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

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Reporting partially on the final results of research conducted under OCSEAP Research Unit 341, "Population Dynamics and Trophic Relationships of Marine Birds in the Gulf of Alaska."

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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-1egged Kittiwakes, Arctic and Aleutian Terns, Common and Thick-billed Murres, and Horned and Tufted Puffins (Table I-l). 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, and Forrester (Fig. I-1).

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

- o To determine the numbers and distribution of each species within the study areas;
- o To determine the habitats used by the different species of breeding birds;
- o 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;

- 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.

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

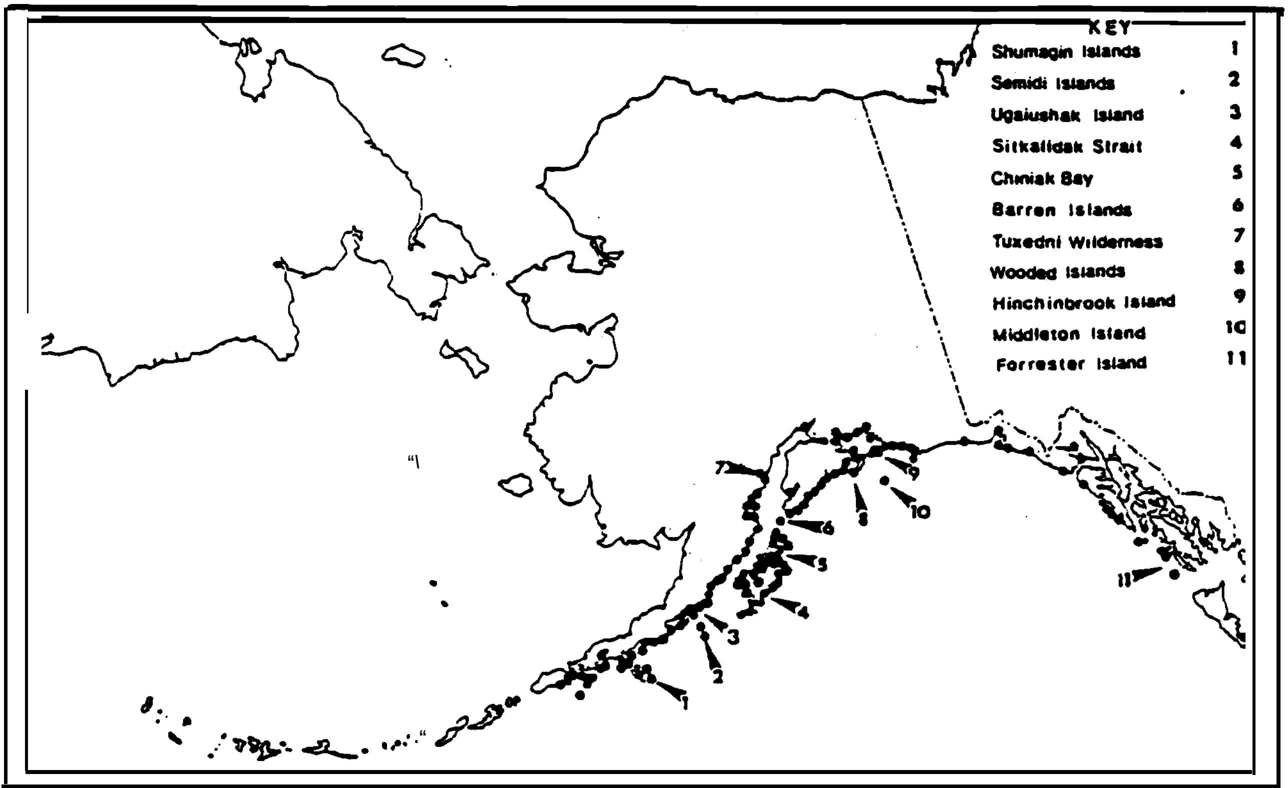
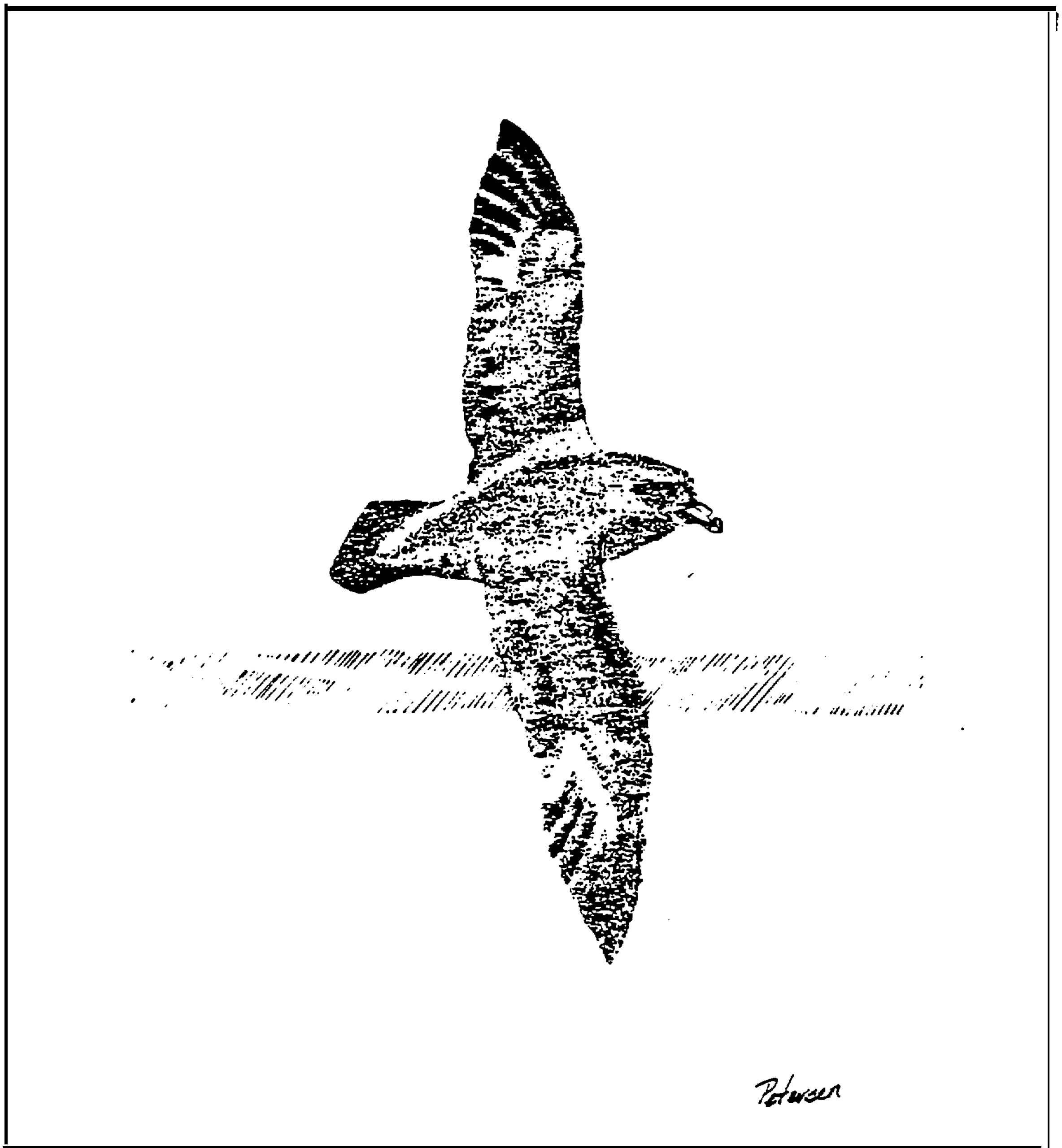


Figure I-1. **Distribution** of seabird nesting colonies in the Gulf of Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

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 Dunne t 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-l). 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 (*Uris 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.

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 onset of breeding varied

varied only by 7 days, being earliest in 1978 (26 May) and latest in 1977 (2 June) (Table II-2, Fig. 11-2). 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 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 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 pretesting 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 2976. 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 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 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 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 lapparent 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.

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

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.

