-	-	-	5.0	-
Isopod (*Ligia* sp.)	0.7	-	-	-	-
Chiton (*Katharina tunicata*)	-	3.0	-	-	-
Diptera	1.4	-	-	-	-

TABLE VII-14

Composition by Weight of Prey Delivered to Black-legged Kittiwake Chicks in the Gulf of Alaska, 1977-78.

Species of prey	Percent of Total Aggregate Weight: Sitkalidak Strait 1977 n=138	Sitkalidak Strait 1978 n=33	Chisik Island 1978 n=14	Middleton Island 1978 n=40
Capelin (*Mallotus villosus*)	37.4	2.0	14.3	-
Pacific sand lance (*Ammodytes hexapterus*)	40.5	64.0	68.6	29.8
Pacific herring (*Clupea harengus pallasi*)	-	-	-	-
Pacific sandfish (*Trichodon trichodon*)	1.9	6.0	-	3.2
Walleye pollock (*Theragra chalcogramma*)	6.6	-	12.2	-
Unidentified fish	5.9	27.2	4.6	45.2
Salmonid eggs and parts	2.3	-	-	-
Euphausiids:				
Thysanoessa spinifera	-	-	-	18.4
Thysanoessa inermis	-	-	0.1	-
Euphausia pacifica	-	-	-	-
Gammarid amphipod (*Paracallisoma alberti*)	-	-	-	0.3
Shrimp (*Pandalopsis* sp.)	5.2	-	-	-
Unidentified Decapoda	-	-	-	0.03
Unidentified Crustacea	-	-	0.1	-
Octopus	-	-	-	0.8
Squid	-	-	-	0.5
Isopod (*Ligia* sp.)	0.1	-	-	-
Chiton (*Katharina tunicata*)	-	0.8	-	-
Diptera	0.1	-	-	-
Total aggregate weight per site	1623.8g	277.0g	97.2g	624.7g

locations but different species were taken at each. At Chisik Island, *Thysanoessa inermis* was taken in small numbers, at Porpoise Rocks *Euphausia pacifica* was taken in moderate numbers, and at Middleton Island *Thysanoessa spinifera* occurred in 20% of the regurgitations and comprised 20% of the aggregate weight. These differences may reflect the availability of different food types rather than preference for different species by kittiwakes at the three sites. Other food items taken by kittiwakes included shrimp (*Pandalopsis* spp.), amphipods, salmonid eggs, squid, octopus, and several intertidal invertebrates.

Kittiwakes fed their chicks primarily two-year-old (age class 1) capelin and sand lance, whose lengths range from 50 to 110 mm (capelin, Jangaard 1974) and 66 to 116 mm (sand lance, Blackburn 1978). A few three-year-old (age class 2) fish of both species were fed to chicks. At Sitkalidak Strait the sand lance fed to chicks in 1978 averaged slightly larger than in 1977 whereas for capelin the reverse was found (Fig. VII-6). For the two years combined the length of fish fed to chicks averaged 94.9 mm (S.E.= 3.64, n=178) for capelin, 104.0 mm (S.E.=2.36, n=222) for sand lance and 112.4 mm (S.E.=4.20, n=14) for sandfish. In 1977 the average weight of 58 fish fed to chicks was 5.7 g (S.E.=0.45).

Researchers at Sitkalidak Strait and Chiniak Bay in 1978 each conducted 3 day-long food watches during which they recorded the number of times chicks were fed during the hours of daylight. The observations at Chiniak Bay (Fig. VII-7 and Table VII-15) seemed to indicate that, even though feeding occurred throughout the day, the majority of feedings took place in the morning. At Sitkalidak Strait (Fig. VII-7 and Table VII-15) feeding of chicks occurred more uniformly throughout the day with a slight peak in the afternoon. The chicks studied at Chiniak Bay had a slightly higher

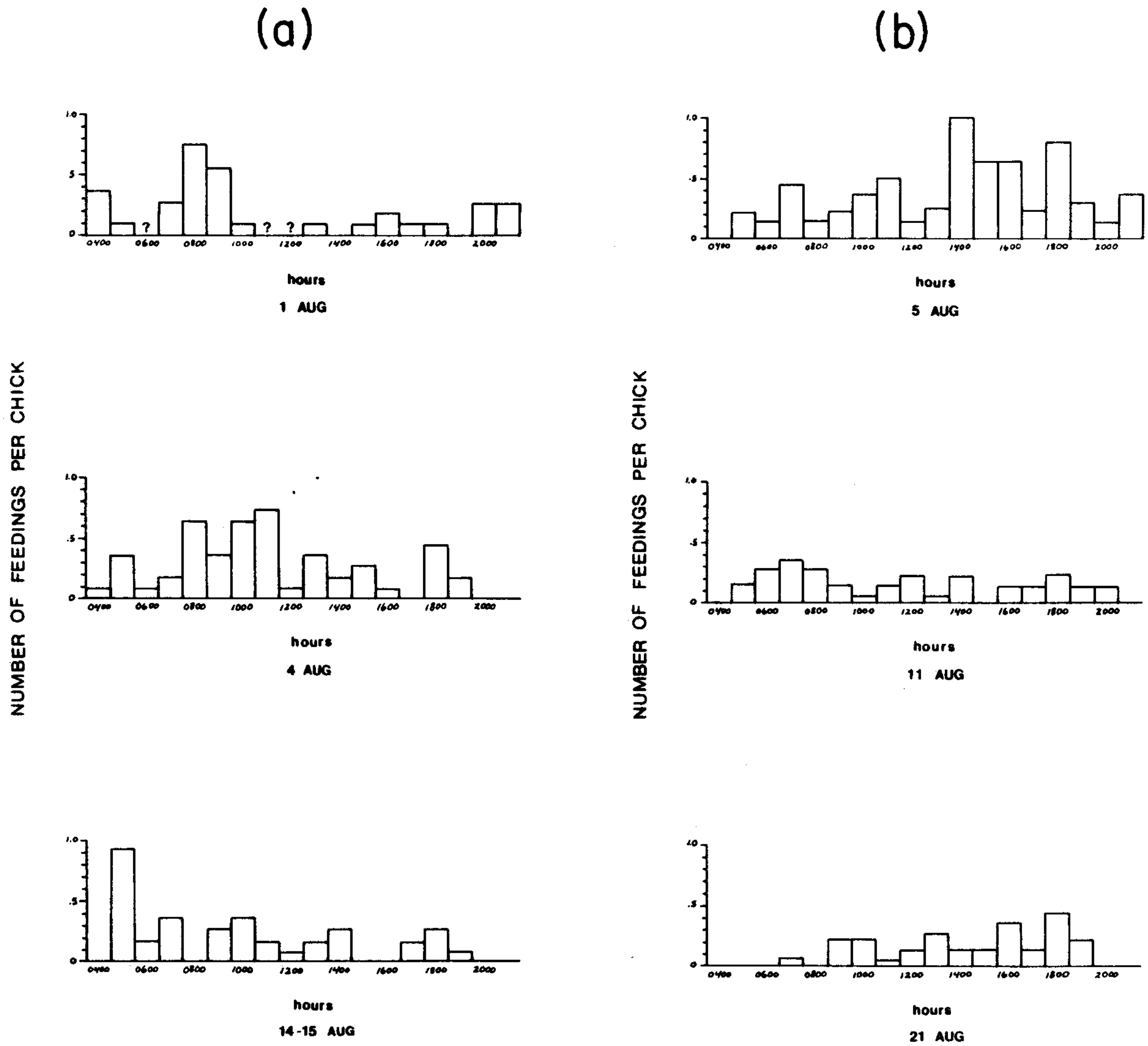


Figure VII-7. Frequencies of feedings per Black-legged Kittiwake chick per hour in (a) Chiniak Bay and (b) Sitkalidak Strait during August, 1978.

TABLE VII-15
Frequencies of Feedings Per Chick Per Hour on Different Days at Chiniak Bay and Sitkalidak Strait, August 1978.

Time of day	Mean number of feedings per chick per hour					
	Chiniak Bay (n=11)			Sitkalidak Strait (n=14)		
	Aug. 1	Aug. 4	Aug. 14	Aug. 5	Aug. 11	Aug. 21
0400-0500	.36	.09	0	-	-	-
0500-0600	.09	.36	.91	.21	.14	0
0600-0700	-	.09	.18	.14	.29	0
0700-0800	.27	.18	.36	.43	.36	.07
0800-0900	.73	.64	0	.14	.29	0
0900-1000	.55	.36	.27	.21	.14	.21
1000-1100	.09	.64	.36	.38	.07	.21
1100-1200	-	.73	.18	.50	.14	.07
1200-1300	-	.09	.09	.13	.21	.14
1300-1400	.09	.36	.18	.25	.07	.29
1400-1500	0	.18	.27	1.00	.21	.14
1500-1600	.09	.27	0	.63	0	.14
1600-1700	.18	.09	0	.63	.14	.36
1700-1800	.09	0	.18	.21	.14	.14
1800-1900	.09	.45	.27	.79	.21	.43
1900-2000	0	.18	.09	.29	.14	.21
2000-2100	.27	0	0	.21	.14	-
2100-2200	.27	0	0	.36	-	-
Mean number of feedings per chick per day	3.2	4.7	3.4	6.5	2.7	2.4

daily feeding rate per chick than those at Sitkalidak Strait. The mean number of feedings per chick per day at Chiniak Bay for the three days was 3.2, 4.7, and 3.4 while the mean total per day at Sitkalidak Strait for the three days was 6.5, 2.7, and 2.4. The overall mean daily rate for the six days of observations was 3.8 feedings per chick per day.

To calculate the approximate food requirement of a Black-legged Kittiwake chick, we weighed regurgitations. However, only at Sitkalidak Strait in 1977 were regurgitations weighed before formalin was added. As a result, the weights there are probably the most useful and least biased for this purpose. Seventy-seven regurgitations had a mean weight of 18.9 grams (S.E.=1.34). We assumed that a regurgitation was equivalent to a feeding. This may not always have been the case. Given a mean feeding rate of 3.8 feedings per day per chick, a mean weight of 18.9 g per feeding, and a mean nestling period of 43 days, an average chick consumed 3,088 g during the nestling period.

In 1977, the Sitkalidak Strait-Kiliuda Bay area had 23,087 kittiwake nests with a mean of 0.74 chicks fledged per nest built, so the minimum food requirement of nestlings raised in this area was close to 53 metric tons. However, in 1978 this same area had only 7,021 active nests and only 0.17 chicks fledged per nest built. This meant that the minimum food requirement in 1978 dropped to about 4 metric tons.

Since throughout the Gulf of Alaska 1977 was a good year and 1976 and 1978 were both poor years in terms of reproductive success of kittiwakes, we can roughly estimate the food required to raise chicks during a year of good and poor production of kittiwakes throughout the region. At 6 colonies studied in 1977 productivity averaged 0.75 chicks fledged per nest built. Among 10 colonies studied in either 1976 or 1978 productivity averaged only

0.24 chicks fledged per nest built. Using censuses of the Gulf of Alaska found in the Catalog of Alaskan Seabird Colonies (Sowls et al. 1978), we estimate that there are roughly 472,000 breeding pairs of Black-legged Kittiwakes in the Gulf of Alaska east of Unimak Pass. Therefore, in a year of good production approximately 1,100 metric tons of prey would be needed by kittiwake chicks while in a poor year only around 350 metric tons would be needed.

FORAGING

At Porpoise Rocks and Sitkalidak Strait in 1977, researchers conducted detailed studies of feeding flocks. The major feeding zone near Porpoise Rocks was at the mouth of Port Etches where the currents of Hinchinbrook Entrance pass into the bay. This area is also where the bottom of Port Etches drops sharply into the deeper waters of Hinchinbrook Entrance. Similarly, the feeding flocks at Sitkalidak Strait formed usually along convergences, especially in areas where there were rapid changes in bottom topography such as near Cathedral Island. No correlation was found between tide height or time before high or low tide and the occurrence or size of the feeding flocks. Larger sample sizes and more observations are recommended in order to be sure that this is true. However, whenever there was wind or rain which disturbed the surface water, the feeding flocks occurred much less frequently.

Feeding flocks remained grouped for as long as 45 minutes at Porpoise Rocks, although the average length was approximately 20 minutes. Most feeding flocks at Sitkalidak Strait lasted 10-20 minutes (n=20).

Feeding aggregations at Porpoise Rocks generally appeared to be initiated by Black-legged Kittiwakes and Glaucous-winged Gulls. Tufted Puffins, Common Murres, and cormorants were then attracted to the area by the feeding gulls. Sealy (1973) presented similar data on the formation of interspecific feeding assemblages in seabirds on the British Columbia coast. At Sitkalidak Strait terns always initiated the assemblages when they were present. Kittiwakes and gulls arrived next and the puffins and cormorants always appeared last. When terns were not part of a feeding flock, kittiwakes and gulls initiated the flocks. The species departed the feeding flocks in the same order in which they arrived.

The initial feeding behavior of terns, kittiwakes, and gulls was surface-plunging, in which birds dived into the water from a height of several meters. Sometimes they completely submerged for a second or two while at other times the birds only partially submerged. As the density of the flock increased, these species changed their behavior to one of surface-seizing, in which the bird sat on the water picking up prey on or near the surface. At this point the puffins and cormorants arrived and their behavior consisted of underwater pursuit. A feeding flock was usually dynamic with birds arriving and leaving constantly. However, birds leaving the flock had not always fed. Many kittiwakes that were collected when leaving feeding flocks at Sitkalidak Strait, for instance, were found to have empty digestive tracts.

COLONY ATTENDANCE

Colony attendance and activity patterns of Black-legged Kittiwakes were studied most intensively at four sites: Chowiet Island in the Semidi Islands (1977-78), Sitkalidak Strait (1978), Middleton Island (1978), and Porpoise Rocks near Hinchinbrook Island (1977). Some observations on colony attendance were recorded at Chiniak Bay incidental to feeding watches.

At Chowiet Island the patterns of daily attendance of kittiwakes during the egg stage (26 May-28 June) were very similar in 1977 and 1978 despite big differences in number of nest attempts and in reproductive success (Fig. VII-8). In contrast, daily attendance patterns during the pre-laying period (before early June) differed greatly between the two years. Attendance ranged from 50% to 75% of the maximum number of breeding adults recorded on the study plots. Even though attendance was similar for the two years, the number of nests built decreased from 426 in 1977 to 288 in 1978.

At Middleton Island daily colony attendance during the chick stage in July varied usually between 45% and 60% of the total breeding population present that year. Single adults attended 60% to 80% of the nests which were attended at any one count, while two adults attended the remaining 20-40%.

Only at Porpoise Rocks and Sitkalidak Strait were diel rhythms of kittiwakes intensively studied in the Gulf of Alaska. On given days the number of kittiwakes present on sample plots was recorded every 15 minutes at Porpoise Rocks in 1977; at Sitkalidak Strait in 1978 the numbers of kittiwakes flying to and from sample plots during 10 minutes of every half hour were recorded. At Porpoise Rocks, the four days of intensive observations coincided with the incubation, hatching, chick-rearing, and post-fledging stages (Fig. VII-9). At Sitkalidak, the four days of observations coincided with early and late incubation and early and late chick stages (Fig. VII-10).

Analysis revealed no significant correlation between attendance and light intensity or tidal state at Porpoise Rocks. In fact, no daily pattern in the number of birds flying to and from the nesting cliff was noted, supporting the suggestion of Cullen (1954) that kittiwake activity may be

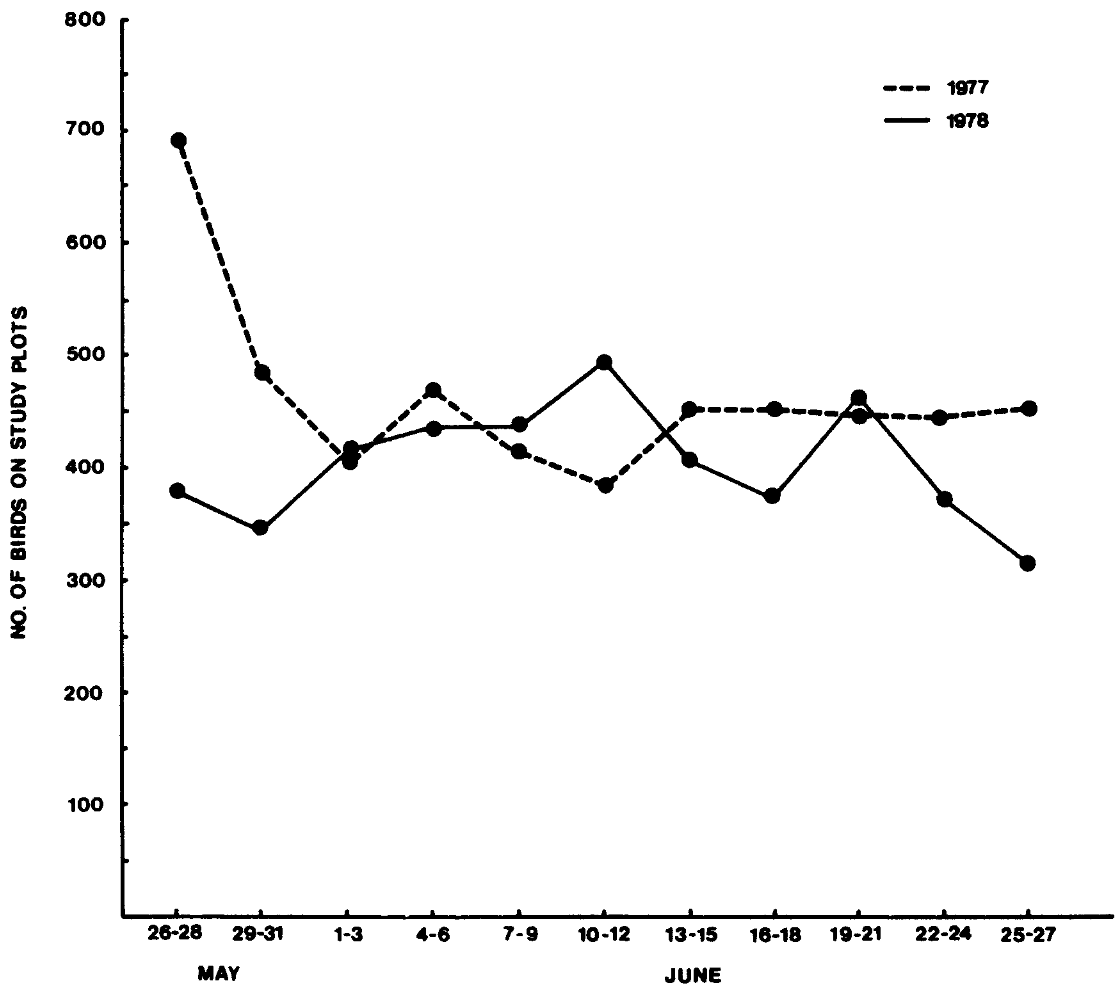


Figure VII-8. Nest site attendance of Black-legged Kittiwakes at the Semidi Islands in 1977 and 1978.

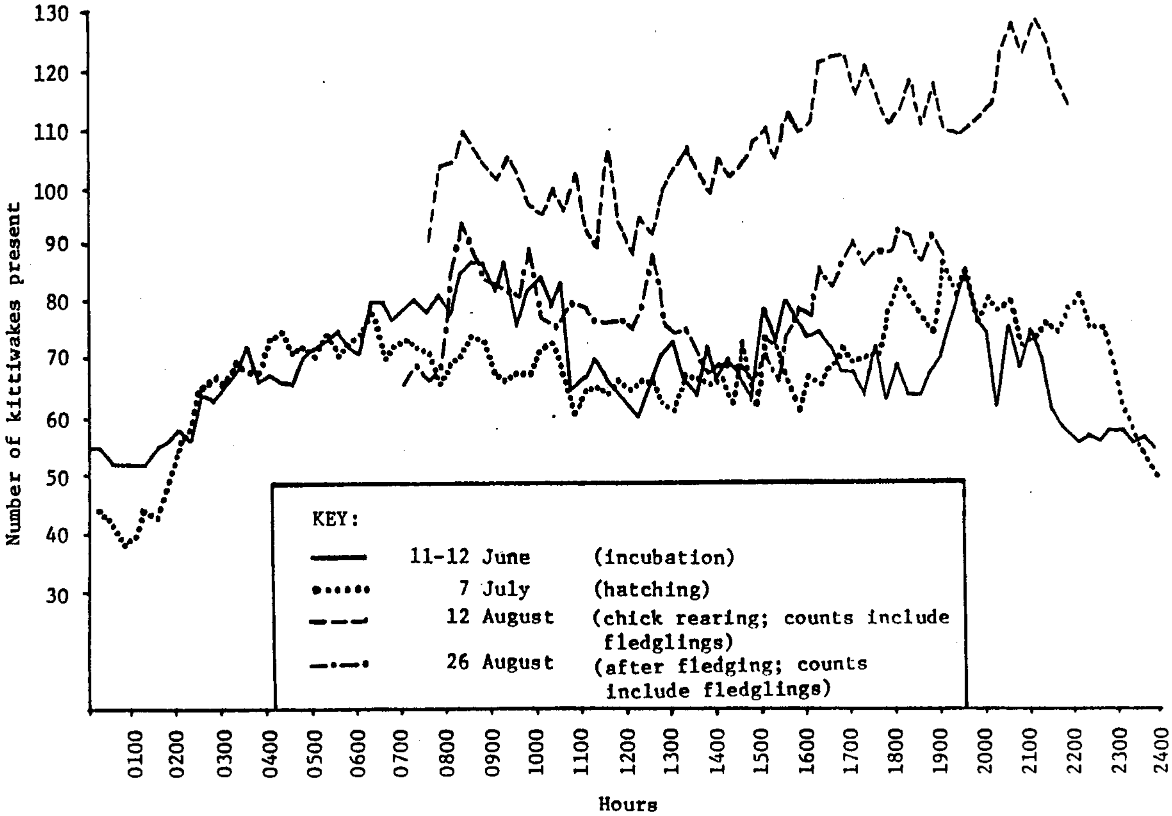


Figure VII-9. Seasonal variation in diel rhythms of Black-legged Kittiwake attendance at a sample plot (n=48 nests) on Porpoise Rocks, Hinchinbrook Island, 1977.

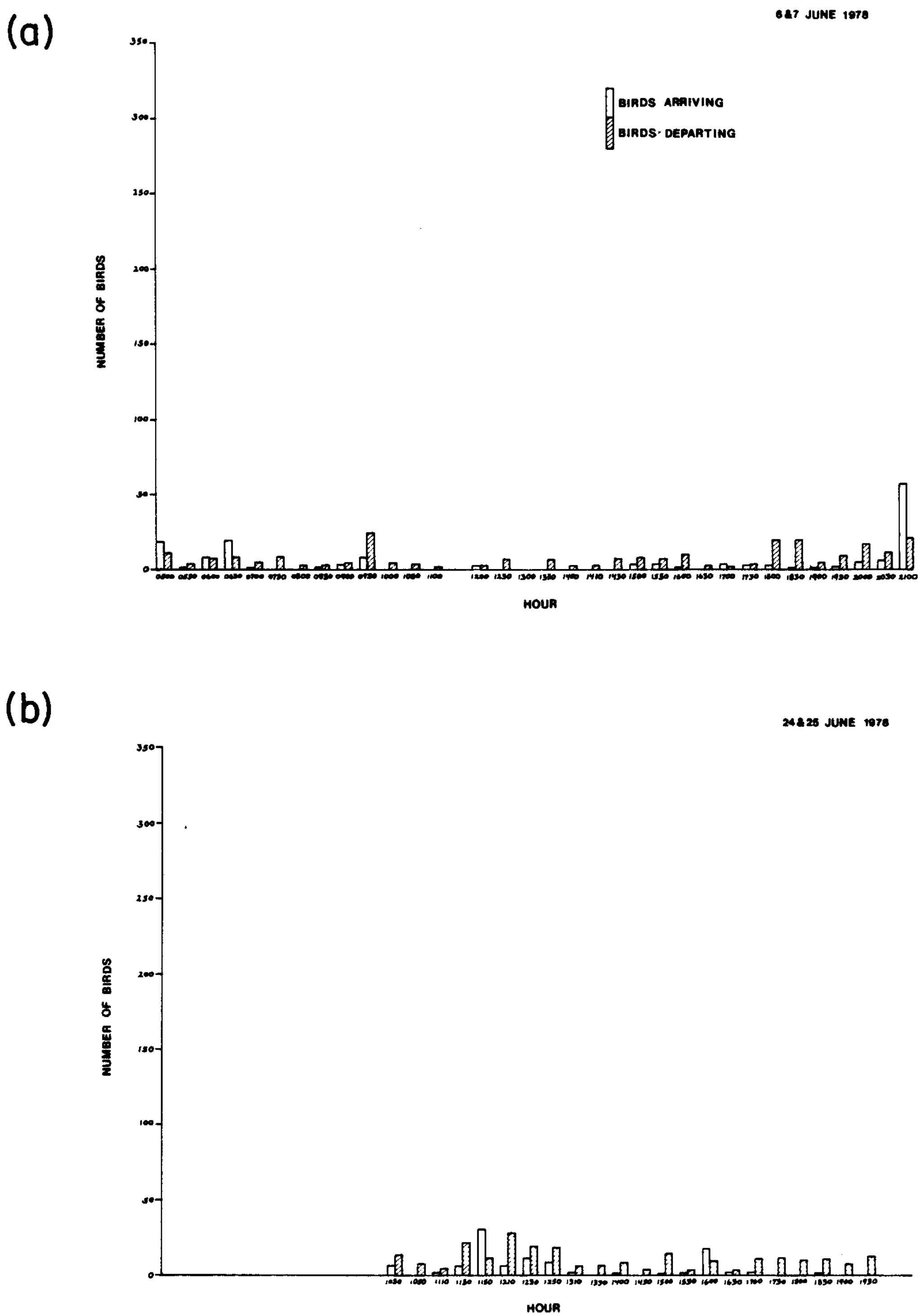
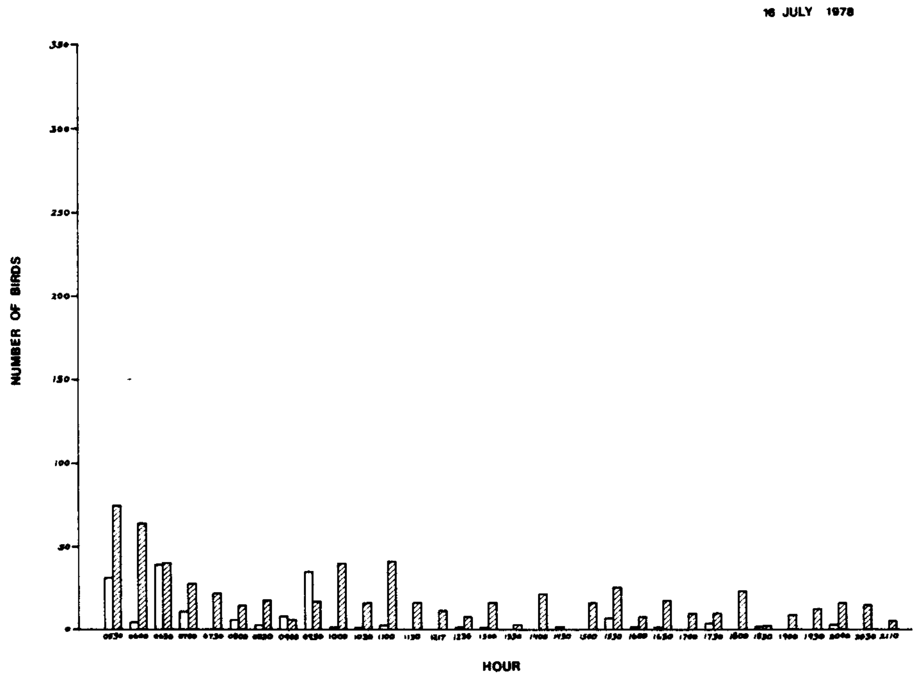


Figure VII-10. Dawn to dusk counts of Black-legged Kittiwakes arriving and departing from the colony, Sitkalidak Strait: (a) 6-7 June 1978, (b) 24-25 June 1978.

(c)



(d)

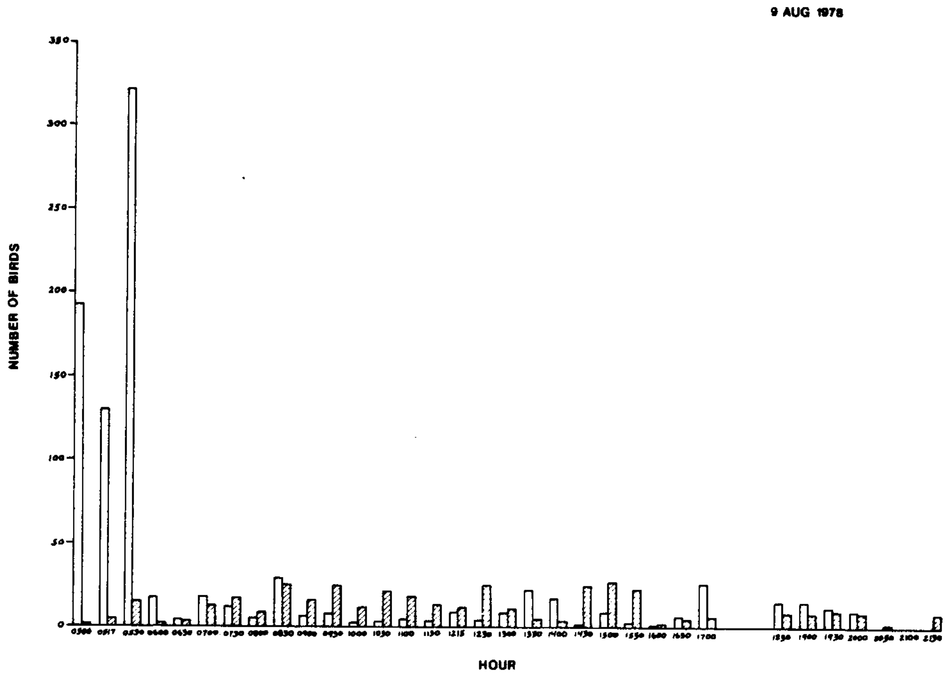


Figure VII-10 (cont.) (c) 16 July 1978, (d) 9 August 1978.

polyphasic. During June the period of lowest nest attendance was between 2400 and 0100, which coincided with the few hours of twilight, suggesting that kittiwakes may have been feeding on the schooling fish that come close to the surface only near darkness (Harris and Hartt 1977). In August, darkness precluded counts during these hours. At Sitkalidak Strait during early and late incubation the numbers of birds arriving and departing were fairly constant throughout the day, with a slight but nonsignificant increase of birds arriving at dusk during early incubation. During the early chick stage there was an increase during the morning hours of birds leaving the nest and during the late chick stage there were large numbers of birds arriving in the early morning. These findings suggest that during the chick stage adult kittiwakes were feeding at night or early morning. Likewise, during the chick-rearing stage at Chiniak Bay in 1978 kittiwakes usually left the colony site in the early morning, often before sunrise. Feeding of chicks occurred mostly in the morning (Figure VII-7) and the number of adults attending the colony peaked in the afternoon and evening.

FACTORS AFFECTING REPRODUCTIVE SUCCESS

Seven factors were identified as having an important influence on reproductive success of kittiwakes in the Gulf of Alaska during the three years of study:

1. Predation of eggs by Glaucous-winged Gulls, Common Ravens and Northwestern Crows;
2. Predation of chicks by Glaucous-winged Gulls and Bald Eagles;
3. Predation of adult kittiwakes by Peregrine Falcons and Bald Eagles;
4. Severe weather causing nests to wash away or chicks to die of exposure;

5. Changes in food availability;

6. Ejection of eggs and chicks from nests due to adult activity or sibling rivalry;

7. The amount of experience the adult kittiwakes had, assuming that those that laid earlier were more experienced.

The productivity at any one site seemed determined by varying combinations of the above factors.

In 1977, it appeared that there was no lack of prey for kittiwakes and that all mortality was caused by predation and weather. The larger clutch sizes and the extreme range of overall reproductive success at the colonies support this conclusion. Laying success was high but due to predation and inclement weather at some colonies, hatching and fledgling success decreased. Also the lack of predators in Chiniak Bay appeared to allow the very high success of a colony on Kulichkof Island. Lower levels of predation at other sites likewise resulted in higher productivity than in other years.

However, in 1978 the availability of capelin appeared to have changed at several sites and this change coincided with a significant reduction in productivity of those seabirds that feed at or near the surface such as kittiwakes. The fact that the productivity of diving species such as Tufted Puffins did not decrease during the same year at the same sites gives some indication of how food availability and reproductive success interrelate. For instance, at Sitkalidak Strait in 1978, the regurgitations of chicks contained significantly fewer capelin than in 1977, when capelin were the major food source. The number of chicks fledged per nest built declined in 1978 at the same site, but the chicks that did survive grew as well as those in the better production year of 1977. A decrease in food availability may have lowered reproductive success by causing a decrease in clutch size and increasing the amount of time required for foraging. An increase in foraging time may have caused eggs and chicks to be less protected from predation, exposure, or other factors that could have caused loss.

Dement'ev and Gladkov (1951) observed diminished fertility in kittiwakes as a function of reduced food availability. This took the form of reduced clutch size as Belopol'skii (1957) had also noted. Similarly, decreases in clutch sizes in the Gulf of Alaska in 1978 correlated with qualitative and quantitative differences in prey taken, which we assumed resulted from changes in distribution or availability of the prey, mainly capelin, in the Kodiak Island vicinity.

Egg loss due to avian predation was undoubtedly the most consistent and common loss recorded in the Gulf of Alaska in any of the years. The degree of loss of eggs or chicks seemed to be correlated with the availability of food for both predators and kittiwakes. For instance, when salmon runs near Porpoise Rocks were on time and abundant, eagles did not prey on seabirds at colony sites nor drive them from nest sites thus exposing the eggs. Likewise, when capelin or some adequate food source was easily available, adult kittiwakes did not have to forage as far from the colony and thus were able to be present at the nest a greater percentage of the time. Increased attendance could have reduced the incidence of chick death from predation or exposure to heat or moisture. B. Braun (pers. comm.) has even observed that adults present at a nest site control intersibling rivalry and therefore help prevent loss due to falling from the nest. This may be one reason that adult kittiwakes with more breeding experience produce more chicks, as Coulson and White (1958a, 1960) have shown.

At both Chisik and Middleton Island in 1978 there was major mortality of newly fledged young. This type of mortality probably occurs frequently, but it is usually hard to measure. At Sitkalidak, many chicks close to fledging were eaten by gulls. At Chisik Island, gulls often preyed on young that fell into or landed on the water near the colony when first attempting to fly. On Middleton Island the flats and ponds below the breeding cliffs offered a unique opportunity to measure some degree of this mortality that new fledglings experience. The flats in 1978 became strewn with the remains of young kittiwakes which had been killed and eaten by gulls. The distribution of wing lengths in a random sample of 113 carcasses indicated that the majority of the kills took place after the young had left their nests and were fully capable of flight. Predation by Glaucous-winged Gulls apparently is one of the important factors affecting productivity of kittiwakes in the Gulf of Alaska throughout all stages of their reproductive process.

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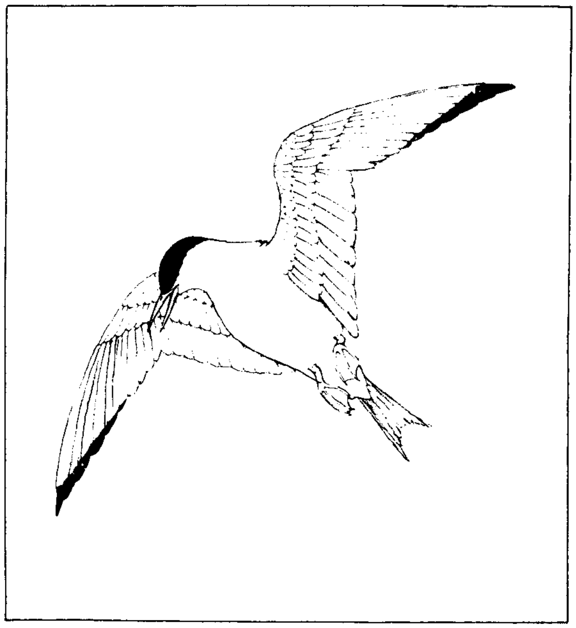
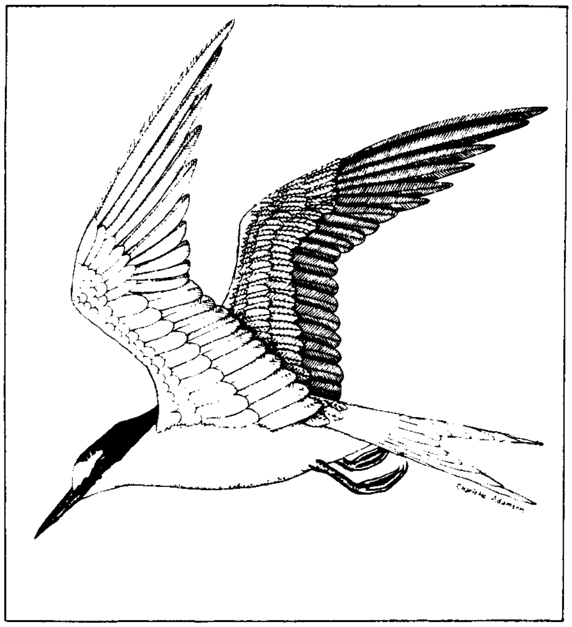
Terns (*Sterna* spp.)



Arctic Tern
(*Sterna paradisaea*)

Aleutian Tern
(*Sterna aleutica*)



by

Patricia A. Baird

ARCTIC AND ALEUTIAN TERNS

(*Sterna paradisaea* and *S. aleutica*)

Arctic and Aleutian Terns are summer visitors to Alaska, with most arriving on the breeding grounds in late May and departing by late August. Only general surveys of distribution and incomplete censuses of colonies had been conducted on these two species in Alaska before the initiation of the OCSEA Program. Studies on the breeding biology and feeding ecology of Arctic Terns before this program were limited to those of European or Atlantic Coast populations (e.g., Hopkins and Wiley 1972; Lemmetyinen 1972, 1973a, 1973b; Coulson and Horobin 1976; Harris 1976; Ladhams 1976; Erwin 1978). There were also other brief accounts of movement, physiology, and behavior (e.g., Clapp 1975, Rahn et al. 1976, Green 1977). For Aleutian Terns, only anecdotal information was available, summarized in Bent (1921), Gabrielson and Lincoln (1959), and Isleib and Kessel (1973).

The U.S. Fish and Wildlife Service has gathered information on the breeding biology of terns at four sites in the Gulf of Alaska:

Sitkalidak Strait	1977	Baird and Moe 1978, Baird 1978
	1978	Baird and Hatch 1979
Chiniak Bay	1975	Dick 1976, Dick et al. 1976
	1977	Nysewander and Hoberg 1978
	1978	Nysewander and Barbour 1979
Hinchinbrook Island	1976	Nysewander and Knudtson 1977
	1977	Sangster et al. 1978
	1978	Kane and Boyd 1979
Naked Island	1978	Oakley and Kuletz 1979

At the first two sites, both in the Kodiak Island archipelago, comprehensive studies were conducted on the comparative breeding and feeding ecology of

Arctic and Aleutian Terns. Less intensive studies at the other two sites, both in Prince William Sound, provide some information on reproductive chronology and success of Arctic Terns. The numbers of breeding birds at each of these four sites can be found in Table VIII-1.

BREEDING DISTRIBUTION AND ABUNDANCE

The circumpolar Arctic Tern has perhaps the most widespread breeding distribution within Alaska of any water bird (Gabrielson and Lincoln 1959, Sowls et al. 1978) (Fig. VIII-1a). It breeds along the coast from Tracy Arm in Southeastern Alaska north to the Beaufort Sea, and throughout the interior regions of the state (Gabrielson and Lincoln 1959, Gill and Dick 1977, Bailey 1978, Sowls et al. 1978). This species exhibits great variation in degree of coloniality, with pairs nesting singly, in loose aggregations, or in dense colonies. About 25,000 Arctic Terns nest in colonies along the coast of Alaska, with approximately 10,800 reported at 81 sites in the Gulf (Sowls et al. 1978). Many times that number may nest along lake and river systems of the Interior and along coastal river deltas, where they generally nest in small groups.

Aleutian Terns, in contrast, have a breeding range that is limited to coastal regions from the vicinity of Yakutat Bay to the southern Chukchi Sea, including the western Aleutian Islands (Jaques 1930, Gabrielson and Lincoln 1959, Gill 1977, Kessel and Gibson 1978, Sowls et al. 1978) (Fig. VIII-1b). The total Alaskan population is estimated at 10,000 birds, projected from a total count of approximately 3,400 at 28 known colony sites. In the Gulf of Alaska, there are about 1,100 birds at 14 sites (Sowls et al. 1978).

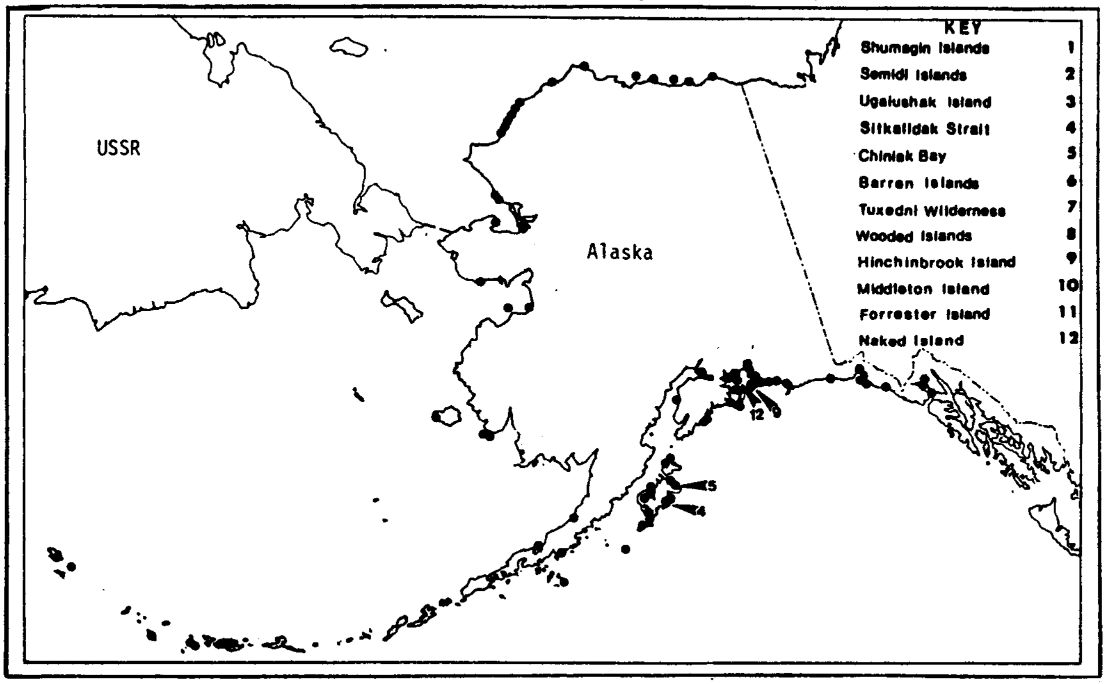
Colonies in the Kodiak Island archipelago comprise about 25% of the total breeding populations of both Arctic and Aleutian Terns in the Gulf of Alaska. However, both species may be historically recent additions to the

TABLE VIII-1
Estimated Numbers of Arctic and Aleutian Terns Nesting at Study Sites in the Gulf of Alaska.

Colony	Arctic Terns			Aleutian Terns		
	1976	1977	1978	1976	1977	1978
Sitkalidak Strait	-	1276	286	-	1064	258
Chiniak Bay	120+	428	266	180+	360+	530
Hinchinbrook Island	24	120	116	0	0	0
Naked Island	55+	-	100	0	-	0

Arctic Tern (*Sterna paradisaea*)

(a)



Aleutian Tern (*Sterna aleutica*)

(b)

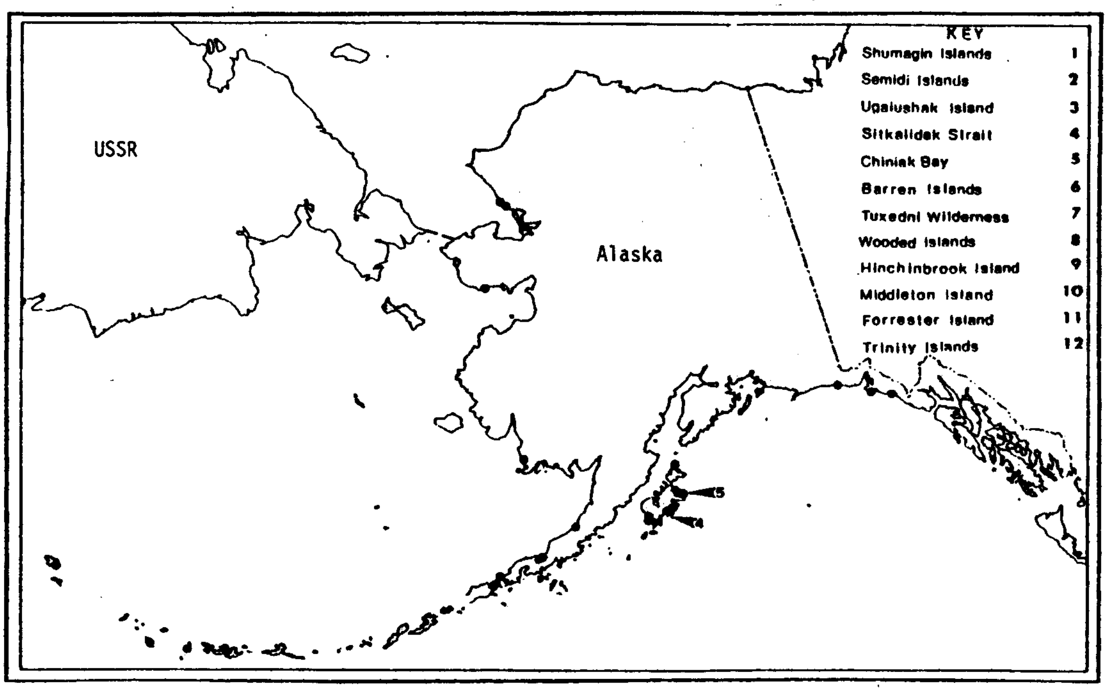


Figure VIII-1. Distribution of breeding colonies of (a) Arctic Terns and (b) Aleutian Terns in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

avifauna of Kodiak, as the natives there have no name for "tern" in their Aleut dialect (S. Hakanson, pers. comm.).

In the Gulf of Alaska, terns customarily nest in small colonies numbering from a few pairs to as many as 1,000 pairs. Arctic Terns may nest alone or in mixed colonies with Aleutian Terns; however, Aleutian Terns rarely nest alone. At Kodiak, the size of tern colonies ranged from 150 to 1,200 birds, and most contained both species. Local breeding populations varied in size from year to year, and by as much as 88% at one study site. Terns have been known to shift their colony sites from year to year, and this may account for some of the variation in numbers; they are sometimes thought of as colonizing species. As an example, on one small island at Kodiak Island, terns colonized an area on which a vigorous Mew Gull colony had been egged out of existence by local natives a decade before.

Nowhere are terns as abundant as the other seabird species. Their habitat requirements and foraging habits may dictate their low numbers at any one location. Unlike other seabirds in the Gulf of Alaska that simply become more pelagic in the winter, the terns completely vacate their breeding grounds for South America, Antarctica (Arctic Terns), and Japan (Aleutian Terns) in the winter months. The Arctic Terns have one of the farthest-ranging migration routes of any bird species--more than 33,000 km.

In the Kodiak archipelago, terns nested primarily on low grassy islands or occasionally in grassy areas on the mainland at the heads of bays. On Naked Island, which is densely forested, nests of Arctic Terns were all within 50 m of the water. At all study areas, both species avoided nesting in tall herbaceous vegetation, preferring open areas with low vegetation such as Sphagnum moss and Calamagrostis (Table VIII-2, Fig. VIII-2). They occasionally placed nests on gravel beaches or in amongst clumps of Iris, Potentilla,

TABLE VIII-2
Parameters of the Nesting Habitat of Arctic and Aleutian Terns.

Species Location year	$\overline{X}$ Density (nests/m^2)	$\overline{X}$ Nearest Neighbor (m)[a]	$\overline{X}$ Slope (°)	Typical Vegetation	Description of Habitat
Arctic Tern					
Sitkalidak Strait					
1977 (n=56)	0.13 (island)	2.50 (island, mixed) 1.10 (island, mono)	11.4	*Calamagrostis*, *Sphagnum*, *Achillea*, *Geranium*	Short grassy areas on high points of islands. Mixed or single species colony.
1978 (n=29)	0.07 (island)				
Chiniak Bay					
1977 (n=87)	0.11 (island)	2.13 (island, mixed)		*Calamagrostis*, *Sphagnum*, *Elymus*	Low wet meadows and beach perimeters of islands and mainland. Some on drier hillsides. Mixed or single species colony.
1978 (n=67)	0.10 (island)				
(n=46)	0.03 (mainland)				
Naked Island					
1978 (n=51)				*Potentilla*, *Elymus*, *Iris*, *Calamagrostis*	Gravel spits, sparsely vegetated, at most 50 m from water.
Aleutian Tern					
Sitkalidak Strait					
1977 (n=46)	0.13 (island)	3.69 (island, mixed)	5.5	*Calamagrostis*, *Sphagnum*, *Achillea*, *Geranium*	Short grassy areas on lower parts of islands. Always mixed species colony.
1978 (n=24)	0.06 (island)				
Chiniak Bay					
1977 (n=22)	0.13 (island)	1.38 (island, mixed)		*Calamagrostis*, *Sphagnum*	Low wet meadows of islands or mainlands. Mixed or single species colony.
(n=11)		30.99 (mainland, mono)			
1978 (n=15)	0.09 (island)				
(n=92)	0.01 (mainland)				

a Colony on island or mainland, monospecific or mixed species.

Figure VIII-2. Nesting habitat of Arctic and Aleutian Terns.

or *Elymus*. There were no apparent differences in the types or amount of vegetation surrounding nests of Arctic and Aleutian Terns at Sitkalidak Strait. However, Arctic Terns tended to choose areas of higher elevation and with steeper slopes than Aleutian Terns, which settled in small monospecific groupings below them.

At a typical mixed colony in Chiniak Bay in 1977, nesting densities were highest in meadows, lowest on hillsides, and intermediate at the water's edge. The following year densities were highest in beach gravel and intermediate in meadows but still lowest on the hillsides (Nysewander and Barbour 1979). Although overall densities of terns nesting at different sites in the Gulf of Alaska were somewhat variable among colonies and between years within individual colonies, densities averaged higher in island colonies (e.g., Arctic: 0.10 nests/m^2, Aleutian: 0.10/m^2) than in mainland colonies (e.g., Arctic: 0.03 nests/m^2, Aleutian: 0.01/m^2) (Table VIII-2). Smaller colonies exhibited the most year-to-year variation. Nesting densities also tended to decrease in colonies that had experienced heavy predation the previous year.

For both Arctic and Aleutian Terns, nearest neighbors were always a bird of the same species. Distance to the nearest neighbor, a measure of clumped nesting, averaged 2.3 m for Arctic Terns and 2.5 m for Aleutian Terns nesting in mixed colonies on islands (Table VIII-2). The average nearest neighbor distance in monospecific colonies was similar for Arctic Terns (1.1 m) but markedly higher for Aleutian Terns (31.0 m). This dispersion of Aleutian Terns in monospecific colonies was on the mainland and this nesting behavior may have rendered them less conspicuous to predators. Such behavior is a common strategy shown by many ground-nesting birds. In a mixed colony, the nonaggressive Aleutian Terns may have gained protection from predators by nesting among the highly aggressive Arctic Terns. Similar relationships have been documented among other species of Laridae (cf. Langham 1974, Baird 1976). In the single monospecific colony of Arctic Terns for which distance to nearest neighbor was measured, pairs nested closer together (average of 1.1 m) than did Arctic Terns nesting in mixed colonies on other islands (Table VIII-2). This may have reflected differences in habitat or else differences in the dynamics of monospecific and mixed colonies.

BREEDING CHRONOLOGY

Terns were among the last species of seabirds to arrive at the nesting site each summer but were the first to lay eggs and the first to depart the breeding grounds. They began to build nests within a few days of their arrival and began to lay eggs within two weeks of their arrival at the colony. For both species the timing of first egg-laying usually varied by little more than a week between years at particular sites, and occurred during the last half of May at all colonies. (Tables VIII-3, VIII-4, Fig. VIII-3).

On Kodiak Island, the first Arctic Terns arrived between the 6th and 12th of May for the years 1974 to 1979, and the first Aleutian Terns arrived a few days to a week later (R. MacIntosh, pers. comm.). Although nesting began soon after arrival, egg laying for both species was sometimes prolonged for a month and half. At Sitkalidak Strait the incubation period for Arctic Terns averaged 21 days, and for Aleutian Terns averaged 22 days. At some colonies, some pairs were still laying eggs while chicks of other pairs were hatching. Our data were not adequate to determine whether the extended nesting period was caused by the late arrival or delayed nesting of some pairs, or by renesting of pairs whose initial nests were destroyed. The breeding cycle of the Aleutian Terns tended to lag about a week behind that of Arctic Terns.

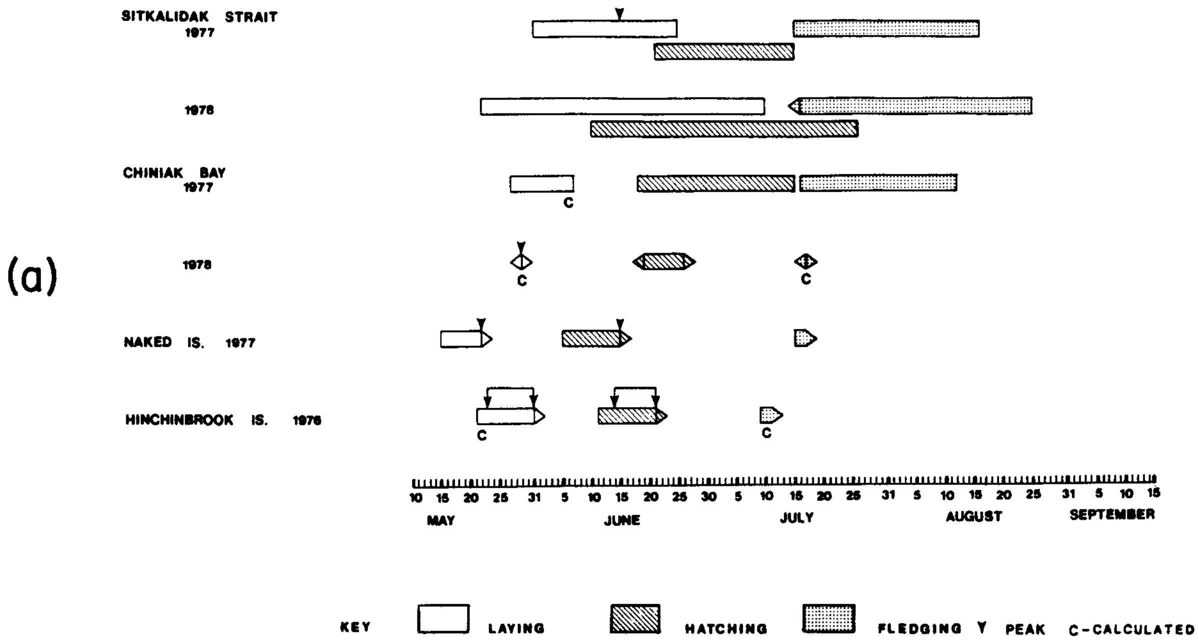
TABLE VIII-3
Breeding Chronology of Arctic Terns in the Gulf of Alaska, 1976-1978.

Colony	Year	Laying	Hatching	Fledging
Sitkalidak Strait	1977	31 May-25 June peak 15 June	21 June-15 July	15 July-16 August
	1978	22 May-10 July	10 June-26 July	16 July-25 August
Chiniak Bay	1977	(27 May-7 June>)[b]	18 June-15 July peak 26 June	(16 July-12 August)
	1978	19 May-23 June peak 28 May-5 June	19 June-2 July peak 26 June	(17 July>)
Naked Island	1978	(15 May>) peak 22 May	peak 9-15 June	
Hinchinbrook	1976	(21 May>) (peak 23-31 May) 19-20 June (renests)	11 June>[a] peak 14-21 June	(9 July>)
	1977		5 June>[a] peak 6-13 June	(3 July>)
	1978	15 May>[a]	12 June>[a] peak 6-17 June	18 July>[a]

[a] End date (>) not determined.
[b] dates in parentheses were derived by calculating from another event.

TABLE VIII-4
Breeding Chronology of Aleutian Terns
in the Gulf of Alaska.

Colony	Year	Laying	Hatching	Fledging
Sitkalidak Strait	1977	28 May-22 June	21 June-30 July	16 July-30 August
	1978	27 May-26 June	19 June-26 July	15 July-8 August
Chiniak Bay	1977	(1 June-23 June)[a]	22 June-15 July peak 1 July	(15 July-5 August)
	1978	23 May-28 June peak 30 May-10 June	28 June-10 July peak 3 July	(20 July>)



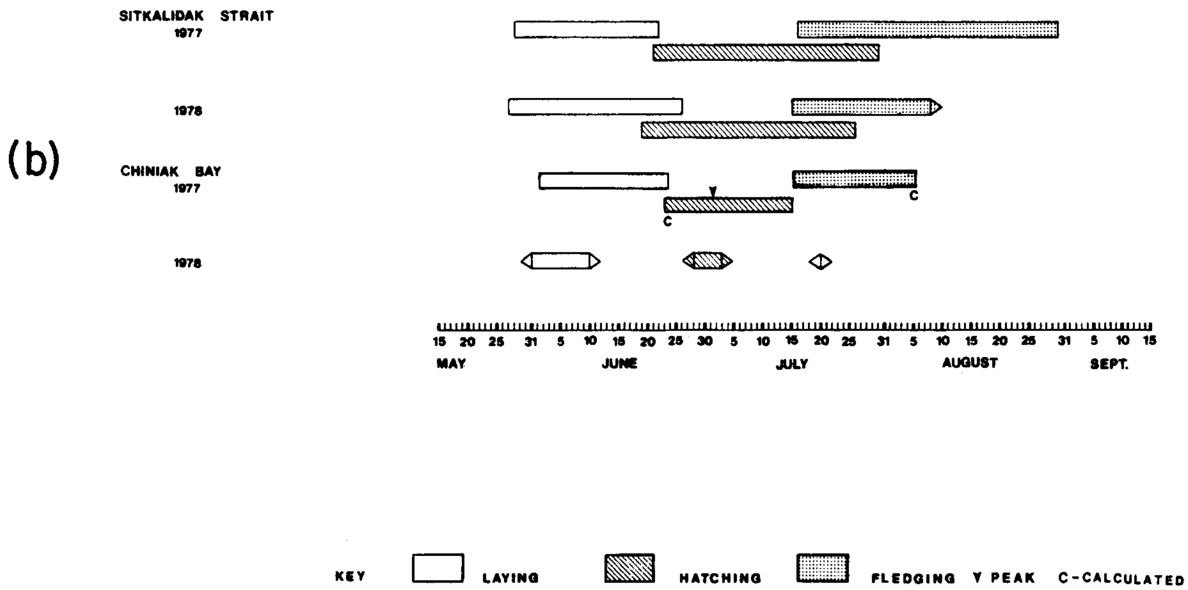


Figure VIII-3. Chronology of major events in the nesting seasons of (a) Arctic Terns and (b) Aleutian Terns in the Gulf of Alaska.

Hatching of eggs at Kodiak began in mid-June, and peaked in late June or early July. The nestling period averaged about 28 days (range = 25-31 days). Fledging of chicks began in mid-July for both species. At colonies on Sitkalidak Strait, fledglings of Arctic Terns were often attacked by the adults and seemed to be driven from the colony area. Most adults and young left the breeding grounds within a week or so after the young fledged. Fledglings of Aleutian Terns, however, remained at the nest for 1 to 2 weeks after they were able to fly well, and were fed and protected by adults during this period. Adult and fledgling Aleutian Terns departed colony areas simultaneously.

The majority of both species of terns left the breeding grounds by mid-August, and all were gone by the end of August. Chiniak Bay seemed to be a staging area for terns in late July and early August when flocks of over 1,000 birds were reported by Dick (1976) and Nysewander and Knudtson (1977).

REPRODUCTIVE SUCCESS

The number of chicks produced at individual colonies differed greatly between 1977 and 1978 (Table VIII-5). This variation resulted primarily from changes in the numbers of breeding pairs and from changes in hatching success (Tables VIII-6, VIII-7). At all colonies, the modal clutch size for both Arctic and Aleutian Terns was two (range one to three), although the mean was usually higher for Arctic than for Aleutian Terns (overall mean: 2.1 and 1.7 eggs per clutch, respectively).

At the Arctic Tern colonies studied in Prince William Sound, productivity appeared to be fairly stable, with the number of breeding pairs, average clutch size, and hatching success showing little variation among years. However, at the two Kodiak Island sites, fewer chicks of both Arctic and Aleutian Terns hatched in 1978 than in 1977. There were drastic reductions in the

TABLE VIII-5
Number of Chicks Hatched[a] at Four Colony Sites
in the Gulf of Alaska.

Colony	Arctic Terns		Aleutian Terns	
	1977	1978	1977	1978
Sitkalidak Strait	1225	138	555	74
Chiniak Bay	402	84	299	76
Naked Island	-	40	-	-
Hinchinbrook Island	98	35-97[b]	-	-

[a] Calculated from: No. chicks = Total no. breeding pairs x mean clutch size (sample) x hatching success (sample).

[b] Minimum - maximum possible: fate of all eggs not accounted for.

TABLE VIII-6
Productivity of Arctic Terns.

	Sitkalidak St.[a]		Chiniak Bay		Naked Is.	Hinchinbrook Is.		
	1977	1978	1977	1978	1978	1976	1977	1978
No. of nests w/eggs	25	29	96	113	28	12	56	58
No. of eggs laid	53	51	212	223	64	24	115	119
No. of eggs hatched	48	28	181	71	56	17	64	35–97[b]
No. of chicks fledged	10–42[c]							
$\overline{X}$ clutch size	2.12	1.79	2.21	1.97	2.29	2.00	2.05	2.05
$\overline{X}$ brood size @ hatching	2.08	1.80	2.01	1.92				
Eggs hatched per eggs laid (hatching success)	0.91	0.54	0.85	0.32	0.87	0.71	0.56	0.29–0.82[b]
Chicks fledged per nest w/eggs	0.40–1.68[c]	1.23				1.08[d]		
% nests w/one or more eggs hatching			93.8	32.7	66.7			

[a] Sheep Island, the least disturbed colony, only.

[b] Fate of all eggs not accounted for.

[c] Range of fledging success:
--minimum figure assumes all chicks not found died;
--maximum figure assumes all chicks not found lived to fledging.

[d] Assuming a chick that lived to 14 days lived to fledging.

TABLE VIII-7
Productivity of Aleutian Terns.

	Sitkalidak St.[a] 1977	Sitkalidak St.[a] 1978	Chiniak Bay 1977	Chiniak Bay 1978
No. of nests w/eggs	23	26	45	121
No. of eggs laid	37	35	35	216
No. of eggs hatched	24	15	75	34
No. of chicks fledged	5-19			
$\overline{X}$ clutch size	1.61	1.35	1.89	1.79
$\overline{X}$ brood size @ hatching	1.71	1.67	1.74	1.63
Eggs hatched per egg laid (hatching success)	0.65	0.43	0.88	0.16
Chicks fledged per nests w/eggs	0.22-0.83[b]			
% nests w/one or more eggs hatching			95.6	15.2

[a] Sheep Island, the least disturbed colony, only.

[b] Range of fledging success:
--minimum figure assumes all chicks not found died;
--maximum figure assumes all chicks not found lived to fledging.

numbers of Arctic and Aleutian Terns nesting in the Sitkalidak Strait area in 1978 and in numbers of Arctic Terns at Chiniak Bay in 1978 (Table VIII-1). The average clutch size also declined significantly ($P < 0.05$) for both species at these sites. This was further compounded by a marked decline in hatching success of 34-43% (Tables VIII-6, VIII-7). The lower hatching success may have been due to predation because of lack of nest-site tenacity in a food-poor year where adults were absent feeding.

Fledging success, the number of chicks fledged per egg hatched, and the overall breeding success could not be accurately determined for either species because chicks were difficult to locate in the tall grass after 1 week of age. However, Lemmetyinen (1973b) found that if terns survived to 2 weeks of age they usually survived until fledging. Thus, figures given for "fledging" are actually those of any chick over 2 weeks old. For chicks at Sitkalidak Strait in 1977, two values are given: a minimum and a maximum success at fledging. The minimum figure reflects the assumption that all chicks not found again died; the maximum figure reflects fledging success if all chicks not found again did fledge. The true figure probably occurred somewhere midway between the two extremes.

GROWTH OF CHICKS

The mean weight of newly hatched chicks was 16.3 g for Arctic Terns and 20.6 g for Aleutian Terns. The mean weight at fledging for Arctic Terns was 115.4 g and for Aleutian Terns was 120.6 g. Differences between years were not significant for either species for hatching or fledging weights. Growth rates were similar for the two species, with most rapid growth occurring within the first 2 weeks of age (Fig. VIII-4). Arctic Terns gained an average of 7.0 g per day during the period of most rapid growth, while Aleutian

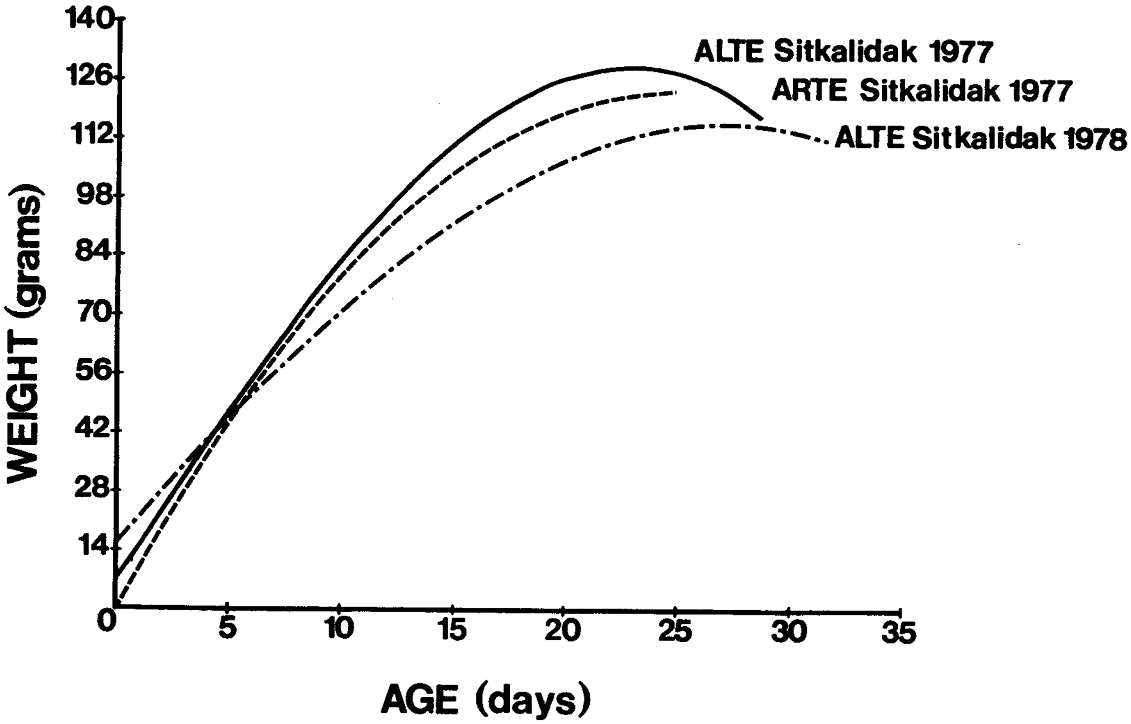


Figure VIII-4. Comparison of regression curves for growth of Arctic and Aleutian Tern chicks in Sitkalidak Strait, 1977-1978.

Terns gained an average of 8.2 g per day (Table VIII-8).

FOOD HABITS AND FEEDING ECOLOGY

Terns normally foraged near the breeding colony; at Sitkalidak Strait, the majority of terns foraged within 1 km. Observations of foraging behavior at colonies were verified by Gould et al. (1978), who found few terns during pelagic surveys off Kodiak Island throughout the summer. Terns usually fed singly or in monospecific or monogeneric groups. When in mixed flocks, they appeared to have stimulated foraging by other species, a pattern also observed for Common Terns (*Sterna hirundo*) on the Atlantic Coast (Bertin 1977).

Samples of foods fed to chicks at Sitkalidak Strait indicated that terns, like many other species of seabirds in the Gulf, foraged primarily on capelin (*Mallotus villosus*) and sand lance (*Ammodytes hexapterus*) (Tables VIII-9, VIII-10). In 1977, these two species of fish occurred in 81.1% of food samples (regurgitations) from chicks of the Aleutian Tern, and in 48.3% of samples from chicks of the Arctic Tern. In the same samples, capelin and sand lance comprised 75.0% of all the numbers of prey from Aleutian Terns and 46.4% of those from Arctic Terns. The two species of fish were similarly important in 1978 although their relative proportions had changed. Capelin decreased in 1978 by about 50% in both frequency of occurrence and total number for both Arctic and Aleutian Terns; sand lance concomitantly increased. We believe that these differences resulted from the relative unavailability of capelin in 1978, and that sand lance replaced capelin as the major food source.

Bill loads brought to chicks at each feeding usually consisted of only one or two fishes. The average time between feedings in 1978 was 48.3 min $\pm$ 7.3 (range = 7-113 min). Chicks were fed from two to five times per 24-hour period (mean = 3.5) in 1977 and from one to seven times per 24-hour period

TABLE VIII-8
Growth of Arctic and Aleutian Tern Chicks
at Sitkalidak Strait.

Age (days)	Weight (g)											
	Arctic Terns						Aleutian Terns					
	1977			1978			1977			1978		
	N	$\overline{X}$	S.E.	N	$\overline{X}$	S.E.	N	$\overline{X}$	S.E.	N	$\overline{X}$	S.E.
0-2	8	17.6	1.8	9	14.2	2.5	6	20.5	2.2	10	20.7	2.1
3-5	1	30.2	-	5	36.8	4.8	3	33.7	7.8	3	37.7	5.4
6-8	3	51.3	10.7	2	80.5	15.5	2	51.5	8.5	2	61.5	13.5
9-11	-	-	-	2	102.0	6.0	1	85.0	-	-	-	-
12-14	-	-	-	1	98.0	-	2	105.0	6.0	3	90.0	5.3
15-17	-	-	-	4	108.3	11.1	1	125.0	-	3	71.7	21.3
18-20	1	136.0	-	2	110.0	11.0	1	118.0	-	4	119.8	7.7
21-23	1	107.5	-	-	-	-	-	-	-	-	-	-
24-26	-	-	-	1	111.0	-	1	117.0	-	-	-	-
27-29	-	-	-	-	-	-	1	127.0	-	-	-	-
30-32	-	-	-	-	-	-	-	-	-	1	112.0	-

TABLE VIII-9

Frequency of Occurrence and Percent Numbers of Prey fed to Arctic Tern Chicks at Sitkalidak Strait, 1977-1978.

Prey Species	1977				1978			
	Frequency of occurrence N=58		Total number prey N=41		Frequency of occurrence N=10		Total number prey N=10	
	%	(N)	%	(N)	%	(N)	%	(N)
Capelin (*Mallotus villosus*)	39.7	(23)	36.6	(15)	20.0	(2)	20.0	(2)
Sand lance (*Ammodytes hexapterus*)	8.6	(5)	9.8	(4)	50.0	(5)	50.0	(5)
Smelt spp. (*Spirinchus* sp.)	3.4	(2)	2.4	(1)				
Unidentified Osmeridae	13.8	(8)	12.2	(5)				
Pacific sandfish (*Trichodon trichodon*)	1.7	(1)	2.4	(1)				
Unidentified sculpins (Cottidae)	3.4	(2)	2.4	(1)				
Crested sculpin (*Blepsias cirrhosis*)	5.2	(3)	7.3	(1)				
Blepsias sp.	3.4	(2)	2.4	(1)				
Cyclopteridae					10.0	(1)	10.0	(1)
Unidentified fish	17.2	(10)	19.5	(8)	10.0	(1)	10.0	(1)
Euphausiids (*Thysanoessa* sp.)					10.0	(1)	10.0	(1)
Isopods	1.7	(1)	2.4	(1)				
Aplacophora	1.7	(1)	2.4	(1)				

TABLE VIII-10
Frequency of Occurrence and Percent Numbers of Prey fed to Aleutian Tern chicks at Sitkalidak Strait, 1977-1978.

Prey Species	1977				1978			
	Frequency of occurrence N=53		Total number prey N=40		Frequency of occurrence N=12		Total number prey N=14	
	%	(N)	%	(N)	%	(N)	%	(N)
Capelin (*Mallotus villosus*)	52.8	(28)	57.5	(23)	25.0	(3)	21.4	(3)
Sand lance (*Ammodytes hexapterus*)	28.3	(15)	17.5	(7)	16.7	(2)	21.4	(3)
Smelt (*Spirinchus* spp.)	5.7	(3)	5.0	(2)				
Pacific sandfish (*Trichodon trichodon*)	1.9	(1)	2.5	(1)				
Kelp greenling (*Hexagrammos decagrammus*)					8.3	(1)	7.1	(1)
Rock greenling (*H. lagocephalus*)					8.3	(1)	7.1	(1)
White spotted greenling (*H. stelleri*)	1.9	(1)	2.5	(1)				
Unidentified fish	7.5	(4)	12.5	(5)	41.7	(5)	42.9	(6)
Euphausiids (*Thysanoessa raschii*)	1.9	(1)	2.5	(1)				

(mean = 2.9) in 1978. In 1977 there seemed to be a slight correlation between the time of feedings and turns of the tide (Baird 1978), but this pattern was not observed in 1978. The number of feedings per day was much lower than that found for Arctic Terns in England (E. K. Dunn, pers. comm.). In 1977, the mean length of prey fed to chicks was 103.9 mm (n=6, S.E.=10.3) for Aleutian Terns and was 111.0 mm (n=4, S.E.=15.6) for Arctic Terns.

The only other site at which information was gathered on foraging habits of Arctic Terns was at Naked Island in 1978. There terns were frequently observed surface-plunging alone or in small groups near the island, and were seen taking sand lance. Both sand lance and walleye pollock (*Theragra chalcogramma*) were found at colonies and thus were probably being fed to chicks.

FACTORS AFFECTING REPRODUCTIVE SUCCESS

The most significant factors influencing reproductive success of Arctic and Aleutian Terns in the colonies studied were human disturbance, predation, and exposure of eggs or young to inclement weather. Predation of eggs and chicks was noted as a major source of mortality at most colonies once nests were built (Table VIII-11); eggs that disappeared were assumed to have been taken by predators. The combined mortality of eggs and chicks was was 30-40%. Eggs that disappeared were assumed to have been taken by predators. River otters (*Lutra canadensis*) or Glaucous-winged Gulls (*Larus glaucescens*) destroyed most eggs at Naked Island in 1978. At Chiniak Bay in 1977 a river otter destroyed many chicks in one colony and the following year weasels (*Mustela* sp.) destroyed almost all eggs at another colony. At Sitkalidak Strait, Glaucous-winged Gulls, Mew Gulls (*Larus canus*), Black-billed Magpies (*Pica pica*), and Northwestern Crows (*Corvus caurinus*) preyed on chicks, and Common Ravens (*Corvus corax*) preyed on eggs of both species of terns. Adult terns were sensitive to predation of their eggs and chicks and to disturbance

TABLE VIII-11
Percent Mortality of Arctic and Aleutian Tern Eggs and Chicks at Sitkalidak Strait in 1977.

Stage of Development	Cause of Mortality	Arctic Terns N=123	Aleutian Terns N=48
Egg Stage	Disappeared (predation)	2.4	16.7
	Avian predation	1.6	0
	Shell damage	2.4	0
	Rolled out of nest	4.9	2.1
	Desertion	1.6	2.1
	Exposure	0.9	0
	Infertility	0.8	4.2
	Death of embryo	5.7	0
	TOTAL, Egg Stage	20.3%	25.1%
Chick Stage	Died pipping	4.9	2.1
	Exposure	1.6	8.3
	Starvation	0	2.1
	Unknown cause	2.4	2.1
	TOTAL, Chick Stage	8.9%	14.6%
	TOTAL, Egg + Chick	29.2%	39.7%

of the colony. They often abandoned their nests if disturbed and when their eggs were preyed on they seldom renested.

Inclement weather was also a major cause of mortality, especially during hatching. Extremely high tides flooded nests located on gravel spits at Hinchinbrook Island during all three years of study there and at Naked Island in 1978, washing away both eggs and newly hatched chicks. Violent storms occurred at Sitkalidak Strait in 1977 and 1978 during hatching, and most of the chicks hatching at the time died. At Chiniak Bay in 1977 and Naked Island in 1978 several chicks close to fledging were found dead after periods of stormy weather.

Human disturbance influenced terns during all phases of their reproductive cycle. The substantial decrease in the number of terns attempting to breed at Sitkalidak Strait in 1978 (Table VIII-1) can be directly attributed to human disturbance. In spring 1978 the vegetation on two islands that supported major tern colonies was burned. The vegetation on Sheep Island, which was burned in April, had partially recovered when terns arrived; however, vegetation on Amee Island, which was burned in May, was absent at their arrival and during nest-building. Subsequently, the numbers of Arctic and Aleutian Terns attempting to nest at Sitkalidak were reduced to 22% and 24%, respectively, of the populations nesting the previous year, greatly decreasing the overall productivity at that study site. Continued human disturbance contributed to mortality of eggs and chicks, further reducing productivity. Each year the tern colonies were heavily disturbed by natives, for whom the gathering of eggs for food was traditional.

During egging, many people of all ages, often with dogs, searched colonies for nests. Tern nests were usually hard to see and, in 1977, several eggs may have been crushed in addition to those that were gathered. However, in 1978 the lack of vegetation made the nests quite visible and many more were egged than in the previous year. Tern colonies were also frequently disturbed by picnickers during the egg and nestling stages. Such disturbance probably caused losses to nests not destroyed by egging.

Although losses caused by human disturbance may be locally severe, in most regions of the state colonies are isolated and rarely visited. Few instances of human disturbance were reported at other sites. In 1976 a helicopter landed in the midst of the colony at Hinchinbrook Island and subsequently all nests were deserted there (Nysewander and Knudtson 1977).

Only at Sitkalidak Strait in 1977 were the causes of mortality of both eggs and chicks quantified (Table VIII-11). At the three colonies studied there, which were subjected to varying amounts of human disturbance, the mortality of eggs was approximately the same for Arctic and Aleutian Terns (20.3% and 25.1%, respectively), whereas the minimum mortality of Aleutian Tern chicks (14.6%) was almost double that of Arctic Tern chicks (8.9%). Predation (by humans or otherwise) and death from exposure were the major causes of mortality of eggs. Several chicks died while pipping, and others died from exposure and starvation. Some dead chicks were found whose cause of death could not be determined, and other chicks that were not found again may have also died. Thus the mortality of chicks does not reflect the proportion that may have been taken by predators. Hatching success in colonies with no human disturbance ranged from 52-91%.

In general, productivity at different colonies was quite variable. Some trends were evident although they were largely masked by local, severe losses caused by exposure during stormy weather and by predation by humans or other species. Since mortality of chicks could not be accurately measured at most sites and was sometimes noted as severe, the number of chicks successfully hatching was not always a good reflection of productivity. However, comparison of the number of chicks produced does allow detection of some differences between years and among colonies.

The total number of chicks hatching decreased at both sites in the Kodiak Island archipelago between 1977 and 1978 but appeared to remain more stable at colonies in Prince William Sound from 1976 through 1978. Lowered productivity at Sitkalidak Strait on Kodiak reflected significant decreases in the number of pairs attempting to breed (due primarily to human disturbance), which were compounded by a slight decrease in clutch sizes and a dramatic decrease in hatching success. At Chiniak Bay on Kodiak Island numbers of pairs attempting to breed at the colonies also varied sporadically among years, but the changes could not be directly linked to either disturbance or differences between years. At Chiniak Bay, then, the large reduction in productivity of both species of terns in 1978 could be traced primarily to the extreme reduction in hatching success. Although not quantified, observations at Kodiak Island colonies in 1978 indicated that adults were off their nests for greater periods of time than in 1977, exposing eggs and chicks more to the elements and to predation. This change in behavior may have been in response to a less abundant or qualitatively poorer food supply in 1978, requiring adults to expend additional time foraging. A poorer food supply may also have been partially responsible for the decrease in number of pairs breeding and reduced clutch size. Sand lance were taken in greater numbers and frequency in 1978, whereas capelin were the dominant prey fed to chicks of both species of terns in 1977. In Prince William Sound the major prey species may have been different from those near Kodiak Island, or else the prey in the Sound may not have changed in composition or abundance as much as they appeared to have around Kodiak Island.

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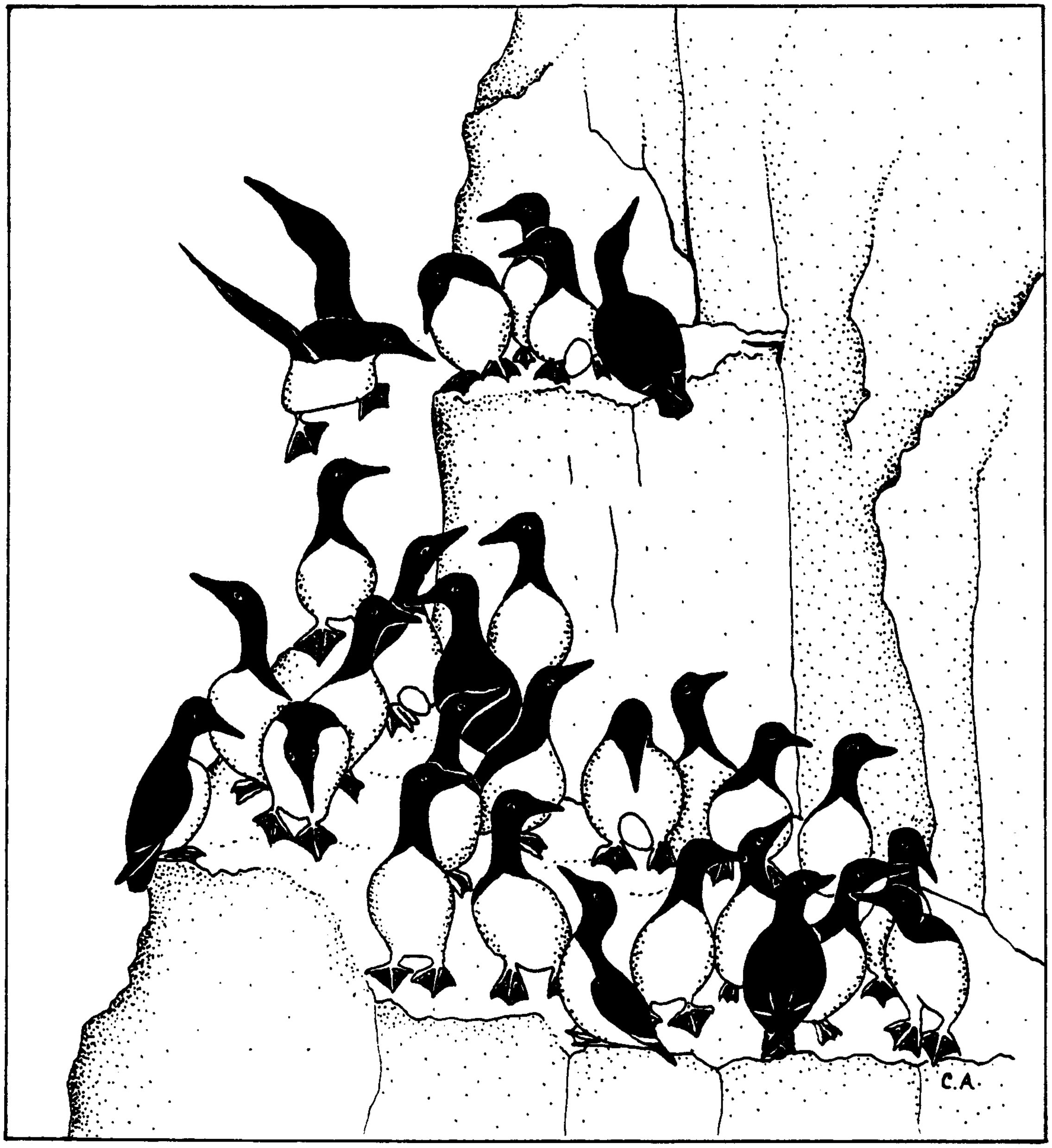
Murres (*Uria* spp.)



by

Margaret R. Petersen

COMMON AND THICK-BILLED MURRES

Uria aalge and _U. lomvia_

Common and Thick-billed Murres represent 25% of all colonial seabirds nesting in Alaska. However, until 1976 the only major study of murres in Alaska was that conducted from 1959-1961 at Cape Thompson (Swartz 1966). Early studies on the breeding biology of murres are summarized by Tuck (1960). Since then, extensive studies of Atlantic and Canadian Arctic populations have added to our knowledge on the nesting behavior and breeding biology of murres (for a review see Gaston and Nettleship 1982).

This report summarizes the results of studies conducted by the Fish and Wildlife Service on 10 widely separated colony areas in the Gulf of Alaska as listed below:

Shumagin Islands	1976	Moe and Day (1979)
Semidi Islands	1976	Leschner and Burrell (1977)
	1977	Hatch (1978)
	1978	Hatch and Hatch (1979)
Ugaiushak Island	1976	Wehle et al. (1977)
	1977	Wehle (1978)
Chiniak Bay	1977	Nysewander and Hoberg (1978)
	1978	Nysewander and Barbour (1979)
Barren Islands	1976	Manuwal and Boersma (1977)
Tuxedni Wilderness	1978	Jones and Petersen (1979)
Middleton Island	1976	Frazer and Howe (1977)
	1978	Hatch et al. (1979)
Hinchinbrook Island	1976	Nysewander and Knudtson (1977)
	1977	Sangster et al. (1978)
	1978	Kane and Boyd (1979)
Wooded Islands	1976	Mickelson et al. (1977)
	1977	Mickelson et al. (1978)
Forrester Island	1976	DeGange et al. (1977)
	1977	DeGange and Nelson (1978)

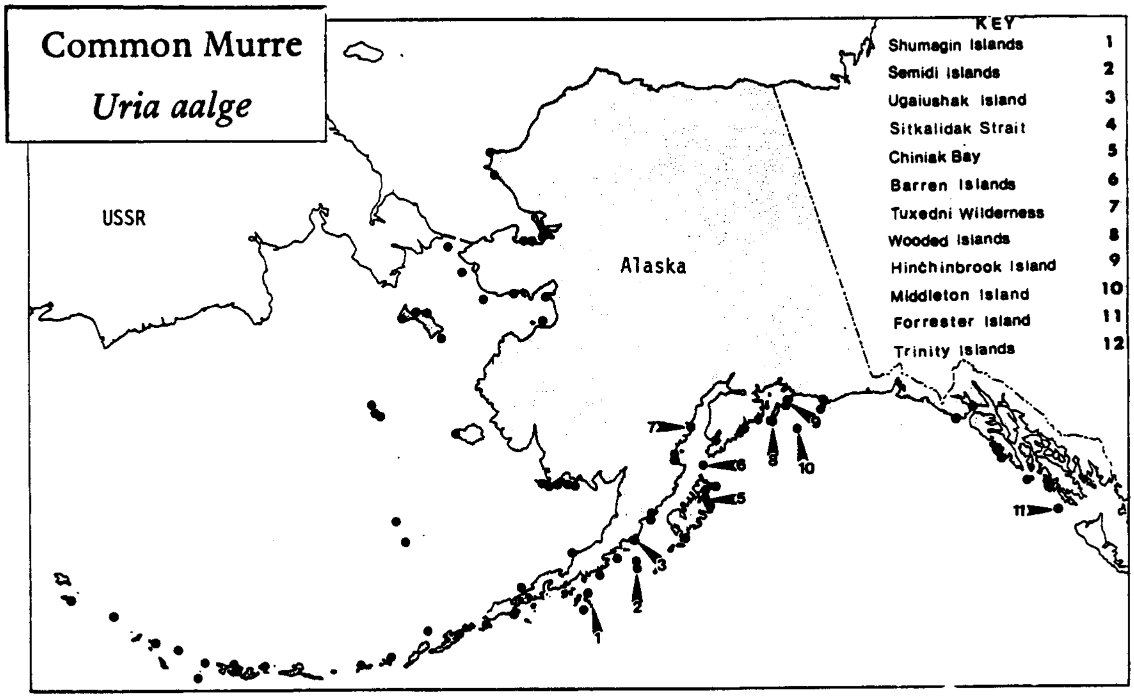
Common Murres were studied at all ten sites and Thick-billed Murres at five (Fig. IX-1). Population estimates and descriptions of nesting habitat were obtained at all colonies studied. Information on reproductive chronology was collected at seven of the study sites. The most intensive studies were at Ugaiushak Island and the Semidi Islands, where detailed information on reproductive success and colony attendance patterns, respectively, was gathered. Some information on feeding ecology was obtained at Ugaiushak and Hinchinbrook islands.

BREEDING DISTRIBUTION AND ABUNDANCE

Murres nest along the coast of Alaska from Forrester Island in southeastern Alaska to Cape Lisburne in the Chukchi Sea (Tuck 1960, Sowls et al. 1978). The Alaskan populations of Common and Thick-billed Murres have been estimated at five million breeding birds for each species, and over 1,600,000 Common and 1,760,000 Thick-billed Murres have been counted (Sowls et al. 1978). The number of birds estimated for the various colonies included in the present study ranged from 500,000 murres at the Semidi Islands to 30 pairs at the Wooded Islands (Table IX-1). The majority of the murres on these colonies were Common Murres. Thick-billed Murres occurred in large numbers only on the Semidi Islands.

NESTING HABITAT

In Alaska, murres typically nest on cliffs of islands and on mainland promontories rising abruptly from the sea. Less commonly they have been observed nesting atop predator-free islands up to several hundred meters from shore. At the colonies studied, murres typically nested tightly packed together on broad rocky ledges, although they were also found in crevices, in the entrances of puffin burrows, in dense *Elymus* and umbels, on unvegetated



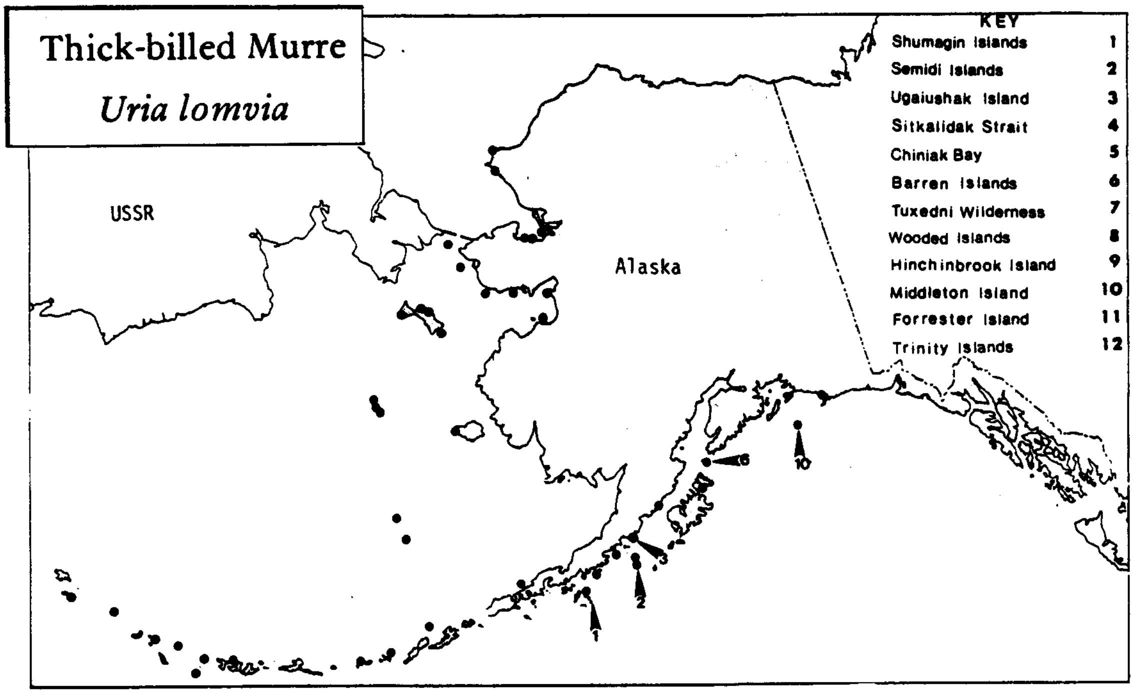


Figure IX-1. Distributions of breeding colonies of Common and Thick-billed Murres in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

TABLE IX-1
Estimated Numbers of Common and Thick-billed Murres Nesting at Study Sites in the Gulf of Alaska.

Colony	Year	Number of Birds	
		Common Murres	Thick-billed Murres
Shumagin Islands	1976	7,200	800
Semidi Islands	1976	480,000	120,000
Ugaiushak Island	1976	9,000	1,000
Chiniak Bay	1977	480	0
Barren Islands	1976	27,500	3,500
Tuxedni Wilderness	1978	10,000	0
Hinchinbrook Island	1977	1,500	0
Wooded Islands	1977	60	0
Middleton Island	1978	10,000	350
Forrester Island	1976	5,000	0

slopes, and on vegetated talus slopes. The dominance of inaccessible cliffs as nesting sites to a large extent results from the extreme vulnerability of murres to predation by land mammals when nesting in other habitats (Petersen 1982).

BREEDING CHRONOLOGY

The complete nesting chronology for both species of murres in the Gulf of Alaska can be estimated from hatching dates by assuming a 34-day incubation period and a 23-day brood-rearing period (Belopol'skii 1957, Tuck 1960). Other investigators have found the dates of egg laying by Common Murres extremely variable among colonies (Belopol'skii 1957, Tuck 1960), but laying dates at each colony studied in the Gulf of Alaska tended to be similar between years (Table IX-2, Fig. IX-2). Initiation of laying at colonies ranged from 28 May to 17 July, with the majority of first eggs laid between 5 and 20 June. Egg-laying by Common Murres spanned periods as long as 45 days at some colonies and as short as 22 days at others. Laying of replacement clutches extended the egg-laying period when eggs were lost early in the season.

Throughout the Gulf of Alaska the majority of eggs hatched during July and August, with the first young appearing in late June at Middleton Island and not scheduled to hatch until late August on Forrester Island in 1976 (Table IX-2). With murres, "fledging" refers to the time the still-flightless chick jumps off the cliff and moves out to sea (Belopol'skii 1957, Tuck 1960). As we were unable to identify individual chicks, we can only estimate the nestling period from the dates chicks were first seen leaving the colonies. Young generally "fledged" at 22 to 24 days of age, but data from the Semidi Islands suggest that some murre young may not fledge until 27 or more days of age.

Limited data on Thick-billed Murres suggest that dates of laying were

TABLE IX-2
Breeding Chronology of Common Murres.[a]

Colony & Year	Laying	Hatching	Fledging
Semidi Is.			
1976	6 June>	(10 July>)	10 Aug.>
1977	5 June-26 June	(9 July>)	8-30 Aug.
1978	8 June>	(12 July>)	8-30 Aug.
Ugaiushak Is.			
1976	17 June-20 July>	12 Aug.>	(4 Sept.>)
1977	24 June- 3 Aug.	(28 July- 7 Sept.)	(20-30 Sept.)
Barren Is.			
1977	20 June-11 July	25 July-15 Aug.[b]	(17 Aug.- 8 Sep.)
1978	25 June-18 July	30 July-25 Aug.	22 Aug.-(17 Sep.)
Tuxedni			
1978	29 June-(9 July>)	10 Aug.-(20 Aug.>)	2 Sep.-(13 Sep.>)
Hinchinbrook Is.			
1976	19 June-31 July	(23 July- 3 Sept.)	(15 Aug.-26 Sept.)
1977	21 June- 5 Aug.	31 July-(8 Sept.)	(21 Aug.- 1 Oct.)
1978	29 June- 6 Aug.	3 Aug.-(9 Sept.)	(26 Aug.- 2 Oct.)
Middleton Is.			
1976	(14 June>)	16 July>	(8 Aug.>)
1978	27 May-(23 June)[b]	(30 June-26 July)	21 July-16 Aug.
Forrester Is.			
1914[c]	11 July- 5 Aug.	13 Aug.>	(6 Sept.>)
1976	(17 July>)	(20 Aug.>)	(13 Sept.>)

[a] Dates in parentheses are calculated using 34 days for incubation period and 23 days for nestling period. At some colonies end (>) dates of periods were not determined.

[b] Estimated by aging embryos or chicks.

[c] From Willett (1915).

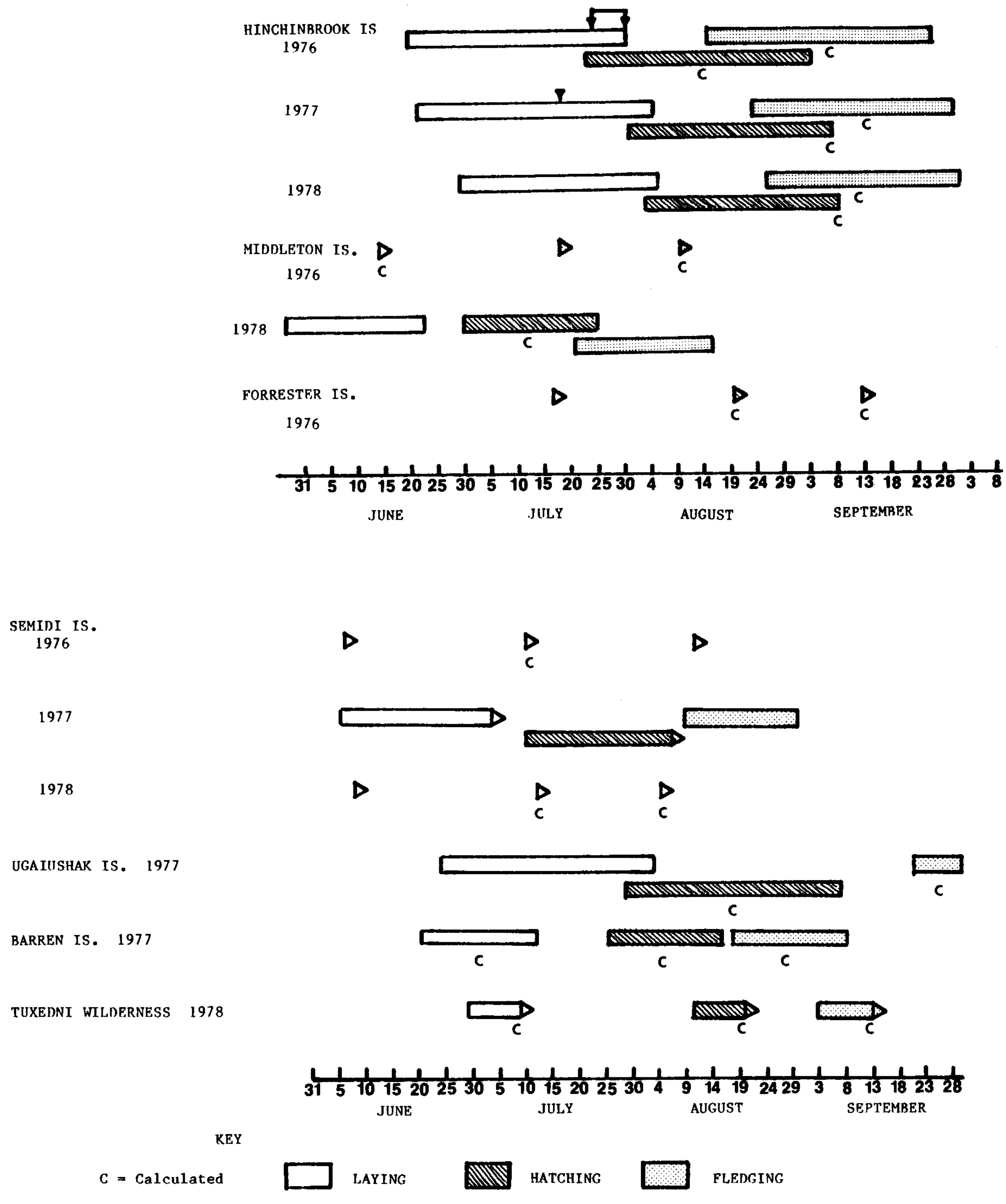


Figure IX-2. Chronology of major events in the nesting season of Common Murres in the Gulf of Alaska.

similar to those of Common Murres at both the Semidi Islands and Middleton Island (Fig. IX-3). A single egg observed at the Semidi Isands was incubated 33 days (12 June-15 July), and the chick fledged in 34 days (on 18 August). This nestling period was longer than that found by other investigators (18 to 25 days; see Tuck 1960).