TABLE 11-3
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

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

		Weight (g)		Wing chord(mm)		Total tarsus(mm)		Culmen(mm)	
Age	n	$\bar{X}$	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
3.3-14	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

Northern Fulmar (*Fulmarus glacialis*)

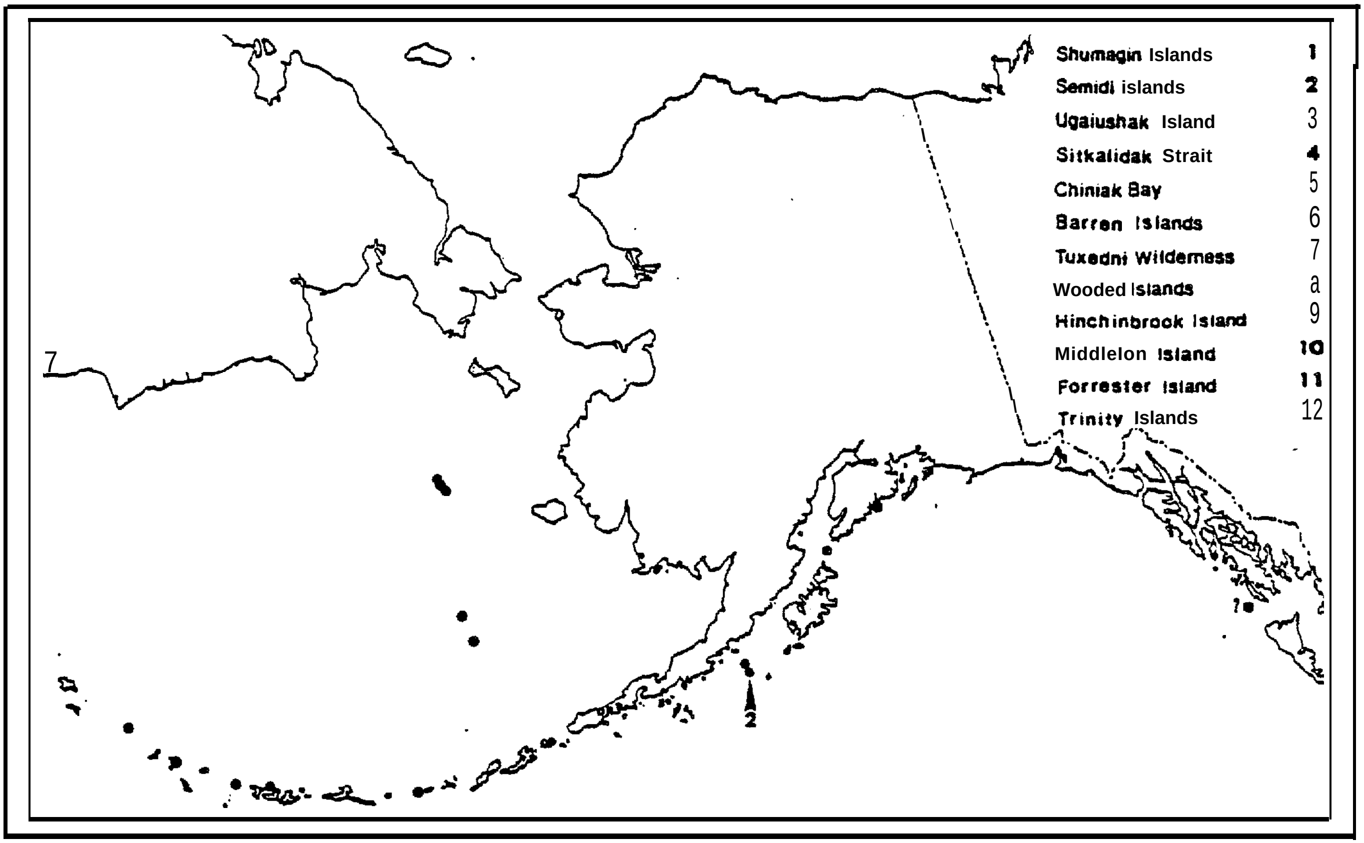


Figure 11-1. Distribution of breeding colonies of Northern Fulmars in Alaska. Site where intensive colony studies were conducted is indicated by arrow.

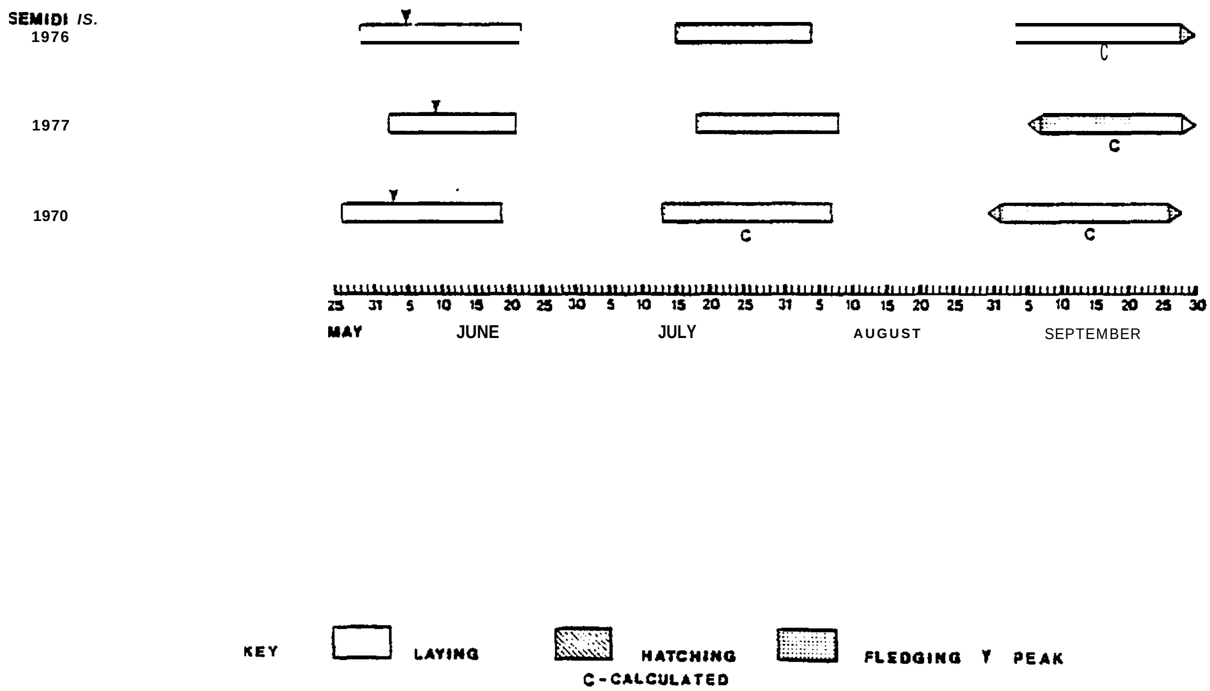


Figure II-2. Chronology of major events in the nesting season of Northern Fulmars at the Semidi Islands in the Gulf of Alaska.