REPRODUCTIVE SUCCESS

Thick-billed and Common Murres lay one egg, but may lay a second if the first is lost early in incubation (Uspenskii 1956, Tuck 1960, Swartz 1966). Hatching success ranged from 15 to 55 percent for Common Murres at three sites and was 54 percent for Thick-billed Murres at Ugaiushak Island (Table IX-3).

Reproductive success of Common Murres was variable, with 0.24 young fledged per breeding pair at Ugaiushak Island and 0.07 at the Wooded Islands. In comparison, Common Murres in colonies near Wales produced 0.7 young per breeding pair (Birkhead 1977b). Thick-billed Murres raised 0.2 fledglings per breeding pair at Ugaiushak Island in 1977, whereas those at Cape Hay, in the Canadian Arctic, raised 0.4 young per pair (Tuck 1960). Our data for murres in the Gulf of Alaska are inadequate, however, to draw any firm conclusions about the long-term productivity of murres within the region.

FOOD HABITS AND FORAGING

Young of murres in other regions are fed a wide variety of foods (Belopol'skii 1957, Tuck 1960). We have only limited data on their food habits at colonies in the Gulf of Alaska. At Ugaiushak Island, young of both species were fed primarily capelin (Mallotus villosus), and near Hinchinbrook Island young Common Murres were fed primarily herring (Clupea harengus pallasi). Fish fed to young in the Gulf of Alaska were similar in size and

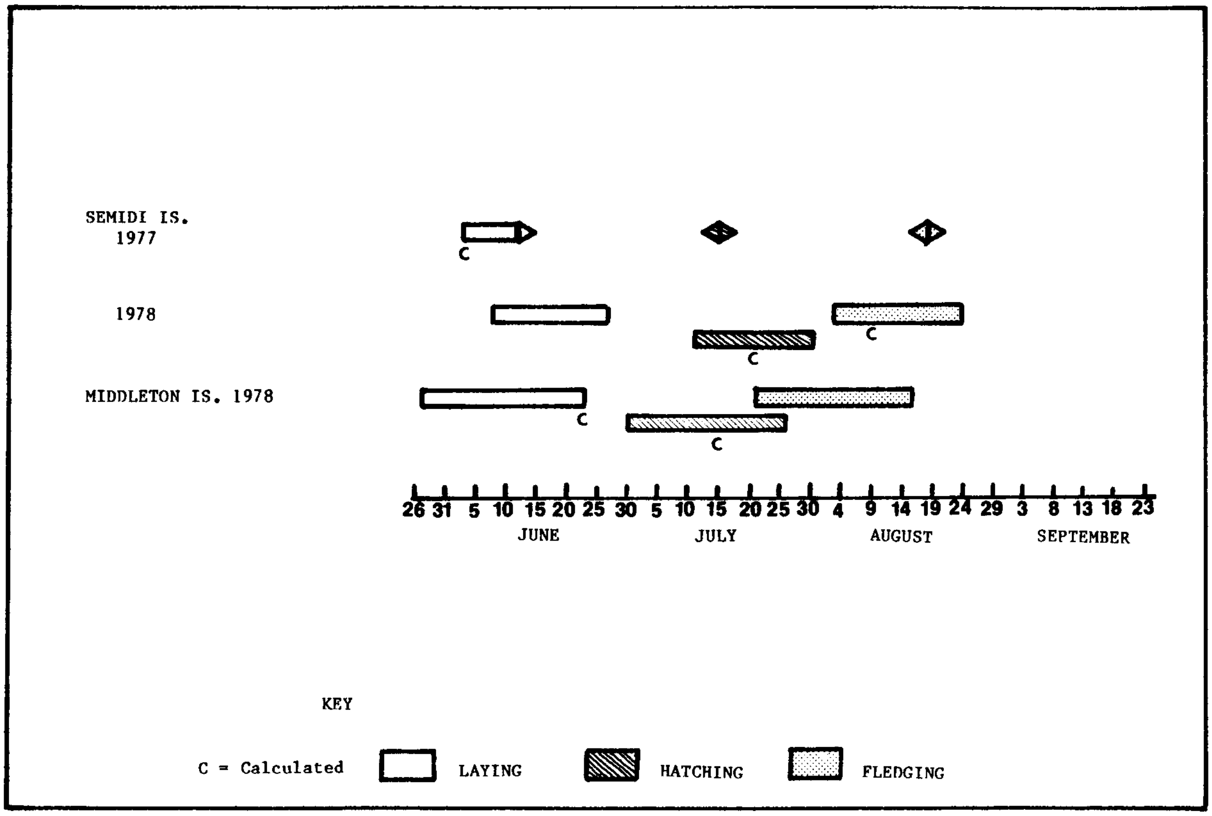


Figure IX-3. Chronology of major events in the nesting season of Thick-billed Murres in the Gulf of Alaska.

TABLE IX-3
Productivity of Common Murres and Thick-billed Murres.

	Ugaiushak Is. 1977		Barren Is. 1977	Hinchinbrook Is. 1977	Hinchinbrook Is. 1978	Wooded Is. 1976
SPECIES	COMU	TBMU	COMU	COMU	COMU	COMU
No. of nests built	55	50	—	—	—	30
No. of nests w/eggs	48	28	—	—	—	—
No. of eggs laid	60[a]	28	207	325	67	—
No. of eggs hatched	26	15	114	103	10	—
No. of chicks fledged	14	12	—	—	—	2
$\overline{X}$ clutch size	1.0	1.0	1.0	1.0	1.0	1.0
Eggs laid per nest built (laying success)	0.82[b]	0.56	—	—	—	—
Eggs hatched per egg laid (hatching success)	0.43	0.54	0.55	0.32	0.15	—
Chicks fledged per chick hatched (fledging success)	0.54	0.80	—	—	—	—
Chicks fledged per nest w/eggs	0.31	0.43	—	—	—	—
Chicks fledged per nest built (reproductive success)	0.25	0.24	—	—	—	.07

[a] Includes replacement eggs.

[b] Excludes replacement eggs.

ecological type to fish fed to young throughout the world as reported by Belopol'skii (1957) and Tuck (1960). Other species of fishes that were fed to murre young in the Gulf of Alaska included walleye pollock (*Theragra chalcogramma*), salmon (*Oncorhynchus keta* and *O. gorbuscha*), Pacific sand fish (*Trichodon trichodon*), lingcod (*Hexagrammos decagrammus*), sable fish (*Anoplopoma fimbria*), prowfish (*Zaprora silenus*), and Pacific sand lance (*Ammodytes hexapterus*)

COLONY ATTENDANCE

Common Murres visit colonies irregularly before laying eggs (Tuck 1960), but a relatively constant number of birds remains on the cliffs during incubation and early brood-rearing (Tuck 1960, Lloyd 1975, Birkhead 1978). Daily counts of Common and Thick-billed Murres at a colony in the Semidi Islands showed a similar pattern. Numbers of birds peaked at about five-day intervals before the onset of egg-laying, there were less extreme fluctuations during incubation and brood-rearing, and numbers decreased sharply when young began leaving cliffs (Fig. IX-4).

Throughout the breeding season at the Semidi Islands, non-incubating and non-breeding adults generally arrived at the colony area at sunrise. The number of birds on ledges was usually highest by 1000 hours, and remained fairly constant until 1600 hours, when non-incubating or non-brooding birds left the nesting ledges. Similarly, before egg-laying at Ugaiushak Island, birds generally left the colonies between 1600 hours and 1800 hours. Thus, at colonies in the Gulf of Alaska, counts of murres should be made during incubation and early brood rearing, and between 1000 hours and 1600 hours in order to obtain data that most accurately represent the numbers of birds using the colonies.

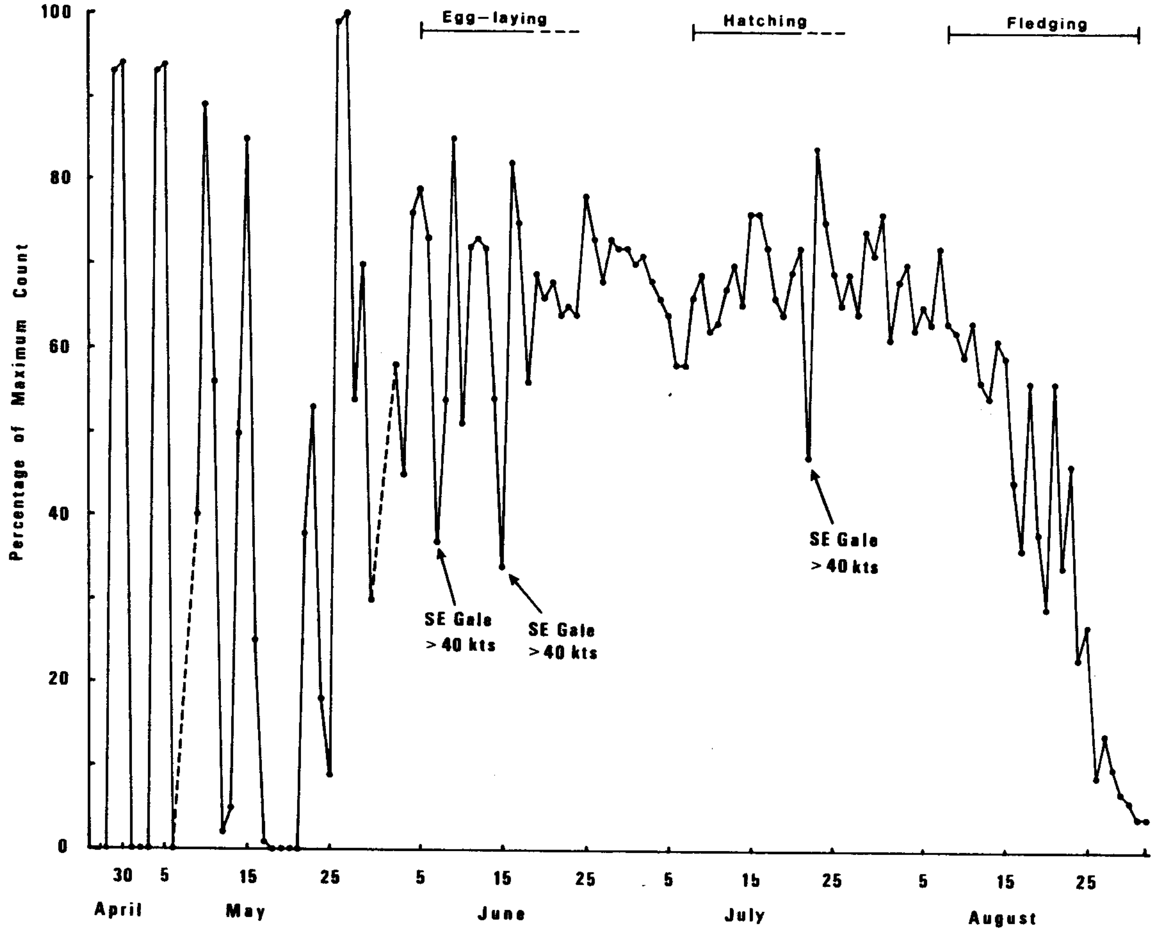


Figure IX-4. Seasonal pattern of colony attendance by Common and Thick-billed Murres at the Semidi Islands in 1977.

FACTORS AFFECTING REPRODUCTIVE SUCCESS

Breeding failure or low reproductive output of murres in the Gulf of Alaska may be relatively common. Murres produced few young at any colony. At Forrester and Hinchinbrook islands in 1976 and at the Wooded Islands in 1977, few birds laid eggs. The cause of this type of nesting failure was not apparent. More commonly, low reproductive success was attributed to losses of eggs and young through natural predation by Glaucous-winged Gulls, Common Ravens, and Bald Eagles; by exposure to storms; or from predation by gulls and ravens following human disturbance.

Murres are particularly vulnerable to disturbance, and adults flush readily from unvegetated slopes and ledges. At such times, eggs or young may be pushed from ledges, or when left unprotected may be taken by predators (Johnson 1938, Murie 1959). Eggs appear to be most vulnerable to predation early in incubation because birds are less attentive to eggs at this time (Birkhead 1977a).

Productivity of Common Murres in Wales has been shown to be influenced by the density of the birds on the ledges and the synchronization of their laying (Birkhead 1977a). Apparently, murres nesting in dense aggregations are more synchronized than those that are less crowded. Synchronized egg laying appears to reduce losses of eggs and young. Crowding of nesting ledges reduces predation because gulls and ravens are less successful at taking eggs and young from a dense group of murres than when the eggs and young are sparsely scattered along the ledges.

Birkhead's findings suggest that reproductive success on each nesting ledge depends on a minimum threshold density. Since murres are highly faithful to their nesting ledges from year to year (Birkhead 1977a), any event, such as an oil spill, which substantially reduced the number of adults breeding, could depress productivity by reducing nesting density. To assess the validity and implications of Birkhead's findings for populations of murres in the Gulf of Alaska, information is needed on reproductive success at specific nesting ledges as well as that averaged over entire colonies. Information on the normal annual variation in reproductive success at specific sites is also needed for assessing long-term productivity of murres in this region.

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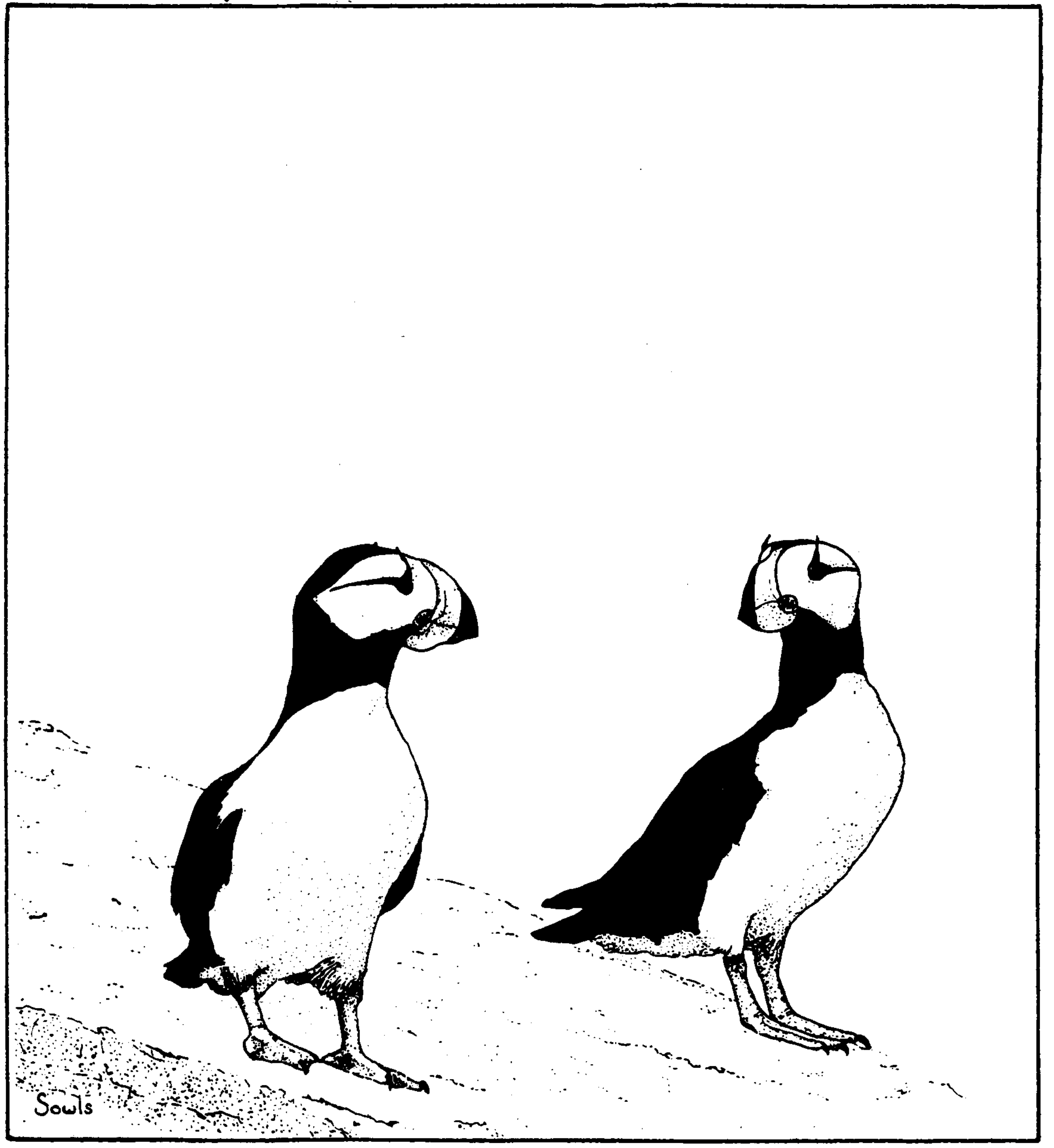
Horned Puffin

(*Fratercula corniculata*)



by

Margaret R. Petersen

HORNED PUFFINS

(*Fratercula corniculata*)

Dement'ev and Gladkov (1951) summarized all known information on the nesting environment and breeding biology of Horned Puffins. Relatively little additional information on their breeding biology was obtained prior to the initiation of the Outer Continental Shelf Environmental Assessment Program (OCSEAP) in 1975. Data on the length of incubation, nestling period, and a detailed description of nesting habitat provided by Sealy (1969, 1973) is based on information from 16 nests found on St. Lawrence Island in the Bering Sea. We began studies of seabirds at several colonies in the Gulf of Alaska in 1976 as part of the OCSEA Program. Studies at most sites were discontinued by OCSEAP after one or two years, but were continued in the Semidi and Barren Islands as a part of the Fish and Wildlife Service Program for Migratory Birds. This report summarizes data on Horned Puffins for the following colony sites and years:

Shumagin Island Group	1976	Moe and Day (1979)
Semidi Island Group	1976	Leschner and Burrell (1977)
	1977	Hatch (1978)
	1978	Hatch and Hatch (1979)
Ugaiushak Island	1976	Wehle et al. (1977)
	1977	Wehle (1978)
Sitkalidak Strait	1977	Baird and Moe (1978)
Barren Islands	1976	Amaral (1977)
	1976-1978	Manuwal and Boersma (1977, 1978)
	1979	Manuwal (1979)
Tuxedni Bay (Chisik Is.)	1978	Jones and Petersen (1979)

BREEDING DISTRIBUTION AND ABUNDANCE

Horned Puffins nest only on the coast and offshore islands of the North Pacific Ocean (see Dement'ev and Gladkov 1951 and Udvardy 1963). In Alaska, their center of abundance is on islands off the southern coast of the Alaska Peninsula from Cook Inlet to Unimak Pass where 77% of the 768,000 Horned Puffins censused in Alaska (Sowls et al. 1978) were found (Figure X-1). Horned Puffins are difficult to census because nests are usually located beneath rocks or in burrows that are often inaccessible. Consequently, counts of the breeding population at many sites are probably low. A more realistic estimate of the Alaska population of Horned Puffins is about 1.5 million birds (Sowls et al. 1978). Numbers of Horned Puffins at the colonies studied varied from a few birds to more than 150,000. Our studies of seabirds occurred on colonies covering the entire spectrum of colony size (Table (X-1).

NESTING HABITAT

Horned Puffins lay eggs in cracks of cliff faces and rock slopes, in crevices beneath piles of large rocks, in shallow burrows in rock-sod slopes, and in burrows in sod-grass slopes. Spacing of nests, as measured by distance to nearest neighbor, was compared for different habitats among colonies and within each colony (Table X-2). At the Shumagin Islands, nests on boulder slopes were closer than those in other habitats ($F=22.42$, $P<0.001$). At the Semidi Islands, distances between nests did not vary among habitats, although nesting densities were higher on boulder slopes than in any other habitat. Spacing between nests in the rock-sod habitat was similar at all colonies.

Spacing of nests was similar among colonies for some habitats. Distances between nests were similar in rock-sod slope habitats. On cliff-face and boulder slope habitats, birds on the Shumagins nested significantly closer together than those on the Semidis ($F=9.89$, $P<0.003$). Variation in the distribution of nests between and within colonies probably reflected availability of suitable nesting sites in different habitats and factors such as presence of predators, stability of the substrate, and preference of puffins for

Horned Puffin (*Fratercula corniculata*)

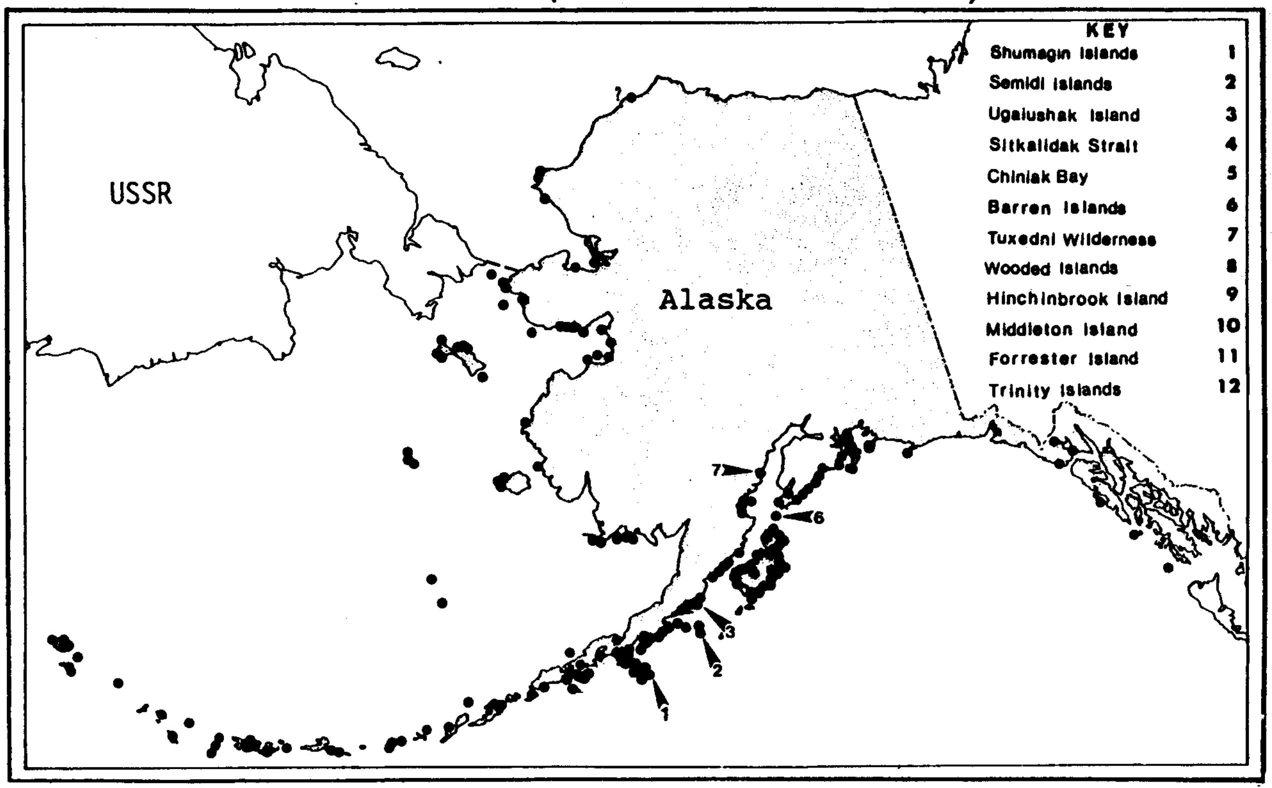


Figure X-1. Distribution of breeding colonies of Horned Puffins in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

TABLE X-1
Estimated Numbers of Horned Puffins Nesting at Study Sites in the Gulf of Alaska.

Colony	Number of birds
Shumagin Islands	100,900
Semidi Islands	164,000
Ugaiushak Island	18,200
Sitkalidak Strait	72
Chiniak Bay	550
Barren Islands	12,700
Tuxedni Bay	5,000
Wooded Islands	30
Hinchinbrook Island	108
Naked Island	114
Forrester Island	870

TABLE X-2
Dispersion of Horned Puffin Nests
in Different Habitats.

Habitat type	Shumagin Islands		Semidi Islands			Tuxedni Wilderness Area		
	N	Nearest Neighbor (m)	N	Density (per m^2)	Nearest Neighbor (m)	N	Density (per m^2)	Nearest Neighbor (m)
Boulder slopes (rock piles)	18	0.91±0.08[a]	28	0.20	2.00±0.28		--	--
Rock-sod slopes	3	1.77±0.79	18	0.05	2.50±0.54	10	0.18±0.04	2.60±0.68
Cliff faces	10	3.30±0.48	15	0.02	1.81±0.29		--	--
Sod-grass slopes		--	9	0.01	2.89±0.60		--	--

[a]Mean ± SE

particular substrates.

Each nest consisted of a small amount of grass beneath the egg. Young Horned Puffins were semiprecocial and often roamed throughout the burrow or crevice system. In most instances, nests were recognizable only by the presence of an egg or young in or near them. Nest cavities were often used for several consecutive years although we don't know if such use was by the same individuals.

BREEDING CHRONOLOGY

Horned Puffins may leave their eggs unincubated for a short time immediately after the egg is laid if the incubating adult is disturbed, thus calculations of laying dates from hatching dates may be incorrect. To calculate laying, hatching, and fledging dates, I used an incubation period of 41 days (N=20, $\bar{X}$=41.2±0.77, range=38-49 days) and a nestling period of 42 days (N=12, $\bar{X}$=42.3±0.85, range=37-46 days). These compare with incubation and nestling periods of 41 days and 38 days respectively for Horned Puffins on St. Lawrence Island (Sealy 1973).

At Kodiak Island and throughout the western Gulf of Alaska, Horned Puffins laid eggs from early-June to early-July (Table X-3, Fig. X-2). Peak of laying generally occurred from 10-25 June, and eggs hatched from mid-July to mid-August. General observations at Naked Island (Oakley and Kuletz 1979) and Wooded Islands (Mickelson et al. 1977, 1978) suggest that the peak of egg-laying may occur in early July in Prince William Sound.

Field crews usually left the study sites prior to fledging. The earliest fledging date we have is 28 August at Tuxedni Bay. Based on calculated dates, fledging at most colonies occurred from early to late September (Table X-3).

REPRODUCTIVE SUCCESS

It was difficult to determine the reproductive success of Horned Puffins

TABLE X-3
Breeding Chronology of Horned Puffins.[a]

Colony	Year	N	Laying	Hatching	Fledging
Shumagin Is.	1976	32	18 Jun.- 4 Jul. Peak: 23-25 Jun.	28 Jul.-14 Aug.	(8 Sep.-25 Sep.)
Semidi Is.	1976	35	14 Jun.- 9 Jul. Peak: 22 Jun.	23 Jul.-17 Aug. Peak: 31 Jul.	(3 Sep.-28 Sep.)
	1977	37	12 Jun.-(26 Jun.)	20 Jul.- 7 Aug. Peak: 29 Jul.	(31 Aug.-18 Sep.)
	1978	33	13 Jun.-29 Jun.	(21 Jul.-10 Aug.)	(1 Sep.-21 Sep.)
Ugaiushak Is.	1976	29	15 Jun.-27 Jun.	23 Jul.-(7 Aug.)	(3 Sep.-18 Sep.)
	1977	44	(14 Jun.-28 Jun.) (Peak: 14-21 Jun.)	25 Jul.- 7 Aug. Peak: 25-30 Jul.	(5 Sep.-18 Sep.)
Barren Is.	1976	14	14 Jun.-20 Jun. Peak: 19 Jun.	22 Jul.-31 Jul.	(2 Sep.-11 Sep.)
	1977	14	12 Jun.-28 Jun.	21 Jul.-10 Aug.	(1 Sep.-21 Sep.)
	1978	16	2 Jun.- 5 Jul.	22 Jul.-17 Aug.	(2 Sep.-28 Sep.)
Tuxedni Bay	1978	29	5 Jun.-29 Jun. Peak: 10-23 Jun.	18 Jul.-10 Aug. Peak: 19-26 Jul.	(28 Aug.-21 Sep.)

[a] Numbers in parentheses are calculated dates.

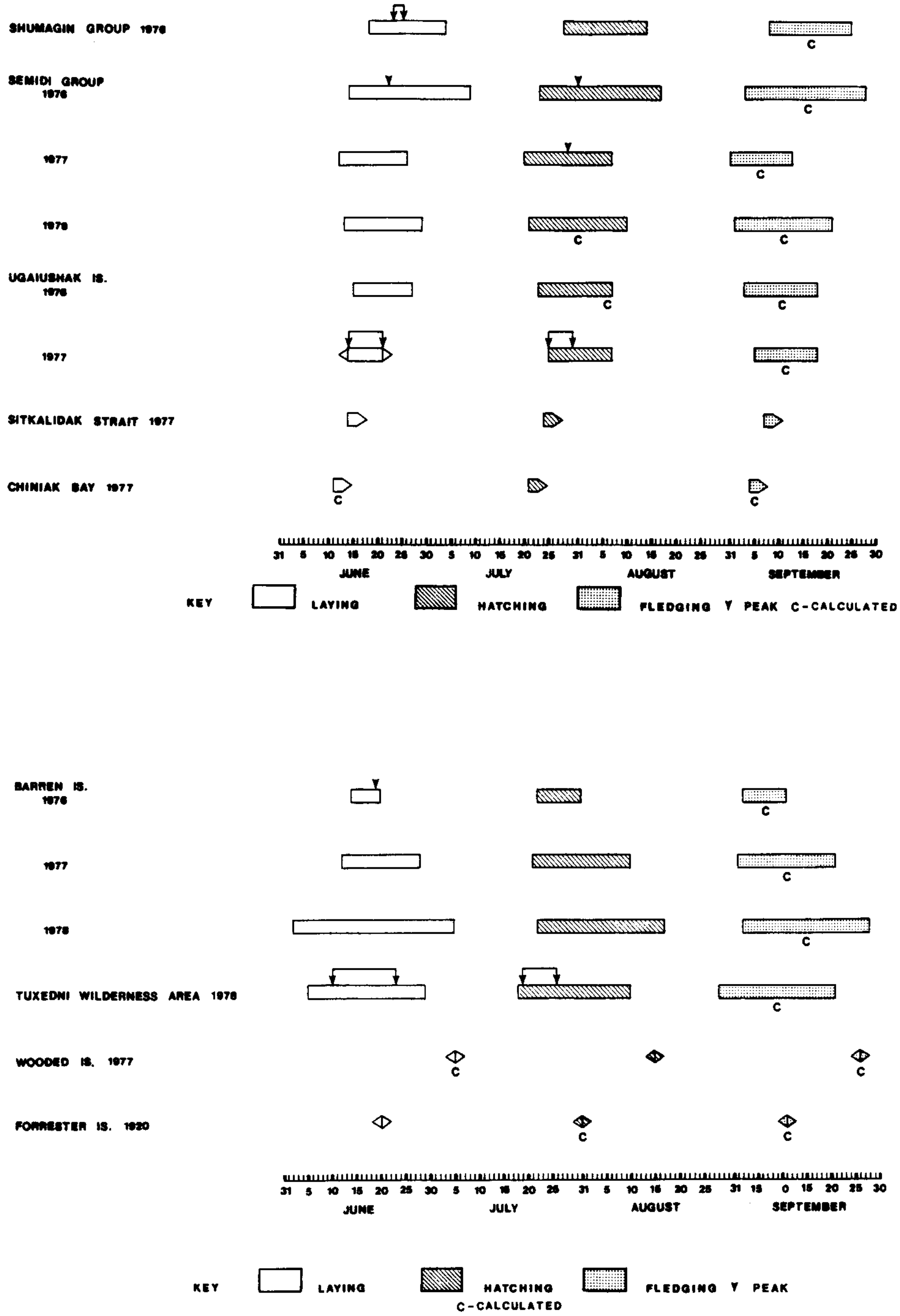


Figure X-2. Chronology of major events in the nesting season of Horned Puffins in the Gulf of Alaska.

for 3 reasons: 1) active nests were not identified unless eggs were present, thus mature birds which failed to lay eggs or those that lost eggs before our observations began were unknown, 2) estimating mortality was made difficult by chicks disappearing in the recesses of the nest cavity, and 3) it was difficult to separate losses due to our disturbances from those due to more natural forms of mortality.

Hatching success varied from 0.67 to 0.93 and fledging success varied from 0.36 to 0.92 (Table X-4). The number of young fledged per nest-with-egg ranged from 0.29 to 0.72. Overall reproductive success was determined for colonies in the Barren Islands and Tuxedni Bay where success was 0.41 and 0.67 chicks fledged per nest attempt, respectively. Samples were insufficient to test statistically for differences in productivity between colonies and between years.

GROWTH OF CHICKS

Growth of Horned Puffin chicks was measured primarily by daily gain in weight (Table X-5), and usually followed a sigmoid curve (Fig. X-3). To compare growth at various sites, we used only the straight-line part of the curve (days 10-34). Between days 10 and 34, 10 chicks at the Barren Islands gained 10.1 $\pm$ 1.0 g per day, 8 chicks at the Shumagins gained 12.6 $\pm$ 1.4 g per day, and 12 chicks at Chisik Island gained 10.7 $\pm$ 0.7 g per day. At the Semidi Islands, chicks were apparently starving in 1976 (Leschner and Burrell 1977) and grew very slowly (12 chicks gained 5.7 g per day). Again in 1977, growth was slow at the Semidi Islands (3 chicks gained 3.4 $\pm$ 1.3 g per day). Chicks at the Semidi Islands were also smaller at fledging age than those elsewhere (Table X-6).

FOOD HABITS AND FORAGING

Adult Horned Puffins fed chicks a variety of small fish (Table X-7).

TABLE X-4
Productivity of Horned Puffins in the Gulf of Alaska, 1976-1978.

	Shumagin Island	Semidi Islands		Ugaiushak Island	Barren Islands			Tuxedni Bay
	1976	1976	1977	1977	1976	1977	1978	1978
No. of nests built						22		25
No. of nests w/eggs	22	48	37	68	14	14	18	24
No. of eggs hatched	16	32	25	52	11	13	16	18
No. of chicks fledged[a]		19	4[b]	10[c]	4	9	13	23[d]
Nests w/eggs per nests built (laying success)						0.64		0.97
Eggs hatched per eggs laid (hatching success)	0.73	0.67	0.68	0.76	0.79	0.93	0.89	0.73
Chicks fledged per egg hatched (fledging success)		0.60	0.50	0.91	0.36	0.69	0.81	0.88
Chicks fledged per nest w/eggs		0.40	0.34	0.69	0.29	0.64	0.72	0.66
Chicks fledged per nest built (reproductive success)						0.41		0.63

[a] Includes those young still alive but not yet fledged, upon termination of studies.

[b] From a subsample of 8 chicks.

[c] From a subsample of 11 chicks.

[d] From a subsample of 26 chicks.

Table X-5.
Weight Gain in Horned Puffin Chicks in the Gulf of Alaska.

Age (days)	Shumagin Islands 1976				Ugaiushak Island 1977				Barren Islands 1977			
	N	$\overline{X}$(g)	SE	Range	N	$\overline{X}$(g)	SE	Range	N	$\overline{X}$(g)	SE	Range
0-2	9	53.9	2.5	38-67	5	53.4	2.7	45-60	7	55.0	3.4	44-66
3-5	8	80.5	8.1	64-136	6	92.5	6.0	80-120	5	77.8	7.8	57-102
6-8	10	122.4	6.5	99-165	7	119.0	10.8	82-160	7	95.7	5.6	60-112
9-11	4	172.5	18.0	140-217	4	153.8	10.9	135-185	4	139.0	12.1	107-165
12-14	7	206.3	18.2	156-239	6	190.8	12.6	150-227	9	147.8	11.7	85-186
15-17	7	253.9	13.4	197-311	4	234.3	20.5	195-292	6	195.8	15.9	148-244
18-20	6	271.5	15.5	209-319	5	252.0	8.8	235-375	4	234.0	19.7	194-288
21-23	4	308.0	14.4	276-377	4	289.8	23.9	240-355	7	223.9	19.3	152-290
24-26	4	323.2	15.0	290-355	4	339.5	12.9	324-378	7	289.9	27.2	205-385
27-29	2	379.0	13.0	366-392	3	347.3	32.1	285-392	6	330.8	27.3	255-422
30-32	3	399.3	15.2	369-417	3	352.7	8.8	340-370	3	358.3	13.6	340-385
33-35	1	397	-	-	2	367.0	7.0	360-374	2	335.0	85.0	250-420
36-38	-	-	-	-	-	-	-	-	1	270	-	-
39-41	-	-	-	-	-	-	-	-	-	-	-	-
42-44	-	-	-	-	-	-	-	-	-	-	-	-
45-47	-	-	-	-	-	-	-	-	-	-	-	-

Table X-5. Continued.

Age (days)	Semidi Islands 1976				Semidi Islands 1977				Tuxedni Bay 1978			
	N	$\overline{X}$(g)	SE	Range	N	X(g)	SE	Range	N	$\overline{X}$(g)	SE	Range
0-2	7	59.9	2.5	50-69	5	56.0	3.3	47-67	7	54.6	2.4	45-60
3-5	9	73.8	4.0	50-89	5	95.6	4.0	84-109	7	89.1	6.9	60-120
6-8	12	93.4	4.4	82-120	3	116.0	7.1	107-130	5	98.0	8.0	90-115
9-11	9	114.3	8.7	65-157	2	147.0	6.0	141-153	3	157.5	20.6	124-196
12-14	11	140.2	7.4	102-175	3	184.3	11.6	169-207	7	193.7	11.4	155-250
15-17	9	154.1	8.9	113-183	2	217.5	9.5	208-227	3	222.7	9.8	205-239
18-20	12	173.3	9.4	110-220	2	245.0	0.0	245-245	3	264.7	15.7	248-296
21-23	13	204.9	9.0	160-271	1	267	-	-	5	307.4	13.6	275-350
24-26	13	219.3	11.3	160-289	-	-	-	-	4	290.0	17.8	240-320
27-29	10	231.7	7.3	190-267	2	255.0	31.0	224-286	4	362.5	12.5	350-400
30-32	8	234.5	8.8	185-286	2	271.0	5.0	266-276	3	333.3	8.8	320-350
33-35	7	247.3	9.5	205-283	1	291	-	-	2	390.0	10.0	380-400
36-38	2	211.5	28.5	183-240	-	-	-	-	3	383.3	28.5	350-440
39-41	-	-	-	-	-	-	-	-	4	372.5	4.3	360-380
42-44	-	-	-	-	-	-	-	-	3	400.0	23.1	360-440
45-47	-	-	-	-	-	-	-	-	1	350.0	-	-

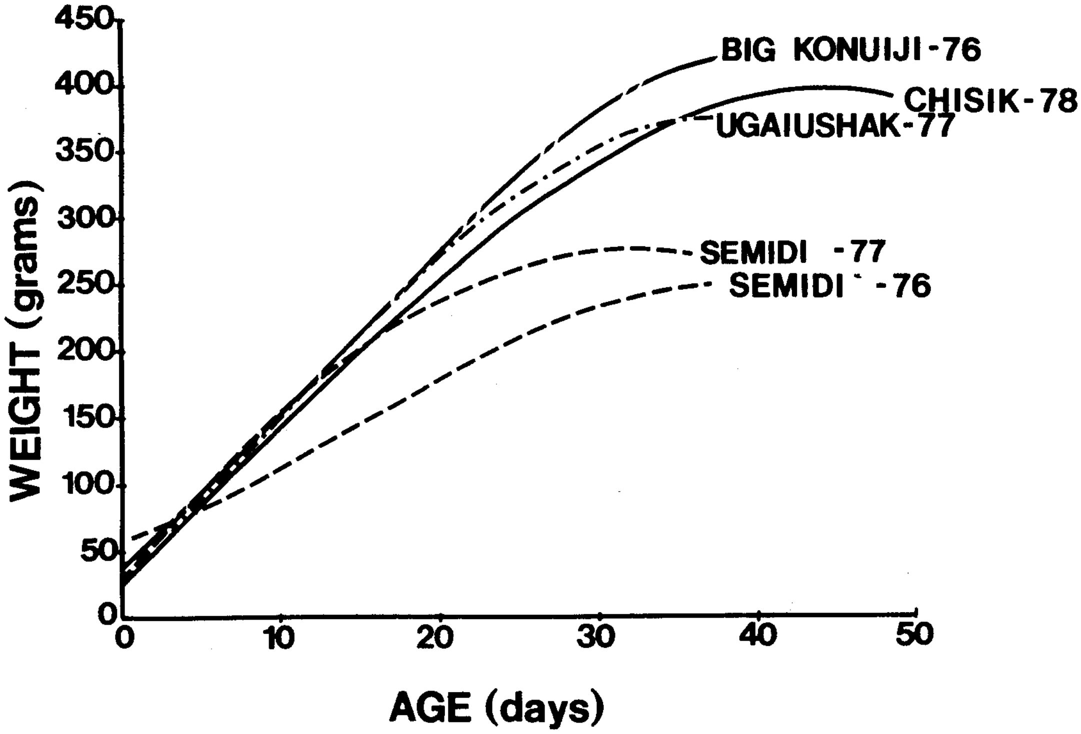


Figure X-3. Comparison of regression curves for growth of Horned Puffin chicks at four study sites in the Gulf of Alaska, 1976-1978.

TABLE X-6a
Measurements of Culmens of Horned Puffin Chicks at Hatching (day 1) and near Fledging (day 35-42).

Barren Islands		Shumagin Islands		Semidi Islands		Tuxedni Bay	
Hatching	Fledging	Hatching	Fledging	Hatching	Fledging	Hatching	Fledging
n=1	n=1	n=5	No Data	n=4	n=5	n=3	n=18
$\bar{X}$=18.0	$\bar{X}$=28.0	$\bar{X}$=17.68		$\bar{X}$=18.25	$\bar{X}$=26.68	$\bar{X}$=18.87	$\bar{X}$=31.41
-	-	SE= .48		SE= .25	SE= .59	SE= .62	SE= .26

TABLE X-6b
Measurements of Tarsi of Horned Puffin Chicks at Hatching and near Fledging.

Barren Islands		Shumagin Islands		Semidi Islands		Tuxedni Bay	
Hatching	Fledging	Hatching	Fledging	Hatching	Fledging	Hatching	Fledging
n=1	n=1	n=5	No Data	n=4	n=5	n=3	n=18
$\bar{X}$=25.0	$\bar{X}$=37.0	$\bar{X}$=18.80		$\bar{X}$=25.00	$\bar{X}$=35.90	$\bar{X}$=20.73	$\bar{X}$=31.79
-	-	SE= .16		SE= .41	SE= .40	SE= .49	SE=0.34

TABLE X-6c
Measurements of Wings of Horned Puffin Chicks at Hatching and near Fledging.

Barren Islands		Shumagin Islands		Semidi Islands		Tuxedni Bay	
Hatching	Fledging	Hatching	Fledging	Hatching	Fledging	Hatching	Fledging
n= 1	n= 1	n= 1	No Data	n= 1	n= 5	No Data	n= 18
$\bar{X}$=30.0	$\bar{X}$=133.0	$\bar{X}$=23.0		$\bar{X}$=25.00	$\bar{X}$=110.40		$\bar{X}$=147.11
-	-	-		-	SE=8.29		SE= 2.43

TABLE X-7
Percent Numbers of Prey Brought to Horned Puffin Chicks, 1976-1978.

Prey species	Shumagin Islands 1976 (N=149)	Barren Islands 1976-1978 (N=77)
Capelin (*Mallotus villosus*)	22.8%	51.9%
Sand lance (*Ammodytes hexapterus*)	63.8%	42.9%
Pacific Cod (*Gadus macrocephalus*)	11.4%	1.3%
Pacific Sandfish (*Trichodon trichodon*)	0.7%	2.6%
Whitespotted Greenling (*Hexagrammos stelleri*)	0%	1.3%
Unidentified Flatfish	0.7%	0%
Unidentified Eel	0.7%	0%

Both male and female puffins brought food to their young several times a day until the chick left the burrow. Seventeen bill loads of fishes brought to young were randomly collected at Koniuji Island in the Shumagin group from 14-28 August 1976. An average of 5.9 items (range=1-16, SE=1.20) was carried by each adult. Bill loads weighed an average of 13.7 g (range=9.6-25.4 g, SE=0.99).

Sand lance (Ammodytes hexapterus) and capelin (Mallotus villosus) were the most common fish fed to Horned Puffin chicks in the Gulf of Alaska. This was particularly true at the Shumagin Islands and Barren Islands, where the two species constituted over 87% and 95%, respectively, of the food items brought to Horned Puffin nests (Table X-7). The two fish were also important foods of Horned Puffin chicks at Ugaiushak and Semidi Islands. Sand lance was the only fish brought to chicks at Tuxedni Bay in 1978. At Buldir Island, in the western Aleutians, the fish most frequently fed to Horned Puffin chicks was Atka Mackeral (Pleurogrammus monopterygius), followed in frequency by sand lance, squid, and Irish lord (Hemilepidotus jordani) (Wehle 1976).

The tendency for Horned Puffins to forage in shallow waters within 2 km of shore has been documented by Willet (1915) at Forrester Island, Swartz (1966) at Cape Thompson, Sealy (1973) at St. Lawrence Island, and Wehle (1976) at Buldir Island. Wehle (1976) felt that depth of water was probably an important factor influencing the feeding distribution of Horned Puffins since he found feeding flocks over sea mounts and other shallow (<180 m) areas. Adults at the Shumagin Islands (1976) fed near shore over shallow waters, and puffins at Tuxedni Bay fed up to 35 km from the colony in waters 50-100 m deep.

COLONY ATTENDANCE

Daily counts of Horned Puffins on colonies were made at the Semidi Islands. Numbers of puffins peaked at 3-day intervals before egg-laying, at 3- to 4-day intervals during incubation, and at 4-day intervals until the young fledged (Fig. X-4). How these attendance patterns relate to the breeding status of individuals, foraging patterns of individuals, availability of food or hourly changes in attendance is unknown.

Wehle (1976) showed that at Buldir Island, Horned Puffins normally arrive on the colony beginning 2 hours before sunset and cease arriving 15 minutes after sunset. When chicks were present, there was a mid-morning peak.

FACTORS AFFECTING REPRODUCTIVE SUCCESS

The proportion of adults that did not migrate to the breeding areas, or that arrived at the nesting areas but did not lay eggs was not determined for any of the populations studied. Without such information, evaluation of all factors affecting productivity is not possible. This discussion is limited to factors influencing mortality of eggs and chicks.

Loss of eggs was the primary cause of low reproductive success. Primary reasons for eggs not hatching include death of embryos, desertion of nests by adults, and the disappearance of eggs from nests (Table X-8). Disturbance of nesting pairs by investigators may have been an important factor contributing to each of these sources of mortality.

Loss of young was primarily attributed to storms. Disappearances of chicks from burrows could result from a number of factors including: predation, movement of young within or outside of the burrow system, and the collapsing of nest chambers. Heavy rains frequently caused flooding of nest chambers, especially those surrounded by rock. Such flooding can cause young to die from exposure or drowning. Losses to mammalian predators (rodents, foxes, etc.) were not a major cause of mortality, although the nesting distribution and selection of nest sites may be influenced by the presence or absence of predators. Because some of the chicks which disappeared

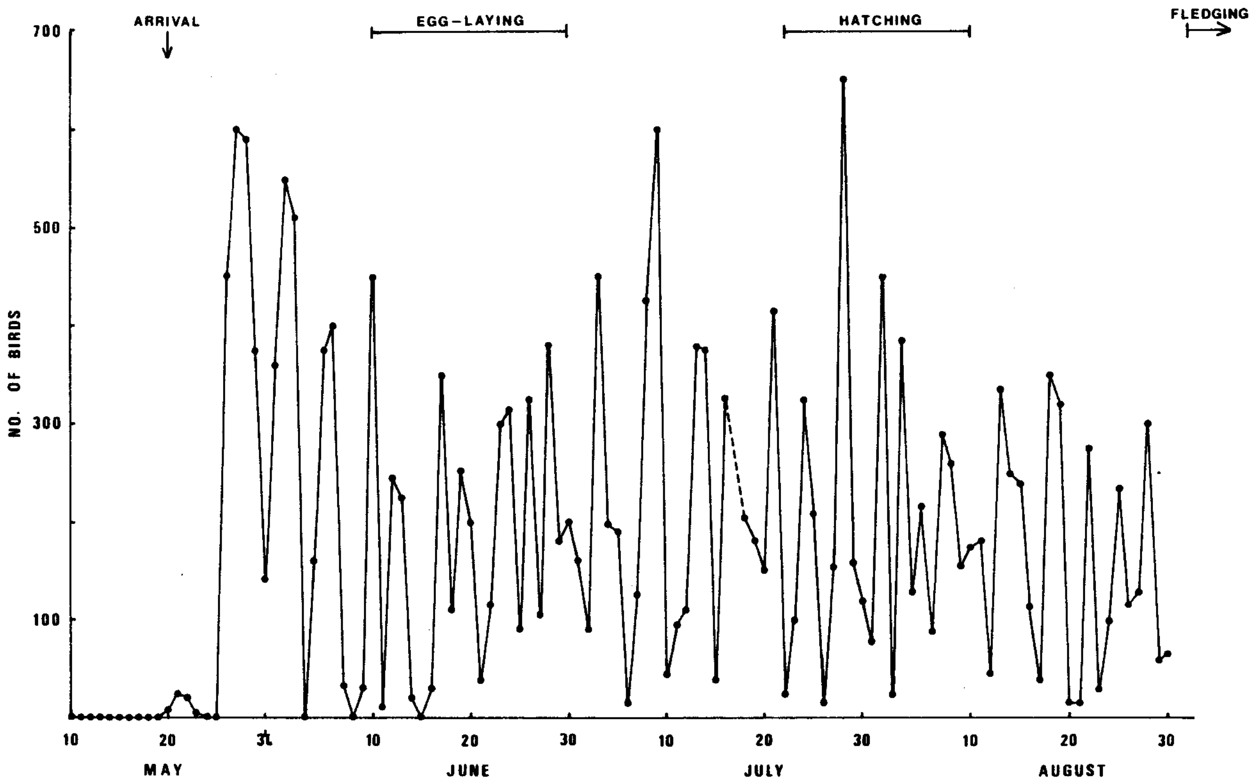


Figure X-4. Daily counts of Horned Puffins on the water made at the same time (0700-0900 h) and location, Semidi Islands, 1977.

TABLE X-8
Mortality of Horned Puffin Eggs and Chicks.

Cause of Mortality	Shumagin Is. 1976(N=22)	Semidi Is. 1976(N=48)	Semidi Is. 1977(N=37)	Ugaiushak Is. 1977(N=68)	Barren Is. 1976(N=14)	Barren Is. 1977(N=14)	Barren Is. 1978(N=18)	Tuxedni Bay 1978(N=24)	TOTAL (All sites)
Egg Stage									
Desertion	13.6%	12.5%	-	11.8%	14.3%	-	11.1%	12.5%	9.8%
Rolled out of burrow	-	4.2%	-	-	-	-	-	4.2%	1.2%
Embryo died	-	2.1%	32.4%	11.8%	7.1%	-	-	16.7%	10.6%
Mammalian Predation	9.1%	-	-	-	-	-	-	-	0.8%
Avian Predation	4.6%	-	-	-	-	-	-	-	0.4%
Disappeared	-	14.6%	-	-	-	-	-	4.2%	3.3%
TOTAL EGGS	27.3%	33.3%	32.4%	23.5%	21.4%	0 %	11.1%	37.5%	26.1%
Chick Stage									
Exposure	-	-	2.7%	7.4%	35.7%	7.1%	11.1%	-	5.7%
Rodent Predation	-	4.2%	-	-	-	-	-	-	0.8%
Fox Predation	4.6%	-	-	-	-	-	-	-	0.4%
Puffin Predation	-	2.1%	-	-	-	-	-	-	0.4%
Disappeared	-	14.6%	2.7%	0 %	7.1%	14.3%	5.6%	12.5%	6.1%
Starved	-	6.3%	-	-	-	-	-	-	1.2%
Deserted	-	-	-	-	7.1%	7.1%	-	-	0.8%
Killed by Unknown Predator	-	-	5.4%	-	-	-	-	-	0.8%
TOTAL CHICKS	4.6%	27.1%	10.8%	7.4%	50.0%	28.6%	16.7%	12.5%	16.3%
TOTAL MORTALITY (Eggs &Chicks)	31.8%	60.4%	43.2%	30.9%	71.4%	28.6%	27.8%	50.0%	42.5%

may not have died, mortality may be overestimated.

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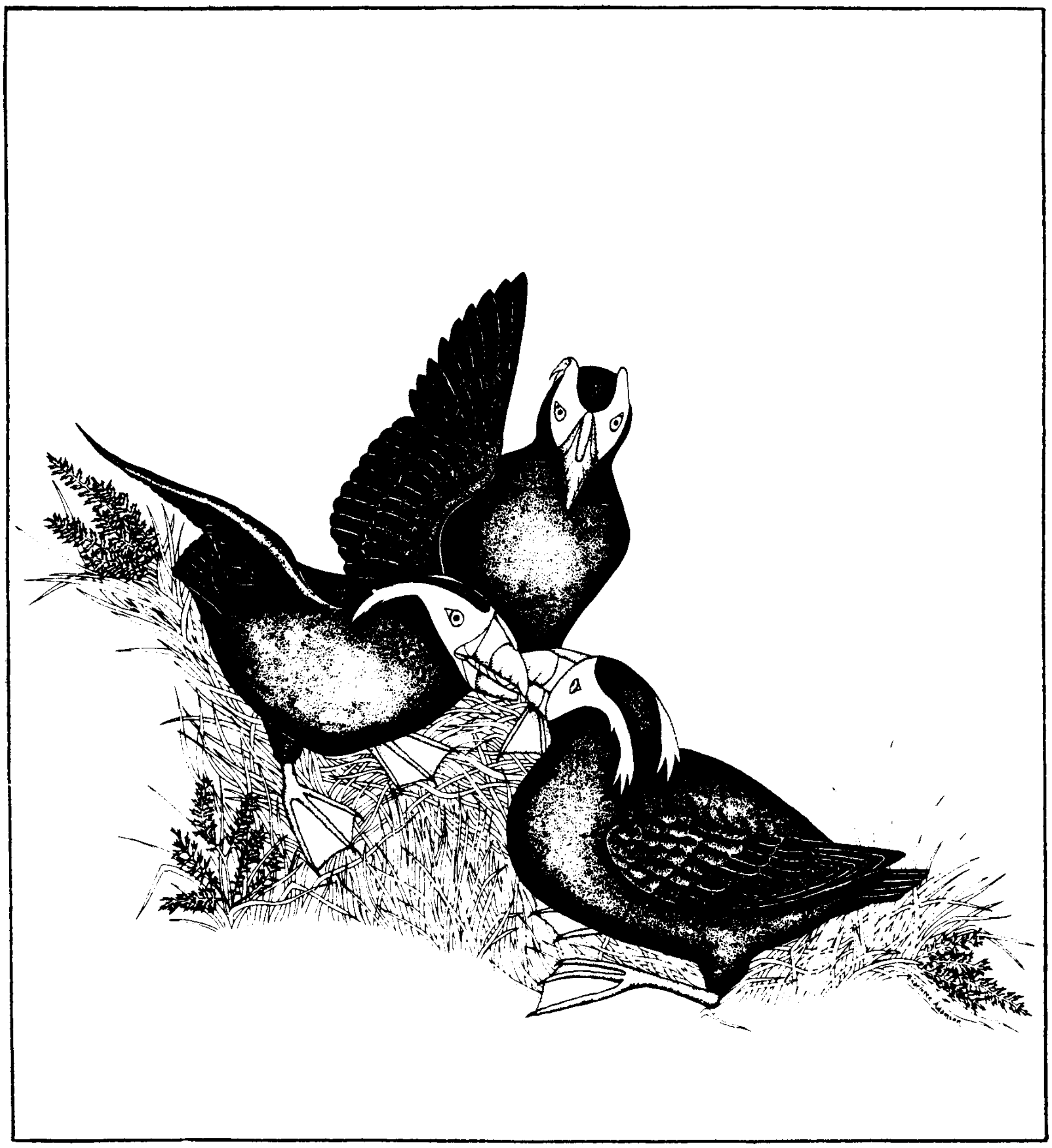
Tufted Puffin (*Lunda cirrhata*)



by

Patricia A. Baird and Robert D. Jones, Jr.

TUFTED PUFFIN
(*Lunda cirrhata*)

Tufted Puffins are among the most ubiquitous and abundant but least studied of Alaskan marine birds. Bent (1919) summarized reports of naturalists who had traveled in Alaska to provide what little was then known of the breeding biology and distribution of Tufted Puffins. Gabrielson and Lincoln (1959) reviewed more recent literature and added their own substantial observations gained on a three-month cruise in Alaska in 1946. Not until the present decade, however, have there been intensive studies of the Tufted Puffin's biology. Shuntov (1972) provided information on their pelagic distribution in the North Pacific Ocean and Bering Sea. Substantially new information on the distribution of nesting colonies was presented at a symposium held in 1975 on the "Conservation of Marine Birds of Northern North America", at which many researchers discussed the distribution and status of Tufted Puffins: Bartonek and Sealy (1979) along the coasts of the Chukchi and Bering Seas; Sekora et al. (1979) in the Aleutian Islands; Sowl (1979) in the Gulf of Alaska; and Manuwal and Campbell (1979) on the coasts of southeastern Alaska, British Columbia and Washington. At the same conference, Ainley and Sanger (1979) discussed the relationships between Tufted Puffins and their prey.

This report synthesizes information on Tufted Puffins collected at the following locations in the Gulf of Alaska and at one location in the Bering Sea (Fig. XI-1):

Cape Peirce	1976	Petersen and Sigman (1977)
Shumagin Group	1976	Moe and Day (1979)
Semidi Group	1976	Leschner and Burrell (1977)
Ugaiushak Island	1976	Wehle et al. (1977)
	1977	Wehle (1978)

Tufted Puffin (*Lunda cirrhata*)

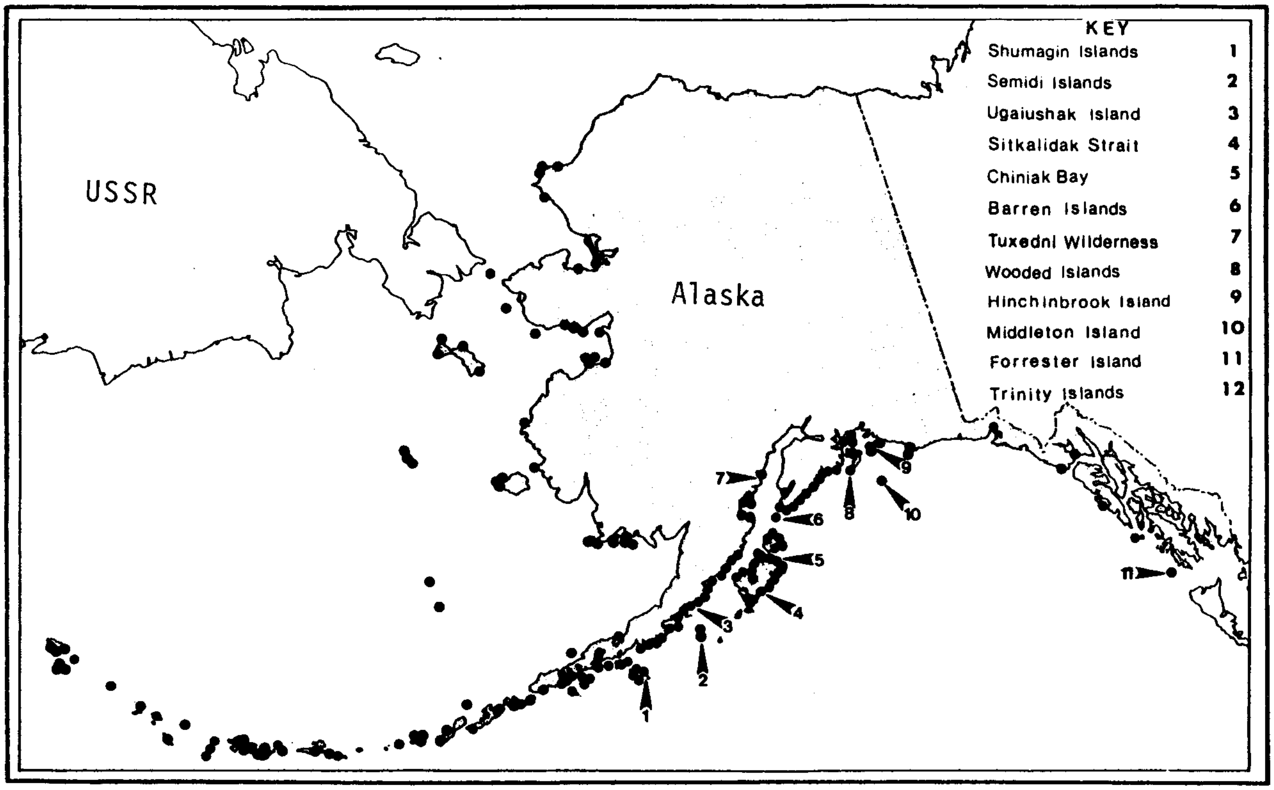


Figure XI-1. Distribution of breeding colonies of Tufted Puffins in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

Sitkalidak Strait	1977	Baird and Moe (1978)
	1978	Baird and Hatch (1979)
Chiniak Bay	1977	Nysewander and Hoberg (1978)
	1978	Nysewander and Barbour (1979)
Barren Islands	1976	Manuwal and Boersma (1977)
	1977	Manuwal and Boersma (1978a)
	1978	Manuwal and Boersma (1978b)
Chisik Island	1978	Jones and Petersen (1979)
Wooded Islands	1976	Mickelson et al. (1977)
	1977	Mickelson et al. (1978)
Hinchinbrook Group	1976	Nysewander and Knudtson (1977)
	1977	Sangster et al. (1978)
Middleton Island	1978	Hatch et al. (1979)
Forrester Island	1976	DeGange et al. (1977)

BREEDING DISTRIBUTION AND ABUNDANCE

This largest of puffins occurs only in the North Pacific where its center of abundance is in the eastern Aleutian Islands and western Gulf of Alaska. Numbers decline rapidly both south and north of this area although colonies extend from Cape Lisbourne in the Chukchi Sea south to southern California and west to Hokkaido in Japan. Tufted Puffins spend the winter in the open north Pacific Ocean and southern Bering Sea (Shuntov 1972).

Sowls et al. (1978) identified 502 colony areas in Alaska (Figure XI-1). Censuses revealed approximately 2.1 million breeding birds on colonies and Sowls et al. (1978) estimated that the total Alaskan population was probably close to 4 million. The western Gulf of Alaska alone accounted for 350 known colonies (70%) containing approximately 1.1 million known birds (52%). Tufted Puffins are the most common breeding bird in many areas, i.e., the Kodiak, Wooded, and Barren islands. The size of their colonies may range from under 50 birds to over 100,000 birds. At Egg Island in the eastern Aleutians there are an estimated 163,300 Tufted Puffins, making it the largest

Tufted Puffin colony in the world (D. J. Forsell, pers. comm.).

Numbers of birds on colonies studied ranged from about 2,400 at Hinchinbrook Island to over 108,000 in the Shumagin Islands. At smaller subcolonies, the numbers of breeding birds were as low as a few pairs. Population sizes in the Gulf of Alaska seem to be relatively stable based on our observations. Year to year variations at the Barren Islands, for example, averaged around 14% during our studies (Table XI-1).

NESTING HABITAT

Tufted Puffins nested most commonly on small offshore islands free of mammalian predation. In such island habitats, they displayed a preference for nesting on steep sea-facing slopes or cliff edges with low herbaceous cover and soil depths of at least 30-40 cm. Many of these islands have suitable burrowing habitat only around the island periphery so that Tufted Puffin colonies in the Gulf of Alaska were frequently doughnut-shaped. Less often they nested in weathered rock crevices or on gradual slopes (Table XI-2).

Vegetation in nesting areas was relatively impoverished as compared to adjacent areas and usually consisted of short forbs, grasses, or sedges, including Angelica lucida, Heracleum lanatum, Festuca spp., Carex spp., and Elymus arenarius mollis. The sparse vegetation around burrows resulted in part from activities of the Tufted Puffins. After a few years the ground around their burrows became quite eroded. Amaral (1977) noted that puffins nesting in rock crevices flew to vegetated areas to obtain nest material. Burrows varied in length and in shape, often depending on the depth and nature of the soil and the steepness of the slope on which they were excavated. Amaral (1977) found that in deep soil some burrows exceeded 160 cm in length. The majority of the burrows, however, were excavated for a distance of approx-

TABLE XI-1
Estimated Numbers of Tufted Puffins Nesting
at Study Sites in the Gulf of Alaska.

Colony	1975	1976	1977	1978
Shumagin group		108,482		
Semidi group		65,200		
Ugaiushak Island		14,000		
Sitkalidak Strait			9,000	10,714
Chiniak Bay	16,600			16,600
Barren Islands	94,000	105,000	93,000	74,000[a]
Wooded Island		4,800		
Hinchinbrook group		2,400		
Middleton Island				3,000
Forrester group		73,400		

[a] Minimum number

TABLE XI-2
Parameters of the Nesting Habitat of Tufted Puffins.

Colony	Description of nesting site	Height above sea level (m)	$\bar{X}$ Density (burrows/m^2)	$\bar{X}$ Soil depth (cm)	$\bar{X}$ Slope (°)
Semidi Is.	Vegetated slopes; boulders in rock piles (Chowiet Island).				
Ugaiushak Is.	Vegetated slopes (East Island); rock crevices in vegetated talus (West Island); burrows w/in 5 m of cliff edge.				
Chiniak Bay	Low vegetation between cliff tops & low grass;		0.49-0.66 cliff habitat		
	flat tops of islands in a ring 1-10 m wide.		0.10 flat habitat		
Sitkalidak Strait	Grassy slopes *Calamagrostis* dominated 50% within 3 m of edge.	4- 25	0.94 (range= 0.30-2.17)	35.8 (range= 34.1-37)	25.0° (range= 21.6-28.8)
Barren Is.	Steep slopes w/*Heracleum*, *Angelica*, *Elymus*;	92-110	0.48 (range= 0.35-0.68)		58-80°:high density 45-50°:low density
	cliff edges w/*Angelica*, *Elymus*, *Festuca*;	35- 49	0.40 (range= 0.15-0.65)		90°:high density 34-37°:low density
	rock talus w/*Angelica*, *Festuca*, moss;	354-408	0.44 (range= 0.38-0.50)		36°:high density 32°:low density
	gradual slopes w/ *Heracleum*, *Angelica*, *Elymus*, *Festuca*, and *Empetrum*.	76- 98	0.18 (range= 0.07-0.33)		36-46°:high density 30-34°:low density
Wooded Is.	Cliff edges grassy slopes, rocky slopes, boulder slides, 83% of burrows w/in 2 m of edge.		0.07 (range= 0.02-0.13)		

imately 30 cm into the hill and then turned at right angles and continued 60-90 cm more. Dick et al. (1976) described several other varieties of burrow shapes and lengths at the colonies around Chiniak Bay, Kodiak Island. Baird and Hatch (1979) measured lengths and shapes of 124 burrows at the Sitkalidak Strait colonies and found that the mean depth into the slope was 51 cm. Side branches occurred in 69% of the burrows and these branches continued for an average of 40.3 cm. Many Tufted Puffins continued to excavate and lengthen their burrows throughout the season.

Apparently, the steepness of the terrain, the proximity to the edge of marine cliffs and the soil depth, were all important for puffins in choice of a nest site at a particular colony (Table XI-2). Amaral (1977) found that on the Barren Islands, densities of burrows were greatest on the steeper parts of the slopes and that soil depth there also was greatest. Sparsest burrow densities occurred at approximately 20° and increased as the slope increased. Highest nesting densities occurred on slopes of 90°. However, in the densest colony at Sitkalidak Strait, the slope was 26.3°. Amaral (1977) found that densities decreased rapidly from the cliff edges and most burrows were within 2 m of the cliff edge. Baird and Hatch (1979) found 50% of the burrows within 3 m of the cliff edge and Mickelson et al. (1977) reported the extreme situation in the Wooded Islands where 83% of all burrows were within 2 m of the cliff edge.

Depending on the characteristics of habitat, the occurrence of mammalian predators, and perhaps other factors, nesting densities varied from scattered to extreme crowding, e.g., Cathedral Island in Sitkalidak Strait had 1 nest/m^2. Nesting densities are probably even higher in some of the larger colonies such as the Baby Islands, Kaligagan Island, and Rootok Island in Unimak Pass and Amagat Island near Morzhovoi Bay, each of which contains more than 100,000 birds. Nearest neighbor distances ranged from 79.8 cm in preferred habitats to 114.5 cm on less preferred sites.

Puffins nested in atypical habitat on Forrester and Middleton islands. At Forrester Island, some puffins had no burrows and simply placed their nests in openings of the dense ground cover of moss (DeGange et al. 1977). At Middleton Island, many pairs nested on a wrecked ship stranded on the beach (Hatch et al. 1979). They located their nests in the closets, storage bins, shower stalls and under the bunks. The nests on the ship were lined with grass and feathers of Black-legged Kittiwakes, whereas the nests in the more typical habitat had no lining.

BREEDING CHRONOLOGY

Tufted Puffins winter at sea and from November through March they are widely dispersed with most of the population at or beyond the edge of the continental shelf (Forsell and Gould 1980). They return to their breeding grounds in early May and begin egg-laying from mid-May through the first week in June. During the period of our studies, nesting began as early as 12 May on Middleton Island in 1978 and as late as 29 May on Ugaiushak Island in 1977. The majority commenced egg-laying the last week of May (Figure XI-2, Table XI-3). At one site there was usually not more than a week's variation in chronology from year to year. In general, the initiation of laying appeared to be roughly synchronous throughout the Gulf in all years. The only clearly significant departure from this synchronous laying was the early nesting at colonies on Middleton Island in 1978. Here, first eggs were laid about two weeks earlier than at any other colonies. Other stages of the nesting season were similarly advanced at Middleton. It is perhaps significant that other species, e.g., Black-legged Kittiwakes, also nested earlier on Middleton Island in 1978 than at other colonies (Hatch et al. 1979).

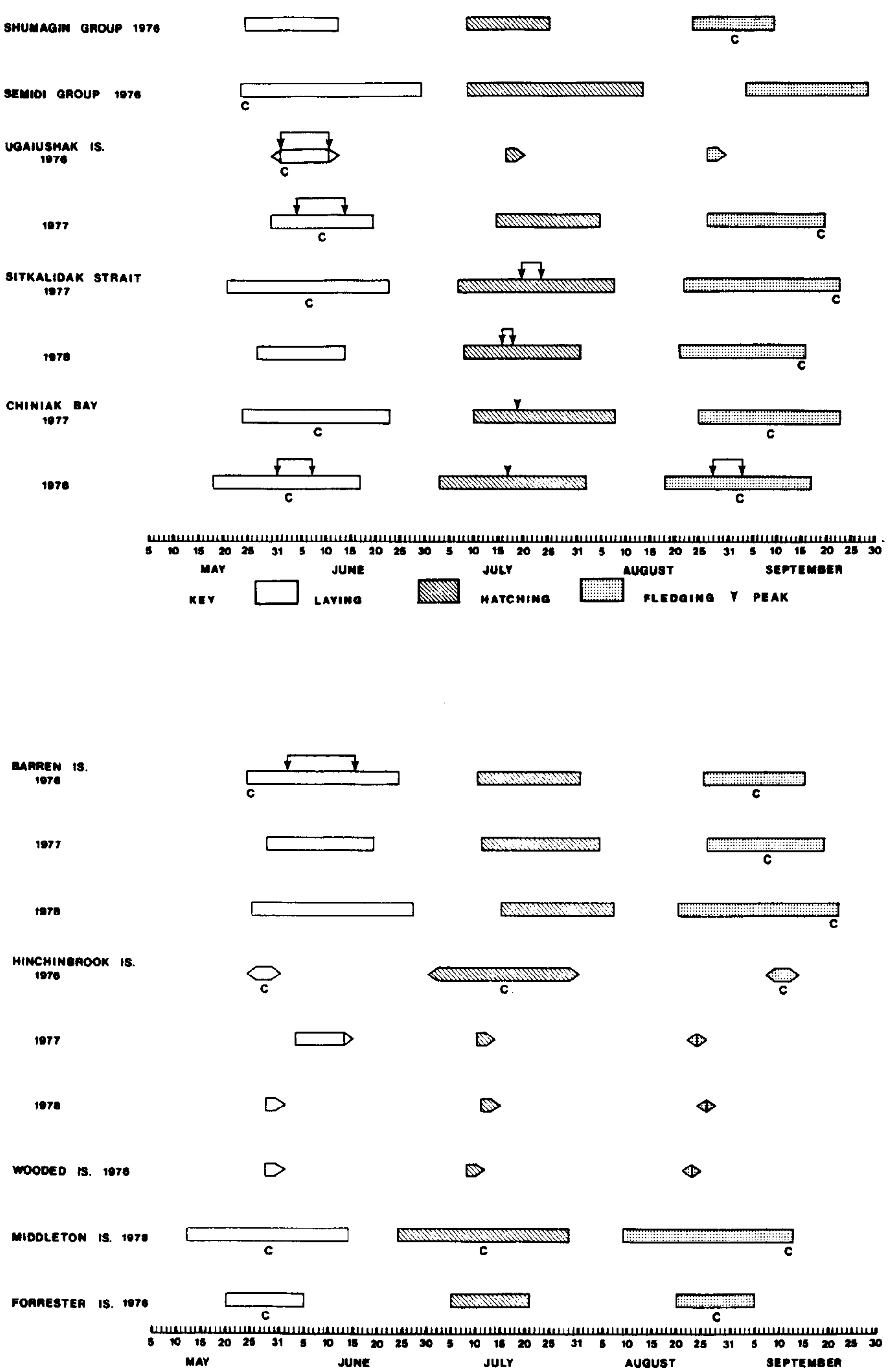


Figure XI-2. Chronology of major events in the nesting season of Tufted Puffins in the Gulf of Alaska.

TABLE XI-3
Breeding Chronology of Tufted Puffins.

Colony Site	Year	Laying	Hatching	Fledging
Shumagin Is.	1976	25 May-13 June (peak 3 June)	9 July-26 July (peak 15 July)	24 Aug.[a]-10 Sept.[a]
Semidi Is.	1976	25 May[a]-30 June	9 July-14 Aug. (peak 19 July)	4 Sept.-29 Sept.[a]
Ugaiushak Is.	1976	2 June >[a,b] (peak 1-11 June)	17 July >[b]	27 Aug. >[b]
	1977	30 May[a]-21 June[a] (peak 4-14 June)[a]	15 July-5 Aug.	27 Aug.-20 Sept.[a]
Sitkalidak St.	1977	22 May[a]-24 June[a]	7 July-8 Aug. (peak 20-24 July)	22 Aug.-23 Sept.[a] (peak 6 Sept.)
	1978	27 May-14 June	5 July-1 Aug. (peak 16-18 July)	21 Aug.-16 Sept.[a] (peak 25 August)
Chiniak Bay	1977	25 May[a]-24 June[a]	10 July-8 Aug. (peak 19 July)	25 Aug.[a]-23 Sept.[a]
	1978	18 May[a]-18 June[a] (peak 1-7 June)[a]	3 July-2 Aug. (peak 17 July)	18 Aug.[a]-17 Sept.[a] (peak 25-31 Aug.)[a]
Barren Is.	1976	25 May[a]-24 June (1-15 June)	10 July-31 July	25 Aug.[a]-15 Sept.[a]
	1977	28 May-19 June	11 July-4 Aug.	26 Aug.[a]-19 Sept.[a]
	1978	25 May-27 June	15 July-7 Aug.	20 Aug.-22 Sept.[a]
Hinchinbrook	1976	< 25-31 May >[b,c]	< 1 July-31 July >[b,c]	< 9 Sept.-12 Sept.>[a,b,c]
Is.	1977	31 May >[b] (4-13 June)	10 July >[b]	24 Aug. >[b]
	1978	28 May >[b]	11 July >[b]	26 Aug. >[b]
Wooded Is.	1976	28 May >[b]	8 July >[b]	< 23 Aug. >[b,c]
Middleton Is.	1978	12 May[a]-14 June[a]	24 June[a]-29 July[a]	9 Aug.[a]-13 Sept.[a]
Forrester Is.	1976	20 May[a]-5 June[a]	5 July-21 July	20 Aug.[a]-5 Sept.[a]

a Date calculated.
b End date (>) not determined.
c Beginning date (<) not deternined.

The incubation period ranged from 41-54 days (X=45) with variability due to egg neglect (Figure XI-2, Table XI-3). Hatching began in the first two weeks of July, and continued for 3-5 weeks with the last chicks hatching as late as mid-August. The majority of Tufted Puffins on all sites had chicks by the first week in August. Variations indicated by data in Table XI-3 may largely have resulted from inadequate sampling or disturbance. The nestling stage for Tufted Puffins ranged from 40-59 days with a mean of 47 days (Figure XI-2, Table XI-3). First puffin chicks left the nest the third week in August, except at Middleton Island where they first left 9 August. The fledgling period continued for a month at most sites. Late fledging of chicks on the Semidi Islands was related to abnormally slow growth. The first chick fledged at 54 days while other chicks in burrows appeared to be starving and were 54-59 days of age when field work was terminated. By the last two weeks in September, the majority of puffin chicks had left nest sites at all colonies studied.

The total period adult puffins remained on colonies extended a maximum of 150 days from early May to late September. The period of nesting, considering all colonies and years of study, extended 135 days from 12 May to 23 September. The nesting period at individual colonies ranged from 108-127 days and averaged 118 days.

REPRODUCTIVE SUCCESS

In common with studies of other burrow nesting species, studies of reproduction in Tufted Puffins encounter numerous difficulties that may produce bias in observations. Chief among these is the extreme sensitivity of puffins to disturbance, in particular at the stages of pre-nesting, egg-laying, and early incubation. Desertion of nests because of disturbance by investigators usually results in serious underestimation of both the number of eggs laid and of the survival of eggs to hatching. Once the egg hatches, however, Tufted Puffins become more tolerant of such intrusions. Likewise, in order to ascertain the activity at burrows or presence of eggs or chicks, one must greatly disturb individual nests and sometimes the whole colony. Attempts to reduce such biases by investigators at individual study areas relied on a variety of techniques, but even similar techniques may produce diverse results in colonies with different biological or physical characteristics.

We monitored Tufted Puffin burrows in what we designated as "disturbed" plots (Table XI-4) and "undisturbed" plots (Table XI-5). Disturbed plots were visited frequently, often at 3-4 day intervals, to determine if and when eggs and chicks were present. Burrows in undisturbed plots were visited a maximum of 3-4 times; once to verify activity at the burrow, sometimes once or twice to check for chicks, and once near fledging. In several cases the burrows were visited only once, just prior to anticipated fledging.

At several sites we checked for activity in Tufted Puffin burrows by placing toothpicks across the burrow entrance. If these were brushed aside within twenty-four hours we concluded the burrow was active. Some amount of visiting in burrows apparently occurred in all the colonies, and some burrows were simply excavated and abandoned. Thus, activity in a Tufted Puffin burrow did not always lead to deposition of an egg and subsequent steps in the reproductive cycle. Our data (Table XI-6) indicate that 84-90% of the burrows at an average colony site were active, but that only 44-70% were used for breeding during a given year.

Laying success, the proportion of active burrows with eggs, averaged 0.57 between 1976 and 1978 among 4 heavily disturbed colonies in the Gulf of Alaska (Table XI-4), and 0.87 in 1977 and 1978 at the relatively undisturbed

TABLE XI-4
Productivity of Tufted Puffins. Data Obtained from Frequently Visited (= Disturbed) Plots.

	Shumagin Islands	Semidi Islands	Ugaiushak Islands		Sitkalidak Strait		Barren Islands			Hinchinbrook Islands	
	1976	1976	1976	1977	1977	1978	1976	1977	1978	1976	1977
No. active burrows	—	—	94	167	93	103	85	100	78	—	—
No. burrows with eggs	51	38	52	99	67	69	40	56	34	70	116
No. of eggs hatched	32	16	31	82	41	36	16	28	12	49	31
No. of chicks fledged	29	9	—	—	35	32	11	22	6	—	26
Laying Success: burrows w/eggs per active burrow	—	—	0.55	0.59	0.72	0.67	0.47	0.56	0.44	—	—
Hatching Success: eggs hatched per eggs laid	0.63	0.42	0.60	0.83	0.61	0.52	0.40	0.50	0.35	0.70	0.27
Fledging Success: chicks fledged per eggs hatched	0.83[a]	0.56	—	—	0.85	0.89	0.69	0.79	0.50	—	0.83
Breeding Success: chicks fledged per nest w/eggs	0.41[a]	0.24	—	—	0.52	0.46	0.28	0.39	0.18	—	0.22
Chicks fledged per active burrow (reproductive success)	—	—	—	—	0.38	0.31	0.13	0.22	0.08	—	—

[a] Based on subsample of 18 chicks and 37 eggs

TABLE XI-5
Productivity of Tufted Puffins. Data Obtained from Infrequently Visited (=Undisturbed) Plots.

Parameter	Barren Is. 1978	Hinchinbrook 1977	Sitkalidak 1977	Sitkalidak 1978	Chiniak Bay 1977	Chiniak Bay 1978	Semidi Is. 1976
No. active burrows	32	--	54	33	30	51	--
No. burrows with eggs	--	16	39[a]	22[a]	25	46	28
No. of eggs hatched	--	--	--	--	22	39	24
No. of chicks fledged	15	9[b]	23	16	20	35	--
Laying Success: burrows w/eggs per active burrow	--	--	--	--	0.83	0.90	--
Hatching Success: eggs hatched per eggs laid	--	--	--	--	0.88	0.85	0.86
Fledging Success: chicks fledged per eggs hatched	--	--	--	--	0.91	0.90	--
Breeding Success: chicks fledged per burrows w/egg	0.94[c]	0.56[b]	0.59	0.73	0.80	0.76	--
Reproductive Success: chicks fledged per active burrow	0.47	--	0.43	0.48	0.67	0.69	--

[a] Extrapolated from data from disturbed plots: 72% of active burrows contained eggs in 1977; 67% of active burrows contained eggs in 1978.

[b] Chicks were checked only once at 25± 5 days of age and it is assumed that all fledged.

[c] Estimated: based on data from 1976-1978 which indicate that ca. 50% of burrows on the Barren Islands contain eggs during any given year.

TABLE XI-6
Percent Occupation of Tufted Puffin Burrows

Study Site and Date	Number of Burrows	Percent Active	Percent Containing Eggs
Ugaiushak			
1976	94	90[a]	55
1977	35	89	46
Chiniak Bay			
1977	104	84	--
1977	(extrapolated from subsample of 42 nests)	--	69
Sitkalidak Strait			
1977	93	--	70
Barren Is.			
1976	85	--	47
1977	100	--	56
1978	78	--	44
Wooded Is.			
1977	93	--	56-60
Semidi Is.	17	--	53

[a] Based on a subsample.

colony in Chiniak Bay (Table XI-5). In the Barren Islands, laying success may have been underestimated because of an inflated count of active burrows, many of which may have been entered only by storm-petrels. Biases caused by disturbance of colonies or by variations in experimental techniques probably resulted in the underestimation of laying success at all colonies although such bias was minimal at colonies in Chiniak Bay. Lowest estimates tend to be most biased so that variation was less than our data indicated.

In the disturbed plots where presence of an egg was manually determined, there was a high desertion rate. Hatching success from these plots ranged from 0.27 to 0.83 (Table XI-4). Hatching success in relatively undisturbed plots at Chiniak Bay and the Semidi Islands averaged 0.86 (Table XI-5). In undisturbed burrows we identified 3 natural causes for nest desertion during the incubation period: 1) infertile eggs, 2) eggs rolling out of the burrow, and 3) flooding.

The probability of a Tufted Puffin chick reaching the point of fledging improved appreciably over the probability of the egg hatching. Fledging success averaged 0.74 (range = 0.50 - 0.89) between 1976 and 1978 at 5 heavily disturbed colonies (Table XI-4) and 0.90 at the relatively undisturbed colony in Chiniak Bay (Table XI-5). Predation was low and burrows sheltered chicks from most weather problems. Low fledging success may have been due to inadequate food deliveries to the chick, which in turn probably stemmed from a lack of food available to the hunting adults and also from occasional flooding of the burrows. Other than persistent starvation and low survival of chicks at the Semidi and Barren islands, there was no clear pattern of differences between colonies or years. There was a greater overall reproductive success on the undisturbed than on the disturbed plots (Tables XI-4 and XI-5). At Sitkalidak Strait in 1978, for instance, 0.5 chicks fledged per active nest in the undisturbed plots whereas only 0.3 chicks fledged per active nest in the disturbed plots. The unweighted average reproductive success (chicks fledged per breeding pair) for Tufted Puffins in disturbed plots was 0.34 compared to 0.73 in undisturbed plots. Excluding the effects of disturbance, Tufted Puffins were clearly among the more consistently successful breeders among marine birds in the Gulf of Alaska. Even with substantial losses to predation there were no reproductive failures at any colony during the period of our study. Such failures or near failures were common for cormorants, kittiwakes, terns, and murres.

GROWTH OF CHICKS

Adult Tufted Puffins weigh about 800 $\pm$ 50 g, and chicks in our studies hatched at about 8% of that weight (Table XI-7). Mean hatching weights did not vary significantly between colonies or years and ranged between 61.4 g and 70.3 g (Table XI-7). The growth of chicks followed a typical sigmoid pattern (Figures XI-3 and XI-4) and chicks gained an average of about 11.5 g per day over the straight line portion of that curve (Tables XI-8 and XI-9). A two-year comparison of chick growth at Sitkalidak Strait in 1977 and 1978 showed no significant differences in hatching weights, fledging weights, or growth curves between those two years (Table XI-7, Figure XI-4). Growth of chicks in wing, tarsus, and culmen, as well as weight, were measured on Middleton Island in 1978. Between 5 and 28 days of age Tufted Puffin chicks showed mean daily increments of 15.2 g in weight, 3.4 mm in wing length, 0.4 mm in tarsus length, and 0.5 mm in culmen length (Table XI-10).

Tufted Puffin chicks normally fledge at 40-50 days of age (Wehle 1980). In our studies, chicks fledged at 530-610 g, about 70% of adult weight. Those at the Semidi Islands in 1976, however, were apparently starving and had reached only about 365 g by 50 days of age (Table XI-8). These chicks

TABLE XI-7
Hatching and Fledging Weights of
Tufted Puffin Chicks.

	Hatching weights (g)				Fledging weights (g)			
	N	$\overline{X}$	SE	F	N	$\overline{X}$	SE	F
1976								
Shumagin group	30	69.4	1.88		8	545.6	26.12	
Semidi group	10	65.9	3.67	0.3894	3	274.3[a]	23.67[a]	33.3188
Ugaiushak Island	18	69.4	3.00	P>0.67	9	573.0	13.11	P=0.00
1977								
Sitkalidak Strait	15	70.3	4.20		14	560.8	37.59	
Ugaiushak Island					6	556.0	37.30	
1978								
Sitkalidak Strait	16	68.1	3.06		5	604.6	24.16	
Chiniak Bay	13	61.4	1.58	2.0449	7	530.1	15.02	5.9401
Middleton Island	8	63.4	2.03	P>0.14	3	609.3	11.57	P>0.016

[a] Chicks not yet fledged at final monitored age of 45 days.

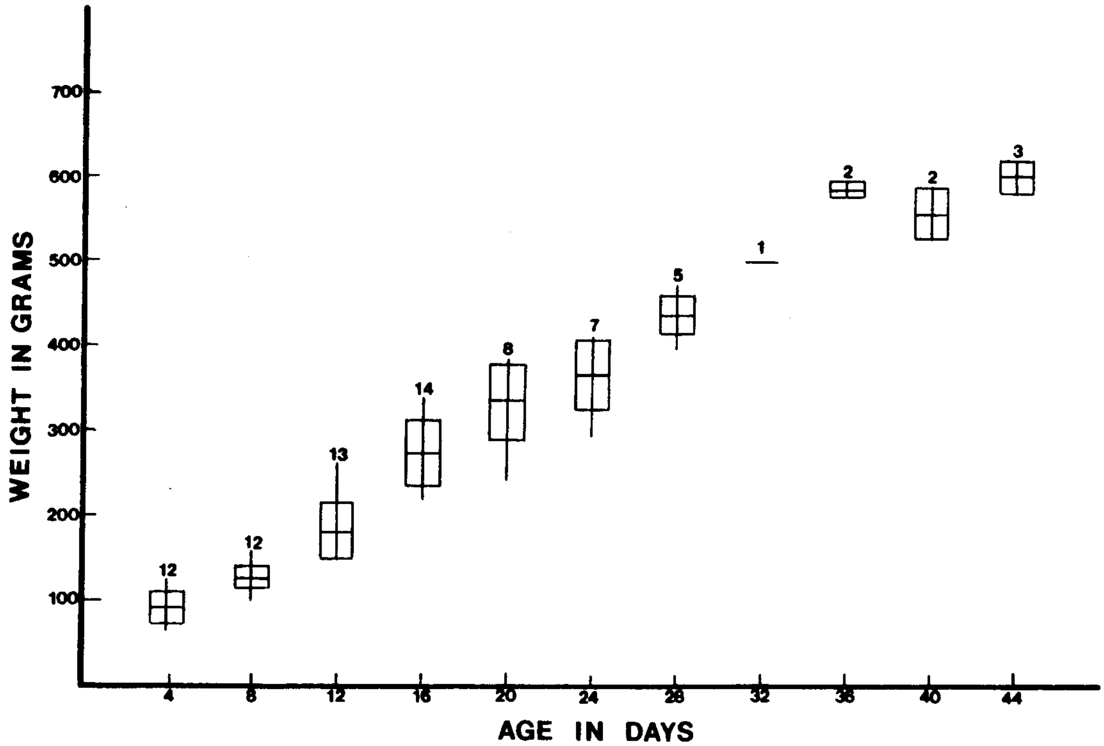


Figure XI-3. Weight gain in Tufted Puffins at Middleton Island in 1978.

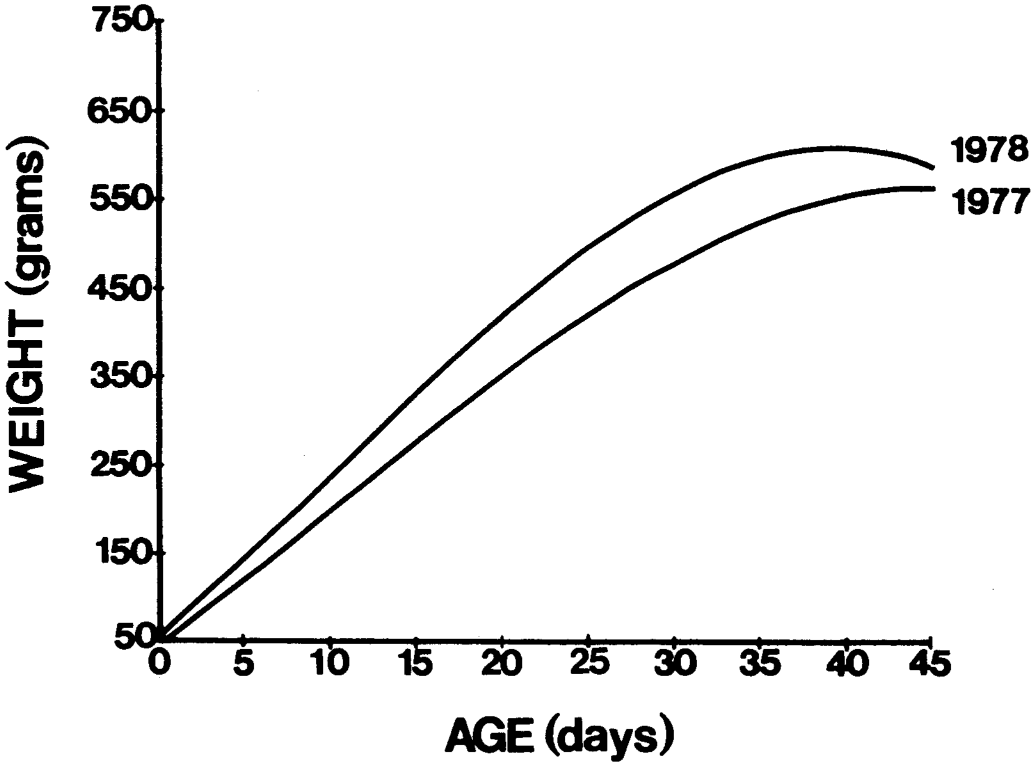


Figure XI-4. Comparison of regression curves of Tufted Puffin chick growth at Sitkalidak Strait in 1977 and 1978.

TABLE XI-8
Growth of Tufted Puffin Chicks.

Chicks at 5 sites[a]				Chicks at the Semidi Islands[b]		
Age (days)	N	Weight (g) $\overline{X}$	SE	N	$\overline{X}$	SE
0-2	100	68.1	1.10	10	65.9	3.68
3-5	83	86.6	2.00	9	88.2	4.43
6-8	62	138.8	3.37	11	107.2	4.54
9-11	79	191.6	3.40	8	126.4	7.52
12-14	55	248.5	4.67	9	147.2	9.66
15-17	76	205.4	4.45	4	189.0	10.76
18-20	59	349.0	5.71	6	205.3	12.69
21-23	77	392.1	5.84	9	234.0	10.86
24-26	52	435.2	6.76	3	251.3	21.88
27-29	64	464.5	10.61	4	280.3	20.54
30-32	55	495.0	7.81	4	241.8	20.5
33-35	51	526.2	11.30	6	273.7	19.85
36-38	57	545.3	9.22	6	260.5	20.67
39-41	57	545.3	11.06	6	296.3	22.92
42-44	47	564.5	13.15	3	274.3	23.67
45-47	22	532.9	20.52	5	315.4	26.75
48-50	2	613.5	48.79	4	363.5	27.32

[a] Shumagin Islands 1976, Ugaiushak Island 1978, Sitkalidak Strait 1977 & 1978, Chiniak Bay 1978, Middleton Island 1978.

[b] Chicks starving and probably did not fledge.

TABLE XI-9
Mean Weight Gain Per Day of Tufted Puffin Chicks Between Days 4 and 46.

Colony	Year	$\overline{X}$ wt. gain/day
Big Koniuji	1976	10.8 g
Semidi Islands	1976	7.3 g[a]
Ugaiushak Island	1976	10.8 g
Sitkalidak Strait	1977	10.8 g
Sitkalidak Strait	1978	12.2 g
Chiniak Bay	1978	11.4 g
Middleton Island	1978	13.0 g

[a] Chicks starving.

TABLE XI-10

Growth of Tufted Puffin chicks, Middleton Island, 1978

Age (days)	n	Weight (g)			Flattened Wing (mm)			Diagonal tarsus (mm)			Exposed Culmen (mm)		
		Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.	Range
0	5	61	4.88	54- 67	21	1.41	20- 23	20.3	0.85	19.4-23.5	22.6	0.62	21.8-23.4
1- 4	12	93	19.04	64-122	26	1.87	23- 29	23.7	1.26	21.8-26.0	24.3	1.18	22.3-26.0
5- 8	12	131	16.11	102-153	31	2.02	27- 35	25.4	0.95	23.8-26.9	26.4	1.08	24.8-28.2
9-12	13	186	32.47	138-262	39	3.90	34- 47	27.3	1.05	25.8-29.3	28.6	1.52	25.9-31.2
13-16	14	276	37.83	221-340	57	6.78	45- 66	29.7	1.40	26.7-32.3	31.4	1.37	29.5-33.8
17-20	8	339	48.88	245-390	71	2.62	66- 74	31.6	1.63	28.2-33.4	33.7	1.18	31.8-35.3
21-24	7	375	41.27	292-410	89	6.79	80-102	32.0	1.47	29.2-34.0	34.7	1.37	32.6-36.3
25-28	5	443	23.30	410-475	103	6.54	96-113	33.7	1.14	31.9-34.8	36.5	0.75	35.4-37.4
29-32	1	512	-	-	97	-	-	32.8	-	-	35.4	-	-
33-36	2	595	7.07	590-600	129	3.54	126-131	34.5	1.27	33.6-35.4	39.4	1.98	38.0-40.8
37-40	2	565	31.82	542-587	140	0.71	139-140	33.5	0.14	33.4-33.6	39.6	0.21	39.4-39.7
41-44	3	609	20.03	590-630	150	1.53	149-152	34.5	1.02	34.3-35.6	43.3	0.31	43.0-43.6

were not monitored further but it is doubtful that they fledged at that light weight.

FOOD HABITS AND FORAGING

Puffins feed their chicks fish or cephalopods, while they themselves eat a more diversified diet including mollusks, crustaceans, and polychaetes (Bent 1919, Cody 1973, Sealy 1973, Wehle 1976). This may express a difference in the economies of eating small items and delivering the "large packages" to the chicks (Cody 1973).

At all of our study sites except Middleton Island, capelin and sand lance together represented more than 86% of numbers (Table XI-11), 84% of bill loads (Table XI-12), and 90% of weight and volume (Table XI-13) of food brought to chicks. Middleton Island was the most oceanic of the colonies studied, and food brought to chicks there included large numbers of squid and octopus. Cods increased in importance at Sitkalidak Strait in 1978, perhaps in response to decreased numbers of capelin. There was a major difference in food brought to young at Sitkalidak Strait and the Barren Islands between 1977 and 1978. In 1977, capelin made up 65% and 57% of the numbers of prey brought to chicks at the two sites respectively. In 1978, sand lance made up 50% and 65% of the numbers of prey.

We strongly suspect that capelin were not available in large numbers in 1978 so that birds had to place greater reliance on sand lance. The unavailability of a major food item, i.e., capelin, in 1978 may have been the major reason for poor productivity that year among surface foragers (see kittiwake and tern sections of this report). Productivity in Tufted Puffins, however, may not have been as severely affected because of their ability to forage throughout the water column and even on the bottom, thus having a wider selection of prey. The range of prey species taken by Tufted Puffins thus

TABLE XI-11
Percent Numbers of Prey Brought to Tufted Puffin Chicks.

Species	Ugaiushak Is. 1977 N = 349	Sitkalidak Strait 1977 N = 332	Sitkalidak Strait 1978 N = 111	Barren Is. 1976 N = 110	Barren Is. 1977 N = 150	Barren Is. 1978 N = 271	Middleton Is. 1978 N = 65
Capelin (*Mallotus villosus*) & Osmerids	12.0	64.9	36.9	94.5	57.0	35.1	
Sand lance (*Ammodytes hexapterus*)	82.0	25.8	49.6		30.3	64.6	60.0
Salmon (*Oncorhynchus*)	0.5	1.6	1.8				
Cod family (Gadidae)	4.9	3.7	10.8		6.0		
Pacific Sandfish (*Trichodon trichodon*)		3.1			0.7		1.5
Prowfish (*Zapora silenus*)				1.8			3.1
Kelp Greenling (*Hexagrammos decagrammus*)					2.7		
Flatfish (Pleuronectidae)						0.4	
Squid & Octopus (Cephalopoda)	0.3	0.9	0.9	3.6	2.7		35.4

TABLE XI-12
Frequency of Occurrence of Prey Species
Brought to Tufted Puffin Chicks.

Prey species	Ugaiushak Is. 1977 (N=64) (N)	%	Sitkalidak Strait 1977 (N=56) (N)	%	Sitkalidak Strait 1978 (N=29) (N)	%	Barren Islands 1977 (N=38) (N)	%	Middleton Island 1978 (N=68) (N)	%
Capelin and Osmerids (*Mallotus villosus*)	(23)	35.9	(42)	75.0	(9)	34.6	(34)	89.5		
Sand lance (*Ammodytes hexapterus*)	(41)	64.1	(21)	37.5	(12)	45.8			(18)	81.3
Salmon (*Oncorhynchus* spp.)	(1)	1.5	(5)	8.9	(1)	3.9				
Cod family (Gadidae)	(9)	14.1	(8)	14.3	(3)	11.5				
Pacific Sandfish (*Trichodon trichodon*)			(8)	14.3					(1)	6.3
Prowfish (*Zapora silenus*)							(2)	5.2	(2)	12.5
Squid Class (Cephalopoda)	(1)	1.5	(2)	3.6	(1)	3.9	(2)	5.2	(14)	87.6

TABLE XI-13
Percent Weight and Volume of Prey
Fed to Tufted Puffin Chicks.

Prey species	Sitkalidak Strait 1977 % wt.	Sitkalidak Strait 1977 % vol.	Middleton Island 1978 % wt.
Capelin (*Mallotus villosus*)	66.9	73.1	
Sand lance (*Ammodytes hexapterus*)	22.1	17.8	51.7
Salmon (*Oncorhynchus* spp.)	4.6	1.5	
Cod family (Gadidae)	4.7	7.2	
Pacific Sandfish (*Trichodon trichodon*)	1.6		1.7
Prowfish (*Zapora silenus*)			10.3
Squid class (Cephalopoda)	0.01	0.05	36.3
Nereid worms	0.02	0.06	

was wider than that available in any one area or time period.

The length of prey fed to Tufted Puffin chicks at Sitkalidak Strait was similar between 1977 and 1978 (Fig. XI-5). The weighted average length of fish brought to chicks at Ugaiushak Island, Sitkalidak Strait, and the Barren Islands was 95.9 mm for capelin and 84.5 mm for sand lance (Table XI-14). These are the one year old age classes for both fish species. Puffins carried an average of about 3.5 prey items per bill load, ranging from 1 to 8 per delivery. Weight of these deliveries varied from a low of 2 to a high of 78 g (a single prowfish Zaprora silenus) for an average, depending on the colony, of 14 to 20 g. The average weight of fish delivered to young at Ugaiushak was 5.6 g $\pm$ 1.0 for capelin, 1.6 g $\pm$ 0.1 for sand lance, 2.7 g $\pm$ 0.3 for cod, and 24.5 g $\pm$ 17.3 for salmon (Table XI-14).

As the chicks grew, they were fed more frequently throughout the day. At Sitkalidak Strait, the mean number of feedings per chick per day was near 1 in the first week of life, 3 during the second week, 2 during the third and fourth weeks, and 2 feedings per day right before fledging (Figure XI-6). Thus, as the chicks grew, the number of feedings per day increased until the chicks had completed over half of their growth, at which point the frequency of feedings declined. Overall, the mean was about 2.1 feedings per chick per day. There appeared to be no significant difference among time periods during the day in the frequency of feedings. In a small percentage of cases, the chicks received no food in one or more 24-hour periods, but both wild and hand-reared specimens exhibited an adaptation to irregular feeding periods (Wehle 1978). A flexibility like this would be advantageous because often times storms prevent the adults from fishing successfully and thus feeding the chicks on a regular schedule.

Assuming a 45-day nestling period, there would be about 94.5 feedings per

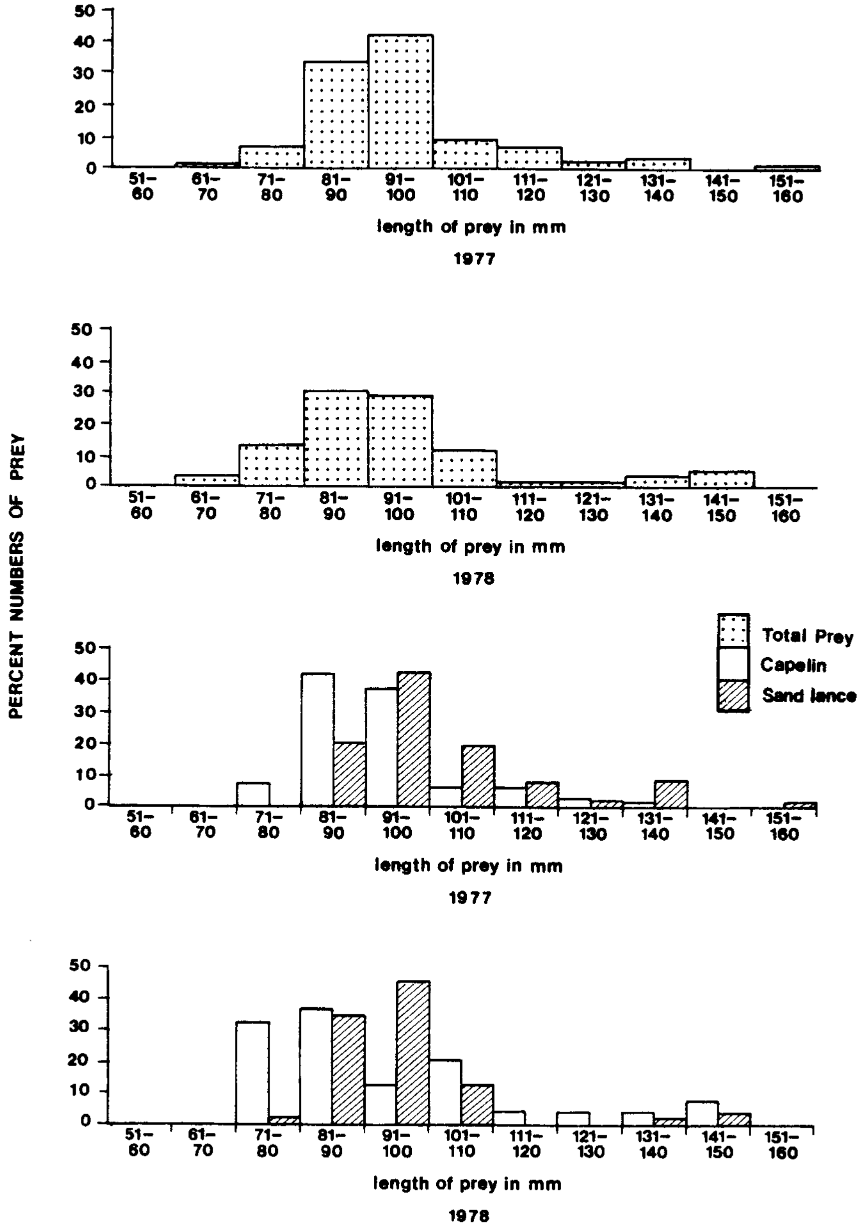


Figure XI-5. Distribution of lengths of prey delivered to Tufted Puffins in Sitkalidak Strait, 1977-1978.

TABLE XI-14
Mean Lengths of Prey Fed to
Tufted Puffin Chicks.

Prey species	Ugaiushak Island 1977 (N)	$\bar{x} \pm$ SE (mm)	Sitkalidak Strait 1978 (N)	$\bar{x} \pm$ SE (mm)	Barren Islands 1977 (N)	$\bar{x} \pm$ SE (mm)
Capelin and Osmerids (*Mallotus villosus*)	(28)	97.0 ± 3.59	(30)	94.9 ± 3.64	(1)	92.0
Sand lance (*Ammodytes hexapterus*)	(124)	79.0 ± 0.83	(54)	97.0 ± 2.19		
Salmon (*Oncorhynchus spp.*)	(2)	149.0 ± 13.05	(2)	137.5 ± 5.50		
Cod family	(15)	74.0 ± 2.20	(9)	71.0 ± 2.53		

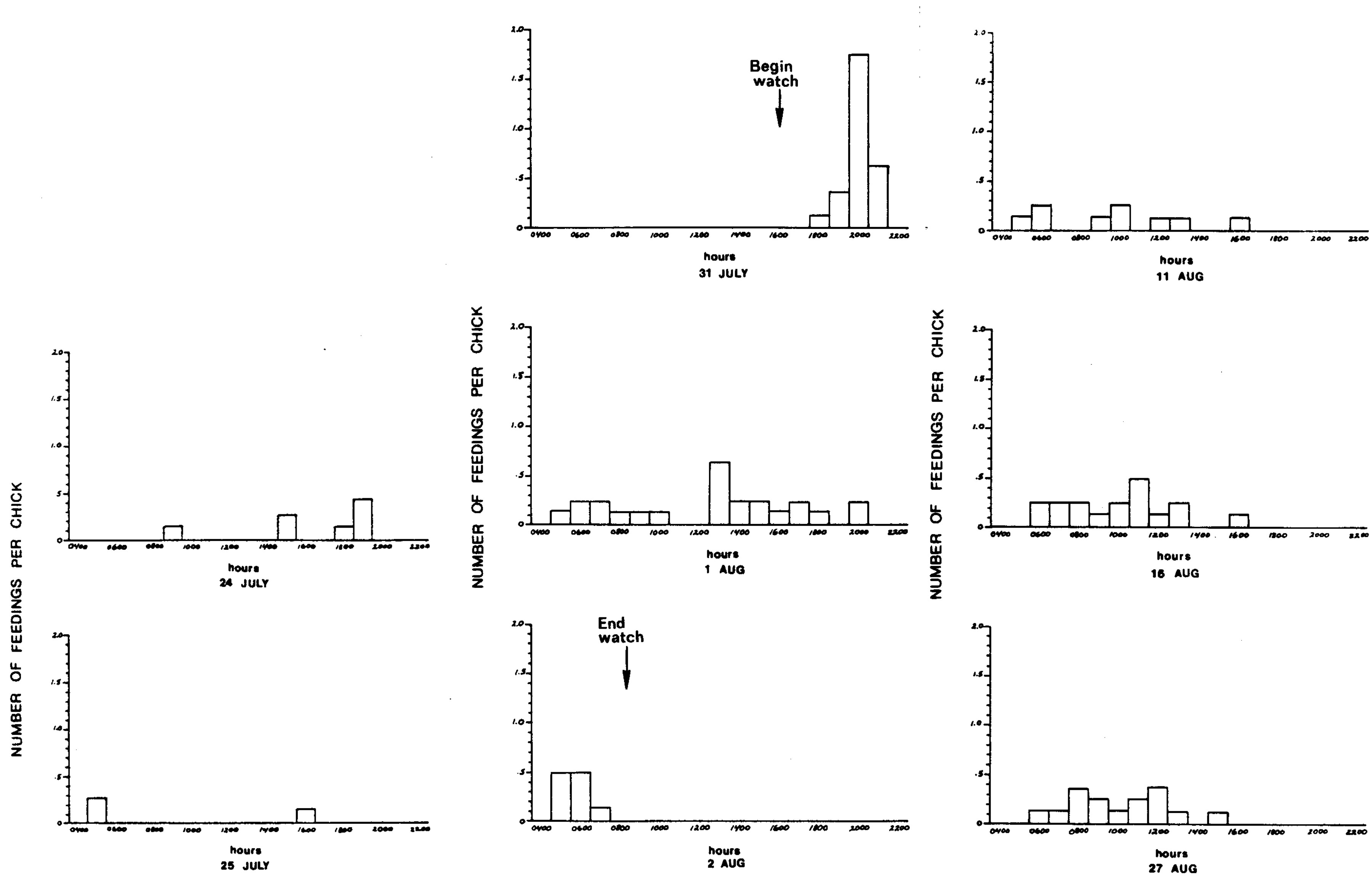


Figure XI-6. Frequency of feedings of Tufted Puffin chicks (n = 10-15 chicks) in Sitkalidak Strait, 1978.

nestling per season. At an average weight per feeding of 16 g, this would be 1,512 g per chick during the nesting stage. At an average reproductive rate of 0.5 chicks fledged per breeding pair, 611,112 breeding pairs in the Gulf of Alaska (updated numbers from Sowls et al. 1978) would produce 275,000 chicks. The total biomass taken from the Gulf of Alaska each season by Tufted Puffins to feed their chicks would thus be in excess of 410 metric tons.

COLONY ATTENDANCE

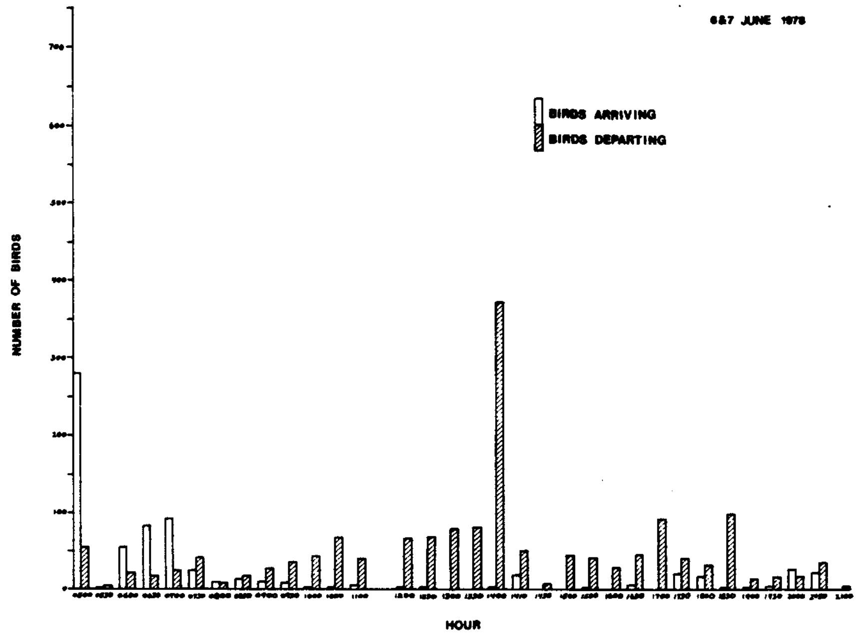
Courtship, copulation, nest site selection and excavation, territorial defense, and egg formation in the females occurred over a period of about three weeks each year. During that time Tufted Puffins arrived and departed the colony in a cyclic manner. At Sitkalidak Strait, the cycle involved 1 day at the colony and 2 days absent. In the Barren Islands, there was a 3- to 5-day cycle, and at Ugaiushak, a 3-day cycle.

Both sexes share incubation duties and the off-duty member disappears for a time, presumably to forage. Tufted Puffins do not maintain regular cycles in the exchange of these activities; indeed they often leave the egg unattended while they loaf outside the burrow or occasionally disappear from the colony for 24 hours or more. Such incubation lapses produce egg chilling and extend the incubation period.

Except for a brief period of brooding the newly hatched chick, the adults devote their final effort of the reproductive cycle to foraging for the chick. The time spent away from the colony in this activity depends upon the distance they must fly to the food and the availability of food where they forage. In between trips they spend much time standing outside their burrows.

Once about every 3 weeks in 1978, one-day and two-day watches were conducted from dawn to dusk at the Sitkalidak Strait colony (Figure XI-7).

(a)



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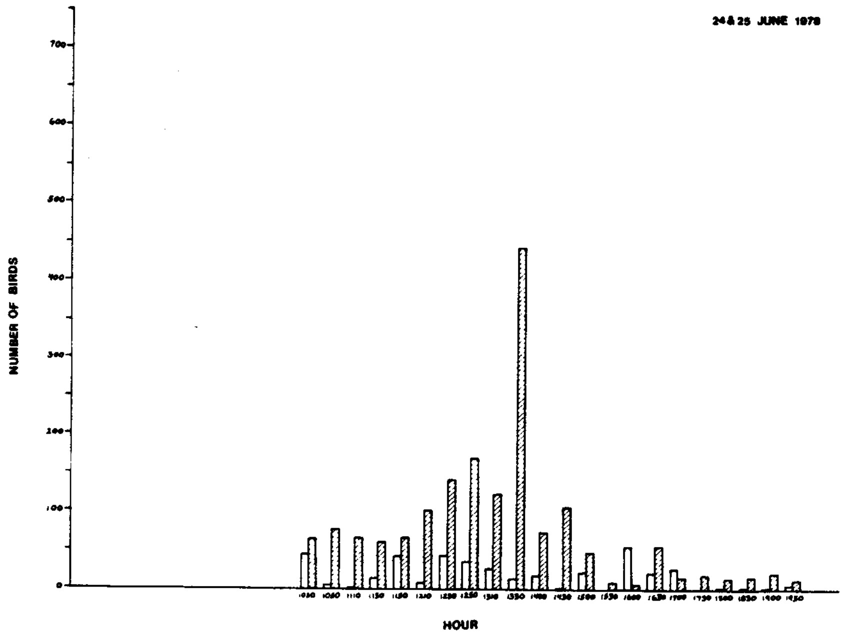
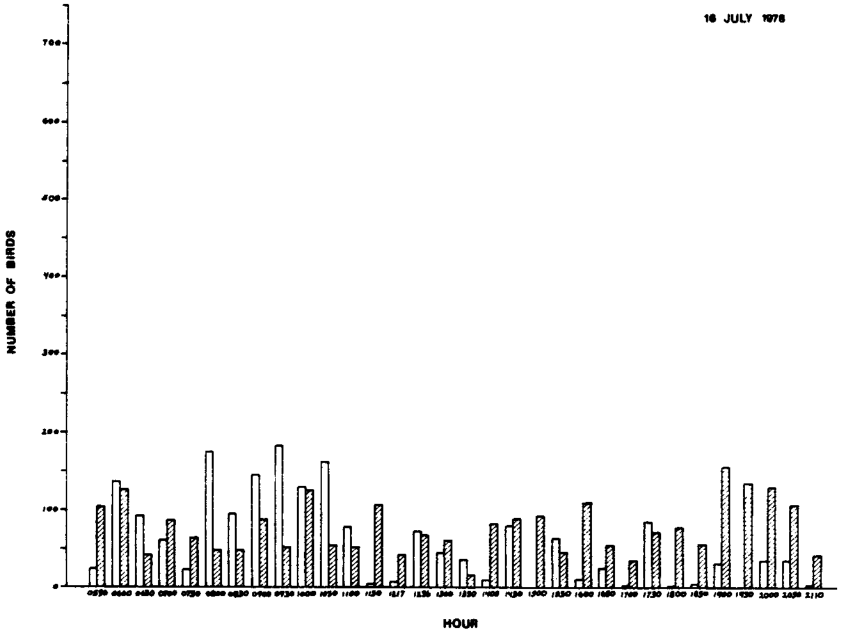


Figure XI-7. Numbers of Tufted Puffins flying to and from the colony, Sitkaldak Strait, on (a) 6-7 June and (b) 24-25 June, 1978.

(c)



(d)

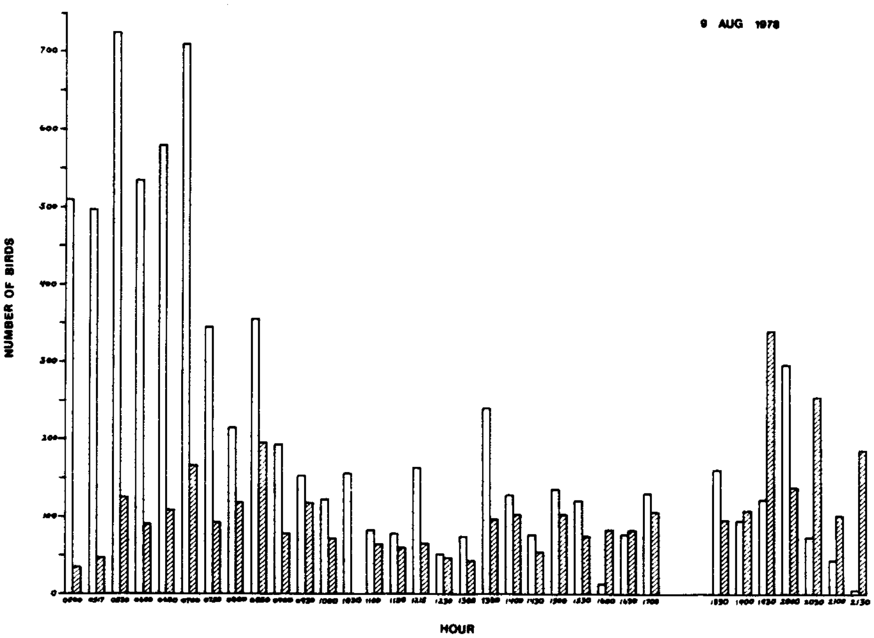


Figure XI-7 (cont.) (c) 16 July and (d) 9 August, 1978.

In June, during the incubation stage, most birds appeared to be departing the colony during the afternoon and arriving in the morning. Unfortunately, fog prevented observations before 0800 hrs when many birds may have arrived. It is also possible that birds were still following a three day cycle at this time. In July (late incubation and early chick stage) the pattern of arrivals and departures of puffins became more uniform although a bimodal pattern was still evident with arrivals outnumbering departures in the morning and the reverse in the evening. The overall turnover rate of adults at the colony appeared to increase through the incubation period. With the increased numbers and age of chicks in August the bimodal pattern of morning arrival and evening departure was still evident and the turnover rate increased dramatically.

FACTORS AFFECTING REPRODUCTIVE SUCCESS

Our studies suggested that food availability was the major factor influencing annual productivity in all seabirds, although other factors like predation, human disturbance, and weather were also important. Like Bedard (1969), we were able to identify "good" and "poor" years (in the sense of food availability) only indirectly through the survival and growth of chicks. Vermeer et al. (1979) speculated that water temperature influenced the behavior, hence availability, of prey species. We did not have data to support nor deny this correlation, nor did we have much information on the ecology of prey captured by Tufted Puffins.

Total mortality ranged from 46-76% per year. Most nesting failures reported in our studies of Tufted Puffins were from egg desertion (9-60%) (Table XI-15). There were not only desertions caused by our investigations into puffin burrows, but also desertions that occurred without human disturbance, e.g., from predation or from inexperience of breeders. Manuwal and

TABLE XI-15
Percent Mortality of Tufted Puffin Eggs and Chicks.

Cause of mortality	Semidi Is. 1976(N=38)		Sitkalidak St. 1977(N=67)		Sitkalidak St. 1978(N=69)		Barren Is. 1976(N=40)		Barren Is. 1978(N=25)	
Egg Stage										
Desertion	50.0	(19)	9.0	(6)	27.5	(19)	60.0	(24)	56.0	(14)
Shell damage	2.6	(1)								
Infertile			9.0	(6)	1.4	(1)				
Egg rolled out					8.7	(6)				
Nest taken over by Horned Puffin	2.6	(1)								
Disappeared			19.4	(13)	4.3	(3)				
TOTAL EGGS	55.3	(21)	37.3	(25)	42.0	(29)	60.0	(24)	56.0	(14)
Chick Stage										
Died hatching	2.6	(1)								
Starvation	5.3	(2)	4.5	(3)	4.3	(3)	5.0	(2)[a]		
Killed by adults	2.6	(1)[a]								
Nest flooded			1.5	(1)			5.0	(2)		
Disappeared	10.5	(4)	3.0	(2)	2.9	(2)	2.5	(1)	8.0	(2)
TOTAL CHICKS	21.1	(8)	9.0	(6)	7.2	(5)	12.5	(5)	8.0	(2)
TOTAL MORTALITY (Eggs & Chicks)	76.3	(29)	46.3	(31)	49.3	(34)	72.5	(29)	64.0	(16)

[a] Deserted by adults.

Boersma (1978) suggested the rate of desertion due to the latter may have approached 10%.

Students of Atlantic puffin populations reported predation and harassment by gulls (Lockley 1953, Nettleship 1972). Though Glaucous Gulls (Larus hyperboreus) and Glaucous-winged Gulls (Larus glaucescens) occurred in the colonies we studied, our workers did not find them to be important predators of puffins or to extensively engage in kleptoparasitism. They reported predation by Bald Eagles (Haliaeetus leucocephalus), Peregrine Falcons (Falco peregrinus), and river otters (Lutra canadensis), although it was not great enough to have seriously affected production in puffins. Red foxes (Vulpes fulva) that reached a usually isolated island colony, however, were very effective predators of puffin eggs, chicks, and adults (Petersen and Sigman 1977).

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DISCUSSION AND SUMMARY

by

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DISCUSSION AND SUMMARY

BREEDING DISTRIBUTION AND ABUNDANCE

Sowls et al. (1978) estimated that over 40 million colonial seabirds (31 species) breed in Alaska of which 35% may be be found in the Gulf of Alaska. The 15 species discussed in this report comprise 90% of the seabird population of the Gulf of Alaska and include 6 species with populations of over 1 million birds each, including in descending order: Fork-tailed Storm-Petrel, Tufted Puffin, Leach's Storm-Petrel, Common Murre, Black-legged Kittiwake, and Horned Puffin. See APPENDIX TABLE 1.

Some seabirds were quite restricted in their breeding distribution, while others were widespread. Fulmars bred on only 4 island groups in the Gulf, 1 colony of 475,000 and 3 colonies of less than 50 birds each. Glaucous-winged Gulls, on the other hand, were ubiquitous and were present on every island surveyed in our studies. Although the majority of sites (80%) had fewer than 1,000 birds, the population of Glaucous-winged Gulls at the Semidi Islands numbered 9500 adults. Arctic Terns, while not as abundant as Glaucous-winged Gulls, were also widespread while their close relatives the Aleutian Terns were restricted to 10 known breeding sites in the Gulf. Aleutian Terns generally bred in mixed colonies with Arctic Terns. Tern colonies consisted of anywhere from a single pair to hundreds of pairs. Colonies of murres were usually large (>100,000), but sometimes contained as few as 60 birds. Common Murres were more numerous than Thick-billed Murres in the Gulf, while the converse was true in the Bering Sea. Cormorants and Mew Gulls both had small to moderately sized colonies. Horned and Tufted Puffins bred throughout the Gulf and the size of their colonies varied from small to large. The largest concentration of Tufted Puffins was at Egg Island in the eastern Aleutian Islands (>370,000 birds) while that of Horned Puffins was at the Semidi Islands (>160,000 birds).

Although historical data are either poor or lacking for comparison, populations of seabirds in the Gulf of Alaska appear to be healthy and the changes in numbers that have been observed appear to be normal cyclical fluctuations, e.g., adjustments to local shifts in food availability, or responses to natural phenomona such as the 1964 earthquake, which altered nesting habitat in some areas. There have also been some local changes in response to human development. Tern and other seabird colonies, for example, are heavily egged by some Native communities. Glaucous-winged Gull populations sometimes have local increases in numbers which are due in great part to the lowered mortality of fledgings during their first winter because of artificial supplies of food.

NESTING HABITAT

The areas in which seabirds nested were usually inaccessible to mammalian predators and these included some mainland areas. Seabirds placed their nests in a wide variety of habitats and situations including steep cliffs, rock crevices, talus slopes, gravel and sandy beaches, vegetated hilltops, and shallow to deep burrows. Nest construction varied from the highly elaborate platform with a deep cup built by a kittiwake or a cormorant, to the thinly-lined burrow of a storm-petrel or puffin and mere scrapes in the sand and gravel for a tern, to none at all for a murre. See APPENDIX TABLE 2.

Most seabirds nested in colonies, and their choice to do so may have resulted in part from lack of available sites, but more likely was a selection for social facilitation and protection from predation. Even though space may have been limited on the colonies, there was very little overlap among species in preferred nesting sites. Northern Fulmars, Black-legged Kittiwakes, cormorants and murres all nest on cliffs, but each species chooses a slightly different cliff habitat. Fulmars prefered vegetated cliffs of more than 50°

slope whereas kittiwakes and cormorants prefered ledges and outcroppings on unvegetated cliffs that were nearly vertical. There may have been some competition for nest sites between kittiwakes and Pelagic Cormorants, and when two or three species of cormorants occurred together, there was vertical stratification with Double-crested Cormorants on the flat tops or uppermost broad ledges, Red-faced Cormorants next, and Pelagic Cormorants at the bottom. Murres laid their eggs very close together on rocky ledges of cliffs or even sometimes in puffin burrows.

The burrowing species occasionally occupied each other's abandoned burrows, and sometimes nested close to a bird of another species. Tufted Puffins occupied the perimeters of islands so that their colony structure was often doughnut-shaped. They preferred grass-sod slopes of 30-40 cm soil depth in order to construct extensive burrow systems, although they were found nesting in closets and drawers of an abandoned shipwreck. By their very presence they modify the habitat in which they live; dense burrow systems sometimes undermined the slopes and caused extensive erosion. Horned Puffins preferred rock crevices or cracks in cliff faces although they occasionally built simple nests beneath boulders or in burrows on rock-sod and sod-grass slopes. In the latter habitat, their burrows were indistinguishable from those of Tufted Puffins. Storm-petrels also built nests sheltered in burrows. Their burrows were much smaller than those of the puffins, although occasionally they occupied abandoned puffin burrows or had side branches off occupied puffin burrows. Their burrows were most abundant within 12 m of the cliff edge or at the bases of slopes. Fork-tailed Storm-Petrels have successfully occupied artificial nest boxes for two consecutive seasons at some colonies.

Ground-nesting terns and gulls occupied the interiors of the islands, sand and gravel beaches, or marshy flats with dry hillocks. Glaucous-winged Gulls often nested singly under the high umbel vegetation, often adjacent to puffin and kittiwake colonies. They also nested in colonies with neighbors as close as 2-10 m. They did not overlap in choice of nesting areas with Mew Gulls which preferred low maritime meadows with Elymus as the dominant vegetation. Mew Gulls were less colonial than either Glaucous-winged Gulls or terns. Both species of terns preferred low grassy islands, but Arctic Terns also nested on gravel bars and sandy beaches. Aleutian Terns usually nested in colonies with Arctic Terns whereas Arctic Terns often nested by themselves. Within a mixed colony, each species tended to form small monospecific aggregations. By nesting with the more aggressive Arctic Terns, Aleutian Terns may have gained some degree of protection from predators.

BREEDING CHRONOLOGY

During the winter months, many of Alaska's seabirds migrate south or become pelagic while some remain year-round in ice-free bays. In the Gulf of Alaska, seabird colonies with a mixture of species were occupied up to 6 months of each year, and activity peaked from June through August. Some eggs and nestlings were present on colonies for time periods varying from about 11-12 weeks for terns to 20-22 weeks for storm-petrels, and adults of some species occupied nesting sites a week or two in advance of egg-laying. Occupation of nesting sites by individual pairs averaged 10-12 weeks; for successful breeding pairs it ranged from 7 weeks for terns to 15 weeks or longer for storm-petrels. The geographic location and associated weather patterns of a colony probably affected its length of occupation; colonies in southeastern Alaska appeared to be active into November, while those to the north and west were frequently abandoned by mid-September. Similarly, birds usually arrived earlier at colonies in southeastern Alaska than at those elsewhere in Alaska. See APPENDIX TABLE 3.

Most of Alaska's seabirds disperse in the winter months. Many become pelagic and range over the north Pacific. Some migrate to more southern waters--Arctic Terns make an annual trip of sometimes more than 33,000 km down to the tip of South America. Other seabirds spend the winter in ice-free bays in the Gulf of Alaska. Beginning mid-March seabirds return to waters near the colonies. The earliest were Black-legged Kittiwakes in mid-March and Northern Fulmars in late March. Others trickled in until the terns, which were the last, arrived in mid-May.

At most sites, egg-laying began in mid- to late-May and the egg-stage lasted until late July or early August. In some species, especially the gulls and cormorants, relaying was common. Alcids, on the other hand, readily abandoned their eggs if disturbed and rarely relayed.

Chicks began to hatch in early- to mid-June and were present until mid-September or later, the greatest abundance of chicks was found on the colonies in July. Most chicks were fed at the nest site until they could fly. Murre chicks, however, moved to the sea when they were still downy, and were accompanied at sea by the male parent. Aleutian Tern chicks, on the other hand, remained at the nest site and were fed there up to 2 weeks after they could fly. Parental care for most chicks lasted, on the average, 4-6 weeks.

Adults and fledglings usually left the colony site within a few days after the young had fledged, and most of the breeding sites were vacated by early to mid-September. Only a few species, e.g., storm-petrels, Northern Fulmars, and the Pelagic Cormorants at Chiniak Bay, remained at the colonies until October.

We found little annual variation in the chronology of Northern Fulmars, gulls, and Tufted Puffins at any one geographical location, whereas storm-petrels, cormorants, and terns had much variation. For most species the onset of the breeding cycle each year varied only 1-2 weeks among different geographical locations except at Middleton Island in 1978 where the breeding schedule was a month ahead of other sites and was protracted for a longer period. Some species breeding in Prince William Sound likewise were 1-2 weeks ahead of those elsewhere in the Gulf of Alaska.

REPRODUCTIVE SUCCESS

Seabirds normally are long-lived but mature slowly; many do not reproduce until they are 4 years of age or older. Seabirds often spend their first year of life at sea. Depending on the species, two- and three-year-olds and sometimes older but subadult birds begin to visit the breeding colonies and may even occupy nest sites, build nests, and engage in some courtship activities. Because of this age-related behavior, the stability of a seabird population is best evaluated by assessing the effects of multiyear cycles in productivity. Since our studies lasted only 1-3 years, the time period was too short for us to determine the long-term population effects of fluctuations in productivity. We did, however, accumulate a large amount of baseline data on the annual and geographical variation that occurs in productivity of seabirds in the Gulf of Alaska. The breeding cycle incorporates a series of easily identified stages leading to the production of young. Loss at any stage results in lowered productivity. In the final analysis it is the number of young fledged per breeding pair and the number of these that subsequently return to breed that indicate the health and stability of the seabird population of a given area.

The number of adults that bred each year varied for some species and this variation may have been associated with the amount of food available within the foraging range of the individual species. For example, in 1978, when capelin were apparently not readily available to surface-foraging seabirds in the Sitkalikak Strait area, there were 49% fewer breeding pairs of Glaucous-winged Gulls than were there in 1977, and fewer young per pair were fledged in

1978. However, the Tufted Puffin and Black-legged Kittiwake populations at this had the same knumber of breeders as in the previous year. See APPENDIX TABLE 4.

Most seabirds had small clutches. Fulmars, storm-petrels and most alcids laid only a single egg, gulls and terns normally laid 2-3, and cormorants laid an average of 3 eggs per clutch although they sometimes laid up to 6 eggs. Gulls and cormorants both averaged smaller clutches in years of apparent low food availability. For most seabird species, an average of 75% of the adults that built nests laid eggs, but in years of low productivity it dropped to near 45% in some species. Glaucous-winged Gulls and Black-legged Kittiwakes had the greatest variability in laying success. In years of "poor" productivity such as 1976 and 1978, it averaged 42-45% while in "good" years it averaged 91-92%.

Hatching success was generally lower than fledging success. Eggs were knocked out of burrows or off ledges by frightened adults, smashed by falling rocks, and eaten by predators, and embryos died from chilling. The heaviest losses of eggs in our studies were from predation, exposure, and desertion, and these events usually occurred because adults were not tenacious to the nest. For some species, e.g., Fork-tailed Storm-Petrel and perhaps Tufted Puffin, egg neglect was common but it rarely resulted in the death of the embryo. Average hatching success ranged from 34% for Common Murres to 87% for Tufted Puffins. For all species whose productivity decreased markedly from one year to the next, loss of eggs was the major problem. Hatching success decreased between years by 50-95% in some cases.

Chicks were very vulnerable to predation and exposure at hatching, especially if an adult was not in almost constant attendance. However, once the chicks began to feather out and grow larger, their chances for survival increased considerably. Fledging success averaged from as low as 37% for Mew Gulls to 93% for Double-crested Cormorants. More commonly, the average was between 70% and 80%. In years of low food availability, however, chicks sometimes starved. The lowest fledging success observed in our studies was 13% for Glaucous-winged Gulls in 1978 at the Barren Islands.

The number of fledglings per nest attempt in our studies ranged from 0.06 (Black-legged Kittiwakes in 1976 at Ugaiushak Island) to 1.95 (Pelagic Cormorants in 1977 at Ugaiushak Island). Tufted Puffins were the only seabirds in our studies whose productivity did not change markedly. Productivity for all species was generally low in 1976 and 1978, and high in 1977. Decreases in productivity from one year to the next occurred at all stages of the breeding cycle, although the stage at which productivity varied was different for each species.

There is much variability then from year to year in the reproductive output of seabirds in Alaska. Fluctuation in population numbers seems to be the norm. The annual overall breeding success averaged less than one clutch per nest for the three years of study, but this is too short a time period to determine how this productivity affects population numbers.

GROWTH OF CHICKS

Growth of seabird chicks is one index by which we can measure how a population is faring. The weight of a chick is most affected by variations in environment, particularly those which affect the food supply, while body parts such as the wing, tarsus, and culmen, grow steadily. Thus, weight is the best criterion by which to compare different populations geographically or among breeding seasons, while the size of body parts is the best indicator of the age of a chick. The development of a chick in both body size and weight is important to its post-fledging success. The typical growth curve for seabird chicks is sigmoid with a nearly linear portion between 10% and 90% of the total growth. The mean weight gained per day during this linear growth can be used to compare populations in different areas and different years. Likewise, peak weight, age at this peak, and age at fledging are important indices of success of a population.

In our studies there was little variation in growth among years or among populations of any species. Seabird chicks gained an average of about 3% of their fledging weight per day during the most rapid period of growth; storm-petrels grew slowest at at about 1% and Aleutian Terns grew fastest at about 7% per day. In 1977 on the Barren Islands adult Fork-tailed Storm-Petrels interrupted incubation more often and their chicks grew more slowly than those on the Barrens in 1978 and those on the Wooded Islands in 1977. Glaucous-winged Gull chicks from different-sized clutches had similar growth patterns, and even those from artificially large clutches grew as fast as chicks from normal-sized clutches. Black-legged Kittiwakes at all colonies had similar rates over the straight-line portion of the growth curve although in some areas their fledging weights were higher. Even in the years of poor productivity those Black-legged Kittiwake chicks that did fledge grew at rates similar to those of more productive years. Horned Puffin chicks within each area had similar growth rates from year to year, but the growth rates of chicks from different geographical areas varied. The growth of Tufted Puffin chicks was significantly slower at the Semidi Islands than anywhere else. The chicks there starved to death and weighed only 274 g at 40 days of age. This may have reflected a scarcity of food in that area during that year. See APPENDIX TABLE 5.

FOOD HABITS AND FEEDING ECOLOGY

Seabirds in the Gulf of Alaska were mainly piscivorous, with capelin (_Mallotus villosus_) and sand lance (_Ammodytes hexapterus_) the predominant prey fed to chicks. These two species of fish comprised 48-84% of the diets of the chicks of all the seabird species. At Middleton Island capelin and sand lance comprised fewer of the prey in the feedings than at other colonies, and pelagic prey like squid and euphausiids appeared in the samples, reflecting the oceanic location of the island. The fish that seabirds fed to their young ranged in size from 60-140 mm in length, indicating a preponderance of two-year-old fish. See APPENDIX TABLE 6.

At most of the colonies studied there was a switch in selected prey between 1977 and 1978. In 1977, capelin dominated in frequency of occurrence, percent numbers, weight, and volume of prey fed to the chicks while sand lance, the second most preferred food item in 1977, predominated in 1978. The switch from capelin to sand lance was most dramatic for gulls and terns, with a decrease in percent frequency of occurrence of capelin ranging from 15% for Aleutian Terns to 50% for Black-legged Kittiwakes. For Tufted Puffins, the only alcid whose food habits were studied thoroughly, the change was not as great nor did it occur throughout the Gulf.

No concomitant mid-water sampling of fish was done during the period the seabirds were studied. However, we believed that capelin were less available to some of the birds in 1978 than they were in 1977. All the surface-feeding birds experienced a great decline in numbers and frequency of occurrence of capelin per bill load, while the deep-diving puffins did not. It is possible that in 1978 the total number of capelin was indeed lower than in 1977 but the fish were more concentrated at greater depths. Surface-feeding gulls and terns could not reach these capelin but the divers could. Sand lance, on the other hand, appeared to be more widely available as prey for all birds in 1978.

Some of the farther-ranging seabirds, and those whose colonies were near the shelfbreak and deep oceanic water, took invertebrates as one of their major sources of prey. Fulmars and storm-petrels fed their chicks squid, amphipods, euphausiids and copepods; and kittiwakes at Middleton Island took 30% invertebrates, 8% of which were euphausiids. Mew Gulls, which often feed inland, sampled a different range of prey. They took not only marine organisms such as capelin and marine invertebrates, but insects (Orthoptera) and fresh-water, three-spined sticklebacks as well. Terns and Glaucous-winged Gulls also occasionally took insects as prey.

At some of the colonies we conducted food watches of the chicks to determine feeding rates. Since we already knew the weight of the average regurgitation or bill load, we were able to estimate crudely the annual biomass of prey needed to raise a chick in the Gulf of Alaska with a success rate similar to what we have found in our studies. Of the four species for which we applied this estimate, the biomass ranged from 50 metric tons for Fork-tailed Storm-Petrels to over 410 metric tons for Tufted Puffins. See APPENDIX TABLE 7.

Seabirds in the Gulf of Alaska partitioned their food resources in many different ways (Fig. XII-1). They feed at different depths and at different distances from the colony. Competition for the more important and abundant food species was reduced through differences in the selection of: prey sizes, foraging depths, capture techniques, foraging areas, and range of acceptable prey substitutes.

COLONY ATTENDANCE

Patterns of nest attendance vary among species. Northern Fulmars and the two storm-petrels were most numerous at colonies before incubation commenced, but many (perhaps 50% of the storm-petrels) may have been non-breeders. The number of Northern Fulmars present at the colony tended to decrease through the breeding season. We obtained no information about incubation shifts but storm-petrels often left eggs unattended for more than 24 hours at a time. This neglect caused the eggs to chill and extended the normal incubation period.

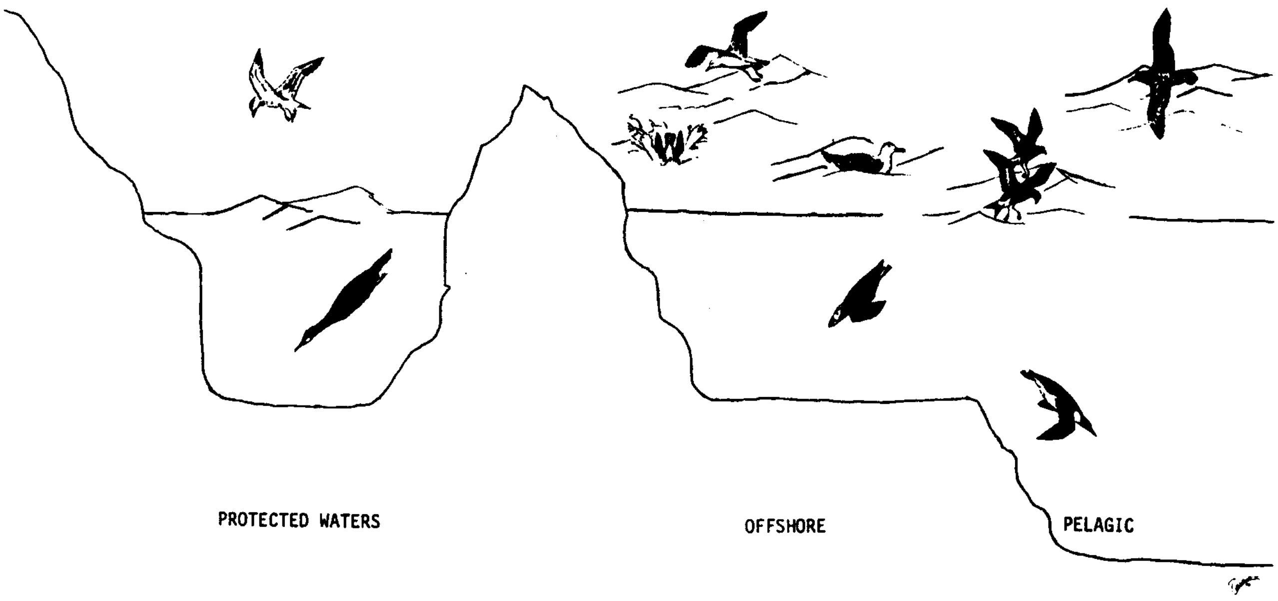

Figure XII-1. Foraging zones and feeding methods of seabirds in the Gulf of Alaska.

Storm-petrels arrived at and departed from the nests only at night, an apparent adaptation to the presence of avian predators. On clear or moonlit nights attendance at the colony was both delayed and reduced. Attendance was also low during storms, when birds remained at sea. The peak attendance of storm-petrels at the colonies was during the darkest part of the summer night. See APPENDIX TABLE 8.

Black-legged Kittiwakes exhibited a different pattern. Their lowest colony attendance was from 2400-0100 hrs. They returned to the colony in the early morning hours and left again before sunrise; they would then return later in the day. During the chick stage, their numbers peaked in the late afternoon and evening. Their absence at night from the colonies reflected their feeding at this time. There was no correlation between time of feeding and stage of the tide. Arctic and Aleutian Terns, on the other hand, departed from and arrived at the colony at particular stages of the tide.

Common and Thick-billed Murres peaked in numbers at the colonies before eggs were laid, as did the fulmars. In the egg and chick stages the numbers were lower but more constant. Murres also showed a diel pattern of attendance; they arrived at sunrise, peaked in attendance around 1000 hrs, and left between 1600-1800 hrs. Horned Puffins peaked two hours before to 1/4 hour after sunset during the egg stage. During the chick stage, they had a mid-morning peak. Tufted Puffins had a regular cycle of attendance and absence during the pre-egg stage. They averaged being off the colony for two days and on for one. During this stage they arrived at the colony at sunrise and left between 1330 and 1400 hrs. During the chick stage there was a greater turnover rate than during incubation.

The different strategies of attendance that were employed by various species were probably determined by prey type, feeding method, feeding area, colony location, and type of nest site. Burrow nesters could afford to range farther from the nest and leave their eggs unattended because the burrow environment was rather constant and provided protection from predation, whereas the ground or cliff nesters could not leave their eggs or chicks unattended for any period of time. It was during the periods of non-attendance by the adults that egg and chick deaths most frequently occurred. The eggs and chicks of some burrow nesters were able to survive the egg-chilling that resulted from extended absences of adults from the nest.

FACTORS AFFECTING REPRODUCTIVE SUCCESS

The most important proximate causes for mortality in seabird eggs and chicks were predation and weather and the ultimate cause of these seemed to be inattentiveness by the adult. The degree of inattentiveness varied among years for all species of seabirds and likewise among individuals in the same population. The most plausible explanation for this variation was variabaility in the amount of time adults needed to search for food; individuals probably vary on the basis of health, experience, or other factors. Variation in search times could have resulted from annual differences in the amount, the patchiness, or the quality of food available. The end result was that to gather enough food to feed themselves and to raise their chicks, adults sometimes strayed farther from the nest and spent a greater amount of time foraging, leaving their eggs or chicks exposed to the elements and to predators. Also, inexperienced breeders may not be as faithful nor as attentive to the nest as experienced birds. Once an egg or chick was preyed upon, adults of most species did not renest but simply abandoned the colony for the duration of the breeding season. Only cormorants and some of the larids seemed to have any success in relaying. See APPENDIX TABLE 9.

Most seabirds were also very sensitive to disturbance. Cormorants and murres were easily disturbed from their cliff sites and eggs and chicks were often knocked out of the nests in the panic flights of the adults. If disturbed, terns and Mew Gulls readily abandoned nests with eggs or chicks in them. These larids were also very sensitive to changes in the nesting habitat and often did not nest in an area that had been disturbed the previous year. Both species of puffins readily abandoned their eggs if disturbed during incubation, and inexperienced adults sometimes abandoned their chicks if disturbed.

NEEDS FOR FURTHER STUDY

A great deal of information is now available on the breeding biology of many species of seabirds in the Gulf of Alaska. First-order investigations on their distributions, abundances, breeding schedules, productivity, and food habits have been completed and baseline criteria have been established. Of course, many questions and data gaps remain. Principal among these are data required to complete life tables and ecosystem models: recruitment, longevity, recolonization potentials, age and sex structures of populations, and age at first breeding. Also, the existence of population, and perhaps productivity, cycles extending over more than three years are suspected and require documentation. Long-term studies are now needed to fill these data gaps and monitor existing populations.

APPENDIX - SUMMARY TABLES

TABLE A-1

Breeding distribution and abundance of seabirds in the Gulf of Alaska. Adapted from Sowls et al. 1978.

Species	Estimated Population	% Alaskan population	Distribution of Colonies
Northern Fulmar	650,000	33	Only one large colony, that on the Semidi Islands. Two or three small colonies elsewhere.
Fork-tailed Storm-Petrel	2,600,000	53	Throughout the Gulf except for extreme northcentral area where good habitat is not available. The largest colony is in the Barren Islands.
Leach's Storm-Petrel	2,080,000	52	Throughout the Gulf except for extreme northcentral area where good habitat is not available. The largest colony is on Petrel Island in southeastern Alaska.
Double-crested Cormorant	4,000	57	Small colonies are scattered throughout the Gulf, but most numerous in the west.
Pelagic Cormorant	34,000	38	Concentrated in the western Gulf. The largest colony is on Middleton Island.
Red-faced Cormorant	50,000	39	Restricted to the western Gulf. The largest colony is on Unga Island in the Shumagin Islands.
Glaucous-winged Gull	370,000	74	Ubiquitous. The largest colony is on Egg Island in the Copper River Delta.
Mew Gull	9,000	90	Small colonies in the northern and western Gulf. The largest colonies are on Bendel Island in the Shumagin Islands and at the mouth of the Alsek River in Dry Bay.
Black-legged Kittiwake	1,350,000	54	Throughout the Gulf but concentrated in the west. The largest colony is on Middleton Island.

Table A-1.
Continued.

Species	Estimated Population	% Alaskan population	Distribution of Colonies
Arctic Tern	20,000	80	Throughout the Gulf but concentrated in the northcentral section from Kodiak to Dry Bay. The largest colony is on Ladder Island in the Kodiak Archipelago.
Aleutian Tern	3,000	30	Small colonies scattered in the northern and western Gulf. The largest colony is at Entrance Point on the Port Moller Spit, Alaska Peninsula.
Common Murre	600,000	12	Throughout the Gulf. The largest colony is on Aghiyuk Island in the Semidi Islands.
Thick-billed Murre	4,000	< 1	Small colonies are scattered through the western Gulf.
Horned Puffin	1,160,000	77	Throughout the Gulf but concentrated in the west. The largest colony is on Amagat Island near Morzhovoi Bay, Alaska Peninsula.
Tufted Puffin	2,320,000	58	Widely distributed throughout the Gulf but concentrated in the west. The largest colony is on Amagat Island near Morzhovoi Bay, Alaska Peninsula.

TABLE A-2
Nesting habitats of seabirds in the Gulf of Alaska.

Species	Habitat occupied	Dominant vegetation	Colony structure
Northern Fulmar	Open nests on cliffs; slopes >50° preferred. No overlap with other species.	Vegetated parts of cliffs; *Elymus*.	Sites clumped and correlated with type of terrain. Density: 0.25-1.0 m^2.
Fork-tailed Storm-Petrel Leach's Storm-Petrel	Sheltered nests in burrows; usually within 12 m of cliff edge or at the bases of slopes. Fork-tails usually in rubble, Leach's in soil.	*Elymus*, umbels, *Calamagrostis*.	Will occupy artificial nest boxes or unoccupied burrows of other speci Extreme crowding in some areas (FTSP: $0.3/m^2$, LSP: $2.4/m^2$.
Double-crested Cormorant	Open nests on broad cliff ledges or flat topped islands.	No vegetation.	Solitary to strongly colonial. Species may be stratified vertically when all 3 together.
Pelagic Cormorant	Open nests on steep cliffs, often next to Black-legged Kittiwakes.	No vegetation.	Solitary to colonial.
Red-faced Cormorant	Open nests on steep cliffs, borad ledges.	No vegetation.	Solitary to colonial.
Glaucous-winged Gull	Open nests on very small to very large islands. Nests near vegetation or out-croppings, secondary cliffs or sheltered driftwood. Sometimes nests on vegetated cliff ledges or within 10 cm of cliff edge.	Mixed-meadows with dense vegetation. Often nests under *Heracleum* or *Angelica*.	Solitary to colonial. Densities $0.1-0.8/m^2$.
Mew Gull	Open nests in maritime meadows, islands in coastal wetlands, and inland lakes. Occasionally in tops of spruce trees and on abandoned equipment.	Sedges and grasses.	Scattered but rarely solitary. Occasionally highly colonial. Densities $0.01-0.07/m^2$.

TABLE A-2
Continued.

Species	Habitat occupied	Dominant vegetation	Colony structure
Black-legged Kittiwake	Open nests on steep cliffs, usually on islands. Sometimes occupies cliff overhangs. Have occupied ledges on a shipwreck.	Sparse, some low Achillea only.	Nests very close (30 cm).
Arctic Tern Aleutian Tern	Open nests on low grassy islands. Occupy grassy meadows sometimes in heads of bays. Arctic Terns sometimes nest on gravel bars.	Calamagrostis. No high vegetation; avoid mixed meadows.	Highest densities on islands. More clumping on mainland. Densities $0.01-0.10/m^2$.
Common Murre Thick-billed Murre	Eggs laid directly on cliff ledges; sometimes in crevices, puffin burrows, or on slopes.	No vegetation on cliffs; unvegetated talus slopes or Elymus or umbels on vegetated slopes.	Very dense; nests almost touching.
Horned Puffin	Sheltered nests in rock crevices, cracks of cliff faces, shallow burrows in rock-sod slopes or extensive burrows in sod-grass slopes.	If on slopes, then in burrows beneath mixed-meadow vegetation.	Solitary nesters to loosely colonial.
Tufted Puffin	Sheltered nests in burrows on islands, on steep sea-facing slopes, on cliff edges, in rock crevices or in rubble. Prefer soil depth 30-40 cm. Burrows can be quite extensive, usually > 100 cm. Have occupied enclosed places on a shipwreck.	Low herbaceous vegetation, Angelica, Heracleum, Festuca, Carex, or Elymus.	Nests within 3 m of edge of island. Modify habitat in which they live by causing soil erosion. Densities

TABLE A-3
Breeding Chronology of Seabirds in the Gulf of Alaska.

Species	Laying To Fledging	Egg Stage[a]	Chick Stage[a]	Fledging[a]	Consistency	Comments
Northern Fulmar	ca. 101 days.	Late May to early August.	Mid-July to early October.	Early September to early October.	Little yearly variation. Predictable. Peaks within 3 days from year to year.	Arrive on colony in mid April.
Fork-tailed Storm-Petrel	ca. 108 days.	Late April to late August.	Early June to late October.	Early August to late October.	Much variation among colonies and years. Maximum difference is 3 weeks	Arrive on colony in late March. Egg neglect may extend egg stage.
Leach's Storm-Petrel	ca. 105 days.	Late April to late August.	Early June to late October.	Mid-August to late October.		
Double-crested Cormorant	ca. 73 days.	Late May to mid-July.	Late June to early September.	Mid-August to early September.	Some variation among sites and years (1-2 weeks). Relaying and renesting common.	
Pelagic Cormorant	ca. 81 days.	Early May to mid-August.	Early June to early October.	Late July to early October.	Same as Double-crested Cormorant.	Data reflect early (3 weeks) schedule on Middleton Is. in 1978.
Red-faced Cormorant	ca. 83 days.	Mid-May to late July.	Mid-June to mid-September.	Early August to mid-September.	Same as Double-crested Cormorant.	Red-faced 1 week earlier than Pelagic at some sites.

TABLE A-3
Continued.

Species	Laying To Fledging	Egg Stage[a]	Chick Stage[a]	Fledging[a]	Consistency	Comments
Glaucous-winged Gull	ca. 69 days.	Late April to early August.	Late May to mid-September.	Early July to mid-September.	Little annual variation at one site (within 1 week). Relaying common.	Data reflect early laying protracted schedule on Middleton Island in 1978.
Mew Gull	ca. 60 days. July	Early May to mid-August.	Mid-June to mid-August.	Early July to mid-August.	Relaying common.	Data reflect early schedule (2.5 weeks) in Anchorage
Black-legged Kittiwake	ca. 67 days.	Late May to early August.	Late June to mid-September.	Early August to mid-September.	Little annual variation. Relaying common.	Data reflect early and protracted season on Middlet Island in 1978. Often arrive on colonies in mid-March.
Arctic Tern	ca. 49 days.	Mid-May to late July.	Early June to late August.	Mid-July to late August.	Some annual variation at 1 site (1-2 weeks). Prince William Sound colonies 1 week earlier than Kodiak colonies.	Latest arrivals (mid-May) and earliest layers of all species.
Aleutian Tern	ca. 50 days.	Late May to late July.	Mid-June to late August.	Mid-July to late August.		Fledglings remain at nest 1-2 weeks after able to fly.

TABLE A-3
Continued.

Species	Laying To Fledging	Egg Stage[a]	Chick Stage[a]	Fledging[a]	Consistency	Comments
Common Murre	ca. 57[b] days	Late May to early September.	Late-June to early October.	Early August to mid-October.	Within one area, little annual variation. Much variation among sites.	Data reflect early schedule on Middleton Island in 1978.
Thick-billed Murre	ca. 57[b] days.	Late May to late July.	Late-June to mid-August.	Late July to mid-August.		
Horned Puffin	ca. 83 days.	Early June to mid-August.	Late July to late September.	Late August to late September.	Little annual variation.	Colonies in Prince Willia Sound 1-2 weeks later tha others. Egg neglect prolongs incubation stage.
Tufted Puffin	ca. 92 days.	Mid May to mid-August.	Early July to mid-September.	Late August to mid-September.	Little variation annually (within 1 week).	Arrive early May. Egg neglect prolongs chick stage. Middleton Is. was 2.5 weeks ahead of other population in 1978.

[a] Early = 1st to 10th, Mid = 11th to 20th, Late = 21st to 31st.

[b] Incubation and brooding period till they jump.

TABLE A-4
Productivity of Seabirds in the Gulf of Alaska, 1976-1978.

Species	Mean and (Range) of: Fledglings/ nest attempt	Fledglings/ nest with eggs	Clutch size	Laying success	Hatching success	Fledging success	Comments
Northern Fulmar	0.27 (0.10-0.36)	0.38 (0.15-0.51)	1.0	0.72 (0.68-0.74)	0.46 (0.22-0.69)	0.71 (0.67-0.74)	1976 poor, 1977 and 1978 good. Scotland population higher.
Fork-tailed Storm-Petrel	0.26 (0.21-0.30)	0.48 (0.24-0.68)	1.0	0.69 (0.68-0.69)	0.68 (0.35-0.94)	0.70 (0.52-0.94)	1976 poor, 1977 and 1978 good. Predator-free area had 3 times the success.
Double-crested Cormorant	0.77	1.31 (0.95-1.67)	3.2 (2.7-3.7)	0.81	0.49	0.93	1976 good, 1977 poor (low clutch size and high predation.
Pelagic Cormorant	0.60 (0-1.95)	1.24 (0.33-2.05)	3.1 (2.2-3.6)	0.89 (0.75-0.96)	0.54 (0.29-0.69)	0.75 (0.44-0.93)	1976 and 1978 poor, 1977 good. Most mortality at egg stage.
Red-faced Cormorant	0.68 (0.00-1.91)	0.88 (0.41-1.35)	2.6 (2.5-3.1)	0.96	0.36 (0.24-0.48)	0.86 (0.81-0.90)	1976 poor, 1977 and 1978 good.
Glaucous-winged Gull	0.76 (0.38-1.15)	0.95 (0.16-1.39)	2.5 (2.0-2.9)	0.70 (0.45-0.92)	0.67 (0.35-0.89)	0.59 (0.18-0.75)	1978 poor, 1977 good.
Mew Gull	0.80 (0.70-0.90)	0.84 (0.70-0.97)	2.7 (2.5-2.9)	0.95 (0.93-1.00)	0.82 (0.72-0.87)	0.37 (0.32-0.55)	Low fledging success.

TABLE A-4
Continued.

Species	Fledglings/ nest attempt	Fledglings/ nest with eggs	Clutch size	Laying success	Hatching success	Fledging success	Comments
	Mean and (Range) of:						
Black-legged Kittiwake	0.41 (0.01-1.23)	0.53 (0.01-1.46)	1.7 (1.4-2.0)	0.76 (0.42-0.91)	0.51 (0.05-0.84)	0.55 (0.13-0.93)	1976 and 1978 poor, 1977 good. Most mortality at egg stage.
Arctic Tern	--	-- (0.40-1.68)	2.06 (1.8-2.3)	--	0.75 (0.29-0.91)	--	Heavy mortality from storms.
Aleutian Tern	--	-- (0.22-0.83)	1.66 (1.4-1.9)	--	0.67 (0.16-0.88)	--	Heavy mortality from storms.
Common Murre	0.16 (0.07-0.25)	0.31	1.0	0.82	0.36 (0.15-0.55)	0.54	
Thick-billed Murre	0.24	0.43	1.0	0.56	0.54	0.80	
Horned Puffin	0.52 (0.41-0.63)	0.53 (0.29-0.72)	1.0	0.81 (0.64-0.97)	0.77 (0.67-0.93)	0.68 (0.36-0.91)	
Tufted[a] Puffin	0.55 (0.43-0.69)	0.73 (0.56-0.94)	1.0	0.87 (0.83-0.90)	0.86 (0.85-0.88)	0.91 (0.90-0.91)	Variability between sites.

[a] Only those data from the infrequently visited plots of Tufted Puffins have been used.

TABLE A-5
Growth of Seabird Chicks in the Gulf of Alaska.

Species	$\bar{X}$ Hatching Weight (g)	$\bar{X}$ Peak Weight (g)	$\bar{X}$ Fledging Weight (g)	$\bar{X}$ Weight gained/ day (g)	Annual Variability	Comments
Northern Fulmar	65	907		Max = 36.5 X = 21.3	Growth similar each year.	
Fork-tailed Storm-Petrel		92-99	65-74	1.5	Growth similar among areas and years except 1977 at Barrens.	Much interrupted incubation in 1977.
Leach's Storm-Petrel		74	66	1.1		
Glaucous-winged Gull	73	979-1156	979-1156	34-38	Growth similar each year.	Growth the same for chicks of different sized clutches & for super normal clutches. Daily gain similar to Western Gulls.
Black-legged Kittiwake	30-42	370-448	350-440	12.0-18.8	Growth similar each year over straight line portion of curve.	Daily gain similar to kittiwakes in Europe. At some colonies chicks fledge at higher weights.
Arctic Tern	16	136	115	7	Growth similar between years & between species.	
Aleutian Tern	21	120	121	8		
Horned Puffin			370-410	3.4-12.6	Growth similar between years in one location, different among areas.	
Tufted Puffin	61-70 $\bar{X}$ = 66		274-609 [a] $\bar{X}$ = 523	7.3-13.0 $\bar{X}$ = 10.9	Growth similar between areas & years except for Semidi Is. chicks, which grew more slowly & eventually starved.	

[a]Semidi Is. chicks = 274 g at 40 days, but did not fledge.
Range for all others = 530-609 g.

TABLE A-6
Food Habits of Seabird Chicks in the Gulf of Alaska.

Species	Major prey	Frequency of occurrence	Percent numbers	Comments
Northern Fulmar	Squid, fish Amphipods Varied diet			
Fork-tailed Storm-Petrel	Amphipods Euphausiids Copepods Fish			
Leach's Storm-Petrel	Euphausiids			
Double-crested Cormorant	Bottom-dwelling coarse fish Smelt			
Glaucous-winged Gull	Capelin Sand lance	1977=37-43% Both prey 1978=22% species 1977=13.2% 49-63% 1978=33.3%	1977=63.8% Both prey 1978=19.7% species 1977=22.8% 75.7-86.6% 1978=56%	1977-1-yr-old fish 1978-2-yr-old fish
Mew Gull	Capelin <u>Macoma baltica</u> Three-spined Stickleback			Mew gulls are eclectic; eat berries, earthworms in other areas.
Black-legged Kittiwake	Capelin Sand lance	1977=56% Both prey 1978=6-14% species 1977=48% 70-104% 1978=64-70%		Mean length fish= 94.9 mm-111.0 mm. The majority therefore are 2-yr-old fish. Prince William Sound: herring were important. All feedings at colonies except at Middleton had 90% fish. Middleton had 78% fish & 18% Euphausiids. % prey weights in 1977: Capelin=37% Sand lance=41%; 1980: Capelin=2-14% Sand lance=64-69%
Arctic Tern	Capelin Sand lance	1977=61% Both prey 1978=20% species 1977=21% 70-82% 1978=50%	1977=51% Both prey 1978=20% species 1977=29% 70-80% 1978=50%	$\bar{X}$ length fish= 111.0 mm
Aleutian Tern	Capelin Sand lance	1977=40% Both prey 1978=25% species 1977=11% 42-25% 1978=17%	1977=43% Both prey 1978=21% species 1977= 9% 42-52% 1978=21%	$\bar{X}$ length fish = 103.9 mm
Common Murres	Capelin Sand lance Herring			
Horned Puffin	Sand lance Capelin			
Tufted Puffin	Capelin Sand lance	1977=85% Both prey 1978 35% species 1977=38% 84% 1978=46%	Both Capelin and Sand lance: Range 60-99.5%. $\bar{X}$=87%. 1978=Capelin #'s decreased from 1977 and #s of sand lance increased.	$\bar{X}$ length=90.3 mm (60-150 mm). Majority of fish= 2-yr-olds. Similarity in sizes between sites & years. Middleton Is.: more pelagic prey; sand lance & squid=88% of prey weight. At other sites: sand lance & capelin=89% of prey weight & 91% of prey volume.

TABLE A-7
Aspects of the Feeding Ecology of Selected Seabirds in the Gulf of Alaska.

Species	$\bar{X}$ number Feedings/day	Estimated food Requirements of nestlings	Foraging area During breeding season
Fork-tailed Storm-Petrel	0.87 feedings/day	593 g/chick	On Continental Shelf.
Leach' Storm-Petrel			Oceanic-beyond Continental Shelf. Long incubation shifts indicate they forage at great distances.
Double-crested Cormorant			Mud bottomed bays, estuaries and narrow channels. Feed singly or in mixed flocks.
Pelagic Cormorant			Intertidal Zone, surf area, deep water, bays and estuaries. Feed in mixed flocks.
Glaucous-winged Gull		2800-4100 g/chick	Close to colony; within 3-10 km. Shallow water (<100 m). Feed along tide rips, convergence lines.
Mew Gull			Not found in the large offshore feeding flocks. Forage in intertidal & along beaches.
Black-legged Kittiwake	3.8 feedings/day at 18.9 g	3088 g/chick	Rip tides, eddying currents over discontinuites in bottom topography, convergence lines mixed feeding flocks. Oftn initiate flocks.
Arctic Tern & Aleutian Tern	1-7 feedings/day		Within 5 km of colony, usually up to 1/2 km from shore. Feed solitarily or in mixed feeding flocks.
Horned Puffin	Several feedings/day. $\bar{X}$ weight of each feeding= 13.7g.		Shallow (50-100m) water. Usually within 2 km of shore but if the shelf is shallow have been found up to 35 km.
Tufted Puffin	2.1 feedings/day; range=1-3. Feeding frequency positively correlated with age. Chicks can be without food for > 24 hours.	1512 g/chick	Tide rips, convergence lines; 500 m - 5 km from colony over varied bottom topography.

TABLE A-8
Attendance of Seabirds at Their Colonies in the Gulf of Alaska.

Species	Seasonal	Diel	Comments
Northern Fulmar	Peak=pre-egg stage in May.	Usually peak in evening.	Numbers on colony may fluctuate greatly, depending on nesting success.
Fork-tailed Storm-Petrel	Peak=pre-egg stage.	Nocturnal. Peak=2330-0230.	Peak numbers may include up to 50% non-breeders. Stay at sea during bad storms. Reduced attendance on clear or moonlit nights. Eggs left unattended $\overline{X}$=11 days/60. Egg chilling extends incubation time.
Black-legged Kittiwake	Lowest numbers= June	Lowest=2400-0100. Leave before sunrise during chick stage. Peak= late afternoon & evening during chick stage.	Absence at night during June probably reflects foraging at night. Attendance not correlated with tides.
Arctic Tern & Aleutian Tern			Pattern of feeding often correlates with change of tides; chicks are usually fed within 2 hours of a tide change.
Common Murre & Thick-billed Murre	Peak=pre-egg stage. Fairly constant numbers in egg & chick stages.	Arrival=sunrise. Peak=1000. Departure=1600-1800.	Extreme fluctuation in numbers during pre-egg stage.
Horned Puffin		Peak=2 hrs before sunset to 1/4 hr after. Mid-morning peak during chick stage.	
Tufted Puffin	Pre-egg: 1-5 day cycles of attendance & absence. Early chick stage= greater turn-over rate than during incuba-tion.	Incubation stage: arrive at sun-rise. Leave at 1330-1400. Late chick stage= arrive at sun-rise. Leave throughout the day with peaks near dusk.	Egg can be left unattended for more than 24 hrs. Resultant egg-chilling extends incubation period.

TABLE A-9
Factors Affecting Reproductive Success of Seabirds in the Gulf of Alaska

Species	Major Mortality	Synergistic Effects	Comments
Northern Fulmar	Eggs: avian predation when eggs unattended.	Inattentiveness by parents caused by greater search time for food.	Incubation shifts longer in poor food years. Food supply exerts early influence on productivity. Critical period = 2-3 wks before & after egg-laying.
Fork-tailed & Leach's Storm-Petrel	Eggs and chicks: mammal predation, weather (flooding of nests).	Poor foraging by adults & therefore chick neglect increases chick mortality. Greater egg neglect = greater hatching failure, decreased growth rate & higher chick mortality.	River otters took 23% of adult breeding population in 1977 on Wooded Is; greater productivity in exclosures. Amount of egg neglect is sensitive indicator of foraging conditions.
Double-crested & Pelagic & Red-faced Cormorant	Eggs: avian predation. Chicks: exposure.	Inattentiveness by adults. Storms also destroyed nests. Poor foraging conditions bring starvation. Dispersed or asynchronous nests have 1.5-3.5 times lower productivity. Possible competition at nest site with Black-legged Kittiwakes. Disturbance by humans.	Cormorants are not tenacious & they readily leave the nest site when disturebe by predators.
Glaucous-winged Gull	Avian predation on chicks & eggs.	Availability of food, weather, inattentiveness.	Availability of food influences all stages of reproduction: number of adults that enter breeding kpopulation, laying, hatching, & fledging success, greater search time for food, less nest attentiveness. Growth rates are the same however in good & bad years.

TABLE A-9
Continued.

Species	Major Mortality	Synergistic Effects	Comments
Mew Gull	Eggs: human disturbance, avian predation. Chicks: storms.	Inattentiveness (adults readily displaced by humans). Poor food supply, starvation. Weather: exposure of both eggs & chicks.	Abandon nest site after egg predation. Starvation with poor food supply. Poor food supply results in inattentiveness by adults.
Black-legged Kittiwakes	Egg: predation by GWGU, CORA, NWCR. Chicks: predation by GWGU, BAEA. Adults: predation PEFA, BAEA.[a]	Inattentivenss. Weather: exposure of eggs & chicks, nests washed away, chicks fall from nest. Snychrony & density of nests.	Years of abundant food, BLKI have low predation; in years with low food there is high predation. Decrease in food; decrease in clutch size, increase in time foraging & time the chicks & eggs are exposed.
Arctic Tern & Aleutian Tern	Human disturbance. Predation, storms. Eggs: preyed on by GWGU, CORA, land otters. Chicks: preyed on by MEGU, GWGU, BBMA & NWCR.	Alteration of habitat. If no human disturbance, then predation most important. Chicks: exposure from less nest attentivenss due to poor foraging conditions & greater search time for food by adults.	In years of poor food, adults spend more time off their nests & leave their chicks exposed to predators & weather. In poor food years there is often a shift in diet with a decrease in success. Many choose not to enter breeding cycle.
Common Murre & Thick-billed Murre	Human disturbance, avian predation, storms.	All factors synergistic. Inattentiveness, sparse & synchronous colonies have low productivity. There is a minimum threshold density for reproductive success.	Murres flush easily, kicking eggs off cliffs. Low reproductive success may be the norm. Often failure of birds to lay eggs.
Horned Puffin	Eggs: avian predation, desertion. Chicks: avian predation.	Storms sometimes caused burrows to collapse &/or flood.	Greatest mortality in egg stage.
Tufted Puffin	Human disturbance, (boats, planes, people); mammalian predation.	Abandonment.	Higher productivity on preferred habitat. Older birds that are more successful may occupy the preferred habitat.

[a]GWGU=Glaucous-winged Gull; CORA=Common Raven; NWCR=Northwest Crow; MEGU=Mew Gull; BAEA=Bald Eagle; BBMA=Black-billed Magpie; PEFA=Peregrine Falcon; BLKI=Black-legged Kittiwake.

FEEDING ECOLOGY OF MARINE BIRDS IN THE NEARSHORE WATERS OF KODIAK ISLAND

by

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U.S. Fish and Wildlife Service
Denver Wildlife Research Center
Migratory Bird Project

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 341

September 1982

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ABSTRACT

The feeding habits of marine birds in the nearshore waters of Kodiak Island were studied during winter 1976-1977 and February 1978 and during summer 1977 and 1978. Our goals were to determine which prey were important to each species of bird and to define geographic, seasonal, and annual patterns of prey use. A total of 1,167 birds of 10 species were collected during the two year study. During both winters, oldsquaws and Steller's eiders ate a broad range of invertebrate prey, and common murres ate primarily gadids. Marbled murrelet feeding habits varied between the two winters; capelin were eaten in 1976-1977, but mysids were eaten during 1978. Pigeon guillemots and crested auklets were collected only during 1976-1977 when guillemots ate a broad range of epibenthic organisms, and auklets ate only mysids.

Except for common murres and pigeon guillemots, seabirds collected during summer ate euphausiids (primarily *Thysanoessa inermis*) during May and early June, capelin during late June and July, and sand lance during July and September. Shearwaters ate similar foods but appeared to divide resources temporally; short-tailed shearwaters were more abundant than sooty shearwaters during May and June whereas sooty shearwaters were more abundant during the second half of summer. Marbled murrelets, tufted puffins, and black-legged kittiwakes also ate similar foods but murrelets generally foraged closer to shore and kittiwakes were restricted to feeding in the upper 1-2 m. Common murres ate a wider range of fish and ate crustaceans less frequently than the other species. Pigeon guillemots fed on epibenthic invertebrates and fish.

Monthly sampling in Izhut Bay and northern Sitkalidak Strait during summer 1978 indicated that capelin were more important to seabirds in the former area than the latter. In addition, the use of capelin by kittiwakes at northern Sitkalidak Strait declined in 1978 compared to 1977 and appeared to have been related to the decrease in productivity observed by other investigators.

Due to the complexity of the fate and effects of petroleum, it is difficult to predict the impacts of a spill. However, oldsquaws, Steller's eiders, and pigeon guillemots would be exposed to hydrocarbons entering the food chain through the benthos, as would some of the more "pelagic" species of seabirds which feed on epibenthic mysids and amphipods during winter. Aside from the danger of the accumulation of pollutants in their food chains, the marine bird community probably depends on a balance between competing stocks of pelagic fishes and crustaceans which fluctuate over time and could be seriously disrupted by the release of massive amounts of oil into the water.

INTRODUCTION

The effects of oil pollution on marine birds have been the subject of numerous reviews (Aldrich 1970, Bourne 1968 and 1976, Clark 1969, Croxal 1975, Tanis and Morzer Bruijns 1969). Vermeer and Vermeer (1974) provide a comprehensive bibliography of literature published between 1922 and 1973 on the effects of oil on birds. Most studies or reports of mortality caused by oil pollution have described the losses which occur when birds encounter oil in large quantities (as during a spill) and their feathers become oiled so that their bouyancy and insulative value are lost. Less attention has been given to the indirect effects that may occur through contamination or changes in abundance of food. Studies reviewed by Varanshi and Malins (1977) address the problem of contaminated food sources but it is difficult to draw conclusions regarding bioaccumulation of pollutants because of lack of information on the food habits of individual species and the complexity of the fate and effects of petroleum.

The present study of the food habits and feeding ecology of marine birds off Kodiak was accompanied by studies of the distribution patterns of birds at sea (Dick 1979, Gould et al. 1978, Forsell and Gould 1981) and the reproductive performance of birds at colonies (Baird and Hatch 1979, Baird and Moe 1978, Nysewander and Barbour 1979, Nysewander and Hoberg 1978). Both the distribution and productivity of seabirds are related to the abundance and distribution of food.

Species using the nearshore waters differ seasonally. Therefore in winter our studies focused on the feeding habits of oldsquaws (*Clangula hyemalis*), Steller's eiders (*Polysticta stelleri*), common murres (*Uria aalge*), pigeon guillemots (*Cepphus columba*), marbled murrelets (*Brachyramphus marmoratus*), and crested auklets (*Aethia cristatella*) while in summer they focused on sooty shearwaters (*Puffinus griseus*), short-tailed shearwaters (*P. tenuirostris*), black-legged kittiwakes (*Rissa tridactyla*), common murres, pigeon guillemots, marbled murrelets, and tufted puffins (*Lunda cirrhata*). All work, including that of companion studies, was conducted between November 1976 and August 1978.

OBJECTIVES

A. To determine the important prey of selected species of marine birds in the Kodiak Island area,

B. to determine which size classes and life history stages of important species of prey were eaten, and

C. to define geographic, seasonal, and annual variations in marine bird feeding habits.

CURRENT STATE OF KNOWLEDGE

Ainley and Sanger (1975) reviewed literature published through spring 1975. Enough information existed to allow them to "broadly characterize" the feeding habits of most species, but they found little information on winter diets. They also noted that no study had yet considered the trophic relationships of an entire seabird community, breeding and non-breeding species included.

Prior studies most relevant to the present study include those by Baird and Hatch (1979), Nysewander and Barbour (1979), and Sanger *et al.* (1978), all conducted within the area with which we were concerned. Studies at colonies in northern Sitkalidak Strait (Baird and Hatch 1979) indicated that, although capelin (*Mallotus villosus*) was the most important food of black-legged kittiwake chicks in 1977, capelin decreased and sand lance (*Ammodytes hexapterus*) increased in importance during 1978. The change from capelin to sand lance was associated with a decline in seabird productivity.

The winter feeding ecology of oldsquaws, common murres, and marbled murrelets was studied by Sanger and Jones (1982) in Kachemak Bay, Alaska. These authors found that oldsquaws ate at least 60 species of prey (including sand lance, *Ammodytes hexapterus*, and the bivalves *Spisula polynyma* and *Mytilus edulis*), murres ate primarily crustaceans (*Neomysis rayii* and pink shrimp, Pandalidae), and murrelets ate primarily fish (capelin and sand lance). They noted that productivity in Kachemak Bay was based on the availability of organic detritus (probably derived from the winter die-off of kelp) and predicted that if oil pollution interfered with the production of detritus, there would be serious long-term consequences for marine birds.

STUDY AREA

The Kodiak Archipelago is located in the northwest Gulf of Alaska, 50 km across Shelikof Strait from the Alaska Peninsula (Figure 1). The topography of the archipelago is extremely rugged; mountains exceeding 1,300 m occur at the south end of Kodiak Island and the coastline is indented by bays, lagoons, and glacially carved fjords.

The topography of the shelf on the Gulf of Alaska side of the archipelago is marked by four shallow banks separated by troughs. Thermal stratification develops over the banks during summer, maintaining phytoplankton in the light-rich upper layers (Hameedi 1980, Kendall et al. 1980), and short term increases in primary productivity occur when storms mix nutrients into the surface waters. Nutrients are also derived from Alaska Stream waters which upwell through the troughs, displacing freshwater runoff from coastal areas (Bureau of Land Management 1976, Hameedi 1980, Kendall et al. 1980).

Copepods are the dominant group of grazers. During summer 1978, copepod volumes in the mid-shelf region exceeded 750,000 animals/m^3 (Kendall et al. 1980). Copepods spawn in time for their juvenile stages (copepodites) to graze on the spring phytoplankton bloom and the copepodites in turn are eaten by euphausiids and pelagic schooling fish (Rogers et al. 1980).

Inshore habitats include fjords, small bays, and intertidal and subtidal kelp beds. Moraines are absent from the mouths of the fjords on the Gulf of Alaska side of the archipelago, or are located far enough below the surface that water is exchanged freely with that in the open ocean (Hayes and Ruby 1979). Stratification from freshwater runoff is therefore short-lived and productivity is low compared to fjords on the Shelikof Strait side of the archipelago (Redburn 1976). The small bays which become stratified during summer are probably more productive; they are important spawning and nursery areas for herring, shrimp, and crabs (Alaska Department of Fish and Game 1977, Redburn 1976). Kelp beds provide feeding areas for mollusks, crustaceans, fish, sea ducks, and sea otters and detritus from the winter die-off of kelp contributes organic matter to the inshore ecosystem.

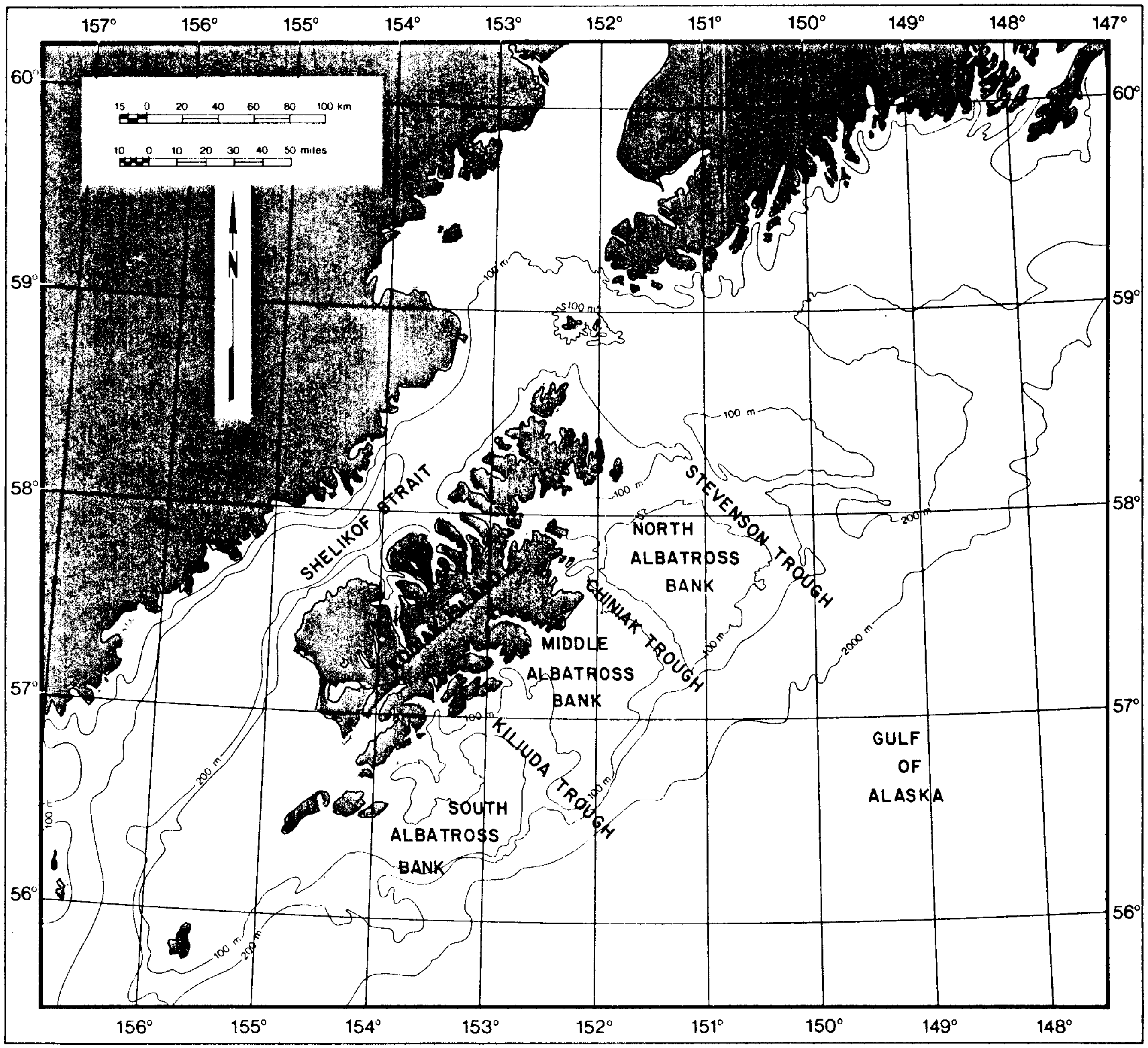

Figure 1. Topography of the Kodiak shelf.

METHODS

COLLECTION OF SPECIMENS

Collection of birds for food samples extended from November 1976 to August 1978. Oldsquaws, Stellar's eiders, common murres, pigeon guillemots, marbled murrelets, and crested auklets were collected in Chiniak Bay during winter 1976-1977 (Table 1). Winter studies of oldsquaw, common murres, and marbled murrelets were resumed during February 1978.

During summer 1977, the study area was extended to Marmot Bay in the north and the Geese Islands in the south and up to 45 km offshore (Figure 2). Collections were made in conjunction with shipboard studies of seabird distribution and abundance (Gould *et al.* 1978, Sanger *et al.* 1978). Species taken were sooty and short-tailed shearwaters, black-legged kittiwakes, tufted puffins, and common murres (Table 2).

Between April and August 1978, birds were collected at two locations (Izhut Bay and northern Sitkalidak Strait) within the broader area studied in 1977. An effort was made to obtain samples from both locations during each month. Studies were conducted onboard the M/V *Commando* in conjunction with plankton and bottom fish studies by the University of Washington's Fisheries Research Institute (FRI) and the Alaska Department of Fish and Game. Oldsquaws, sooty and short-tailed shearwaters, black-legged kittiwakes, common murres, tufted puffins, pigeon guillemots, and marbled murrelets were collected (Table 3). Relatively few birds were collected during April and May when densities were low.

At the time of collection, specimens were weighed to the nearest gram and stomachs were injected (via the esophagus) with 10% buffered formalin. Within two hours, gastrointestinal tracts were dissected out and morphological measurements (total length, diagonal tarsus, wing chord, culmen length, gape, presence or absence of brood patch, sex, fat index, and gonad length) were made. Except when pertinent to our results, morphological data will not be presented in this report.

In the laboratory, digestive tracts, esophagus to gizzard, were opened longitudinally and notes were made of the prey which were found in each section (esophagus, proventriculus, and gizzard). The drained, wet weight (to the nearest 0.1 g) and displacement volume (1.0 ml) of the combined contents of the proventricus, ventriculus, and gizzard were also recorded. Prey items were then identified to the lowest taxon.

ANALYSIS OF DATA

Data were grouped by predator, location, month, and year of collection. Where only a few birds were collected at each location and the foods they contained were similar, samples were combined for a given month. Three indices of importance were calculated for each type of prey: percent number, percent volume, and percent frequency of occurrence. The first two indices describe the amount of each prey eaten while the third describes its importance to the predator population. The Index of Relative Importance (Pinkas *et al.* 1971) was then calculated for each prey species by adding the percent of the total number of each type of prey

Table 1. Numbers of birds collected in Chiniak Bay during winter 1976-1977 and 1978.

Species	November 1976-April 1977 Number Collected	November 1976-April 1977 Percent W/ Food	February 1978 Number Collected	February 1978 Percent W/ Food
Oldsquaw	9	100	24	100
Steller's Eider	3	100		
Common Murre	4	100	9	67
Pigeon Guillemot	8	100		
Marbled Murrelet	18	100	19	84
Crested Auklet	2	100		
Total	42	100	52	88

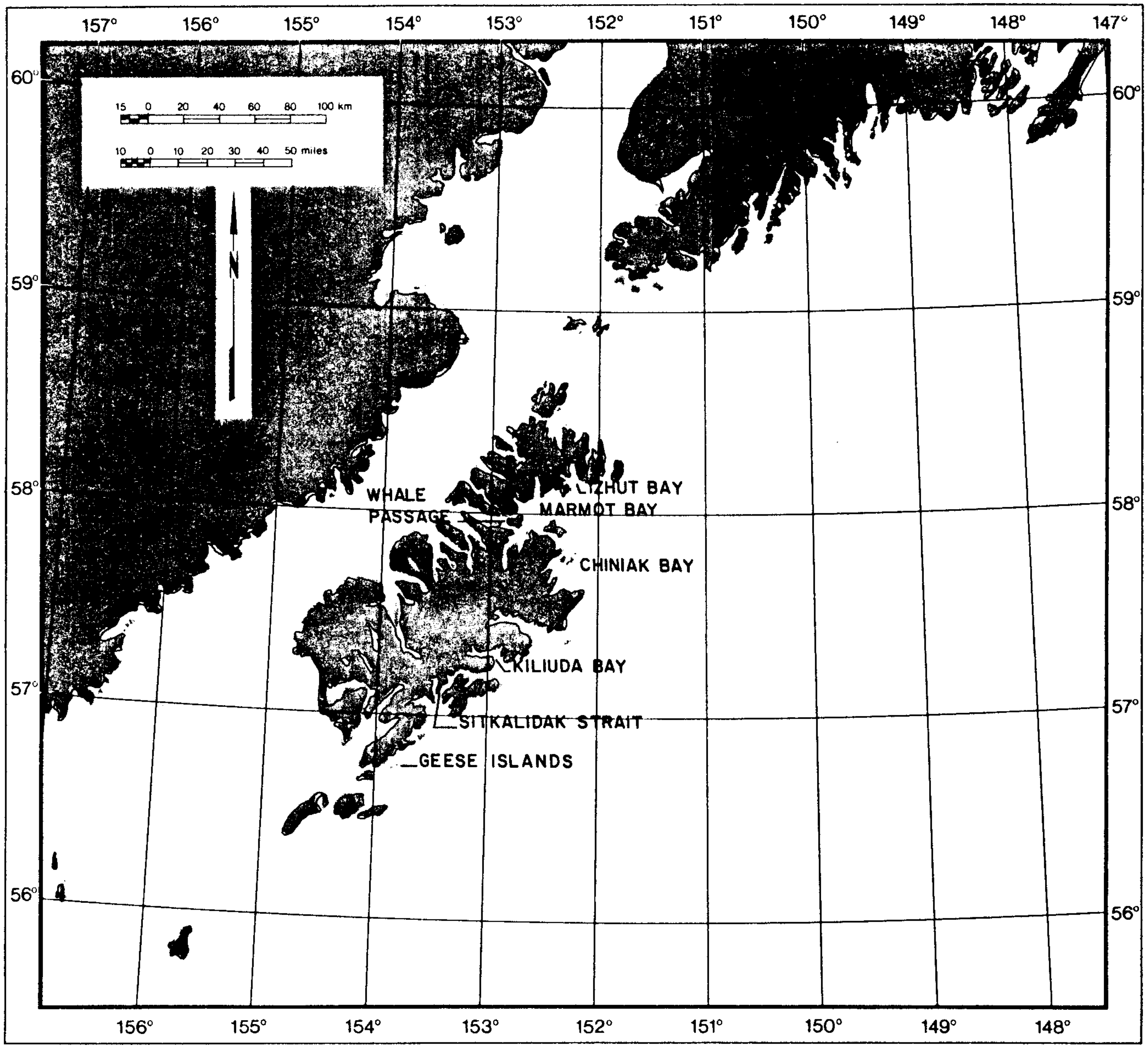

Figure 2. Study area.

Table 2. Numbers of birds collected, spring and summer 1977.

Month	Sooty Shearwater	Short-tailed Shearwater	Black-legged Kittiwake	Common Murre	Tufted Puffin
May	0	27	4	1	3
June	7	29	16	13	41
July	6	45	21	16	22
Aug.	6	43	21	7	28
Sept.	16	14	26	7	6
Total	35	158	88	44	100
Percent W/ Food	94	94	93	59	89

Table 3. Numbers of birds collected, spring and summer 1978. (IZH=Izhut Bay, NSS=Northern Sitkalidak Strait).

	Oldsquaw			Sooty Shearwater			Short-tailed Shearwater			Black-legged Kittiwake			Common Murre		
Month	IZH	NSS	Tot.	IZH	NSS	Tot.	IHZ	NSS	Tot.	IZH	NSS	Tot.	IZH	NSS	Tot.
April	2	5	7	0	0	0	0	0	0	1	2	3	4	8	12
May	0	0	0	0	0	0	0	5	5	6	0	6	0	17	17
June	0	0	0	39	13	52	1	0	1	25	22	47	15	9	24
July	0	0	0	11	17	28	0	2	2	3	17	20	3	11	14
Aug.	0	0	0	20	16	36	0	0	0	10	13	23	2	6	8
Total	2	5	7	70	46	116	1	7	8	45	54	99	25	51	75
Percent W/ Food			100			96			75			>99			72

Table 3 (cont.)

	Pigeon Guillemot			Marbled Murrelet			Tufted Puffin		
Month	IZH	NSS	Tot.	IZH	NSS	Tot.	IZH	NSS	Tot.
April	7	6	13	3	0	3	0	2	2
May	5	0	5	4	5	9	10	21	31
June	7	1	8	13	11	24	24	15	39
July	6	3	9	4	8	12	8	25	33
Aug.	6	3	9	10	2	12	24	22	46
Total	31	13	44	34	26	60	66	85	151
Percent W/ Food			82			70			72

to the percent of total volume, and multiplying that sum by percent frequency of occurrence.

Length frequency histograms were plotted for euphausiids (Thysanoessa spp.), capelin, and sand lance found in the stomachs. Euphausiids were straightened and the linear distance between the tip of the rostrum and the urosome was measured to the nearest mm. Regressions were derived for the relationships between total length and vertebral column length and total length and parasphenoid bone length for capelin and sand lance (Sanger et al. 1978) so that total lengths could then be estimated from the lengths of parts found in stomachs. Fork lengths of walleye pollock (Theragra chalcogramma) were estimated from otolith lengths (Frost and Lowry 1981). Values given are mean length, standard deviation, and sample size. Means of samples from different locations, months, or years were compared by t-test or single classification analysis-of-variance, described by Zar (1974).

The life history stages (larvae, juveniles, and spawning adults) of sand lance were estimated from the length-at-age relationship presented by Warner and Dick (1981). These authors were unable to clarify the relationship between length and age for capelin, perhaps because they combined sexes. Dragesund et al. (1973, cited by Jangaard 1974) have shown that males grow faster than females after age one.

RESULTS

SHEARWATERS

Sooty and short-tailed shearwaters breed in the southern hemisphere on islands off Chile, Australia, and New Zealand and, during the austral winter, migrate northward to the North Pacific Ocean and Bering Sea. They were the most abundant seabirds over the Kodiak shelf from May to September 1977, their numbers comprising approximately one third of the total number of seabirds in Alaskan waters during summer (Patrick Gould, USFWS, pers. comm.). Their combined density peaked at 75 birds/km^2 in July (Gould et al. 1978) and throughout the summer, was highest along the edges of the troughs. Density inshore increased as the season progressed. In May-June 1977, 89% of the shearwaters identified to species were short-tailed shearwaters; during July-September, 93% were sooty shearwaters. During 1978, when surveys were restricted to inshore areas, large flocks of short-tailed shearwaters were seen only twice, once in late May and again in early June. During July and August, only individual short-tailed shearwaters were seen, with flocks of sooty shearwaters which were abundant over the shelf.

Shearwaters are pursuit divers (Ashmole 1971). Compared with other shearwater species, members of the genus *Puffinus* are well adapted for swimming underwater with wings and feet (Brown et al. 1978), however they are poorly adapted compared to the diving ducks and alcids. Shearwaters can dive to at least 5 m; sooty shearwaters have taken bait from salmon hooks and short-tailed shearwaters have been caught in gill nets at that depth (Brown et al. 1978).

Sooty Shearwater. Capelin and cephalopods were the only identifiable prey eaten by sooty shearwaters during 1977 and the latter were represented only by beaks which occurred in 76% of the stomachs (Table 4). The jaws of nereid polychaetes were present in small amounts. During June 1978, capelin and *T. inermis* predominated in stomachs collected in both Izhut Bay and northern Sitkalidak Strait (Tables 5 and 6), but during July and August, sand lance became more important in the latter area (Figure 3, Tables 7-10).

Capelin eaten by sooty shearwaters during 1977 averaged 91 $\pm$ 18.6 mm total length (n=130) and those >100 mm were long enough to have been spawning adults (Krasnow, unpubl. data). Capelin eaten during 1978 averaged 107 $\pm$ 19.8 mm (n=244) and were significantly larger than those eaten the previous year ($P<0.001$) (Figure 4). During June 1978, when capelin was important to sooty shearwaters in both locations, capelin in Izhut Bay were significantly larger than those in northern Sitkalidak Strait ($P<0.001$). Sexually mature male capelin (identified by spawning ridges) occurred in two stomachs collected in northern Sitkalidak Strait during August. Sand lance eaten during 1978 averaged 78 $\pm$ 5.5 mm TL (n=135) (Figure 5) and were probably juvenile, age group 0 or I, fish (Dick and Warner, in press).

Cephalopods occurred in 68% of the stomachs in 1978 but were represented mostly by beak fragments. Exceptions were an intact head in a stomach from northern Sitkalidak Strait in June and egg masses in eight stomachs collected in both Izhut Bay and northern Sitkalidak Strait during August. (Squids of the family Gonatidae are abundant in the North Pacific and spawn pelagic eggs in masses, Bublitz 1980).

Table 4. Indices of relative importance of prey eaten by sooty shearwaters June-September 1977.

Species	% No.	% Vol.	% FO	IRI
Nereidae	1.4	*	6.1	9
Cephalopoda	39.4	2.5	75.8	3,176
Osteichthyes	1.1	3.2	12.1	52
Osmeridae	2.2	2.7	12.1	59
Mallotus villosus	55.9	91.6	57.6	8,498

*Less than 0.1%. (n=33, + 2 empty stomachs; 365 items, 699 ml volume)

Table 5. Indices of relative importance of prey eaten by sooty shearwaters, Izhut Bay, June 1978.

Species	% No.	% Vol.	% FO	IRI
Cephalopoda	9.2	1.1	71.8	740
Thysanoessa inermis	66.8	10.4	18.0	1,390
T. spinifera	0.1	0.2	2.6	1
Osteichthyes	0.5	10.3	10.3	8
Mallotus villosus	23.0	87.0	66.7	7,337
Trichodon trichodon	0.1	1.0	2.6	3
Ammodytes hexapterus	0.1	*	2.6	<1

*Less than 0.1%. (n=39; 768 items, 1,161 ml volume)

Table 6. Indices of relative importance of prey eaten by sooty shearwaters, northern Sitkalidak Strait, June 1978.