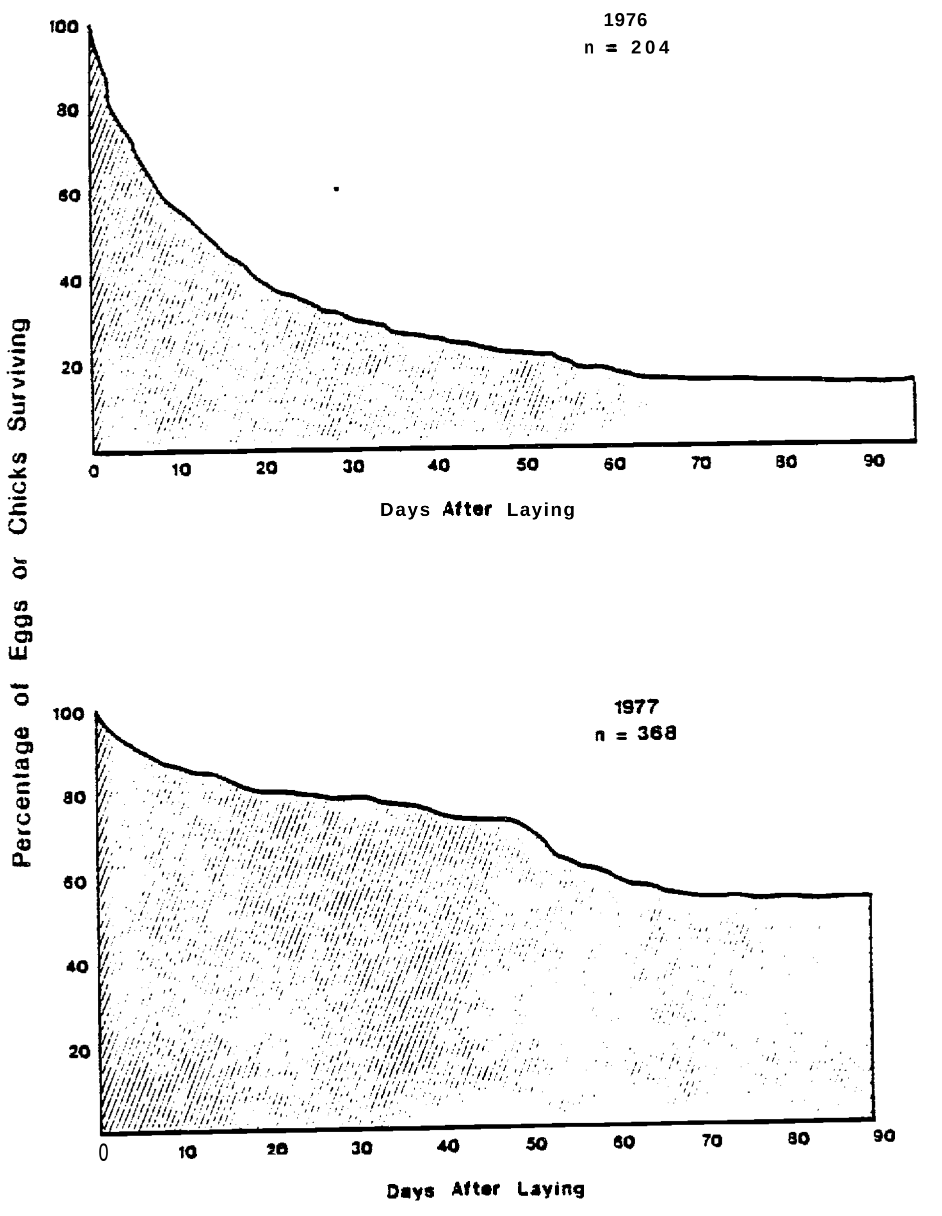


Figure II-3. Survivorship of Northern Fulmar eggs and nestlings at the Semidi Islands in 1976 and 1977.

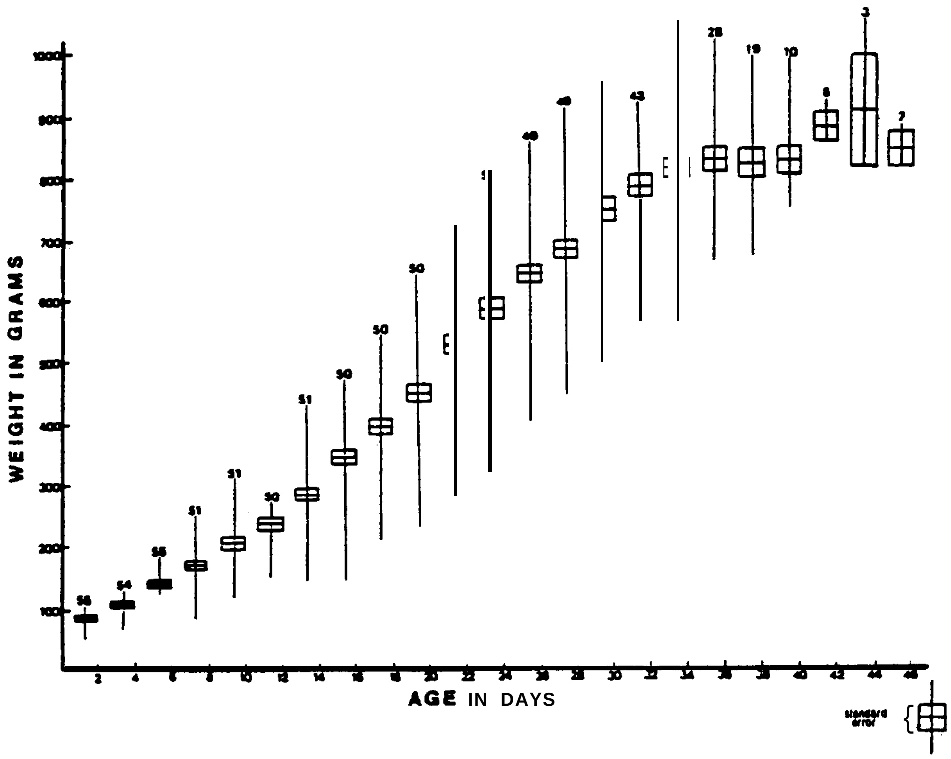


Figure II-4. Growth of Northern **Fulmar** chicks at the **Semidi** Islands. Data for 1976 and 1977 combined.

(a)

(b)