Species	% No.	% Vol.	% FO	IRI
Cephalopoda	27.2	3.6	91.7	2,824
Calanoidea	0.7	0.1	8.3	7
Hyperiidea	0.4	0.1	8.3	4
Thysanoessa inermis	39.1	5.4	8.3	369
Osteichthyes	1.8	1.6	25.0	85
Osmeridae	2.2	6.6	8.3	73
Mallotus villosus	28.3	80.0	50.0	5,415
Ammodytes hexapterus	0.4	2.6	8.3	25

(n=12; 279 items, 230 ml volume)

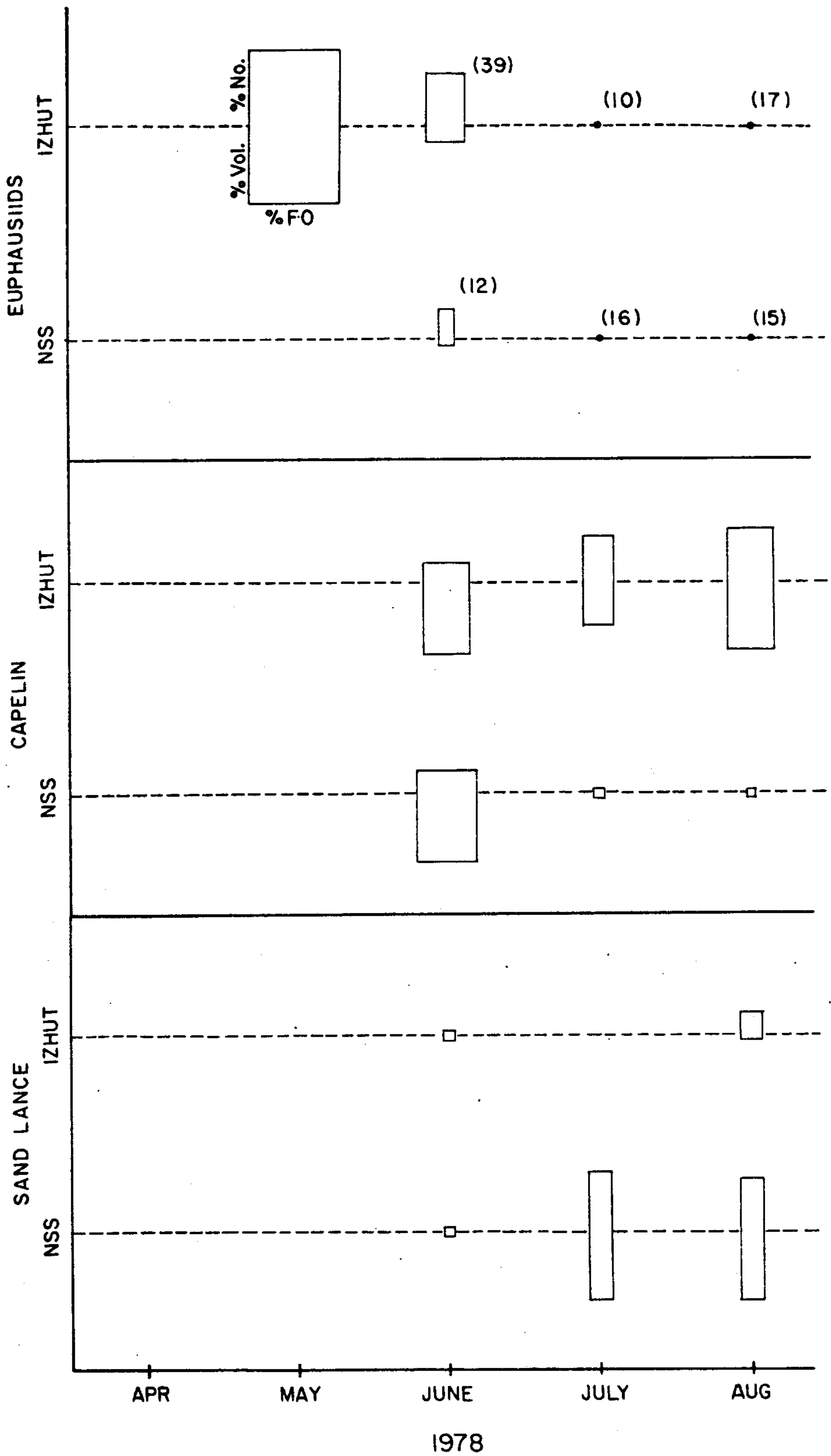

Figure 3. Relative importance of euphausiids, capelin, and sand lance to sooty shearwaters, Izhut Bay vs. northern Sitkalidak Strait, 1978. Sample sizes are in parentheses.

Table 7. Indices of relative importance of prey eaten by sooty shearwaters, Izhut Bay, July 1978.

Species	% No.	% Vol.	% FO	IRI
Cephalopoda	43.2	3.5	80.0	3,736
Osteichthyes	4.5	1.9	20.0	128
Mallotus villosus	52.3	94.7	30.0	4,410

(n=10, + 1 empty stomach; 44 items, 155 ml volume)

Figure 8. Indices of relative importance of prey eaten by sooty shearwaters, northern Sitkalidak Strait, July 1978.

Species	% No.	% Vol.	% FO	IRI
Cephalopoda	23.9	2.5	75.0	1,980
Osteichthyes	5.1	14.0	31.2	596
Mallotus villosus	0.7	0.8	6.2	9
Ammodytes hexapterus	70.3	82.7	43.8	6,701

(n=16, + 1 empty stomach; 138 items, 198 ml volume)

Table 9. Indices of relative importance of prey eaten by sooty shearwaters, Izhut Bay, August 1978.

Species	% No.	% Vol.	% FO	IRI
Cephalopoda	6.6	0.3	27.8	192
Osteichthyes	2.9	1.3	16.7	70
Mallotus villosus	61.3	89.4	61.1	9,208
Microgadus proximus	1.5	1.6	5.6	17
Ammodytes hexapterus	27.7	7.4	16.7	586

(n=17, + 2 empty stomachs; 133 items, 790 ml volume)

Table 10. Indices of relative importance of prey eaten by sooty shearwaters, northern Sitkalidak Strait, August 1978.

Species	% No.	% Vol.	% FO	IRI
Cephalopoda	29.3	4.1	66.7	2,228
Osteichthyes	17.2	18.1	53.3	1,882
Mallotus villosus	0.9	2.3	6.7	21
Trichodon trichodon	0.9	0.9	6.7	12
Ammodytes hexapterus	51.7	74.6	20.0	2,526

(n=15, + 1 empty stomach; 116 items, 177 ml volume)

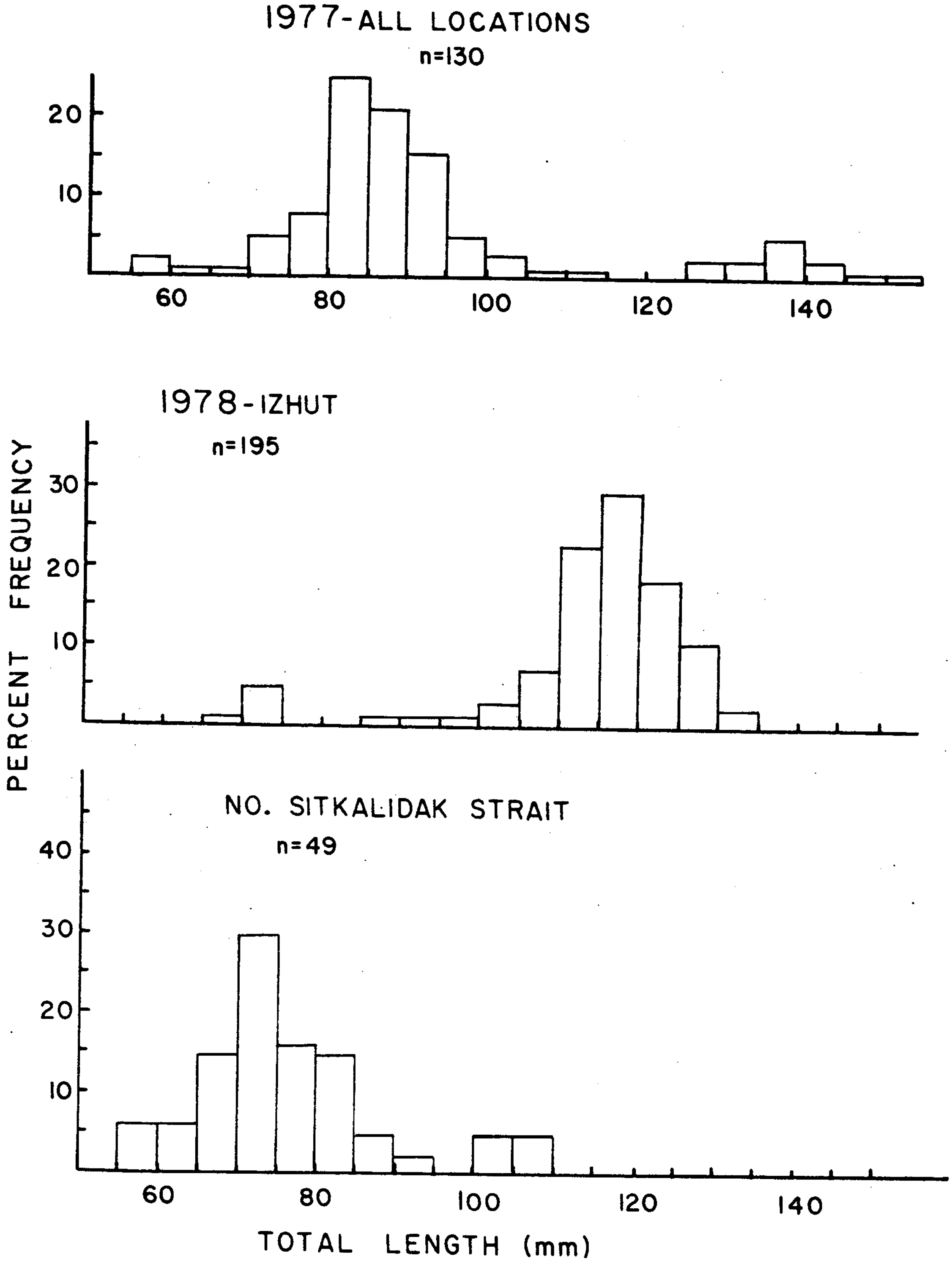

Figure 4. Length frequencies of capelin eaten by sooty shearwaters, 1977.

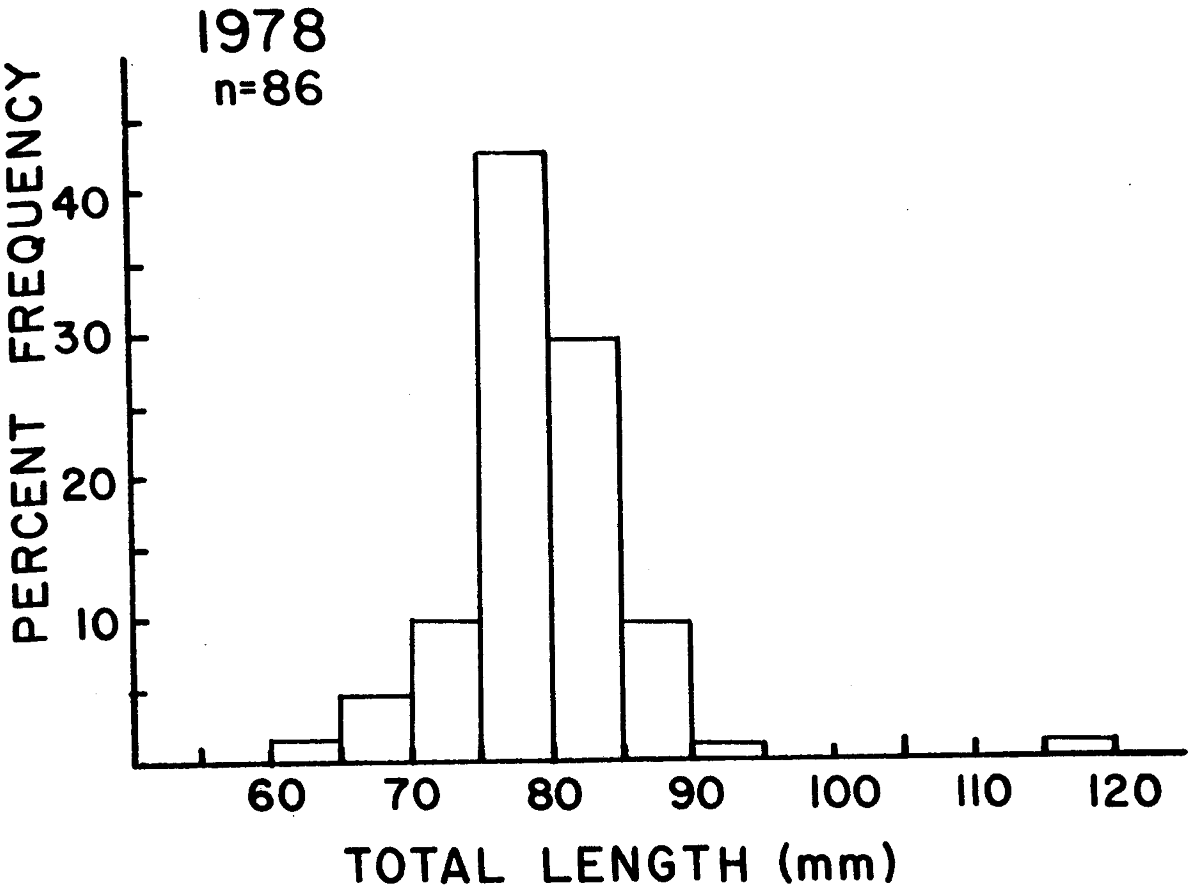

Figure 5. Length frequencies of sand lance eaten by sooty shearwaters, 1978.

Short-tailed Shearwater. Euphausiids were the most important prey of short-tailed shearwaters during both May and June 1977 and during May 1978 (Tables 11-13). On 22 June 1977, a concentration of 8,000-10,000 short-tailed shearwaters was seen feeding by head dipping outside the southern entrance to Sitkalidak Strait. Eighteen of the twenty-two birds collected contained *T. inermis* and *T. spinifera*, an average of 204 euphausiids per stomach. On 26 May 1978, four more shearwaters were collected from a flock of 50,000-100,000 sitting on the water outside the northern entrance to Sitkalidak Strait. These also contained *T. inermis*, which we could see swarming just below the surface. The euphausiids in the two sets of stomachs averaged 22 ± 1.7 mm (n=481) and 23 ± 2.6 mm (n=24) TL, respectively (Figure 6). April is mid-spawning season for the genus *Thysanoessa* (Kendall et al. 1980), and the swarms on which the shearwaters were feeding may have been spawning aggregations.

Thysanoessa inermis, *T. spinifera*, and *T. raschii* all occurred in short-tailed shearwater stomachs collected in Whale Passage during August 1977. The mean length of *T. spinifera* was the longest, followed by that of *T. inermis* and then *T. raschii* (Figure 7, $P<0.001$).

Capelin dominated the percent volume and frequency of occurrence of prey in short-tailed shearwater stomachs during July-September 1977 (Tables 14-16) and capelin averaged 90 ± 18.2 mm TL (n=163) (Figure 8). Sand lance from stomachs collected in July and September 1977 averaged 54 ± 10.7 mm (n=24) while those from stomachs collected in July 1978 were significantly larger, averaging 74 ± 2.7 mm TL (n=7) ($P<0.001$) (Figure 9).

Capelin comprised 83% of the volume of prey in Whale Passage during August 1977, but large numbers of euphausiids were also eaten (Table 17). Capelin in the stomachs of black-legged kittiwakes and tufted puffins collected at the same time had been feeding on euphausiids, calanoid copepods (Calanoida), hyperiid amphipods (Hyperiidea), and cumaceans (Cumacea). Apparently, zooplankton were entrained into the surface waters by the mixing of water in the passage as the tide changed, attracting a variety of vertebrate predators.

Fragments of cephalopod beaks were found in 38% of the short-tailed shearwater stomachs collected in 1977 and were represented in samples from all locations and all months. Like sooty shearwaters, short-tailed shearwaters may have ingested cephalopods at some distance from the study area, such as over the shelf or during migration across the Pacific Ocean. No evidence of predation on cephalopods occurred in stomachs collected during 1978.

OLDSQUAW

The oldsquaw is the most abundant duck nesting on the arctic tundra (Bellrose 1976). Much of the population winters along the Pacific coast from the Bering Sea to California. Forsell and Gould (1981) estimated that 65,000 oldsquaws were present in the nearshore waters of Kodiak Island between November 1979 and February 1980 and Dick (1979) reported that 3,000-5,000 resided in Chiniak Bay during winter 1976-1977. Dick noted that in moderate weather, small groups (or sometimes dense aggregations of up to a thousand) occurred over the reefs around Bird and Holiday Islands. As wind speed increased, the birds moved farther inshore.

Table 11. Indices of relative importance of prey eaten by short-tailed shearwaters, May 1977.

Species	% No.	% Vol.	% FO	IRI
Gastropoda	*	*	3.7	0
Cephalopoda	2.5	8.2	70.4	753
Euphausiacea	4.9	6.6	22.2	255
T. inermis/spinifera	92.5	85.2	51.9	9,223

*Less than 0.1%. (n=27; 2,127 items, 141 ml volume)

Table 12. Indices of relative importance of prey eaten by short-tailed shearwaters, June 1977.

Table	% No.	% Vol.	% FO	IRI
Cephalopoda	0.4	0.7	19.2	21
Euphausiacea	0.2	0.5	7.7	5
T. inermis/spinifera	99.0	91.6	80.8	15,401
Decapoda	0.2	*	3.8	1
Telmessus chieragonus	0.1	*	3.8	0
Osteichthyes	*	0.3	7.7	2
Osmeridae	0.1	6.8	7.7	53

*Less than 0.1%. (n=26, + 3 empty stomachs; 4,109 items, 385 ml volume)

Table 13. Indices of relative importance of prey eaten by short-tailed shearwaters, northern Sitkalidak Strait, May 1978.

Species	% No.	% Vol.	% FO	IRI
Thysanoessa inermis	100.0	100.0	100.0	200,000

(n=4, +1 empty stomach; 830 items, 71 ml volume)

Table 14. Indices of relative importance of prey eaten by short-tailed shearwaters, July 1977.

Species	% No.	% Vol.	% FO	IRI
Cephalopoda	0.4	0.8	34.9	42
T. inermis/spinifera	97.3	42.4	18.6	2,598
Decapoda	*	*	2.3	<1
Osteichthyes	0.1	1.0	16.3	18
Osmeridae	0.4	11.9	20.9	257
Mallotus villosus	0.7	38.4	32.6	1,275
Ammodytes hexapterus	1.0	5.5	11.6	75

*Less than 0.1%. (n= 43, + 2 empty stomachs; 5,923 items, 1,123 ml volume)

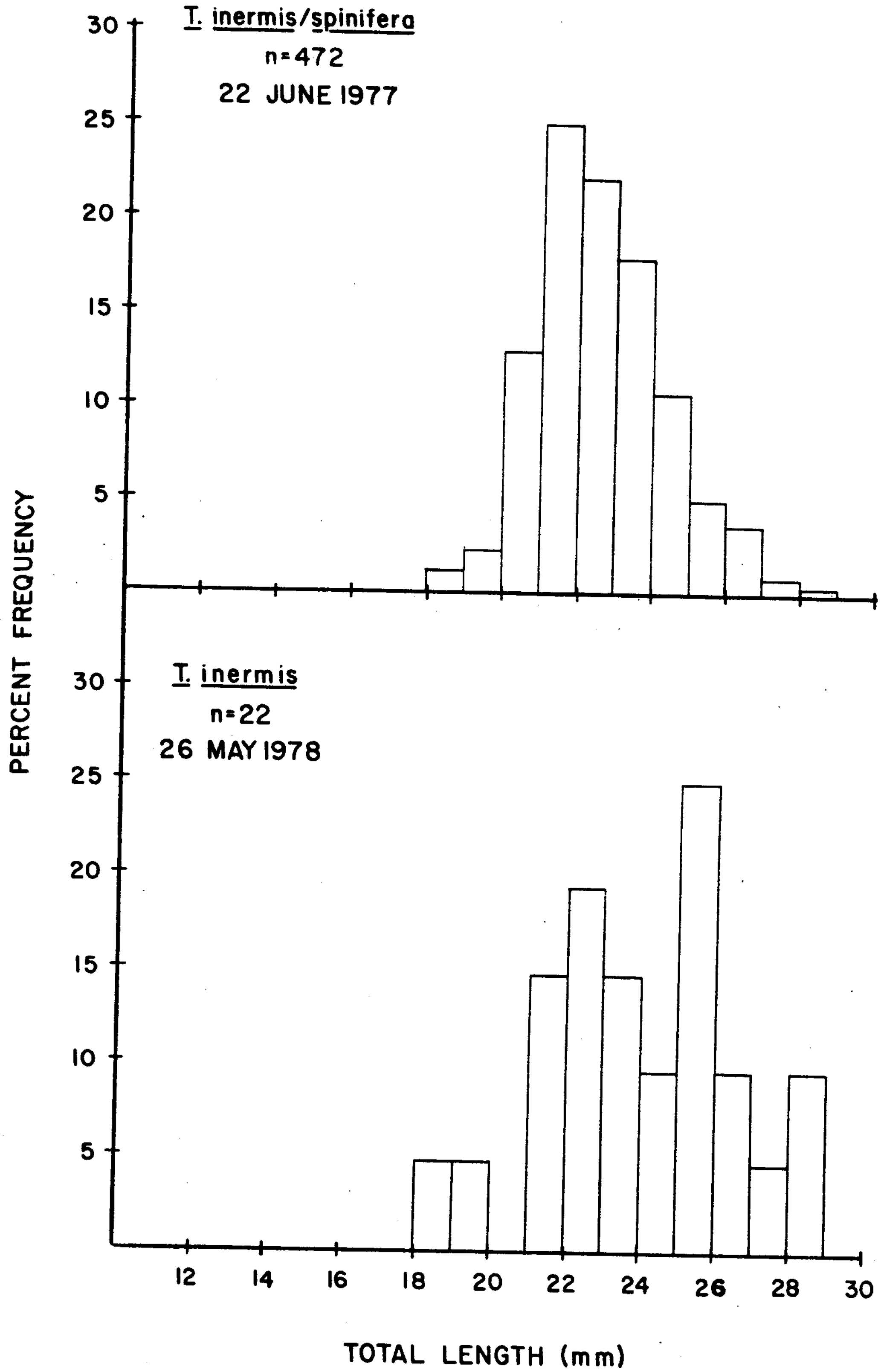

Figure 6. Length frequencies of euphausiids eaten by short-tailed shearwaters, 1977 and 1978.

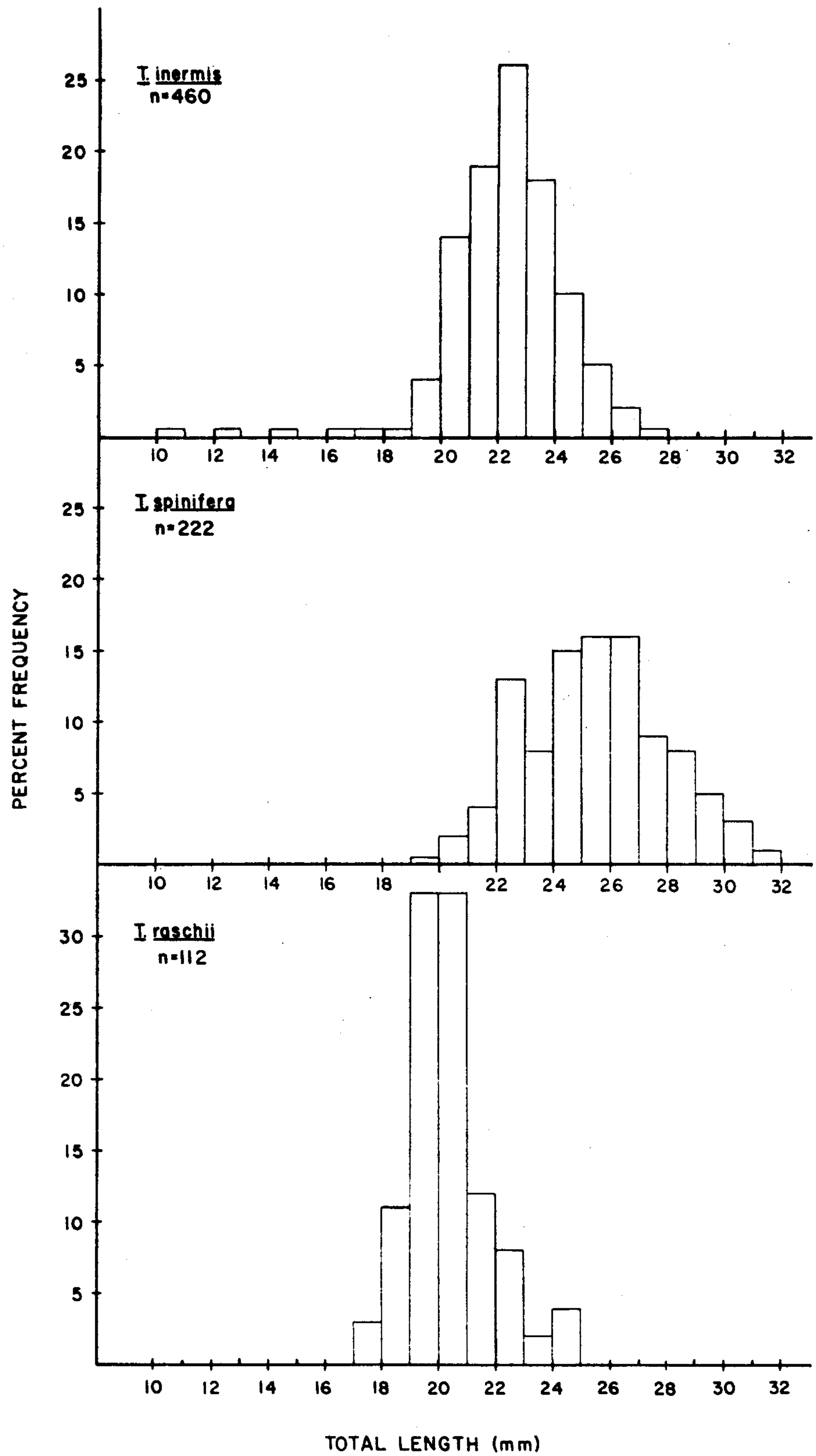

Figure 7. Length frequencies of euphausiids eaten by short-tailed shearwaters, Whale Passage, August 1977.

Table 15. Indices of relative importance of prey eaten by short-tailed shearwaters, August 1977.

Species	% No.	% Vol.	% FO	IRI
Nereidae	11.1	1.1	11.0	134
Cephalopoda	2.8	0.9	22.0	81
Euphausiacea	37.5	0.4	11.0	417
T. inermis/spinifera	16.5	1.7	22.0	405
Osteichthyes	2.8	4.7	22.0	165
Mallotus villosus	29.2	91.1	33.0	3,970

(n=9, + 4 empty stomachs; 72 items, 117 ml volume)

Table 16. Indices of relative importance of prey eaten by short-tailed shearwaters, September 1977.

Species	% No.	% Vol.	% FO	IRI
Nereidae	1.0	0.1	14.0	15
Cephalopoda	0.5	1.2	35.7	61
T. inermis	0.4	*	7.1	3
T. spinifera	0.9	0.1	7.1	7
T. raschii	20.2	1.0	7.1	150
T. spp.	61.0	2.9	7.1	454
Osteichthyes	0.7	1.7	1.0	2
Osmeridae	0.2	2.0	14.0	31
Mallotus villosus	14.9	89.3	1.8	188
Ammodytes hexapterus	0.2	1.8	7.1	14

(n=14; 912 items, 399 ml volume)

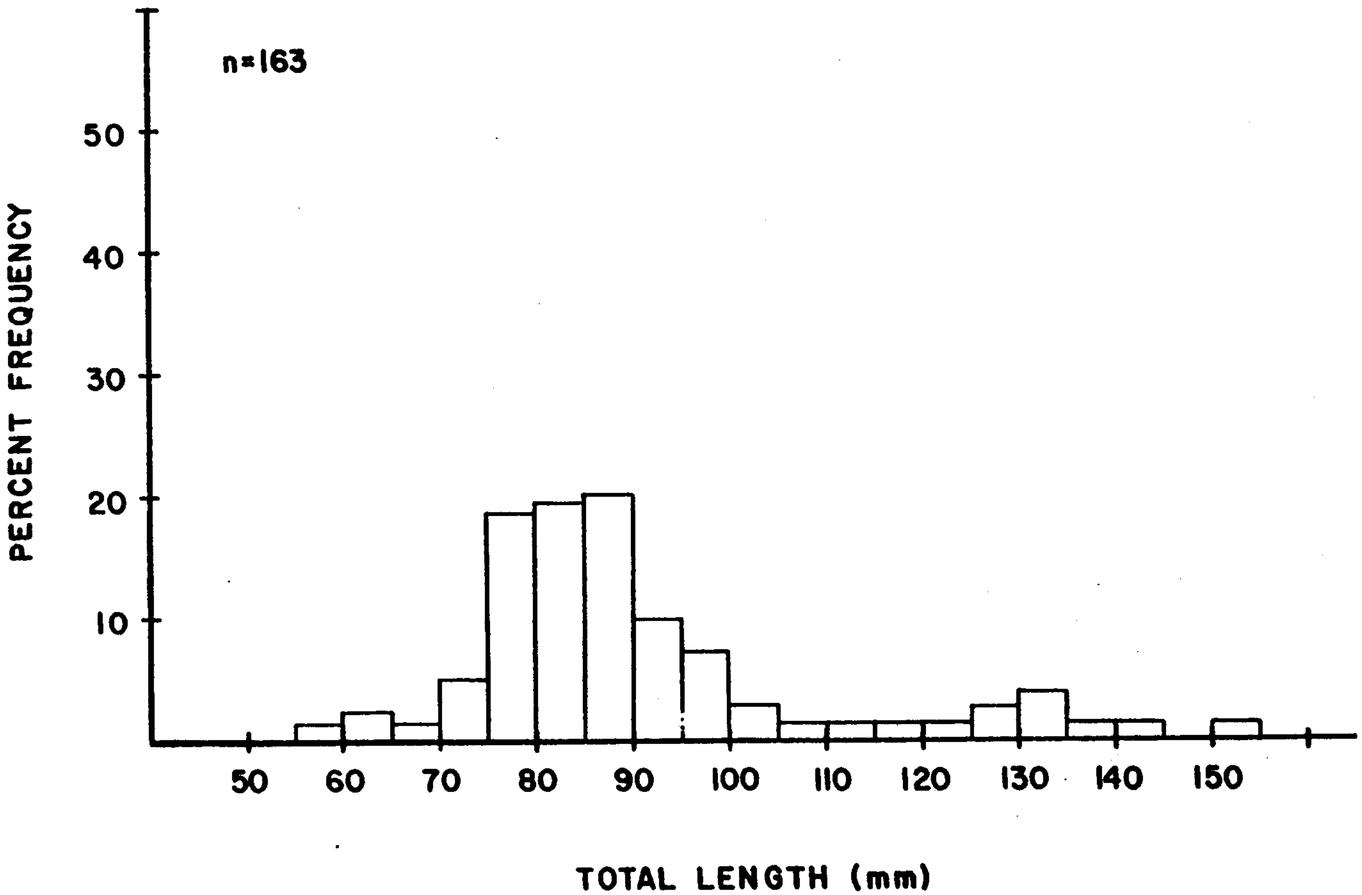

Figure 8. Length frequencies of capelin eaten by short-tailed shearwaters, 1977.

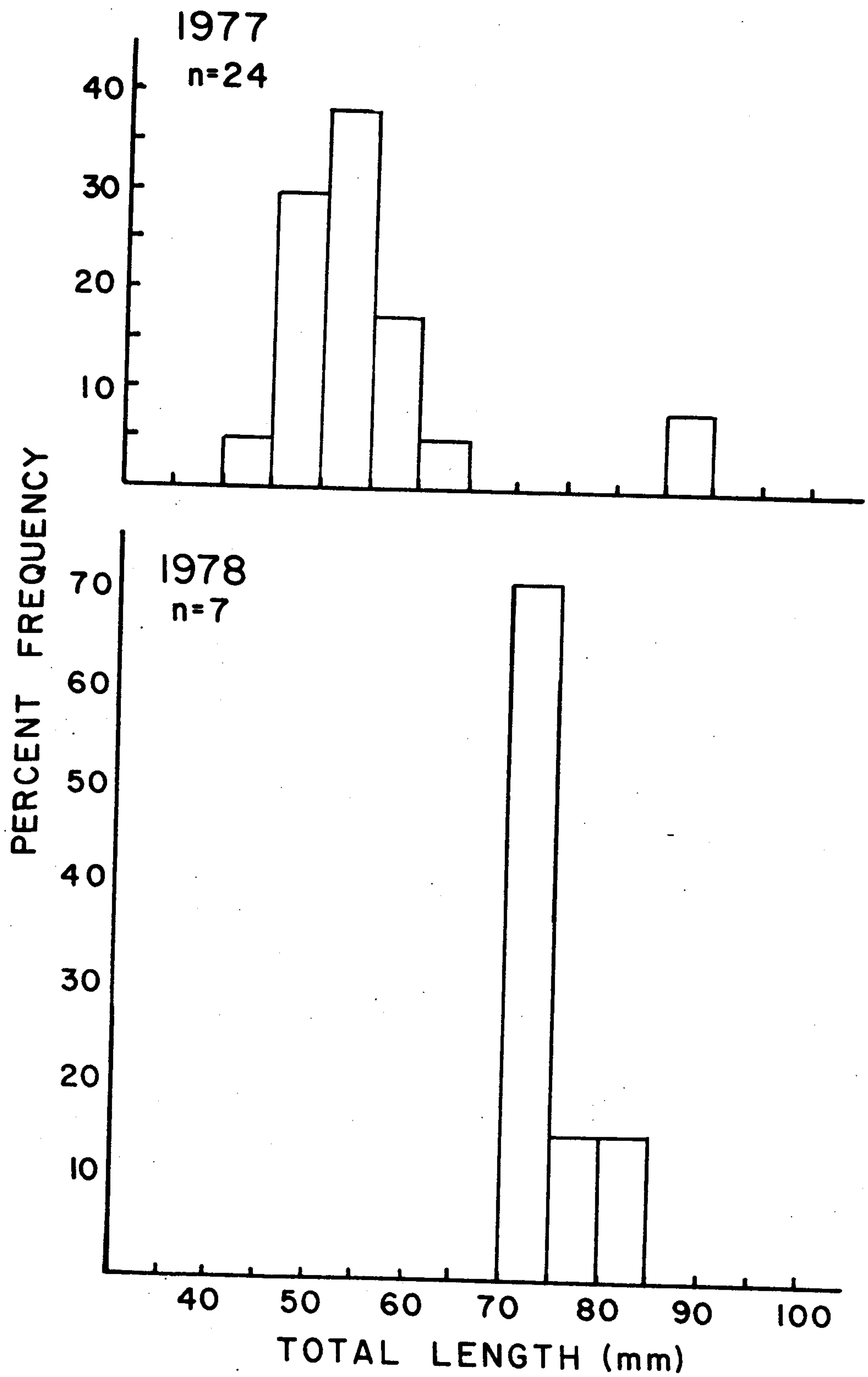

Figure 9. Length frequencies of sand lance eaten by short-tailed shearwaters, 1977 and 1978.

Table 17. Indices of relative importance of prey eaten by short-tailed shearwaters, Whale Passage, August 1977.

Species	% No.	% Vol.	% FO	IRI
Nereidae	12.3	2.1	25.0	360
Cephalopoda	1.5	1.6	12.5	39
Euphausiacea	41.5	0.8	12.5	529
Thysanoessa inermis/ spinifera	18.5	3.2	25.0	542
Osteichthyes	3.1	8.9	25.0	299
Mallotus villosus	23.1	83.4	25.0	2,662

(n=8, +3 empty stomachs; 65 items, 62 ml volume)

Although oldsquaws are able to dive at least 48 m in search of food (Ellarson 1956, cited by Bellrose 1976), they commonly feed on epibenthic prey in shallow areas and in the intertidal (Sanger et al. 1978). The relative importance of mobile versus sessile prey in stomachs collected between 5 December 1976 and 27 March 1977 varied, suggesting that oldquaw turned to a more predictable food source (gastropods, bivalves, and barnacles) when mobile prey (mysids and amphipods) were not available (Table 18). Larval osmerids (Osmeridae) (35 $\pm$ 2.4 mm TL, n=7) occurred in stomachs collected during March.

On 23 February 1978, the blue mussel (*Mytilus edulis*) was the most important prey in stomachs collected near Woody Island while the gastropods *Lacuna variegata* and *Alvinia compacta* predominated in stomachs collected the next day (Tables 19 and 20). Crustaceans (Gammaridea and Decapoda) were relatively unimportant in these collections, comprising only 27 and 7% of the number of prey in the two samples respectively. One stomach collected on 23 February contained a small stichaeid fish (65 mm TL) and another, collected on 24 February contained 208 unidentified fish eggs.

Oldsquaws were again sampled during April 1978. Two from Izhut Bay ate only euphausiids and unidentified zoea larvae (Brachyura) while five from northern Sitkalidak Strait contained a total of 27 taxa of invertebrates plus sand lance (Tables 21 and 22). The importance of sea urchins (*Stongylocentrotus* sp.) in the latter collection may have been underestimated as fragments of spines and tests occurred in 100% of the stomachs.

STELLER'S EIDER

Kodiak is at the eastern edge of the wintering range of the Steller's eider, a species which nests along the arctic coast of Alaska and the Soviet Union (Bellrose 1976). An estimated 1,500-2,000 eiders were present in Chiniak Bay during winter 1976-1977, concentrated in sheltered areas near Gull, Uski, Woody, and Holiday Islands (Dick 1979). Forsell and Gould (1981) estimated that 1,000-1,200 wintered in the archipelago in 1980 with largest numbers in Chiniak Bay and suggested that populations vary between years, depending on weather patterns in other wintering areas.

Like oldsquaw, eiders ate a diverse range of prey. Two collected near Bird Island in December 1976 contained a total of 31 taxa including polychaetes, gastropods, bivalves, crustaceans, and sea cucumbers (Holothuroidea) (Table 23). A third, collected in a lagoon on the northwest side of Long Island during February 1977, contained only a single polychaete, a gastropod, a bivalve, and a crustacean (Table 24). Total lengths of gastropods ranged from 2-4 mm (mean=3 mm, n=11) and those of bivalves ranged from 3-20 mm (mean=11 mm, n=28).

BLACK-LEGGED KITTIWAKE

Black-legged kittiwakes were more abundant inshore in summer than in winter. During summer 1977, the density of kittiwakes within the bays ranged from 10-12

Table 18. Indices of relative importance of prey eaten by oldsquaws, Chiniak Bay, December 1976-March 1977.

Species	% No.	% Vol.	% FO	IRI
Gastropoda	0.1	0.4	22	11
Margarites sp.	*	0.1	11	1
Alvinia sp.	0.1	0.1	11	2
Bittium sp.	0.1	0.3	11	4
Natica clausa	0.1	0.8	11	10
Turridae	0.1	0.5	11	7
Odostomia sp.	0.1	*	11	1
Bivalvia	0.2	0.7	33	30
Musculus sp.	0.1	0.1	11	2
Scaphopoda	0.1	0.1	11	2
Cirripedia	0.3	1.1	56	78
Mysidacea	26.3	36.7	11	693
Acanthomysis sp.	59.9	32.3	44	4,057
Neomysis sp.	0.4	0.4	22	18
Thysanoessa inermis	1.2	1.2	22	53
T. inermis/spinifera	0.1	0.3	11	4
T. raschii	4.3	2.6	22	152
T. spp.	2.3	3.3	22	123
Amphipoda	0.4	8.2	11	95
Lysianassidae	0.3	0.1	22	9
Decapoda	0.1	1.5	11	18
Crangon septemspinosa	0.1	0.3	11	4

Table 18 (cont.)

Echinoidea	0.1	0.4	22.0	11
Ophiuroidea	0.1	0.1	11.0	2
Osmeridae	3.3	8.2	11.0	127

*Less than 0.1%. (n=9; 1,410 items, 132 ml volume)

Table 19. Indices of relative importance of prey eaten by oldsquaw, Woody Island, Chiniak Bay, 23 February 1978.

Species	% No.	% Vol.	% FO	IRI
Nemertea	0.3	1.3	7.1	11
Polychaeta	2.0	0.4	14.3	34
Harmothoe sp.	0.3	0.3	7.1	4
Phole minuta	1.4	0.1	7.1	11
Syllidae	0.3	0.3	7.1	4
Nereidae	0.3	0.1	7.1	3
Cirratulidae	0.3	0.3	7.1	4
Flabelligeridae	0.3	0.3	7.1	4
Ophellidae	0.3	0.1	7.1	3
Owenia sp.	0.6	0.4	14.3	14
Pectinaria sp.	0.9	0.6	21.4	32
Gastropoda	0.9	0.4	21.4	28
Margarites pupillas	2.3	0.4	14.3	39
Lacuna variegata	4.0	1.0	28.6	143
Littorina sitkana	1.7	0.4	7.1	15

Table 19 (cont.)

Alvinia compacta	8.6	1.1	42.9	416
Cingula katherinae	1.2	0.6	7.1	13
Balcis sp.	0.9	0.6	7.1	11
Trichotropis cancellata	3.8	0.3	7.1	29
Trichotropis insignis	0.6	0.3	7.1	6
Admete couthouyi	0.3	0.1	7.1	3
Odostomia sp.	0.6	0.3	14.3	13
Retusa sp.	0.6	*	7.1	4
Aglaja diomedea	0.3	*	7.1	2
Bivalvia	4.0	6.8	42.9	463
Glycymeris subobsoleta	1.4	0.3	7.1	12
Mytilus edulis	2.0	33.2	50.0	1,760
Musculus vernicosus	1.7	0.6	14.3	33
Macoma sp.	0.6	0.7	14.3	19
Saxidomus sp.	0.3	0.9	7.1	8
Saxidomus gigantea	0.9	0.4	14.3	19
Psephidea lordi	1.7	0.3	7.1	14
Protothaca staminea	1.4	3.5	14.3	70
Mya sp.	0.9	0.3	7.1	8
Harpactacus sp.	0.6	0.1	7.1	5
Cirripedia	0.3	0.6	7.1	6
Acanthomysis sp.	6.0	0.3	7.1	45
Cumacea	4.6	0.1	7.1	33
Amphipoda	12.1	9.7	28.6	624
Gammaridea	0.9	3.9	21.4	103

Table 19 (cont.)

Eualus pusiola	1.4	1.8	14.3	46
Crangon septemspinosa	0.3	0.8	7.1	8
Paralithodes camstchatica	0.3	0.7	7.1	7
Ophiuroidea	0.3	0.3	7.1	4
Ophiopholis aculeata	13.0	8.7	7.1	154
Amphiopholis pugetana	9.8	7.6	7.1	124
Echinoidea	0.6	0.3	14.3	13
Strongylocentrotus sp.	0.3	0.6	7.1	6
S. droebachiensis	1.4	3.8	7.1	37
Microporina borealis	0.3	0.6	7.1	6
Stichaeidae	0.3	3.4	7.1	26

*Less than 0.1% (n=14; 347 items, 71 ml volume)

Table 20. Indices of relative importance of prey eaten by oldsquaw, Cliff Point, Chiniak Bay, 24 February 1978.

Species	% No.	% Vol.	% FO	IRI
Foraminifera	2.1	0.4	30.0	75
Polychaeta	0.4	9.1	30.0	285
Hemipodus borealis	0.2	2.2	10.0	24
Travisia sp.	0.2	2.2	10.0	24
Owenia sp.	0.6	2.2	30.0	84
Pectinaria granulata	0.2	0.2	10.0	4
Gastropoda	1.9	3.3	20.0	104

Table 20 (cont.)

Archeogastropoda	0.3	0.2	10.0	6
Achmaeidae	0.9	3.1	10.0	40
Margarites pupillas	0.3	0.2	20.0	10
Lacuna spp.	0.3	*	10.0	3
Lacuna variegata	16.4	19.1	60.0	2,130
Littorina sitkana	1.8	0.2	10.0	20
Alvinia compacta	27.8	2.2	70.0	2,100
Nucella lima	0.3	1.1	10.0	14
Turridae	0.3	0.4	10.0	7
Oenopota sp.	2.8	3.1	20.0	118
Odostomia sp.	2.2	0.9	20.0	62
Philine sp.	0.3	0.2	10.0	5
Onchidoris bilamellata	0.2	0.2	10.0	4
Bivalvia	0.4	1.1	30.0	45
Glycymeris subobsoleta	0.3	0.2	10.0	5
Mytilus edulis	0.2	*	10.0	2
Axinopsida serricata	0.2	0.2	10.0	4
Psephidia lordi	0.3	0.4	20.0	14
Protothaca staminea	1.3	10.7	50.0	600
Cumacea	0.3	0.2	10.0	5
Amphipoda	2.6	4.2	30.0	204
Gammaridea	2.6	17.6	40.0	808
Hymenodora frontalis	1.0	6.7	20.0	154
Pagurus sp.	0.2	0.7	10.0	9
Paralithodes camtschatica	0.4	6.4	20.0	136

Table 20 (cont.)

Cancer oregonensis	0.2	0.2	10.0	4
Osteichthyes	30.8	0.4	20.0	624

*Less than 0.1% (n=10; 679 items, 45 ml volume)

Table 21. Indices of relative importance of prey eaten by oldsquaw, Izhut Bay, April 1978.

Species	% No.	% Vol.	% FO	IRI
Thysanoessa raschii	91.7	81.4	50.0	8655
T. sp.	3.3	10.0	50.0	665
Brachyura	5.0	8.6	100.0	1360

(n=2; 60 items, 7 ml volume)

Table 22. Indices of relative importance of prey eaten by oldsquaw, northern Sitkalidak Strait, April 1978.

Species	% No.	% Vol.	% FO	IRI
Foraminifera	0.4	0.2	20.0	12
Polychaeta	0.2	0.9	20.0	22
Eteone longa/californica	0.2	0.2	20.0	8
Opheliidae	0.2	0.2	20.0	8
Gastropoda	0.4	0.4	20.0	16

Table 22 (cont.)

Margarites sp.	0.2	0.2	20.0	8
Lacuna variegata	41.3	19.6	80.0	4,872
Alvinia compacta	2.2	0.6	60.0	168
Trichotropis cancellata	0.2	0.2	20.0	8
Natica sp.	0.4	0.9	20.0	26
Nassarius sp.	0.4	0.2	20.0	12
Olivella baetica	1.5	0.4	20.0	38
Mangelia spp.	7.7	10.9	40.0	744
Odostomia spp.	0.2	*	20.0	4
Turbonilla spp.	1.5	3.0	20.0	90
Retusa spp.	0.6	0.2	20.0	16
Bivalvia	4.5	2.2	60.0	402
Glycymeris subobsoleta	0.2	0.2	20.0	8
Mytilidae	0.2	0.9	20.0	22
Mytilus edulis	0.2	0.2	20.0	8
Astarte spp.	1.1	0.9	20.0	40
Spisula polynyma	0.2	0.4	20.0	12
Psephidia lordi	2.6	1.7	20.0	86
Protothaca staminea	1.1	0.4	20.0	30
Cirripedia	0.9	5.1	80.0	6
Cumacea	22.6	8.7	20.0	626
Gammaridea	2.2	2.6	20.0	96
Decapoda	0.2	1.7	20.0	38
Pagurus sp.	0.4	0.4	20.0	16
Brachyura	0.2	0.4	20.0	12
Ophiuroidea	0.2	0.4	20.0	12

Table 22 (cont.)

Echinoidea	1.1	3.3	100.0	440
Ammodytes hexapterus	4.3	32.2	40.0	1,460

(n=5; 465 items, 23 ml volume)

Table 23. Indices of relative importance of prey eaten by Steller's eiders, Bird Island, Chiniak Bay, 12 December 1976.

Species	% No.	% Vol.	% FO	IRI
Anthozoa	0.3	0.4	50.0	35
Nemertea	1.2	1.8	50.0	150
Polychaeta	0.3	6.1	50.0	320
Polynoidea	2.8	0.1	50.0	145
Phyllodocidae	5.2	4.0	100.0	920
Eteone sp.	2.2	1.6	50.0	190
Syllidae	0.3	1.6	50.0	95
Nereidae	3.1	2.2	100.0	530
Lumbrineridae	0.6	1.6	50.0	110
Orbinidae	7.7	0.1	50.0	390
Cirratulidae	0.3	1.6	100.0	190
Flabelligeridae	0.3	1.6	50.0	95
Ophellidae	3.4	6.1	100.0	950
Oweniidae	0.3	4.6	50.0	245
Owenia fusiformis	0.3	1.6	50.0	95
Pectinaria sp.	0.6	1.2	50.0	90

Table 23 (cont.)

Ampharetidae	0.3	1.6	50.0	95
Sabellidae	1.8	1.6	50.0	170
Acmaeidae	0.3	0.4	50.0	35
Margarites sp.	2.2	0.7	100.0	290
Lacuna sp.	1.5	0.4	50.0	95
Barleeia sp.	1.8	0.4	50.0	110
Natica clausa	0.6	0.4	50.0	50
Odostomia sp.	1.5	0.4	50.0	95
Bivalvia	0.6	2.2	50.0	140
Macoma sp.	0.9	0.4	50.0	65
Protothaca staminea	0.6	1.1	50.0	85
Hiatella sp.	9.3	9.8	100.0	1,910
Lepas sp.	0.6	0.1	50.0	35
Isopoda	0.9	0.4	50.0	65
Leptochelia savignyi	0.3	0.4	50.0	35
Gammaridea	23.5	4.9	100.0	2,840
Lysianassidae	0.6	0.4	50.0	50
Pandalidae	0.3	0.2	50.0	25
Cucumaria lubricata	23.8	38.6	100.0	6,240
Eupentacta quinquesemita	0.3	0.4	50.0	35

(n=2; 224 items, 116 ml volume)

Table 24. Indices of relative importance of prey eaten by Steller's eiders lagoon on Long Island, Chiniak Bay, 27 February 1977.

Species	% No.	% Vol.	% FO	IRI
Pectinaria sp.	16.7	24.6	100.0	4,130
Littorina sp.	16.7	1.8	100.0	1,850
Bivalvia	16.7	45.6	100.0	6,230
Mysella sp.	16.7	1.8	100.0	1,850
Crustacea	16.7	24.6	100.0	4,130
Gammaridea	16.7	1.8	100.0	1,850

(n=1; 6 items, 6 ml volume)

Tables 25. Indices of relative importance of prey eaten by black-legged kittiwakes, May 1977.

Species	% No.	% Vol.	% FO	IRI
Parathemisto japonica	1.1	0.6	25.0	43
Thysanoessa inermis	82.2	14.3	100.0	9,650
Osmeridae	15.6	52.9	75.0	5,138
Gadidae	1.1	32.2	25.0	833

(n=4; 90 items, 65 ml volume)

birds/km^2, whereas during winter 1979-1980, density was only 1-7 birds/km^2 (Forsell and Gould 1981, Gould *et al*. 1978). Although over 107,000 kittiwakes nest in the Kodiak Archipelago, 52% in Izhut Bay and in northern Sitkalidak Strait (Sowls *et al*. 1978), most of the kittiwakes examined were non-breeders. Only 22% of 54 birds during summer 1977 and 38% of 29 during 1978 showed evidence of brood patch formation.

Kittiwakes initiated most of the 53 interspecific feeding assemblages which Sealy (1973) watched form off British Columbia. Once kittiwakes located concentrations of prey their light plumage and highly visible behavior (hovering and diving) attracted other birds to the area. Hoffman *et al*. (1981) have called kittiwakes "catalysts" because of their role as initiators of interspecific feeding flocks. However, kittiwakes can dive only 1-2 m below the surface (Burtt 1974), and once a large number of birds has been attracted to a prey concentration, fish may be driven far enough below the surface that kittiwakes are unable to reach them.

In 1977, kittiwakes fed on euphausiids during May, capelin during June, and capelin and sand lance during July-September (Tables 25-29). In 1978, capelin were the most important prey in Izhut Bay throughout the summer but in northern Sitkalidak Strait, kittiwakes ate mostly *T. inermis* during May and June and sand lance during July and August (Figure 10, Tables 30-38). Euphausiids averaged 23 mm TL (Figure 11) during both years and were probably mature individuals, taken from surface spawning swarms. More than one size class of capelin was eaten during each year, but on the average, those from stomachs collected in 1978 were significantly larger ($P<0.001$) than those from stomachs collected in 1977 (Figure 12). Sand lance were mostly age group I fish, averaging 97 $\pm$ 10.3 mm TL (n=8) and 90 $\pm$ 20.4 mm, n=44) during the two years, respectively (Figure 13).

Cephalopods, which occurred regularly in the diets of sooty and short-tailed shearwaters, were not eaten by kittiwakes. Bublitz (1980) reported that juvenile gonatid squids (17-50 mm dorsal mantle length) are frequently caught in the upper meter of the water column in the Gulf of Alaska and Bering Sea and suggested that squid escape predation by dashing below the 1-2 m depth to which kittiwakes can dive. Juvenile *Loligo vulgaris* can swim at speeds of up to 128 cm/sec (Packard 1969). Alternatively, cephalopods appear to concentrate at depths of 20-30 m during the day and to rise into the upper 10 m at night (Nishiyama and Bublitz, in preparation), so that they may be unavailable if kittiwakes feed only during the day.

COMMON MURRE

Murres were more abundant in the Kodiak Archipelago during winter than summer; a within-bay density of 10 birds/km^2 was reported in September 1977 (Gould *et al*. 1978) compared with 70 birds/km^2 in February 1980 (Forsell and Gould 1980). Dick (1979) estimated that 150-300 common murres wintered in Chiniak Bay during 1976-1977; small groups occurred over both open and protected water.

Most of the murres which were collected during summer were non-breeders; only 15% of the 28 examined during 1977 and 15% of the 41 examined during 1978 had brood patches. Breeding birds may have been nesting at one of the six small colonies (a total of 2,000 birds) located in Marmot and Chiniak Bays (Sowls *et al*. 1978).

Table 26. Indices of relative importance of prey eaten by black-legged kittiwakes, June 1977.

Species	% No.	% Vol.	% FO	IRI
Euphausiacea	18.2	0.2	6.2	115
Osteichthyes	1.5	0.5	6.2	13
Osmeridae	16.7	13.1	31.2	930
Mallotus villosus	62.1	86.1	56.2	8,336
Theragra chalcogramma	1.5	0.1	6.2	10

(n=19, + 1 empty stomach; 55 items, 110 ml volume)

Table 27. Indices of relative importance of prey eaten by black-legged kittiwakes, July 1977.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	9.1	4.5	25.0	341
Osmeridae	20.0	13.7	30.0	1,010
Mallotus villosus	61.8	80.0	40.0	5,673
Ammodytes hexapterus	9.1	1.8	5.0	54

(n=20, + 1 empty stomach; 55 items, 110 ml volume)

Table 28. Indices of relative importance of prey eaten by black-legged kittiwakes, August 1977.

Species	% No.	% Vol.	% FO	IRI
Nereidae	7.0	0.1	14.3	102
Crustacea	2.3	*	4.8	11
Osteichthyes	2.3	0.6	4.8	14
Mallotus _villosus_	83.7	96.3	81.0	14,580
Theragra _chalcogramma_	4.7	2.9	4.8	36

(n=21; 43 items, 171 ml volume)

Table 29. Indices of relative importance of prey eaten by black-legged kittiwakes, September 1977.

Species	% No.	% Vol.	% FO	IRI
Nereidae	1.0	0.2	8.3	10
Bivalvia	1.0	0.5	8.3	12
Thysanoessa _inermis_	1.0	0.2	4.2	5
_T_. _spinifera_	31.5	4.8	4.2	152
_T_. _spp_.	18.5	2.7	4.2	88
Osteichthyes	4.5	6.6	37.5	417
Mallotus _villosus_	28.5	28.6	16.7	951
Gadidae	2.0	3.1	16.7	86
Theragra _chalcogramma_	0.5	0.5	4.2	4
Ammodytes _hexapterus_	11.5	52.4	25.0	1,598

(n=24, + 2 empty stomachs; 200 items, 124 ml volume)

Table 30. Indices of relative importance of prey eaten by black-legged kittiwakes, Izhut Bay, April 1978.

Species	% No.	% Vol.	% FO	IRI
Theragra chalocogramma	50.0	70.0	100.0	12,000
Ammodytes hexapterus	50.0	30.0	100.0	8,000

(n=1; 4 items, 32 ml volume)

Table 31. Indices of relative importance of prey eaten by black-legged kittiwakes, northern Sitkalidak Strait, April 1978.

Species	% No.	% Vol.	% FO	IRI
Paracallisoma alberti	12.0	10.0	100.0	2,200
Osteichthyes	88.0	90.0	100.0	17,800

(n=1; 8 items, 18 ml volume)

Table 32. Indices of relative importance of prey eaten by black-legged kittiwakes, northern Sitkalidak Strait, May 1978.

Species	% No.	% Vol.	% FO	IRI
Thysanoessa inermis	96.8	92.8	100.0	18,960
Osteichthyes	2.2	1.5	50.0	185
Mallotus villosus	1.0	5.7	16.7	112

(n=6; 343 items, 47 ml volume)

Table 33. Indices of relative importance of prey eaten by black-legged kittiwakes, Izhut Bay, June 1978.

Species	% No.	% Vol.	% FO	IRI
Nereidae	6.7	0.2	9.7	67
Mollusca	0.6	0.1	3.2	2
Bivalvia	1.2	0.4	6.4	10
Calanoidea	4.2	0.2	6.4	28
Thysanoessa inermis	45.5	2.9	6.4	310
Osteichthyes	5.5	4.3	22.6	222
Mallotus villosus	32.7	92.2	67.7	8,456
Gadidae	0.6	*	3.2	2
Trichdon trichodon	0.6	0.3	6.4	6
Ammodytes hexapterus	2.4	2.6	6.4	32

*Less than 0.1%. (n=31; 165 items, 318 ml volume)

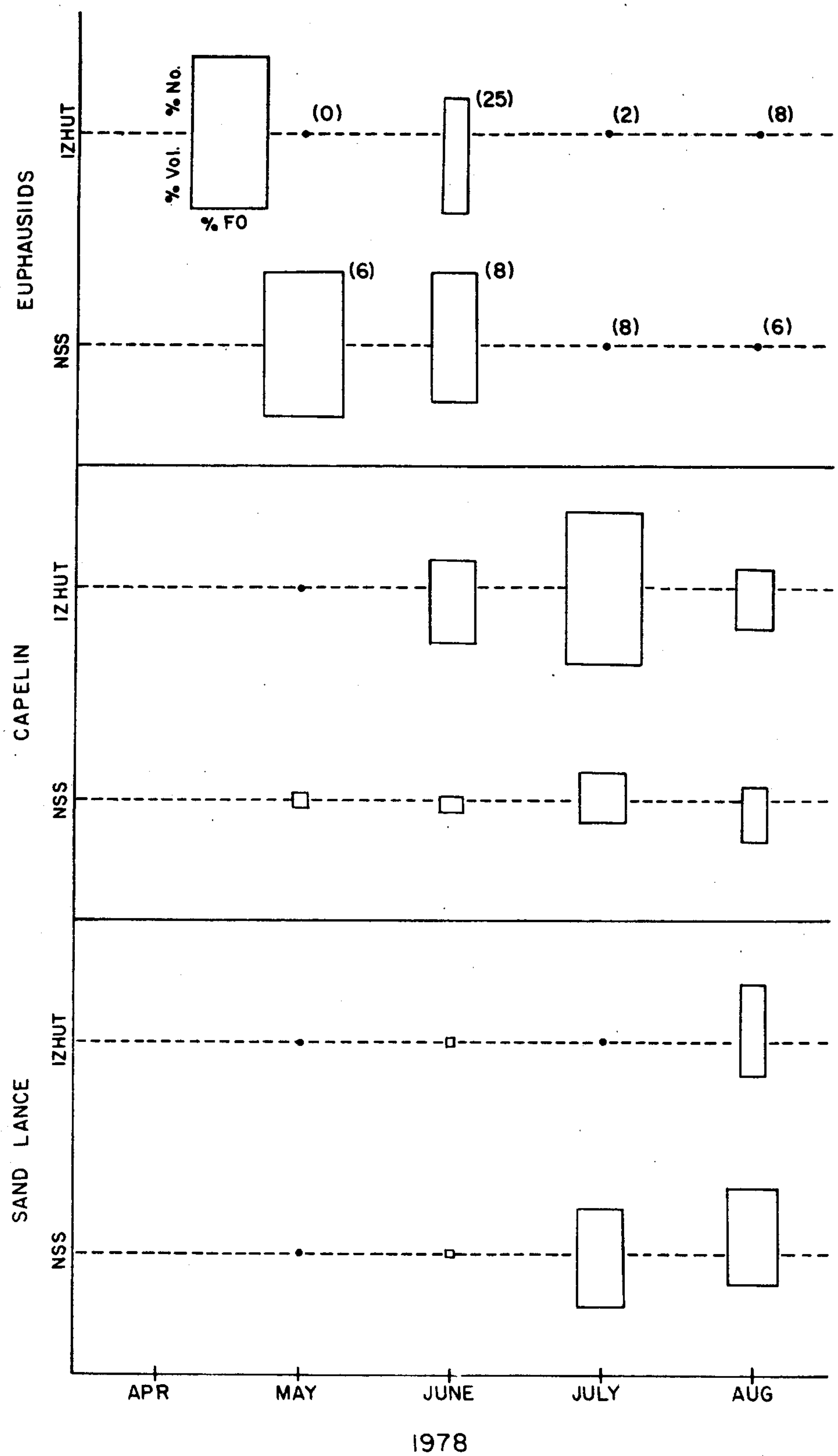

Figure 10. Relative importances of euphausiids, capelin, and sand lance to black-legged kittiwakes, Izhut Bay vs. northern Sitkalidak Strait, 1978. Sample sizes are in parentheses.

Table 34. Indices of relative importance of prey eaten by black-legged kittiwakes, northern Sitkalidak Strait, June 1978.

Species	% No.	% Vol.	% FO	IRI
Gastropoda	0.3	0.1	6.7	3
Bivalvia	0.3	0.1	6.7	3
Mytilus edulis	0.3	0.2	6.7	3
Amphipoda	0.3	1.1	6.7	9
Thysanoessa inermis	95.6	69.2	40.0	6,592
Osteichthyes	1.8	9.0	40.0	432
Mallotus villosus	1.2	17.1	26.7	489
Ammodytes hexapterus	0.3	3.0	6.7	22

(n=15; 340 items, 84 ml volume)

Table 35. Indices of relative importance of prey eaten by black-legged kittiwakes, Izhut Bay, July 1978.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	25.0	5.0	33.3	999
Mallotus villosus	75.0	95.0	66.7	11,339

(n=3; 4 items, 20 ml volume)

Table 36. Indices of relative importance of prey eaten by black-legged kittiwakes, northern Sitkalidak Strait, July 1978.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	20.0	17.0	38.5	1,425
Mallotus villosus	28.0	24.6	38.5	2,025
Gadidae	4.0	0.1	7.7	32
Ammodytes hexapterus	48.0	58.4	38.5	4,096

(n=13; 25 items, 106 ml volume)

Table 37. Indices of relative importance of prey eaten by black-legged kittiwakes, Izhut Bay, August 1978.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	11.6	4.4	11.1	178
Mallotus villosus	23.3	53.7	66.7	5,136
Ammodytes hexapterus	65.1	41.9	33.3	3,563

(n=9; 43 items, 115 ml volume)

Table 38. Indices of relative importance of prey eaten by black-legged kittiwakes, northern Sitkalidak Strait, August 1978.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	20.8	8.8	50.0	1,480
Mallotus villosus	20.8	48.4	20.0	1,384
Ammodytes hexapterus	58.3	42.8	40.0	4,044

(n=19, + 4 empty stomachs; 67 items, 206 ml volume)

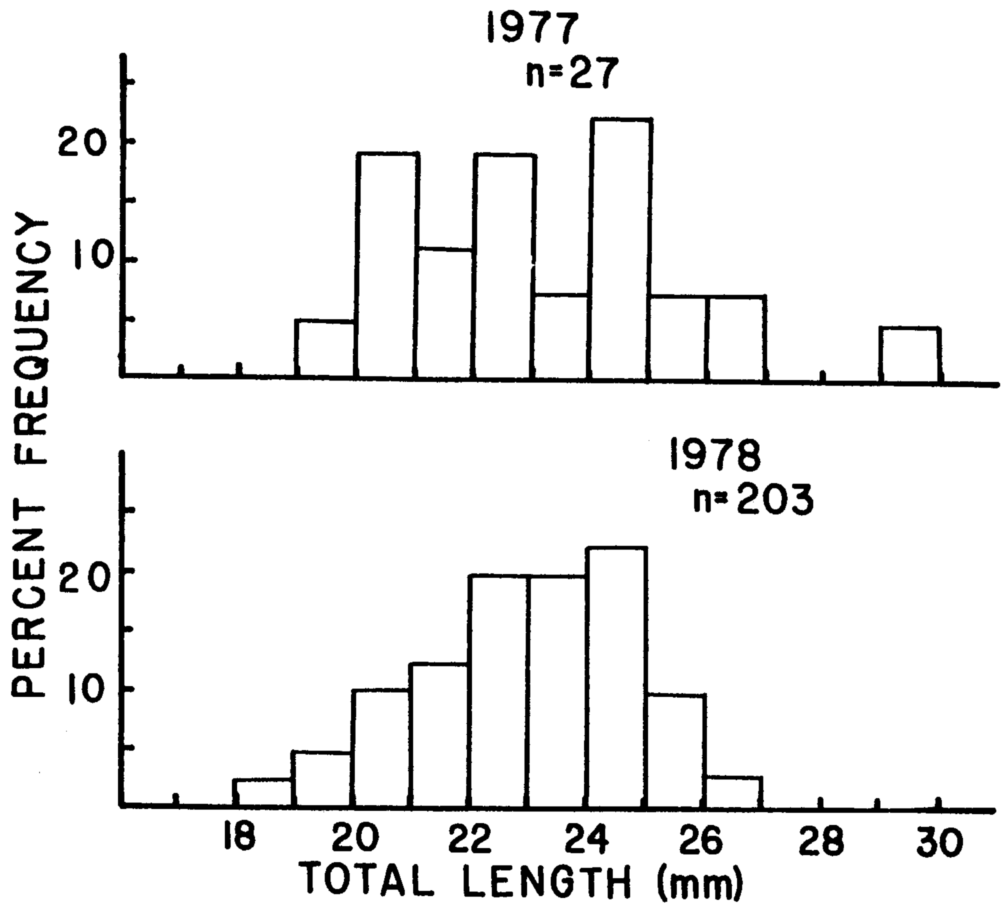

Figure 11. Length frequencies of euphausiids eaten by black-legged kittiwakes, 1977 vs. 1978.

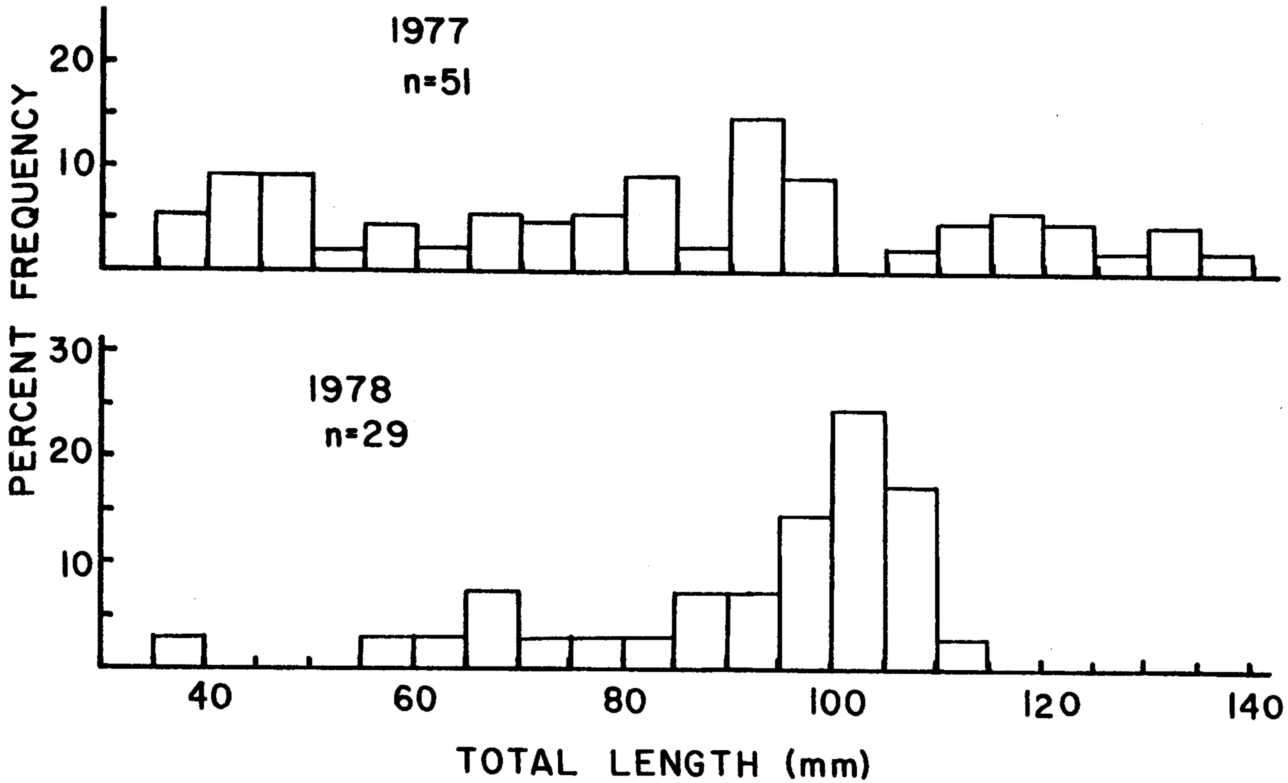

Figure 12. Length frequencies of capelin eaten by black-legged kittiwakes, 1977 and 1978.

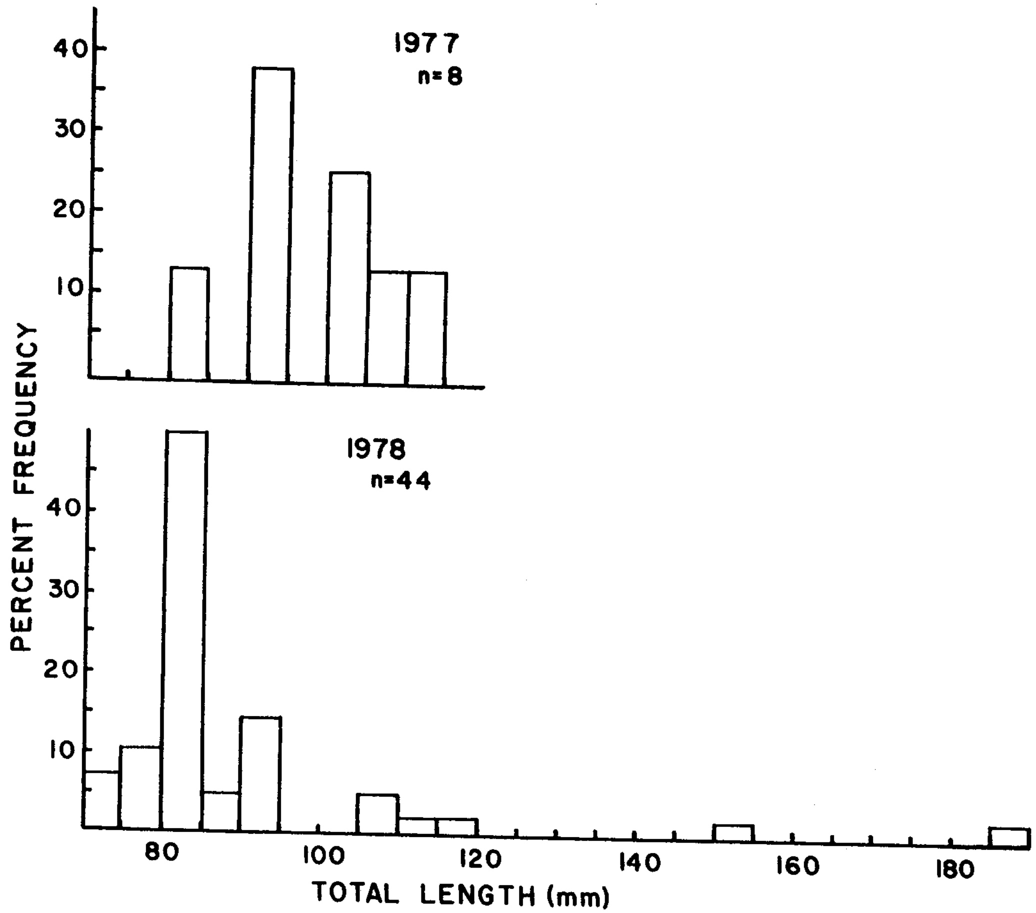

Figure 13. Length frequencies of sand lance eaten by black-legged kittiwakes, 1977 and 1978.

Common murres pursue their prey underwater, using their wings for power. Their wings are well adapted for underwater flight (Spring 1971, Krasnow, pers. obs.). Fishermen have reported catching murres in crab pots set at 130 m in Shelikof Strait (Forsell and Gould 1981), constituting a depth record for the family Alcidae.

Murres were collected near Long and Woody Islands during January and February 1977 and during February 1978. Gadids were an important prey during both winters but pandalid shrimp and capelin were also important in 1977 (Tables 39 and 40). Two whole walleye pollock, measuring 150 and 160 mm TL, were found in a stomach collected near the southern tip of Long Island on 26 February 1978. These were the only freshly ingested pollock found during this study, except for one pollock in a kittiwake stomach. Pandalids eaten by murres averaged 57 $\pm$ 2.5 mm TL (n=5) and four capelin averaged 57 $\pm$ 32.7 mm TL.

A large proportion of the murres collected during summer (41% in 1977 and 21% in 1978) had empty stomachs. Murres ate only fish during 1977. Capelin was the most important species, although gadids (including walleye pollock) were also eaten during June, August, and September and sand lance were important in stomachs collected at Whale Passage during September (Tables 41-44).

During summer 1978, murres again ate capelin, pollock, and sand lance but cephalopods, euphausiids, cods (Pacific cod, *Gadus macrocephalus* and Pacific Tomcod, *Microgadus proximus*), sandfish (*Trichodon trichodon*), and pricklebacks (*Lumpenus* spp.) were also eaten (Table 45). In northern Sitkalidak Strait, the chronology of feeding was similar to that exhibited by black-legged kittiwakes--except that pollock was substituted for euphausiids: murres ate pollock during April, capelin and pollock during May, capelin during June, capelin and sand lance during July, and sand lance during August (Figure 14).

Capelin from stomachs collected in 1978 averaged 97 $\pm$ 17.0 mm TL (n=47), 9 mm longer than those eaten in 1977 (88 $\pm$ 11.6 mm, n=32). Similarly, sand lance averaged 104 $\pm$ 28.3 mm TL (n=15) in 1978 compared to 95 $\pm$ 7.3 mm (n=34) in 1977 (Figure 15). For both species the differences between years were significant ($P<0.001$). Two pollock, one with an otolith length of 12 and another with an otolith length of 14 mm, were estimated to have measured 116 and 130 mm FL, respectively. One whole squid (39 mm DML) occurred in a stomach collected in northern Sitkalidak Strait during July.

PIGEON GUILLEMOT

The pigeon guillemot was the most neritic of the alcids. During winter 1979-1980, Forsell and Gould (1981) observed 6,000-8,000 guillemots along the shorelines of southern Afognak, and Kodiak and Sitkalidak Islands. Dick (1979) observed 300 guillemots wintering in shallow, protected waters of Chiniak Bay in early 1977.

More than 900 guillemots nest in Izhut, Marmot, and Chiniak Bays and in southern Sitkalidak Strait (Sowls *et al.* 1978). Pairs of guillemots are commonly seen inshore during summer; Gould *et al.* (1978) reported a peak density of 0.9 birds/ km^2 during August 1977.

Table 39. Indices of relative importance of prey eaten by common murres, Chiniak Bay, January-February 1977.

Species	% No.	% Vol.	% FO	IRI
Nereidae	1.0	0.2	25.0	30
Acanthomysis sp.	27.0	5.6	25.0	815
Pandalus sp.	11.0	50.9	25.0	1,548
Mallotus villosus	50.0	27.9	25.0	1,948
Gadidae	9.0	12.8	75.0	1,635
Trichodon trichodon	1.0	2.1	25.0	78
Ammodytes hexapterus	1.0	0.5	25.0	38

(n=4; 100 items, 43 ml volume)

Table 40. Indices of relative importance of prey eaten by common murres, Long and Woody Islands, Chiniak Bay, February 1978.

Species	% No.	% Vol.	% FO	IRI
Amphipoda	3.7	0.2	16.7	65
Gammaridea	1.2	0.6	16.7	30
Thysanoessa inermis	1.2	0.2	16.7	23
Pandalus borealis	1.2	0.4	16.7	27
Mallotus villosus	7.3	2.4	33.0	320
Gadidae	4.9	1.7	16.7	110
Theragra chalcogramma	75.6	90.7	66.7	11,092
Lumpenus maculatus	1.2	2.4	16.7	60
Ammodytes hexapterus	3.7	1.7	16.7	90

(n=6, +3 empty stomachs; 82 items, 197 ml volume)

Table 41. Indices of relative importance of prey eaten by common murres, June 1977.

Species	% No.	% Vol.	% FO	IRI
Osmeridae	19.1	24.6	28.6	1,250
Mallotus villosus	57.1	54.4	42.9	4,783
Gadidae	23.8	21.1	28.6	1,284

(n=7, +6 empty stomachs; 21 items, 57 ml volume)

Table 42. Indices of relative importance of prey eaten by common murres, July 1977.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	40.0	30.8	50.0	3,540
Osmeridae	10.0	46.2	12.5	703
Mallotus villosus	50.0	23.0	37.8	2,759

(n=8, +8 empty stomachs; 10 items, 13 ml volume)

Table 43. Indices of relative importance of prey eaten by common murres, August 1977.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	20.0	9.5	25.0	738
Osmeridae	20.0	23.8	25.0	1,095
Mallotus villosus	40.0	42.9	25.0	2,072
Theragra chalocogramma	20.0	23.8	25.0	1,095

(n=4, +2 empty stomachs; 5 items, 21 ml volume)

Table 44. Indices of relative importance of prey eaten by common murres, September 1977.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	0.9	0.4	14.3	19
Mallotus villosus	56.1	56.4	57.1	6,424
Theragra chalcogramma	1.9	1.1	14.3	43
Ammodytes hexapterus	44.0	42.1	42.9	3,694

(n=7; 107 items, 264 ml volume)

Table 45. Indices of relative importance of prey eaten by common murres, April-August 1978.

Species	% No.	% Vol.	% FO	IRI
Cephalopoda	0.7	1.1	3.7	7
Thysanoessa inermis	19.5	0.6	1.8	36
Osteichthyes	2.2	1.5	16.7	62
Osmeridae	0.2	*	1.8	<1
Mallotus villosus	35.8	52.1	38.9	3,419
Gadidae	9.1	1.8	38.9	424
Gadus macrocephalus	0.2	*	1.8	<1
Microgadus proximus	1.6	3.2	1.8	9
Theragra chalcogramma	15.3	17.4	16.7	546
Trichodon trichodon	1.3	3.7	7.4	37
Lumpenus sagitta	0.2	*	1.8	<1
L. maculatus	0.2	*	1.8	<1
Ammodytes hexapterus	12.6	18.5	24.1	750

*Less than 0.1%. (n=54, +21 empty stomachs; 542 items, 774 ml volume)

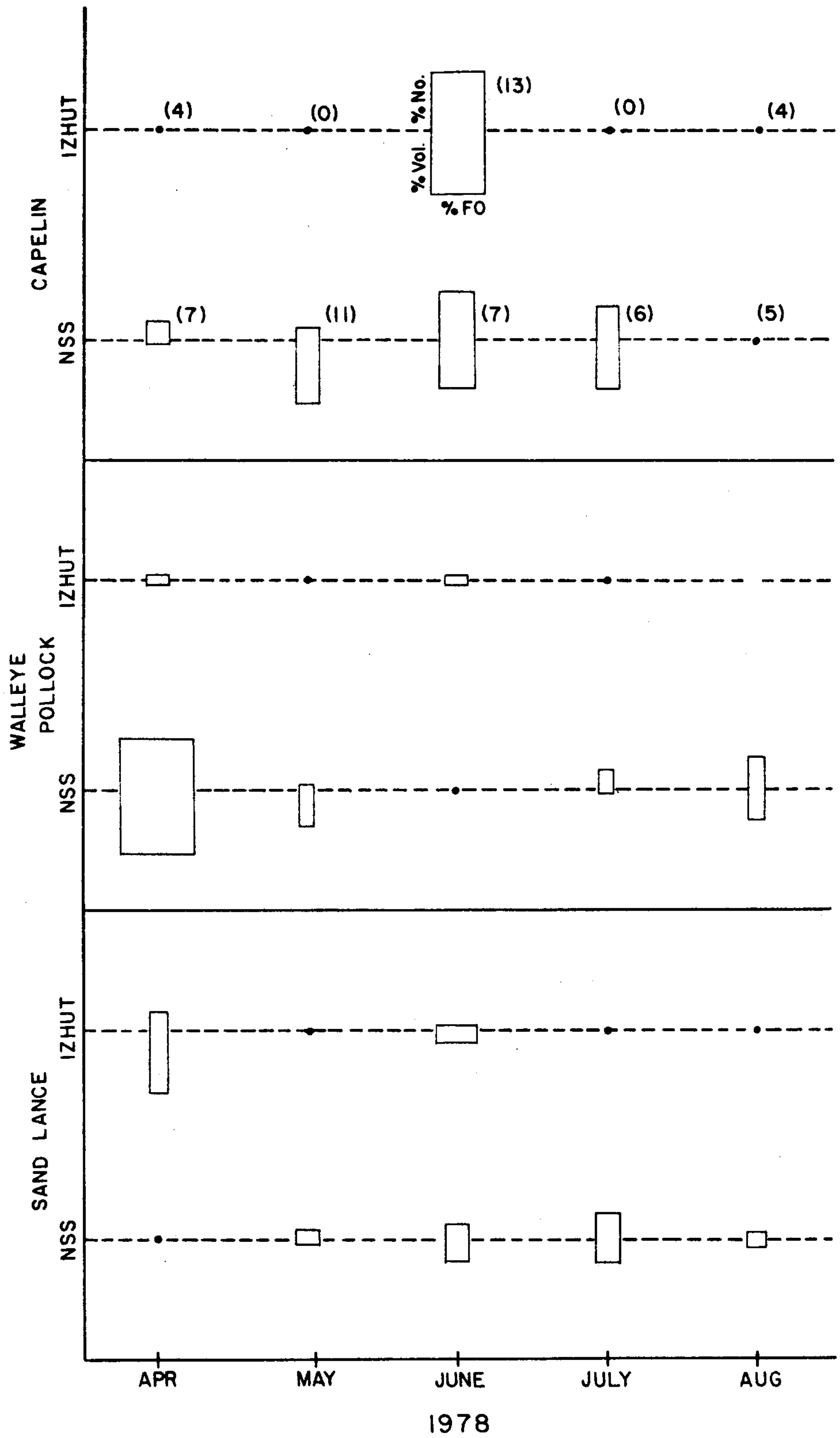

Figure 14. Relative importances of capelin, walleye pollock, and sand lance to common murres, Izhut Bay vs. northern Sitkalidak Strait, summer 1978. Sample sizes are in parentheses.

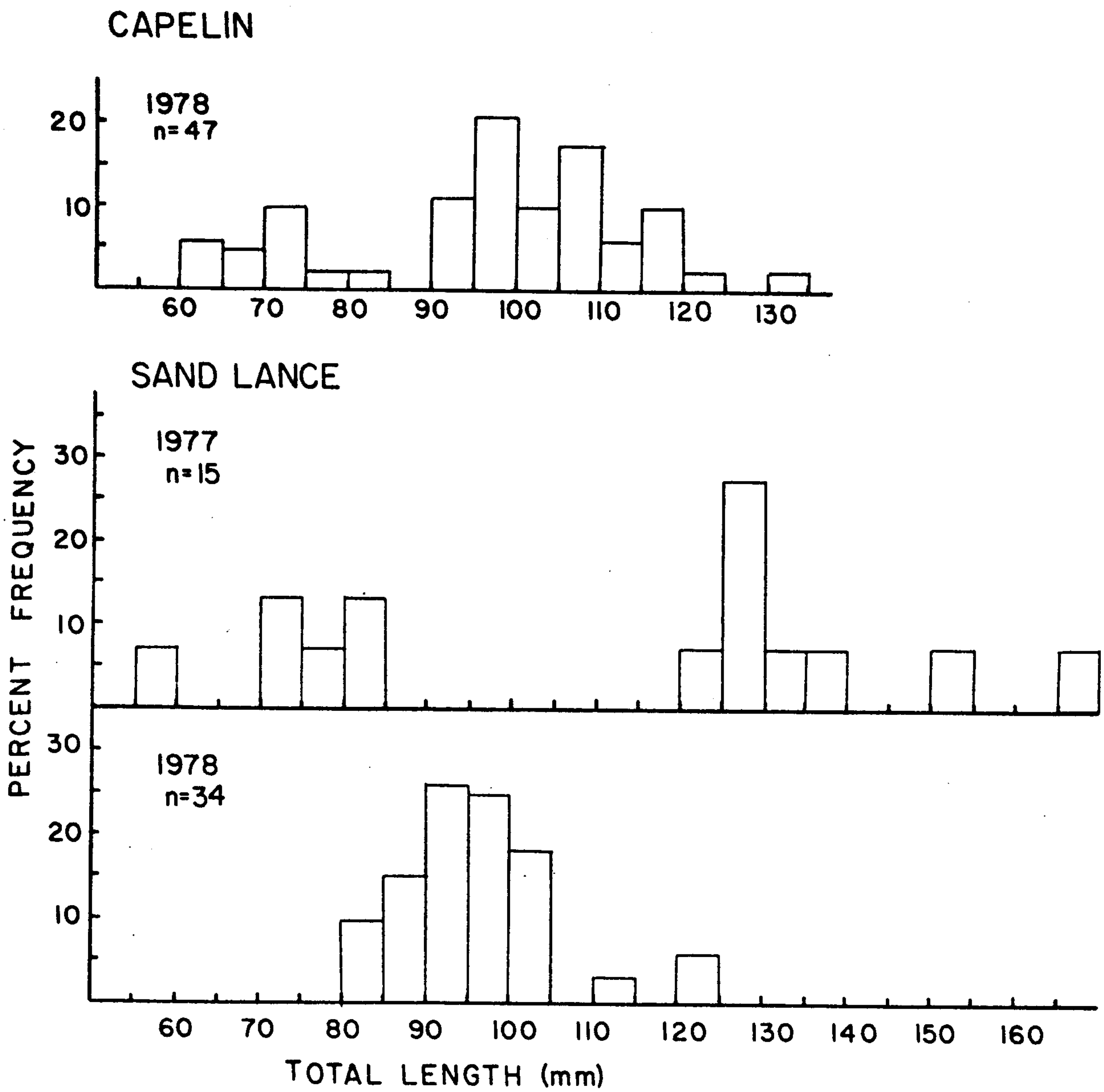

Figure 15. Length frequencies of capelin eaten by common murres, summer 1978, and sand lance, summer 1977 and 1978.

There was no evidence of brood patch formation on guillemots collected during April or May 1978 (n=15) but between June and August, patches were present, forming, or refeathering on 72% of 18 examined.

The guillemot, like the common murre, marbled murrelet, and tufted puffin, dives in pursuit of its prey, but unlike the others, the guillemot feeds almost exclusively on epibenthic organisms. The maximum depth to which it dives is unknown, but Katherine Kuletz (University of California, Irvine, pers. comm.) observed that guillemots nesting at Naked Island, Prince William Sound, fed shoreward of the 100 m contour.

Within the epibenthic habitat of Chiniak Bay, guillemots fed opportunistically; each set of stomachs collected between 21 November 1976 and 27 February 1977 contained a different array of prey. Invertebrates comprised 88% of the total prey number and 55% of the total volume (Table 46). The only measurable prey items were 27 "stout coastal shrimp" (Heptacarpus brevirostris), that occurred in a stomach collected in St. Paul Harbor during November (24 $\pm$ 10.2 mm TL).

During the summer of 1978, Cancer oregonensis, capelin, and unidentified gadids became the guillemot's most important prey (Table 47). Cancer oregonensis and unidentifiable fish were eaten during April and unidentified decapods, "smooth pink shrimp" (P. jordani), C. oregonensis, and stichaeid fish were eaten during May (Tables 48 and 49). Capelin and unidentified gadids increased in importance during June-August (Figure 16, Tables 50-52).

Guillemots collected in Izhut Bay consumed a wider range of prey (17 species/25 stomachs) than those from northern Sitkalidak Strait (5 species/11 stomachs) (Table 53) although there was little difference in patterns of prey use throughout the summer between the two areas. Measurable prey included five hippolytid shrimp (30 $\pm$ 6.2 mm), seven brachyuran crabs (11 $\pm$ 4.1 mm), three capelin (107-110 mm), and two Myoxocephalus sculpins (31 and 38 mm TL).

MARBLED MURRELET

Marbled murrelets were year-round residents of the archipelago and murrelets concentrated in protected inshore areas during both winter and summer (Forsell and Gould 1981, Gould et al. 1978). Between November 1976 and April 1977, 150-300 were present in Chiniak Bay, in groups of up to five (Dick 1979). They were usually seen shoreward of the 50 m contour but probably captured their prey throughout the water column. During summer 1977, murrelets fed alone or in pairs. Densities in inshore waters peaked in July at 3 birds/km^2 (Gould et al. 1978).

Two nests of marbled murrelets have been found in the Kodiak area, one on Pyramid Peak, approximately 700 m above the town of Kodiak (Hoeman 1965), and one on E. Amatuli Island, approximately 125 km north (Simons 1980). Both nests contained a single egg and were shallow depressions on the tundra. Nesting is probably common in the Kodiak area; we saw pairs of murrelets in most coves along the shorelines of Izhut and Kiliuda Bays during June-August 1978 and of 26 examined, 69% showed evidence of brood patch development. During June, three females had eggs in their shell glands and three more had follicles which had ruptured, indicating that eggs had recently been laid. At dusk on 17 July 1977, Gerald Sanger,

Table 46. Indices of relative importance of prey eaten by pigeon guillemots, November 1976-February 1977.

Species	% No.	% Vol.	% FO	IRI
Lacuna vincta	16.1	1.8	12.5	224
Gammaridea	1.1	2.9	12.5	50
Decapoda	1.1	1.2	12.5	29
Heptacarpus brevirostris	62.4	28.6	12.5	1,138
Pandalidae	3.2	11.8	25.0	375
Pandalus goniurus	4.3	8.2	25.0	328
Osteichthyes	3.2	18.2	25.0	535
Gadidae	1.1	0.2	12.5	16
Cottidae	1.1	3.5	12.5	58
Trichodon trichodon	1.1	0.3	12.5	18
Stichaeidae	1.1	10.3	12.5	143
Lumpenus sagitta	3.2	7.6	12.5	135
Pleuronectidae	1.1	4.8	12.5	74

(n=8; 93 items, 66 ml volume)

Table 47. Indices of relative importance of prey eaten by pigeon guillemots, Izhut Bay and northern Sitkalidak Strait, April-August 1978.

Species	% No.	% Vol.	% FO	IRI
Polychaeta	0.6	*	2.8	2
Nereidae	0.6	*	2.8	2
Musculus sp.	1.3	0.2	2.8	4
Veneridae	0.6	0.5	2.8	3
Dolichopus sp.	0.6	*	2.8	2
Crustacea	0.6	0.4	2.8	3
Decapoda	8.4	3.2	19.5	226
Hippolytidae	0.6	0.3	2.8	3
Lebbeus sp.	0.6	0.1	2.8	2
Heptacarpus tridens	3.2	0.9	2.8	12
Heptacarpus sp.	1.3	1.1	5.6	13
Pandalidae	0.6	0.1	2.8	2
Pandalus jordani	2.0	4.1	2.8	17
Pagurus sp.	0.6	0.1	2.8	2
Brachyura	0.6	0.4	2.8	3
Hyas lyratus	4.5	3.0	2.8	21
Cancer oregonensis	33.1	7.4	30.6	1,239
Osteichthyes	13.0	8.9	36.1	791
Mallotus villosus	9.1	31.7	19.4	792
Gadidae	5.8	7.8	16.7	227
Microgadus proximus	0.6	0.4	2.8	3
Myoxocephalus sp.	4.5	3.3	2.8	22
Trichodon trichodon	1.3	15.9	5.6	96

Table 47 (cont.)

Stichaeidae	2.6	4.1	2.8	19
Lumpenus sp.	0.6	2.0	2.8	7
Pholis laeta	0.6	1.9	2.8	7
Pleuronectidae	1.3	2.0	2.8	9

(n=36, +8 empty stomachs; 154 items, 195 ml volume)

Table 48. Indices of relative importance of prey eaten by pigeon guillemots, Izhut Bay and northern Sitkalidak Strait, April 1978.

Species	% No.	% Vol.	% FO	IRI
Nereidae	1.3	*	10.0	13
Musculus sp.	2.6	1.1	10.0	37
Dolichopus sp.	1.3	0.4	10.0	17
Decapoda	11.7	8.9	40.0	824
Hippolytidae	1.3	1.8	10.0	31
Lebbeus sp.	1.3	0.7	10.0	20
Heptacarpus tridens	6.5	6.8	10.0	133
Heptacarpus sp.	1.3	0.7	10.0	20
Pandalidae	1.3	0.7	10.0	20
Pagurus sp.	1.3	0.7	10.0	20
Hyas lyratus	9.1	21.1	10.0	302
Cancer oregonensis	50.6	33.9	60.0	5,070
Osteichthyes	6.5	9.6	50.0	805
Gadidae	2.6	*	10.0	26
Pholis laeta	1.3	13.6	10.0	149

(n=10, +3 empty stomachs; 77 items, 28 ml volume)

Table 49. Indices of relative importance of prey eaten by pigeon guillemots, Izhut Bay and northern Sitkalidak Strait, May 1978.

Species	% No.	% Vol.	% FO	IRI
Polychaeta	9.1	0.6	33.3	323
Heptacarpus sp.	9.1	10.0	33.3	636
Pandalus jordani	27.3	43.9	33.3	2,371
Cancer oregonensis	18.2	1.1	66.7	1,287
Stichaeidae	36.4	44.4	33.3	2,691

(n=3, +2 empty stomachs; 11 items, 18 ml volume)

Table 50. Indices of relative importance of prey eaten by pigeon guillemots, Izhut Bay and northern Sitkalidak Strait, June 1978.

Species	% No.	% Vol.	% FO	IRI
Cancer oregonensis	9.1	0.3	14.3	134
Osteichthyes	36.4	2.6	28.6	1,115
Mallotus villosus	40.9	53.6	57.1	5,396
Trichodon trichodon	4.6	38.5	14.3	616
Pleuronectidae	9.1	5.1	14.3	203

(n=7; 22 items, 78 ml volume)

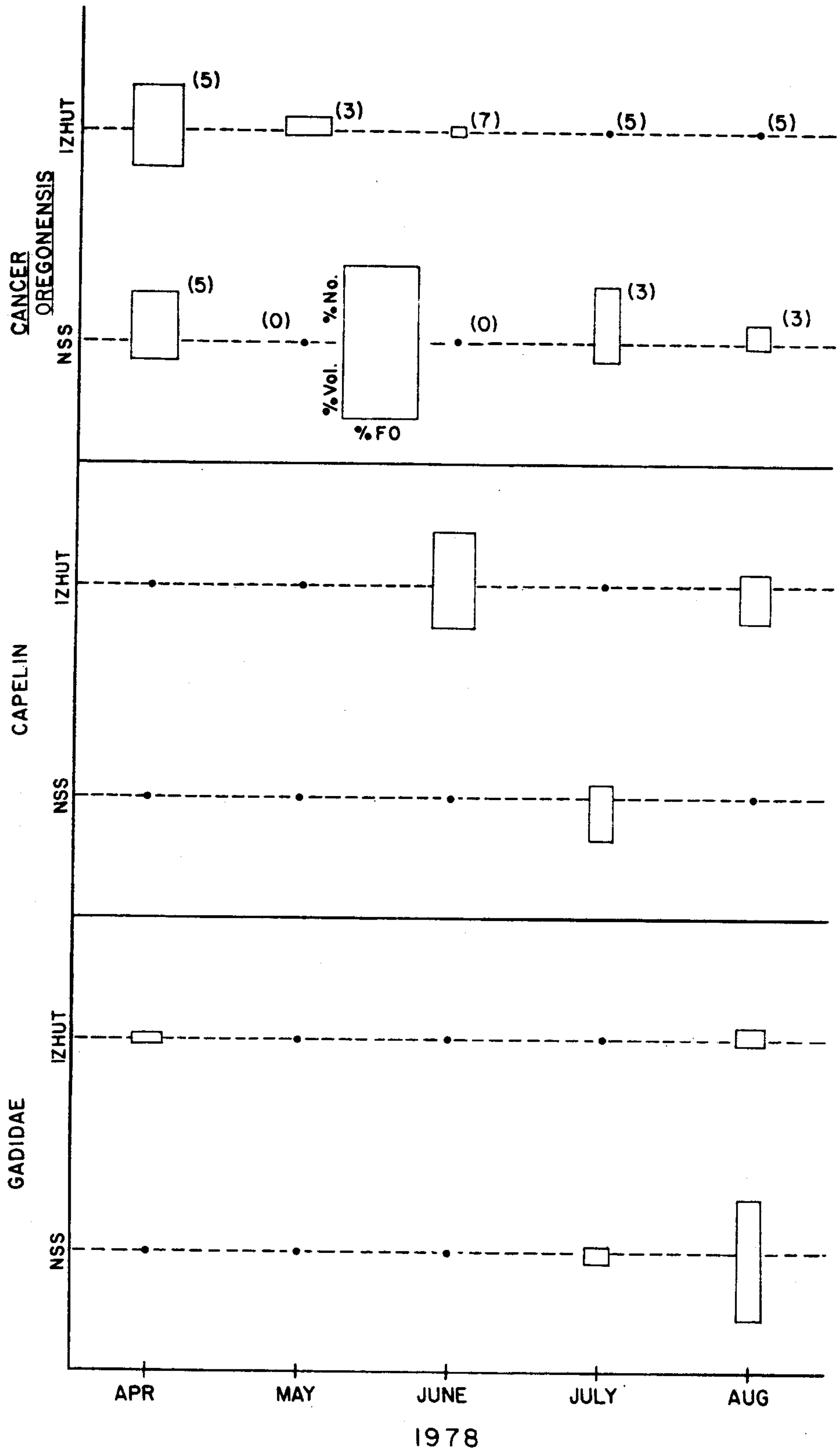

Figure 16. Relative importances of Cancer oregonensis, capelin, and gadids to pigeon guillemots, Izhut Bay vs. northern Sitkalidak Strait, summer 1978. **Sample sizes are in parentheses.**

Table 51. Indices of relative importance of prey eaten by pigeon guillemots, Izhut Bay and northern Sitkalidak Strait, July 1978.

Species	% No.	% Vol.	% FO	IRI
Crustacea	5.0	2.3	12.5	91
Decapoda	15.0	7.4	25.0	560
Cancer oregonensis	40.0	11.4	12.5	643
Osteichthyes	20.0	30.3	50.0	2,515
Mallotus villosus	10.0	28.6	12.5	483
Gadidae	5.0	8.6	12.5	170
Lumpenus sp.	5.0	11.4	12.5	205

(n=8, +1 empty stomach; 20 items, 35 ml volume)

Table 52. Indices of relative importance of prey eaten by pigeon guillemots, Izhut Bay and northern Sitkalidak Strait, August 1978.