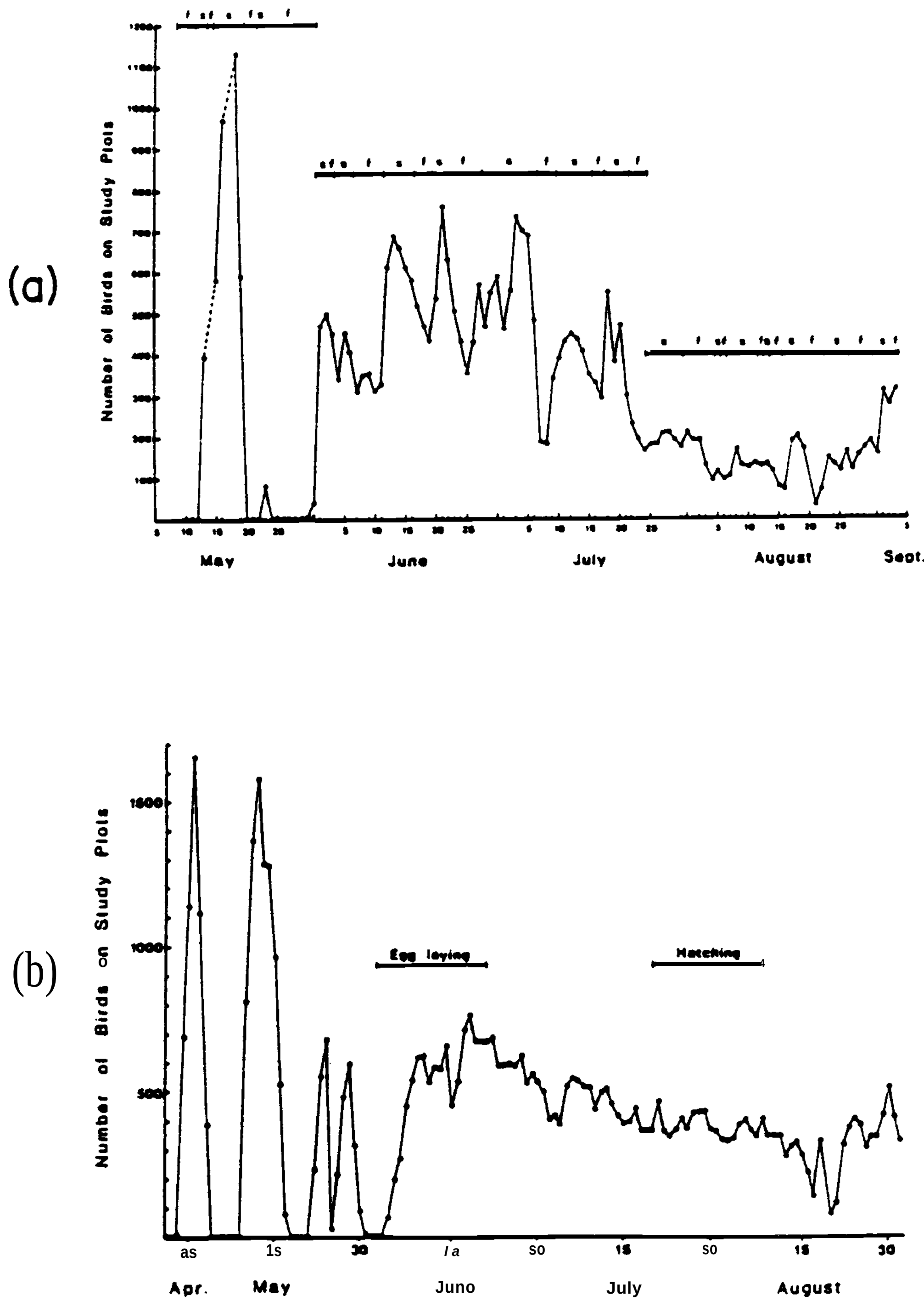
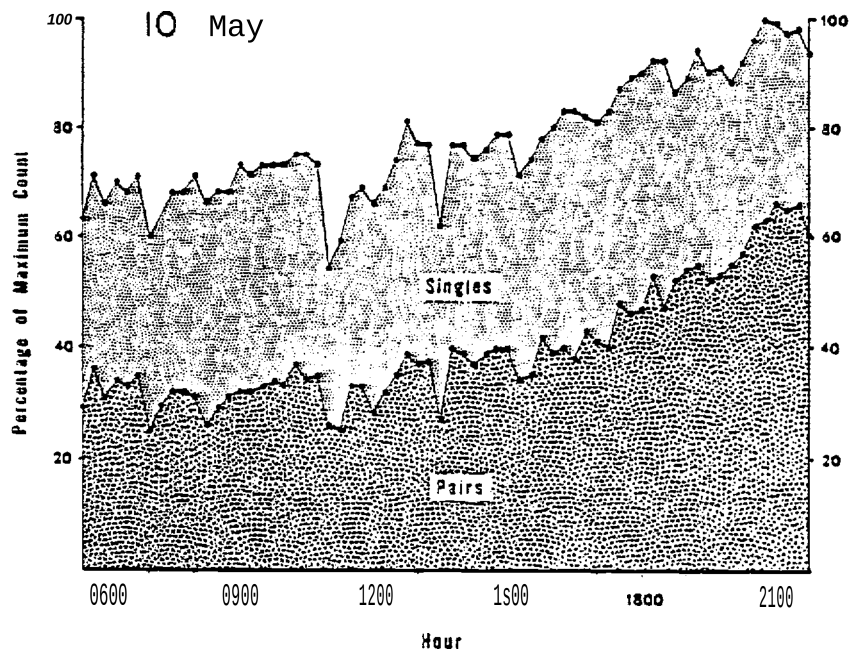


Figure II-5. Seasonal patterns of colony attendance of Northern **Fulmars** at the **Semidi** Islands in (a) 1976 and (b) 1977. Periods of fair (f) and stormy (s) weather during 1976 are indicated.



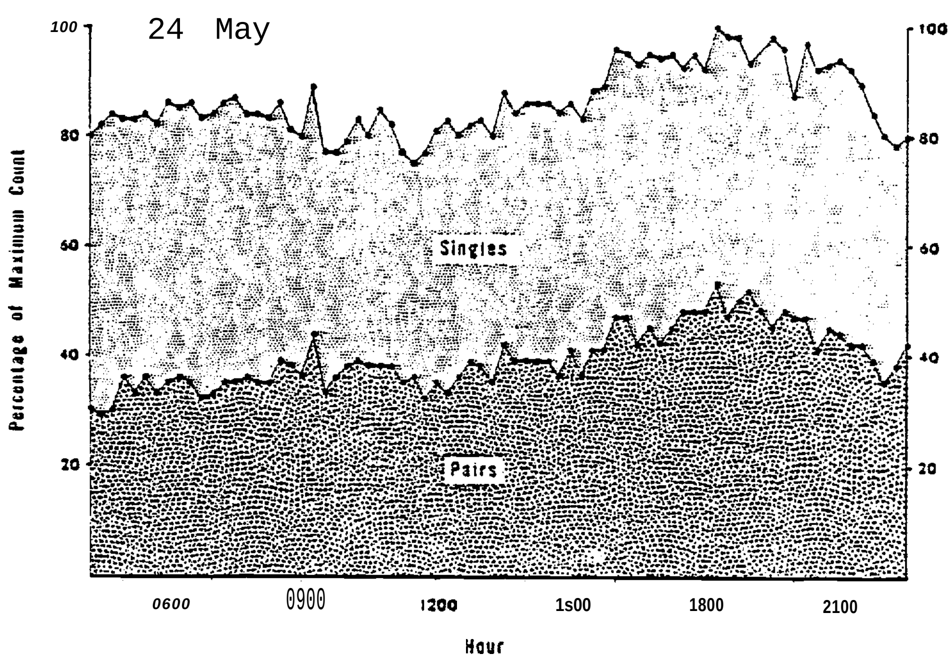


Figure II-6. Diel attendance patterns of Northern Fulmars during the pre-egg stage, Semidi Islands, 1977.

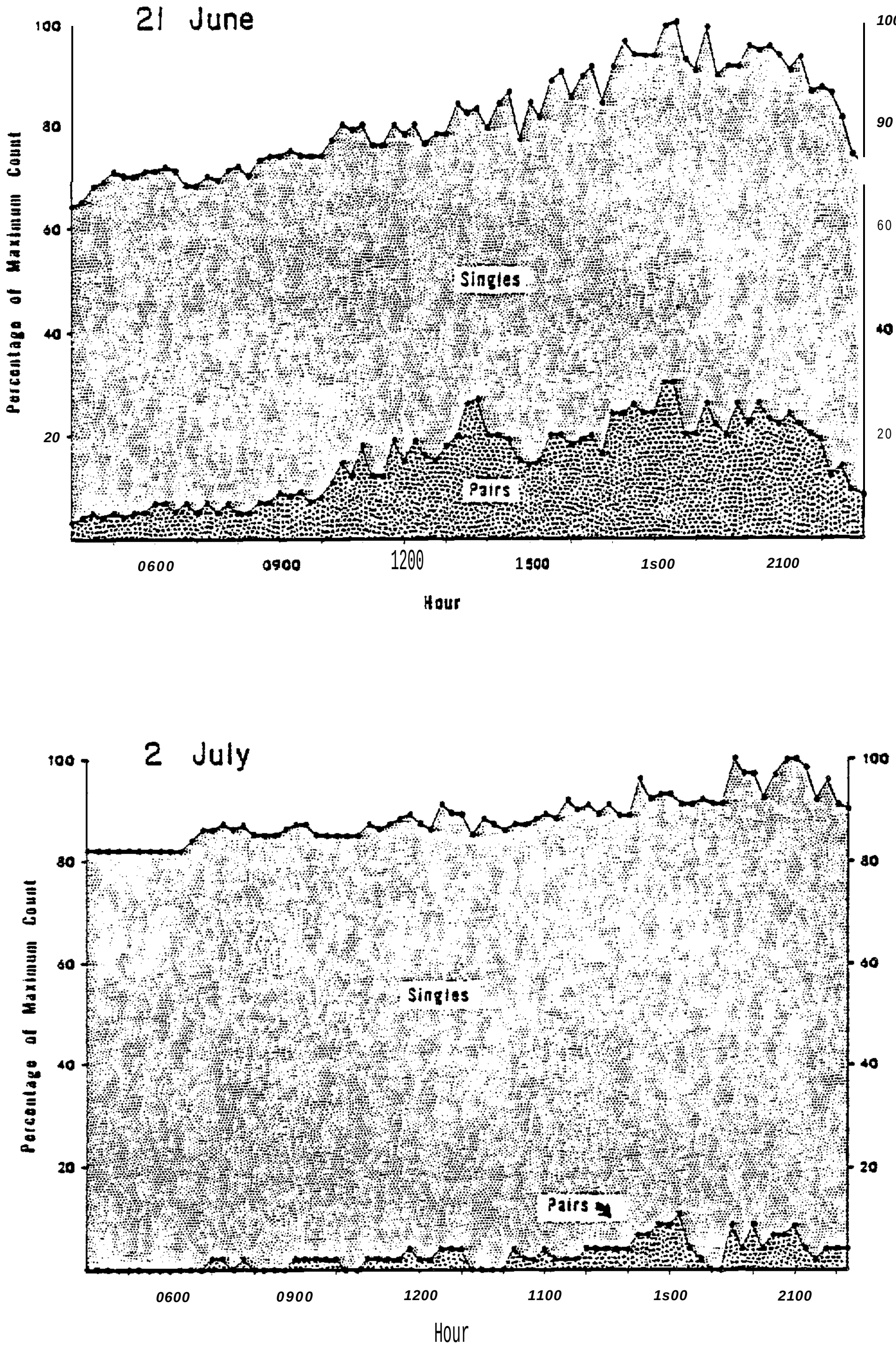


Figure II-7. **Diel** attendance patterns of Northern **Fulmars** during incubation, **Semidi** Islands, 1977.

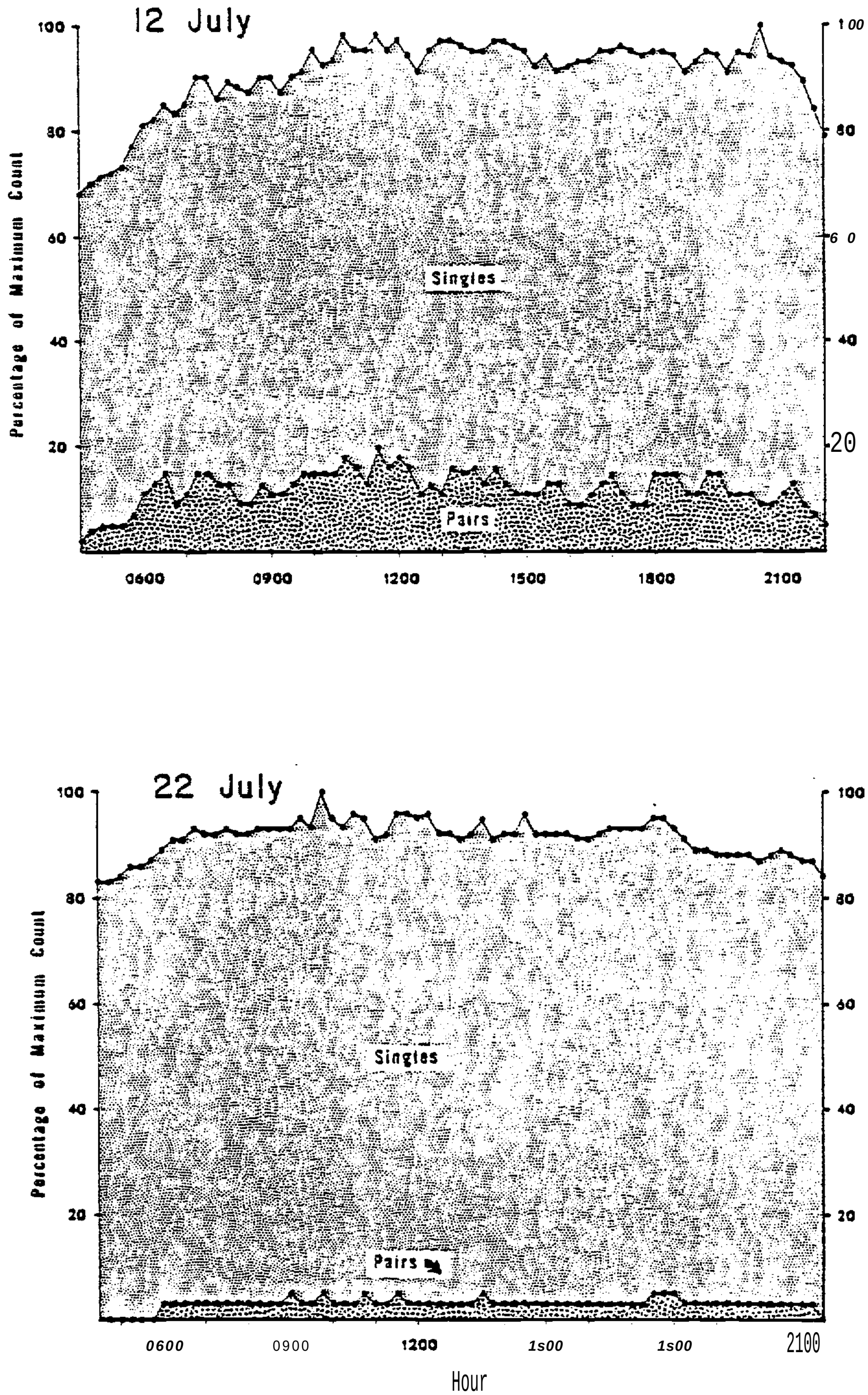


Figure 11-8. **Diel** attendance patterns of Northern **Fulmars** during late incubation and **early nestling** stages, **Semidi** Islands, 1977.

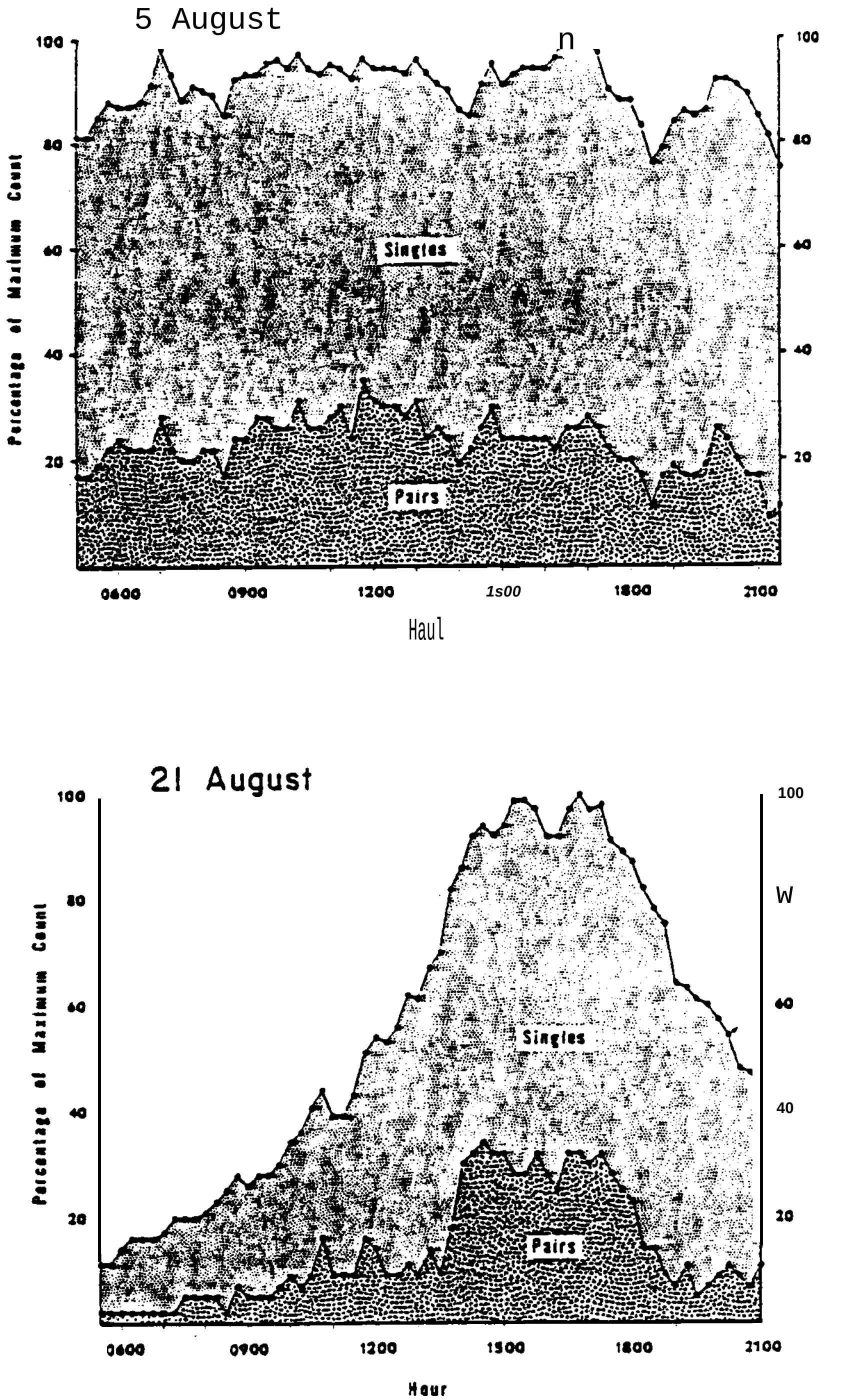


Figure II-9. **Diel** attendance patterns of Northern **Fulmars** during the nestling stage, **Semidi** Islands, 1977.