Species	% No.	% Vol.	% FO	IRI
Veneridae	4.0	2.8	12.5	85
Decapoda	4.0	3.3	12.5	91
Brachyura	4.0	2.2	12.5	78
Cancer oregonensis	4.0	2.8	12.5	85
Osteichthyes	8.0	5.5	25.0	338
Mallotus villosus	12.0	27.6	25.0	990
Gadidae	28.0	33.7	50.0	3,085
Microgadus proximus	4.0	2.2	12.5	78
Myoxocephalus sp.	28.0	17.7	12.5	571
Trichodon trichodon	4.0	2.8	12.5	85

(n=8, +1 empty stomach; 25 items, 36 ml volume)

Table 53. Types of prey eaten by pigeon guillemots in Izhut Bay versus northern Sitkalidak Strait, April-August 1978.

Izhut Bay	Northern Sitkalidak Strait
Polychaetes	
Nereidae	
Bivalves	
Musculus sp.	
Veneridae	
Insects	
Dolichopus sp.	
Decapoda	
Hippolytidae	
Lebbeus sp.	
Heptacarpus tridens	
Pandalus jordani	
Pagurus sp.	*Hyas lyratus*
Cancer oregonensis	*Cancer oregonensis*
Fish	
Mallotus villosus	*Mallotus villosus*
Gadidae	*Microgadus* sp.
Myoxocephalus sp.	*Pholis* sp.
Trichodon sp.	
Stichaeidae	
Lumpenus sp.	
Pleuronectidae	
(25 stomachs)	(11 stomachs)

Douglas Forsell, and Juan Guzman observed and heard marbled murrelets flying over Big Kitoi Lake, Afognak Island, for several minutes. Although none of the murrelets were observed landing, it seemed likely that they were nesting in the large Sitka spruces in the vicinity.

Capelin and unidentified osmerids and euphausiids predominated in stomachs during winter 1976-1977 but mysids were the most important prey during the following winter (Tables 54 and 55). Capelin eaten in 1976-1977 averaged 42 $\pm$ 10.7 mm TL (n=22) and were probably age group 0 fish, spawned the previous summer (Figure 17). Euphausiids averaged 20 $\pm$ 1.6 mm (n=23) and one *Neomysis rayii* measured 34 mm TL. Two or three size classes of *Neomysis* were present in February 1978. These may have represented different age classes of one species, different species, or have been an artifact of small sample size. The distribution of *Acanthomysis* total lengths was unimodal (15 $\pm$ 1.8 mm, n=94) (Figure 18). One capelin measured 30 mm TL and the average fork length of three walleye pollock was estimated from otolith lengths to have been 122 $\pm$ 13.3 mm FL.

Marbled murrelets collected in Izhut Bay in 1978 ate capelin and euphausiids during May and June, and sand lance during July and August. Those from northern Sitkalidak Strait showed a similar chronology of feeding habits except that euphausiids were eaten in May and capelin and sand lance were both important during June (Figure 19, Tables 56-64). *Thysanoessa inermis* eaten in April and May averaged 22 $\pm$ 2.7 mm TL (n=54) (Figure 20). Capelin averaged 40 $\pm$ 19.8 mm TL (n=14) and were approximately one year old. Four measurable sand lance occurred in stomachs collected during April (92-105 mm, mean=97 mm TL), and were larger than nine eaten during July and August (57-80 mm, mean=68 mm TL).

On 3 August 1978, two fledgling murrelets, each with an egg tooth, were collected on the water in Izhut Bay. One was alone but the other was collected with an adult male which accompanied it. The stomach of the solitary chick contained only unidentifiable fish flesh and bones while the stomachs of the other chick and the adult male contained a gadid otolith and a sand lance (65 mm TL), respectively.

CRESTED AUKLET

Most of the crested auklets which breed in the Gulf of Alaska probably visit the Kodiak Archipelago during winter (Forsell and Gould 1981). An estimated 50,000 were present during winter 1979-1980, with peak numbers during December and January. Dick (1979) first saw crested auklets in Chiniak Bay on 8 January and last saw them on 27 February 1977. He estimated that a total of 500-1,000 were present. Except for a single auklet seen over the shelf on 16 July 1976, no crested auklets have been recorded in the Kodiak area during summer (Gould *et al.* 1978). The nearest known breeding colonies occur at the Shumagin Islands (Sowls *et al.* 1978), 400 km southwest of Kodiak.

Crested auklets are planktivorous. Those at St. Lawrence Island in the Bering Sea have been reported to eat a variety of crustaceans early in the breeding season but only euphausiids (*Thysanoessa* sp.) during the chick-rearing period (Bedard 1969). These auklets fed in tidal eddies in water 10-50 m deep, leading Bedard to speculate that they were diving at least 35 m to obtain epibenthic prey.

Table 54. Indices of relative importance of prey eaten by marbled murrelets, Chiniak Bay, December 1976-April 1977.

Species	% No.	% Vol.	% FO	IRI
Nereidae	0.3	0.1	5.6	3
Chaetognatha	0.2	*	5.6	1
Mysidacea	1.8	0.3	11.11	23
Acanthomysis spp.	0.5	0.3	5.6	4
Neomysis rayii	0.2	0.3	5.6	2
Thysanoessa inermis	36.4	16.2	22.2	1,169
T. spinifera	0.3	0.5	5.6	5
T. spp.	2.9	3.7	11.1	74
Osteichthyes	0.3	0.3	5.6	3
Osmeridae	21.4	19.3	38.9	1,584
Mallotus villosus	35.6	59.1	5.6	526

(n=18; 612 items, 76 ml volume)

Table 55. Indices of relative importance of prey eaten by marbled murrelets, Chiniak Bay, February 1978.

Species	% No.	% Vol.	% FO	IRI
Mysidacea	11.6	12.2	18.8	447
Acanthomysis spp.	74.8	55.1	81.2	10,548
Neomysis spp.	8.1	15.1	37.5	870
Neomysis rayii	1.4	3.0	6.2	27
Thysanoessa raschii	0.6	0.1	6.2	4
Gammaridea	0.6	2.5	18.8	58
Decapoda	0.1	1.2	6.2	8
Pandalidae	0.1	0.8	6.2	6
Pandalus goniurus	0.1	0.6	6.2	4
Osteichthyes	0.6	1.9	25.0	62
Osmeridae	0.8	4.5	6.2	33
Mallotus villosus	0.7	2.6	12.5	41
Theragra chalcogramma	0.4	0.2	6.2	4

(n=16, +3 empty stomachs; 837 items, 80 ml)

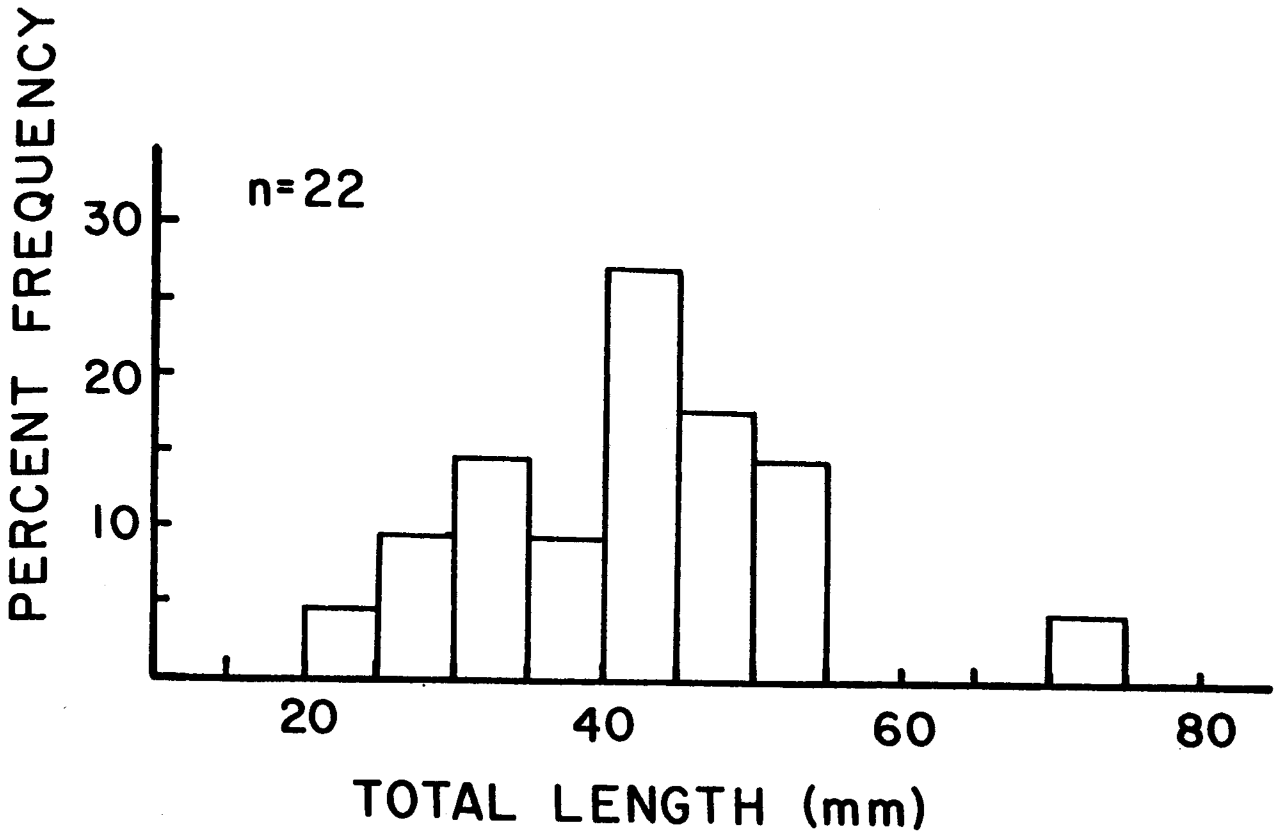

Figure 17. Length frequencies of capelin eaten by marbled murrelets, winter 1976-1977.

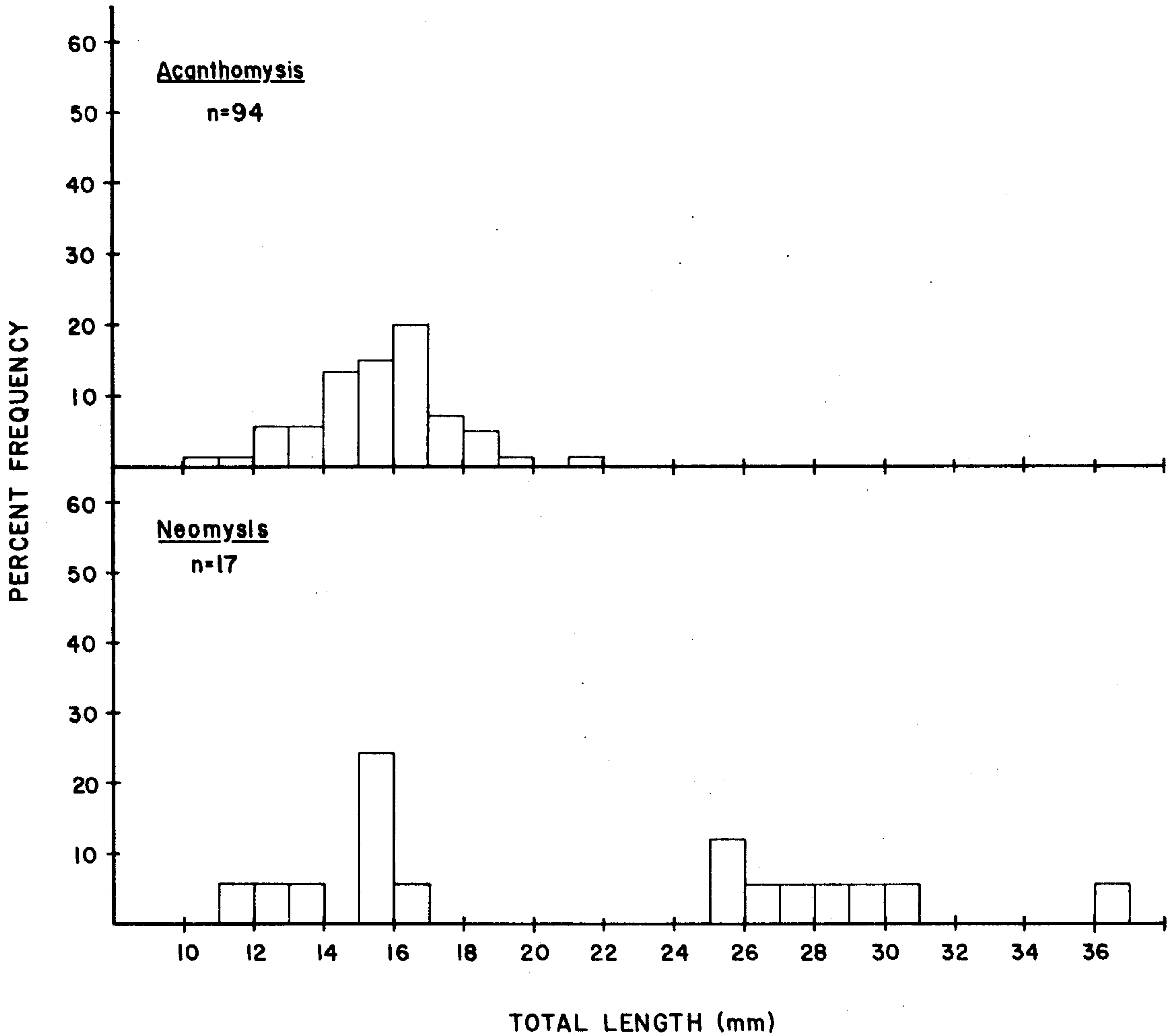

Figure 18. Length frequencies of mysids eaten by marbled murrelets, winter 1978.

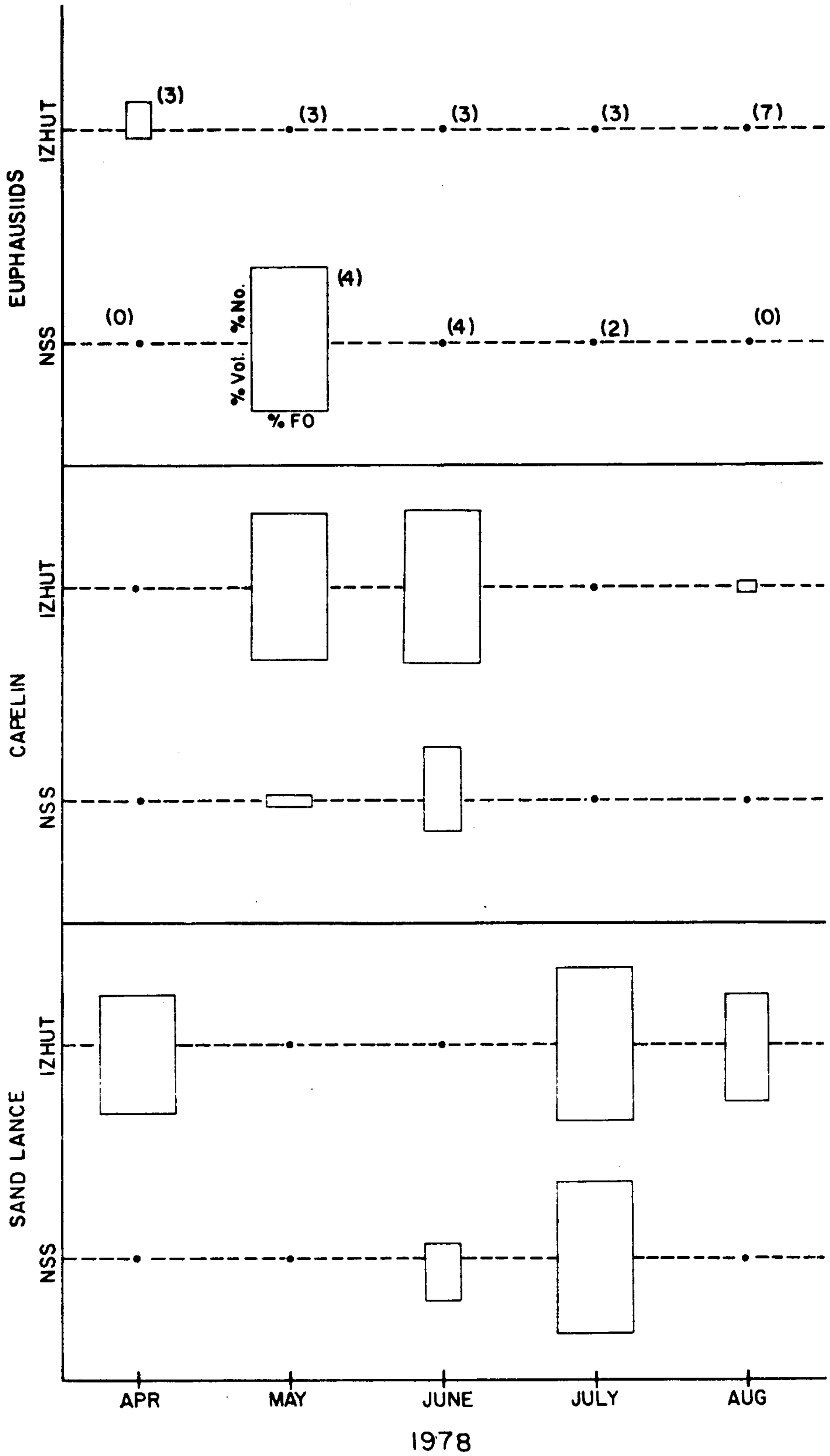

Figure 19. Relative importances of euphausiids, capelin, and sand lance to marbled murrelets, Izhut Bay vs. northern Sitkalidak Strait, summer 1978. Sample sizes are in parentheses.

Table 56. Indices of relative importance of prey eaten by marbled murrelets, Izhut Bay, April 1978.

Species	% No.	% Vol.	% FO	IRI
Thysanoessa raschii	37.5	9.4	33.3	1,562
Osteichthyes	4.2	3.1	33.3	243
Ammodytes hexapterus	58.3	87.5	66.7	9,725

(n=3; 24 items, 24 ml volume)

Table 57. Indices of relative importance of prey eaten by marbled murrelets, Izhut Bay, May 1978.

Species	% No.	% Vol.	% FO	IRI
Crustacea	1.4	0.4	33.3	60
Osteichthyes	2.7	6.8	33.3	316
Osmeridae	2.7	7.1	33.3	326
Mallotus villosus	93.2	85.7	33.3	5,957

(n=3; 74 items, 14 ml volume)

Table 58. Indices of relative importance of prey eaten by marbled murrelets, northern Sitkalidak Strait, May 1978.

Species	% No.	% Vol.	% FO	IRI
Thysanoessa inermis	96.6	92.5	100.0	18,910
Osteichthyes	0.8	2.5	25.0	82
Mallotus villosus	2.6	5.0	25.0	190

(n=4, +2 empty stomachs; 177 items, 12 ml volume)

Table 59. Indices of relative importance of prey eaten by marbled murrelets, Izhut Bay, June 1978.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	80.0	50.0	57.1	7,423
Mallotus villosus	20.0	50.0	42.9	3,003

(n=7, +6 empty stomachs; 15 items, 14 ml volume)

Table 60. Indices of relative importance of prey eaten by marbled murrelets, northern Sitkalidak Strait, June 1978.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	37.5	32.7	57.1	4,008
Mallotus villosus	43.8	27.3	28.6	2,033
Trichodon trichodon	6.2	3.0	14.3	132
Ammodytes hexapterus	12.5	37.0	28.6	1,416

(n=7, +4 empty stomachs; 16 items, 11 ml volume)

Table 61. Indices of relative importance of prey eaten by marbled murrelets, Izhut Bay, July 1978.

Species	% No.	% Vol.	% FO	IRI
Ammodytes hexapterus	100.0	100.0	100.0	200,000

(n=3, +1 empty stomach; 12 items, 22 ml volume)

Table 62. Indices of relative importance of prey eaten by marbled murrelets, northern Sitkalidak Strait, July 1978.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	50.0	33.3	50.0	4,165
Ammodytes hexapterus	50.0	66.7	50.0	5,835

(n=4, +4 empty stomachs; 6 items, 21 ml volume)

Table 63. Indices of relative importance of prey eaten by marbled murrelets, Izhut Bay, August 1978.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	15.8	12.8	22.2	635
Mallotus villosus	5.3	7.7	11.1	144
Gadidae	5.3	5.1	11.1	115
Theragra chalcogramma	5.3	10.3	11.1	173
Ammodytes hexapterus	68.4	64.1	44.4	5,883

(n=9, +1 empty stomach; 19 items, 39 ml volume)

Table 64. Indices of relative importance of prey eaten by marbled murrelets, northern Sitkalidak Strait, August 1978.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	100.0	100.0	100.0	200,000

(n=2; 2 items, 2 ml volume)

Table 65. Indices of relative importance of prey eaten by crested auklets, Chiniak Bay, 24 January 1977.

Species	% No.	% Vol.	% FO	IRI
Acanthomysis sp.	99.3	99.7	100.0	19,900
Hyperiidea	0.7	0.3	50.0	50

(n=2; 297 items, 12 ml volume)

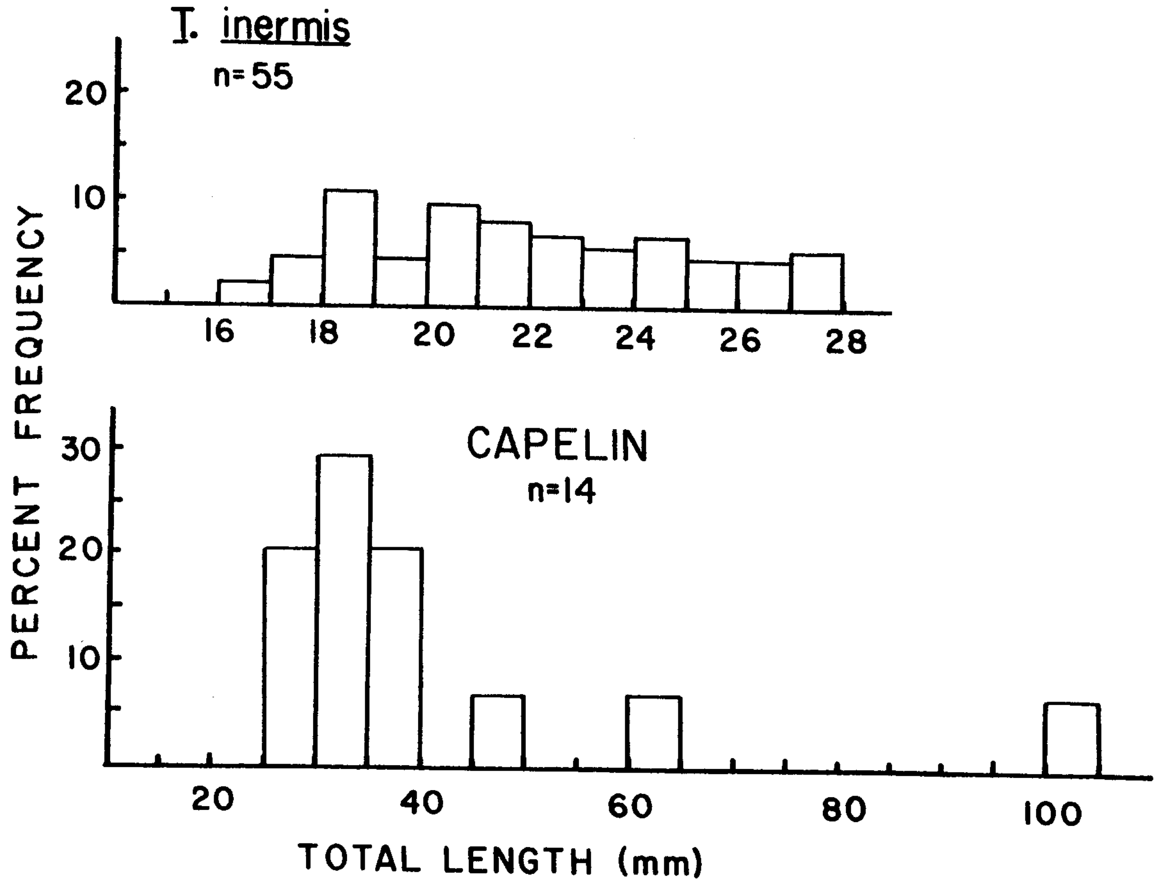

Figure 20. Length frequencies of euphausiids and capelin eaten by marbled murrelets, summer 1978.

Two auklets were collected in Chiniak Bay, in the southwest bight of Woody Island, on 24 January 1977. Both were packed with Acanthomysis sp. (Table 65) which averaged 12 ± 1.0 mm TL (n=26) (Figure 21). A marbled murrelet, collected in the same area 15 minutes earlier, contained a capelin which had been feeding on mysids.

TUFTED PUFFIN

Tufted puffins are the most abundant seabirds, numbering some 100,000 pairs, nesting in the Kodiak area (Sowls et al. 1978). During summer 1977, the density of puffins within the bays peaked at 21 birds/km^2 in August while density over the shelf was much lower and fluctuated between 3-6 birds/km^2. In contrast, Hunt et al. (1981) noted that at the Pribilof Islands, puffins were distributed uniformly out to at least 80 km from land. Approximately half of the puffins sampled were breeding adults; 54% of the 57 examined in 1977 and 60% of the 86 examined in 1978 showed evidence of brood patch development. Tufted puffins are pursuit divers (Ashmole 1971) and, like common murres, they may dive more than 100 m in search of prey.

In summer 1977, capelin was the most important food of tufted puffins at most collection sites, exceeded in importance only by walleye pollock in northern Sitkalidak Strait in August and by sand lance at Whale Passage in September (Tables 66-68). Cephalopod remains occurred in 14% of the stomachs and recently ingested squid occurred in stomachs collected during June and July.

In 1978, puffins collected in Izhut Bay ate euphausiids during May, capelin during June, and capelin and sand lance during July and August (Figure 22). Feeding habits in northern Sitkalidak Strait were similar except that more euphausiids were eaten during May, and less capelin and more sand lance were eaten during July (Tables 69-76). Cephalopods occurred in 11% of the stomachs during 1978; recently ingested squid occurred in two stomachs from northern Sitkalidak Strait during July and in one stomach from each location during August.

Measurable T. inermis occurred in tufted puffin stomachs during August 1977 (24 ± 1.0 mm TL, n=14) and were only slightly larger than those which occurred in stomachs collected during May and June 1978 (23 ± 1.9 mm, n=246) (Figure 23). Capelin eaten during 1977 (82 ± 15.4 mm, n=328) were smaller than those eaten during 1978 (89 ± 20.5 mm, n=114) ($P<0.001$) (Figure 24) whereas sand lance were larger during the first year (92 ± 8.0 mm, n=12) than during the second (80 ± 10.9 mm, n=151) ($P<0.001$) (Figure 25).

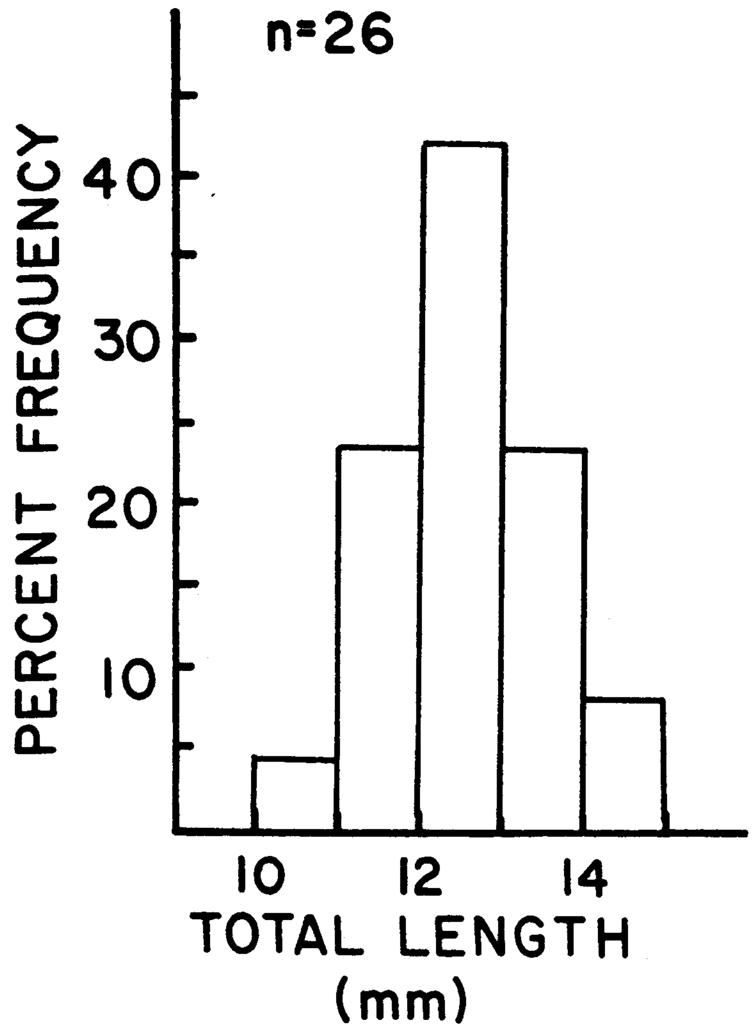

Figure 21. Length frequencies of mysids eaten by crested auklets, January 1976.

Table 66. Indices of relative importance of prey eaten by tufted puffins, May-September 1977.

Species	% No.	% Vol.	% FO	IRI
Nereidae	0.1	*	1.1	<1
Cephalopoda	1.3	1.0	13.5	38
Decapoda	0.1	*	1.1	<1
Thysanoessa inermis	30.0	2.5	5.6	182
T. raschii	0.3	*	2.2	1
T. spinifera	2.8	0.3	5.6	17
T. spp.	7.5	0.6	5.6	45
Osteichthyes	1.6	1.8	19.1	65
Osmeridae	0.1	0.5	1.1	1
Mallotus villosus	52.2	86.8	68.5	9,522
Gadidae	0.2	0.1	2.2	1
Theragra chalcogramma	1.9	4.2	6.7	41
Trichodon trichodon	0.1	0.4	1.1	1
Ammodytes hexapterus	1.5	1.8	3.4	11

*Less than 0.1%. (n=89, +11 empty stomachs; 1,090 items, 1,509 ml volume)

Table 67. Indices of relative importance of prey eaten by tufted puffins, northern Sitkalidak Strait, August 1977.

Species	% No.	% Vol.	% FO	IRI
Nereidae	2.3	0.3	10.0	26
Cephalopoda	2.3	1.3	10.0	36
Osteichthyes	2.3	0.9	10.0	32
Mallotus villosus	35.6	30.8	40.0	2,656
Theragra chalcogramma	43.2	54.8	50.0	4,900
Trichodon trichodon	2.3	4.7	10.0	70
Ammodytes hexapterus	9.1	7.2	20.0	326

(n=10, +1 empty stomach; 44 items, 114 ml volume)

Table 68. Indices of relative importance of prey eaten by tufted puffins, Whale Passage, September 1977.

Species	% No.	% Vol.	% FO	IRI
Mallotus villosus	14.3	10.0	100.0	2,430
Ammodytes hexapterus	85.7	90.0	100.0	17,570

(n=1; 14 items, 21 ml volume)

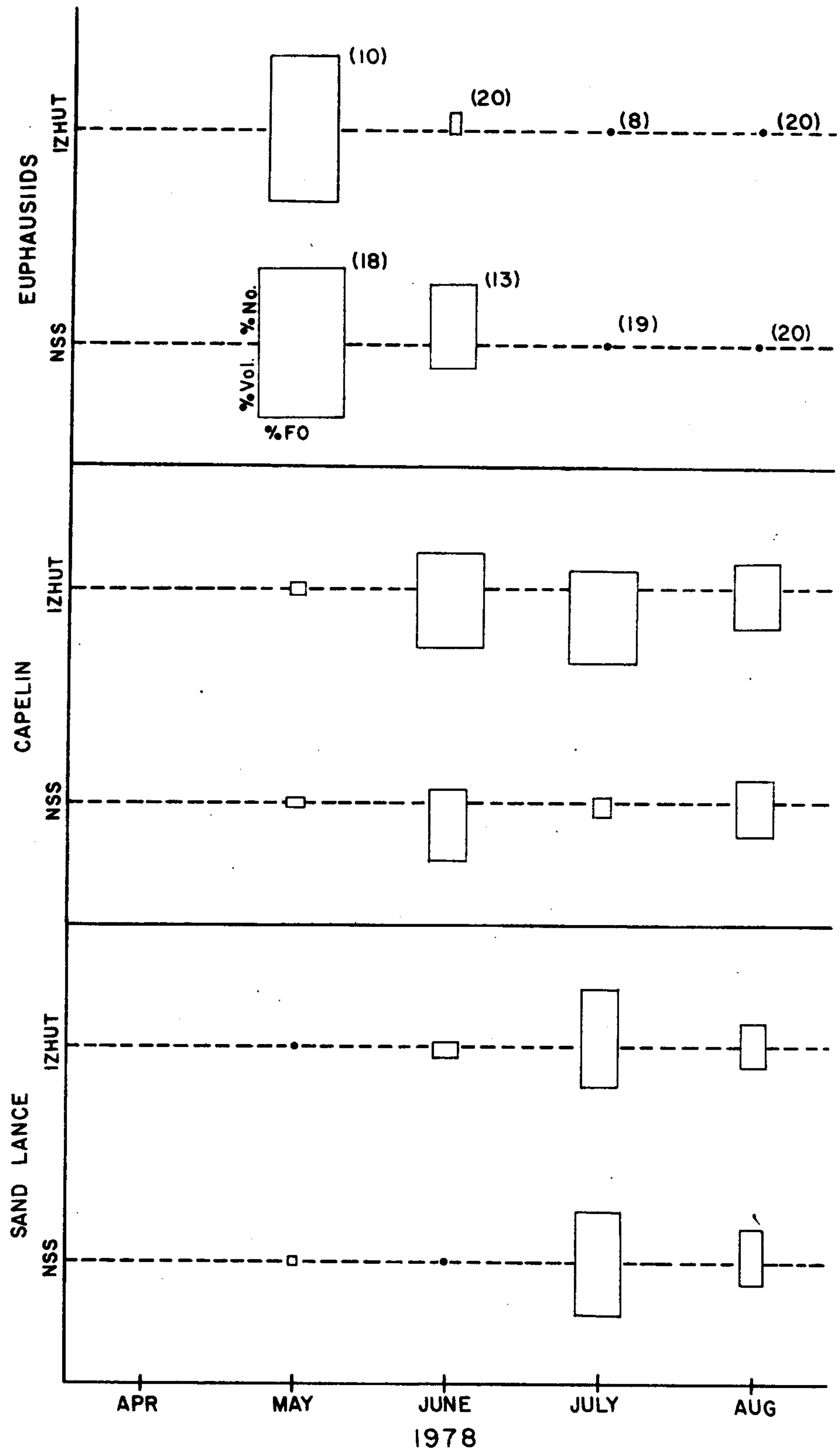

Figure 22. Relative importances of euphausiids, capelin, and sand lance to tufted puffins, Izhut Bay vs. northern Sitkalidak Strait, 1978. Sample sizes are in parentheses.

Table 69. Indices of relative importance of prey eaten by tufted puffins, Izhut Bay, May 1978.

Species	% No.	% Vol.	% FO	IRI
Nereidae	0.6	0.4	10.0	10
Cephalopoda	0.2	0.1	10.0	3
Hyperia medusarum	0.2	0.3	10.0	5
Thysanoessa inermis	84.7	84.2	80.0	13,512
T. spinifera	5.6	4.8	40.0	416
T. inermis/spinifera	7.8	4.4	10.0	122
Osteichthyes	0.7	3.8	40.0	180
Mallotus villosus	0.2	0.4	10.0	6
Theragra chalcogramma	0.2	1.8	10.0	20

(n=10; 678 items, 109 ml)

Table 70. Indices of relative importance of prey eaten by tufted puffins, northern Sitkalidak Strait, May 1978.

Species	% No.	% Vol.	% FO	IRI
Nereidae	0.1	0.2	5.0	2
Limacina helicina	0.1	0.1	5.0	1
Cephalopoda	0.2	0.2	10.0	4
Euphausiacea	0.2	0.4	5.0	3
Thysanoessa inermis	87.2	85.0	70.0	12,054
T. spinifera	4.1	3.7	25.0	195
T. inermis/spinifera	6.2	5.5	15.0	176
Osteichthyes	0.2	0.7	15.0	14
Osmeridae	0.1	0.3	5.0	2
Mallotus villosus	0.4	1.1	10.0	15
Theragra chalcogramma	0.1	0.1	5.0	1
Hemilepidotus jordani	0.1	0.5	5.0	3
Trichodon trichodon	1.1	2.1	20.0	64
Ammodytes hexapterus	0.1	0.5	5.0	3

(n=20, +1 empty stomach; 1,312 items, 196 ml volume)

Table 71. Indices of relative importance of prey eaten by tufted puffins, Izhut Bay, June 1978.

Species	% No.	% Vol.	% FO	IRI
Cephalopoda	1.4	0.5	8.7	17
Thysanoessa inermis	24.6	3.0	4.4	121
Paguridae	0.7	*	4.4	3
Osteichthyes	2.8	2.3	17.4	89
Mallotus villosus	43.0	72.3	73.9	8,521
Hemilepidotus jordani	23.9	10.4	26.1	895
Ammodytes hexapterus	3.5	11.4	13.0	194

*Less than 0.1%. (n=23; 142 items, 282 ml volume)

Table 72. Indices of relative importance of prey eaten by tufted puffins, northern Sitkalidak Strait, June 1978.

Species	% No.	% Vol.	% FO	IRI
Cephalopoda	1.2	1.9	21.4	66
Thysanoessa inermis	76.0	26.9	28.6	2,943
Osteichthyes	4.0	4.2	28.6	235
Mallotus villosus	16.8	65.4	42.9	3,526
Gadidae	0.4	1.3	7.1	12
Hemilepidotus jordani	1.6	1.2	7.1	20

(n=14; 250 items, 153 ml)

Table 73. Indices of relative importance of prey eaten by tufted puffins, Izhut Bay, July 1978.

Species	% No.	% Vol.	% FO	IRI
Mallotus villosus	24.0	51.6	87.5	6,615
Gadidae	1.3	0.1	12.5	18
Ammodytes hexapterus	74.7	48.3	50.0	6,150

(n=8; 75 items, 176 ml volume)

Table 74. Indices of relative importance of prey eaten by tufted puffins, northern Sitkalidak Strait, July 1978.

Species	% No.	% Vol.	% FO	IRI
Cephalopoda	13.9	5.4	14.3	276
Caridea	0.6	0.1	4.8	3
Pandalidae	7.0	0.6	4.8	36
Osteichthyes	2.3	1.4	18.1	67
Mallotus villosus	9.9	16.5	14.3	378
Gadidae	4.1	2.9	23.8	167
Theragra chalcogramma	0.6	2.7	4.8	16
Cottidae	0.6	0.2	4.8	4
Hemilepidotus sp.	0.6	0.4	4.8	5
Ammodytes hexapterus	60.5	69.8	52.4	6,828

(n=21, +4 empty stomachs; 172 items, 267 ml volume)

Table 75. Indices of relative importance of prey eaten by tufted puffins, Izhut Bay, August 1978.

Species	% No.	% Vol.	% FO	IRI
Osteichthyes	3.5	6.8	13.6	140
Mallotus villosus	33.7	46.4	54.5	4,365
Gadidae	3.5	2.3	13.6	79
Theragra chalcogramma	26.7	19.3	9.1	419
Trichodon trichodon	3.5	1.6	13.6	69
Ammodytes hexapterus	29.1	23.5	31.8	1,673

(n=22, +2 empty stomachs; 86 items, 270 ml volume)

Table 76. Indices of relative importance of prey eaten by tufted puffins, northern Sitkalidak Strait, August 1978.

Species	% No.	% Vol.	% FO	IRI
Cephalopoda	2.8	1.6	9.5	42
Pandalidae	2.8	0.2	4.8	14
Osteichthyes	7.0	4.2	23.8	266
Mallotus villosus	25.4	40.9	52.4	3,474
Gadidae	11.3	3.4	19.0	279
Theragra chalcogramma	5.6	6.0	9.5	110
Trichodon trichodon	5.6	15.0	19.0	391
Ammodytes hexapterus	39.4	28.7	19.0	1,294

(n=21, +1 empty stomach; 71 items, 241 ml volume)

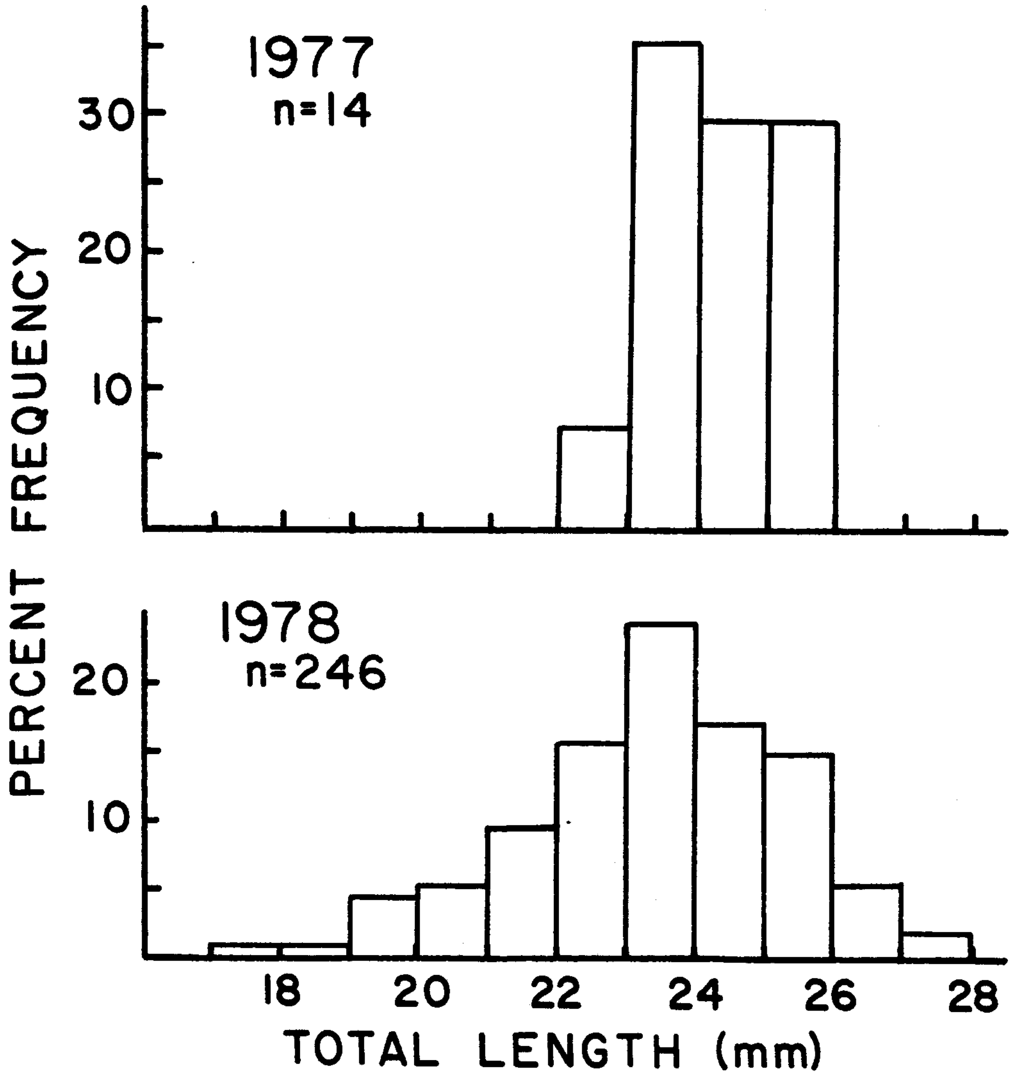

Figure 23. Length frequencies of euphausiids eaten by tufted puffins, 1977 and 1978.

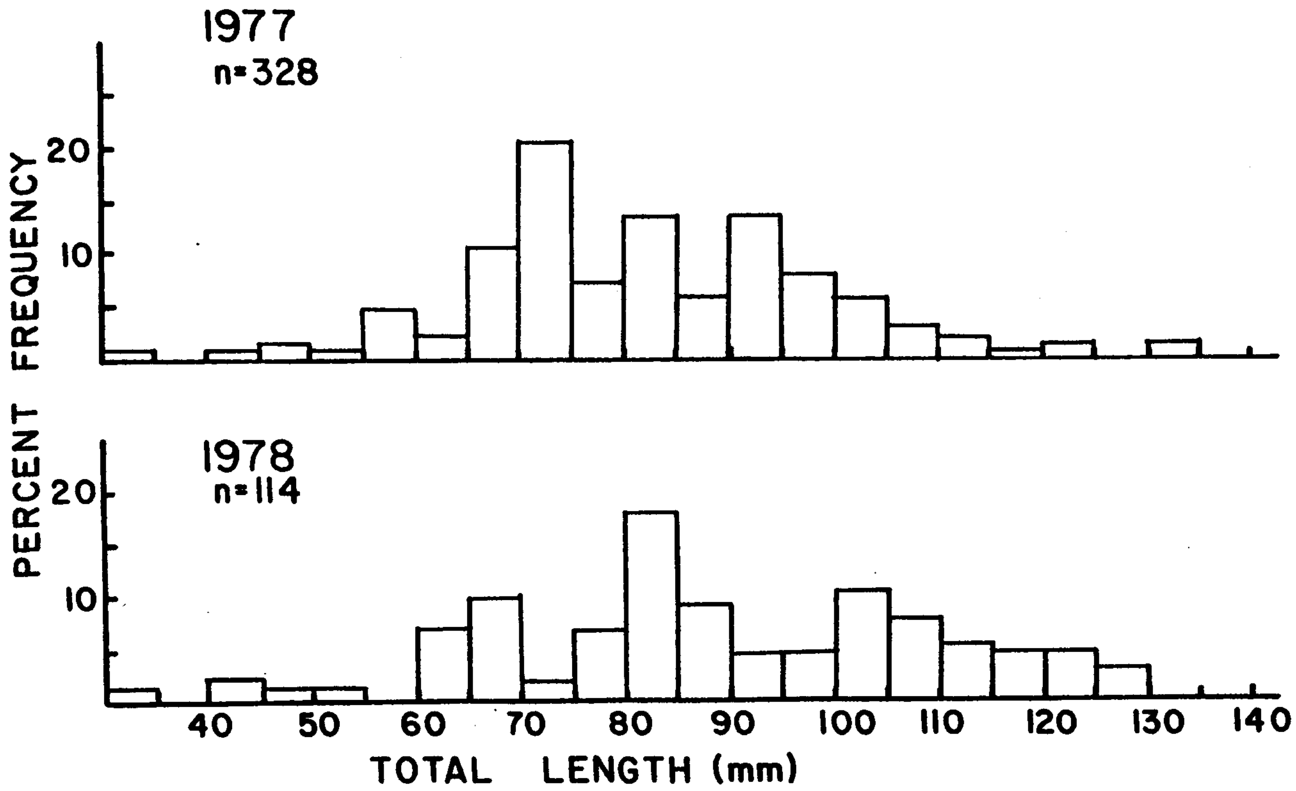

Figure 24. Length frequencies of capelin eaten by tufted puffins, 1977 and 1978.

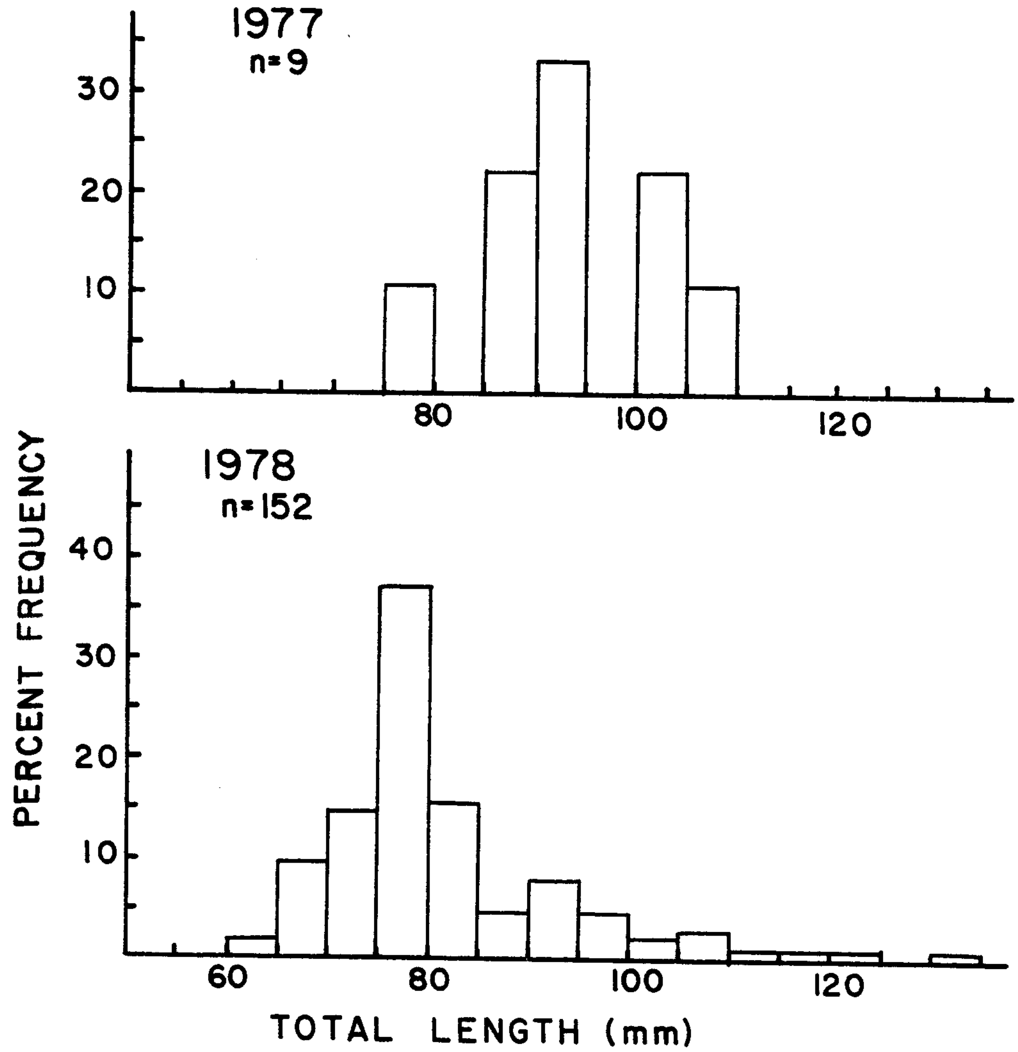

Figure 25. Length frequencies of sand lance eaten by tufted puffins, 1977 and 1978.

DISCUSSION

FEEDING ECOLOGY

Common murres and marbled murrelets showed no consistent differences in the importance of major prey species between winter and summer of a given year. Invertebrates were more important (percent number and volume of prey) to common murres in winter than in summer 1977 and were more important to marbled murrelets in winter than in summer 1978 (Figure 26). The reverse was true for common murres in 1978, however. Walleye pollock predominated in their stomachs during winter and _T. inermis_ comprised 20% of the number of prey during summer. The feeding habits of oldsquaw were so varied that no clear differences between winter and spring were apparent.

For most seabird species in the Kodiak area, distinct seasonal trends were apparent from spring through late summer 1978. Sooty shearwaters, black-legged kittiwakes, marbled murrelets, and tufted puffins exploited a similar suite of prey: sand lance and euphausiids during spring, capelin during early summer, and sand lance during late summer. This chronology was probably related to the seasonal occurrence and distribution of prey. For example, during May, swarms of _T. inermis_ were abundant at the surface outside the northern entrance to Sitkalidak Strait (Kendall _et al_. 1980) and these were fed on by large flocks of short-tailed shearwaters, black-legged kittiwakes, and tufted puffins (Krasnow and Sanger, pers. obs.).

All life stages of sand lance are common in the pelagic and mesopelagic zones of the bays and in the intertidal throughout the summer (Harris and Hartt 1977). Spawning of sand lance has been observed only on beaches along the western shoreline of Afognak Island during the high tide series in October (Warner and Dick 1981). They disappear from the nearshore zone in fall and may bury themselves in the substrate in deeper water during winter (Warner and Dick 1981).

Immature and ripening capelin feed in the surface waters of the bays during spring and summer (Harris and Hartt 1977). Beach spawning has been observed during the spring tide series in late May at Monashka, Pillar Creek, and Roslyn Beaches in Chiniak Bay and spawn-ready or spawned-out capelin have been caught in Izhut, Monashka, and Alitak Bays, and near Sitkalidak Island (Warner and Dick 1981). Beach spawning capelin are a predictable source of food and at least some seabirds prey on them; over 300 glaucous-winged gulls, 11 bald eagles (_Haliaeetus leucocephalus_), 27 pelagic cormorants (_Phalacrocorax pelagicus_), 3 magpies (_Pica pica_), and 6 northwestern crows (_Corvus caurinus_) ate spawning capelin at Roslyn Beach on the morning of 25 May 1982 (Krasnow, pers. obs.), but shearwaters, kittiwakes, and puffins were not in evidence.

When the feeding habits of black-legged kittiwakes and tufted puffins were compared between summers, capelin decreased and sand lance increased in importance in 1978. The increased use of sand lance appeared to be linked to a change in the abundance of capelin in the epipelagic zone; juveniles were abundant in the surface waters during June-September 1976 (Harris and Hartt 1977), but during 1978, most were found along the bottoms of the troughs (Rogers _et al_. 1980). Conversely, juvenile sand lance increased in abundance in the surface waters

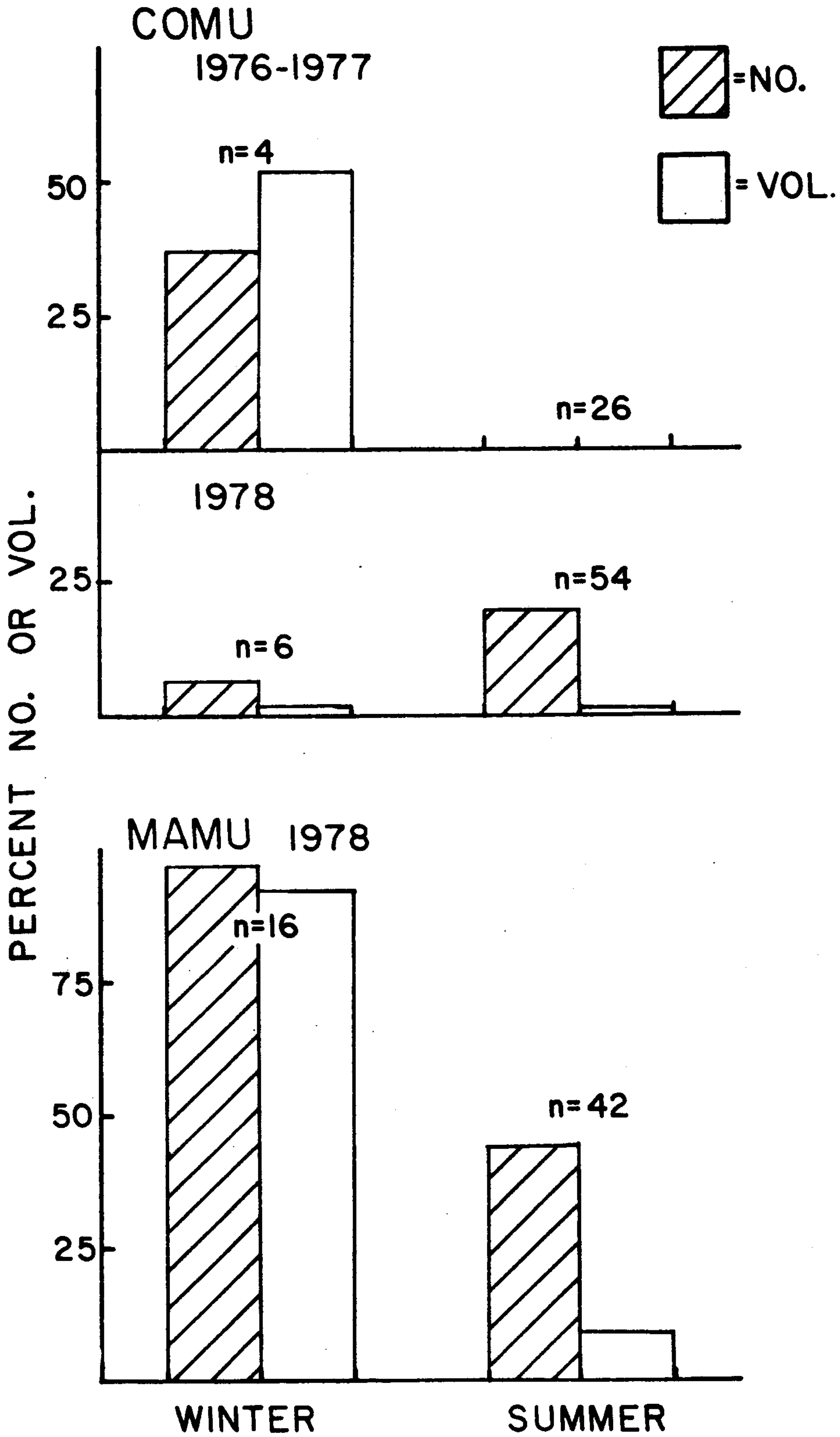

Figure 26. Relative importances of invertebrate prey in winter vs. summer to common murres and marbled murrelets.

during 1978 (Rogers et al. 1980).

This inverse relationship in the availability of capelin and sand lance was reflected in the relative use of these two species by breeding seabirds in northern Sitkalidak Strait (Baird and Hatch 1979). Fewer capelin and more sand lance were fed to black-legged kittiwake chicks during 1978 than in 1977. Productivity of kittiwakes declined from 0.74 young fledged per nest attempt to 0.17, suggesting that the availability of food was depressed below some "critical level". The productivity of kittiwakes in Chiniak Bay also decreased, from 1.23 young fledged per nest attempt in 1977 to 0.77 in 1978 (Nysewander and Barbour 1979). These authors noted that the beach spawning capelin sought by sport fishermen during May and June did not appear during 1978. However, food samples were not collected at breeding colonies in Chiniak Bay in 1978 and the assumption that fewer capelin were brought to chicks than during the previous year was not substantiated.

Because capelin live only three or four years and most spawn only once, poor recruitment of a given year class can lead to cycles of abundance and near absence (Warner and Dick 1981). Historically, there could be an increase in numbers of sand lance during periods when capelin are scarce, but in 1978, neither capelin nor sand lance were available to kittiwakes in sufficient quantities to meet reproductive needs (Baird and Hatch 1979). Kittiwake production also dropped abruptly at the Pribilof Islands in 1978 (Hunt et al. 1981b) and the change was attributed to a decrease in the consumption of walleye pollock.

Tufted puffins in Kodiak had comparatively good productivity in 1978 (Baird and Hatch 1979, Nysewander and Barbour 1979). The number of capelin per bill load delivered to puffin chicks in northern Sitkalidak Strait was lower in 1978 than in 1977, but the decrement was smaller than that observed for kittiwakes. Baird and Hatch therefore suggested that capelin were more available to puffins feeding at depth than to kittiwakes feeding at the surface. Fisheries data indicate that the distribution of capelin was indeed different in the two years but that in 1978, most fish were caught in the deep troughs, beyond the diving range of puffins. It is more likely that puffins were merely more successful than kittiwakes in exploiting the few fish that were available; when fed on by mixed flocks of birds, capelin are soon driven to depths beyond the reach of kittiwakes but are still vulnerable to predation by puffins.

Our data also suggested that, within the same year, there are local differences in the relative availability of major prey species. For example, capelin were consistently the most important prey for black-legged kittiwakes in Izhut Bay from June through August 1978; euphausiids occurred in large numbers in a few stomachs in early summer and some sand lance were taken in late summer. In northern Sitkalidak Strait, however, euphausiids were the most important prey in June, and sand lance predominated the rest of the summer. Lesser numbers of capelin were taken throughout the season.

Of the species studied, the common murre was the most specialized and its diet did not follow the seasonal and annual patterns that were common to the other species. Murres collected during summer were almost entirely piscivorous although those collected during winter ate some invertebrates. The morphological and behavioral adaptations that enable common murres to be efficient predators of fish probably evolved in response to competition with the thick-billed murre, Uria lomvia (Spring 1971). In Kodiak, where thick-billed murres are not abundant, piscivory still helps to alleviate competition between common murres and the rest of the seabird feeding assemblage.

Pigeon guillemots and marbled murrelets were also distinct in that they fed primarily in shallow water. However, guillemots ate primarily epibenthic and demersal organisms while murrelets obtained their prey throughout the water column. Both species used more crustaceans during April and May 1978 than later in the summer. The diets of guillemots from Kodiak resembled those of birds collected during May and June 1979 at Naked Island, Prince William Sound (Katherine Kuletz, University of California, Irvine, pers. comm.). Sand lance was absent from stomachs collected at Kodiak although it occurred in 33% of those from Naked Island. _Cancer oregonensis_ was important at both locations.

When the feeding habits of seabirds in Kodiak are compared with those of seabirds from the Pribilof Islands (Hunt _et al_. 1981a), several important similarities and differences are evident. Some authors have suggested that invertebrates do not supply all of the nutrients necessary for egg laying and the growth of seabird chicks (Tuck and Squires 1955, Belopol'skii 1957, Bedard 1969, Hunt _et al_. 1981a) so a change in diet from invertebrates before egg laying to fish during egg laying and incubation is expected.

Because common murres collected at the Pribilof Islands during summer ate mostly fish, Hunt _et al_. (1981) questioned whether the predominance of amphipods in 12 stomachs collected by Preble and McAtee (1923) during winter was an artifact of their small sample size (18 stomachs) or reflected a seasonal change in diet. Our results, and those of Sanger _et al_. (1978) indicate that crustaceans are sometimes more important to murres during winter, possibly because of a decrease in the availability of forage fish.

Tufted puffins ate mostly fish both at the Pribilofs and at Kodiak Island. Crustaceans were more important at Kodiak but because some of the samples from the Pribilof Islands were bill loads to chicks, a higher frequency of occurrence of fish would have been expected.

Because most oil spills in subarctic waters have occurred during winter (Clark and Finley 1977), seaducks, murres, and auklets in the Kodiak area are likely to suffer the highest mortalities from direct oiling (Forsell and Gould 1981). However, if hydrocarbons accumulate in food chains to be passed on to higher trophic levels, even the shearwaters, kittiwakes, and puffins which are abundant during summer will be affected.

Little effort has been made to confirm the hypothesis that hydrocarbons accumulate in food chains and are eventually incorporated into the tissues of vertebrate predators. It is possible that most seabird prey can degrade hydrocarbons or that contaminated individuals die and are degraded, moving the pollutants back toward the bottom of the food chain. Because "considerable quantities" of hydrocarbons from the *Florida* spill were found in the muscle and brain tissues of a juvenile herring gull collected while feeding in the adjacent marsh one month after the spill (Sanders *et al.* 1980) there is evidence that the danger of food chain accumulation is real. It is important that background levels of hydrocarbons in marine bird tissues be measured so that if an increase occurs after a spill, it can be demonstrated.

The degree to which benthic prey organisms are affected by a spill depends on the concentration and chemical composition of oil reaching the sediments and the physiological capacity of each species to degrade hydrocarbons (Clark and Finley 1977). Soft-shelled clams (*Mya arenaria*), edible blue mussels, and edible oysters (*Ostrea edulis*) for example, lack the hydroxylase enzymes which degrade polycyclic aromatic hydrocarbons (Vandermuelen and Penrose 1976, cited by Clark and Finley 1977). Individuals that are not killed accumulate hydrocarbons in their tissues and exhibit impaired growth, and/or productivity (Sanders *et al.* 1980). Juvenile *Mytilus edulis* affected by the *Florida* spill were sexually sterile during their first reproductive season (Clark and Finley 1977). Fiddler crabs (*Uca pugnax*) exhibited impaired equilibria and escape responses, which increased their vulnerability to predation (Sanders *et al.* 1980). In the Kodiak area, oldsquaw, Steller's eiders, and pigeon guillemots feed heavily on benthic fauna but some of the "pelagic" species (common murres and marbled murrelets) eat epibenthic and demersal mysids and amphipods, and would also be vulnerable to food chain effects.

Euphausiids, and the eggs and larvae of many of the species of fish and crustaceans eaten by marine birds, are planktonic and because the distribution of planktonic organisms in nature is patchy, the effect of petroleum hydrocarbons on their survival has been difficult to assess. Zooplankton biomass decreased significantly after the *Argo Merchant* spill but this may have represented migration from the area rather than mortality (Grose 1977, cited by Clark and Finley 1977). Copepods ingested particles of fuel oil from the wreck of the *Arrow* without apparent harm (Conover 1971). However, 70% of the pollock eggs obtained from the *Argo Merchant* slick were dead and nearly all had oil particles adhering to them.

Because organisms react in such diverse and sometimes contradictory ways to oil contamination, it is not possible to predict the exact impact of a future spill, only to say that certain types of mortality and/or impairment of behavior, growth, or reproductive output can be expected (Clark and Finley 1977). However, we have determined that the productivity of marine birds responds to changes in the availability of their prey; in 1978, a decrease in availability of capelin appeared to lead to the reproductive failure of black-legged kittiwakes. However, the factors which caused capelin to decline in availability, the number of years it remained in short supply, and whether or not sand lance increased in abundance while capelin were scarce, were not investigated.

Capelin live only four years and most spawn only once so that high mortality of one year class could reduce the total stock size by as much as 25% (Warner and Dick 1981). Because capelin and sand lance both have planktonic larvae which feed on copepod nauplii, poor recruitment of capelin could leave more food available for sand lance and lead to an increase sand lance abundance. This kind of competitive interaction is thought to have occurred between the Pacific sardine (*Sardinops sagax caeruleus*) and the northern anchovy (*Engraulis mordax*) (Cushing 1975). Marine bird communities may have become adapted to balances between competing stocks of forage fish. If that is true and oil pollution disrupts such a balance, the effect on seabird populations could be catastrophic.

NEEDS FOR FURTHER STUDY

We have little information on the feeding ecology of seabirds over the continental shelf and no information on that which takes place at the shelf break. During summer, the densities of kittiwakes and puffins are higher in the bays than offshore, but because the area of the shelf is much larger, the porportion of the total population which feeds there may be greater. In winter, it is likely that the survival of many seabirds depends on what happens hundreds of kilometers offshore. Also, specimens from the shelf break may contain more freshly ingested cephalopods.

Our two years of data indicate that seasonal and annual variations in feeding habits occur in the Kodiak area, and have a significant effect on seabird productivity. Our data only begin to suggest sources for that variation however, and our hypotheses need to be confirmed. In addition, we need more information about the diets of the small alcids. The winter feeding ecology of the crested auklet is of particular interest because the majority of those which nest in the Gulf of Alaska probably winter in the Kodiak area. Other species which are abundant but for which we have little or no data are the northern fulmar, fork-tailed storm petrel, pelagic and red-faced cormorants, glaucous-winged gull, mew gull, arctic tern, Cassin's auklet, and horned puffin.

In light of interest in the development of commercial fisheries for capelin and sand lance and the importance of these fish in the diets of marine birds, these species deserve further study. With regard to vulnerability to oil spills, we need information on the relative importance of intertidal versus demersal spawning for capelin and an attempt should be made to differentiate between spawning stocks for both species. The presence of multiple stocks, whose larvae are separated in space or time, would decrease the potential for significant losses to a single oil pollution event.

ACKNOWLEDGEMENTS

Anthony R. DeGange, Douglas J. Forsell, Allan K. Fukuyama, Patrick J. Gould, Valerie F. Hironaka, Robert D. Jones, Jr., David R. Nysewander, Margaret R. Petersen, and David W. Wiswar, all of the U. S. Fish and Wildlife Service, assisted us in our field studies, as did Juan Guzman and Patos Fuentes of the University of Calgary. Allan K. Fukuyama, Valerie F. Hironaka, and David W. Wiswar sorted and identified the samples, James Blackburn (Alaska Department of Fish and Game, Kodiak) helped with the identifications of larval fish, and personnel at the Marine Sorting Center, Institute of Marine Sciences, University of Alaska, verified our identifications of invertebrates. Patrick J. Gould, Colleen M. Handel, Scott A. Hatch, and Calvin J. Lensink reviewed earlier versions of this manuscript. We are grateful to all these people and to many others. Finally, we thank our "tracker", Laurie Jarvela (NOAA OCSEAP Project Office), for his patience and for cheerfully and promptly responding to our requests for maps and reports.

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Appendix. Taxonomic list of prey.

Ph. Protozoa
- Cl. Rhizopodea
  - O. Foraminiferida

Ph. Cnidaria
- Cl. Anthozoa

Ph. Rhyncocoela (Nemertea)

Ph. Annelida
- Cl. Polychaeta
  - F. Polynoidae
    - *Harmothoe* sp.
  - F. Sigalionidae
    - *Phloe minuta*
  - F. Phyllodocidae
    - *Etone californica*
    - *E. longa*
  - F. Syllidae
  - F. Nereidae
  - F. Glyceridae
    - *Hemipodus borealis*
  - F. Lumbrineridae
  - F. Orbiniidae
  - F. Cirratulidae
  - F. Flabelligeridae
  - F. Opheliidae
    - *Travisia* sp.
  - F. Oweniidae
    - *Owenia fusiformis*
  - F. Pectinariidae
    - *Pectinaria granulata*
  - F. Ampharetidae
  - F. Sabellidae

Ph. Mollusca
- Cl. Gastropoda
  - O. Archeogastropoda
    - F. Acmaeidae
    - F. Trochidae
      - *Margarites pupillas*
  - O. Mesogastropoda
    - F. Lacunidae
      - *Lacuna variegata*
      - *L. vincta*

F. Littorinidae
Littorina sitkana
F. Rissoidae
Alvinia compacta
Cingula katharinae
Barleeia sp.
F. Cerithiidae
Bittium sp.
F. Eulimidae
Balcis sp.
F. Trichotropididae
Trichotropis insignis
T. cancellata
F. Naticidae
Natica clausa
O. Neogastropoda
F. Muricidae
Nucella lima
F. Nassariidae
Nassarius sp.
F. Olividae
Olivella baetica
F. Cancellaridae
Admete couthouyi
F. Turridae
Mangelia sp.
Oenopota sp.
F. Pyramidellidae
Odostomia sp.
Turbonilla sp.
O. Cephalaspidea
F. Philinidae
Philine sp.
F. Aglajidae
Aglaja diomedeum
F. Retusidae
Retusa sp.
O. Thecosomata
F. Limacinidae
Limacina helicina
O. Nudibranchia
F. Onchidorididae
Onchidoris bilamellata
Cl. Polyplacophora
F. Mopaliidae
Katharina tunicata
Cl. Bivalvia
O. Arcoida
F. Glycymerididae
Glycymeris subobsoleta

O. Mytiloida
F. Mytilidae
Mytilus edulis
Musculus vernicosus
O. Veneroida
F. Thyasiridae
Axinopsida serricata
F. Montacutidae
Mysella sp.
F. Astartidae
Astarte sp.
F. Mactridae
Spisula polynyma
F. Tellinidae
Macoma sp.
F. Veneridae
Saxidomus gigantea
Psephidea lordi
Protothaca staminea
O. Myoida
F. Myidae
Mya sp.
F. Hiatellidae
Hiatella sp.
O. Scaphopoda
O. Cephalopoda

Ph. Arthropoda
Cl. Crustacea
Copepoda
O. Calanoida
O. Harpacticoida
F. Harpacticidae
Harpacticus sp.
Cirripedia
O. Thoracica
F. Lepadidae
Lepas sp.
Malacostraca
Pericarida
O. Mysida
F. Mysidae
Acanthomysis sp.
Neomysis rayii
O. Cumacea
O. Tanaidacea
F. Paratanaidae
Leptochelia savignyi
O. Isopoda
O. Amphipoda
Gammaridea

F. Lysianassidae

Paracallisoma alberti

Hyperiidea

F. Hyperiidae

Parathemisto japonica

Eucarida

O. Euphausiacea

F. Euphansiidae

Thysanoessa inermis

T. raschii

T. spinifera

O. Decapoda

Natantia

F. Oplophoridae

Hymenodora frontalis

F. Hippolytidae

Lebbeus sp.

Eualus pusiola

Heptacarpus brevirostris

H. tridens

F. Pandalidae

P. borealis

P. goniurus

P. jordani

F. Crangonidae

Crangon septemspinosa

Reptantia

Anomura

F. Paguridae

Pagurus sp.

F. Lithodidae

Paralithodes camtschatica

Brachyura

F. Majidae

Hyas lyratus

F. Atelecyclidae

Telmessus cheiragonus

F. Cancridae

Cancer oregonensis

Cl. Insecta

Dolichopus sp.

Ph. Ectoprocta

Microporina borealis

Ph. Echinodermata

Cl. Ophiuroidea

O. Iphiurida

F. Ophiactidae

Ophiopholis aculeata

F. Amphiuridae

Amphiopholis pugetana

Cl. Echinoidea
O. Echinoida
F. Strongylocentrotidae
Strongylocentrotus droebachiensis
Cl. Holothuroidea
O. Dendrochirotida
F. Cucumariidae
Cucumaria lubricata
Eupentacta quinquesemita

Ph. Chaetognatha

Ph. Chordata
Cl. Osteichthyes
O. Salmoniformes
F. Osmeridae
Mallotus villosus
O. Gadiformes
F. Gadidae
Gadus macrocephalus
Microgadus proximus
Theragra chalcogramma
O. Scorpaeniformes
F. Cottidae
Hemilepidotus sp.
Myoxocephalus sp.
O. Perciformes
F. Trichodontidae
Trichodon trichodon
F. Stichaeidae
Lumpenus sagitta
L. maculatus
F. Pholidae
Pholis laeta
F. Ammodytidae
Ammodytes hexapterus
O. Pleuronectiformes
F. Pleuronectidae

DIETS AND FOOD WEB RELATIONSHIPS OF SEABIRDS IN THE GULF OF ALASKA AND ADJACENT MARINE REGIONS

by

Gerald A. Sanger

U.S. Fish and Wildlife Service
Denver Wildlife Research Center
Migratory Bird Project

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 341

January 1983

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DIETS AND FOOD WEB RELATIONSHIPS OF SEABIRDS IN THE GULF OF ALASKA AND ADJACENT MARINE REGIONS

by
Gerald A. Sanger

ABSTRACT

Overall diets of 39 species of marine birds (four procellariiforms, three cormorants, six sea ducks, one phalarope, two jaegers, 17 gulls, two terns, and 13 alcids) inhabiting the Gulf of Alaska and adjacent marine regions are summarized with food web diagrams, tables, and text. Diets of the Northern Fulmar, Sooty and Short-tailed Shearwaters, Pelagic Cormorant, Black-legged Kittiwake, Common and Thick-billed Murres, Marbled and Kittlitz's Murrelets, and Horned and Tufted Puffins are compared among seasons and geographic regions. Overall food web relationships within the procellariiforms, cormorants, *Larus* gulls, kittiwakes, terns, murrelets, auklets, and puffins are each compared and discussed.

Pacific Sand Lance (*Ammodytes hexapterus*), Capelin (*Mallotus villosus*), the euphausiid *Thysanoessa inermis*, and unidentified squids were generally the most important prey to pelagic birds in the Gulf of Alaska, as were Blue Mussels (*Mytilus edulis*), and the clams *Protothaca staminea*, *Spisula polynyma*, *Macoma* spp. and *Mya* spp. to sea ducks. In general, seabirds appear to utilize commercially-important species of prey in the Gulf of Alaska to only a small degree, but possible future fisheries for Capelin and Pacific Sand Lance could have serious consequences to breeding seabirds if other suitable prey were not available.

Future studies of seabird feeding ecology in the Gulf of Alaska should focus on the relationship between reproductive success and the distribution and availability of prey, and on defining annual, seasonal and geographic variations in diets and the trophic relationships between primary producers, seabirds, fishes, and other apex predators.

INTRODUCTION

Sowl and Bartonek (1974) drew attention to the magnitude of seabird populations in Alaska, and pointed out the lack of the most basic information about them. From the onset of the Alaskan Outer Continental Shelf Environmental Assessment Program (OCSEAP), seabirds were recognized as important components of coastal and offshore ecosystems (NOAA 1975). Although little data were available, seabirds were presumed to play an important role in recycling nutrients (NOAA 1975; Sanger 1972), and in helping stabilize populations of forage fishes by cropping superabundant concentrations during the spring-summer nesting season (NOAA 1975).

Marine birds have long been known to be particularly vulnerable to direct oiling from oil spills (e.g., Vermeer and Vermeer 1974; Bourne 1972; King and Sanger 1972). They also are believed to suffer indirectly from marine oil pollution from its effect on populations of prey animals and through the effect of petroleum contaminants being concentrated in succeeding trophic levels of the food chain (NOAA 1975); however, there are few substantiating data for the latter idea (Krasnow and Sanger 1982).

A key to understanding and mitigating possible indirect effects of oil pollution to marine birds is through knowledge of their diets (feeding habits) and trophic relationships. Guidelines for baseline OCSEAP studies prior to petroleum exploration and development on the outer continental shelf of Alaska included a list of official tasks for work needed on seabirds (NOAA 1975). Task A-6 stated the need to, "Describe (the) dynamics and trophic relationships of selected species (of seabirds) at offshore and coastal study sites."

A research program that considered the status and distribution of populations, reproductive ecology, and trophic relationships (OCSEAP Research Unit 341: Population dynamics and trophic relationships of marine birds in the Gulf of Alaska and southern Bering Sea) was developed in order to address major concerns as to the effects of petroleum development. Field studies were conducted from 1975 to 1978, and focused mainly in the Gulf of Alaska and the southeastern Bering Sea. Prior reports have provided detailed descriptions of the feeding ecology of marine birds in Kachemak Bay (Sanger and Jones 1982) and at Kodiak Island (Krasnow and Sanger 1982).

The main objective of this report is to summarize information on the diets of 39 species of marine birds, based on data pooled from all seasons and geographic areas studied. Secondary objectives are to describe food web relationships in selected, phylogenetically-related groups of birds based on the pooled data, and as data allow, to compare the diets of birds by season and geographic region. A description of the diets of the birds is emphasized, and more detailed analyses and interpretation will be published in the scientific literature.

METHODS

ORIGIN OF FOOD SAMPLES

Food samples were obtained from birds collected at sea during all seasons, but primarily between spring and early fall, and from nestlings or their parents on breeding colonies, primarily between early summer and early fall, depending on species of bird.

Birds collected at sea came from four main areas or periods: 1. From the Kodiak Island area during the spring-summer seasons of 1977 and 1978 and during the intervening winter (Krasnow and Sanger 1982); 2. From Kachemak Bay in Cook Inlet (Sanger and Jones 1982, in press); 3. From collections during OCSEAP cruises from 1975 through 1978 in the Gulf of Alaska and southeastern Bering Sea, mostly incidental to other research activities aboard the vessels; and 4. From specimens that had drowned in salmon gillnets deployed from research vessels of the National Marine Fisheries Service (NMFS) south of the Aleutian Islands and the Alaska Peninsula from 1969 to 1971, and from collections by personnel of the NMFS Marine Mammal Division in the southeastern Bering Sea in 1973 and 1974.

Food samples were collected from nestlings or their parents at a number of breeding colonies in the Gulf of Alaska and the southeastern Bering Sea (Figure 1). Analyses of resulting data has been reported elsewhere for each colony (e.g., Moe and Day 1977; Leschner and Burrell 1977; and especially Baird 1983). Such sampling was the most consistent in the Kodiak area (Baird and Moe 1978), and along with simultaneous collections at sea in adjacent areas, produced the most comprehensive data among the geographic regions (Krasnow and Sanger 1982; and below).

FIELD METHODS

Birds were generally collected at sea by shotgun, from skiffs deployed from the larger research vessels. Less frequently, birds were collected directly from the larger vessel. Whenever possible, attempts were made to collect birds that appeared to be actively feeding. Due to limited opportunities for collecting birds on the open ocean, however, they were sometimes collected regardless of their behavior. Whenever possible, series of specimens were collected at the same time and location, and attempts were made to collect samples of all species from feeding flocks of mixed species.

Usually within five minutes of collection, specimens were weighed with a small spring scale to the nearest g, and their stomachs were injected with buffered 10% formalin to stop post-mortem digestion (van Koersveld 1950). They were tagged with a label indicating field number, weight, and time of collection.

When possible, specimens were processed aboard ship. Standard ornithological measurements were recorded, the age and sex of the specimen was determined, and the digestive tract was removed and preserved in buffered 10% formalin. When this was not possible, specimens were frozen intact in the ship's freezer and processed at the FWS laboratory at a later date.

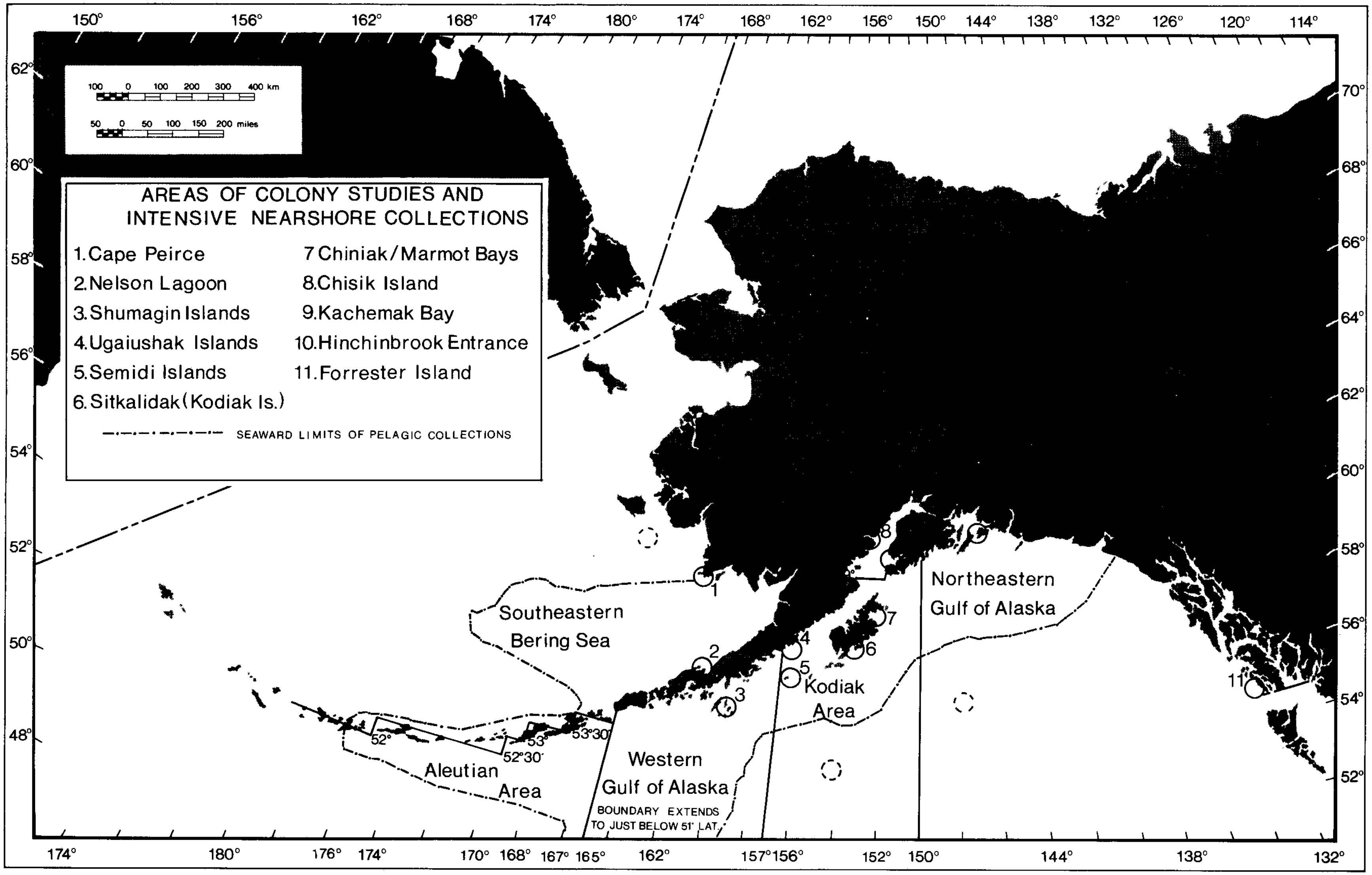


Figure 1. Map of Alaska, showing locations of study camps and marine regions.

Food samples from nestlings on breeding colonies were collected by various means, depending on species of bird and individual field situation (Baird 1983). Generally, samples were collected from cormorants, gulls and terns by startling chicks on the nest; this usually caused them to regurgitate their most recent meal. Most samples from nestlings of terns and puffins were collected by startling parent birds returning to their nests or burrows with prey in their bills, which usually caused them to drop the prey. Some samples were collected from chicks of horned and tufted puffins by taping their bills shut, and then later collecting prey left in their burrows by their parents (Baird and Moe 1978). All food samples from chicks were preserved in plastic bags with either 50% isopropyl alcohol (earlier samples) or buffered 10% formain.

LABORATORY METHODS

Frozen specimens were stored in a laboratory freezer until processing. Specimens were thawed and processed as noted above. Depending on the workload of laboratory personnel, stomach contents were then analyzed, or they were stored in 50% isopropanol and analyzed at a later date.

To analyze the stomach contents, the digestive tract was opened with fine-pointed scissors and any non-food items such as rocks or plastic debris were removed. Stomach contents were drained of excess moisture, weighed to the nearest 0.1 g, and their volume measured to the nearest ml by water displacement. Prey items were then counted and identified to the lowest possible taxon, and the volume of each kind of prey was visually estimated as a percent of the total. Prey identifications were verified by consultation with taxonomic specialists (see Acknowledgments) and voucher specimens were accumulated for comparison with subsequent collections.

The greatest length of whole specimens was measured to the nearest mm, and recognizable parts such as fish otoliths (Frost and Lowry 1981), fish vertebral columns and parasphenoid bones (Sanger et al. 1978), and cephalopod beaks were measured to the nearest 0.1 mm.

ANALYSES AND PRESENTATION OF DATA

Data are analyzed and presented in three general modes: 1. The general feeding habits of each species is described, based on data pooled from all regions, seasons and years of data collection; 2. The general food web relationships of selected, phylogenetically-related groups of birds are described, based on data pooled as above; and 3. Where data permit, the feeding habits of species of seabirds are compared among major geographic regions (Figure 1) and seasons, based on data pooled from all years of collection. Seasons are defined here as: Winter, November through March; Spring, April through 15 May; Summer, 16 May through August; and Fall, September and October.

Data on feeding habits of each species are presented in appendix tables that list for each kind of prey the aggregate percent volume (cf. Martin et al. 1946; Swanson et al. 1974), aggregate percent numbers, percent frequency of occurence in the pooled sample of birds, and an Index of Relative Importance (see below). Species accounts summarize information in the appendix tables, which are often quite extensive, and food web diagrams convey a visual summary of the relative importance of the main foods of each bird species.

Pinkas *et al*. (1971) discussed the shortcomings of using either volume, numbers, or frequency of occurrence alone to depict the importance of prey. Differential digestion rates of hard and soft-bodied prey may distort their original relative volumes, percent numbers can make an abundant small prey seem more important than sparse larger ones, and percent frequency of occurrence ignores numbers and volume. To overcome these problems, these authors combined the three values into an Index of Relative Importance (IRI), as defined below:

IRI = %FO (%V + %N), where

%FO = percent frequency of occurrence of a prey taxon or group of taxa in a sample of n birds

%V = percent aggregate volume of a prey taxon or group of taxa in the combined volume of all taxa in the stomachs of the sample of n birds

%N = percent aggregate numbers of a prey taxon, or group of taxa in the combined numbers of all taxa in the stomachs of the sample of n birds.

Generalized information about the seasonal distribution and abundance of the birds is given below for orientation, but the reader is referred to Gould *et al*. (1982) for full details.

RESULTS

SEASONAL AND GEOGRAPHIC CHARACTERISTICS OF THE SAMPLES

In total, there are data from 2,995 food samples from 39 species of seabirds. Sample sizes varied considerably among months, with about 71% of the samples between June and August, 10% from the five months between November and March, 10% in April and May, and about 9% in September and October.

Disparity also existed in numbers of birds collected among geographic regions. Most food samples (2,188 or 74%) were from the Kodiak Island area. Numbers of samples from other regions were: Northeastern Gulf of Alaska, 264 (8.9%); Cook Inlet, 201 (6.8%); southeastern Bering Sea, 179 (6.1%); western Gulf of Alaska, 79 (2.7%); and, Aleutian Islands, 44 (1.5%).

Even when all samples are pooled, sample sizes are very small for some birds. The average sample size for all species was 74, but for 16 (40%) of these, it was fewer than 10. Only 15 species (38%) had samples greater than 30, and the following seven of these had samples of 100 or more: Sooty shearwater (*Puffinus griseus*), short-tailed shearwater (*P. tenuirostris*), glaucous-winged gull (*Larus glaucescens*), black-legged kittiwake (*Rissa trydactyla*), common murre (*Uria aalge*), marbled murrelet (*Brachyramphus marmoratum*), and tufted puffin (*Fratercula cirrhata*).

DIETS, POOLED DATA

Order Procellariiformes (Tube-nosed Birds)

We have data on four of the forteen species of procellariiformes known to occur in Alaskan waters: Northern fulmar (*Fulmarus glacialis*), sooty shearwater, short-tailed shearwater; and, fork-tailed storm-petrel (*Oceanodroma furcata*). Fulmars and fork-tailed storm-petrels occur in Alaskan waters year-round, but the two shearwaters breed in the southern hemisphere and migrate to the North Pacific during the boreal summer, when they usually dominate seabird numbers in Alaskan waters from spring through fall (Gould *et al.* 1982).

Compared with other seabirds, the feeding ecology of the procellariiforms is relatively uncomplicated. In the subarctic North Pacific Ocean, procellariiforms range in size from storm petrels of 45 - 50 g, to albatrosses of 3 - 3.5 kg. All species feed on a relatively few prey species. Storm petrels feed right at the surface, fulmars are able to dive for their food to at least 0.5 M (S. Hatch, pers. commun.) and perhaps as deep as "several meters" (Nelson 1979), and the two shearwaters pursue their prey to depths of at least 5 M (Brown *et al.* 1978).

Northern Fulmar. Forty-six birds were sampled, of which 43 (93.5%) had food in their stomachs. Most were from the Kodiak Island area (N = 21) and the northeast Gulf of Alaska (N = 16). At least 10 species of prey were in the birds' stomachs.

Squid dominated the diet of fulmars; they accounted for 72% by numbers, 63% by volume, and occurred in 81% of all samples (Figure 2, Appendix Table 1). Squid of the family gonatidae were identified from five (12%) of the stomachs, but identification to lower taxa was impossible. Crustaceans and unidentified fish were of secondary importance to fulmars. Capelin and walleye pollock were the only fish identified, and were present in only trace amounts.

The euphausiid *Thysanoessa inermis* was found in only one bird, but it accounted for 4.7% of numbers and 1.4% of the total prey volume. The amphipods *Parathemisto pacifica* and *Paracallisoma alberti* were present in the stomachs in trace amounts. Unidentified gammarid amphipods accounted for 1.7% of prey numbers and 2.3% of the volume. In view of the common occurence of *P. alberti* (Gammaridea, Lysianassidae) in a number of seabird species in the Gulf of Alaska (Sanger and Boersma, in prep.) these unidentified amphipods may well have been *P. alberti*.

Other trace prey included nereid polychaetes, unidentified bivalves and remains of a fork-tailed storm-petrel in one bird. The medusae (jellyfish) *Cyanea capillata* and unidentified medusae are sometimes important prey of fulmars in the vicinity of the eastern Aleutian Islands (R. Day, pers. commun. to P. J. Gould), but we found none in the samples we studied.

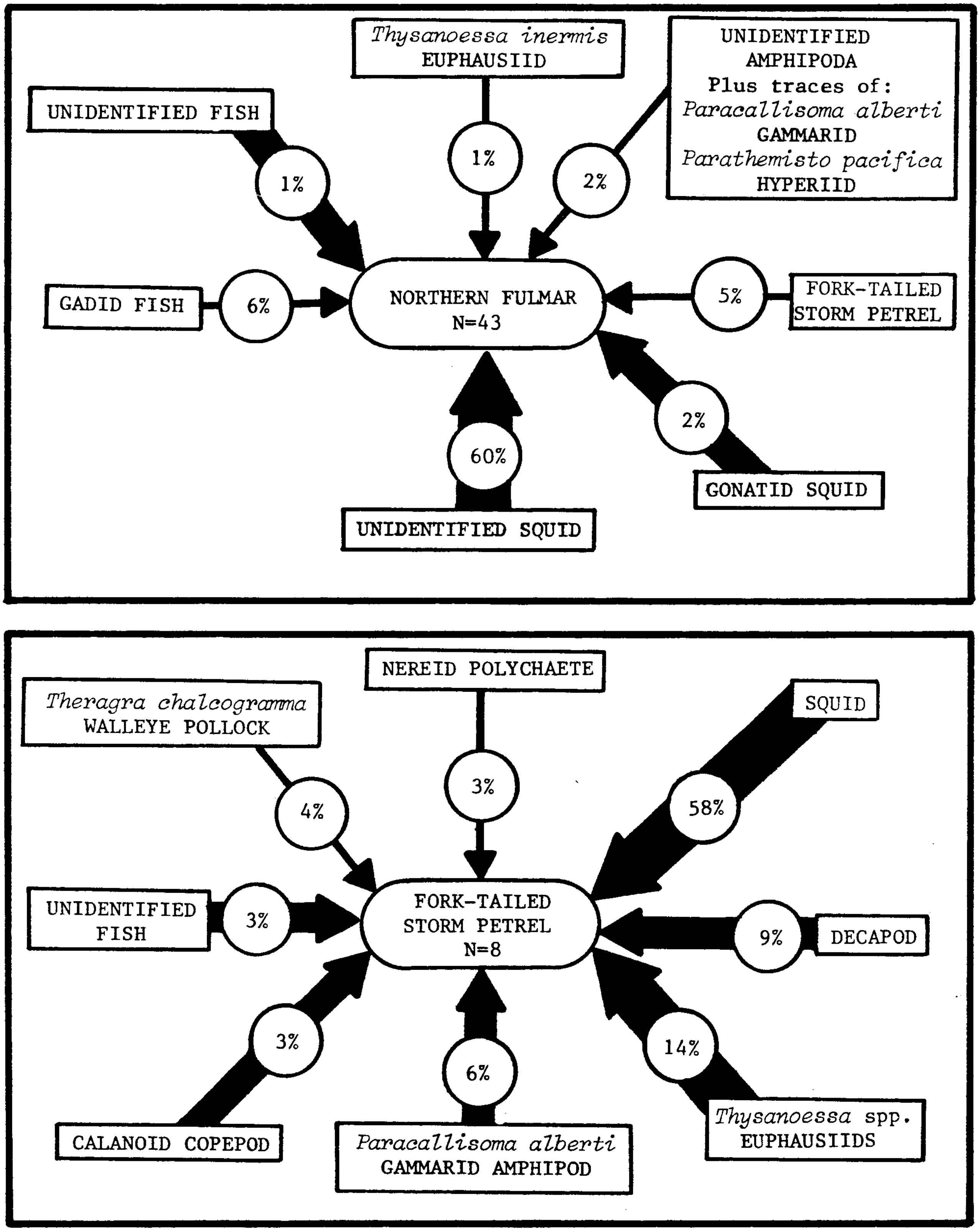


Figure 2. Food webs for northern fulmars (top) and fork-tailed storm petrels (bottom), showing main prey as indicated by pooled data. % aggregate volumes shown, and arrow sizes based on exponential increments of prey's IRI: small = 10 - 99; medium = 100 - 999; large = 1,000 and up. Only prey with both an IRI of at least 10 and which comprised at least 1% of the volume are included.

However, it seems unlikely that medusae remain recognizable in bird stomachs very long after ingestion, and the birds may pick the medusae apart while eating them.

Sooty Shearwater. A total of 187 sooty shearwaters was collected, of which 178 (95.2%) had food in their stomachs; 161 of these (86%) were from the Kodiak Island area.

Of the 14 kinds of prey identified, capelin was overwhelmingly the most important; it comprised 23% of all numbers and 83% of the volume, and occured in 50% of birds with food in their stomachs (Figure 3, Appendix Table 2). Other major prey, in descending order of importance, included squid, Pacific sand lance, and the euphausiid *Thysanoessa inermis*.

Although squid accounted for low proportions of total volume, unidentified squid comprised 38% of numbers and occured in 41% of the birds with food in their stomachs. Unidentified cephalopods were likely squid, but the condition of beaks remaining in stomachs rendered them indistinguishable from octopus beaks. Unidentified gonatids and *Onychoteuthis* spp. squids were present in trace amounts.

T. inermis was moderately important to sooty shearwaters, but other crustaceans were of only minor or trace importance. Other fish, present in trace amounts only, included Pacific tomcod, Pacific sandfish, and a myctophid (lantern fish), *Stenobrachius nannochir*.

Short-tailed Shearwater. Two-hundred-twenty-eight (228) birds were collected, of which 201 (88.2%) had food in their stomachs; 184 (80.7%) were from the Kodiak area, and 31 (13.6%) were from the southeastern Bering Sea. Fourteen prey species were identified.

Euphausiids dominated the diet of short-tailed shearwaters, comprising 85% of the numbers, 46% of the volume, and occurring in 22% of all stomachs with food (Figure 3, Appendix Table 3). Most euphausiids could be identified only to genus (*Thysanoessa*); of those identifiable to species, *T. inermis* was the most important, while *T. raschii* and *T. spinifera* were of relatively minor importance.

Capelin was the next most important prey, comprising 41% of the volume. Walleye pollock and Pacific sand lance were present in trace amounts. Squid, including unidentified cephalopods, were of relatively minor importance. Unidentified gonatids were present in trace amounts. Squid occurred in 37% of birds with food in their stomachs, however, so squid may be more important to short-tails than these data suggest.

Fork-tailed Storm-petrel. Fourteen storm-petrels were sampled, of which eight (57%) had food in their stomachs. Six prey species were identified. Squid, including unidentified cephalopods, was the most important kind of prey (Figure 2, Appendix Table 4), but none were identifiable to a taxa lower than order.