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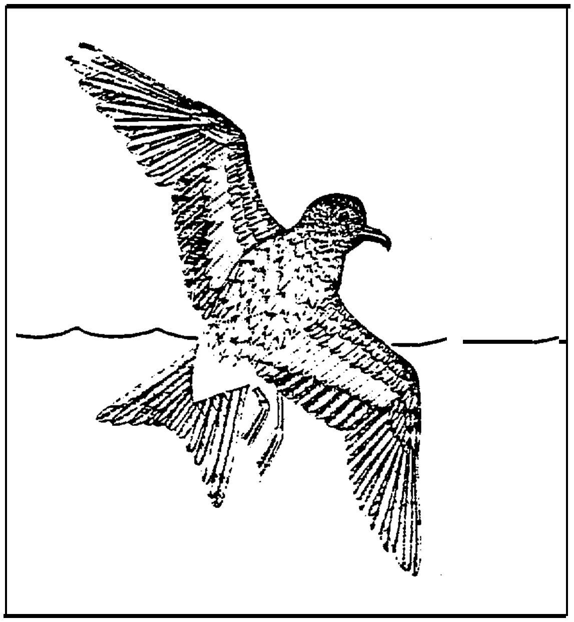
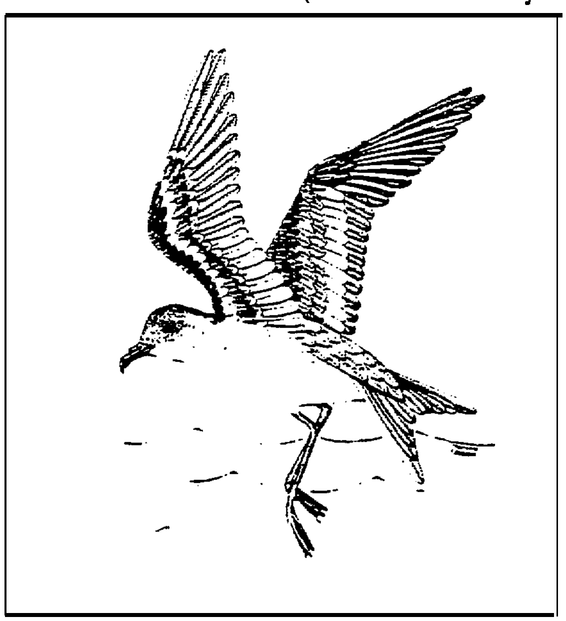
Storm-Petrels (*Oceanodroma* SPP.)

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



Fork-tied 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-l). 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 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 Leachrs 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, but egg neglect was also prevalent in 1976. The mean incubation period of Fork-tailed Storm-Petrels at the Wooded Islands in 197? 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-1aying 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 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 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, 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 Calamus 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 Calamus 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 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 l-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.

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 111-10). 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 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.

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 1s.)	1976	3,000	6,000
East Amatuli (Barren Is.)	1976-78	150,000	
Fish Island (Wooded 1s.)	1976-77	1-2,000	100
Petrel Island (Forrester Is. Grp)	1976	80,000	700,000

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

Species	Location	N	Yeer	Laying First	Laying Last	Hatching Firm	Hatching Peak	Hatching Last	Fledging First	Fledging Last
Fork-tailed Storm-Petrel	Shumagin 1s.	2	1976	24 April	9 June	10 June		27 July	9 Aug	26 Sept
	Wooded le.	30	1976	22 April	12 May	3 June	20 June	11 July	2 hug	9 Sept
		85	1977	29 April	8 June	10 June	30 June	15 Aug	9 Aug	14 Aug
	Barren 1s.	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 Ott
		56	1978	30 April	1 June	LO June	25 June	a Aug	9 Aug	7 Ott
	Forrester Is.	Unk.	1976	26 April	31 May	7 June	20 June	18 July	6 Aug	17 Sept
Leach's Stem-?etrel	Shumagin Is.	6	1976	21 April	26 June	L June		6 Aug	12 Aug	18 Ott
	Wooded Ia.	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 act	

TABLE III-3

Productivity of Fork-tailed Storm-Petrels.

	Barren Islands 1976	Barren Islands 1977 Light Disturbance	Barren Islands 1977 Heavy Disturbance	Barren Islands 1978	Wooded Islands 1976 Soil	Wooded Islands 1977 Soil	Wooded Islands 1977 Rock	Wooded Islands 1977 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]	753	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	13.68	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] Burrowa 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 baaed on all nests found; the second (in parentheses) incorporates an estimate of hatching success based on six eggs found, four of which hatched.

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 L976 & 1978 (combined)				Barren Islands 1977			
	N	X̄ wt .(g)	SE	Range	N	X̄ wt. (g)	SE	Range
0	9	10.3	0..50	7-15	32	9.4	0.2	7-11
L-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	L.0	7-23
5-6	107	19.3	0.45	10-30	36	16.6	0.6	9-24
7-a	115	23.0	0.52	15-36	12	22.6	L.3	17-32
9-10	140	27.8	0.53	15-47	34	24.5	1.1	12-41
11-12	3.38	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	L.3	17-48
17-18	L27	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	L.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	S3.2	2.9	41-74
25-26	118	67.1	0.83	45-94	29	52.2	2.7	17-78
27-28	LOS	70.1	0.91	54-88	12	58. L	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.S	48-74
33-34	122	77.1	0.76	48-9 7	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	53-10'4				
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				

TABLE 111-5
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	25.4	0.2	14-17
7-8	22	10.1	0.1	9.3-11.5	14.0	0.3	11.3 -1s.2	16.7	0.3	15-21
9-10	28	10.3	0.1	9.4-11.9	L5.3	0.2	13.3-19.1	18.3	0.3	16-24
11-K	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.?	19-37
17-18	29	11.9	0.1	10.5 -12.s	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	22.9-15.1	24.5	0.3	22.5-27.2	57.7	1.9	40-76
29-30	21	23.7	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	58-90
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	23.6-15.3	26.0	0.1	24. 4-27. 4	96.7	2.1	80- 111
3940	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-?7.6	111. 0	2.1	93-129
43-44	26	14.6	0.1	13.6-35.6	26.3	0.2	24.4-27.6	118.5	2.0	105-L37
45-46	27	14.5	0.1	13.9-25.S	26.5	0.2	26.0-27.7	125.5	1.7	102-136
47-48	22	14.7	0.1	23.7-25.7	26.6	0.1		132.5	2.0	227-149
49-50	17	14.7	0.1	13.7 -2.5.7	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	25.4	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	16.7	0.1	14.0-15.S	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)	n	Weight (g) $\bar{x}$	SE	Range	Culmen (mm) $\bar{x}$	SE	Range	Tarsus (mm) $\bar{x}$	SE	Range	n	Wing (mm) $\bar{x}$	SE	Ran
1-5	0							-	.-		0			
6-10	2	25.5	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	33.6-14.0	23.2	0.2	22.0-23.7	4	68.8	3.8	61-49
41-45	10	65.8	2.5	66-79	14.5	0.2	13.9-15.5	23.2	0.2	22. S-23.9	6	76.8	4.0	78-89
46-SO	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	14.4-25.0	22.8	0.4	22.0-28.8	4	337.5	2.5	233-143
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	254-158

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)					
$\bar{X}$		59.7	57.8	59.5	
SE		0.2	0.2	0.2	
n		353	299	337	
Range		48-74			
Peak nestling weight (g)					
$\bar{X}$	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)					
$\bar{X}$	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)					
$\bar{X}$	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)					
$\bar{X}$	64.4	61.0			59.5
SE	1.0	0.5			0.3
n	7	47			20
Range	61-68	50-65			52-63

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 1976 (n=83)		1977 (n=70)		Frequency of occurrence 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]								
Cottoidea			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 pares 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	9.00	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	75.1	18	12	66.7						226	169	
41-50	226	i69	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.