Cephalopods accounted for 58% of the prey volume. Euphausiids were also important prey, accounting for 60% of their numbers, and 14% of their volume. Prey of secondary or minor importance included unidentified

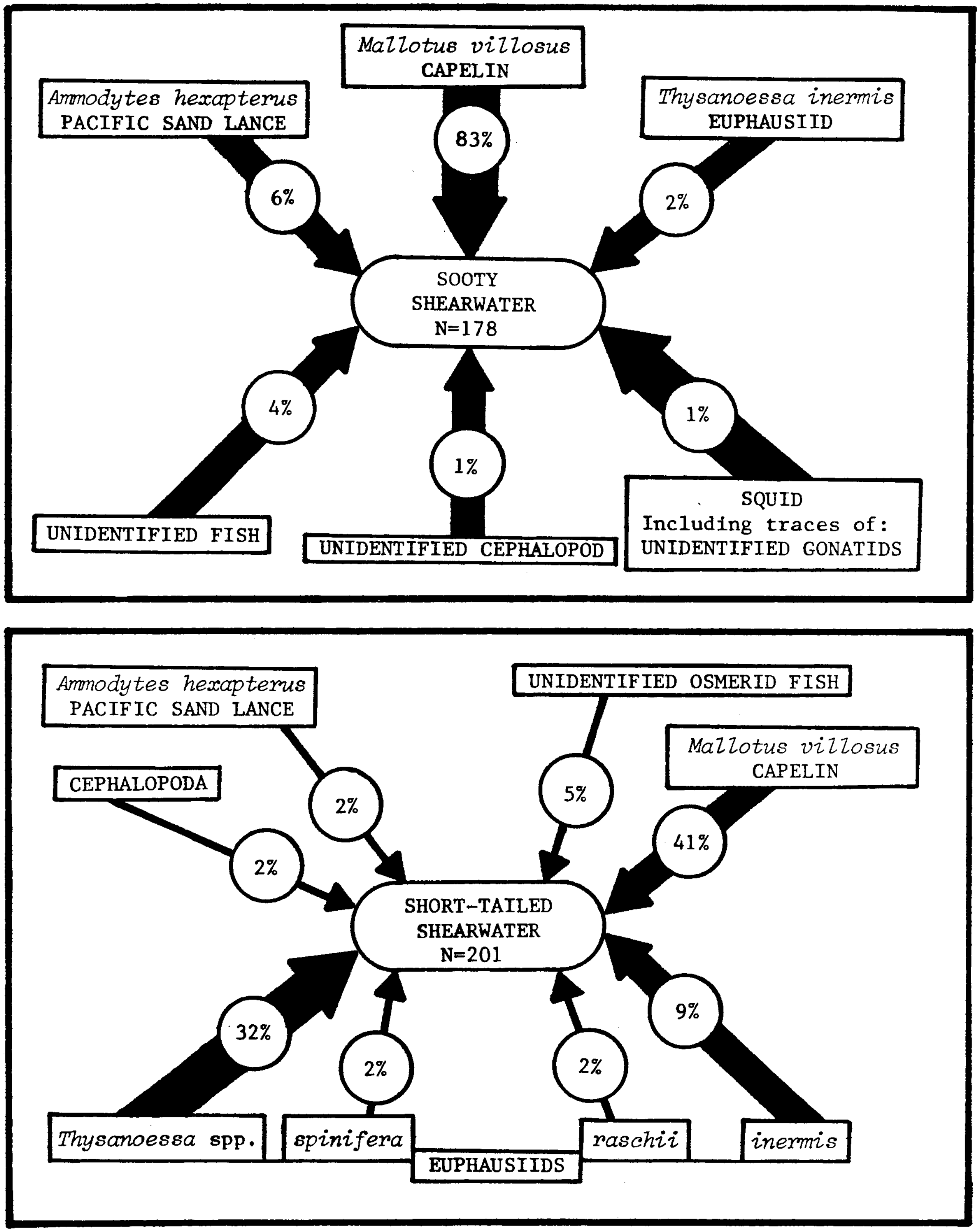


Figure 3. Food webs for sooty shearwaters (top) and short-tailed shearwaters (bottom), showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

decapods (probably shrimp), the gammarid amphipod *Paracallisoma alberti*, calanoid copepods, walleye pollock, and nereid polychaetes.

Capelin was the major prey in regurgitations of parent birds returning to the Barren Islands to feed their nestlings (D. Boersma, pers. commun.).

Food Web Relationships. Table 1 and Figure 4 compare the relative importance of all kinds of prey among the four procellariiformes. Capelin was the main fish prey; it was of at least moderate importance to all species except fulmars. Pacific sand lance were moderately important to both species of shearwaters. Gadids were present in trace or minor amounts in the diets of all four bird species. The commercially important walleye pollock was not found in the abundant shearwaters and it was of only minor importance to fulmars and storm-petrels.

The procellariiforms ate a minimum of nine species of crustaceans, of which *Thysanoessa* euphausiids were important to all four species, particularly short-tailed shearwaters. *T. inermis* was the most important species to fulmars and both shearwaters, while *T. spinifera* was most important to the storm-petrels.

Calanoid copepods were also found in all four bird species; they were most important to the storm-petrels, but were of minor or trace importance to the other three. Similarly, amphipods were found in all four species of birds. The pelagic gammarid amphipod *Paracallisoma alberti* was moderately important to the storm-petrels. A large predatory hyperiid, *Parathemisto libellula*, was a trace prey of short-tailed shearwaters, but it should be considered important in the Bering Sea where it is a major component of micronekton over shelf waters (Bowman 1960; Wing 1976).

Although data indicate that cephalopods are of major importance in the diet of procellariiforms, this animal group was particularly difficult to identify to species because of their usual advanced state of digestion in stomachs samples. The relative importance of different species of cephalopods to procellariiformes therefore remains unknown.

Phalacrocoracidae (Cormorants)

Cormorants are rather large seabirds, averaging about 1.6 to 2.8 kg in weight, depending on species. They feed on or near the bottom by swimming with their large feet in pursuit of their prey (by pursuit diving of Ashmole 1971). Three species are included in our samples: Double-crested cormorant, *Phalacrocorax auritus*; pelagic cormorant, *P. pelagicus*; and red-faced cormorant, *P. urile*. All three are year-round residents in nearshore waters of Alaska (Gould *et al*. 1982). Sample sizes for adults and nestlings of all three species were generally small, but those from pelagic cormorants included 16 adults and 15 nestlings.

Double-crested Cormorant. Two adult birds were collected and regurgitations from two nestlings were obtained. The stomach of one adult was empty, and the other had unidentified fish remains. Both nestlings

Table 1. Comparative importance of prey to procellariiform seabirds, based on data pooled from food samples from birds in Alaskan waters. Importance levels of prey based on their Indices of Relative Importance: 0-9 = trace(tr); 10-99 = 1; 100-999 = 2; 1,000-9,999 = 3

PREY NAME	Importance of Prey to Bird Species: Northern Fulmar N = 43	Sooty Shearwater N = 178	Short-tailed Shearwater N = 201	Fork-tailed Storm-petrel N = 8
POLYCHAETA				
Unidentified Nereid	tr	tr	tr	1
GASTROPOD, Unidentified	-	-	tr	-
BIVALVE, Unidentified	tr	-	-	-
CEPHALOPODA				
Unidentified	2	2	1	2
Unidentified Gonatid	2	tr	tr	-
Onychoteuthis borealijaponicus	-	tr	-	-
Unidentified Squid	3	3	tr	3
CRUSTACEA				
Calanoid Copepod	1	tr	tr	2
Amphipoda				
Paracallisoma alberti	tr	tr	-	2
Unidentified Gammarid	1	-	tr	-
Parathemisto pacifica	tr	tr	tr	-
Parathemisto libellula	-	-	tr	-
Euphausiacea				
Thysanoessa inermis	1	2	2	-
Thysanoessa raschii	-	tr	1	-
Thysanoessa spinifera	-	tr	1	2
Thysanoessa sp.	-	tr	3	2
Decapoda				
Telmesus chieragonus	-	-	tr	-
Unidentified	-	-	tr	2
FISHES				
Mallotus villosus	tr	3	2	-
Stenobrachius nannochir	-	tr	-	-
Theragra chalcogramma	tr	-	tr	1
Microgadus proximus	-	tr	-	-
Unidentified Gadid	1	-	-	-
Trichodon trichodon	-	tr	-	-
Ammodytes hexapterus	-	2	1	-
Unidentified	2	2	1	1
BIRDS				
Oceanodroma furcata	1	-	-	-

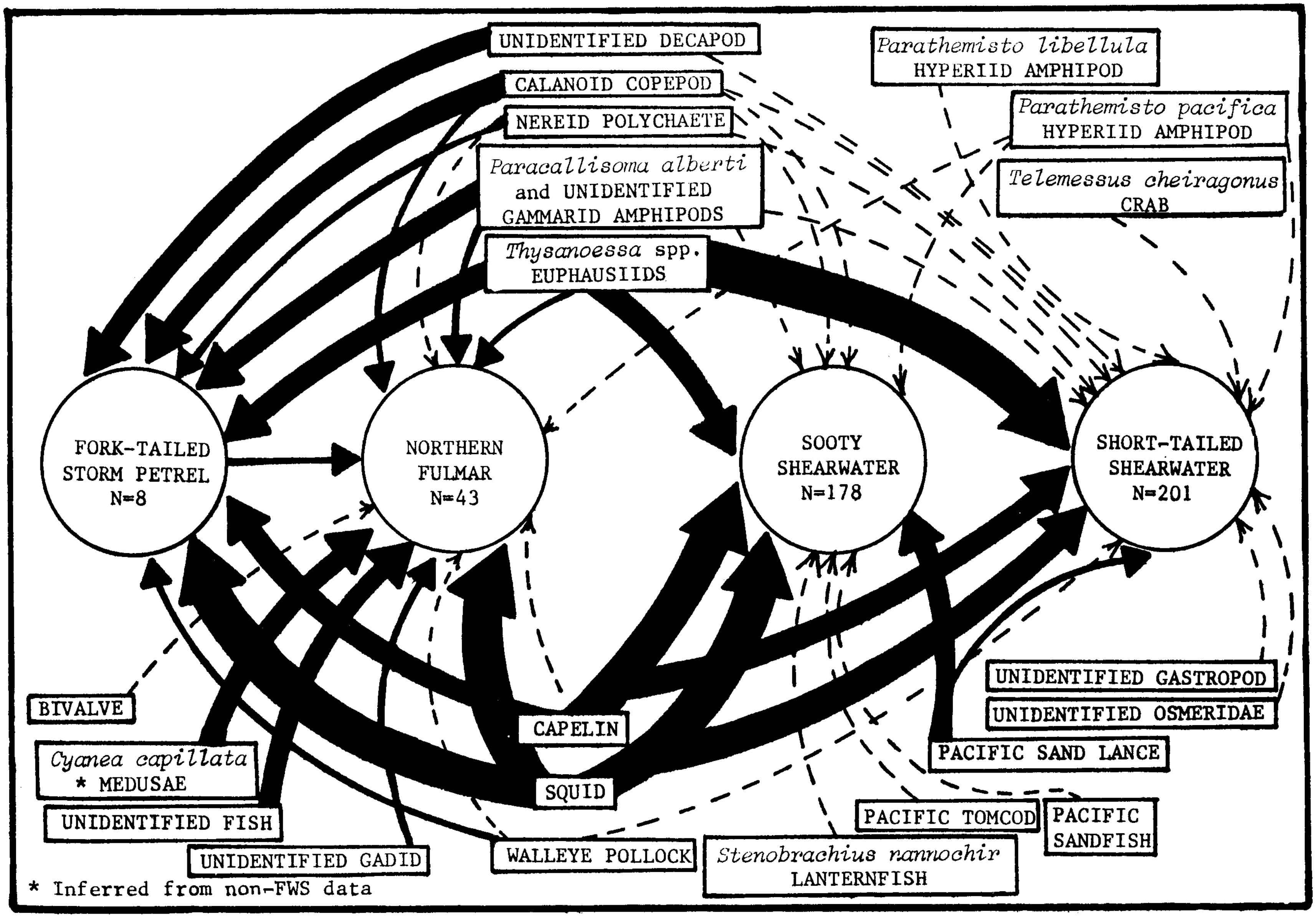


Figure 4. Food web relationships among four species of procellariiform seabirds, based on pooled data. Arrow sizes based on exponential increments of prey's IRI for each bird species: Dashed = 0 - 9; small = 10 - 99; medium = 100 - 999; large = 1,000 and up.

regurgitated unidentifiable fish remains, and one had eaten the shrimp *Crangon septemspinosa* (Appendix Table 5).

Pelagic Cormorant. Sixteen adults were collected, and all had food in their stomachs. The birds had eaten at least nine kinds of prey; fish predominated, particularly Pacific sand lance. Sand lance occured in 62% of the stomachs, and accounted for 46% of total prey volume; their IRI was 7,424 (Figure 5, Appendix Table 6). The next most important prey was capelin (IRI = 160). Walleye pollock was of minor importance (IRI = 52). Other fish, crustaceans, and sea urchins were of minor or trace importance.

Fifteen regurgitation samples were collected from nestlings, all from the Kodiak area. At least five kinds of prey were present. Fish and dipteran flies (attracted to the birds' generally-dirty nests) were the main prey items, unidentified decapods were of minor importance, and unidentified polychaetes were present in trace amounts (Figure 5, Appendix Table 7). Fish prey were mostly sand lance (IRI = 3,889) and unidentified fish (IRI = 3,595), plus unidentified gadids (IRI = 18).

Red-faced Cormorant. Two adults, one each from the southeastern Bering Sea and Kodiak Island, had eaten at least six species of prey. Pacific sand lance (71% of total volume) and the shrimp *Lebbeus polaris* (12% of volume) were the main kinds of prey (Appendix Table 8). Other prey, in descending order of importance, included unidentified fish, Irish lord (*Hemilepidotus* sp.), a pandalid shrimp (*Pandalus jordani*), unidentified nereid polychaetes, and valviferan isopods (crustacea).

Seven regurgitation samples from Kodiak nestlings revealed at least four kinds of prey. Pacific sand lance was dominant (65% of numbers, 81% of volume, and 71% frequency of occurence), capelin was moderately important, and other prey included dipteran flies, and unidentified osmerid and gadid fishes (Figure 6, Appendix Table 9).

Food Web Relationships. The generally small samples prevent all but the most tentative of conclusions about food web relationships in the cormorants. However, comparisons of the relative importance of all kinds of prey of adults and nestlings of all three species (Table 2, Figure 7) reveal general trends. Fish was the only general prey category eaten by adults and nestlings of all three species. Pacific sand lance stood out as major prey of adults and nestlings of both pelagic and red-faced cormorants. Capelin, heavily utilized by a number of other seabird species, was of only moderate importance to nestling red-faced cormorants. The two adult red-faced cormorants in our samples had eaten three species of crustaceans, but crustaceans in general were sparsely utilized by the cormorants in our samples.

Anatidae (Subfamily Athyinae, Sea Ducks)

Sea ducks are medium-sized diving birds that feed by swimming under water with their webbed feet. They eat sessile or slowly moving benthic and demersal prey, and some species include plant material in their diets. Most species breed inland near fresh water, and all species winter

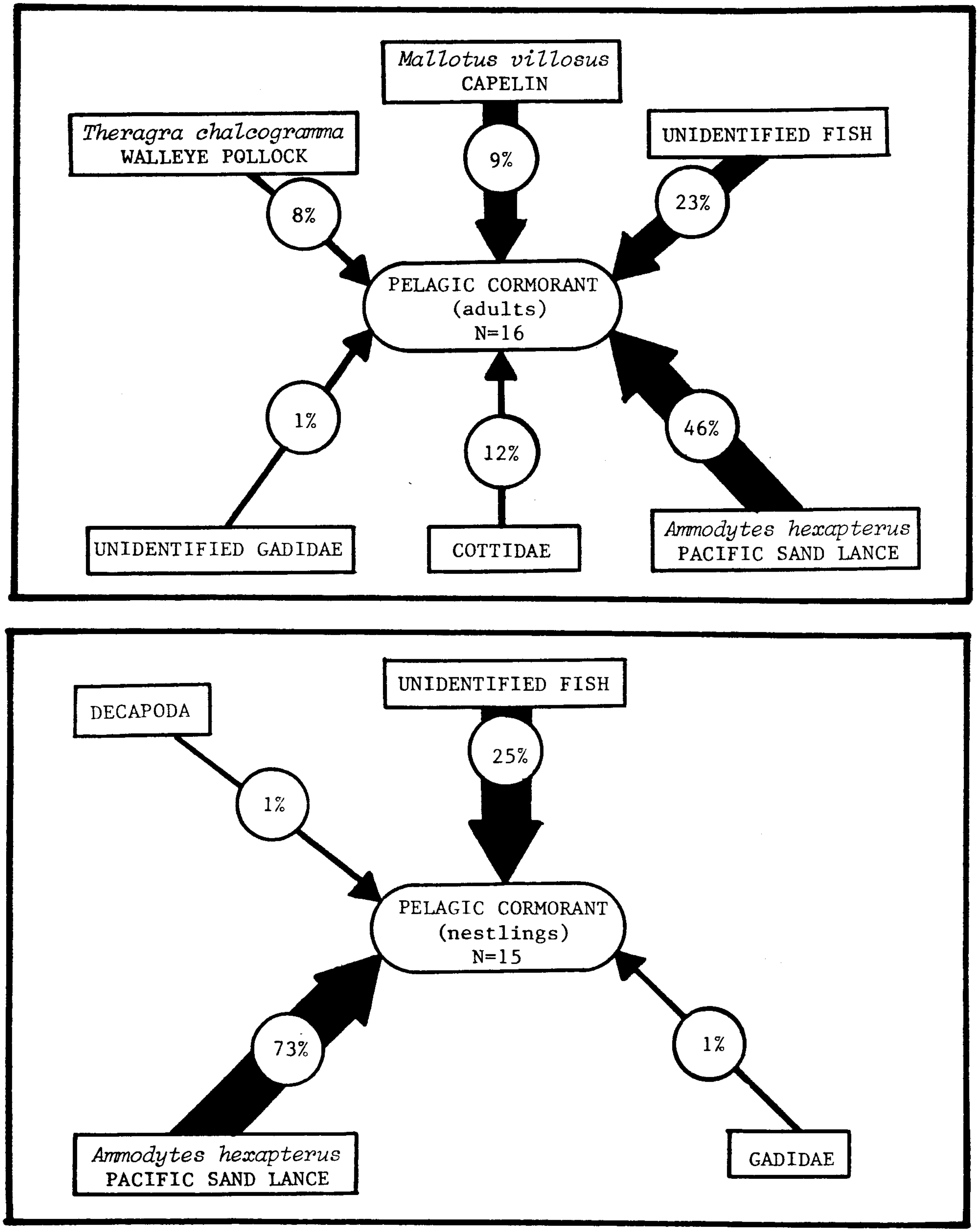


Figure 5. Food webs for adult (top) and nestling (bottom) pelagic cormorants, showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

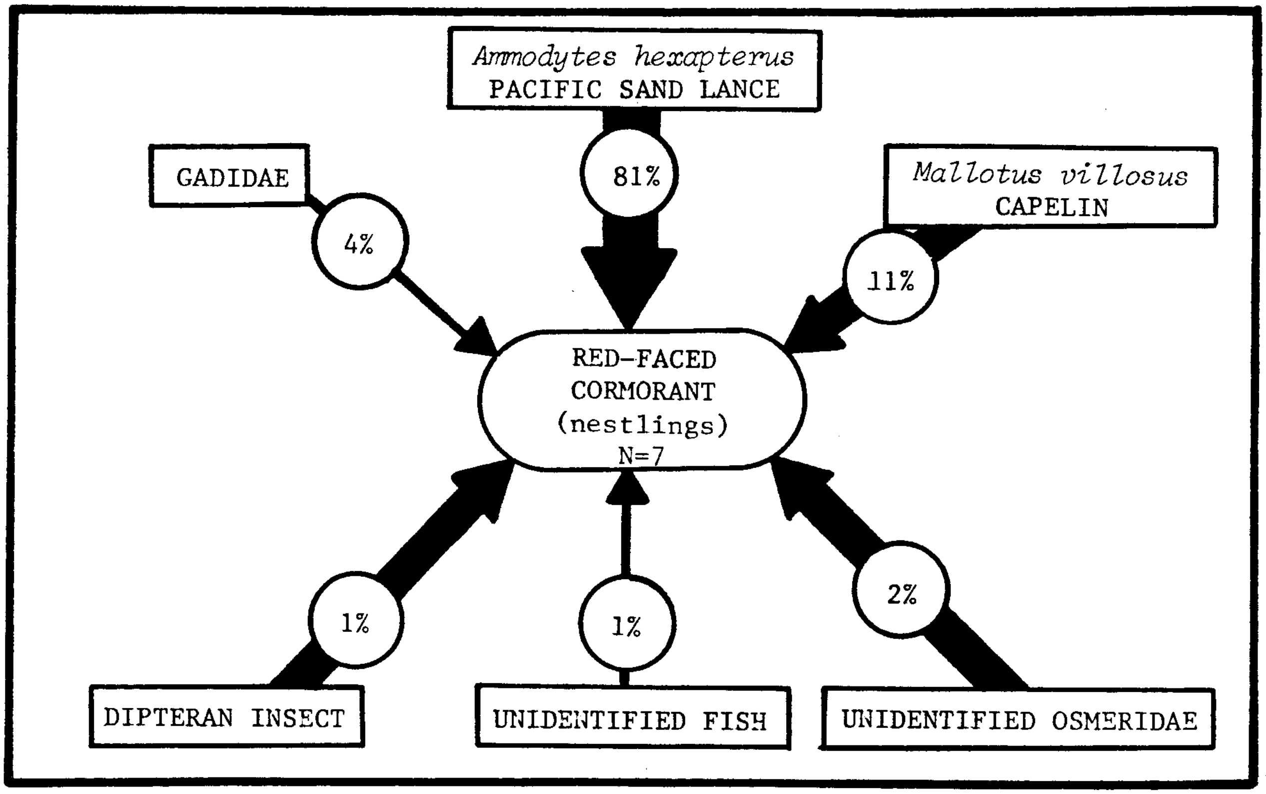


Figure 6. Food web for red-faced cormorant nestlings, showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

Table 2. Comparative importance of prey to adult and nestling cormorants, based on data pooled from food samples from birds in Alaskan waters. Importance levels of prey based on their Indices of Relative Importance: 0-9 = trace(tr); 10-99 = 1; 100-999 = 2; 1,000-9,999 = 3

PREY NAME	Importance of Prey to Cormorant Species					
	Pelagic		Double-crested		Red-faced	
	(adult) N = 16	(nestling) N = 15	(adult) N = 1	(nestling) N = 2	(adult) N = 2	(nestling) N = 7
POLYCHAETA						
Nereidae	--	--	--	--	2	--
Unidentified	--	1	--	--	--	--
ECHINODERMATA						
Echinoida	tr	--	--	--	--	--
INSECTA						
Diptera	--	2	--	--	--	2
CRUSTACEA						
Mysida	tr	--	--	--	--	--
Gammaridean Amphipoda	1	--	--	--	--	--
Valviferan Isopod	--	--	--	--	2	--
Unidentified Crab	--	1	--	--	--	--
Shrimp						
Lebbeus polaris	--	--	--	--	3	--
Pandalus jordani	--	--	--	--	2	--
Crangon septemspinosa	--	--	--	3	--	--
Unidentified	1	--	--	--	--	--
FISH						
Mallotus villosus	2	--	--	--	--	2
Unidentified Osmeridae	--	--	--	--	--	2
Hemilepidotus sp.	--	--	--	--	2	--
Theragra chalcogramma	1	--	--	--	--	--
Unidentified Gadidae	1	1	--	--	--	1
Ammodytes hexapterus	3	3	--	--	3	3
Unidentified Cottidae	1	--	--	--	--	--
Unidentified	2	3	3	3	2	1

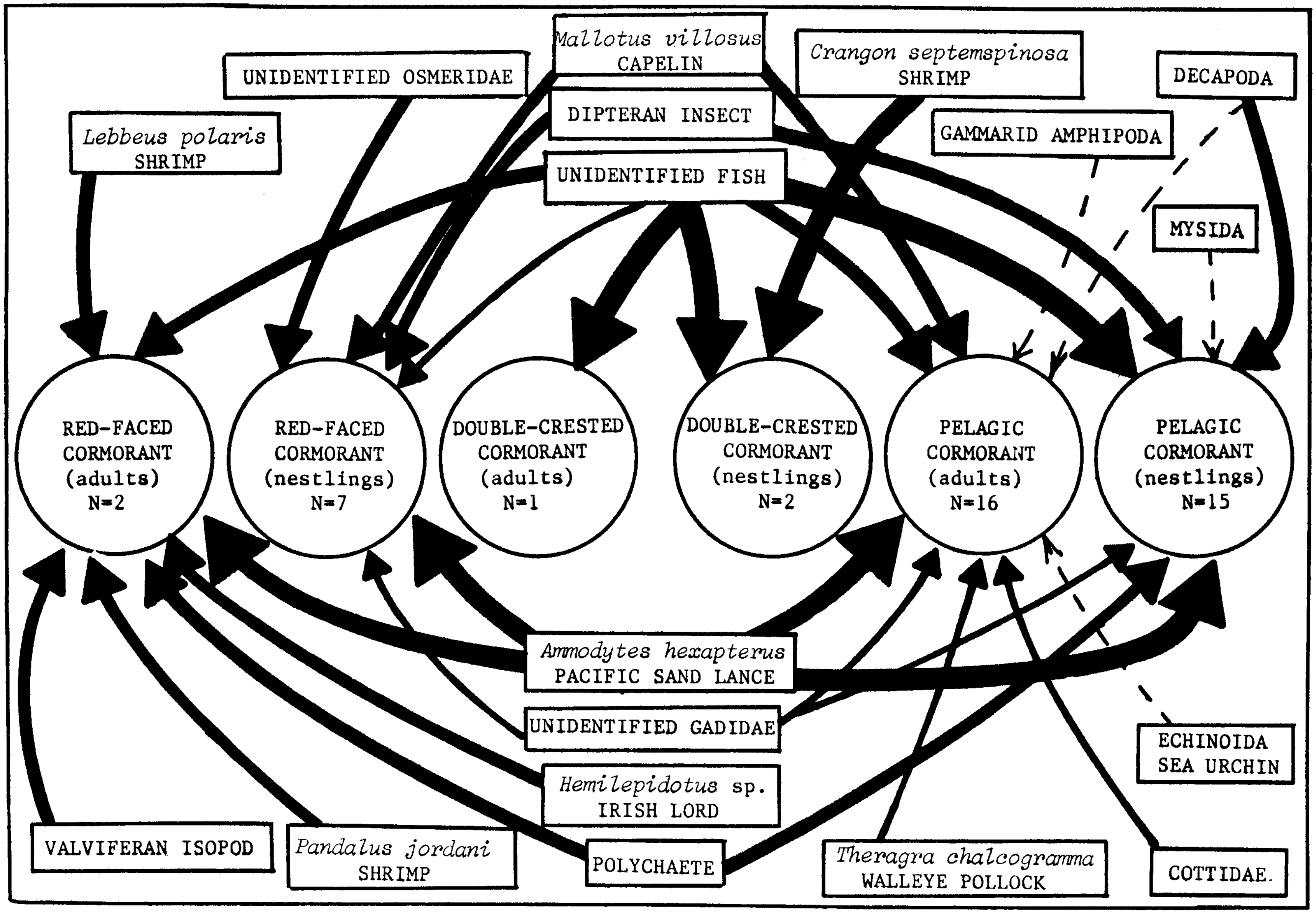


Figure 7. Food web relationships among adults and nestlings of double-crested, pelagic, and red-faced cormorants, based on data pooled from all years, seasons, and regions. See Fig. 4 caption.

on coastal marine waters. Juvenile birds spend at least their first year of life at sea. The species for which we have data are: Oldsquaw, Clangula hyemalis; harlequin duck, Histrionicus histrionicus; Steller's eider, Polysticta stelleri; white-winged scoter, Melanitta deglandi; surf scoter, M. perspicillata; and, black scoter, M. nigra.

Oldsquaw. Seventy birds were collected, mostly from Kodiak Island (N = 41) and Cook Inlet (N = 28). There were no empty stomachs. Oldsquaws were extreme generalists. They ate at least 94 species of prey, but at least 40 (43%) of these were of trace importance only (Appendix Table 10).

The most important major taxa of prey, in descending order of their IRI values were: Crustaceans, 1,830; bivalves, 1,015; gastropods, 782; fish, 301; echinoderms, 137; and, polychaetes, 123 (Figure 8, Appendix Table 10).

No single species of prey stood out in importance. The mysid crustacean Acanthomysis sp. was the most important species of prey overall, with an IRI of 250, and an overall prey volume of 9%. Other relatively important prey were (IRI and % volume): Pacific sand lance (202 and 12%), the bivalves Mytilus edulis (167 and 3%) and Glycymeris subobsoleta (171 and 1%), and the gastropods (snails) Lacuna vareigata (177 and 3%) and Alvinia compacta (113 and 1%) (Figure 8, Appendix Table 10).

Harlequin Duck. Five birds were collected in lower Cook Inlet in summer, and all had food in their stomachs. Two species of periwinkle snails were found in their stomachs: Littorina saxatilis and L. sitkana, which comprised 38% and 6% of the volume, respectively (Figure 9, Appendix Table 11). In addition, gastropods formed 46% of the volume of prey, and unidentified molluscs, 10%.

Steller's Eider. Three Steller's eiders were collected at Kodiak Island in winter. All had food in their stomachs, including at least 38 species of prey. The IRI values of the major groups of prey are: Holothurians (sea cucumbers) (4,956); crustaceans (3,810); polychaete worms (2,648); bivalves (2,008); and, gastropods (420) (Figure 10, Appendix Table 12).

The most important species of prey were (IRI and % volume): Cucumaria sp. (sea cucumber) (4,901 and 50%); gammarid amphipods (3,110 and 7%); Hiatella sp. (boring clam) (1,473 and 13%); and the polychaete families opheliidae (600 and 6%), phyllodocidae (561 and 3%), and nereidae (258 and 1%).

White-winged Scoter. Forty-six white-winged scoters were collected, and 44 (96%) had food in their stomachs. Together they had eaten at least 36 species of prey; eight (17%) of these were of trace occurence only.

Bivalves were overwhelmingly the most important major group of prey (IRI = 4,204; vol = 80%)(Figure 11, Appendix Table 13). Other major taxonomic groups of prey present in the stomachs were as follows (IRI and % volume): Gastropods, 246 and 12%; fishes (and fish eggs), 163 and 4%; crustaceans, 16 and 1%; polychaetes, 4 and 1%; echinoderms, 2 and 1%.

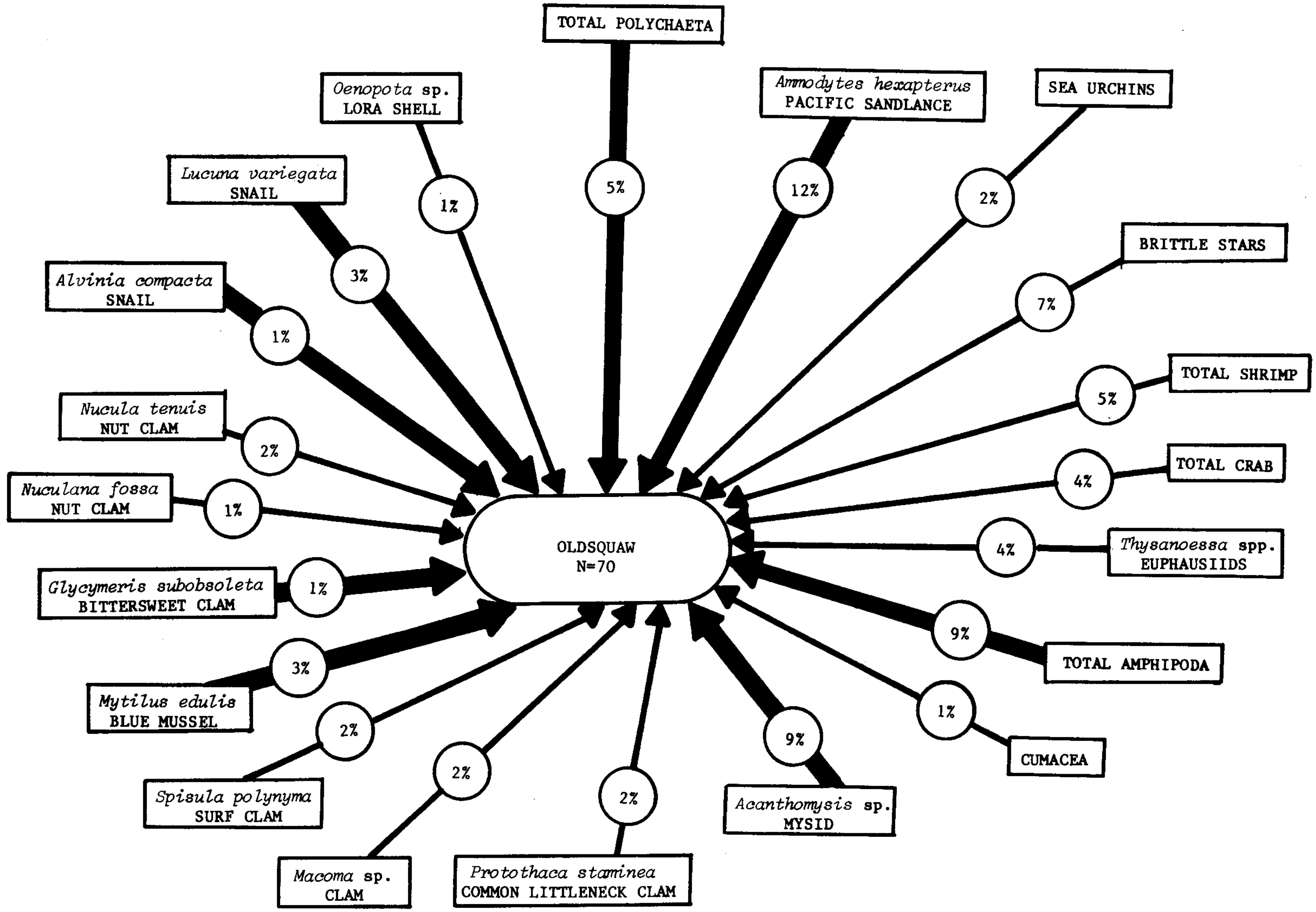


Figure 8. Food web for oldsquaws, showing main prey items as indicated by data pooled from all years, seasons and regions. See Fig. 2 caption.

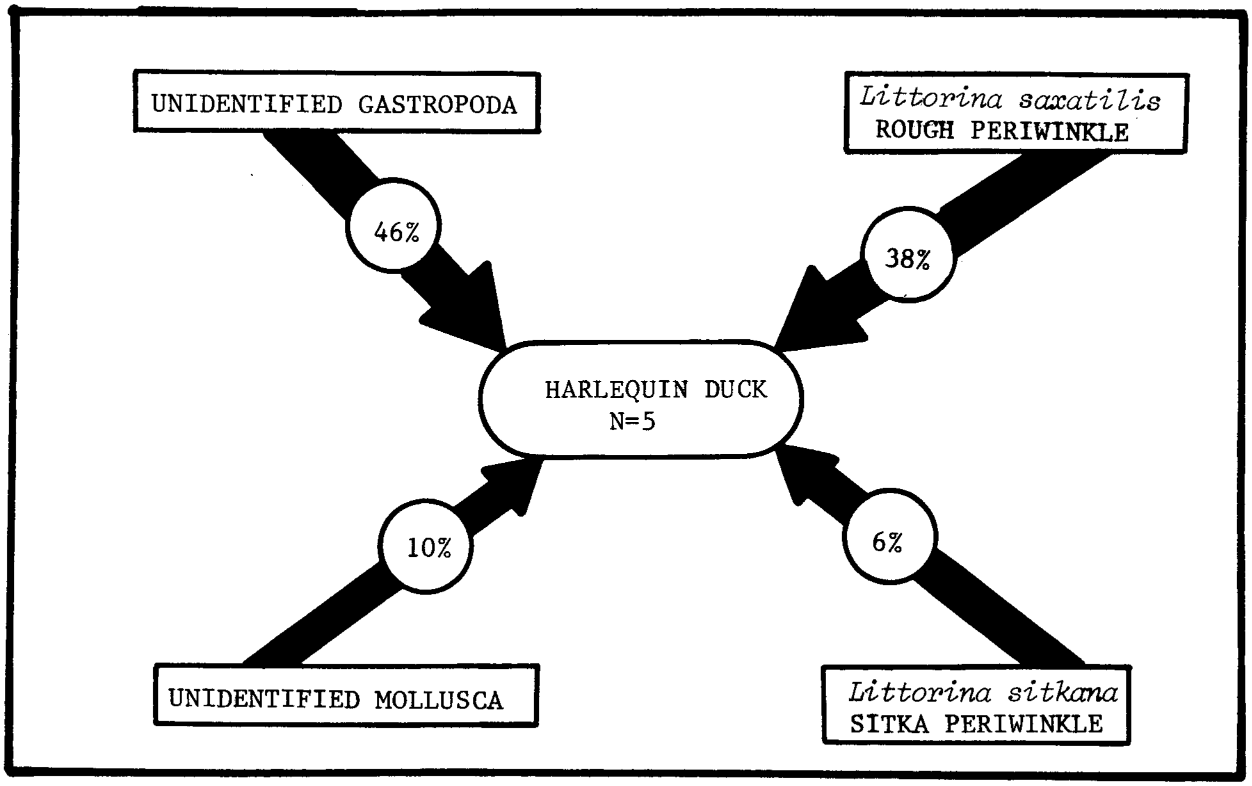


Figure 9. Food web for harlequin ducks, showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

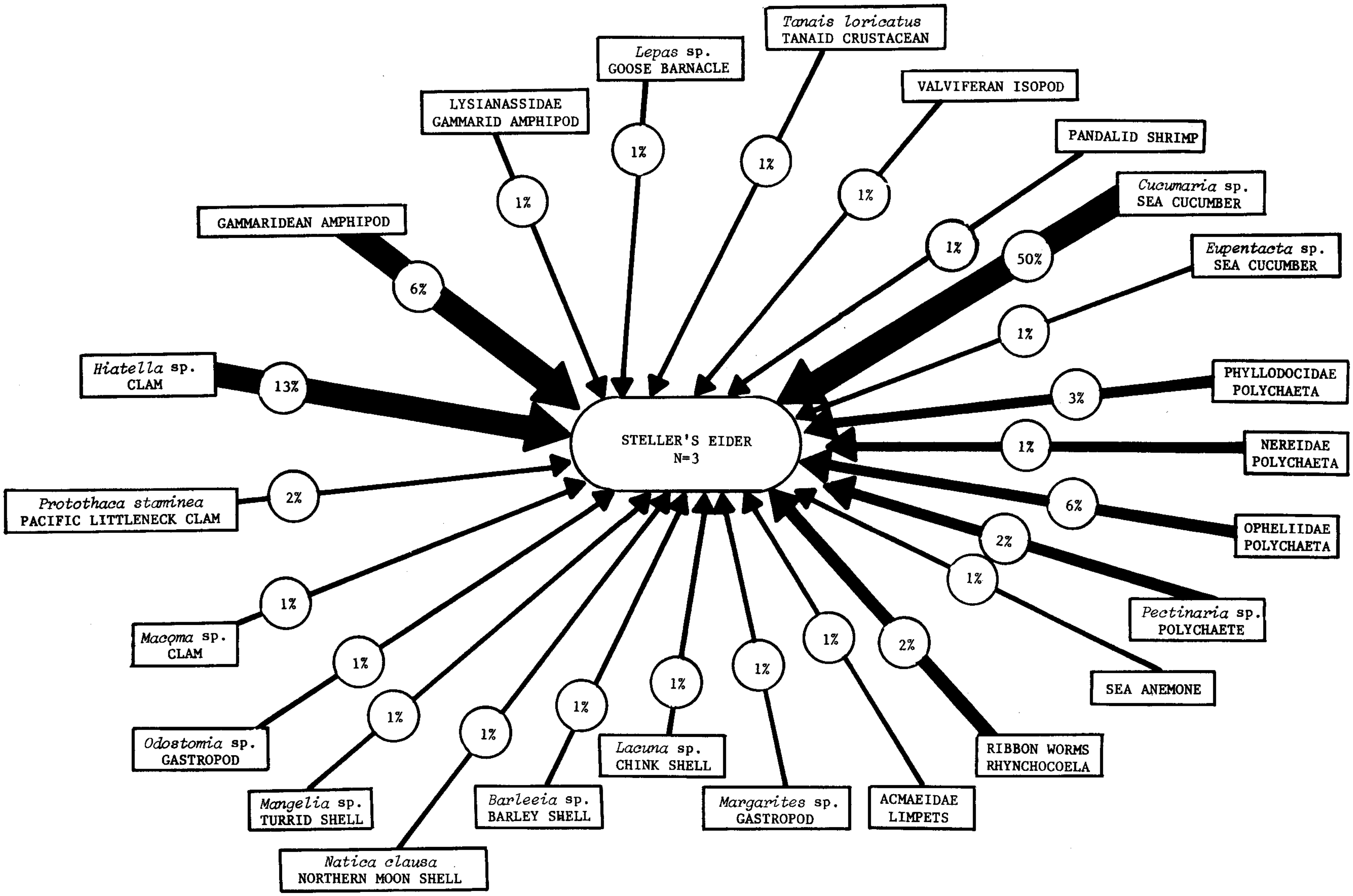


Figure 10. Food web for Steller's eiders, showing main prey items as indicated by data pooled from all years, seasons and regions. See Fig. 2 caption.

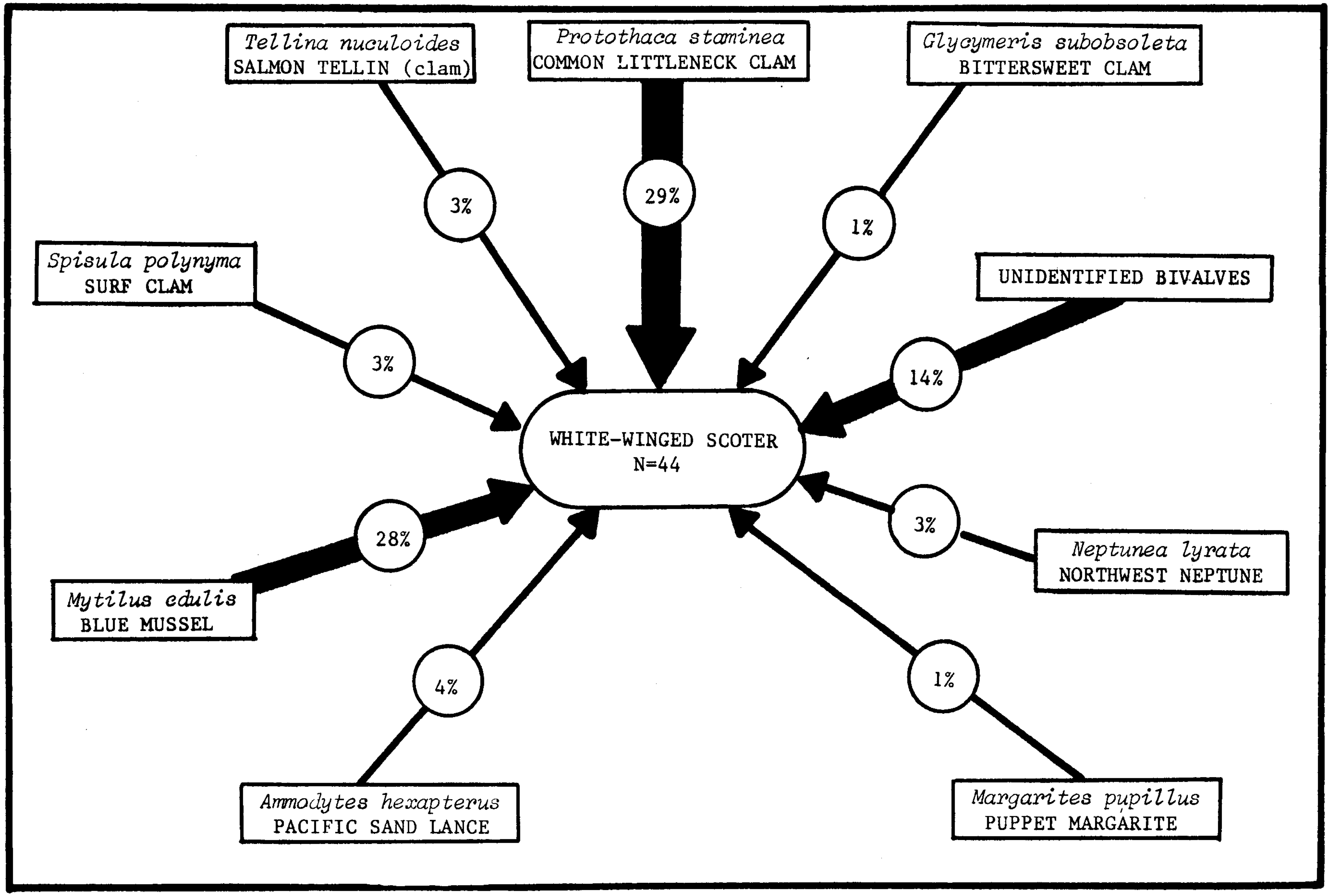


Figure 11. Food web for white-winged scoters, showing main prey items as indicated by data pooled from all years, seasons and regions. See Fig. 2 caption.

The most important prey species overall were (IRI and volume) the common littleneck clam (1,068 and 36%) and the blue mussel (611 and 28%) (Figure 11, Appendix Table 13). The most important gastropods were *Margarites pupillus* (10 and 1%) and *Neptunea lyrata* (13 and 3%). The scoters had eaten Pacific sand lance (11 and 4%), possibly when the fish were buried in the substrate. Unidentified fish eggs comprised 66% of the numbers of prey, but their low overall volume ($\leq$ 0.1%) and frequency of occurence (one bird, 2.3%) resulted in a moderately low IRI of 150.

Surf Scoter. Ten of 11 surf scoters had food in their stomachs. The birds had eaten a minimum of 12 species of prey, as well as plant material.

The IRI of bivalves in total was 7,310. They accounted for 75% of prey numbers, 71% of the volume, and they occured in five of the 10 birds with food in their stomachs (Figure 12, Appendix Table 14). *Mytilus edulis* (blue mussel) was the single most important prey species (IRI 816, vol 16%), and other bivalves of moderate importance were *Nucula tenuis* and *Musculus discors* (1% and 10% of volume, respectively). However, unidentified bivalves accounted for 14% of prey numbers, 40% of the volume, and had an IRI of 2,700 (Appendix Table 14).

The polychaete worm *Nephtys* sp. accounted for 14% of the volume, and had an IRI of 198. The rest of the prey species were all considerably less important. The surf scoter was the only species of waterfowl that had eaten plant material.

Black Scoter. Six of seven black scoters collected had food in their stomachs, and they had eaten at least four species of prey. *Mytilus edulis* was overwhelmingly the most important prey species; it had an IRI of 19,210, it occured in all six birds, comprised 98% of the prey volume, and 94% of the numbers (Figure 12, Appendix Table 15). Three other species of prey each occured in a single bird; they were the gastropod *Margarites pupillus*, the common littleneck clam (*Protothaca staminea*), and unidentified barnacles.

Phalaropodidae (Phalaropes)

Red and red-necked phalaropes (*Phalaropus fulicarius* and *Lobipes lobatus*) occur in pelagic waters off Alaska during spring and fall migrations (Gould *et al*. 1982). Phalaropes feed by seizing small prey while sitting on the water's surface. They often swim rapidly in small circles, which stirs their prey to the surface of the water. We collected seven red-necked phalaropes, but no red phalaropes.

Red-necked Phalarope. All seven birds collected had food in their stomachs, and together they had eaten at least seven kinds of prey. Nereid polychaetes were the most important overall; they comprised 66% of the numbers, 47% of the volume, occured in five (71%) of the seven birds, and had an IRI of 8,068 (Figure 13, Appendix Table 16). The next most important prey and their IRI values were unidentified fish (1,025), unidentified insects (680), and unidentified decapods (443).

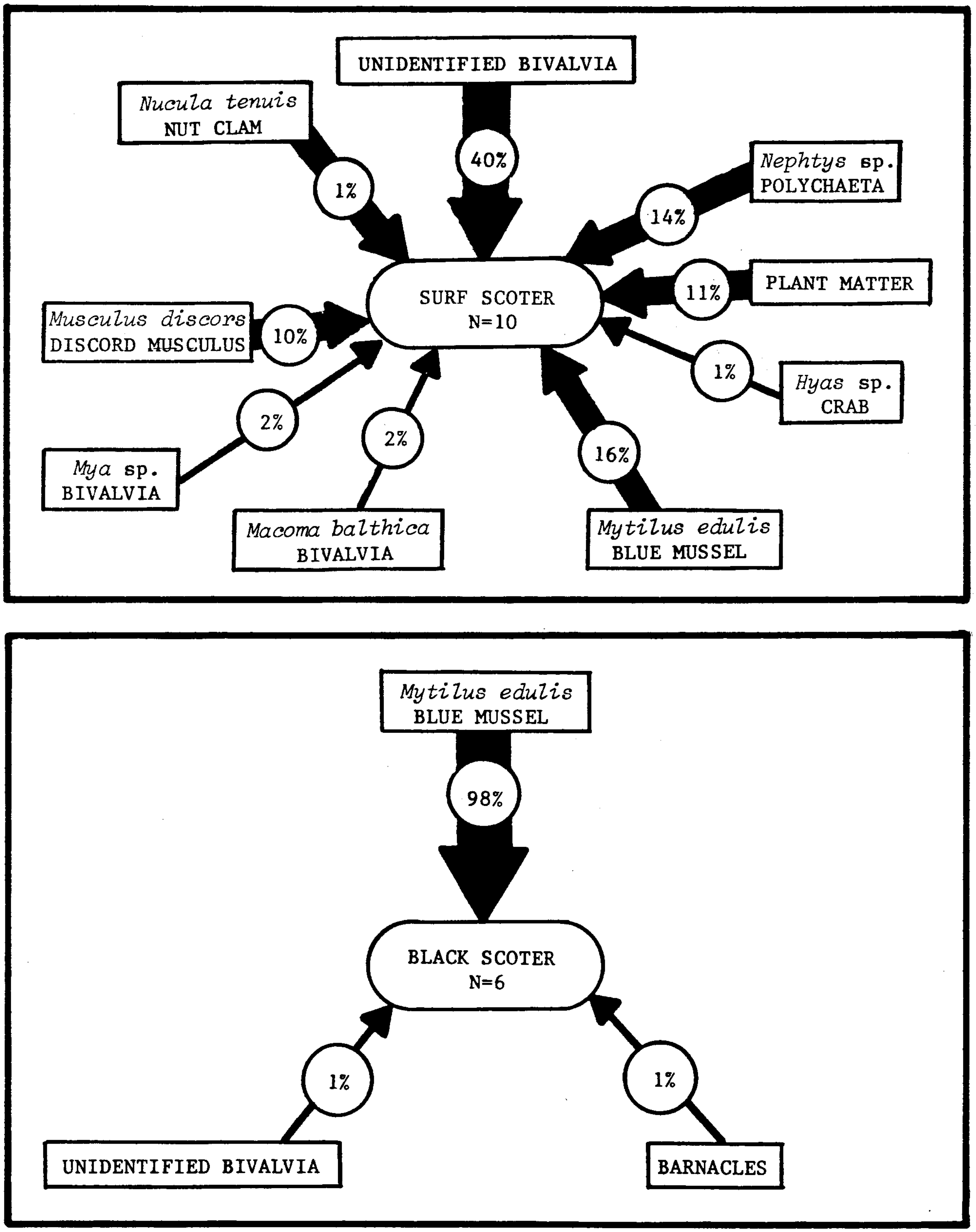


Figure 12. Food web for surf scoters (top) and black scoters (bottom), showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

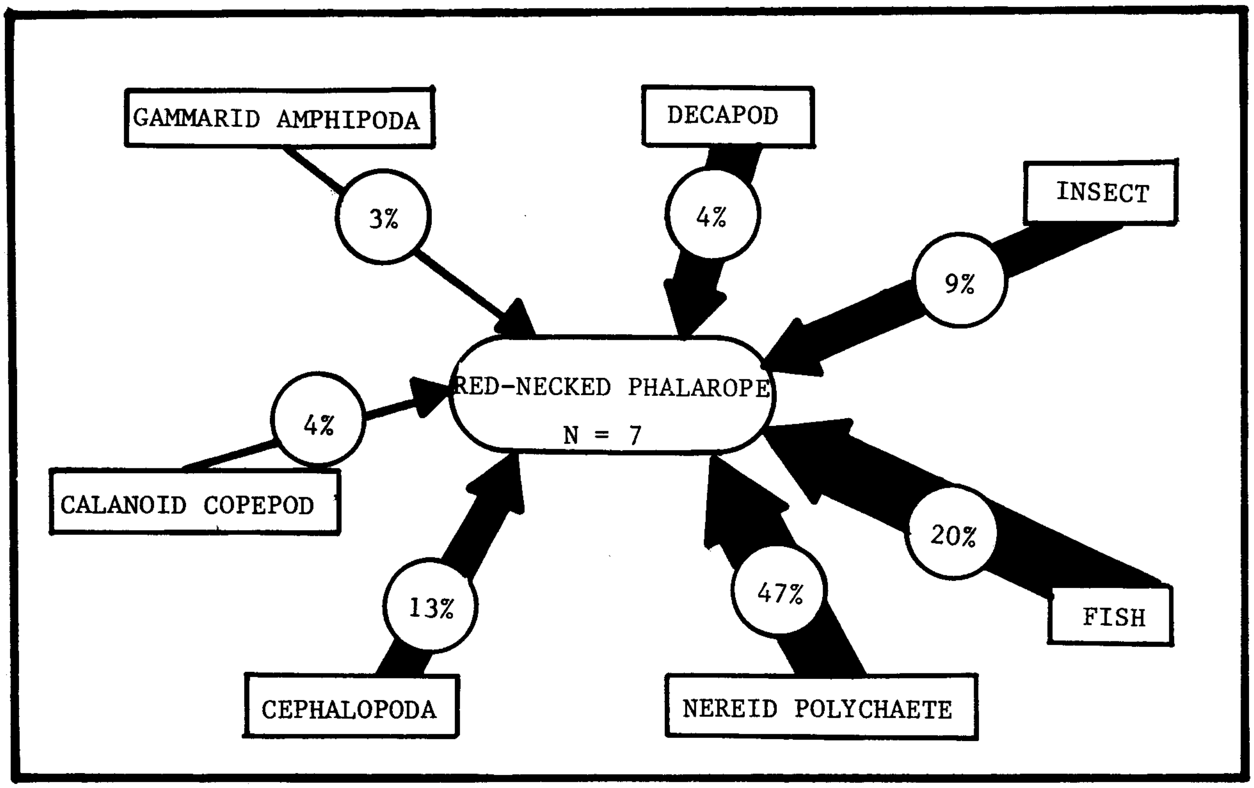


Figure 13. Food web for red-necked phalaropes, showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

Stercorariidae (Jaegers)

Jaegers are strong flying pelagic birds that generally resemble gulls in appearance. They are best known for their feeding behavior of aerial piracy (Ashmole 1971), where they chase other seabirds and force them to drop or disgorge their prey. The overall importance of this mode of feeding in relation to other feeding methods is quite unclear, however, and it may be overated.

Four species of jaegers occur in Alaskan waters from spring through early fall (Gould et al. 1982). We have a very limited amount of data for two, pomerine and parasitic jaegers (Stercorarius pomerinus and S. parasiticus): Capelin and Pacific sand lance were found in the stomachs of two pomerine jaegers, and capelin were in the stomachs of two parasitic jaegers (Appendix Table 17).

Laridae (Subfamily Larinae, Gulls)

Gulls occur in a variety of terrestrial and marine habitats in Alaska, including oceanic and coastal marine waters, and the intertidal zone (Gould et al. 1982). Most species for which we have dietary data occur in Alaskan waters year round, although some display considerable seasonal shifts in distribution. Gulls are well known as scavengers, but the importance of this mode of feeding may be over rated (Pierotti, in press). Gulls also feed by surface seizing, dipping, piracy, and intertidal foraging (Ashmole 1971).

We have data for eight of the 17 species of gulls which have occurred in Alaska (Kessel and Gibson 1978): Glaucous gull, Larus hyperboreus; glaucous-winged gull, L. glaucescens; herring gull, L. argentatus; mew gull, L. canus; Bonaparte's gull, L. philadelphia; black-legged kittiwake, Rissa tridactyla; red-legged kittiwake, R. brevirostris; and, Sabine's gull, Xema sabini. Sample sizes for glaucous-winged gulls and black-legged kittiwakes are in the 100's, but range only from two to 14 for the other six species.

Glaucous Gull. Six of seven glaucous gulls collected in the Bering Sea had food in their stomachs, and together they had eaten a minimum of five species of prey. Decapod crustaceans comprised 78% of the total prey volume and had an IRI of 1,324 (Figure 14, Appendix Table 18). Unidentified fish comprised another 14% of the volume and had an IRI of 240. Other prey, whose IRI values ranged from 207 to 415, included gammarid amphipods, dipteran flies, and unidentified salmonid fishes and small mammmals.

Glaucous-winged Gull. Sixty-eight adult birds were collected for feeding studies, and 66 (97%) of these had food in their stomachs. A minimum of 23 species of prey was found. The general category of prey most prevalent was fish. Total fish had an IRI of 5,667 and made up 95% of prey numbers and 61% of the volume (Appendix Table 19). Unidentified fish had an IRI of 4,484 and they comprised 29% of the volume. Identifiable fish included capelin (IRI 165, vol 12%) and Pacific sand lance (IRI = 80, vol = 10%). There were no walleye pollock in the stomachs.

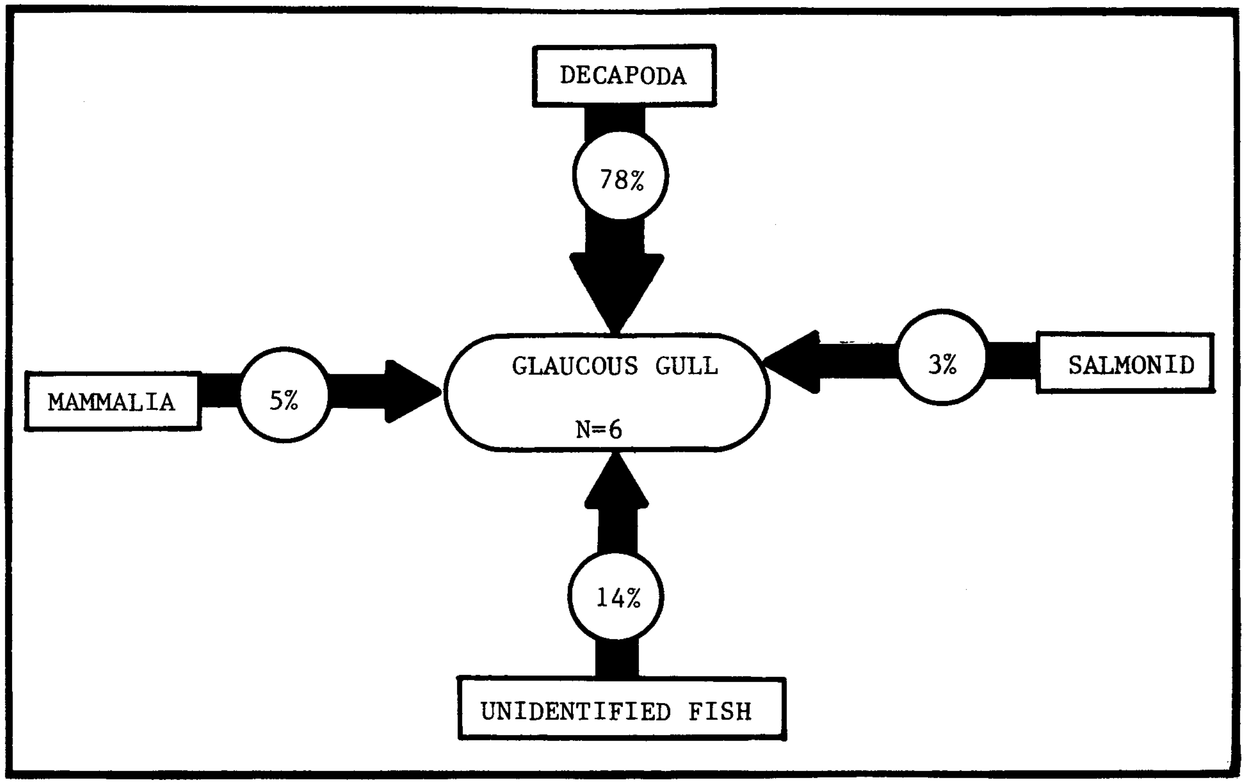


Figure 14. Food web for glaucous gulls, showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

One bird had eaten an ancient murrelet (Synthliboramphus antiquus) chick that accounted for 19% of total prey volume. Other kinds of prey were relatively insignificant to adult gulls; these included pelagic polychaetes, gastropods, chitons, bivalves, pelagic and intertidal crustaceans, flies, and sea urchins (Figure 15, Appendix Table 19).

Food samples from sub-adult glaucous-winged gulls totaled 157, and included 115 regurgitations from nestlings, and stomach contents from 42 flying birds. Data from these samples are pooled for this analysis. Twenty-four (57%) of the 42 flying young had food in their stomachs (Appendix Table 20).

Fish predominated in the diet of sub-adults as well as adults; their IRI's and % volumes were: Total fish (4,841, 87%); unidentified fish (2,260, 30%); sand lance (1,466, 35%); and, capelin (1,096, 19%). Fish of minor importance to sub-adult birds included walleye pollock, Pacific sandfish and unidentified gunnels (Figure 15, Appendix Table 20). Blue mussels had an IRI of 108 and comprised 5% of the volume. Other prey of minor importance included polychaetes, gastropods, chitons, bivalves, pelagic and intertidal crustaceans, flies, sea stars and sea urchins.

Herring Gull. Five adult herring gulls all had food in their stomachs, which included at least four species of prey. Four of the birds were collected in the northeast Gulf of Alaska in fall, and one was collected in lower Cook Inlet in summer. Unidentified fish and gooseneck barnacles (lepadidae) were the most important prey, with the latter accounting for 62% of total prey volume (Figure 16, Appendix Table 21). Other prey included unidentified bivalves and decapods, and the shrimp Crangon septemspinosa.

Mew Gull. Thirteen adults were collected; 11 (85%) of these had food in their stomachs, which included at least 10 prey species. The most important general category of prey was crustaceans, which had an IRI value of 6,152 and comprised 80% of the volume (Figure 16, Appendix Table 22). Total fish was of secondary importance (IRI = 549; vol = 17%). The most important species of prey was Crangon septemspinosa (IRI = 442, vol = 22%). Pacific sand lance comprised 10% of the volume. Other prey included unidentified polychaetes, gastropods, bivalves, dipteran and tipulid flies, and gadid fishes.

Food Web Relationships Among the Larger Larus Gulls. Table 3 & Figure 17 compare the relative importance of the different kinds of prey among the four larger species of Larus gulls. Fish was by far the most important group of prey; the birds ate at least eight species in seven families. Each gull species had at least one species of fish with an importance level of two or more in its diet. Capelin were quite important to both adult and sub-adult glaucous-winged gulls, but they were not eaten by the other gulls. Sand lance were important to glaucous-wings, particularly sub-adults, and to mew gulls. Other identifiable fish were generally of little importance to only one or two gull species (Table 3). Unidentified fish occured in each of the four species at importance level two or three.

Other kinds of prey were generally less important to the gulls than

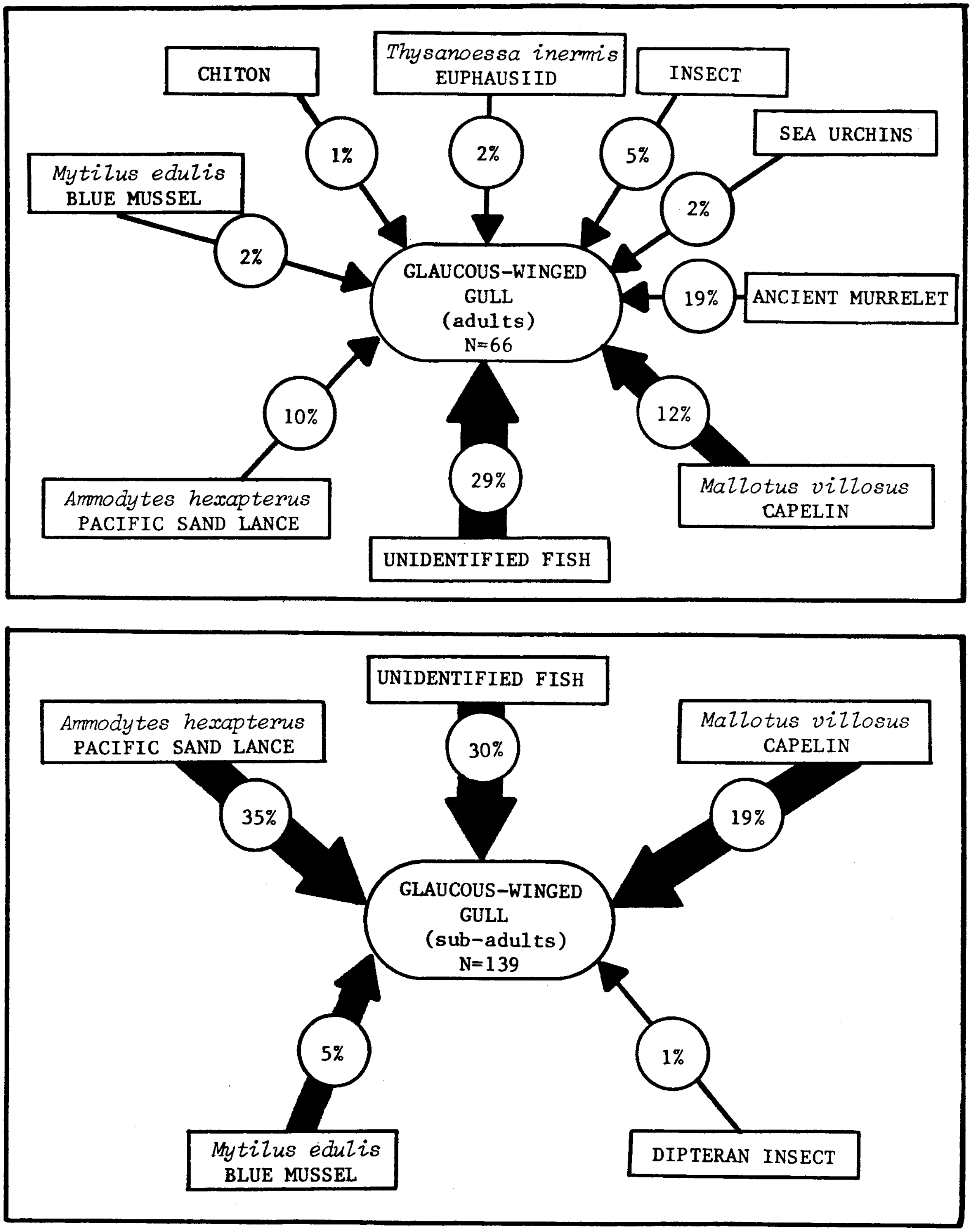


Figure 15. Food webs for adult (top) and sub-adult (bottom) glaucous-winged gulls, showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

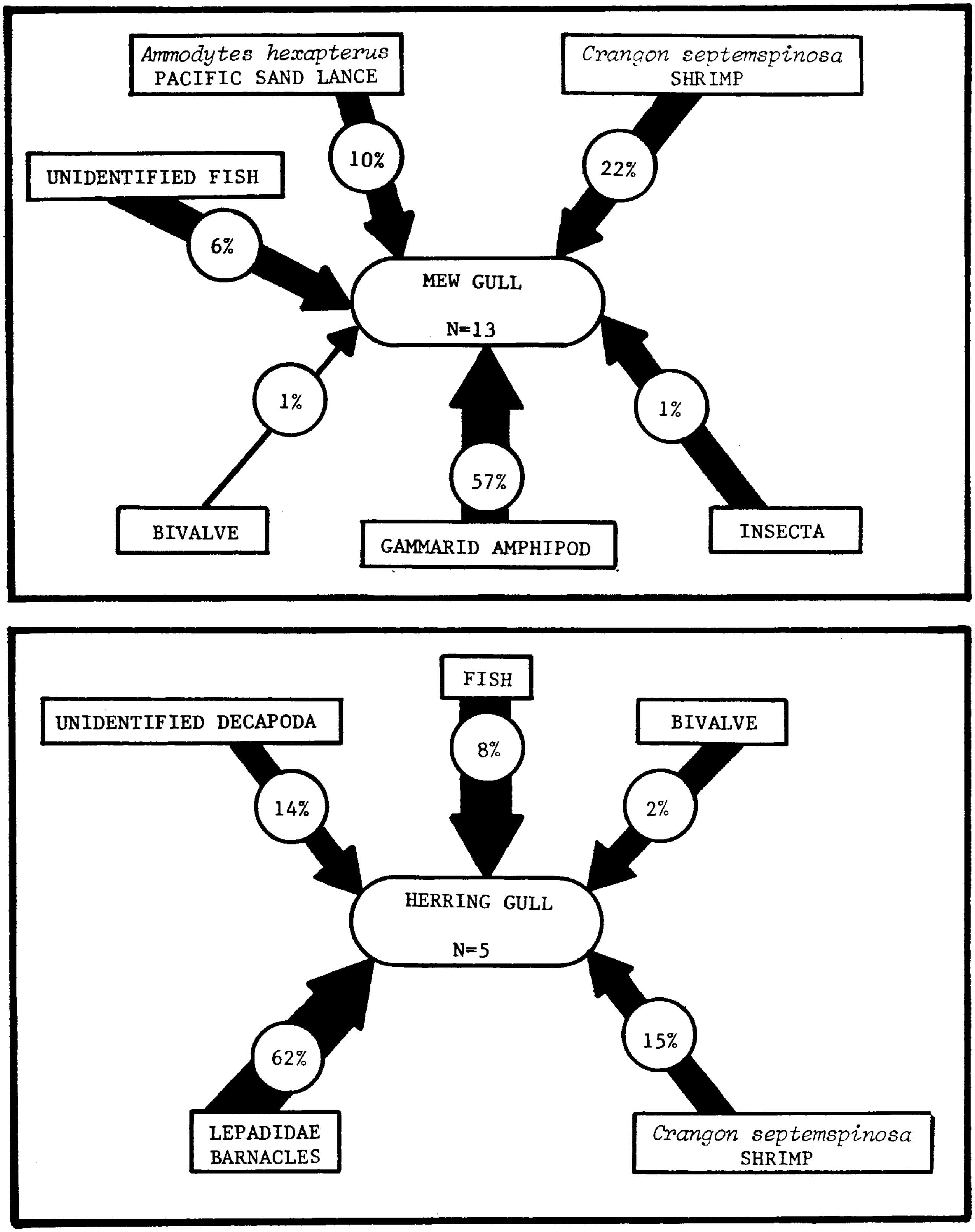


Figure 16. Food web for mew (top) and herring gulls (bottom), showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

Table 3. Comparative importance of prey to the larger *Larus* gulls, based on data pooled from food samples from birds in Alaskan waters. Importance levels of prey based on their IRI values: 0-9 = trace(tr); 10-99 = 1; 100-999 = 2; 1,000+ = 3.

PREY NAME	Importance of Prey to Gull Species				
	Glaucous	Glaucous-winged		Herring	Mew
		adult	sub-ad.		
	N = 7	N = 68	N = 157	N = 5	N = 13
POLYCHAETA					
Opheliidae	-	-	tr	-	-
Nereidae	-	tr	-	-	-
Unidentified	-	-	-	-	tr
GASTROPODS					
Acmaeidae (Limpet)	-	-	tr	-	-
Colisella pelta Limpet	-	tr	-	-	-
Littorina sitkana Sitka Periwinkle	-	tr	-	-	-
Buccinum baeri Baer's Buccinum	-	tr	-	-	-
Unidentified	-	-	tr	-	1
CHITONS					
Katharina tunicata Black Katy Chiton	-	tr	tr	-	-
Unidentified	-	1	tr	-	-
BIVALVES					
Mytilus edulis Blue Mussel	-	1	2	-	-
Siliqua sp. Razor Clam	-	-	tr	-	-
Hiatella arctica Arctic Saxicave	-	-	tr	-	-
Clinocardium sp. Cockle	-	tr	-	-	-
Unidentified	-	tr	tr	2	1
CRUSTACEANS					
Barnacles					
Lepadidae	-	-	-	3	-
Balanidae	-	tr	-	-	-
Amphipods					
Unident. Gammaridea	-	-	tr	-	3
Unident. Gammaridae	2	-	-	-	-
Valviferan Isopod	-	tr	-	-	-
Euphausiids					
Thysanoessa inermis	-	1	-	-	-
T. raschii	-	tr	-	-	-

Table 3. Comparative Importance of prey to *Larus* gulls, page 2 of 2

PREY NAME	Glaucous	Glaucous-winged adults	Glaucous-winged sub-ad.	Herring	Mew
Shrimps					
Crangon septemspinosa	-	tr	-	2	2
Pandalus borealis Pink Shrimp	-	tr	-	-	-
Crabs					
Telmessus cheiragonus Helmet Crab	-	tr	tr	-	-
INSECTS					
Dipteran Flies	2	tr	1	-	tr
Tipulid Flies	-	-	-	-	tr
Unidentified	-	1	-	-	2
ECHINODERMS					
Leptasterias hexactis Brooding Sea Star	-	-	tr	-	-
Amphipolis pugetana Brittle Star	-	-	tr	-	-
Strongelocentrotus droebachiensis Green Sea Urchin	-	1	tr	-	-
FISHES					
Salmonidae	2	-	-	-	-
Mallotus villosus Capelin	-	2	3	-	-
Hypomesus pretiosus Surf Smelt	-	tr	-	-	-
Theragra chalcogramma Walleye Pollock	-	-	tr	-	-
Gadidae, Unidentified	-	-	tr	-	tr
Hexagrammidae	-	tr	-	-	-
Trichodon trichodon Pacific Sandfish	-	-	tr	-	-
Pholidae (Gunnel)	-	-	tr	-	-
Ammodytes hexapterus Pacific Sand Lance	-	1	3	-	2
BIRDS					
Synthliboramphus antiquus Ancient Murrelet	-	1	-	-	-
Cepphus columba Pigeon Guillemot	-	-	tr	-	-
MAMMAL, Unidentified	2	-	-	-	-

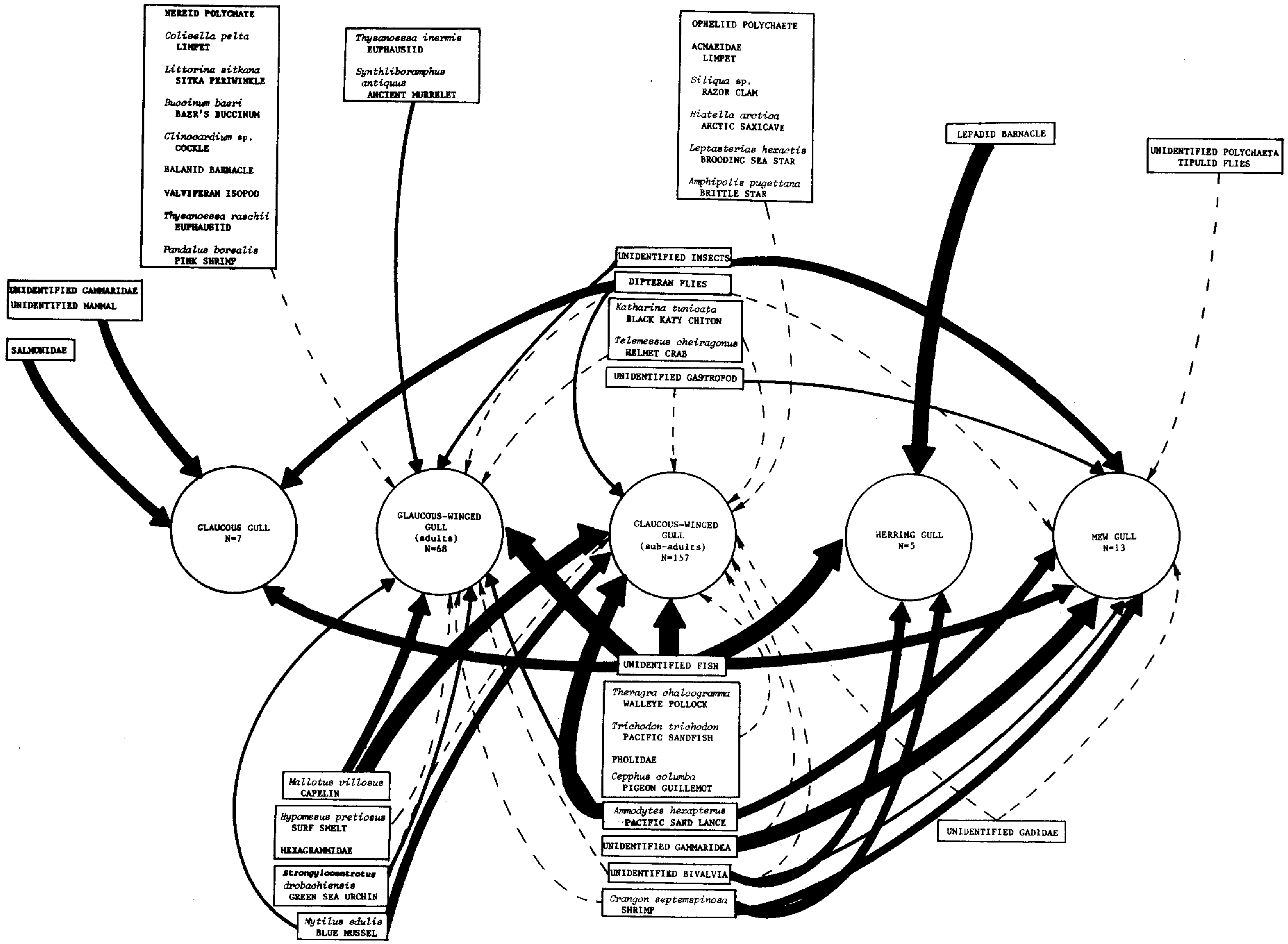


Figure 17. Food web relationships among the larger Larus gulls, based on data pooled from all years, seasons and regions. See Fig. 4 caption.

fish, and they were usually in the stomachs of only one or two gull species. Exceptions were gammarid amphipods and dipteran flies, which were eaten by all species except herring gulls, and the shrimp Crangon septemspinosa, which was eaten by all species except glaucous gulls.

Bonaparte's Gull. Four Bonaparte's gulls had food in their stomachs; all were collected at Nelson Lagoon, located near Port Moller on the north side of the Alaska Peninsula. Only two kinds of prey were in their stomachs: the shrimp Crangon septemspinosa and unidentified gammarid amphipods (Appendix Table 21). In view of the abundance of the gammarid amphipod Anisogammarus pugettensis at Nelson Lagoon (Petersen 1980), those in the gulls likely included this species.

Black-legged Kittiwake. Birds collected for feeding studies included 328 adults; 273 (83%) of these had food in their stomachs, which included a minimum of 23 species of prey. Fish was the most important general category of prey, accounting for 88% of the volume, 32% of the numbers of all prey, and had an IRI of 4,274 (Appendix Table 23). Crustaceans were of moderate importance overall (IRI = 406), and other groups of prey were of only minor or trace importance.

Capelin was decidedly the most important species of prey; it comprised 15% of the numbers, 51% of the volume, and occured in 36% of all adult birds with food in their stomachs. Together, these values resulted in an IRI of 2,354 (Appendix Table 23). Other prey species were relatively less important, but the most important of these were Pacific sand lance (IRI 329, vol 17%), and the the euphausiid Thysanoessa inermis (IRI 313, vol 5%) (Figure 18, Appendix Table 23). Walleye pollock also made up 5% of the volume, but low numbers (1%) and frequency of occurence (5%) resulted in a low IRI value of 32.

Minor and trace prey included pelagic polychaetes, pteropods, chitons, blue mussels, unidentified cephalopods, barnacles, copepods, gammarid and hyperiid amphipods, shrimp, crabs, Pacific cod and Pacific sand fish (Figure 18, Appendix Table 23).

Food samples from sub-adult birds totaled 215, and included 129 regurgitations from nestlings and stomach contents from 86 flying young. Fifty-five (64%) of the latter had empty stomachs (Appendix Table 24). Data from all of these samples are pooled here. The same general dietary trends observed for adult birds were repeated, with the notable exception that Pacific sand lance and capelin were both major prey of the sub-adults (Figure 18). Sand lance had an IRI of 4,127, accounted for 44% of numbers, 39% of volume and occured in 50% of all sub-adult food samples (Appendix Table 24). Respective data for capelin are IRI 2,697, numbers 32%, volume 36% and frequency of occurence 40%. All other prey were of only minor or trace importance.

Red-legged Kittiwake. Three birds were collected, two from the southeastern Bering Sea, and the third a few miles south of Adak Island (Aleutians) in the North Pacific Ocean. All had food in their stomachs. Unidentified fish comprised 74% of the combined volume of stomach contents, and Pacific ambereye shrimp and unidentified decapods (probably shrimp) each accounted for 12.5% of the volume. Unidentified cephalopod

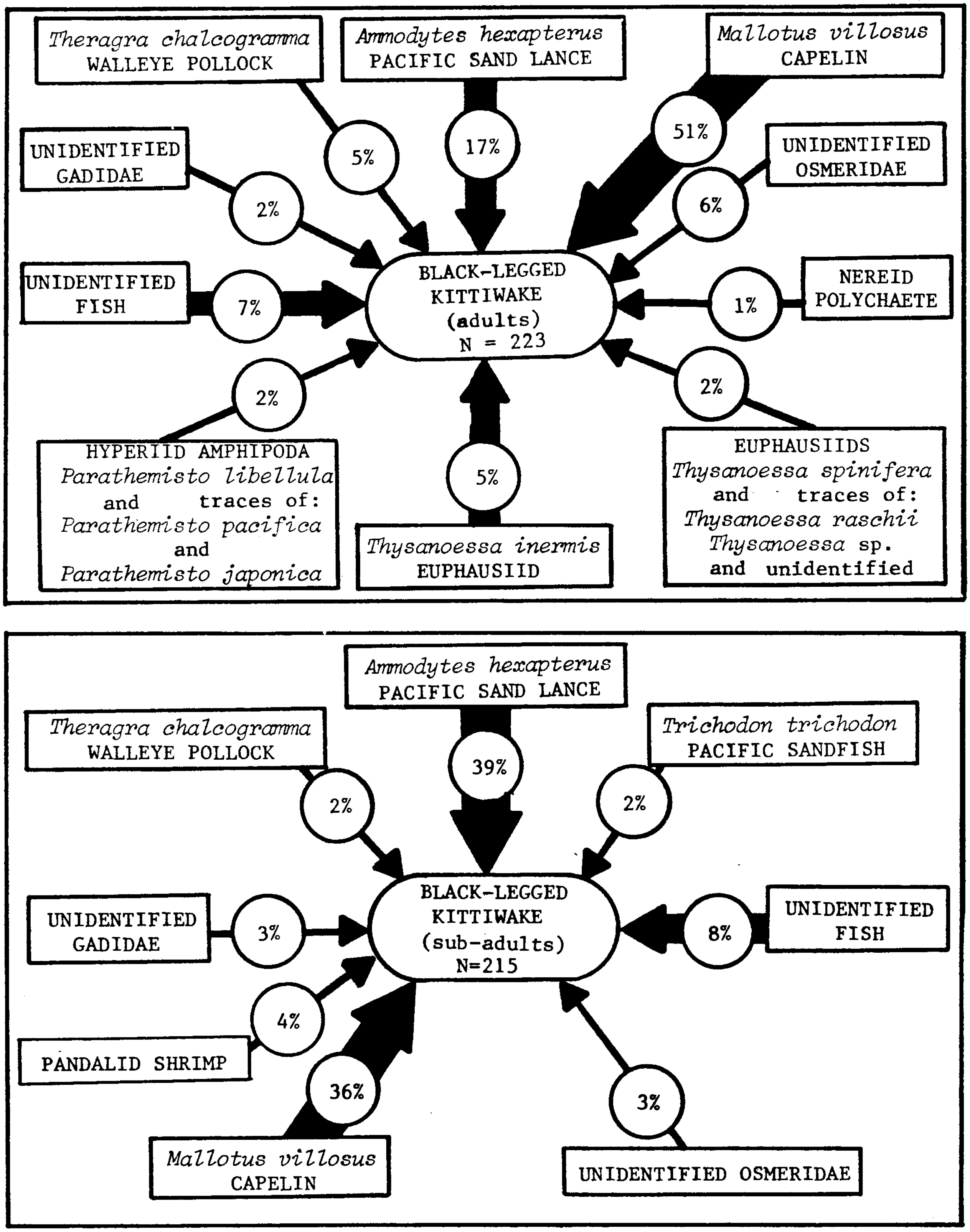


Figure 18. Food web for adult (top) and sub-adult (bottom) black-legged kittiwakes, showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

beaks and the euphausiid Thysanoessa inermis were present in small amounts (Figure 19, Appendix Table 25). Walleye pollock and lantern fishes (myctophids), common in the diet of birds from near the Pribilof Islands (Hunt et al. 1981), were not present in these birds.

Food Web Relationships Among Kittiwakes. The importance of different prey species to adult and sub-adult black-legged kittiwakes, and to red-legged kittiwakes are compared in Table 4 and Figure 20. The small sample size for red-legs (N = 3) makes such a comparison quite tentative, however. Alsq, two of the red-legs were from the southeastern Bering Sea, while most of the black-legs were from the Gulf of Alaska.

The euphausiid Thysanoessa inermis was the only prey eaten by both age groups of black-legged kittiwakes, and by red-legged kittiwakes. In general, fish was the most important kind of prey to kittiwakes. Capelin, walleye pollock and sand lance were important to adult and sub-adult black-legged kittiwakes, but were not present in the stomachs of the three red-legs. However, pollock was very important in the diet of nestling red-legged kittiwakes in the Pribilof Islands (Hunt et al. 1981).

Sabine's Gull. One adult bird collected in the southeastern Bering Sea had pieces of avian egg shell in its stomach.

Laridae (Terns, Subfamily Sterninae)

Terns exist in a variety of marine habitats in Alaska in spring and summer, but they occur mostly in nearshore and protected waters close to their breeding colonies (Gould et al. 1981). Terns feed mostly by plunging beneath the water's surface after they have spotted prey while flying or hovering above the water (Ashmole 1971). We have data on the feeding habits of adult and subadult arctic terns (Sterna paradisea) and Aleutian terns (S. aleutica). Most food samples were collected in the vicinity of Kodiak Island.

Arctic Tern. Of 36 adult birds collected, 34 (94%) had food in their stomachs, which included a minimum of eight prey species. Crustaceans, primarily euphausiids, were the most important prey group; they comprised 98% of the numbers and 82% of the volume of all prey, and had an IRI of 9,511 (Appendix Table 26).

The euphausiid Thysanoessa inermis was decidedly the most important prey species to adult arctic terns. It comprised 93% of prey numbers, 82% of the volume, and occured in 53% of the stomachs, which resulted in an IRI of 8,930 (Figure 21, Appendix Table 26). T. spinifera was of moderate importance (IRI 211). Fish in the terns' diet included capelin (IRI 130) and Pacific sand lance (IRI 126). Prey of minor or trace importance included T. raschii, the hyperiid amphipod Parathemisto libellula (from birds from the Bering sea), unidentified decapod crustaceans and nereid polychaetes.

Thirty-two food samples from sub-adult birds included 20 regurgitations from nestlings at Kodiak Island and 12 stomachs samples from flying birds; 11 (91.7%) of the latter had food in their stomachs. In marked

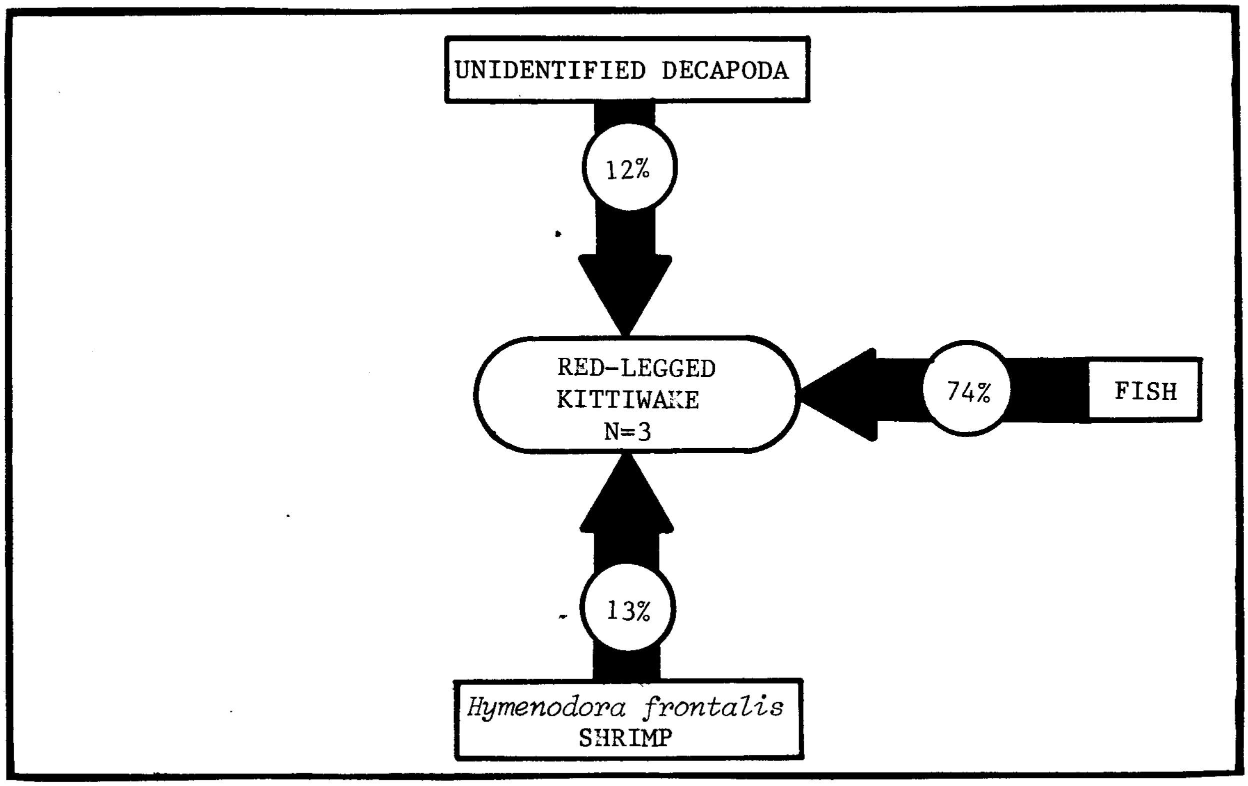


Figure 19. Food web for red-legged kittiwakes, showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

Table 4. Comparative importance of prey to kittiwakes, based on data pooled from food samples from birds in Alaskan waters. Importance levels of prey based on their IRI values: 0-9 = trace(tr); 10-99 = 1; 100-999 = 2; 1,000+ = 3.

PREY NAME	Importance of Prey to Bird Species		
	Black-legged Kittiwake (adults) N = 273	Black-legged Kittiwake (sub-adults) N = 184	Red-legged Kittiwake (adults) N = 3
POLYCHAETES, Nereidae	1	-	-
PTEROPOD, *Limacina helicina*	tr	-	-
CHITON, *Katharina tunicata*	tr	tr	-
MUSSEL, *Mytilus edulis*	tr	-	-
CEPHALOPOD, Unidentified	tr	-	2
CRUSTACEANS			
Calanoid Copepod	tr	-	-
Ligia pallasi	-	tr	-
Paracallisoma alberti Gammaridean Amphipod	1	-	-
Hyperiid Amphipods			
Parathemisto libellula	1	-	-
P. pacifica	tr	-	-
P. japonica	tr	-	-
Decapods			
Hymenodora frontalis Pacific Ambereye Shrimp	-	tr	3
Pandalus borealis Pink Shrimp	-	tr	-
Pandalopsis dispar Sidestripe Shrimp	tr	tr	-
Cancer sp. (Crab)	tr	-	-
Unidentified Cancrid Crab	-	tr	-
Euphausiids			
Thysanoessa inermis	2	tr	2
T. raschii	tr	-	-
T. spinifera	1	-	-
Barnacle	tr	-	-
INSECT, Dipteran Fly	-	tr	-

Table 4. Comparative importance of prey to kittiwakes, page 2 of 2

PREY NAME	Importance of Prey to Bird Species: Black-legged Kittiwake (adults) N = 273	Black-legged Kittiwake (sub-adults) N = 184	Red-legged Kittiwake (adults) N = 3
FISH			
Clupea harengus Pacific Herring	tr	-	-
Onchorhynchus gorbuscha Pink Salmon	-	tr	-
O. nerka Red Salmon	-	tr	-
Mallotus villosus Capelin	3	3	-
Gadus macrocephalus Pacific Cod	tr	tr	-
Theragra chalcogramma Walleye Pollock	1	1	-
Microgadus proximus Pacific Tomcod	-	tr	-
Trichodon trichodon Pacific Sandfish	tr	1	-
Ammodytes hexapterus Pacific Sand Lance	2	3	-
Unidentified	2	2	3

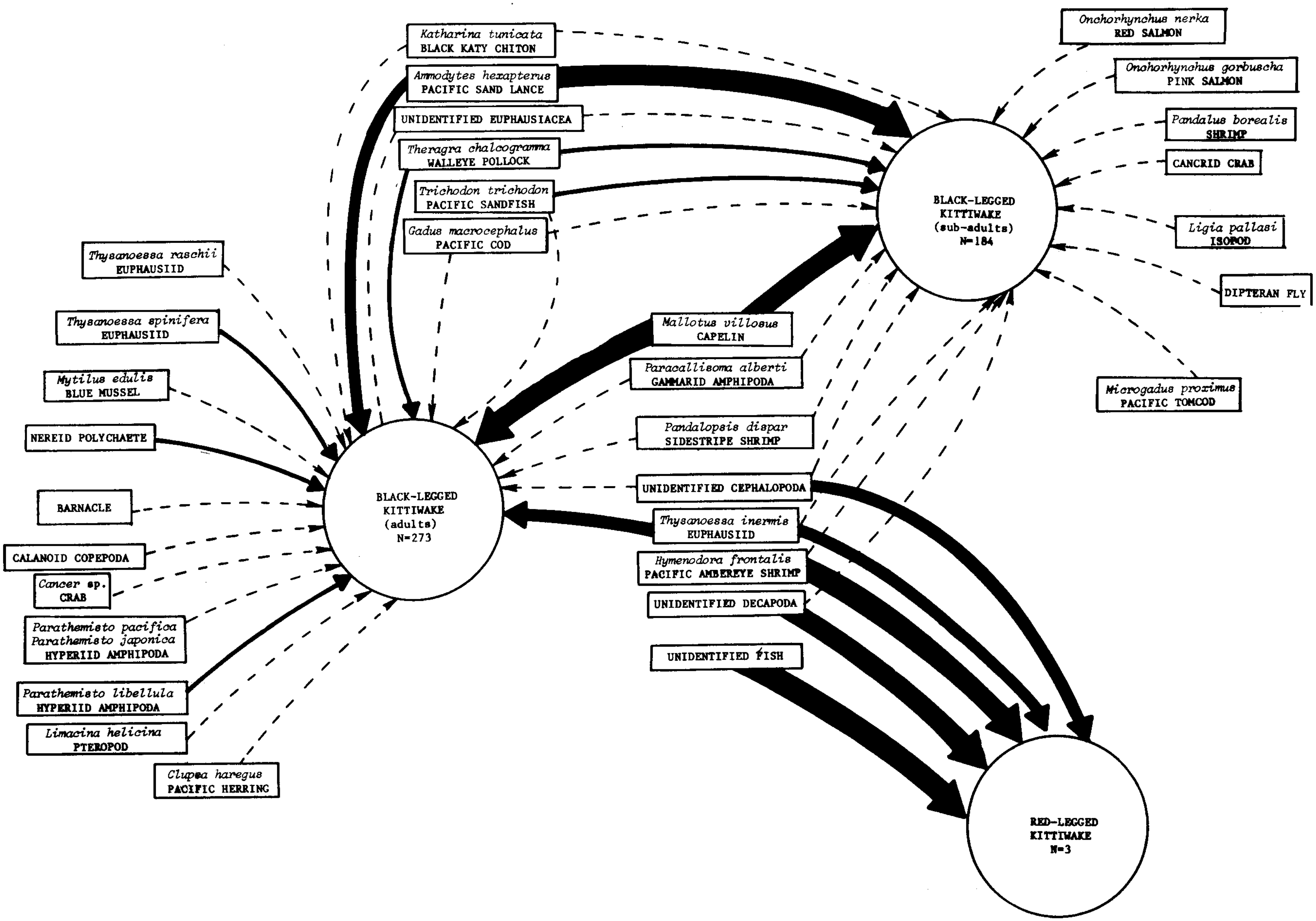
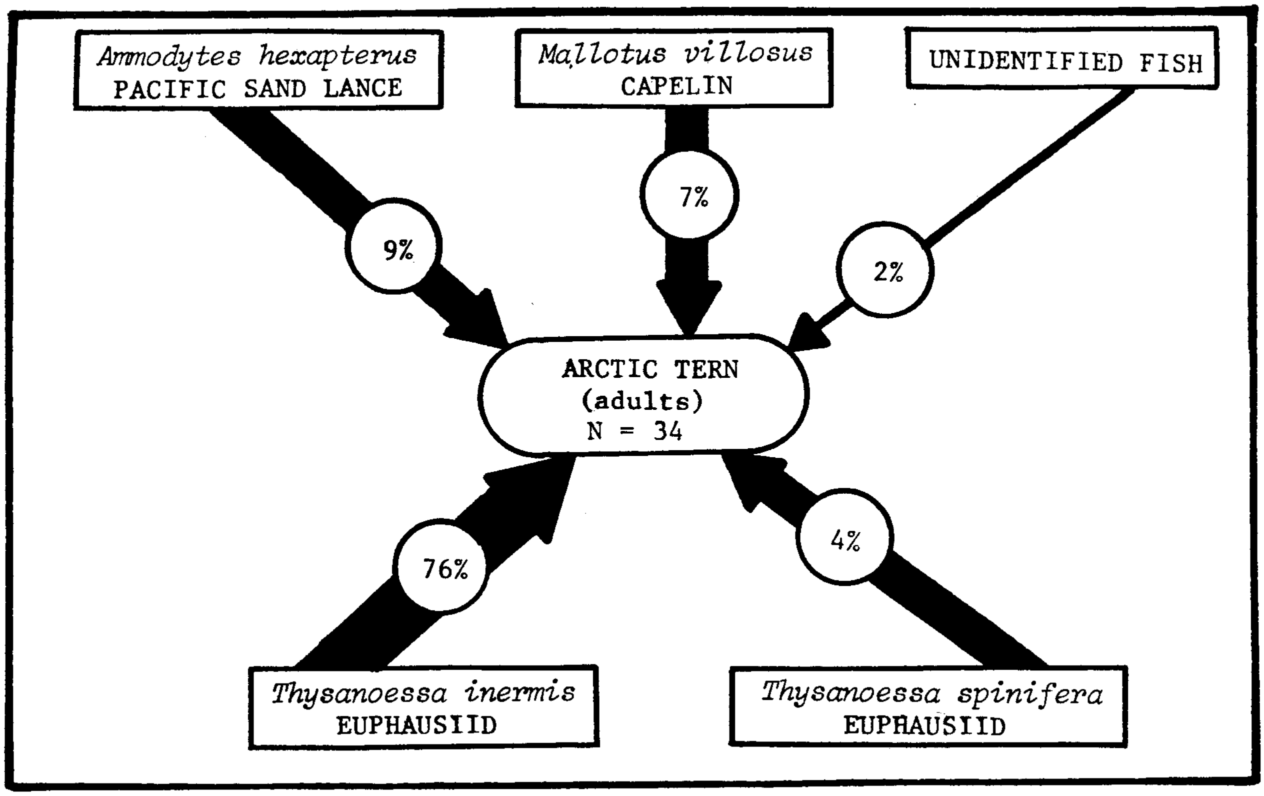


Figure 20. Food web relationships among adult and sub-adult black-legged kittiwakes, and red-legged kittiwakes, based on data pooled from all years, seasons, and regions. See Fig. 4 caption.