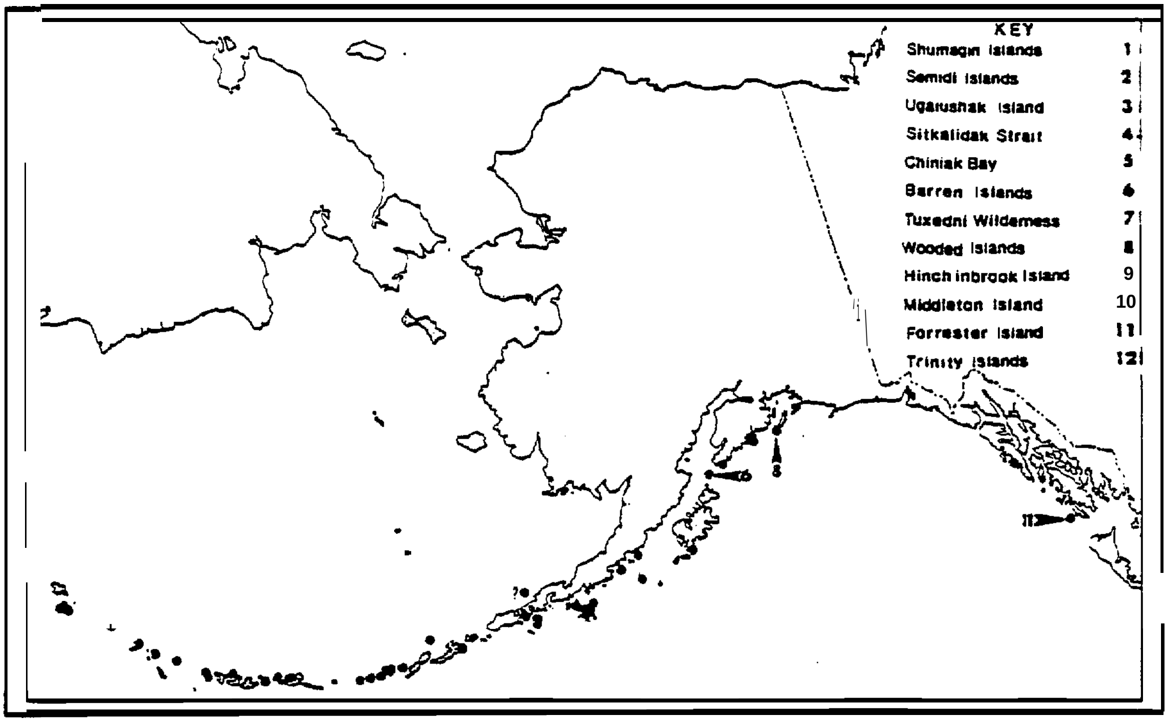
TABLE 111-10
Mortality of Fork-tailed Storm-Petrel Eggs and Chicks in Different Habitats at Wooded Islands.

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	(6)	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	(L)	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	(lo)	16.0	(4)	18.7	(58)
TOTAL MORTALITY (EGGS + CHICKS)	70.7	(53)	75.0	(2.53)	36.4	(22)	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.

Fork-tailed Storm Petrel (*Oceanodroma furcata*)

(a)



Leach's Storm Petrel (*Oceanodroma leucorhoa*)

(b)

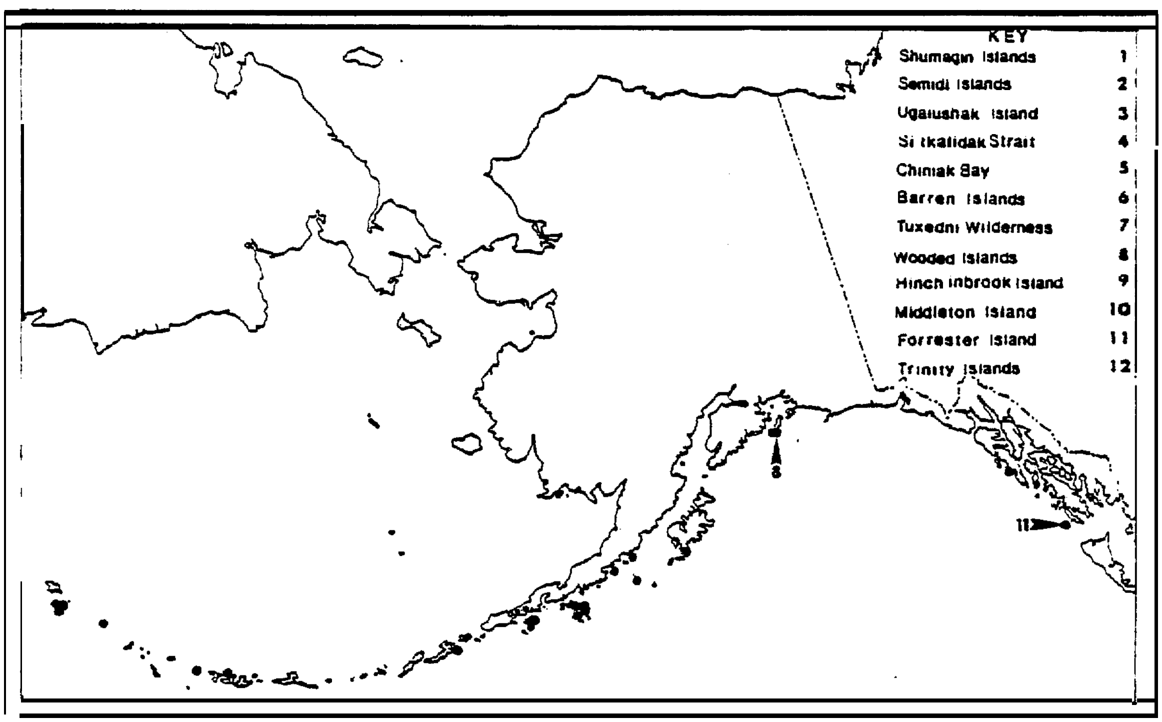


Figure III-1. Distribution of breeding colonies of (a) Fork-tailed Storm-Petrels and (b) Leach's Storm Petrels in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