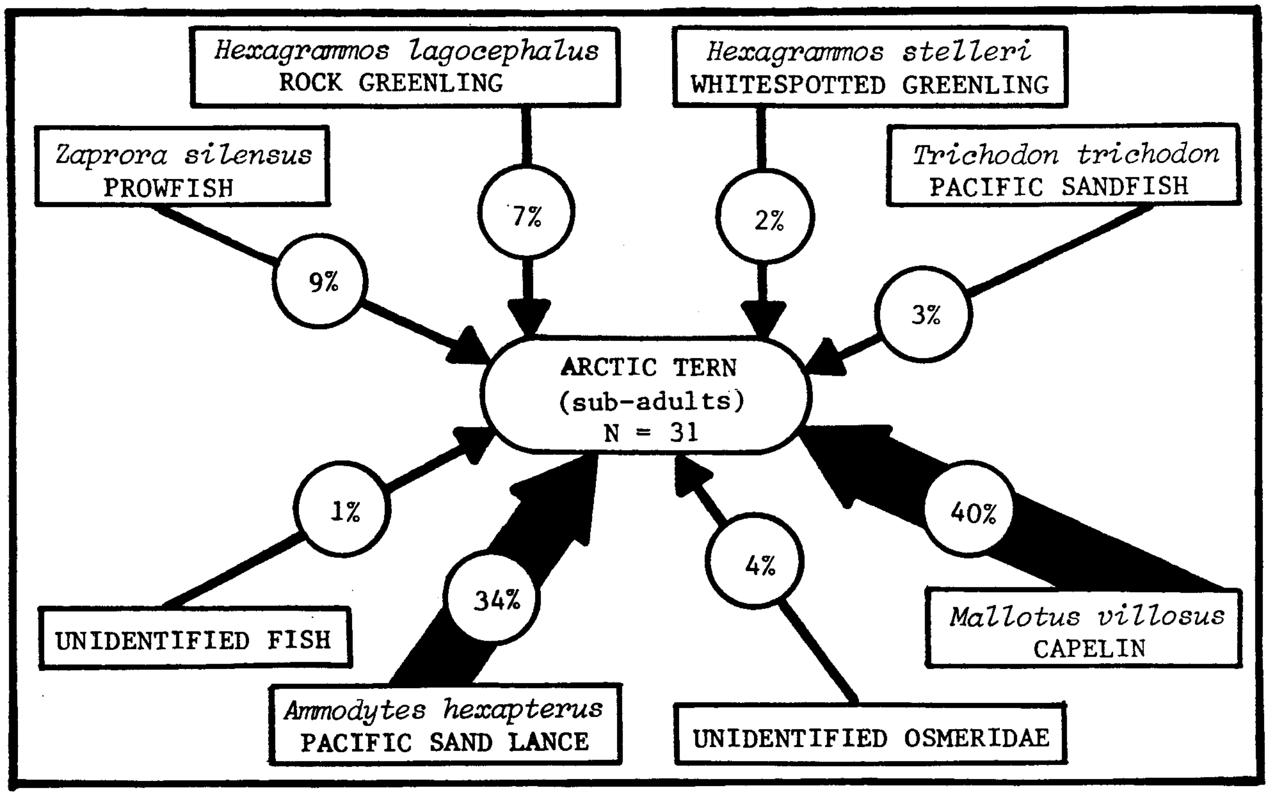


Figure 21. Food webs for adult (top) and sub-adult (bottom) arctic terns, showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

contrast to the adults, the diet of sub-adults was exclusively fish (Figure 21, Appendix Table 27). At least six species were included in the diet, and of these, capelin was the most important. It accounted for 50% of prey numbers, 40% of their volume, and it occured in 48% of the samples, for an IRI of 4,368. Sand lance was also important to nestling arctic terns, and had an IRI of 1,745. The other fish, all of minor importance, included rock and white-spotted greenlings, Pacific sandfish, and prowfish.

Aleutian Tern. At least eight prey species had been eaten by the 13 adults (93% of 14 collected) with food in their stomachs. As with adult arctic terns, crustaceans were the most important major prey taxon. Their IRI was 3,590, and crustaceans comprised 89% of prey numbers, and 66% of the volume (Appendix Table 28). Fish were relatively more important than they were to adult arctics, however, and had an IRI of 1,186.

The euphausiid *Thysanoessa inermis* was the most important prey species; it accounted for 88% of the numbers, 55% of the volume and it occured in 23% of the stomachs. Sand lance (IRI 521), capelin (IRI 137) and unidentified fish (IRI 157) were relatively less important (Figure 22, Appendix Table 28). The isopod crustacean *Pentidotea* sp. (IRI 87) comprised 10% of the volume. Other prey, all of minor or trace importance, included nereid polychaetes, the isopod *Synidotea* sp., and, unidentified insects and gadid fishes.

Forty-eight food samples were collected from sub-adult birds. These included 43 nestling regurgitations from Kodiak Island, and stomachs from five flying birds; four of the latter had food in their stomachs. Subadults had eaten at least eight species of prey (Figure 22, Appendix Table 29). Except for traces of *Thysanoessa* euphausiids and unidentified insects, the diet of nestling Aleutian terns was exclusively fish, which accounted for 97% of prey volume and 99% of the numbers, and had an IRI of 2,273. Unidentified fish had an IRI of 1,524, and sand lance, the most important prey species, had an IRI of 335. Other fish in the diet included rock greenling, Atka mackeral, silverspotted sculpin and Pacific sandfish.

In addition to the samples described above, 11 bill loads that were intended for nestlings (Appendix Table 30) had been dropped by adult birds at a nesting colony at Kodiak Island that was utilized by both species. In addition to the prey noted above for both tern species, these samples included juvenile silver salmon, surf smelt, unidentified pricklebacks, and juvenile Pacific halibut.

Food Web Relationships Between Terns. Together, the terns ate at least 22 prey species, including at least seven crustaceans, 13 fish, and one each nereid polychaete, cheliferate arthropod, and insect (Table 5, Figure 23). There was, however, relatively little overlap among the prey of terns in our samples. The euphausiid *Thysanoessa inermis* was quite important to adults of both tern species, while capelin and sand lance were more heavily utilized by subadults of both species than by adult terns. The rock greenling and Pacific sandfish were both of low or trace importance to sub-adults of both species. Otherwise, there was little overlap among the prey of terns in our samples.

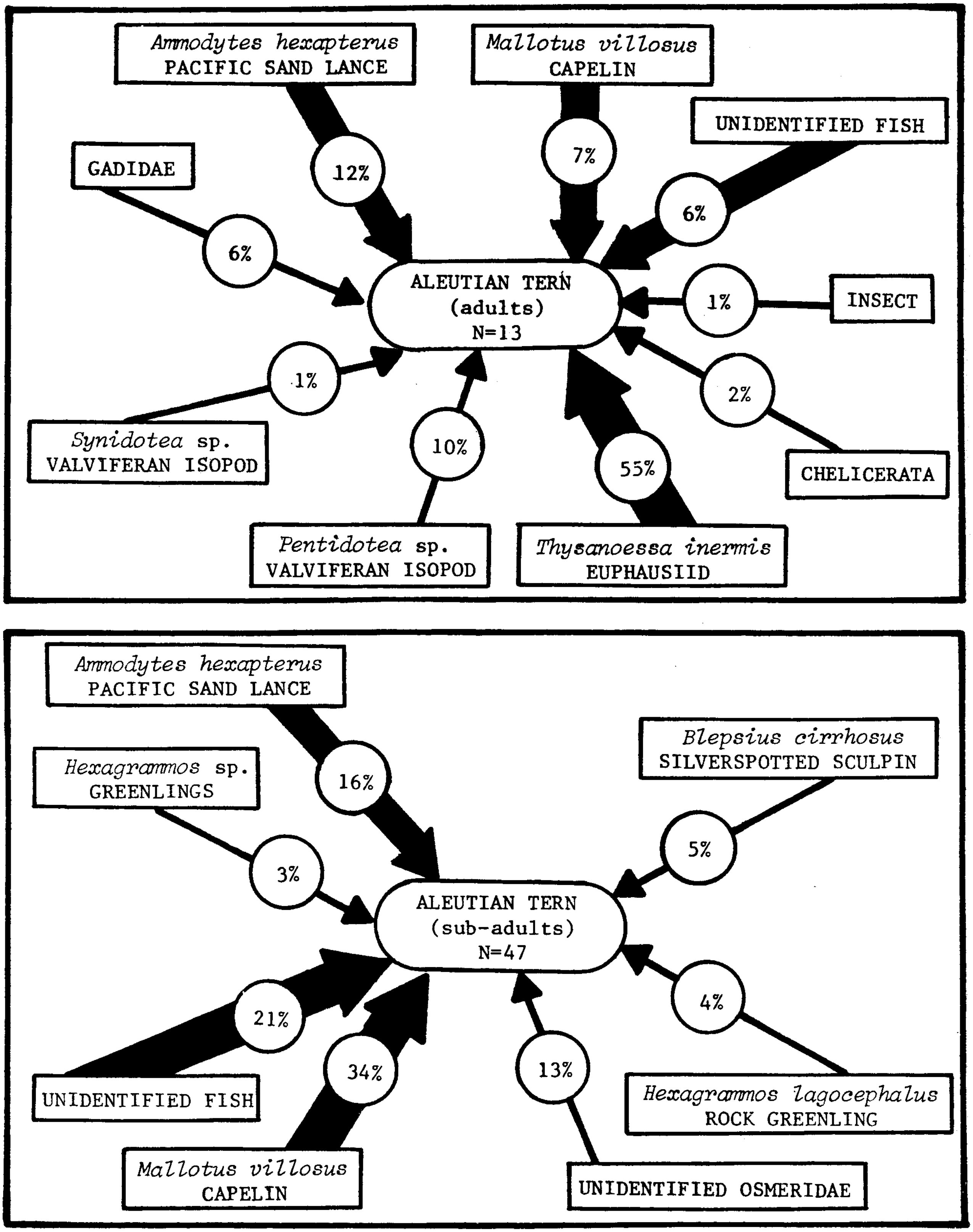


Figure 22. Food webs for adult (top) and sub-adult (bottom) Aleutian terns, showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

Table 5. Comparative importance of prey to arctic and Aleutian terns, based on data pooled from food samples from birds in Alaskan waters. Importance levels based on IRI values: 0-9 = trace(tr); 10-99 = 1; 100-999 = 2; 1,000+ = 3.

PREY NAME	Importance of Prey to Tern Species: Arctic adults N = 34	Arctic sub-ad. N = 31	Aleutian adults N = 13	Aleutian sub-ad. N = 47	Either/or nestlings N = 11
POLYCHAETES, Nereidae	tr	-	tr	-	-
CHELICERATE ARTHROPOD	-	-	1	-	-
CRUSTACEA					
Isopods					
Synidotea sp.	-	-	1	-	-
Pentidotea sp.	-	-	1	-	-
Unidentified Decapod	tr	-	-	-	-
Parathemisto libellula Hypereiid Amphipod	tr	-	-	-	-
Euphausiids					
Thysanoessa inermis	3	-	3	-	-
T. raschii	tr	-	-	-	-
T. spinifera	2	-	-	-	-
T. sp.	-	-	-	tr	-
INSECT, Unidentified	-	-	1	tr	-
FISH					
Onchorhynchus kisutch Silver Salmon	-	-	-	-	2
Hypomesus pretiosus Surf Smelt	-	-	-	-	2
Mallotus villosus Capelin	2	3	2	3	2
Hexagrammos lagocephalus Rock Greenling	-	1	-	1	2
Hexagrammos stelleri Whitespotted Greenling	-	1	-	-	-
Pleurogrammus stelleri Atka Mackeral	-	-	-	tr	-
Blepsius cirrhosus Silverspotted Sculpin	-	-	-	1	1
Stichaeidae (Pricklebacks)	-	-	-	-	1
Trichodon trichodon Pacific Sandfish	-	1	-	tr	-
Zaprora silensus Prowfish	-	1	-	-	-
Gadidae	-	-	1	-	-
Ammodytes hexapterus Pacific Sand Lance	2	3	2	2	3
Hippoglossus stenolepis Pacific Halibut	-	-	-	-	2

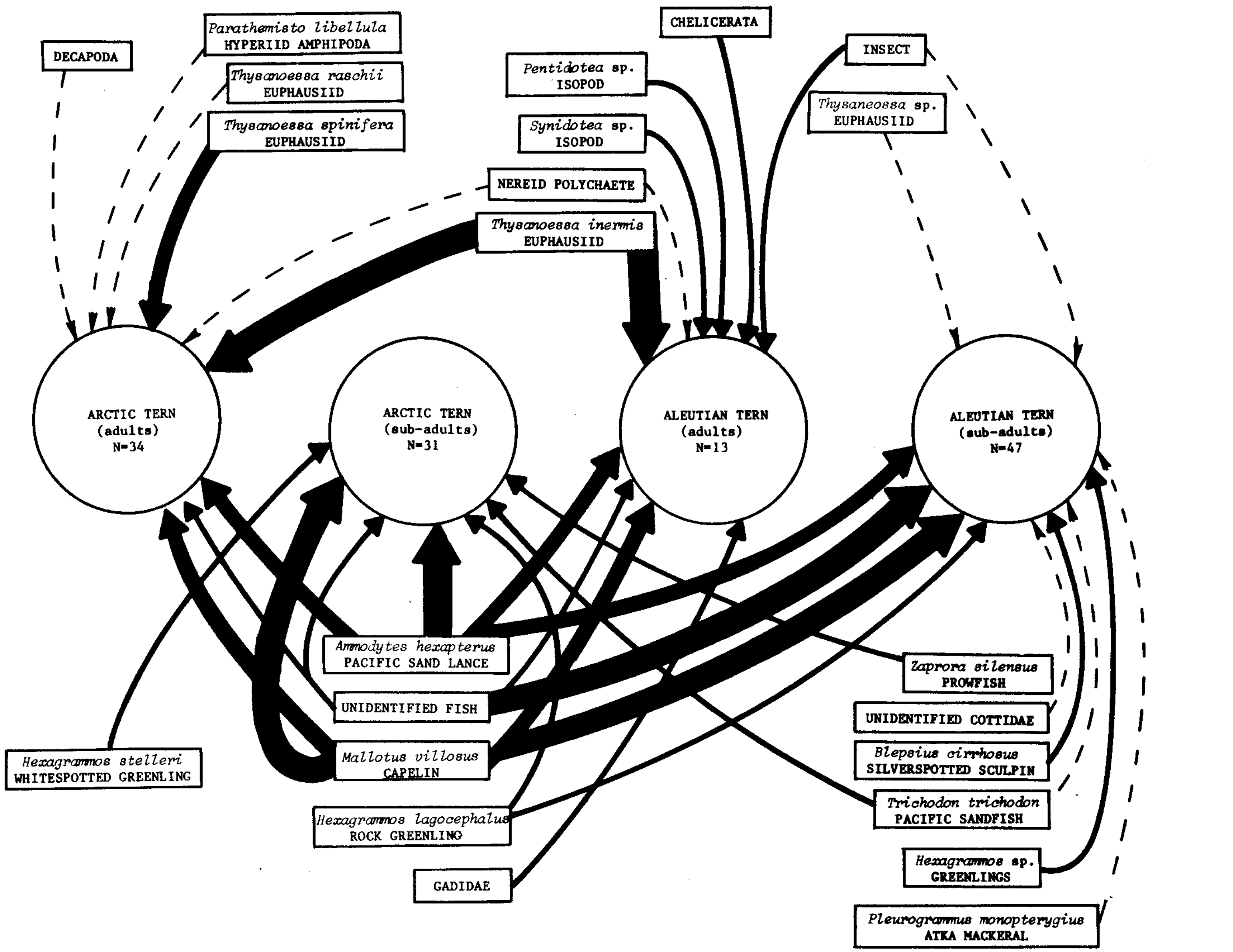


Figure 23. Food web relationships among adult and sub-adult arctic and Aleutian terns, based on data pooled from all years, seasons, and regions. See Fig. 4 caption.

Alcidae (Murres, Murrelets, Auklets, and Puffins)

The alcids are a large, diverse group of pelagic seabirds with 16 species nesting in Alaska. Members of the family forage and occur mostly over the continental shelf relatively close to land, particularly during the spring-summer nesting season (Gould et al. 1982). In winter, however, some species such as the tufted puffin (Fratercula cirrhata) range hundreds of km into the oceanic environment, far from land (Shuntov 1972; Gould et al. 1982).

Alcids range in size from the 90 g least auklet (Aethia pusilla) to the common (Uria aalge) and thick-billed murre (U. lomvia) of a kg or more. All alcids feed by pursuit diving (Ashmole 1971), and depending on species and water depth, they apparently feed throughout the water column, at depths ranging down to at least 40 m for some auklets (Bedard 1969) and to 125 m for the common murre (Gould et al. 1982). Diets indicate that some species feed on or very near the bottom (see below).

We have data on the feeding habits of the 13 following species: Common murre, thick-billed murre, pigeon guillemot (Cepphus columba), marbled murrelet (Brachyramphus marmoratus), Kittlitz's murrelet (B. brevirostris), ancient murrelet (Synthliboramphus antiquus), Cassin's auklet (Ptychoramphus aleuticus), parakeet auklet (Cyclorrhynchus psittacula), crested auklet (Aethia cristatella), least auklet, rhinoceros auklet (Cerorhinca monocerata), horned puffin (Fratercula corniculata), and tufted puffin.

Common Murre. Of 251 birds sampled, 166 (66.1%) had food in their stomachs; common murres ate at least 23 species of prey (Appendix Table 31). Overall, fish was the most important major taxon of prey; they comprised 81% of the volume and had an IRI of 2,995. Crustaceans were relatively less important (IRI 474), and polychaetes, cephalopods, insects and echinoderms were all of trace importance only.

Capelin (vol 30%, IRI 1,003) was the most important prey species, followed by Pacific sand lance (IRI 607), walleye pollock (IRI 297) and the mysid Neomysis rayii (IRI 162) (Figure 24, Appendix Table 31). The next most important prey was the euphausiid Thysanoessa inermis (IRI 41), and all other prey were of minor or trace importance only. Pandalid shrimp, including pink shrimp (Pandalus borealis), humpy shrimp (P. goniuris) and unidentified Pandalus sp., together accounted for 4% of overall diet volume.

Thick-billed Murre. Sixty-four stomach samples from thick-billed murres were obtained, and 38 (59%) of these contained food. At least 14 species of prey were present. Cephalopods were the dominant major taxon, and accounted for 47% of the numbers, 26% of the volume, and they occured in 51% of the stomachs with food, for an IRI of 3,765 (Appendix Table 32). In comparison, fish comprised 44% of the volume (IRI 1,181) and crustaceans 30% of the volume (IRI 678).

One or more species of cephalopods certainly would have been the most important species of prey of Thick-billed Murres, if they had been identifiable. The hyperiid amphipod Parathemisto libellula, however, was the

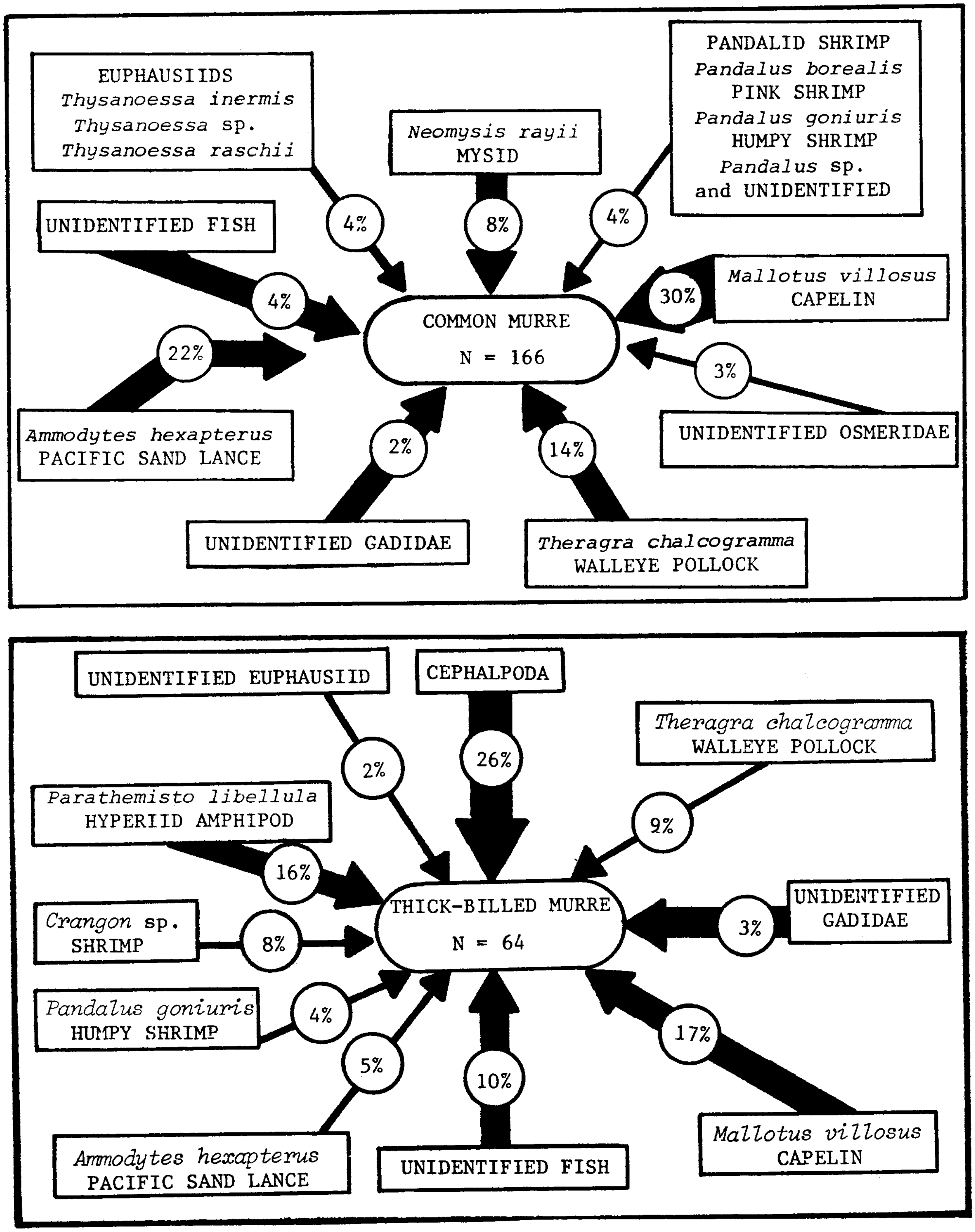


Figure 24. Food webs for common (top) and thick-billed murres (bottom), showing main prey items as indicated by data pooled from all years, seasons and regions; see Fig. 2 caption.

most important species of identifiable prey (volume 16%, IRI 438). Capelin (volume 17%, IRI 156) and gadid fishes as a group (volume 13%, IRI 176) were the next most important prey (Figure 24, Appendix Table 32).

Food Web Relationships Between the Murres. A comparison of the importance of different prey to the two murres (Table 6) may reflect geographic and seasonal differences as much as interspecific ones. It is seen, however, that capelin, Pacific sand lance and walleye pollock were the only prey that were of more than trace or minor importance to both species. In general, fish were most important to common murres, and cephalopods, fish and crustaceans were important to thick-billed murres.

Pigeon Guillemot. Sixty-four guillemots were collected, and 58 (91%) had food in their stomachs; they had eaten at least 29 species of prey. Major prey taxa were dominated by fishes (numbers 24%, volume 60%, IRI 3,176) and crustaceans (numbers 67%, volume 37%, IRI 2,336) (Appendix Table 33).

The diet of guillemots was characterized by a variety of prey species, none of which were dominant (Figure 25, Appendix Table 33). The red rock crab (*Cancer oregonensis*) had the highest IRI value (516); it comprised 17% of prey numbers, but only 6% of the volume. Capelin made up 19% of the prey volume, but only 4% of the numbers (IRI 277), and Pacific sandfish accounted for 12% of the volume and 3% of the numbers (IRI 102). Shrimps ($\leq$ 10 spp.) accounted for 20% of the prey volume (IRI 282) and total crabs ($\leq$ 5 spp.) made up 11% of the volume (IRI 788). Shrimps occured in only 5% of the stomachs with food, however, but crabs were found in 22% of the stomachs. Other prey, all of minor or trace importance, included nereid polychaetes, the gastropod *Lacuna vincta*, venerid and *Musculus* sp. bivalves, mysids, gammarid amphipods, and at least five species of fish in addition to capelin and Pacific sandfish.

Marbled Murrelet. Of 158 birds collected, 129 (82%) had food in their stomachs. The murrelets atė a minimum of 16 prey species, including seven crustaceans and four fishes (Appendix Table 34). Fish accounted for 50% of the prey numbers, 76% of their volume, and they were eaten by 26% of the birds with food in their stomachs, for an IRI of 3,337. In contrast, crustaceans accounted for 49% of prey numbers, 23% of the volume, and they occured in only 8% of the stomachs, for an IRI of 617. Other major taxa of prey were relatively unimportant.

Capelin, which accounted for 38% of prey numbers and 27% of their volume (IRI 1,692), was by far the most important prey species (Figure 26, Appendix Table 34). The next most important prey and their IRI's were sand lance (741), the mysid *Acanthomysis* sp. (327), and the euphausiid *Thysanoessa inermis* (132). Other prey were of minor or trace importance, none having an IRI higher than 22.

Kittlitz's Murrelet. Sixteen Kittlitz's murrelets were collected and 15 had food in their stomachs. As with marbled murrelets, crustaceans and fish were the major kinds of prey (Appendix Table 35). Unidentified fish and four species of identifiable fishes made up 65% of prey numbers and 70% of the volume, for an IRI of 5,404, while three species of crustaceans comprised 35% of prey numbers and 30% of their volume, for an IRI of 1,730.

Table 6. Comparative importance of prey to murres, based on data pooled from stomach samples collected in Alaskan waters. Importance levels based on IRI values, as follows: trace (tr) = 0 - 9; 1 = 10 - 99; 2 = 100 - 999; 3 = 1,000+

PREY NAME	Importance of Prey to Bird Species: Common Murre N = 166	Thick-billed Murre N = 38
POLYCHAETE, Nereidae	tr	tr
GASTROPOD, Unidentified	-	tr
CEPHALOPODA, Unidentified/Unidentified Squid/ Unidentified Gonatid Squid	tr	3
CRUSTACEA		
Calanoid Copepod	-	tr
Leucon sp. (Cumacean)	tr	-
Neomysis rayii (Mysid)	2	-
Gammarid Amphipods		
Protomedeia sp.	tr	-
Anonyx sp.	tr	-
Unidentified	tr	tr
Hyperiid Amphipods		
Parathemisto libellula	-	2
P. pacifica	-	tr
Euphausiids		
Thysanoessa inermis	1	tr
T. raschii	tr	-
T. sp./Unidentified	1	1
Decapods		
Eualus stimpsoni (Shrimp)	tr	-
Pandalus borealis (Pink Shrimp)	1	-
P. goniuris (Humpy Shrimp)	tr	1
Crangon franciscorum (Bay Crangon Shrimp)	tr	-
C. sp. (Crangon Shrimp)	-	1
INSECT, Unidentified	tr	-
ECHINODERM		
Amphipodia sp. (Brittle Star)	tr	-
FISH		
Clupea harengus (Pacific Herring)	tr	-
Mallotus villosus (Capelin)	3	2
Gadus macrocephalus (Pacific Cod)	tr	-
Boreogadus saida (Arctic Cod)	-	tr
Microgadus proximus (Pacific Tomcod)	tr	-
Theragra chalcogramma (Walleye Pollock)	2	1
Trichodon trichodon (Pacific Sandfish)	tr	-
Lumpenus maculatus (Daubed Shanny)	tr	-
L. saggita (Snake Prickleback)	tr	-
Ammodytes hexapterus (Pacific Sand Lance)	2	1

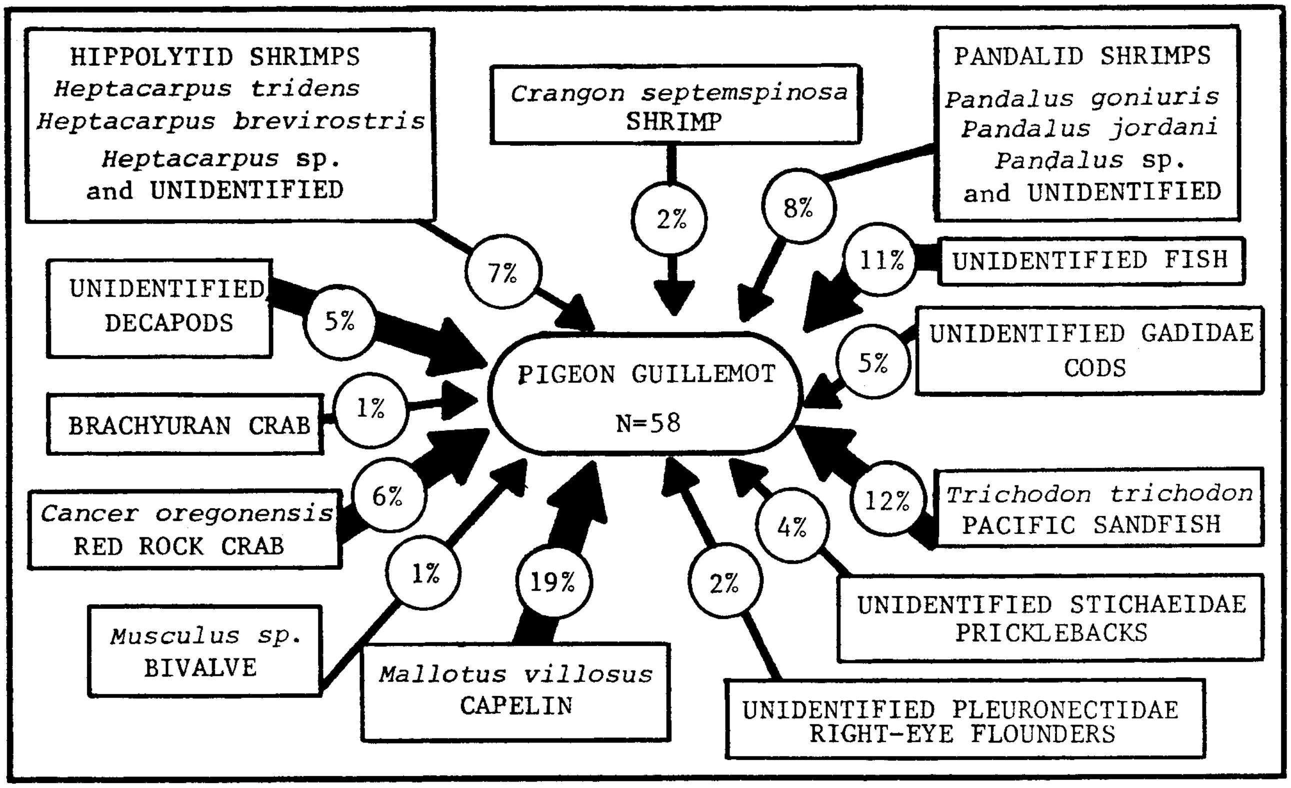


Figure 25. Food web for pigeon guillemots, showing main prey items as indicated by data pooled from all years, seasons and regions. See Fig. 2 caption.

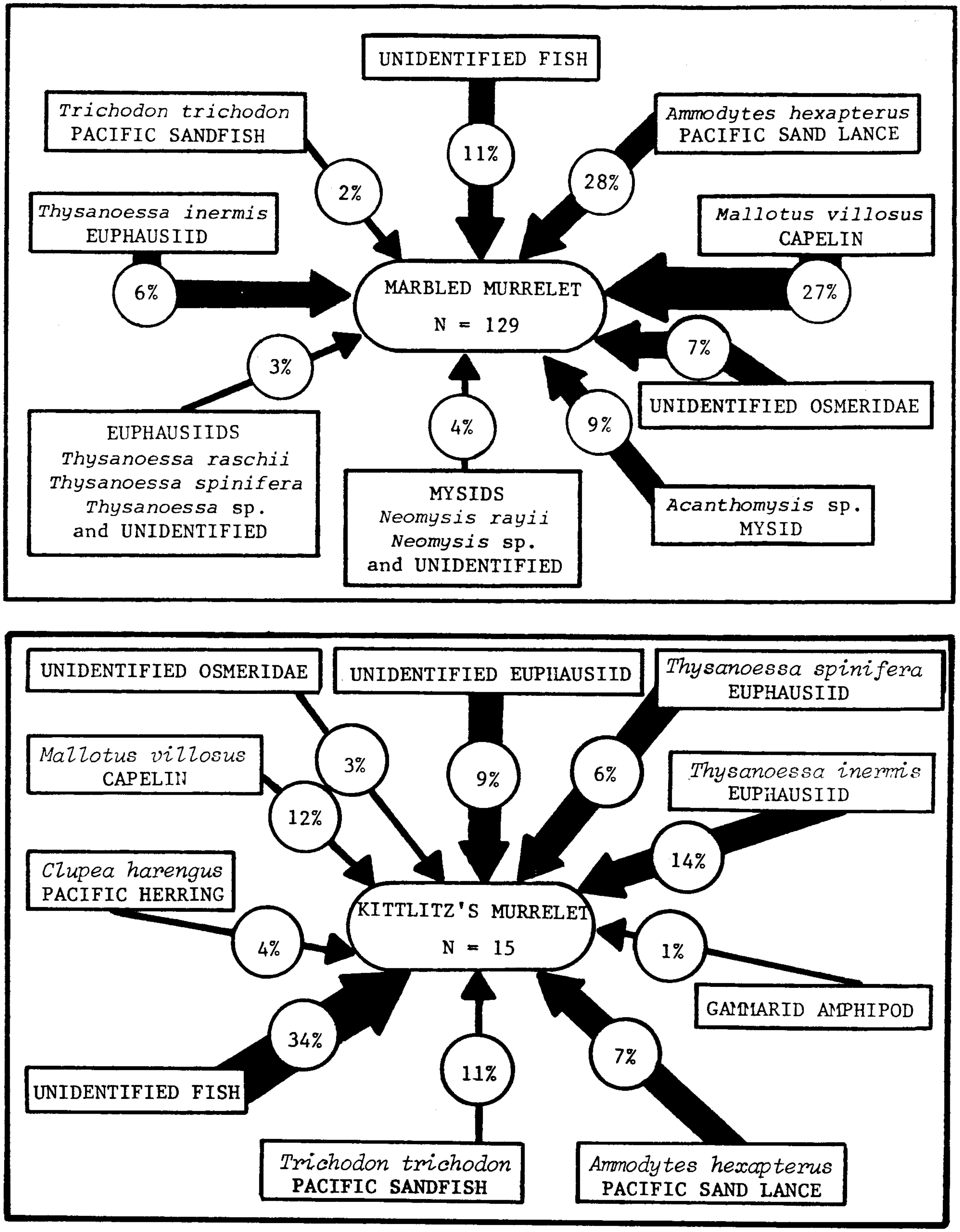


Figure 26. Food webs for marbled (top) and Kittlitz's murrelets (bottom), showing main prey items as indicated by data pooled from all years, seasons and regions. See Fig. 2 caption.

In contrast to marbled murrelets, the most important prey species to Kittlitz's murrelets was a crustacean, the euphausiid Thysanoessa inermis (Figure 26, Appendix Table 35). This species accounted for 25% of the numbers and 14% of the volume of prey, although it occured in only 3 of the 15 birds with food in their stomachs (IRI 788). This information could be misleading, however, because unidentifiable fish comprised 53% of the numbers and 34% of the prey volume. A species of fish could therefore have been more important to the birds than the euphausiid.

Pacific sand lance (IRI 183) was the most important species of identifiable fish, accounting for 7% each of prey numbers and volume. Capelin (IRI 92) and Pacific sandfish (IRI 87) were the next most important fish prey, and accounted for 12% and 11% of the prey volume, respectively (Appendix Table 35). Each of these species, however, occured in only one stomach. The euphausiid Thysanoessa spinifera occured in two birds, and accounted for 6% each of prey numbers and volume and had an IRI of 152.

Ancient Murrelet. Fifteen (83%) of the 18 murrelets collected had food in their stomachs, which included at least five prey species. Crustaceans were the most important major taxon of food; they occured in 33% of the stomachs and accounted for 56% and 57%, respectively, of the prey numbers and volume, for an IRI of 3,786. Fish also occured in 33% of the stomachs, but in contrast to crustaceans, they respectively accounted for only 43% of prey numbers and 42% of the volume, for an IRI of 2,817 (Appendix Table 36).

Thysanoessa inermis was the most important species of prey to ancient murrelets, respectively accounting for 52% and 49% of of prey numbers and volume, which contributed to an IRI of 3,353. Unidentified gadid fishes (IRI 437) made up 18% of the volume, and unidentified fish (IRI 460) accounted for 11% of the volume. No other prey had an IRI higher then 56 (Figure 27, Appendix Table 36).

Cassin's Auklet. Eight Cassin's auklets all had food in their stomachs. Crustaceans (IRI 8,780) dominated the diet, but fish (IRI 408) and squid (IRI 101) were also present (Appendix Table 37). At least six species of prey were found in the stomachs.

Calanoid copepods dominated both prey numbers (78%) and volume (59%), and they occured in four (50%) of the birds, for an IRI of 6,870. Unidentifiable decapods (crabs and shrimp) had an IRI of 1,250, a result of their occuring in 50% of the stomachs and accounting for 16% of the prey numbers and 9% of their volume. Unidentified fish (IRI 408), the euphausiid Thysanoessa spinifera (IRI 315), and unidentifiable squid (IRI 101) rounded out the prey, plus one gammarid amphipod was found in one bird.

Food Web Relationships Among Three Murrelets and Cassin's Auklet. Specimens of the preceeding four species were all collected in the Gulf of Alaska, so major geographic differences in their diet are eliminated. A direct comparison of the main components of their diets (Table 7, Figure 28) shows that, in general, fish and planktonic crustaceans were the main prey of all four species. Mysids of the genera Acanthomysis and Neomysis were of low to moderate importance to marbled and ancient murrelets, but were absent from the diets of the other species.

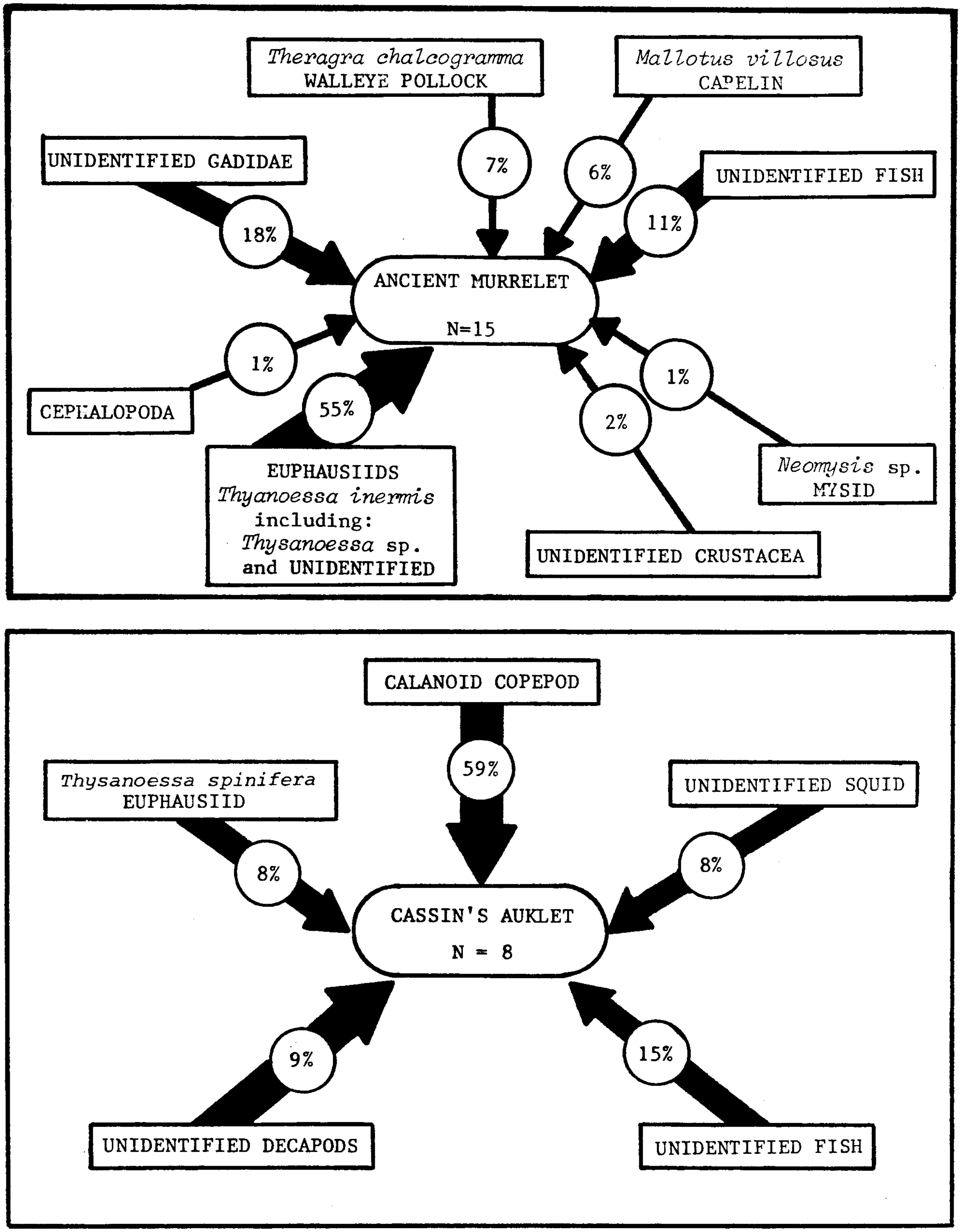


Figure 27. Food webs for ancient murrelets (top) and Cassin's auklets (bottom), showing main prey items as indicated by data pooled from all years, seasons and regions. See Fig. 2 caption.

Table 7. Comparative importance of prey to murrelets and the Cassin's Auklet, based on data pooled from birds collected in the Gulf of Alaska. Importance levels of prey based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000+ = 3

PREY NAME	Importance of Prey to Bird Species			
	Marbled Murrelet N = 129	Kittlitz's Murrelet N = 15	Ancient Murrelet N = 15	Cassin's Auklet N = 8
POLYCHAETA, Nereidae	tr	-	-	-
GASTROPOD, *Littorina sitkana* Sitka Periwinkle				
BIVALVE, *Mytilus edulis* Blue Mussel	tr	-	-	-
CEPHALOPODA, Squid & Unident.	tr	-	1	2
CRUSTACEA				
Calanoid Copepod	-	-	-	3
Gammarid Amphipod	tr	1	-	tr
Mysida				
Acanthomysis sp.	2	-	-	-
Neomysis rayii	tr	-	-	-
N. sp.	1	-	1	-
Euphausiids				
Thysanoessa inermis	2	2	3	-
T. raschii	1	-	-	-
T. spinifera	tr	2	-	2
T. sp./Unidentified	1	2	2	-
Pink Shrimp				
Pandalus borealis	tr	-	-	-
CHAETOGNATHA, Arrow Worms	tr	-	-	-
FISH				
Clupea harengus Pacific Herring	-	1	-	-
Mallotus villosus Capelin	3	1	1	-
Unidentified Osmeridae	2	1	-	-
Theragra chalcogramma Walleye Pollock	tr	-	1	-
Unidentified Gadidae	tr	-	2	-
Trichodon trichodon Pacific Sandfish	1	1	-	-
Ammodytes hexapterus Pacific Sand Lance	2	2	-	-
Unidentified	2	3	2	2

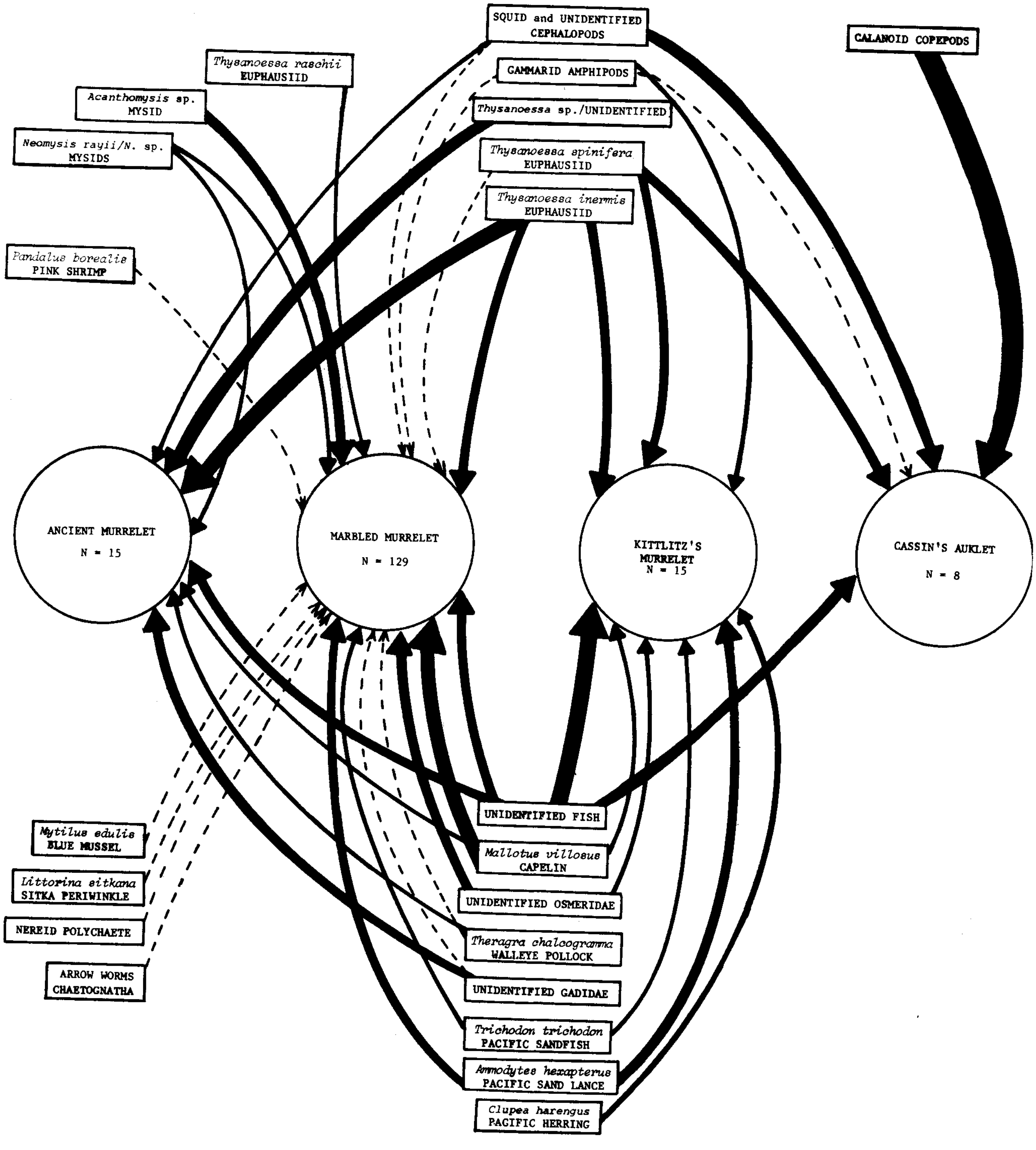


Figure 28. Food web relationships among ancient, marbled and Kittlitz's murrelets, and Cassin's auklets, based on data pooled from all years, seasons, and regions. See Fig. 4 caption.

Euphausiids of the genus Thysanoessa were of moderate or high importance to all four alcids; T. inermis was of moderate or high importance to all species except the Cassin's auklet, and T. spinifera was of moderate importance to Kittlitz's murrelets and Cassin's auklets. Calanoid copepods were heavily eaten by Cassin's auklets, but were not eaten by the other species.

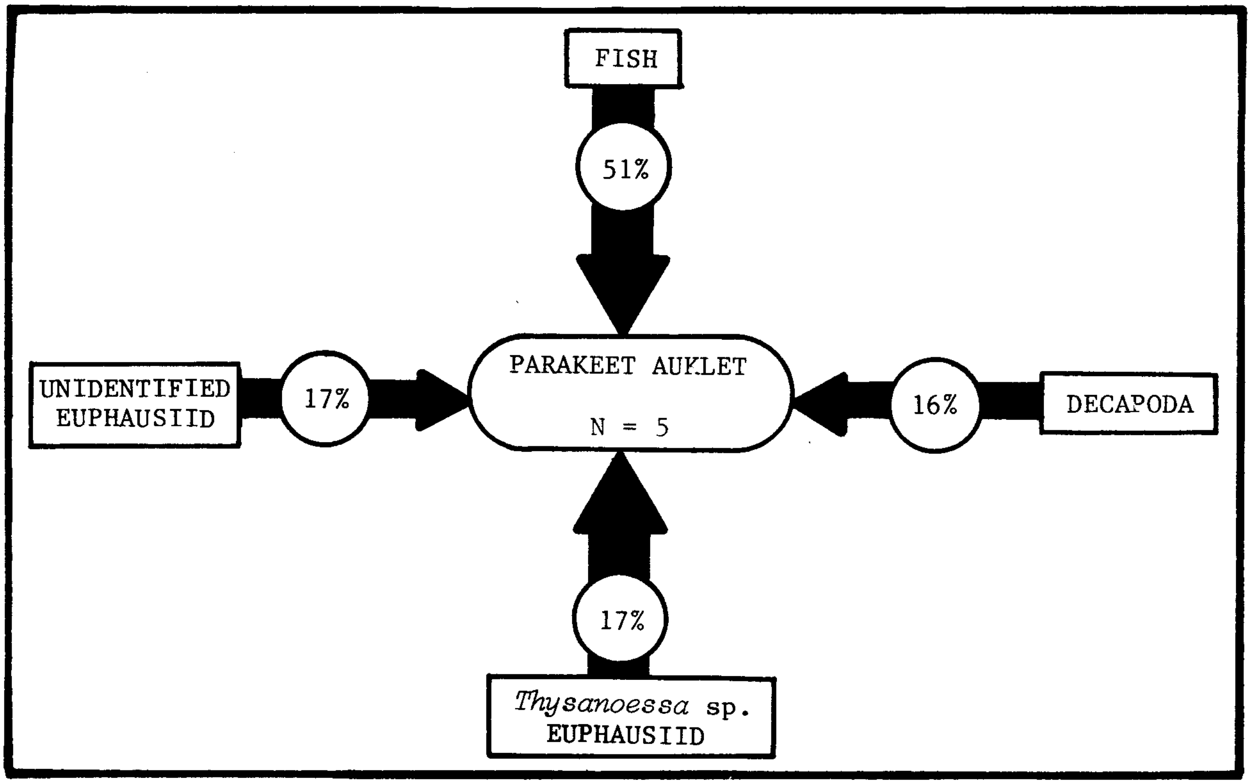
No one species of fish was eaten by all four of these alcids, although unidentified fish had importance levels of two or three for all four birds. Capelin were of high importance to marbled murrelets, and low importance to Kittlitz's and Ancient murrelets. Sand lance were moderately important to marbled and Kittlitz's murelets, but they were not eaten by Ancient murrelets nor Cassin's auklets. Pacific sandfish were eaten by both marbled and Kittlitz's murrelets, but were of low importance to each. None of the fish remains in the Cassin's auklets were identifieble.

Parakeet Auklet. Thirteen birds were collected, but only five (38%) had food in their stomachs. They had eaten at least three species of prey, including two crustaceans and unidentified fish. Euphausiids of the genus Thysanoessa made up 93% of total prey numbers and 17% of the volume, but they were found in only one of the five stomachs. Unidentified fish accounted for 6% of prey numbers, 51% of the volume and occured in two birds. Unidentified decapods (shrimps and crabs) equaled 16% of the prey volume, but they occured in only one stomach (Figure 29, Appendix Table 38).

Least Auklet. Three Least Auklets were collected, and all had food in their stomachs. At least four kinds of prey were found, but none were identifiable to species. Calanoid copepods accounted for 55% of prey numbers and 18% of their volume, gammarid amphpods made up 12% and 7%, respectively of numbers and volume, and equivalent figures for chaetognaths (arrow worms) were 28% and 31%. Unidentified decapods made up 11% of the volume, but only 3% of the numbers (Figure 29, Appendix Table 39).

Crested Auklet. At least three kinds of crustaceans were found in 13 birds with food in their stomachs out of 25 collected. The mysid Acanthomysis accounted for 80% of prey numbers and 43% of the volume, but was found in only two (15%) of the stomachs, and the euphausiid Thysanoessa inermis made up 15% of the numbers, 25% of the volume, and it was found in four of 13 birds (31%) with food. Unidentified hyperiid amphipods made up the remainder of prey (Figure 30, Appendix Table 39).

Food Web Relationships Among the Auklets. Unidentifid decapods were found in both Parakeet and Least Auklets, and Thysanoessa euphausiids had been eaten by Parakeet and Crested Auklets, but there was otherwise no overlap in the kinds of prey eaten by birds in our samples (Table 8, Figure 31) Diets of these three species in the Bering Sea (e.g., Bedard 1969; Hunt et al. 1981) show a fair degree of overlap in prey species. Thus, the small amount of overlap observed here may be a result of the small sample sizes, and the locations of the collections. The three Least Auklets all came from the Bering Sea, but collections of the other two species were from scattered locations in the Gulf of Alaska, as well as the Bering Sea.



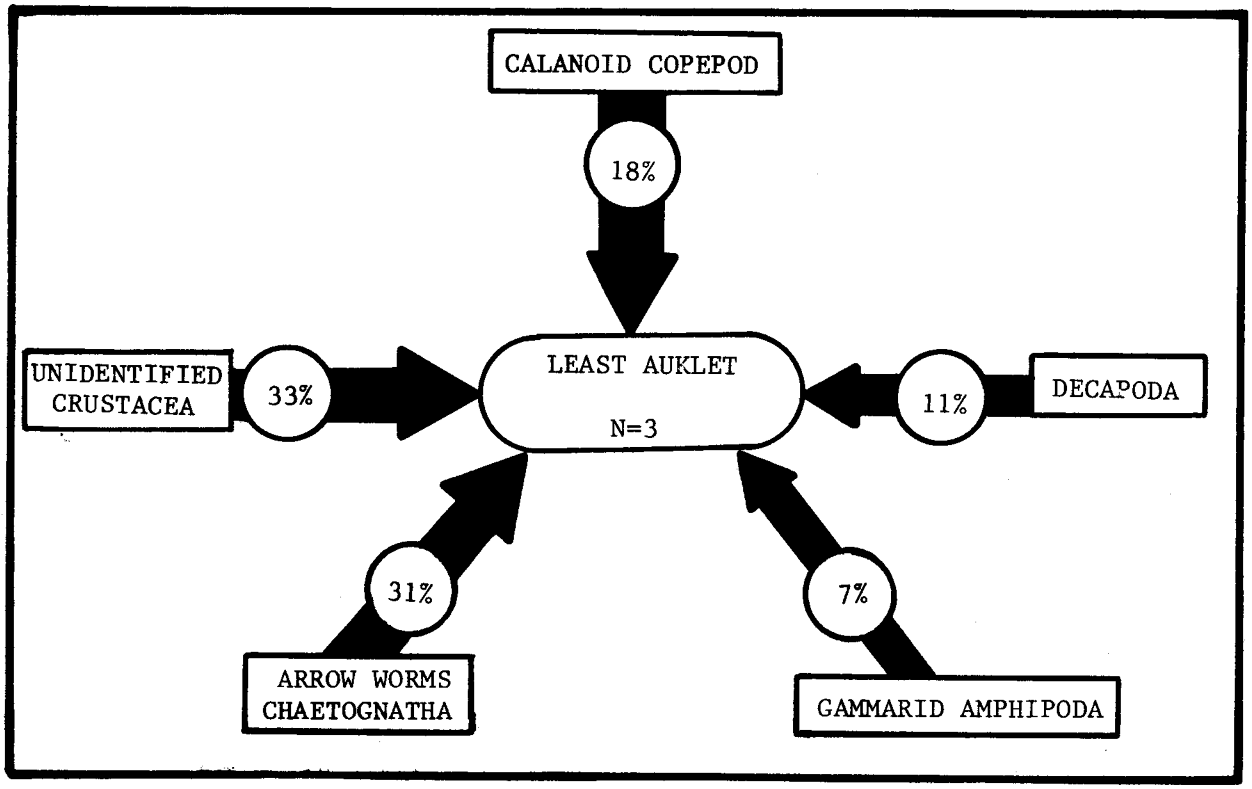


Figure 29. Food webs for parakeet (top) and least (auklets), showing main prey items as indicated by data pooled from all years, seasons and regions. See Fig. 2 caption.

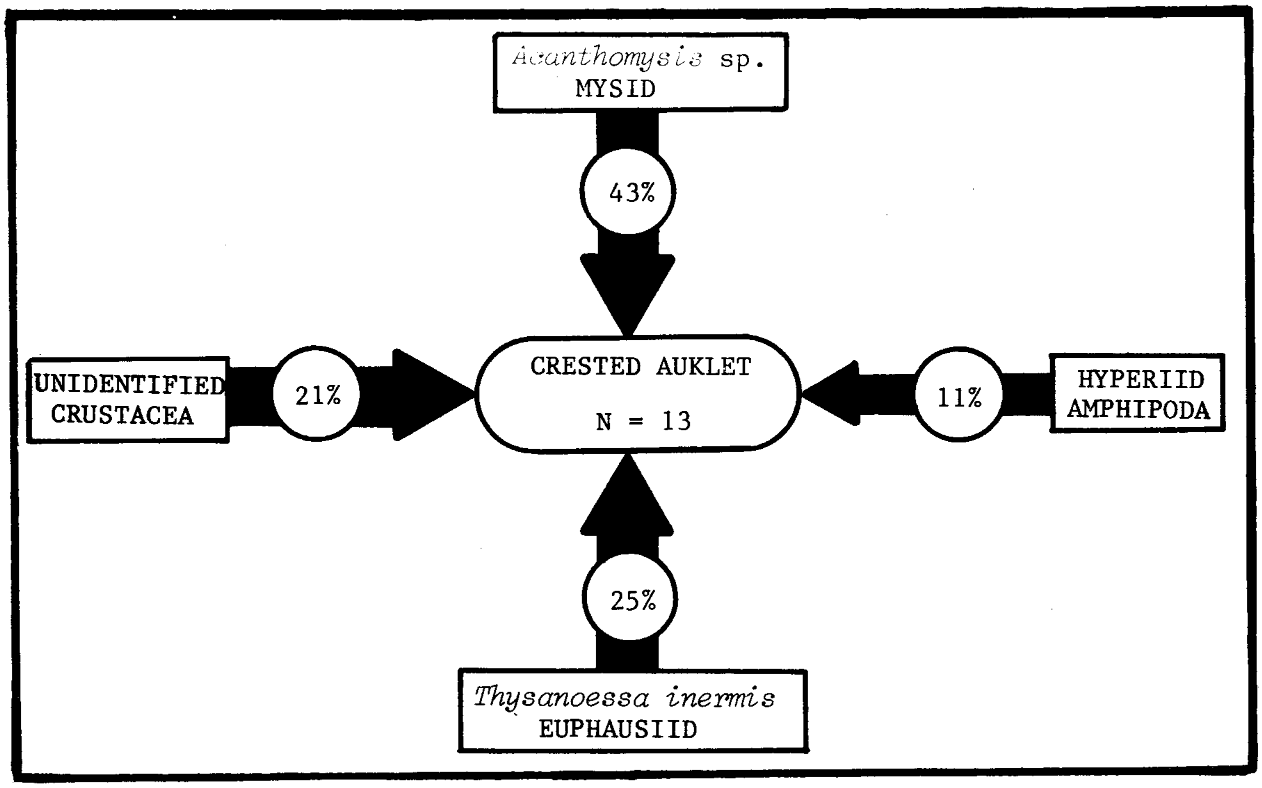


Figure 30. Food web for crested auklets, showing main prey items as indicated by data pooled from all years, seasons and regions. See Fig. 2 caption.

Table 8. Comparative importance of prey to Parakeet, Least, and Crested Auklets, based on data pooled from food samples from birds collected in Alaskan waters. Importance levels of prey based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000+ = 3

	Importance of Prey to Bird Species		
PREY NAME	Parakeet Auklet N = 13	Least Auklet N = 3	Crested Auklet N = 5
CRUSTACEA			
Calanoid Copepoda	-	3	-
Gammarid Amphipoda	-	2	-
Hyperiid Amphipoda	-	-	2
Acanthomysis sp. Mysid	-	-	3
Thysanoessa inermis Euphausiid	-	-	3
Thysanoessa sp. Euphausiid	3	-	-
Decapoda Shrimps and Crabs	2	2	-
FISH, Unidentified	3	-	-
CHAETOGNATHA Arrow Worms	-	3	-

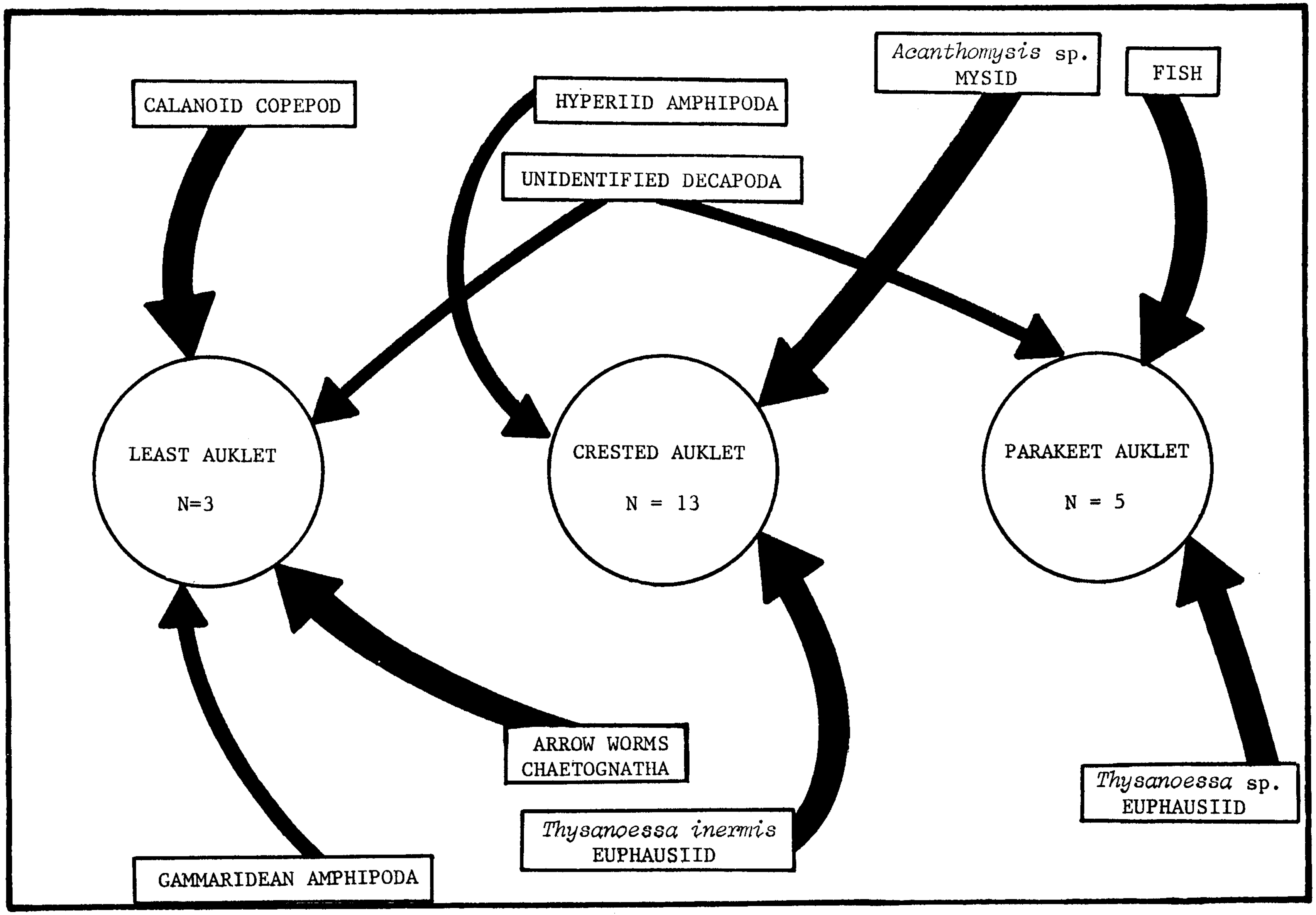


Figure 31. Food web relationships among least, crested, and parakeet auklets based on data pooled from all years, seasons, and regions. See Fig. 2 caption.

Rhinoceros Auklet. Twenty-one adult rhinoceros auklets were collected, and 16 (76%) had food in their stomachs. At least five species of prey were present, including four fishes and unidentified cephalopods (Appendix Table 40). Capelin (IRI 1,061) was the most important identifiable species of prey, and it accounted for 24% and 61%, respectively, of their numbers and volume. The next most important prey, Pacific sand lance, made up 12% of the prey volume, and had an IRI of 372. Other identifiable fish in the diet included rockfish (Sebastes sp.) (IRI 152) and Pacific saury (IRI 58, volume 6%). Unidentifiable fish had an IRI of 2,114, but accounted for only 10% of the volume (Figure 32, Appendix Table 40).

Twenty-five regurgitation samples from nestlings revealed a minimum of nine species of prey, all of them fish (Appendix Table 41). Pacific herring and Pacific sand lance were by far the most important species. Each occured in 44% of the samples, and they respectively accounted for 37% and 33% of the volume, and 67% and 23% of the prey numbers. Herring had an IRI of 2,439, and sand lance, 4,578 (Figure 32, Appendix Table 41). Rockfish (Sebastes sp.) had an IRI of 101, and values for all other fish were below 84. Species included were saury, rock and kelp greenlings, sablefish, and pollock. Capelin, which were quite important to adult rhinoceros auklets, as well as many other species of seabirds, comprised only 7% of the prey volume of the nestling rhinos, 1% of their numbers, and it occured in only one sample (4%), for an IRI of 32. This may have been because all samples were from Forrester Island near the Canadian border, where capelin may not be as abundant as in areas farther north such as Kodiak (Hart 1973).

Horned Puffin. Of 54 adult horned puffins collected, 40 (74%) had food in their stomachs and they had eaten at least 13 species of prey. Fish was the most important major taxon of prey (IRI 9,141), and crustaceans, squid, polychaetes and chitons were all of relatively minor importance (Appendix Table 42).

Capelin was the most important prey of adult horned puffins. This forage fish made up 51% of all prey numbers, 50% of their volume, and it occured in 28% of the samples, for an IRI of 2,793 (Figure 33, Appendix Table 42). Sand lance was the next most important prey, accounting for 27% of the overall prey volume, and having an IRI of 736. The remaining 11 species were of minor or trace importance in the diet, although gonatid squid (in one stomach only) accounted for 10% of the volume. Four bill load samples from parent birds, intended for nestlings, included three species of fish: Pacific herring, kelp greenling and sand Lance (Figure 33, Appendix Table 43).

Tufted Puffin. Four-hundred-forty adult birds were collected, and 364 (83%) had food in their stomachs, including a minimum of 22 prey species. Six major taxa of prey were found, and fish (IRI 4,844), crustaceans (IRI 604) and cephalopods (IRI 362) had the highest IRI values (Appendix Table 44).

Despite the large number of prey species, only three had IRI values over 100: Capelin (3,464), the euphausiid Thysanoessa inermis (497), and Pacific Sand Lance (254) (Appendix Table 44). Indeed, no other prey had an

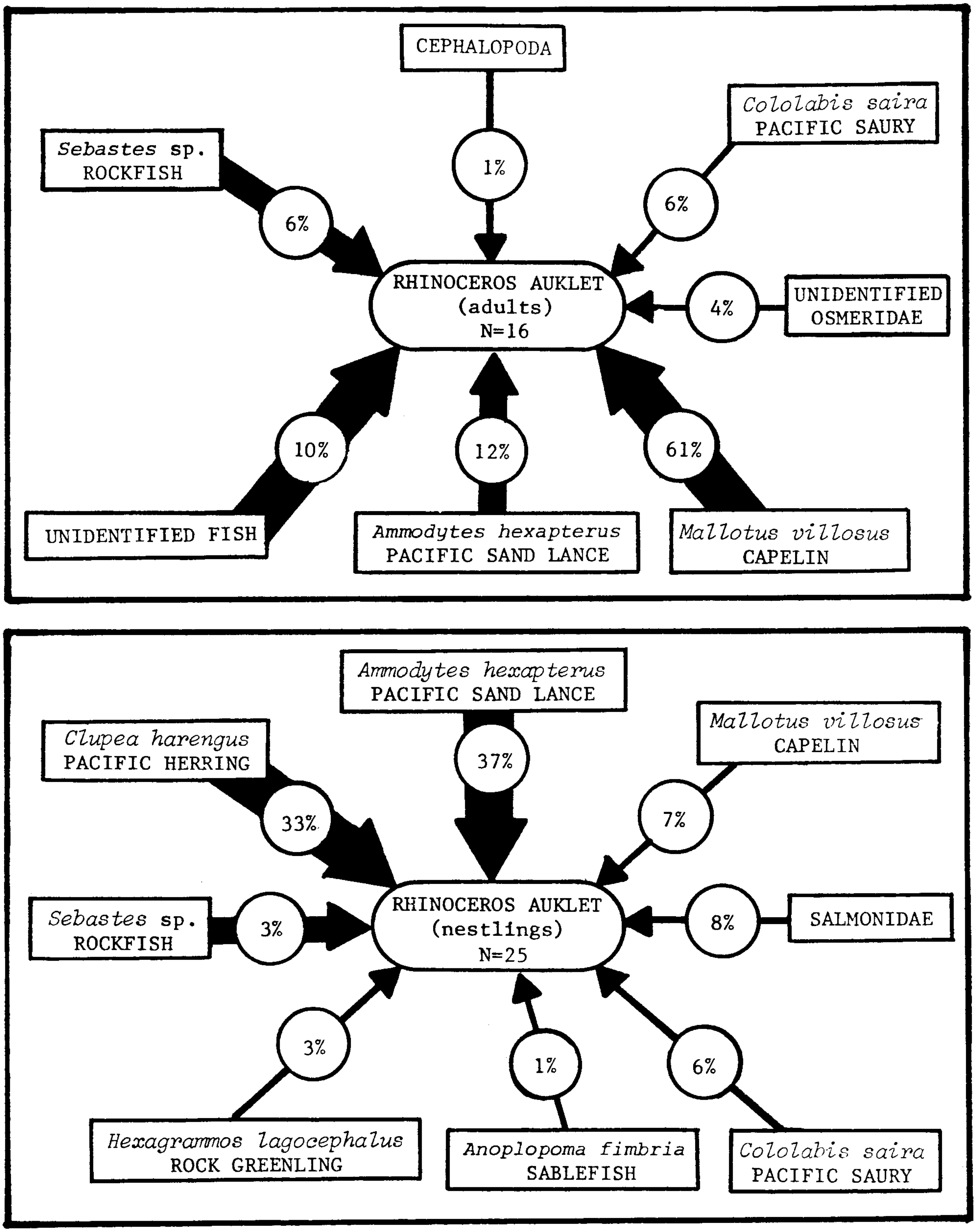


Figure 32. Food webs for adult (top) and nestling (bottom) rhinoceros auklets, showing main prey items as indicated by data pooled from all years, seasons and regions. See Fig. 2 caption.

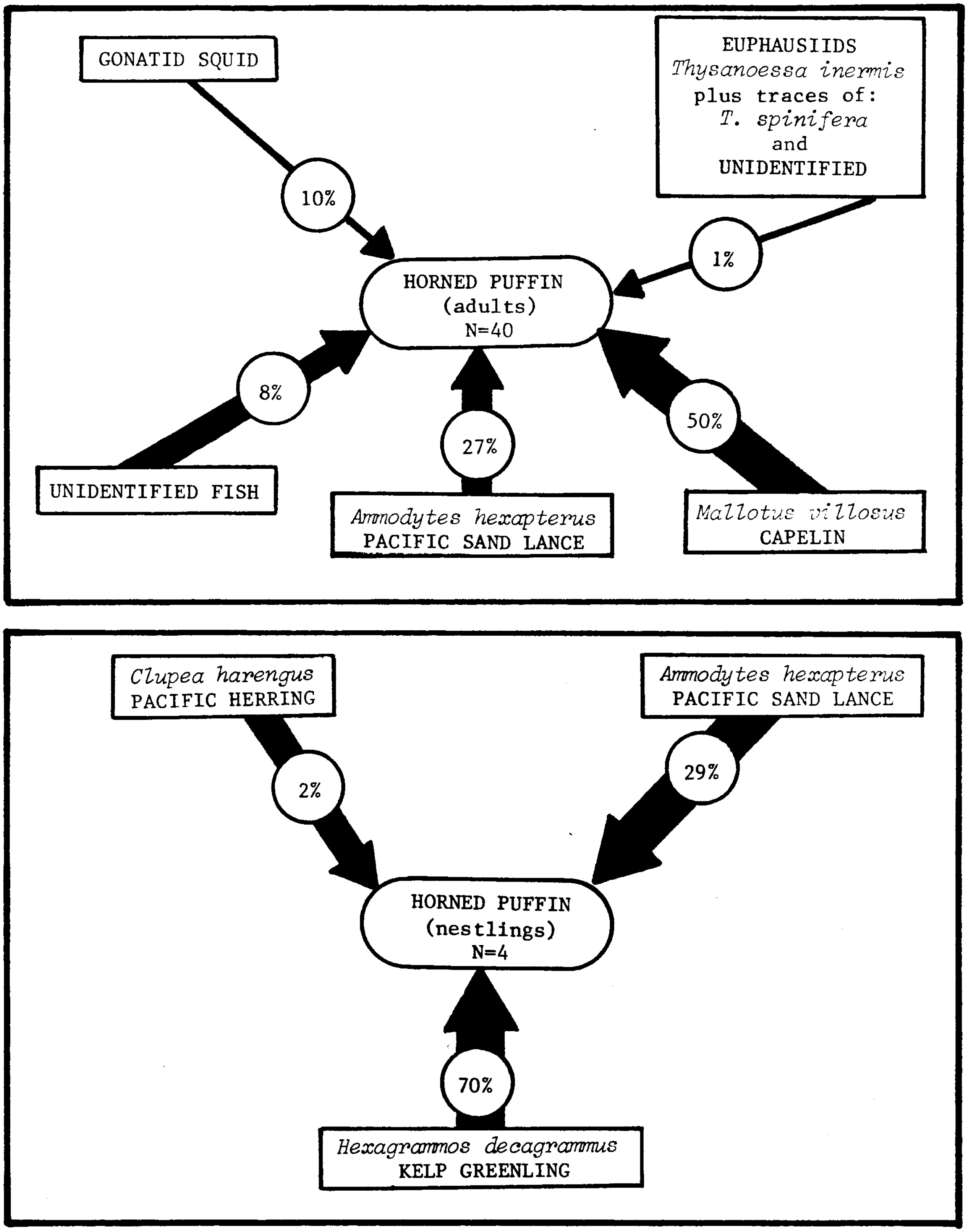


Figure 33. Food webs for adult (top) and nestling (bottom) horned puffins, showing main prey items as indicated by data pooled from all years, seasons and regions. See Fig. 2 caption.

IRI higher than 29 (walleye pollock). Capelin accounted for 61% of the total prey volume, and 17% of the numbers, Thysanoessa inermis 8% and 39% of the same units respectively, and Pacific sand lance 15% and 5%. Walleye pollock made up 4% of the volume, but only 2% of the numbers, and it occured in 5% of the samples (Figure 34, Appendix Table 44). Unidentified cephalopods accounted for 22% of the numbers and 3% of the volume.

The diet of subadult Tufted Puffins was dominated by capelin (IRI 5,850) and Pacific sand lance (IRI 2,998) (Appendix Table 45). Fifty-three percent of the volume of the 60 samples with food was capelin, and 35% was sand lance. These two species accounted for 42% and 40%, respectively, of prey numbers, and they respectively occured in 62% and 40% of the samples (Figure 34, Appendix Table 45). Nereid polychaetes accounted for 10% of the numbers, and had an IRI of 17; no other prey had an IRI higher than 7.

Food Web Relationships Among Puffins. Together, the rhinoceros auklets (a puffin; cf. Storer 1945), and horned and tufted puffins in our samples had eaten a minimum of 29 species of prey, nearly half (14) of them fish. Of these 29 species, however, only three were eaten by all three puffins: Capelin, walleye pollock and Pacific sand lance (Table 9, Figure 35). Unidentified squids were found in all three birds. In general, capelin appeared to be relatively more important in the diets of adult birds than they were to nestlings and subadults, while the opposite was observed with sand lance.

Except for euphausiids, crustaceans occured in the diets of the puffins in trace amounts only. Euphausiids of the genus Thysanoessa were of low to moderate importance to adult horned and tufted puffins, but were absent from the diets of juveniles of all three birds, and from adult rhinoceros auklets.

Pacific herring were of moderate or high importance to subadult rhinoceros auklets and horned puffins (N = 4). Pacific saury were of low importance to both adult and nestling rhinoceros auklets, and Sebastes sp. rockfish were of moderate importance to both age groups (Table 9). Neither species of fish was found in the diets of the other two puffins, however.

DIETS, REGIONAL/SEASONAL DATA

Eleven species of birds with the most comprehensive regional and seasonal data in our data base are discussed in this section. Tables summarize and compare data on the relative importance of prey for each bird species, utilizing prey "importance levels" that are based on exponential increments of the prey's Index of Relative Importance (IRI; see preceeding sections of report); i.e., 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; etc. Sample sizes are often small even when pooled from several years, although there are exceptions, particularly for the Kodiak region. As a general rule, only data sets with a sample size of at least three are included in the tables. In a few cases, however, samples of one or two are included when they provide continuity in comparisons.

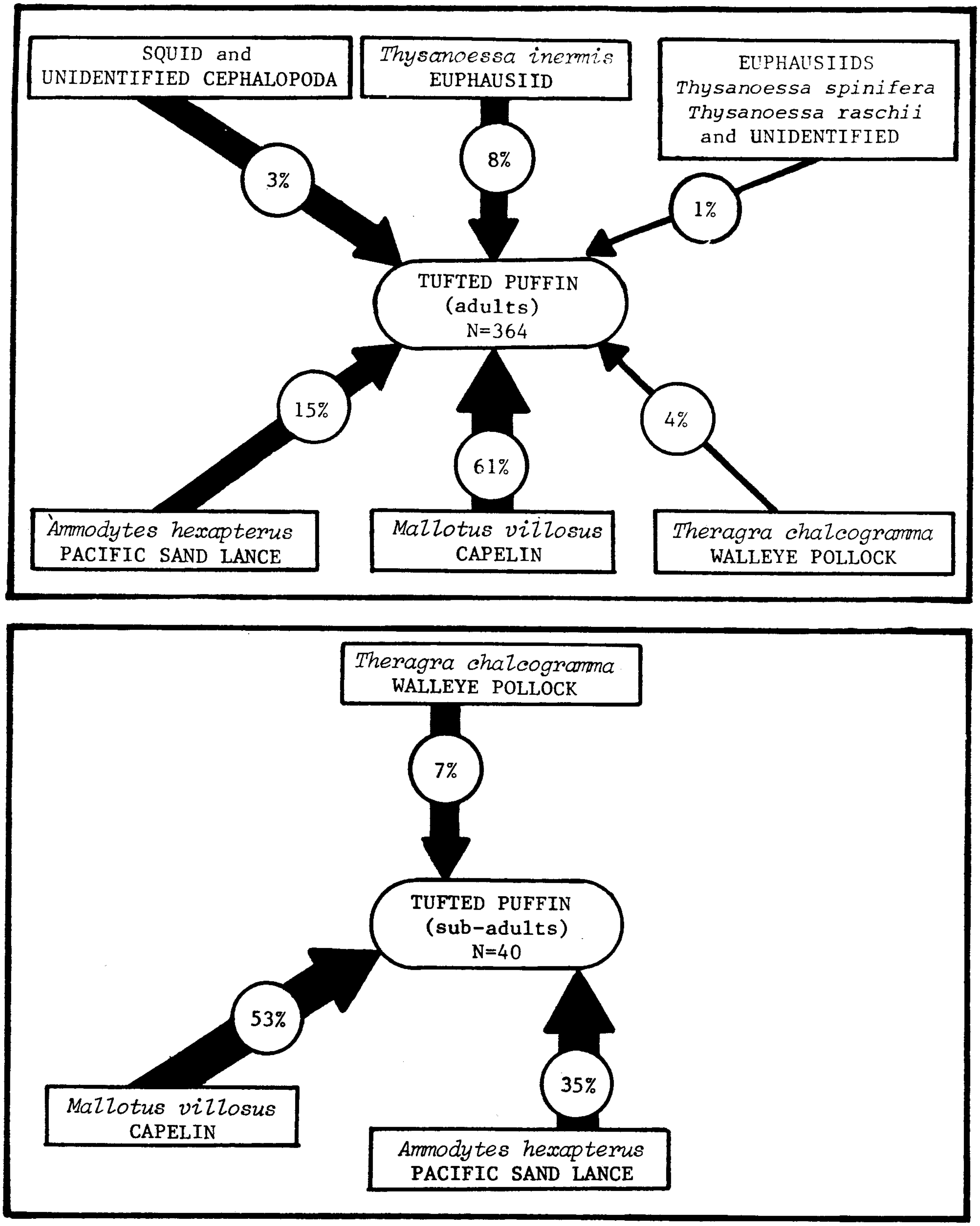


Figure 34. Food webs for adult (top) and sub-adult (bottom) tufted puffins, showing main prey items as indicated by data pooled from all years, seasons and regions. See Fig. 2 caption.

Table 9. Comparative importance of prey to adult and sub-adult puffins, based on data pooled from food samples from birds in Alaskan waters. Importance levels of prey based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000+ = 3

	Importance of Prey to Bird Species					
	Rhinoceros Auklets		Horned Puffins		Tufted Puffin	
	Adults	Nestlngs	Adults	Nestlings	Adults	Sub-Ads.
PREY NAME	N = 16	N = 25	N = 40	N = 4	N = 364	N = 60
POLYCHAETA, Nereidae	-	-	1	-	tr	1
PTEROPODA						
Limacina helicina	-	-	-	-	tr	-
POLYPLACOPHORA, Chiton	-	-	tr	-	-	-
ACARINA, Unident. Mite	-	-	-	-	tr	-
CEPHALOPODA						
Squid & Unidentified	1	-	1	-	2	tr
Gonatid Squid	-	-	1	-	-	-
Unidentified Octopi	-	-	-	-	-	tr
CRUSTACEA						
Calanoid Copepod	-	-	-	-	tr	-
Anisogammarus pugettensis Gammarid Amphipod	-	-	tr	-	-	-
Unident. Gammarid	-	-	-	-	tr	-
Parathemisto libellula Hyperiid Amphipod	-	-	-	-	tr	-
Acanthomysis sp. Mysid	-	-	tr	-	-	-
Euphausiids						
Thysanoessa inermis	-	-	1	-	2	-
T. spinifera	-	-	tr	-	1	-
T. raschii	-	-	-	-	tr	-
T. sp.	-	-	-	-	1	-
Unidentified	-	-	tr	-	tr	-
Decapods						
Pandalus montagui Pandalid Shrimp	-	-	tr	-	-	-
P. sp.	-	-	-	-	tr	-
Pagurid Crab	-	-	-	-	tr	-

Table 9. Comparative importance of prey to puffins, page 2 of 2

	Importance of Prey to Bird Species					
	Rhinoceros Auklets		Horned Puffins		Tufted Puffin	
	Adults	Nestlngs	Adults	Nestlings	Adults	Sub-Ads.
PREY NAME	N = 16	N = 25	N = 40	N = 4	N = 364	N = 60
FISH						
Clupea harengus Pacific Herring	-	3	-	2	-	-
Onchorhynchus nerka Red Salmon	-	-	-	-	tr	-
Unident. Salmonid	-	1	-	-	-	-
Mallotus villosus Capelin	3	1	3	-	3	3
Unident. Osmerid	1	-	-	-	tr	-
Microgadus proximus Pacific Tomcod	-	-	-	-	tr	-
Theragra chalcogramma Walleye Pollock	-	tr	tr	-	1	2
Cololabis saira Pacific Saury	1	1	-	-	-	-
Gasterosteus aculeatus Threespine Stickleback	-	-	tr	-	-	-
Trichodon trichodon Pacific Sandfish	-	-	-	-	tr	tr
Sebastes sp. Rockfish	2	2	-	-	-	-
Anoplopoma fimbria Sablefish	-	1	-	-	-	-
Hexagrammos decagrammus Kelp Greenling	-	tr	-	3	-	-
H. lagocephalus Rock Greenling	-	1	-	-	-	-
Unident. Cyclopterid Snailfish	-	-	-	-	tr	-
Ammodytes hexapterus Pacific Sand Lance	2	3	2	3	2	3
Unidentified	3	tr	2	-	-	-

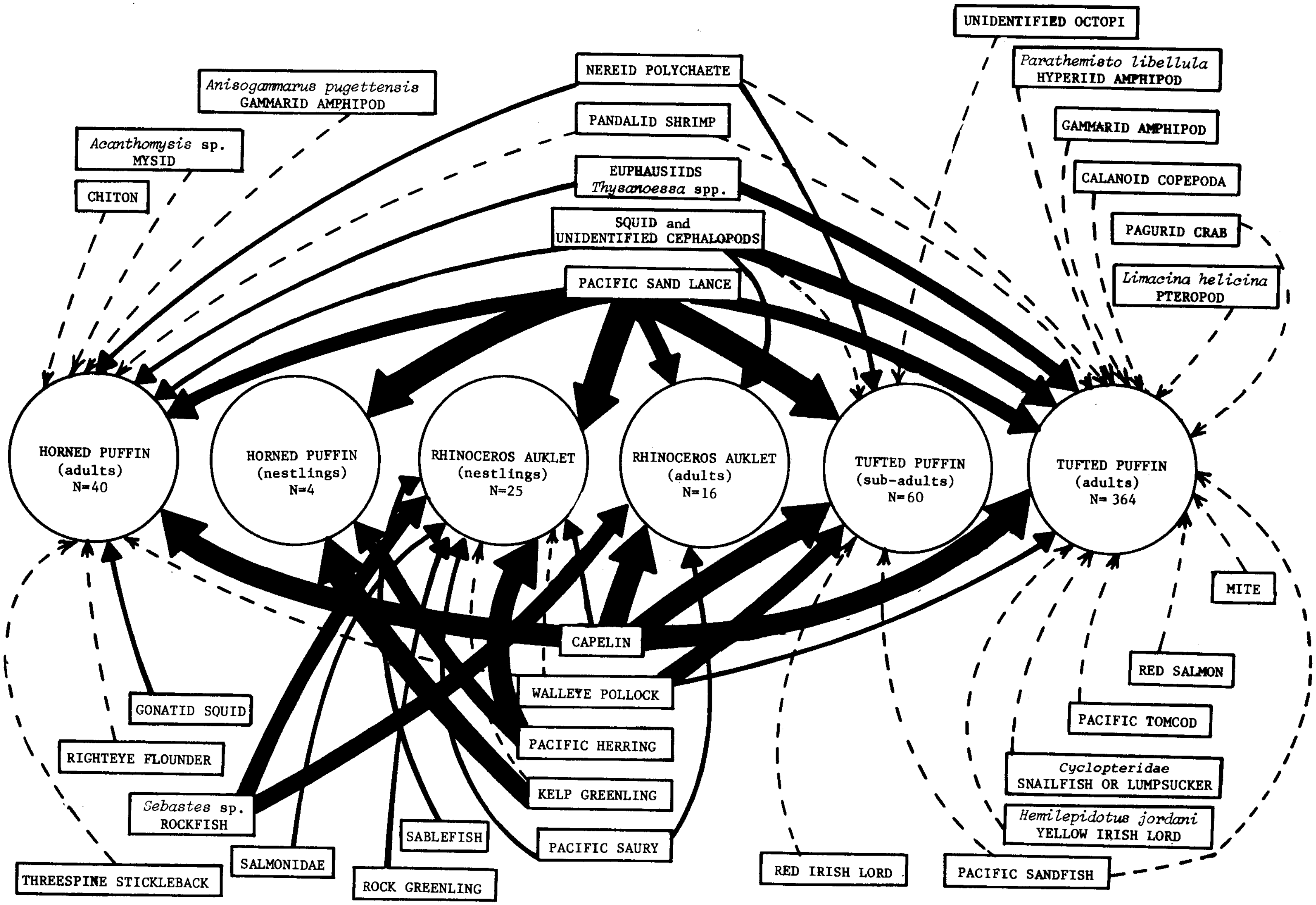


Figure 35. Food web relationships among adults and sub-adults of the three species of North Pacific puffins, based on data pooled from all years, seasons, and regions. See Fig. 4 caption.

Prey are listed as "present" in these cases, rather than by numerical importance level.

Complete, computer-generated listings of percent numbers, volume and frequency of occurence of the prey of all bird species for each set of regional/seasonal data are on file at the U.S. Fish and Wildlife Service, Research-Migratory Birds, 1011 E. Tudor Rd, Anchorage, AK 99503.

Northern Fulmar

Food samples from fulmars were restricted to the Kodiak and Northeast Gulf of Alaska (NEGOA) regions, and the spring, summer, and fall seasons (Table 10). In general, cephalopods (including gonatid squid and "unidentified") were important foods eaten in both regions.

Euphausiids had been eaten by birds in the Kodiak region in summer and fall. Other crustaceans eaten in the region included calanoid copepods and amphipods. In contrast, crustaceans had been less heavily utilized by 15 birds sampled in the NEGOA. Capelin and unidentified gadid fishes were eaten by birds from Kodiak, while walleye pollock had been eaten by birds from NEGOA.

Sooty Shearwater

Sooties were sampled in the Aleutian, Western Gulf of Alaska (WGOA), Kodiak, and NEGOA regions, and during the spring, summer and fall seasons (Table 11). Cephalopods, including unidentified squid, were consistently important in the diet of birds from all four regions and all three seasons sampled.

Fish had been eaten by birds collected in WGOA, Kodiak and NEGOA. In particular, capelin were important to birds from Kodiak and NEGOA in summer, and Kodiak in fall. A lanternfish (Myctophidae), *Stenobrachius nannochir*, occured in the diet of birds from WGOA in spring.

Crustaceans appeared to be utilized by Sooty Shearwaters less heavily than other prey, although the gammarid amphipod *Paracallisoma alberti* was important to birds from the Aleutian and WGOA regions, and euphausiids were of moderate importance in the diet of birds from the Kodiak and NEGOA regions in summer.

Short-tailed Shearwater

Samples of Short-tailed Shearwaters for comparative purposes are available only from the Bering Sea and Kodiak regions, and the spring, summer and fall seasons (Table 12).

Cephalopods were present in the diet of birds sampled in both regions, during all seasons sampled. Crustaceans were relatively important to birds in both areas and all three seasons sampled. The large (20-60 mm) hyperiid amphipod *Parathemisto libellula* was utilized by birds from the Bering Sea in fall, and euphausiids of the genus *Thysanoessa* had been eaten by birds from both areas. *T. inermis* was especially important to birds from the Kodiak Region.

Table 10. Comparison of the importance of the main prey species of northern fulmars in Alaskan waters by major geographic region and season. Prey Importance levels based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000 - 9,999 = 3; 10,000 and up = 4.
Seasons: Sp = Spring; Su = summer; F = fall.

	Kodiak			Northeastern Gulf of Alaska	
	Sp	Su	F	Su	F
Sample Size =	4	5	3	3	12
PREY NAME					
Nereid Polychaete	-	-	-	-	1
Unidentified Bivalve	-	-	-	-	2
Gonatid Squid	4	-	-	-	-
Unidentified Cephalopod	-	3	4	-	4
Calanoid Copepod	-	2	-	-	-
Parathemisto pacifica Hyperiid Amphipod	-	1	-	-	-
Gammarid Amphipod	-	-	-	2	-
Thysanoessa inermis	-	2	-	-	-
Unidentified Euphausiid	-	-	3	-	-
Unidentified Crustacean	-	-	-	-	1
Capelin	-	2	-	-	-
Walleye Pollock	-	-	-	3	-
Unidentified Gadid Fish	-	-	2	-	1
Unidentified Fish	-	-	2	2	1

Table 11. Comparison of the importance of the main prey species of sooty shearwaters in Alaskan waters by major geographic region and season. Prey Importance levels based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000 - 9,999 = 3; 10,000 and up = 4.

	Aleutians	Western Gulf of Alaska	Kodiak		Northeastern Gulf of Alaska
	Su	Sp	Su	F	Su
Sample Size =	3	3	133	19	16
PREY NAME					
Nereid Polychaete.....	-	-	tr	tr	-
Onychoteuthis sp...... Squid	-	-	-	-	tr
Gonatid Squid.........	-	-	-	-	2
Un. Squid/Cephalopod..	3	2	3	3	3
Calanoid Copepod......	-	-	tr	-	-
Paracallisoma alberti. Gammarid Amphipod	2	3	-	-	-
Parathemisto pacifica. Hyperiid Amphipod	3	-	-	-	-
Un. Hyperiid Amphipod.	-	-	tr	-	-
Thysanoessa inermis...	-	-	2	-	tr
T. raschii............	-	-	-	-	tr
T. spinifera..........	-	-	tr	-	-
T. sp./Un. Euphausiid.	-	-	-	-	2
Capelin...............	-	-	3	4	3
Stenobrachius nannochir (Mytophid)	-	3	-	-	-
Pacific Tomcod........	-	-	tr	-	-
Pacific Sandfish......	-	-	tr	-	-
Pacific Sand Lance....	-	-	2	-	-
Unidentified Fish.....	-	3	2	1	tr

Table 12. Comparison of the importance of the main prey species of short-tailed shearwaters in Alaskan waters, by major geographic region and season. Prey Importance levels based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000 - 9,999 = 3; 10,000 and up = 4. Seasons: Sp = spring; Su = summer; F = fall.

	Bering Sea		Kodiak		
	Su	F	Sp	Su	F
Sample Size =	24	6	3	141	21
PREY NAME					
Nereid Polychaete.....	-	-	-	tr	tr
Unident. Gastropod....	-	-	-	tr	-
Gonatid Squid.........	-	1	-	-	-
Un. Squid/Cephalopod..	2	2	2	1	1
Parathemisto libellula Hyperiid Amphipod	-	3	-	-	-
P. pacifica........... Hyperiid Amphipod	-	tr	-	-	-
Gammarid Amphipod	-	-	-	-	tr
Thysanoessa inermis...	tr	-	3	2	tr
T. raschii............	2	-	-	1	1
T. spinifera..........	-	-	-	1	tr
T. sp./Un. Euphausiid.	3	-	-	3	2
Telmessus chieragonus. Crab	-	-	-	tr	-
Unident. Decapod......	-	-	-	tr	-
Unident. Crustacean...	-	-	3	-	tr
Capelin...............	-	-	-	2	3
Walleye Pollock.......	-	2	-	-	-
Pacific Sand Lance....	tr	-	-	1	tr
Unidentified Fish.....	-	1	2	1	2

Fish were utilized more sporadically by the birds sampled than were cephalopods or crustaceans. In the Bering Sea, walleye pollock had been eaten by birds collected in the fall, and in the Kodiak region, capelin were important in the diet of birds collected in summer and fall. Pacific sand lance were present in the diets of birds from both areas, but were of low importance compared to other foods.

Pelagic Cormorant

Food samples from this species were obtained from five birds collected in the spring in the Kodiak region, and from four birds each in summer in Kodiak and the NEGOA regions (Table 13). Except for sea urchins and unidentified decapods (shrimps and crabs), the diet of birds collected consisted of fish. Capelin and pollock were important to birds from the Kodiak region, and Pacific sand lance were important dietary components to birds from both regions.

Black-legged Kittiwake

Comparative samples were available from the summer and fall seasons, and from the Bering, WGOA, Kodiak, lower Cook Inlet (LCI), and NEGOA regions (Table 14). Over this broad geographical range, kittiwakes ate a wide variety of crustaceans, fish, and other prey, although they ate many of these in trace amounts only.

In general, amphipods appeared to be important foods of kittiwakes in all areas. The gammarid amphipod *Paracallisoma alberti* was eaten by birds from the WGOA and NEGOA in fall, while the hyperiid amphipod *Parathemisto libellula* was important to birds from the Bering and LCI regions in fall. The occurence of *P. libellula* in birds from LCI is noteworthy, since it provides records of this crustacean at the sea surface in an area between its previously-known disjunct distribution over shelf waters of the Bering Sea (the apparant center of its distribution) and southeastern Alaska (Wing 1976). Similarly, the occurence of a specimen of *Parathemisto japonica* in a summer bird from the Kodiak region represents an eastward extension from its previously-known eastern range limit near Unimak Pass (Fukuchi 1970).

Euphausiids assumed moderate to low importance to birds from the Kodiak and NEGOA regions, but they were absent from the diet of 10 birds from the Bering region. *Thysanoessa inermis* was common in the diet of summer birds from Kodiak and NEGOA, while *T. spinifera* was moderately important to fall birds from Kodiak and to summer birds from the NEGOA region.

Capelin were prominent in the diet of birds from the Kodiak region, especially in summer. Walleye pollock had been eaten by birds from all regions, but appeared to be most important in the Bering region. Pacific sand lance were consistently present in the diet of birds from the Kodiak, LCI and NEGOA regions. Four birds from the LCI region in fall had eaten Pacific herring, but this species was otherwise absent from the diet of birds from other areas.

Table 13. Comparison of the importance of the main prey species of adult pelagic cormorants in Alaskan waters, by major geographic region and season. Prey Importance levels based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000 - 9,999 = 3; 10,000 and up = 4. Seasons: Sp = spring; Su = summer.

	Kodiak		Northeastern Gulf of Alaska
	Sp	Su	Su
Sample Size =	5	4	4
PREY NAME			
Echinoid (Sea.Urchin).	-	2	-
Unident. Decapod......	1	-	-
Capelin...............	-	3	-
Walleye Pollock.......	2	-	-
Unident. Cottid Fish..	-	-	3
Pacific Sand Lance....	4	3	3

Table 14. Comparison of the importance of the main prey species of black-legged kittiwakes in Alaskan waters, by major geographic region and season. Prey Importance levels based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000 - 9,999 = 3. Seasons: Su = summer; F = fall.

	Bering Sea		W Gulf of Ak.	Kodiak		Lower Cook Inlet	NE Gulf of AK	
	Su	F	F	Su	F	F	Su	F
Sample Size =	4	6	5	201	28	4	16	3
PREY NAME								
Nereid Polychaete.....	2	-	-	2	tr	-	2	-
Unident. Cephalopod...	-	1	-	-	-	-	1	-
Katharina tunicata.... Chiton	-	-	-	tr	-	-	-	-
Limacina helicina..... Pteropod	-	-	-	-	-	-	2	-
Blue Mussel...........	-	-	-	tr	-	-	tr	-
Calanoid Copepod......	-	-	-	tr	-	-	-	-
Gooseneck Barnacle....	-	-	-	tr	-	-	-	-
Amphipods								
Paracallisoma alberti.	-	-	3	-	-	-	-	3
Unidentified Gammarid.	-	-	-	tr	tr	-	-	-
Parathemisto libellula	-	3	-	-	-	3	-	-
P. pacifica...........	-	-	2	-	-	-	-	-
P. japonica...........	-	-	-	tr	-	-	-	-
Euphausiids								
Thysanoessa inermis...	-	-	-	2	tr	-	2	-
T. raschii............	-	-	-	tr	-	-	-	-
T. spinifera..........	-	-	-	tr	2	-	2	-
Decapods								
Hymenodora frontalis.. Pac. Ambereye Shrimp	-	-	-	-	-	-	-	-
Pandalopsis dispar.... Sidestripe Shrimp	-	-	-	-	1	-	-	-
Unident. Pandalid.....	-	-	-	-	1	-	-	-
Cancer sp. (Crab).....	-	-	-	-	-	2	-	-
Unidentified..........	-	-	2	-	-	-	-	-
Fish								
Pacific Herring.......	-	-	-	-	-	3	-	-
Capelin...............	-	-	-	3	2	-	-	-
Unident. Osmerid......	-	-	-	1	-	-	2	3
Pacific Cod...........	-	1	-	-	-	-	-	-
Walleye Pollock.......	2	3	2	tr	1	2	1	-
Unidentified Gadid....	-	-	3	tr	1	-	-	2
Pacific Sandfish......	-	-	-	tr	-	-	-	-
Pacific Sand Lance....	-	-	-	2	3	3	3	-
Unidentified..........	3	-	2	2	2	2	2	3

Common Murre

Compared with other species, sample sizes from murres were distributed fairly evenly among all seasons in the Bering, LCI, NEGOA, and particularly in the Kodiak regions (Table 15). The overall diet of common murres was dominated by fish, but they had eaten some crustaceans.

Mysids were important foods of birds collected in winter in Kodiak (*Acanthomysis* sp.) and LCI (*Neomysis rayii*). Euphausiids were of moderate importance to birds collected in summer in the Bering Sea (*Thysanoessa raschii*) and Kodiak (*T. inermis*). Shrimps had low to moderate importance for birds collected in winter in Kodiak (unidentified pandalids), and LCI (pink and humpy shrimp; *Eualus* sp.), and in LCI in spring (pink shrimp and *Crangon franciscorum*).

The kittiwakes collected had eaten at least 10 species of fish from the four regions sampled, but three species stood out as important foods: Capelin, walleye pollock, and Pacific sand lance. Capelin had been eaten by birds in the Bering region in summer, in the Kodiak region during all seasons, in the LCI region in winter, spring and fall, and in the NEGOA region in summer. Pollock was an important food of Kodiak birds in winter and spring, but less so in summer and fall. In the LCI region, pollock were of low or moderate importance in winter and spring. Pacific sand lance were present in the diet of birds from the Bering region in summer, and they were present in Kodiak birds during all four seasons (lowest importance in winter, intermediate in spring and summer, and highest in the fall). In the LCI region in winter sand lance were a trace item in the murres' diet, but in the NEGOA region in summer they were an important food in the diet of nine birds collected.

Thick-billed Murre

Thick-bills were collected in the Bering, Aleutian, WGOA and Kodiak regions (Table 16). Unidentified cephalopods were the only prey of murres collected in winter in the Aleutian and WGOA regions, and they were also prominent in the diet of Aleutian birds in summer. *Parathemisto libellula* was an important food of birds from the Bering region in summer and fall, and euphausiids were similarly important to Aleutian birds in summer; *Thysanoessa inermis* was a component in samples from the Kodiak region in summer.

Capelin were important to summer birds from Kodiak, but they were otherwise absent from the diet of thick-billed murres. Arctic Cod, a species not found south of the Bering Sea, was of moderate importance there to birds collected in summer, while pollock had been eaten by birds taken from both the Bering and Kodiak regions in summer, but not elsewhere. The "unidentified gadids" important to birds from the Bering region in fall were likely walleye pollock (*cf.* notes on prey identity in a preceeding section). Pacific sand lance were found only in thick-bills collected in summer in the Bering and Kodiak regions.

Marbled Murrelet

Marbled murrelets were collected in all four regions of the Gulf of Alaska: WGOA, Kodiak, LCI, and NEGOA (Table 17). Fish were generally the

Table 15. Comparison of the importance of the main prey species of common murres in Alaskan waters, by major geographic region and season. Prey Importance levels based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000 - 9,999 = 3; 10,000 and up = 4; x = present. Seasons: W = winter; Sp = spring; Su = summer; F = fall.

	Bering Sea			Kodiak				Lower Cook Inlet			NE Gulf of AK	
	W	Su	F	W	Sp	Su	F	W	Sp	F	W	Su
Sample Size =	1	6	1	11	11	81	8	23	9	5	2	9
PREY NAME												
Nereid Polychaete.....	-	-	-	tr	-	-	-	tr	-	-	-	-
Unidentified Squid....	-	-	-	-	-	tr	-	-	-	-	-	-
Acanthomysis sp.......	-	-	-	2	-	-	-	-	-	-	-	-
Neomysis rayii........	-	-	-	-	-	-	-	3	-	-	-	-
Anonyx sp.(gamm. amph)	-	-	-	-	-	-	-	-	-	-	x	-
Gammarid Amphipod.....	-	-	-	1	-	-	-	-	-	-	-	-
Euphausiids												
Thysanoessa inermis...	-	-	-	tr	-	2	-	-	-	-	-	-
T. raschii............	-	2	-	-	-	tr	-	-	-	-	-	-
T. sp./Un. Euphausiid.	-	-	-	-	-	2	-	-	-	-	-	-
Shrimp												
Eualus sp.............	-	-	-	-	-	-	-	tr	-	-	-	-
Pink Shrimp...........	-	-	-	tr	-	-	-	2	3	-	-	-
Humpy Shrimp..........	-	-	-	-	-	-	-	tr	-	-	-	-
Unidentified Pandalid.	-	-	-	2	-	-	-	1	-	-	-	-
Crangon franciscorum..	-	-	-	-	-	-	-	1	2	-	-	-
Unidentified Shrimp...	-	-	-	-	-	-	-	1	2	-	-	-
Unidentified Insect...	-	-	-	-	-	-	-	-	-	-	x	-
Fish												
Pacific Herring.......	-	-	-	-	-	-	-	1	-	-	-	-
Capelin...............	-	3	-	2	2	3	3	1	2	3	-	1
Pacific Cod...........	-	-	-	-	-	tr	-	-	-	-	-	-
Pacific Tom Cod.......	-	-	-	-	-	tr	-	-	1	-	-	-
Walleye Pollock.......	-	-	x	3	3	1	1	1	2	-	-	-
Unidentified Gadid....	x	2	-	2	3	1	-	tr	2	-	-	-
Pacific Sandfish......	-	-	-	tr	-	1	-	-	-	-	-	-
Daubed Shanny.........	-	-	-	1	-	-	-	-	2	-	-	-
Snake Prickleback.....	-	-	-	-	-	-	-	-	-	-	-	2
Pacific Sand Lance....	-	2	-	1	2	2	3	tr	-	-	-	3
Pleuronectid flounder.	-	-	-	-	-	tr	-	-	-	-	-	-
Unidentified Fish.....	-	3	-	-	1	2	1	1	2	3	-	2

Table 16. Comparison of the importance of the main prey species of thick-billed murres in Alaskan waters, by major geographic region and season. Prey Importance levels based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000 - 9,999 = 3; 10,000 and up = 4; x = present Seasons: W = winter; Sp = spring; Su = summer; F = fall.

	Bering Sea			Aleutians			W Gulf of AK	Kodiak
	Sp	Su	F	W	Sp	Su	W	Su
Sample Size =	1	5	3	4	2	4	4	9
PREY NAME								
Nereid Polychaete.....	-	-	2	-	-	-	-	-
Unident. Gastropod....	-	-	-	-	-	-	-	1
Unident. Cephalopod...	-	-	-	4	x	3	4	1
Calanoid Copepod......	-	-	-	-	-	1	-	-
Gammarid Amphipod.....	-	-	-	-	-	1	-	-
Parathemisto libellula	-	3	3	-	-	-	-	-
P. pacifica...........	-	-	-	-	x	-	-	-
Thysanoessa inermis...	-	-	-	-	-	-	-	1
Unident. Euphausiid...	-	-	-	-	-	3	-	-
Unident. Decapod......	-	-	-	-	-	-	-	1
Crangon sp. (shrimp)..	-	2	-	-	-	-	-	-
Unidentified Crustacea	-	-	2	-	-	-	-	-
Capelin...............	-	-	-	-	-	-	-	3
Arctic Cod............	-	2	-	-	-	-	-	-
Walleye Pollock.......	-	1	-	-	-	-	-	2
Unidentified Gadid....	x	1	3	-	-	-	-	2
Pacific Sand Lance....	-	2	-	-	-	-	-	2
Unidentified Fish.....	-	2	3	-	-	3	-	2

Table 17. Comparison of the importance of the main prey species of marbled murrelets in Alaskan waters, by major geographic region and season. Prey Importance levels based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000 - 9,999 = 3; 10,000 and up = 4; x = present. Seasons: W = winter; Sp = spring; Su = summer; F = fall.

	W Gulf of AK	Kodiak			Lower Cook Inlet			NE Gulf of AK	
	Su	W	Sp	Su	W	Sp	F	Su	F
Sample Size =	5	31	11	45	13	6	2	15	1
PREY NAME									
Nereid Polychaete.....	-	tr	-	-	-	-	-	-	-
L. sitkana(Periwinkle)	-	-	-	1	-	-	-	-	-
Unident. Gastropod....	-	-	-	tr	-	-	-	-	-
Blue Mussel...........	-	-	-	tr	-	-	-	-	-
Cephalopoda...........	-	-	-	tr	-	-		-	-
Acanthomysis sp.......	-	3	-	-	-	-	-	-	-
Neomysis rayii........	-	1	-	-	-	-	x	-	-
N. sp./Un. Mysid......	-	2	-	-	2	-	-	-	-
Gammarid Amphipod.....	-	tr	-	-	1	-	-	-	-
Euphausiids									
Thysanoessa inermis...	-	2	2	1	1	-	-	3	-
T. raschii............	-	tr	1	-	2	3	-	-	-
T. spinifera..........	-	tr	-	-	1	-	-	1	-
T. sp./Un. Euphausiid.	2	1	-	tr	2	2	-	1	-
Pandalus borealis.....	-	tr	-	-	-	-	-	-	-
Unident. Decapod......	-	-	-	tr	-	-	-	-	-
Arrow Worm (Chaetog.).	-	tr	-	-	-	-	-	-	-
Fish									
Capelin...............	-	2	3	3	3	3	-	1	x
Unidentified Osmerid..	2	2	1	-	tr	2	-	-	-
Walleye Pollock.......	-	tr	-	-	tr	-	-	-	-
Unidentified Gadid....	-	-	-	tr	tr	-	-	-	-
Pacific Sandfish......	2	-	-	1	-	-	-	2	-
Pacific Sand Lance....	2	-	2	3	2	-	x	3	x
Unidentified Fish.....	3	1	1	3	2	-	-	2	-

most important kinds of prey, but crustaceans were also sometimes heavily utilized. In addition, birds from the Kodiak region had eaten small amounts of nereid polychaetes, periwinkle "snails," blue mussels, cephalopods and arrow worms (Chaetognatha). The periwinkles and mussels indicate that the murrelets collected had foraged on the bottom.

Capelin were prominent in the diet of birds taken in the Kodiak region during winter, spring and summer, and in the LCI region during winter and spring. Small amounts of capelin were found in the stomachs of birds from the NEGOA region in summer. Pacific sand lance had been eaten by birds in all regions: In WGOA, Kodiak, and NEGOA in summer; in Kodiak in spring; and, in LCI in winter. Pacific sandfish were of moderate importance in the summer diets of birds from the WGOA and NEGOA regions, but of low importance to summer birds from Kodiak. Walleye pollock and unidentified gadids occured in trace amounts during winter in the stomachs of murrelets from the Kodiak and LCI regions, and during summer in Kodiak birds.

During summer in the WGOA region, unidentified euphausiids were the only prey besides fish. Mysids were important winter foods of birds from the Kodiak and LCI regions, and euphausiids of the genus *Thysanoessa* figured heavily in the winter and spring diets of birds collected in both the Kodiak and LCI regions. *T. inermis* had a low importance to summer birds from Kodiak, but in the NEGOA region in summer it was relatively more important.

Kittlitz's Murrelet

This little-known species was collected in the Bering region in spring, and in the Kodiak and NEGOA regions in summer (Table 18). The diet of murrelets from the Bering region was solely crustaceans (the euphausiid *T. spinifera*) and unidentified gammarid amphipods), while in the Gulf of Alaska regions, the birds' diets consisted of both crustaceans and fish.

In the Kodiak region, *T. inermis*, capelin and Pacific sand lance were equally important in the diet of birds collected, while in the NEGOA region Kittlitz's murrelets had eaten euphausiids (*T. spinifera* and unidentified), Pacific herring, unidentified osmerids, and Pacific sandfish.

Horned Puffin

Horned puffins were collected during summer in the Aleutian, WGOA, Kodiak, LCI and NEGOA regions, and during fall and winter in the Kodiak region (Table 19). In the Aleutian region, gonatid squid and unidentified cephalopods and unidentified fish were the main prey of three birds collected, and they had eaten nereid polychaetes as well.

Although capelin was the main prey of summer birds from the WGOA region, this was the only region where crustaceans made up a substantial portion of the diet as well. The euphausiid *Thysanoessa inermis* and the shrimp *Pandalus montagui* assumed moderate importance there, along with unidentified euphausiids and Pacific sand lance.

In the Kodiak region Pacific sand lance and pleuronectid flatfish

Table 18. Comparison of the importance of the main prey species of Kittlitz's murrelets in Alaskan waters, by major geographic region and season. Prey Importance levels based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000 - 9,999 = 3; 10,000 and up = 4; x = present Seasons: Sp = spring; Su = summer.

	Bering Sea	Kodiak	NE Gulf of AK
	Sp	Su	Su
Sample Size =	3	7	4
PREY NAME			
Gammarid Amphipods....	2	-	-
Thysanoessa inermis...	-	2	-
T. spinifera..........	3	-	2
Unident. Euphausiids..	3	-	3
Pacific Herring.......	-	-	2
Capelin...............	-	2	-
Unidentified Osmerid..	-	-	2
Pacific Sandfish......	-	-	3
Pacific Sand Lance....	-	2	-
Unidentified Fish.....	-	3	3

Table 19. Comparison of the importance of the main prey species of horned puffins in Alaskan waters, by major geographic region and season. Prey Importance levels based on their IRI values, as follows: 0 - 9 = trace (tr); 10 - 99 = 1; 100 - 999 = 2; 1,000 - 9,999 = 3; 10,000 and up = 4; x = present. Seasons: W = winter; Su = summer; F = fall.

	Aleutians	W Gulf of AK	Kodiak			L Cook Inlet	NE Gulf of AK
	Su	Su	W	Su	F	Su	Su
Sample Size =	3	6	1	15	8	3	2
PREY NAME							
Nereid Polychaete.....	2	-	-	1	-	-	-
Unidentified Chiton...	-	-	-	1	-	-	-
Gonatid Squid.........	3	-	-	-	-	-	-
Unident. Cephalopod...	3	-	-	-	-	-	-
Anisogammarus pugettensis (Gam. Amphipod)	-	-	-	1	-	-	-
Acanthomysis (Mysid)..	-	-	x	-	-	-	-
Thysanoessa inermis...	-	2	x	-	-	-	-
T. spinifera..........	-	-	x	-	-	-	-
Unident. Euphausiid...	-	2	-	-	-	-	-
Pandalus montagui.....	-	2	-	1	-	-	-
Pacific Herring.......	-	-	-	-	-	-	-
Capelin...............	-	3	x	1	4	-	-
Unidentified Osmerid..	-	-	-	-	-	-	-
Walleye Pollock.......	-	-	-	-	1	-	-
Unident. Gadidae......	-	-	-	-	1	-	-
Three-spine Stickleback	-	-	-	-	1	-	-
Kelp Greenling........	-	-	-	-	-	-	-
Pacific Sand Lance....	-	2	-	3	2	-	x
Pleuronectid Flounder.	-	-	-	2	-	-	-
Unidentified Fish.....	3	3	x	3	-	4	-

were the most important summer prey, but the 15 birds collected had also eaten lesser amounts of capelin, *P. montagui*, a gammarid amphipod (*Anisogammarus pugettensis*), nereid polychaetes, and chitons. The fall diet, however, was dominated by capelin, with lesser amounts of Pacific sand lance present, and small amounts of pollock and three-spined sticklebacks. Mysids, euphausiids, and capelin were present in the stomach of the lone bird collected in winter.

Unidentified fish was the only prey found in summer birds from the LCI region, and Pacific sand lance was the only prey in two birds from the NEGOA region in summer.

Tufted Puffin

The tufted puffin had the distinction of being the only species sampled extensively enough to compare among all six geographic regions. Only the summer season was represented in all regions, however, and other seasons had sporadic regional sampling (Table 20). Ninteen kinds of prey occurred in the samples, although six of them were present in trace quantities only, in birds sampled during summer in the Kodiak region (n = 282).

Unidentified cephalopods and squid had been eaten in all regions except LCI, and they had an importance level of 4 (IRI $\geq$ 10,000) for birds sampled during both winter and summer in the Aleutian region, and during winter in the WGOA region. Cephalopopds and squid were of relatively low importance to summer puffins from the Kodiak region, however.

The hyperiid amphipod *Parathemisto libellula* was present in winter and fall birds from the Bering region, but not elsewhere. Unidentified euphausiids were present in summer birds from the Aleutian region, and euphausiids of the genus *Thysanoessa* had been eaten by birds collected during summer in the WGOA region, and during spring and summer in the Kodiak region. *T. inermis* was the most important prey of birds collected in the WGOA region, and in the Kodiak region in spring; it assumed lesser importance to Kodiak birds in summer, however, and was not present in nine birds collected there during fall. *T. spinifera* was moderately important to Kodiak birds in spring, but decreased to trace presence in birds collected there during summer. Pandalid shrimp were of only trace importance in summer birds from Kodiak.

Among fish eaten by tufted puffins, capelin was by far the most important to birds from the Kodiak region in summer and fall, and least important there in spring. Capelin were of intermediate importance in the stomachs of birds collected during summer in the Bering, WGOA, and NEGOA regions, but capelin were not found in birds collected in the Aleutian or LCI regions. Walleye pollock, in contrast, was the most important fish prey to birds from the Bering region in summer and fall, and least important to Kodiak birds during spring and summer, and to NEGOA birds in summer.

Unidentified gadids were important to birds sampled during winter in the Aleutian region. Pacific sand lance were of moderate importance to birds collected in the Kodiak region in summer and fall, they were of

Table 20. Comparison of the importance of the main prey of tufted puffins in Alaskan waters, by major geographic region and season. Prey Importance levels based on IRI values: 0-9 = trace (tr); 10-99 = 1; 100-999 = 2; 1,000-9,999 = 3; 10,000 and up = 4; x = present Seasons: W = winter; Sp = spring; Su = summer; F = fall.

	Bering Sea			Aleutians		W Gulf of AK			Kodiak			Lower Cook Inlet		NE Gulf of AK
	W	Su	F	W	Su	W	Sp	Su	Sp	Su	F	Sp	Su	Su
Sample Size =	1	8	3	4	4	3	2	8	14	282	9	2	2	22
PREY NAME														
Nereid Polychaete.....	-	-	2	-	1	-	-	-	1	tr	-	-	-	-
Limacina helicina..... Pteropod	-	-	-	-	-	-	-	-	-	tr	-	-	-	-
Cephalopods/Squid.....	-	1	-	4	4	4	x	2	tr	2	1	-	-	3
Calanoid Copepods.....	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Gammarid Amphipods....	-	-	-	-	-	-	-	-	tr	-	-	-	-	-
Parathemisto libellula	x	-	3	-	-	-	-	-	-	-	-	-	-	-
Thysanoessa inermis...	-	-	-	-	-	-	-	3	4	2	-	-	-	-
T. raschii............	-	-	-	-	-	-	-	-	-	tr	-	-	-	-
T. spinifera..........	-	-	-	-	-	-	-	-	2	tr	-	-	-	-
Unident. Euphausiids..	-	-	-	-	2	-	-	-	2	tr	-	x	-	-
Pandalid Shrimp.......	-	-	-	-	-	-	-	-	-	tr	-	-	-	-
Pagurid Crab..........	-	-	-	-	-	-	-	-	-	tr	-	-	-	-
Unident. Decapods.....	-	-	-	-	-	-	-	1	-	tr	1	-	-	-
Unident. Crustacea....	-	1	-	-	-	-	-	-	-	tr	-	-	-	tr
Red Salmon............	-	-	-	-	-	-	-	-	-	tr	-	-	-	-
Capelin...............	-	2	-	-	-	-	-	2	1	3	3	-	-	2
Pacific Tom Cod.......	-	2	-	-	-	-	-	-	-	tr	-	-	-	-
Walleye Pollock.......	-	3	3	-	-	-	-	2	tr	1	-	-	-	1
Unidentfied Gadid.....	-	-	3	3	-	-	-	2	-	tr	-	-	-	1
Irish Lord............	-	-	-	-	-	-	-	-	-	tr	-	-	-	-
Unidentified Cottid...	-	-	-	-	-	-	-	-	-	tr	-	-	-	-
Snailfish/Lumpsucker..	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Pacific Sandfish......	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Pacific Sand Lance....	-	1	-	-	-	-	-	-	-	2	2	-	-	3
Unidentified Fish.....	-	3	-	1	-	2	x	2	1	1	2	x	x	2

high importance to summer birds from the NEGOA, low importance to summer birds from the Bering region, and they were absent from the stomachs of birds collected in all other seasons and regions.

DISCUSSION

It is evident from the lengthy lists of prey in the appendices that the 33 species of pelagic seabirds discussed in this report collectively eat a wide variety of fishes, crustaceans, cephalopods, and other prey. The minimum number of prey species eaten by a single species of pelagic bird range up to 29 (pigeon guillemot), and a few other species have lists of prey numbering in the 20's (glaucous-winged gull, black-legged kittiwake and common murre, 23 each; tufted puffin, 22).

Only a relatively few species of prey, however, stand out as having general importance to the entire community of pelagic birds studied. As determined by either the total number of species eating a prey, or by the cumulative IRI of the prey for all species eating it, or both (Table 21), two fishes stand out clearly as the most important species of prey to the plagic bird community as a whole: Pacific Sand Lance and Capelin. Sand lance were eaten by 17 species of birds, in which its cumulative IRI was 41,655, and capelin were eaten by 21 species of birds, in which its cumulative IRI was 30,973. Cephalopods (unknown number of species) were eaten by 12 bird species, and had a cumulative IRI of 20,208. The euphausiid Thysanoessa inermis was the third most important food species in general, and the most important crustacean to pelagic birds, being eaten by 16 species, and having a cumulative IRI of 19,496.

Although the cumulative importance of other prey to pelagic birds drops off considerably beyond these three species and total cephalopods, temporal and geographic influences on the apparent overall importance of other species of prey need to be considered. For example, epitoke (breeding) stages of nereid polychaetes, which swarm in dense concentrations at the water's surface (Meglitsch 1972), occured in 16 species of pelagic birds, and had a cumulative IRI of 8,239. Most of this value, however, was accounted for by the presence of nereids in seven red-necked phalaropes in which their IRI was 8,068. IRI values for the other 15 bird species ranged from less than one (five species) to 79 (Black-legged kittiwake). Nereids are extremely soft bodied and swarm at the surface at night (Meglitsch 1972). Their remains in the birds, which were collected from a few to several hours after dawn, usually consisted of only chitinous jaws. Had the birds been collected at night, however, the volume of nereids in their stomachs would have been much larger, resulting in correspondingly higher IRI values. Thus, these data probably underestimate the general importance of nereids to pelagic seabirds.

Similarly, few birds (about 6% of the total) were collected in the eastern Bering Sea where Walleye Pollock and the hyperiid amphipod Parathemisto libellula are major prey species of the bird community (Hunt et al. 1981). Pollock were eaten by 14 species of birds we studied (Table 21), but their cumulative IRI was relatively low (722), as was that of P. libellula (457). For the constrasting reason that about 74% of the samples were from the Kodiak region, the importance of Capelin to

Table 21. Summary of the overall utilization of the main and/or commercially-important prey of pelagic seabirds, as indicated by cumulative IRI of prey for all bird species eating it, and by the number of bird species eating it.

Kind or Species of Prey	Number of Bird Spp. Eating Prey	Cumulative IRI
Pacific Sand Lance	17	41,655
Capelin	21	30,973
Cephalopods	12	20,208
Thysanoessa inermis	16	19,496
Nereid Polychaetes	16	8,239
Pacific Herring	5	2,654
Mysids (*Acanthomysis* plus *Neomysis rayii*)	6	2,537
Thysanoessa spinifera	10	1,492
Walleye Pollock	14	722
Salmon spp.	4	585
Parathemisto libellula	5	457
Pandalid Shrimp	9	136
Pacific Halibut	1	112
Razor Clam	1	108
Sablefish	1	61
Pacific Cod	2	trace

Alaskan marine birds in general may not be as great as suggested by these data at face value. Capelin are apparently abundant around Kodiak (I. Warner, pers. commun.), but their relative abundance elsewhere in Alaskan waters is unknown.

Our data for the foods of marine waterfowl are relatively sketchy, although they are fairly well known for a few species in winter in Kachemak Bay (Sanger and Jones in press) and at Kodiak Island (Krasnow and Sanger 1982). In general, however, blue mussels (*Mytilus edulis*) and the clams *Protothaca staminea*, *Spisula polynyma*, *Macoma* spp., and *Mya* spp. should be considered important foods of marine waterfowl in the Gulf of Alaska. Interestingly, capelin were eaten by oldsquaws and Pacific sand lance were eaten by both oldsquaws and white-winged scoters, further indicating the importance of these two fishes to the marine bird community.

UTILIZATION OF COMMERCIALLY-IMPORTANT PREY BY SEABIRDS

Walleye pollock support a world-class fishery in the eastern Bering Sea (Frost and Lowry 1981), and their heavy use by seabirds and other vertebrates there has been well documented (Frost and Lowry 1981; Hunt *et al*. 1981). The results of the present study, however, suggest far less dependence by birds on currently harvested species of fish and shellfish in the Gulf of Alaska. Commercially valuable species eaten by the birds we studied include Pacific herring, pollock, Pacific cod, salmon, sablefish, razor clams, and pandalid shrimps, but their cumulative IRI values are generally low (Table 21). However, no attempt was made to sample birds at times and in areas known to harbor concentrations of commercial species that were potentially of sizes eaten by the birds (Krasnow and Sanger 1982; Sanger, unpublished data). The scarcity of juvenile salmon and herring in the diets of the birds is particularly curious, because they would seem to be ideal sizes to be eaten by seabirds, and salmon smolts generally migrate to sea during late spring and summer, the seasons for which our seabird feeding habits data are most complete.

At present, the eastern subarctic Pacific Ocean is the only major geographic region in the northern hemisphere without a commercial fishery for Capelin (Jangaard 1974). There is little information available on the size of capelin stocks in Alaskan waters, but in addition to the species' heavy utilization by seabirds and by pinnipeds (Pitcher 1980; Kajimura, personal communication), capelin have been caught in abundance with shrimp trawls during surveys in Kodiak Island waters (Irving Warner, pers. communication). Consequently, the development of fisheries for capelin or sand lance could have far more serious consequences to seabirds than existing fisheries do; this is a situation that warrants continued close observation.

POTENTIAL EFFECTS OF PETROLEUM DEVELOPMENT

The negative effects of direct oiling to seabirds has already been dealt with extensively (e.g., Vermeer and Vermeer 1974). Indirect effects of petroleum pollution to seabirds are suspected to be adverse, but they are relatively unknown (Krasnow and Sanger 1982). On the basis of this study, however, any pollution event that would substantially affect populations of the main prey discussed above would presumably have serious negative consequences to marine birds and their ecosystems.

NEEDS FOR FURTHER STUDY

Data discussed in this report are largely pooled from food samples collected over extensive geographic regions and during several years and seasons. This allows fairly broad, generalized conclusions to be made about the kinds of foods seabirds eat and how they relate trophically, but this information needs to be viewed very cautiously when applied to the dynamic ecosystems of which seabirds are a part. The ocean is constantly changing, both physically and biologically; some of these changes are fairly predictable, but some are not.

To further our understanding of how seabirds relate to their oceanic environment, future studies must emphasize replicate collections of seabird food samples and their prey in nature during all seasons and within well-defined geographic/oceanographic frames. Petroleum pollution or negative environmental perturbations take place on well-defined geographic and time scales, and it could be misleading to the detriment of seabird populations to assume that the information in this report would be adequate to address information needs from a particular pollution event.

The diets of nestlings and the feeding ecology of marine birds as related to their productivity in the Gulf of Alaska is discussed in some detail by Baird (1983), but relationships between seabird productivity, the proximity of nesting colonies to foraging areas at sea, and the distribution and availability of prey populations remain essentially unknown. Similarly, information and ideas about the nature of trophic relationships between primary productivity and seabirds appear to be scanty. Enough information appears to be available from OCSEAP studies in other disciplines and the literature, however, to at least begin to form hypotheses about these relationships.

ACKNOWLEDGEMENTS

This study was conducted under the general direction of C. J. Lensink throughout its duration, and J. C. Bartonek and K. D. Wohl in its earlier stages. A number of personnel of the OCSEAP Juneau Project Office helped with various aspects, and in particular I thank G. Lapiene for help with field logistics and L. Jarvela, our official "tracker" for help and encouragement.

People who collected specimens and data in the field included P. Arneson, P. Baird, G. Burrell, R. Day, M. Dick, A. DeGange, D. Forsell, D. Frazer, A. Fukuyama, P. Fuentes, R. Gill, P. Gould, J. Guzman, J. Hall, C. Handel, C. Harrison, M. Hatch, S. Hatch, V. Hironaka, E. Hoberg, R. Jones, P. Jorgenson, G. Keyser, M. Kirchhoff, P. Knudtson, L. Krasnow, C. Larson, L. Leshner, R. Lohse, R. MacIntosh, K. Metzner, A, Moe, J. Nelson, D. Nysewander, M. Petersen, M. Phillips, E. Possardt, K. Powers,

M. Rauzon, Gerald Sanger, Gregory Sanger, M. Sanger, A. Sowls, C. Slater, I. Warner, H. Wehle, D. Wiswar, and K. Wohl.

Most of the specimens were processed and food samples were identified by P. Baird, Sanger, and C. Vita initially, and by A. Fukuyama, V. Hironaka, and D. Wiswar for the latter, majority of the lab work. G. Mueller and staff, Marine Sorting Center, University of Alaska, were particularly helpful with prey identifications. They and other taxonomic specialists who helped included J. Blackburn (fishes), T. E. Bowman (amphipods), K. Coyle (crustaceans), W. Driskell (gastropods), C. Fiscus (squid), N. Foster (gastropods, clams), K. Frost and L. Lowry (fish otoliths), H. Jones (polychaetes), H. Kajimura (fish bones), G. McDonald (nudibranchs), and G. Mueller (bryozoans, crustaceans, ophiuroids and polychaetes).

S. Diehl, C. Pearce, T. Martinson, and particularly D. Wiswar, helped with data reduction, and Diehl and Martinson assisted with the graphics. D. Amos, G. Fidler, and S. Miller wrote computer programs for data analyses and syntheses. An early draft of this report was improved by reviews of D. Forsell, S. Hatch, and C. Lensink.

This study was supported by the Bureau of Land Management through interagency agreement with the National Oceanic and Atmospheric Administration, under which a multi-year program responding to the needs of petroleum development of the Alaskan continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office, Juneau.

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Appendix Table 1. Data on Indices of Relative Importance (IRI) for prey of northern fulmars, pooled from birds collected in Alaskan waters.

Species: Northern Fulmar (Fulmarus glacialis) Minimum # Prey Species = 10

N = 46 No. Empty = 3(6.5%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereidae	1.3	<.1	2.3	3
CLAMS, Unidentified	3.0	<.1	2.3	7
CEPHALOPODA				
Gonatid Squid	12.6	2.5	11.6	175
Unidentified Squid	58.9	60.1	81.4	9,687
Total Squid	71.5	62.6	81.4	10,916
CRUSTACEA				
Unidentified	<.1	<.1	4.6	2
Calanoid Copepod	8.2	1.0	2.3	21
Amphipoda				
Paracallisoma alberti	<.1	<.1	2.3	<1
Parathemisto pacifica	<.1	<.1	2.3	<1
Unidentified	1.7	2.3	9.3	37
Total Amphipoda	1.7	2.3	9.3	37
Euphausiacea				
Thysanoessa inermis	4.7	1.4	2.3	14
Unidentified	1.7	<.1	2.3	4
Total Euphausiacea	6.4	1.4	2.3	17
Total Crustacea	16.3	1.4	2.3	195
FISHES				
Mallotus villosus	<.1	2.3	2.3	6
Unidentified Gadidae	1.2	6.1	7.0	51
Theragra chalcogramma	1.2	2.8	2.3	9
Unidentified	3.0	15.4	11.6	213
Total Osteichthyes	5.4	26.6	7.0	224
BIRDS				
Oceanodroma furcata Fork-tailed Storm Petrel	<.1	5.1	2.3	12

Appendix Table 2. Data on Indices of Relative Importance (IRI) for prey of sooty shearwaters, pooled from birds collected in Alaskan waters.

Species: Sooty Shearwater (Puffinus griseus)   Min. # Prey Species = 14

N = 187   No. Empty = 9(4.8%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereidae	0.2	<.1	1.1	<1
CEPHALOPODA				
Unidentified	7.7	1.0	28.4	247
Squid				
Gonatidae	1.9	0.1	2.3	4
Onychoteuthis borealijaponicus	0.0	0.0	0.6	<1
Unidentified	38.1	1.0	40.9	1,599
Total Squid	40.7	1.1	40.9	1,710
Total Cephalopoda	47.7	2.1	40.9	2,037
CRUSTACEA				
Calanoid Copepod	0.1	0.0	0.6	<1
Amphipoda				
Paracallisoma alberti	0.2	0.0	1.1	<1
Parathemisto pacifica	1.1	0.1	0.6	<1
Unidentified Hyperiidea	0.0	0.0	0.6	<1
Total Amphipoda	1.3	0.1	1.1	2
Euphausiacea				
Thysanoessa inermis	19.2	2.5	5.1	111
Thysanoessa raschii	0.1	0.0	0.6	<1
Thysanoessa spinifera	0.0	0.1	0.6	<1
Thysanoessa sp.	0.5	0.0	0.6	<1
Unidentified	0.1	0.0	0.6	<1
Total Euphausiacea	19.9	2.7	5.1	115
Total Crustacea	21.3	2.8	5.1	123
FISHES				
Mallotus villosus Capelin	22.7	83.1	50.0	5,290
Unidentified Osmerid	0.3	0.4	3.4	2
Stenobrachius nannochir Lanternfish	0.0	0.6	0.6	<1
Microgadus proximus Pacific Tomcod	0.0	0.2	0.6	<1
Trichodon trichodon Pacific Sandfish	0.1	0.2	1.1	<1
Ammodytes hexapterus Pacific Sandlance	6.0	6.5	8.0	100
Unidentified	1.8	4.1	18.8	112
Total Fish	30.9	95.1	50.0	6,300

Appendix Table 3. Data on Indices of Relative Importance (IRI) for prey of short-tailed shearwaters, pooled from birds collected in Alaskan waters.

Species: Short-tailed Shearwater (*Puffinus tenuirostris*)

Minimum # Prey Species = 14

N = 228 No. Empty = 27(11.8%)

PREY SPECIES	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereidae	0.1	<.1	2.5	<1
GASTROPODA, Unidentified	<.1	<.1	1.0	<1
CEPHALOPODA				
Unidentified	0.6	1.5	36.8	77
Squid				
Gonatidae, Unidentified	<.1	<.1	0.5	<1
Unidentified	<.1	<.1	0.5	<1
Total Cephalopoda	0.6	1.5	36.8	77
CRUSTACEA				
Unidentified	0.3	0.5	2.0	2
Calanoid Copepod	<.1	<.1	0.5	<1
Amphipods				
Gammaridea, Unidentified	<.1	<.1	0.5	<1
Parathemisto libellula	1.7	1.3	1.5	4
Parathemisto pacifica	<.1	<.1	0.5	<1
Total Amphipods	1.7	1.3	1.5	4
Euphausiids				
Thysanoessa inermis	12.8	9.1	13.9	305
T. raschii	2.6	1.8	9.0	40
T. spinifera	3.5	2.3	9.0	52
Thysanoessa sp.	74.4	32.0	22.4	2,383
Euphausiidae, Unidentified	1.3	0.4	2.0	3
Unidentified	0.6	0.4	6.0	6
Total Euphausiids	95.2	46.0	22.4	3,163
Decapod, Unidentified	0.1	<.1	1.5	<1
Telmesus cheiragonus	<.1	<.1	0.5	<1
Total Crustacea	97.3	47.8	22.4	3,250
FISHES				
Unidentified	0.1	1.9	11.9	24
Mallotus villosus	1.3	41.0	19.9	841
Osmeridae, Unidentified	0.2	4.9	7.5	38
Theragra chalcogramma	<.1	0.7	0.5	<1
Ammodytes hexapterus	0.3	2.2	4.0	10
Total Fishes	1.9	50.7	19.9	1,047

Appendix Table 4. Data on Indices of Relative Importance (IRI) for prey of Fork-tailed Storm Petrels, pooled from birds collected in Alaskan waters.

Species: Fork-tailed Storm Petrel (*Oceanodrama furcata*) Min. # Prey Species = 6

N = 14 No. With Food = 8(57.1%)

PREY SPECIES	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA				
Unidentified Nereid	1.6	2.8	12.5	55
CEPHALOPODA				
Unidentified Squid	3.2	42.8	25.0	1,150
Unidentified	6.3	15.7	37.5	826
Total Cephalopoda	9.5	58.5	37.5	2,550
CRUSTACEA				
Paracallisoma alberti Gammaridean Amphipod	3.2	5.7	12.5	111
Calanoid Copepod	11.1	2.7	12.5	173
Euphausiacea				
Thysanoessa spinifera	47.6	11.3	12.5	737
Thysanoessa sp.	12.7	3.1	12.5	197
Total Euphausiacea	60.3	14.4	12.5	934
Unidentified Decapoda	1.6	8.6	12.5	127
Total Crustacea	76.2	31.4	12.5	1,345
FISHES				
Theragra chalcogramma Walleye Pollock	1.6	4.3	12.5	73
Unidentified	11.1	2.9	12.5	175
Total Fishes	12.7	7.2	12.5	249

Appendix Table 5. Data on Indices of Relative Importance (IRI) for prey of nestling double-crested cormorants from food samples collected in Alaskan waters.

Species: Double-crested Cormorant, N = 2 (*Phalacrocorax auritus*) Min. # Prey Species = 2

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
CRUSTACEA				
Crangon septemspinosa	25.0	2.8	50.0	1,390
FISH				
Unidentified	75.0	97.2	100.0	17,220

Appendix Table 6. Data on Indices of Relative Importance (IRI) for prey of adult pelagic cormorants, pooled from birds collected in Alaskan waters.

Species: Pelagic Cormorant, N = 16 (none empty) (*Phalacrocorax pelagicus*) Min. # Prey Species = 9

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
ECHINODERMATA				
Echinoida (Sea Urchins)	0.5	0.1	6.3	4
CRUSTACEA				
Mysida (Opposum Shrimps)	0.5	<.1	6.3	3
Gammaridean Amphipoda	3.0	0.1	6.3	19
Unidentified Decapoda	1.5	0.4	18.8	35
FISHES				
Mallotus villosus	4.0	8.8	12.5	160
Theragra chalcogramma	0.5	7.8	6.3	52
Unidentified Gadidae	7.0	1.3	6.3	52
Ammodytes hexapterus	73.1	45.7	62.5	7,424
Unidentified Cottidae	0.5	12.3	6.3	80
Unidentified	9.5	23.4	25.0	822

Appendix Table 7. Data on Indices of Relative Importance (IRI) for prey of nestling pelagic cormorants, pooled from food samples collected in Alaskan waters.

Species: Pelagic Cormorant (nestlings), N = 15 (*Phalacrocorax pelagicus*) Min. # of Prey Species = 5

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA				
Unidentified	1.7	<.1	6.7	11
INSECTA				
Diptera	22.0	0.2	26.7	593
CRUSTACEA				
Crab	1.7	1.0	6.7	18
FISH				
Ammodytes hexapterus	44.1	72.7	33.3	3,889
Gadidae	1.7	1.0	6.7	18
Unidentified	28.8	25.1	66.7	3,595

Appendix Table 8. Data on Indices of Relative Importance (IRI) for prey of adult red-faced cormorants, pooled from birds collected in Alaskan waters.

Species: Red-faced Cormorant (adults) (*Phalacrocorax urile*)   Min. # of Prey Species = 6

N = 2 (neither empty)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA				
Unidentified Nereidae	1.3	0.8	50.0	105
CRUSTACEA				
Valviferan Isopod	1.3	0.8	50.0	105
Shrimp				
Lebbeus polaris	32.0	11.8	50.0	2,188
Pandalus jordani	2.7	3.0	50.0	281
FISH				
Unidentified	10.7	6.4	50.0	856
Hemilepidotus jordani	1.3	6.4	50.0	389
Ammodytes hexapterus	50.7	70.9	50.0	6,078

Appendix Table 9. Data on Indices of Relative Importance (IRI) for prey of nestling red-faced cormorants, pooled from food samples collected in Alaskan waters.

Species: Red-faced Cormorant (nestlings) (*Phalacrocorax urile*)   Min. # Prey Species = 4

N = 7 (regurgitation samples)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
INSECTA				
Diptera	9.8	0.9	42.9	458
FISH				
Mallotus villosus	14.6	11.1	28.6	735
Unidentified Osmeridae	7.3	1.8	28.6	260
Gadidae	1.2	4.2	14.3	77
Ammodytes hexapterus	64.6	81.3	71.4	10,424
Unidentified	2.4	0.8	14.3	46

Appendix Table 10. Data on Indices of Relative Importance (IRI) for prey of oldsquaws, pooled from birds collected in Alaskan waters.

Species: Oldsquaw (Clangula hyemalis) Minimum # Prey Species = 94
N = 70 No. Empty Stomachs = 0

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
FORAMINIFERA	0.2	0.1	7.1	2
RHYNCHOCOELA, Unidentified	<.1	0.2	1.4	<1
POLYCHAETA				
Unidentified	0.2	2.2	18.6	45
Harmothoe extenuata	<.1	0.1	1.4	<1
Harmothoe sp.	<.1	<.1	1.4	<1
Phloe minuta	0.5	0.1	4.3	3
Anaitides mucosa	<.1	0.1	1.4	<1
Phyllodoce sp.	<.1	<.1	1.4	<1
Eteone longa	<.1	<.1	1.4	<1
Eteone sp.	<.1	0.1	2.9	<1
Phyllodocidae, Unidentified	<.1	<.1	1.4	<1
Syllidae, Unidentified	<.1	<.1	1.4	<1
Nereidae, Unidentified	<.1	0.1	2.9	<1
Glycinde picta	<.1	<.1	1.4	<1
Glycinde sp.	<.1	0.1	1.4	<1
Lumbrinereis sp.	<.1	<.1	1.4	<1
Cirratulidae, Unidentified	<.1	<.1	1.4	<1
Flabelligeridae, Unident.	<.1	<.1	1.4	<1
Travisia sp.	<.1	0.2	1.4	<1
Opheliidae, Unidentified	0.2	<.1	4.3	1
Owenia sp.	0.1	0.3	8.6	3
Pectinaria gouldii	<.1	<.1	1.4	<1
Pectinaria sp.	0.2	0.7	10.0	9
Ampharete sp.	<.1	0.6	1.4	1
Ampharetidae, Unidentified	0.2	0.6	1.4	1
Total Polychaeta	1.4	5.2	18.6	123
GASTROPODA				
Unidentified	0.8	0.8	18.6	30
Acmaeidae, Unidentified	0.1	0.3	1.4	1
Margarites pupillus	0.1	0.1	5.7	1
Margarites sp.	<.1	<.1	1.4	<1
Limpet species	<.1	0.1	2.9	<1
Lacuna variegata	3.2	3.0	28.6	177
Lacuna sp.	<.1	<.1	1.4	<1
Littorina sitkana	2.5	0.1	4.3	11
Alvinia compacta	2.7	0.6	34.3	113
Alvinia sp.	<.1	<.1	1.4	<1
Cingula katherinae	<.1	0.1	1.4	<1
Bittium sp.	<.1	0.1	1.4	<1

Appendix Table 10. Pooled IRI Data - Oldsquaws, page 2 of 4

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
Cerithiopsis sp.	<.1	<.1	1.4	<1
Melanella sp.	<.1	0.1	1.4	<1
Trichotropis insignis	<.1	<.1	1.4	<1
Trichotropus cancellata	0.1	0.1	2.9	1
Natica clausa	0.1	1.1	2.9	3
Natica sp.	<.1	0.1	1.4	<1
Unident. Mesogastropoda	0.1	0.2	1.4	<1
Trophonopsis pacificus	<.1	<.1	1.4	<1
Nucella lima	<.1	0.1	1.4	<1
Mitrella tuberosa	0.2	0.6	1.4	1
Neptunea sp.	<.1	<.1	1.4	<1
Nassarius sp.	<.1	<.1	1.4	<1
Olivella baetica	0.1	<.1	2.9	<1
Admete couthouyi	<.1	0.1	2.9	<1
Mangelia sp.	0.4	0.7	5.7	6
Oenopota sp.	0.9	1.3	8.6	19
Turridae, Unidentified	0.1	0.3	5.7	2
Odostomia sp.	0.3	0.2	17.1	9
Turbonilla sp.	0.1	0.2	1.4	<1
Philine sp.	<.1	<.1	1.4	<1
Aglaja diomedeum	<.1	<.1	2.9	<1
Retusa sp.	0.1	<.1	5.7	1
Onchidoris bilamellata	<.1	0.6	4.3	3
Total Gastropoda	11.9	10.9	34.3	782
BIVALVES				
Unidentified	0.4	2.0	25.7	63
Nucula tenuis	0.5	1.5	14.3	29
Nuculana fossa	0.4	0.6	11.4	12
Glycymeris subobsoleta	11.1	0.8	14.3	171
Glycymeris sp.	<.1	<.1	1.4	<1
Mytilus edulis	4.5	2.8	22.9	167
Musculus vernicosus	0.1	0.1	2.9	<1
Musculus sp.	<.1	<.1	1.4	<1
Mytilidae,Unident.	<.1	<.1	1.4	<1
Axinopsida sp.	<.1	<.1	1.4	<1
Orobitella sp.	<.1	<.1	1.4	<1
Astarte alaskensis	<.1	<.1	1.4	<1
Astarte esquimalti	<.1	<.1	1.4	<1
Clinocardium sp.	<.1	<.1	1.4	<1
Spisula polynyma	5.3	2.3	11.4	87
Macoma balthica	<.1	<.1	1.4	<1
Macoma sp.	2.0	1.5	7.1	25
Saxidomus gigantia	<.1	0.1	4.3	1
Saxidomus sp.	<.1	0.1	1.4	<1
Psephidia lordi	0.3	0.2	8.6	5
Protothaca staminea	0.4	2.0	22.9	56
Mya sp.	0.3	0.2	11.4	6
Total Bivalves	25.3	14.2	25.7	1,015

Appendix Table 10. Pooled IRI Data - Oldsquaws, page 3 of 4

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
SCAPHOPODA	<.1	<.1	1.4	<1
CRUSTACEA				
Harpacticus sp. (Copepod)	<.1	<.1	1.4	<1
Barnacles				
Unidentified	0.1	0.7	10.0	7
Gooseneck, Unidentified	<.1	0.4	7.1	3
Mysida				
Unidentified	24.2	10.3	2.9	99
Acanthomysis sp.	25.9	9.1	7.1	250
Neomysis sp.	<.1	0.1	2.9	1
Total Mysida	50.1	19.5	7.1	494
Cumacea				
Unidentified	1.4	0.5	8.6	16
Lamprops sp.	<.1	0.1	1.4	<1
Tanaidacea				
Unidentified	0.1	<.1	1.4	<1
Isopoda				
Gnorimosphaeroma oregonensis	<.1	<.1	1.4	<1
Amphipoda				
Gammaridea, Unidentified	0.3	5.8	17.1	105
Gammaridae	0.9	2.9	18.6	71
Lysianassidae	<.1	0.1	2.9	<1
Hyperiidea, Unidentified	0.1	0.3	1.4	1
Total Amphipoda	1.3	9.1	18.6	193
Euphausiacea				
Thysanoessa inermis	0.2	0.3	2.9	1
Thysanoessa raschii	1.1	2.0	4.3	13
Thysanoessa sp.	0.3	1.2	4.3	7
Total Euphausiacea	1.6	3.5	4.3	22
Decapoda				
Unidentified	0.1	0.8	5.7	5
Shrimp				
Unidentified	0.2	0.1	1.4	<1
Hymenodora frontalis	0.1	0.6	2.9	2
Spirontocaris spina	<.1	0.4	2.9	1
Eualus pusiolus	<.1	0.3	2.9	1
Pandalidae, Unidentified	0.1	0.6	1.4	1
Pandalus goniuris	0.2	1.6	2.9	5
Crangon septemspinosa	<.1	0.2	2.9	1
Total Shrimp	0.7	4.6	2.9	15
Crabs				
Unidentified	0.1	0.2	2.9	1
Pagurus sp.	<.1	0.1	2.9	<1
Paralithodes camtschatica	<.1	0.7	2.9	2
Brachyuran, Unidentified	<.1	0.2	4.3	1

Appendix Table 10. Pooled IRI Data - Oldsquaws, page 4 of 4

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
Hyas lyratus	0.3	0.9	5.7	7
Cancer sp.	0.1	0.8	4.3	4
Cancer magister	0.1	1.2	5.7	8
Cancer oregonensis	<.1	<.1	1.4	<1
Total Crabs	0.6	4.1	5.7	27
Total Crustacea	55.9	42.5	18.6	1,830
ECHURIA				
Echiurus echiurus	<.1	0.3	1.4	>1
BRYOZOA				
Microporina borealis	<.1	0.2	2.9	1
ECHINODERMATA				
Ophiuroidea (Brittle Stars)				
Unidentified	0.1	3.8	7.1	28
Ophiopholis aculeata	0.7	2.3	2.9	9
Amphipolis pugetana	0.4	1.3	2.9	5
Total Ophiuroids	1.2	7.4	7.1	61
Echinoida (Sea Urchins)				
Unidentified	0.1	1.3	12.9	18
Strongylocentrotus drobachiensis	<.1	0.6	1.4	1
Strongylocentrotus sp.	<.1	<.1	1.4	<1
Strongylocentrotidae	<.1	<.1	1.4	<1
Total Echinoida	0.1	1.9	12.9	26
Total Echinodermata	1.3	9.3	12.9	137
FISH				
Unidentified	2.0	0.3	7.1	16
Mallotus villosus	0.4	1.7	1.4	3
Unidentified Osmeridae	<.1	0.6	1.4	1
Cottidae	<.1	1.0	1.4	1
Stichaeidae	<.1	0.4	1.4	1
Ammodytes hexapterus	0.6	12.2	15.7	202
Total Fish	3.0	16.2	15.7	301

Appendix Table 11. Data on Indices of Relative Importance (IRI) for prey of Harlequin Ducks, pooled from birds collected in Alaskan waters.

Species: Harlequin Duck (Histrionicus histrionicus) Min. # of Prey Species = 2
N = 5 (none empty)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
MOLLUSCA, Unidentified	1.3	10.4	20.0	234
GASTROPODA				
Littorina sitkana Sitka Periwinkle	9.1	5.9	40.0	600
Littorina saxatilis Rough Periwinkle	83.1	38.1	40.0	4,848
Unidentified	6.5	45.6	60.0	3,126
Total Gastropoda	98.7	89.6	60.0	11,298

Appendix Table 12. Data on Indices of Relative Importance (IRI) for prey of Steller's eiders, pooled from birds collected in Alaskan waters.

Species: Steller's Eider (Polysticta stelleri) Minimum # Prey Species = 38
N = 3 (none empty)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
ANTHOZOA (Sea Anenomes)	0.3	0.8	33.3	37
RHYNCHOCOELA (Ribbon Worms)	1.2	2.4	33.3	121
POLYCHAETA				
Polynoidae	2.8	<.1	33.3	92
Eteone sp.	2.1	<.1	33.3	71
Phyllodocidae	5.2	3.2	66.7	561
Syllidae	0.3	<.1	33.3	10
Nereidae	3.1	0.8	66.7	258
Lumbrinereidae	0.6	<.1	33.3	20
Orbiniidae	7.6	<.1	33.3	255
Cirratulidae	0.3	<.1	33.3	10
Flabelligeridae	0.3	<.1	33.3	10
Opheliidae	3.4	5.6	66.7	600
Pectinaria sp.	0.6	1.7	66.7	154
Ampharetidae	0.3	<.1	33.3	10
Sabellidae	1.8	<.1	33.3	61
Total Polychaeta	28.4	11.3	66.7	2,648

Appendix Table 12. Pooled IRI Table - Steller's Eider, page 2 of 2

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
GASTROPODA				
Acmaeidae	0.3	0.5	33.3	26
Margarites sp.	1.5	0.5	33.3	67
Lacuna sp.	1.5	0.5	33.3	67
Littorina sp.	0.3	0.1	33.3	15
Barleeia sp.	1.8	0.5	33.3	77
Natica clausa	0.6	0.8	33.3	47
Mangelia sp.	0.6	0.8	33.3	47
Odostomia sp.	1.5	0.8	33.3	78
Total Gastropoda	8.1	4.5	33.3	420
Bivalves				
Unidentified	0.6	3.5	66.7	276
Mysella sp.	0.3	0.1	33.3	15
Macoma sp.	0.9	0.5	33.3	47
Protothaca staminea	0.6	1.5	33.3	69
Hiatella	9.2	12.9	66.7	1,473
Total Bivalves	11.6	18.5	66.7	2,008
CRUSTACEA				
Unidentified	0.3	1.7	33.3	67
Lepas sp.	0.6	0.8	33.3	47
Tanais loricatus (Tanaid)	0.3	0.5	33.3	26
Valviferan Isopod	0.9	0.8	33.3	57
Gammaridean Amphipods				
Unidentified	23.2	6.5	100	2,975
Lyssianassidae	0.6	0.8	33.3	47
Pandalidae (Shrimp)	0.3	0.8	33.3	37
Total Crustacea	26.2	11.9	100	3,810
ECHINODERMATA				
Sea Cucumbers				
Cucumaria sp.	23.5	50.0	66.7	4,901
Eupentacta sp.	0.3	0.5	33.3	26

Appendix Table 13. Data on Indices of Relative Importance (IRI) for prey of white-winged scoters, pooled from birds collected in Alaskan waters.

Species: White-winged Scoter (Melanitta deglandi) Min. # Prey Species = 36

N = 46 Number Empty = 2(4.3%)

PREY NAME	% NUMBER	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA				
Halosydna brevisetosa	0.1	0.5	4.5	3
Nephtys sp.	<.1	0.2	2.3	1
MOLLUSCA, Unidentified	<.1	0.1	2.3	<1
GASTROPODA				
Unidentified	0.4	1.7	15.9	33
Margarites pupillus	1.5	0.7	4.5	10
Margarites sp.	0.4	0.5	4.5	4
Lacuna sp.	0.1	2.2	2.3	5
Littorina saxitalis	<.1	<.1	2.3	<1
Littorina sp.	<.1	<.1	2.3	<1
Natica clausa	0.1	3.1	2.3	7
Neptunea lyrata	0.3	2.7	4.5	13
Olivella baetica	0.2	0.4	4.5	3
Admete couthouyi	0.4	0.4	4.5	4
Admete sp.	<.1	<.1	2.3	<1
Oenopota sp.	0.3	0.1	4.5	2
Total Gastropoda	3.7	11.8	15.9	246
BIVALVES				
Unidentified	0.9	13.9	38.6	571
Nucula tenuis	0.2	0.1	2.3	1
Glycymeris subobsoleta	13.7	1.3	4.5	68
Glycymeris sp.	<.1	<.1	2.3	<1
Mytilus edulis	1.9	27.9	20.5	611
Astarte rolandi	9.3	0.1	4.5	43
Spisula polynyma	0.4	3.3	6.8	25
Macoma sp.	0.1	1.0	4.5	5
Tellina nuculoides	1.6	2.6	4.5	19
Humilaria kennerlyi	<.1	<.1	2.3	<1
Protothaca staminea	0.9	28.5	36.4	1,068
Mya sp.	<.1	0.1	2.3	<1
Total Bivalves	29.1	79.8	38.6	4,204

Appendix Table 13. Pooled IRI Data - White-winged Scoters, page 2 of 2

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
CRUSTACEA				
Barnacle, Unidentified	<.1	0.4	2.3	1
Gooseneck Barnacle	<.1	<.1	2.3	<1
Shrimp, Unidentified	<.1	0.1	2.3	<1
Crabs				
Unidentified	0.2	0.4	9.1	5
Pagurus sp.	<.1	<.1	2.3	<1
Brachyura oxyrhyncha	<.1	<.1	2.3	<1
Cancer magister	<.1	0.7	2.3	2
Total Crustacea	0.2	1.6	9.1	16
SIPUNCULA, *Sipunculus* sp.	<.1	0.4	2.3	1
ECHINODERMATA				
Ophiuroidea (Brittle Stars)	0.1	<.1	2.3	<1
Echinoida (Sea Urchins)				
Strongylocentrotidae, Unid.	<.1	<.1	2.3	<1
Strongylocentrotus droebachiensis Green Sea Urchin	<.1	0.6	2.3	1
Unidentified	<.1	<.1	2.3	<1
Holothuroidea (Sea Cucumbers)	<.1	0.4	2.3	1
FISHES				
Ammodytes hexapterus	0.6	4.3	2.3	11
Eggs, unidentified	65.9	0.0	2.3	150

Appendix Table 14. Data on Indices of Relative Importance (IRI) for food of surf scoters, pooled from birds collected in Alaskan waters.

Species: Surf Scoter (*Melanitta perspicillata*) Min. # Food Items = 13
N = 11 No. Empty = 1(9.1%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA				
Nephtys sp.	5.6	14.2	10.0	198
Terebellidae	2.8	0.2	10.0	30
MOLLUSCA, Unidentified	2.8	1.8	10.0	45
GASTROPODS, Turridae	2.8	0.2	10.0	30
BIVALVES				
Unidentified	13.9	40.1	50.0	2,700
Nucula tenuis	8.3	1.0	30.0	279
Mytilus edulis	25.0	15.8	20.0	816
Musculus discors	13.9	9.5	10.0	234
Macoma balthica	2.8	2.1	10.0	49
Saxidomus gigantea	2.8	0.2	10.0	30
Protothaca staminea	5.6	0.2	10.0	58
Mya sp.	2.8	2.2	10.0	50
Total Bivalves	75.1	71.1	50.0	7,310
CRUSTACEA				
Hyas sp. (Crab)	2.8	1.0	10.0	38
Crangon septemspinosa	2.8	0.4	10.0	32
PLANT MATTER	2.8	10.5	10.0	133
ORGANIC MATTER, Unidentified	2.8	0.7	10.0	35

Appendix Table 15. Data on Indices of Relative Importance (IRI) for prey of black scoters, pooled from birds collected in Alaskan waters.

Species: Black Scoter (*Oidemia nigra*) Minimum # Prey Species = 4
N = 7 No. Empty = 1(14.3%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
GASTROPODA				
Margarites pupillus	1.4	0.3	16.7	26
BIVALVES				
Mytilus edulis	94.2	97.9	100	19,210
Protothaca staminea	1.4	0.4	16.7	30
Unidentified	1.4	0.6	16.7	33
CRUSTACEANS, Barnacles	1.4	0.8	16.7	36

Appendix Table 16. Data on Indices of Relative Importance (IRI) for prey of red-necked phalaropes, pooled from birds collected in Alaskan waters.

Species: Red-necked Phalarope (*Phalaropus lobatus*) Minimum # Prey Species = 7
N = 7 (none empty)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereidae	65.7	47.2	71.4	8,068
CEPHALOPODA, Unidentified	7.1	13.1	14.3	289
CRUSTACEA				
Calanoid Copepod	1.4	4.4	14.3	83
Decapod	11.4	4.1	28.6	443
Gammaridean Amphipods				
Gammaridae	1.4	1.5	14.3	41
Unidentified	1.4	1.5	14.3	41
Total Crustacea	14.2	10.0	28.6	692
INSECTA, Unidentified	7.1	8.7	42.9	680
FISH, Unidentified	4.3	19.6	42.9	1,025

Appendix Table 17. Data on Indices of Relative Importance (IRI) for prey of pomerine and parasitic jaegers, each pooled from birds collected in Alaskan waters.

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
Species: Pomerine Jaeger (*Stercorarius pomarinus*) N = 2 (neither empty)				Minimum # Prey Species = 2
FISH				
Mallotus villosus	66.7	85.7	50	7,619
Theragra chalcogramma	33.3	14.3	50	2,381
Species: Parasitic Jaeger (*Stercorarius parasiticus*) N = 2 (neither empty)				Minimum # Prey Species = 1
FISH				
Mallotus villosus	100	100	100	20,000

Appendix Table 18. Data on Indices of Relative Importance (IRI) for prey of glaucous gulls, pooled for birds collected in the Bering Sea.

Species: Glaucous Gull (*Larus hyperboreus*) Minimum # Prey Species = 5
N = 7 No. Empty = 1(14.3%)

PREY NAME	% NUMBER	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
CRUSTACEA				
Gammarid Amphipod	28.6	0.4	14.3	415
Decapod	14.3	78.3	14.3	1,324
INSECT, Diptera	14.3	0.2	14.3	207
FISHES				
Salmonidae	14.3	2.5	14.3	400
Unidentified	14.3	13.7	14.3	240
MAMMAL, Unidentified	14.3	4.9	14.3	274

Appendix Table 19. Data on Indices of Relative Importance (IRI) for prey of adult glaucous-winged gulls, pooled from birds collected in Alaskan waters.

Species: Glaucous-winged Gull (*Larus glaucescens*) Minimum # Prey Species = 23
N = 68 No. empty = 2(2.9%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereidae	0.3	0.3	3.0	2
MOLLUSCA				
Unidentified	<.1	0.1	1.5	<1
Gastropoda				
Colisella pelta	<.1	0.2	1.5	<1
Littorina sitkana	0.2	0.6	1.5	1
Buccinum baeri	<.1	0.2	1.5	<1
Total Gastropods	0.2	1.0	1.5	2
Amphineura (Chitons)				
Katharina tunicata	<.1	<.1	1.5	<1
Unidentified	0.1	1.1	10.6	13
Bivalves				
Mytilus edulis	0.2	2.4	9.1	24
Clinocardium sp.	<.1	0.4	1.5	1
Unidentified	0.1	0.3	6.1	2
CRUSTACEA				
Gooseneck Barnacle	<.1	0.5	3.0	2
Acorn Barnacle	<.1	0.3	3.0	1
Valviferan Isopod	<.1	0.1	1.5	<1
Euphausiids				
Thysanoessa inermis	2.1	1.5	4.5	16
T. raschii	<.1	0.1	1.5	<1
Unidentified	1.6	1.5	1.5	5
Total Euphausiids	3.7	3.1	4.5	31
Shrimp				
Pandalus borealis	0.1	2.1	1.5	3
Crangon septemspinosa	<.1	0.2	1.5	<1
Crab				
Telmessus cheiragonus	<.1	0.7	1.5	1
INSECTS				
Diptera	<.1	0.1	1.5	<1
Unidentified	0.3	4.6	3.0	15
ECHINODERMATA				
Echinoida (Sea Urchins)	0.1	2.1	7.6	17
FISHES				
Hypomesus pretiosus	0.1	4.0	1.5	6
Mallotus villosus	0.3	11.8	13.6	165
Gadidae	<.1	0.1	1.5	<1
Hexagrammidae	<.1	5.6	1.5	8
Ammodytes hexapterus	0.5	10.0	7.6	80
Unidentified	93.9	29.4	36.4	4,484
Total Fish	94.8	60.9	36.4	5,667
BIRDS				
Synthliboramphus antiquus	0.1	18.6	1.5	28
Unidentified	<.1	1.2	1.5	2

Appendix Table 20. Data on Indices of Relative Importance (IRI) for prey of sub-adult Glaucous-winged Gulls, pooled from birds and food samples collected in Alaskan waters.

Species: Glaucous-winged Gull (*Larus glaucescens*) Minimum # Prey Species = 19

Sample Type	N	Number Empty
Nestling Regurgitations	115	-
Flying Sub-adults	42	18 (42.8%)
TOTAL	157	18 (11.4%)

PREY NAME	% NUMBER	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Opheliidae	0.1	0.6	0.7	<1
MOLLUSCA				
Gastropods				
Acmaeidae (Limpets)	0.1	0.1	0.7	<1
Unidentified	0.1	<.1	0.7	<1
Amphineurns (Chitons)				
Katharina tunicata	0.2	0.9	2.9	3
Unidentified	0.2	0.4	2.2	1
Bivalves				
Mytilus edulis	8.5	5.1	7.9	108
Siliqua sp.	0.1	0.8	0.7	1
Hiatella arctica	0.1	<.1	0.7	<1
Unidentified	0.1	0.9	1.4	1
Total Bivalves	8.8	6.8	7.9	123
CRUSTACEANS				
Gammaridean Amphipods	1.9	0.3	1.4	3
Telmessus chieragonus	0.1	0.1	0.7	<1
Unidentified Brachyuran	0.1	0.1	0.7	<1
Unidentified	0.1	0.1	0.7	<1
Total Crustaceans	2.2	0.6	1.4	4
INSECTS, Diptera	11.3	0.7	1.4	17
ECHINODERMS				
Leptasterias hexactis	0.1	0.7	0.7	1
Amphipolis pugetana	0.2	1.0	2.2	3
Strongylocentrotus droebachiensis	0.1	0.5	1.4	1
FISH				
Mallotus villosus	13.7	18.7	33.8	1,096
Unidentified Osmerid	0.6	0.8	2.9	4
Theragra chalcogramma	0.1	0.7	1.4	1
Unidentified Gadidae	0.1	<.1	0.7	<1
Trichodon trichodon	0.6	2.1	2.2	6
Pholidae (Gunnels)	0.1	0.3	0.7	<1
Ammodytes hexapterus	14.6	35.1	29.5	1,466
Unidentified	47.1	29.5	29.5	2,260
Total Fish	76.9	87.2	29.5	4,841
BIRD				
Cepphus columba	0.1	0.5	0.7	<1

Appendix Table 21. Data on IRI's for prey of Herring Herring and Bonaparte's Gulls, each pooled from birds collected in Alaskan waters.

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
Species: Herring Gull (*Larus argentatus*) N = 5 (none empty)			Minimum # Prey Species = 4	
BIVALVE, Unidentified	16.7	1.5	20.0	364
CRUSTACEA				
Lepadid Barnacle	16.7	61.5	20.0	1,564
Decapod, Unidentified	16.7	13.8	20.0	610
Crangon septemspinosa	16.7	15.2	20.0	638
Total Crustacea	50.1	90.5	20.0	2,812
FISH, Unidentified	33.3	7.8	40.0	1,647
Species: Bonaparte's Gull (*Larus philedelphia*) N = 4 (none empty)			Minimum # Prey Species = 2	
CRUSTACEA				
Gammaridean Amphipoda	96.2	42.3	50.0	6,923
Crangon septemspinosa	3.8	57.7	50.0	3,077

Appendix Table 22. Data on Indices of Relative Importance (IRI) for prey of mew gulls, pooled from birds collected in Alaskan waters.

Species: Mew Gull (*Larus canus*) N = 13 No. Empty = 2(15.4%) — Minimum # Prey Species = 10

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Unidentified	1.1	0.3	9.1	13
GASTROPODS, Unidentified	1.1	<.1	9.1	10
BIVALVES, Unidentified	0.4	1.0	9.1	13
CRUSTACEA				
Gammaridean Amphipods	86.4	57.0	36.4	5,214
Crangon septemspinosa	2.3	22.0	18.2	442
Crangon sp.	0.8	0.5	9.1	11
Total Crustacea	89.5	79.5	36.4	6,152
INSECTS				
Dipteran Flies	0.4	0.3	9.1	7
Tipulid Flies	0.4	0.2	9.1	6
Unidentified	4.2	1.4	18.2	102
Total Insects	5.0	1.9	18.2	126
FISH				
*Ammodytes hexapterus**	1.1	10.4	9.1	105
Gadidae	0.4	0.6	9.1	9
Unidentified*	1.5	6.1	27.3	207
Total Fish	3.0	17.1	27.3	549

*Included in regurgitation sample from 1 nestling.

Appendix Table 23. Data on Indices of Relative Importance (IRI) for prey of adult Black-legged Kittiwakes, pooled from birds collected in Alaskan waters

Species: Black-legged Kittiwake (Rissa tridactyla) Minimum # Prey Spp. = 23
N = 328 No. Empty Stomachs = 55(16.8%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereidae	8.0	0.7	9.2	79
MOLLUSCS				
Limacina helicina	5.0	0.6	0.7	4
Katharina tunicata	0.1	0.6	0.7	<1
Unidentified	<.1	<.1	0.4	<1
Bivalves				
Mytilus edulis	<.1	<.1	0.4	<1
Unidentified Mytilid	<.1	<.1	0.4	<1
Unidentified	0.2	0.1	1.5	<1
Cephalopod, Unidentified	0.2	0.1	1.5	1
CRUSTACEA				
Unidentified	0.1	0.1	0.7	<1
Barnacle	<.1	0.1	0.4	<1
Calanoid Copepod	0.5	0.1	1.8	<1
Gammaridean Amphipods				
Gammaridae	<.1	<.1	0.4	<1
Paracallisoma alberti	0.6	0.2	1.8	1
Unidentified	<.1	<.1	0.4	<1
Hypereiid Amphipods				
Parathemisto libellula	5.7	1.5	1.5	10
P. pacifica	0.1	<.1	0.4	<1
P. japonica	<.1	<.1	0.4	<1
Total Amphipods	6.4	1.7	1.8	15
Euphausiids				
Thysanoessa inermis	36.0	4.7	7.7	313
T. raschii	0.4	<.1	0.4	<1
T. spinifera	6.9	1.4	1.5	12
T. sp.	1.9	0.2	0.7	1
Unidentified	1.0	0.2	1.5	2
Total Euphausiids	46.2	6.5	7.7	406
Pandalopsis dispar	0.1	0.2	0.4	<1
Unident. Pandalid Shrimp	0.2	0.7	0.4	<1
Cancer sp. (Crab)	0.2	<.1	0.4	<1
Unidentified Decapod	0.1	<.1	0.4	<1
Total Crustacea	54.4	10.3	7.7	498

(cont'd)

Appendix Table 23. Pooled IRI Data, adult Black-legged Kittiwakes, p. 2 of 2

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
FISH				
Unidentified	4.9	7.0	26.7	320
Clupea harengus	0.5	0.2	0.4	<1
Mallotus villosus	15.3	50.9	35.5	2,354
Unidentified Osmeridae	2.2	5.9	6.6	53
Gadidae (Cods)				
Gadus macrocephalus	<.1	<.1	0.4	<1
Theragra chalcogramma	0.9	5.3	5.1	32
Unidentified	0.7	1.7	5.5	13
Total Gadidae	1.6	7.0	5.5	47
Trichodon trichodon	<.1	<.1	0.4	<1
Ammodytes hexapterus	7.8	17.1	13.2	329
Total Fish	32.3	88.1	35.5	4,274

Appendix Table 24. Data on Indices of Relative Abundance (IRI) for prey of sub-adult black-legged kittiwakes, pooled from birds and food samples collected in Alaskan waters.

Species: Black-legged Kittiwake (Rissa tridactyla) Minimum # Prey Spp. = 17

Sample Type	N	Number Empty
Nestling Regurgitations	129	-
Flying Birds	86	31 (36.0%)
TOTAL	215	31 (14.4%)

PREY NAME	% NUMBER	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
MOLLUSCA				
Katharina tunicata	0.1	<.1	0.5	<1
CRUSTACEA				
Unidentified	0.6	<.1	1.1	1
Ligia pollasi	0.1	0.1	0.5	<1
Paracallisoma alberti	0.1	0.1	0.5	<1
Thysanoessa inermis	0.1	<.1	0.5	<1
Unidentified Euphausiid	0.1	0.1	0.5	<1
Unidentified Decapod	0.1	0.1	0.5	<1
Hymenodora frontalis	0.1	0.1	0.5	<1
Pandalus borealis	0.3	0.4	0.5	<1
Pandalus sp.	0.7	1.1	1.6	3
Pandalopsis dispar	1.9	2.3	0.5	2
Unidentified	1.0	0.6	2.2	4
Total Pandalid Shrimp	3.9	4.4	2.2	18
Cancrid Crab	0.1	<.1	0.5	<1
Total Crustacea	5.2	4.9	2.2	22
INSECT, Dipteran Fly	0.7	<.1	1.1	1
FISH				
Onchorhynchus gorbuscha	0.3	<.1	0.5	<1
O. nerka	3.7	0.2	0.5	2
Mallotus villosus	31.7	36.3	39.7	2,697
Unidentified Osmerid	1.6	2.9	3.3	15
Gadidae				
Gadus macrocephalus	0.1	0.1	0.5	<1
Microgadus proximus	0.4	0.5	0.5	1
Theragra chalcogramma	1.0	2.3	3.3	11
Unidentified	1.6	2.5	3.8	16
Total Gadidae	3.1	5.4	3.8	32
Trichodon trichodon	1.8	2.4	3.8	16
Ammodytes hexapterus	44.2	39.3	49.5	4,127
Unidentified	7.1	8.4	14.1	219
Total Fish	93.5	94.9	49.5	9,326

Appendix Table 25. Data on Indices of Relative Importance (IRI) for prey of red-legged kittiwakes, pooled from birds collected in the Bering Sea (N = 2) and the Aleutian Islands regions (N = 1).

Species: Red-legged Kittiwake (*Rissa brevirostris*) Minimum # Prey Species = 4

N = 3 (none empty)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
CEPHALOPOD, Unidentified	12.5	0.5	33.3	433
CRUSTACEANS				
Thysanoessa inermis Euphausiid	12.5	0.5	33.3	433
Hymenodora frontalis Pacific Ambereye Shrimp	25.0	12.5	33.3	1,249
Unidentified Decapod	25.0	12.3	66.7	2,488
FISH, Unidentified	25.0	74.2	66.7	6,616

Appendix Table 26. Data on Indices of Relative Importance (IRI) for prey of adult Arctic terns, pooled from birds collected in Alaskan waters.

Species: Arctic Tern (Sterna paradisea) Minimum # Prey Species = 8
N = 36 Number Empty = 2(5.6%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereid	0.1	<.1	2.9	<1
CRUSTACEA				
Parathemisto libellula	0.4	1.0	2.9	4
Thysanoessa inermis	92.6	76.1	52.9	8,930
T. raschii	0.1	0.5	2.9	2
T. spinifera	4.4	3.6	26.5	211
Total Euphausiids	97.1	80.2	52.9	9,379
Unidentified Decapod	0.1	1.0	2.9	3
Total Crustaceans	97.6	82.2	52.9	9,511
FISH				
Mallotus villosus	0.6	6.8	17.6	130
Ammodytes hexapterus	1.4	9.4	11.8	126
Unidentified	0.4	1.6	11.8	24
Total Fish	2.4	17.8	17.6	356

Appendix Table 27. Data on Indices of Relative Importance for prey of sub-adult Arctic terns, pooled from birds and food samples collected in Alaskan waters (all from Kodiak Island area).

Species: Arctic Tern (Sterna paradisea) Minimum # Prey Species = 6

Sample Type	N	Number Empty
Nestling Regurgitations	20	-
Flying Sub-adults	12	1(8.3%)
TOTAL	32	1(3.0%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
FISH				
Mallotus villosus	50.1	40.3	48.4	4,368
Unidentified Osmeridae	5.9	4.4	6.5	66
Hexagrammos lagocephalus	5.9	7.1	3.2	42
H. stelleri	2.9	1.8	3.2	15
Trichodon trichodon	2.9	3.1	3.2	19
Zaprora silensus	2.9	8.8	3.2	38
Ammodytes hexapterus	26.5	33.6	29.0	1,745
Unidentified	2.9	0.9	3.2	12
Total Fish	100	100	48.4	9,680

Appendix Table 28. Data on Indices of Relative Importance (IRI) for prey of adult Aleutian terns, pooled from birds collected in Alaskan waters.

Species: Aleutian Tern (Sterna aleutica) Minimum # Prey Species = 8
N = 14 Number Empty = 1(7.1%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereid	1.2	0.1	7.7	10
CHELICERATE ARTHROPOD	0.4	1.8	7.7	17
CRUSTACEA				
Thysanoessa inermis	88.5	54.7	23.1	3,306
Synidotea sp.	0.4	0.9	7.7	10
Pentidotea sp.	0.4	10.5	7.7	83
Total Crustacea	89.3	66.1	23.1	3,590
INSECT, Unidentified	1.2	1.4	15.4	39
FISH				
Mallotus villosus	1.6	7.3	15.4	137
Gadidae	0.4	5.5	7.7	45
Ammodytes hexapterus	4.7	12.2	30.8	521
Unidentified	1.2	5.6	23.1	157
Total Fish	7.9	30.6	30.8	1,186

Appendix Table 29. Data on Indices of Relative Importance (IRI) for prey of sub-adult Aleutian terns, pooled from food samples collected in Alaskan waters.

Species: Aleutian Tern (Sterna aleutica) Minimum # Prey Species = 8

Sample Type	N	Number Empty
Nestling Regurgitation	43	-
Flying Sub-adults	5	1(20%)
TOTAL	48	1(2.1%)

PREY NAME	% NUMBER	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
EUPHAUSIIDS, Thysanoessa sp.	1.5	0.1	2.1	3
INSECT, Unidentified	1.5	<.1	2.1	3
FISH				
Mallotus villosus	32.8	33.9	34.0	2,273
Unidentified Osmerid	13.4	12.8	12.8	335
Hexagrammos lagocephalus	1.5	3.8	2.1	11
Hexagrammos sp.	1.5	3.2	2.1	10
Pleurogrammus monopterygius	1.5	2.5	2.1	9
Cottidae	3.0	0.6	2.1	8
Blepsius cirrhosus	4.5	5.1	6.4	61
Trichodon trichodon	1.5	1.3	2.1	6
Ammodytes hexapterus	10.4	15.8	12.8	335
Unidentified	26.9	20.9	31.9	1,524
Total Fish	97.0	99.9	34.0	6,695

Appendix Table 30. Data on Indices of Relative Importance (IRI) for prey of nestlings of Arctic and/or Aleutian terns, pooled from bill loads dropped at a nesting colony used by both species on Kodiak Island, Alaska.

Species: Arctic and/or Aleutian Terns (Sterna paradisea and/or S. aleutica)
N = 11

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
FISH				
Ochorhynchus kisutch Silver Salmon	7.1	13.0	9.1	183
Hypomesus pretiosus Surf Smelt	7.1	8.3	9.1	140
Mallotus villosus Capelin	14.3	16.9	18.2	567
Unidentified Osmeridae	7.1	2.6	9.1	89
Hexagrammos lagocephalus Rock Greenling	7.1	5.2	9.1	112
Blepsius cirrhosus Silverspotted Sculpin	7.1	2.6	9.1	89
Stichaeidae (Pricklebacks)	7.1	3.9	9.1	100
Ammodytes hexapterus Pacific Sand Lance	28.6	39.7	36.4	2,484
Hippoglossus stenolepis Pacific Halibut	7.1	5.2	9.1	112
Unidentified	7.1	2.6	9.1	89

Appendix Table 31. Data on Indices of Relative Importance (IRI) for prey of common murres, pooled from birds collected in Alaskan waters.

Species: Common Murre (*Uria aalge*) Minimum # Prey Species = 23
N = 251 No. Empty = 85 (33.9%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereidae	<.1	<.1	0.6	<1
CEPHALOPODA				
Unidentified Squid	<.1	0.2	0.6	<1
Gonatidae	0.1	0.1	0.6	<1
CRUSTACEA				
Unidentified	0.2	0.2	1.8	1
Neomysis rayii (Mysid)	16.5	8.1	6.6	162
Leucon sp. (Cumacean)	0.8	<.1	0.6	<1
Amphipoda				
Gammaridea	<.1	<.1	0.6	<1
Protomedeia sp.	<.1	<.1	0.6	<1
Anonyx sp.	0.1	0.1	0.6	<1
Euphausiids				
Thysanoessa inermis	16.2	1.0	2.4	41
T. raschii	0.5	0.3	0.6	<1
T. sp.	19.0	2.4	1.8	38
Total Euphausiids	35.7	3.7	2.4	94
Decapods				
Unidentified	0.2	0.2	1.2	<1
Eualus c.f. *stimpsoni* Shrimp	<.1	0.1	0.6	<1
Pandalidae				
Pandalus borealis	1.1	2.8	3.6	14
P. goniuris	<.1	0.1	0.6	<1
P. sp.	0.3	0.9	3.0	3
Unidentified	0.2	0.6	1.8	1
Total Pandalidae	1.6	4.3	3.6	21
Crangon franciscorum	0.2	0.9	2.4	3
Total Decapods	2.0	5.5	3.6	27
Total Crustacea	54.3	17.6	6.6	474
INSECTA, Unidentified	<.1	0.1	0.6	<1
ECHINODERMATA, *Amphipodia* sp.	0.2	<.1	0.6	<1
FISHES				
Unidentified	4.0	4.5	24.0	204
Clupea harengus	<.1	0.9	0.6	1
Mallotus villosus	14.1	29.9	22.8	1,003
Unidentified Osmerid	1.1	2.8	7.2	28
Gadidae				
Gadus macrocephalus	0.1	<.1	0.6	<1
Microgadus proximus	0.8	1.2	1.8	4

Appendix Table 31. Pooled IRI Data, Common Murres, p. 2 of 2

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
Theragra chalcogramma	7.2	14.3	13.8	297
Unidentified	4.2	2.5	18.0	121
Total Gadidae	12.3	18.0	18.0	547
Trichodon trichodon	0.3	1.3	2.4	4
Lumpenus maculatus	0.2	0.4	1.8	1
L. saggita	0.3	1.0	1.2	2
Ammodytes hexapterus	11.4	22.3	18.0	607
Total Fish	43.7	81.1	24.0	2,995

Appendix Table 32. Data on Indices of Relative Importance (IRI) for prey of Thick-billed Murres collected in Alaskan waters.

Species: Thick-billed Murre (*Uria lomvia*) Minimum # Prey Species = 14
N = 64 # Empty Stomachs = 26 (40.6%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Neridae	0.7	0.3	2.7	3
GASTROPODA, Unidentified	0.5	<.1	2.7	1
CEPHALOPODA, Unidentified	47.4	25.9	51.4	3,765
CRUSTACEA				
Unidentified	0.7	<.1	2.7	2
Calanoid Copepod	0.2	<.1	2.7	1
Gammarid Amphipod	0.2	<.1	2.7	1
Parathemisto libellula	24.4	16.1	10.8	438
P. pacifica	1.1	0.3	2.7	4
Thysanoessa inermis	0.5	<.1	2.7	1
Unidentified Euphausiid	1.8	2.0	2.7	10
Pandalus goniuris	0.5	3.8	5.4	23
Crangon sp.(Shrimp)	3.4	7.5	2.7	29
Unidentified Decapod	0.2	0.1	2.7	1
Total Crustacea	33.0	29.8	10.8	678
FISH				
Mallotus villosus	2.7	16.6	8.1	156
Boreogadus saida	1.6	0.5	2.7	6
Theragra chalcogramma	1.6	9.1	8.1	86
Unidentified Gadidae	7.7	3.2	16.2	176
Total Gadidae	10.9	12.8	16.2	384
Ammodytes hexapterus	1.8	4.8	10.8	71
Unidentified	3.2	9.7	18.9	243
Total Fish	18.6	43.9	18.9	1,181

Appendix Table 33. Data on Indices of Relative Importance (IRI) for prey of pigeon guillemots, pooled from birds collected in Alaskan waters.

Species: Pigeon Guillemot (*Cepphus columba*) Minimum # Prey Species = 29
N = 64 Number of Empty Stomachs = 6 (9.4%)

PREY NAME	% NUMBER	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA				
Nereidae	0.6	<.1	3.4	2
Unidentified	0.3	0.6	1.7	2
GASTROPODA, *Lacuna vincta*	4.2	0.4	1.7	8
BIVALVES				
Musculus sp.	3.1	0.6	3.4	13
Unidentified Veneridae	0.3	0.3	1.7	1
Unidentified	0.3	0.3	1.7	1
CRUSTACEA				
Mysidae	0.6	0.1	1.7	1
Gammarid Amphipods	0.3	0.6	1.7	1
Unidentified Decapod	7.5	5.3	8.6	111
Unidentified	0.3	0.2	1.7	1
Shrimps				
Spirontocaris arcuata	0.3	0.4	1.7	1
S. spinus	0.8	0.1	1.7	2
Lebbeus sp.	0.6	0.6	3.4	4
Eualus fabricii	0.3	0.1	1.7	1
E. sp.	1.1	0.9	1.7	4
Heptacarpus tridens	1.4	0.5	1.7	3
H. brevirostris	16.2	5.8	1.7	38
H. sp.	0.6	0.7	3.4	4
Unidentified Hippolytid	0.3	0.2	1.7	1
Total Hippolytidae	18.5	7.2	3.4	87
Pandalid Shrimps				
Pandalus goniuris	1.1	1.8	3.4	10
P. jordani	0.8	2.4	1.7	6
P. sp.	0.6	1.8	1.7	4
Unidentified	1.1	2.5	5.2	19
Total Pandalidae	3.6	8.5	5.2	63
Crangon septemspinosa	4.5	2.3	1.7	12
Sclerocrangon alata	1.1	0.1	1.7	2
Total Shrimps	33.9	20.3	5.2	282
Crabs				
Dermaterus manotti	0.3	0.4	1.7	1
Brachyuran sp.	3.1	1.1	10.3	43
Hyas lyratus	2.0	1.8	1.7	7
Telmessus cheiragonus	0.3	0.6	1.7	1
Cancer oregonensis	17.3	5.7	22.4	516
Unidentified	1.4	1.2	6.9	18
Total Crabs	24.4	10.8	22.4	788
Total Crustacea	67.0	37.3	22.4	2,336

Appendix Table 33. Pooled IRI data, pigeon guillemot, page 2 of 2

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
INSECT, Dolichopodid Fly	0.3	<.1	1.7	<1
FISH				
Mallotus villosus	3.9	19.0	12.1	277
Microgadus proximus	0.3	0.2	1.7	1
Gadidae	2.8	4.7	12.1	90
Myoxocephalus sp.	2.0	2.0	1.7	7
Cottidae	0.3	0.7	1.7	2
Trichodon trichodon	2.8	12.0	6.9	102
Lumpenus sagitta	0.8	1.5	1.7	4
L. sp.	0.3	1.2	1.7	3
Stichaeidae	1.4	4.5	3.4	20
Pholis laeta	0.3	1.2	1.7	2
Pleuronectidae	0.8	2.2	3.4	11
Unidentified	8.7	11.0	37.9	747
Total Fish	23.6	60.2	37.9	3,176

Appendix Table 34. Data on Indices of Relative Importance (IRI) for prey of Marbled Murrelets, pooled from birds collected in Alaskan waters.

Species: Marbled Murrelet (Brachyramphus marmoratum) Minimum # Prey Species = 16
N = 158 Number of Empty Stomachs = 29 (18.3%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereidae	0.1	<.1	0.8	<1
GASTROPODA				
Littorina sitkana	0.6	0.2	0.8	1
Unidentified	<.1	<.1	0.8	<1
BIVALVIA, Mytilus edulis	<.1	<.1	0.8	<1
CEPHALOPODA, Unidentified	<.1	0.2	0.8	<1
CRUSTACEA				
Gammarid Amphipoda	0.3	0.4	3.1	2
Mysida				
Acanthomysis sp.	20.9	9.3	10.9	327
Neomysis rayii	0.4	0.6	2.3	2
Neomysis sp.	2.7	2.1	4.7	22
Unidentified Mysidae	0.3	0.3	1.6	1
Unidentified	6.3	1.3	2.3	18
Total Mysida	30.6	13.6	10.9	482
Euphausiids				
Thysanoessa inermis	9.6	5.9	8.5	132
T. raschii	3.8	1.4	3.9	20
T. spinifera	0.2	0.4	2.3	1
T. sp.	4.5	1.2	4.7	27
Unident. Euphausiidae	0.1	0.2	1.6	<1
Unidentified	0.1	0.2	0.8	<1
Total Euphausiids	18.3	9.3	8.5	235
Pandalus borealis	<.1	0.1	0.8	<1
Unidentified Decapod	<.1	<.1	0.8	<1
Total Crustacea	49.2	23.4	8.5	617
CHAETOGNATHA, Unidentified	<.1	<.1	0.8	<1
FISH				
Mallotus villosus	37.5	26.7	26.4	1,692
Unidentified Osmeridae	6.3	7.2	10.9	147
Theragra chalcogramma	0.1	0.1	1.6	<1
Unidentified Gadidae	0.1	0.5	1.6	1
Trichodon trichodon	0.3	2.3	3.9	10
Ammodytes hexapterus	3.5	28.4	23.3	741
Unidentified	2.0	11.2	25.6	337
Total Fish	50.0	76.4	26.4	3,337

Appendix Table 35. Data on Indices of Relative Importance (IRI) for prey of Kittlitz's murrelets, pooled from birds collected in Alaskan waters.

Species: Kittlitz's Murrelet (*Brachyramphus brevirostris*) Min. # Prey Spp. = 7
N = 16 Number of Empty Stomachs = 1 (6.2%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
CRUSTACEA				
Gammarid Amphipoda	1.1	0.9	6.7	13
Euphausiids				
Thysanoessa inermis	24.9	14.5	20.0	788
T. spinifera	5.9	5.5	13.3	152
Unidentified	3.2	8.8	26.7	321
Total Euphausiids	34.0	28.8	26.7	1,667
Total Crustacea	35.1	29.7	26.7	1,730
FISH				
Clupea harengus	0.5	3.8	6.7	29
Mallotus villosus	1.6	12.1	6.7	92
Unidentified Osmeridae	1.1	2.7	6.7	25
Trichodon trichodon	1.6	11.4	6.7	87
Ammodytes hexapterus	7.0	6.7	13.3	183
Unidentified	53.0	33.6	40.0	3,464
Total Fish	64.8	70.3	40.0	5,404

Appendix Table 36. Data on Indices of Relative Importance (IRI) for prey of ancient murrelets, pooled from birds collected in Alaskan waters.

Species: Ancient Murrelet (*Synthliboramphus antiquus*) Min. # Prey Spp. = 5
N = 18 Number of Empty Stomachs = 3 (16.7%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
CEPHALOPODA, Unidentified	0.8	0.8	6.7	11
CRUSTACEA				
Unidentified	0.4	1.9	6.7	16
Neomysis sp.	0.8	0.8	6.7	11
Euphausiids				
Thysanoessa inermis	51.9	48.7	33.3	3,353
T. sp.	2.5	0.8	6.7	22
Unidentified	0.8	5.1	13.3	79
Total Euphausiids	55.2	54.6	33.3	3,656
Total Crustacea	56.4	57.3	33.3	3,786
FISH				
Mallotus villosus	34.4	6.2	6.7	16
Theragra chalcogramma	1.2	7.2	6.7	56
Unidentified Gadidae	4.1	17.7	20.0	437
Unidentified	2.9	10.9	33.3	460
Total Fish	42.6	42.0	33.3	2,817

Appendix Table 37. Data on Indices of Relative Importance (IRI) for prey of Cassin's auklet, pooled from birds collected in Alaskan waters.

Species: Cassin's Auklet (*Ptychoramphus aleuticus*) Min. # Prey Spp. = 6
N = 8 (None empty)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
CEPHALOPODA, Squid	0.4	7.7	12.5	101
CRUSTACEA				
Calanoid Copepods	78.4	59.0	50.0	6,870
Gammarid Amphipods	0.2	0.4	12.5	8
Thysanoessa spinifera	4.2	8.4	25.0	315
Unidentified Decapods	15.9	9.1	50.0	1,250
Total Crustacea	98.7	76.9	50.0	8,780
FISH, Unidentified	0.9	15.4	25.0	408

Appendix Table 38. Data on Indices of Relative Importance (IRI) for prey of parakeet auklets, pooled from birds collected in Alaskan waters.

Species: Parakeet Auklet (*Cyclorrhynchus psitaccula*) Min. # Prey Spp. = 3
N = 13 Number of Empty Stomachs = 8 (61.5%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
CRUSTACEA				
Euphausiids				
Thysanoessa sp.	93.3	16.7	20.0	2,200
Unidentified	0.2	16.7	20.0	338
Total Euphausiids	93.5	33.4	20.0	2,538
Decapoda, Unidentified	0.7	15.8	40.0	660
FISH, Unidentified	5.8	50.8	40.0	2,264

Appendix Table 39. Data on Indices of Relative Importance (IRI) for prey of least auklets (top) and crested auklets (bottom), each pooled from birds collected in Alaskan waters.

Species: Least Auklet (*Aethia pusilla*) Min. # Prey Spp. = 4
N = 3 (None Empty)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
CRUSTACEA				
Calanoid Copepoda	55.2	17.7	66.7	4,863
Gammarid Amphipoda	11.9	6.7	33.3	621
Decapoda	3.0	11.0	33.3	467
Unidentified	1.5	33.4	33.3	1,165
Total Crustacea	71.6	68.8	66.7	9,365
CHAETOGNATHA, Arrow Worms	28.4	31.1	66.7	3,964

Species: Crested Auklet (*Aethia cristatella*) Min. # Prey Spp. = 3

N = 25 Number of Empty Stomachs = 12 (48%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
CRUSTACEA				
Acanthomysis sp. Mysid	79.5	42.7	15.4	1,880
Hyperiid Amphipod	3.5	10.9	15.4	221
Thysanoessa inermis Euphausiid	15.4	25.0	30.8	1,242
Unidentified	1.6	21.4	46.2	1,064

Appendix Table 40. Data on Indices of Relative Importance (IRI) for prey of adult rhinoceros auklets, pooled from birds collected in Alaskan waters.

Species: Rhinoceros Auklets (Cerohynchus monocerata) Min. # Prey Spp. = 5
N = 21 Number of Empty Stomachs = 5 (23.8%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
CEPHALOPODA, Unidentified	6.1	1.0	6.3	44
FISH				
Mallotus villosus	24.2	60.6	12.5	1,061
Unidentified Osmeridae	3.0	4.1	6.3	45
Cololabis saira	3.0	6.2	6.3	58
Sebastes sp.	18.2	6.2	6.3	152
Ammodytes hexapterus	18.2	11.5	12.5	372
Unidentified	27.3	10.3	56.3	2,114
Total Fish	93.9	98.9	56.3	10,855

Appendix Table 41. Data on Indices of Relative Importance (IRI) for prey of nestling rhinoceros auklets, pooled from birds collected in Alaskan waters.

Species: Rhinoceros Auklet (Cerohynchus monocerata) Min. # Prey Spp. = 9
N = 25 (nestling regurgitations)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
FISH				
Clupea harengus	22.6	32.9	44.0	2,439
Unidentified Salmonid	0.3	7.7	4.0	32
Mallotus villosus	1.2	6.9	4.0	32
Theragra chalcogramma	0.3	0.1	4.0	2
Cololabis saira	0.9	6.0	12.0	83
Sebastes sp.	3.4	2.9	16.0	101
Unidentified Scorpaenid	1.2	0.3	8.0	13
Hexagrammos decagrammus	0.6	1.1	4.0	7
H. lagocephalus	2.1	3.4	12.0	67
Anoplopoma fimbria	0.3	1.3	4.0	61
Ammodytes hexapterus	66.8	37.3	44.0	4,578
Unidentified	0.3	<.1	4.0	1

Appendix Table 42. Data on Indices of Relative Importance (IRI) for prey of adult horned puffins, pooled from birds collected in Alaskan waters.

Species: Horned Puffin (Fratercula corniculata) Min. # Prey Spp. = 13
N = 54 Number of Empty Stomachs = 14 (25.9%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereidae	3.0	0.2	5.0	16
POLYPLACOPHORA (Chitons)	0.4	0.2	2.5	1
CEPHALOPODA				
Gonatid Squid	3.0	10.4	2.5	34
Unidentified	8.7	0.1	2.5	22
CRUSTACEA				
Acanthomysis sp. (Mysid)	0.4	0.3	2.5	2
Anisogammarus pugettensis	0.4	0.1	2.5	1
Euphausiacea				
Thysanoessa inermis	2.7	0.1	5.0	14
T. spinifera	0.4	0.3	2.5	2
Unidentified	0.4	0.4	2.5	2
Total Euphausiacea	3.5	0.8	5.0	22
Pandalus montagui	1.1	0.5	5.0	8
Total Crustacea	5.8	1.9	5.0	38
FISH				
Mallotus villosus	51.3	50.2	27.5	2,793
Theragra chalcogramma	0.4	0.5	2.5	2
Unidentified Gadid	0.4	0.3	2.5	2
Gasterosteus aculeatus	1.1	1.2	2.5	6
Ammodytes hexapterus	15.2	26.9	17.5	736
Unidentified Pleuronectid	2.3	0.2	2.5	6
Unidentified	8.4	7.8	55.0	890
Total Fish	79.1	87.1	55.0	9,141

Appendix Table 43. Data on Indices of Relative Importance (IRI) for prey of nestling Horned Puffins, pooled from samples from the northern Gulf of Alaska.

Species: Horned Puffin (Fratercula corniculata) Min. # Prey Spp. = 3
N = 4 (bill load samples)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
FISH				
Clupea harengus	5.9	1.5	25.0	185
Hexagrammos decagrammus	41.2	70.0	50.0	5,559
Ammodytes hexapterus	52.9	28.5	50.0	4,072

Appendix Table 44. Data on Indices of Relative Importance (IRI) for prey of adult tufted puffins, pooled from birds collected in Alaskan waters.

Species: Tufted Puffin (Fratercula cirrhata) Min. # Prey Spp. = 22
N = 440 Number of Empty Stomachs = 76 (17.3%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereidae	0.2	0.1	2.2	1
PTEROPODA, Limacina helicina	<.1	<.1	0.3	<1
CEPHALOPODA				
Squid	16.9	0.6	4.1	72
Unidentified	5.2	2.1	14.6	106
Total Cephalopods	22.1	2.7	14.6	362
ACARINA, Unidentified Mite	1.6	<.1	0.3	<.1
CRUSTACEA				
Unidentified	0.8	0.2	1.9	2
Calanoid Copepod	0.1	<.1	0.3	<1
Gammarid Amphipod	<.1	<.1	0.3	<1
Parathemisto libellula	1.1	0.1	0.5	1
Euphausiids				
Thysanoessa inermis	39.1	8.4	10.4	497
T. raschii	<.1	<.1	0.5	<1
T. spinifera	2.0	0.4	4.1	10
T. sp.	4.0	0.9	2.7	14
Unidentified	0.1	<.1	0.5	<1
Total Euphausiids	45.2	9.7	10.4	571
Pandalus sp.	0.3	0.1	0.3	<1
Pandalid Shrimp	0.2	<.1	0.5	<1
Unidentified Shrimp	<.1	<.1	0.3	<1
Pagurid Crab	<.1	<.1	0.3	<1
Unidentified	0.1	0.2	1.4	<1
Total Crustacea	47.8	10.3	10.4	604
FISH				
Onchorhynchus nerka	<.1	0.2	0.3	<1
Mallotus villosus	17.0	61.3	44.2	3,464
Unidentified Osmerid	0.1	0.2	1.1	<1
Gadidae (Cods)				
Microgadus proximus	0.4	1.0	0.8	1
Theragra chalcogramma	1.9	3.6	5.2	29
Unidentified	0.5	0.6	4.9	5
Total Gadidae	2.8	5.2	5.2	42
Hemilepidotus jordani	0.6	0.8	2.2	3
H. sp.	<.1	<.1	0.3	<1
Unidentified Cottid	<.1	<.1	0.3	<1
Cyclopteridae	<.1	<.1	0.3	<1
Trichodon trichodon	0.4	1.3	3.8	7
Ammodytes hexapterus	5.1	14.6	12.9	254
Total Fish	26.0	83.6	44.2	4,844

Appendix Table 45. Data on Indices of Relative Importance (IRI) for prey of subadult tufted puffins, pooled from food samples collected in Alaska.

Species: Tufted Puffin (*Fratercula cirrhata*) Min. # Prey Spp. = 7
N = 80 Number of Empty Stomachs = 20 (25%)

PREY NAME	% NUMBERS	% VOLUME	% FREQUENCY OF OCCURENCE	IRI
POLYCHAETA, Nereidae	9.5	0.4	1.7	17
CEPHALOPODA				
Unidentified Octopi	0.4	0.1	1.7	1
Unidentified	0.4	0.5	1.7	1
FISH				
Mallotus villosus	42.1	52.7	61.7	5,850
Theragra chalcogramma	4.5	6.8	10.0	113
Unidentified Gadid	1.2	1.2	1.7	4
Hemilepidotus hemilepidotus	0.4	0.1	1.7	1
Trichodon trichodon	0.8	1.2	3.3	7
Ammodytes hexapterus	39.7	35.3	40.0	2,998
Unidentified	0.8	1.8	1.7	4
Total Fish	89.5	99.1	61.3	11,561

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