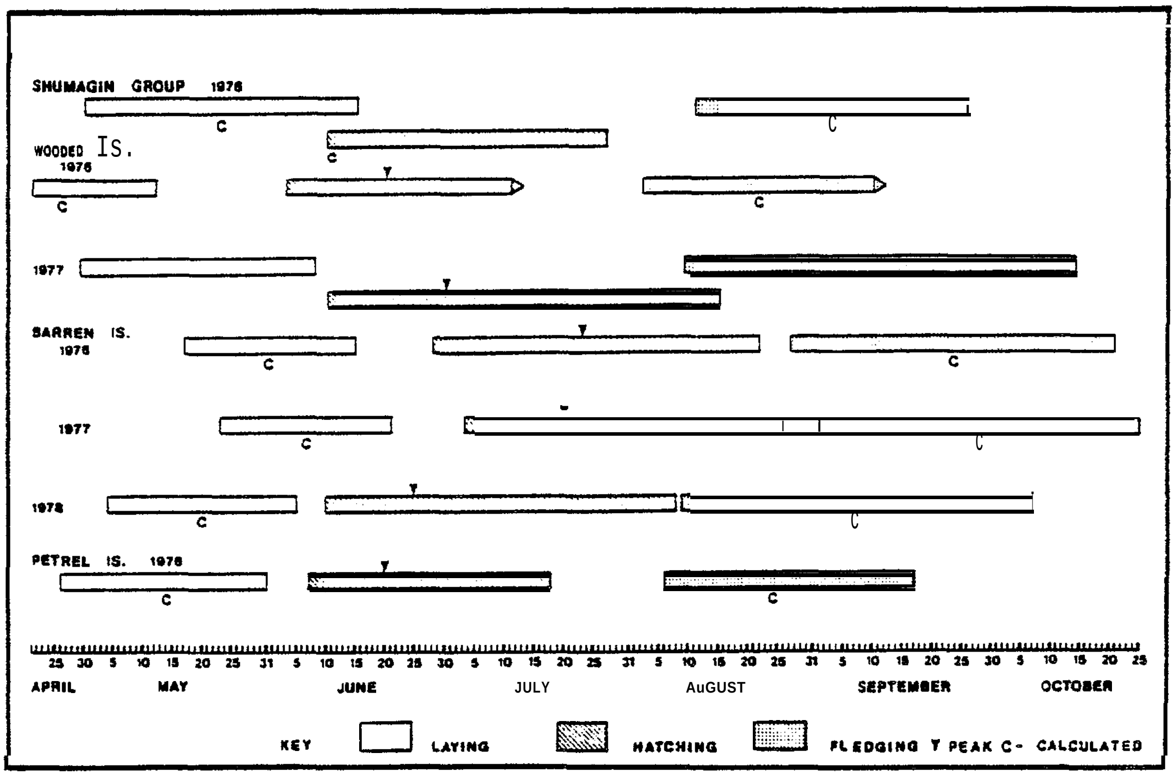


Figure III-2. Chronology of major events in the nesting season of Fork-tailed Storm-Petrels in the Gulf of Alaska.

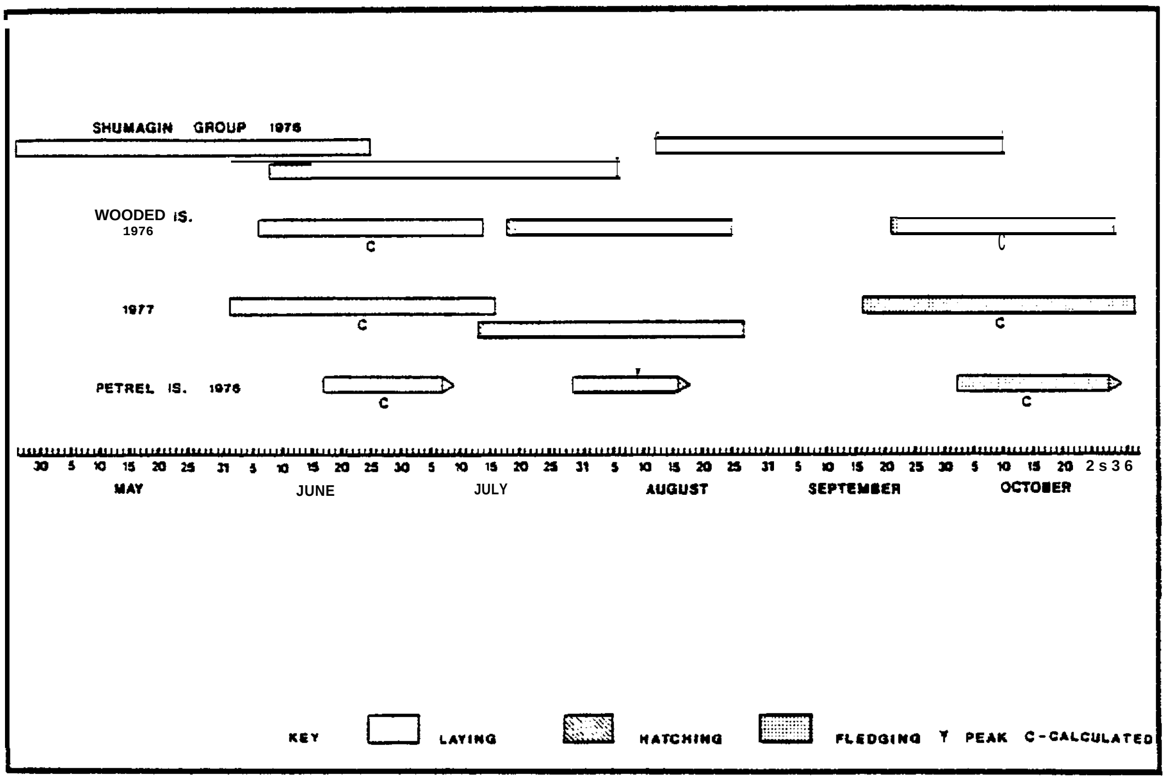


Figure III-3. Chronology of major events in the nesting season of Leach's Storm-Petrels in the Gulf of Alaska.

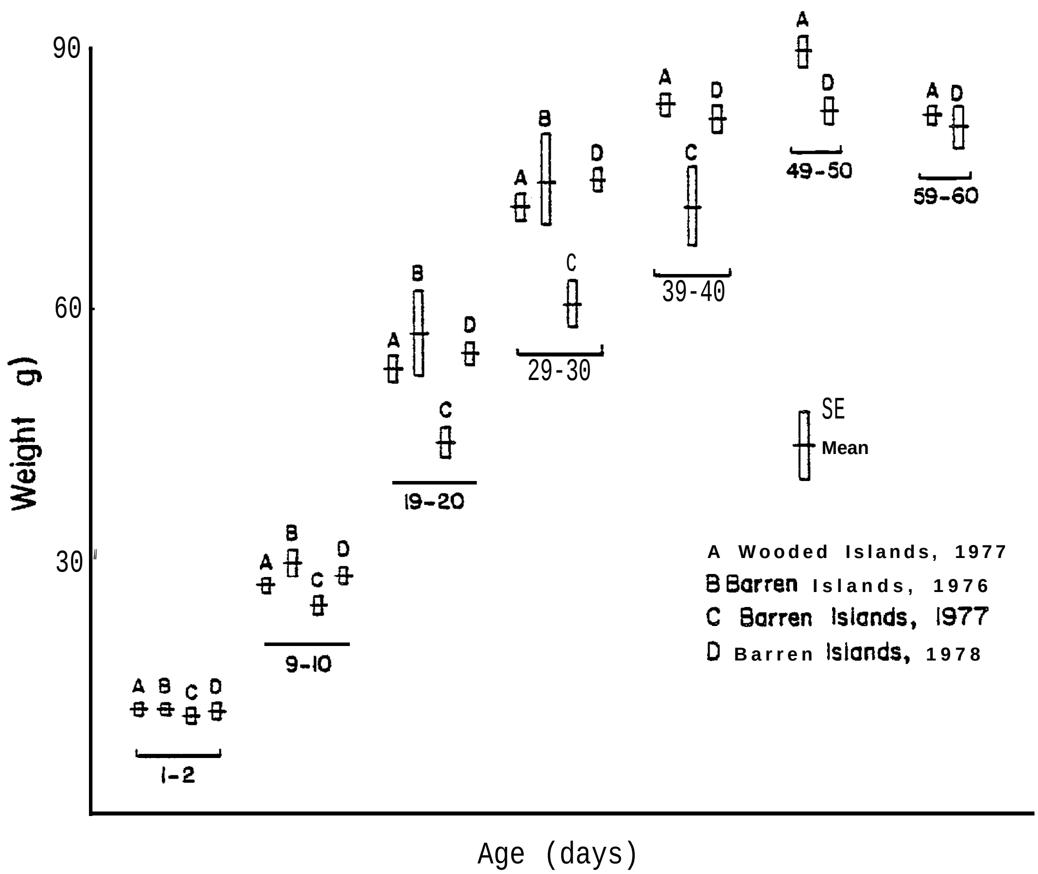


Figure III-4. Comparison of mean weights of Fork-tailed Storm-Petrel nestlings at the Wooded Islands and the Barren Islands between 1976 and 1978.

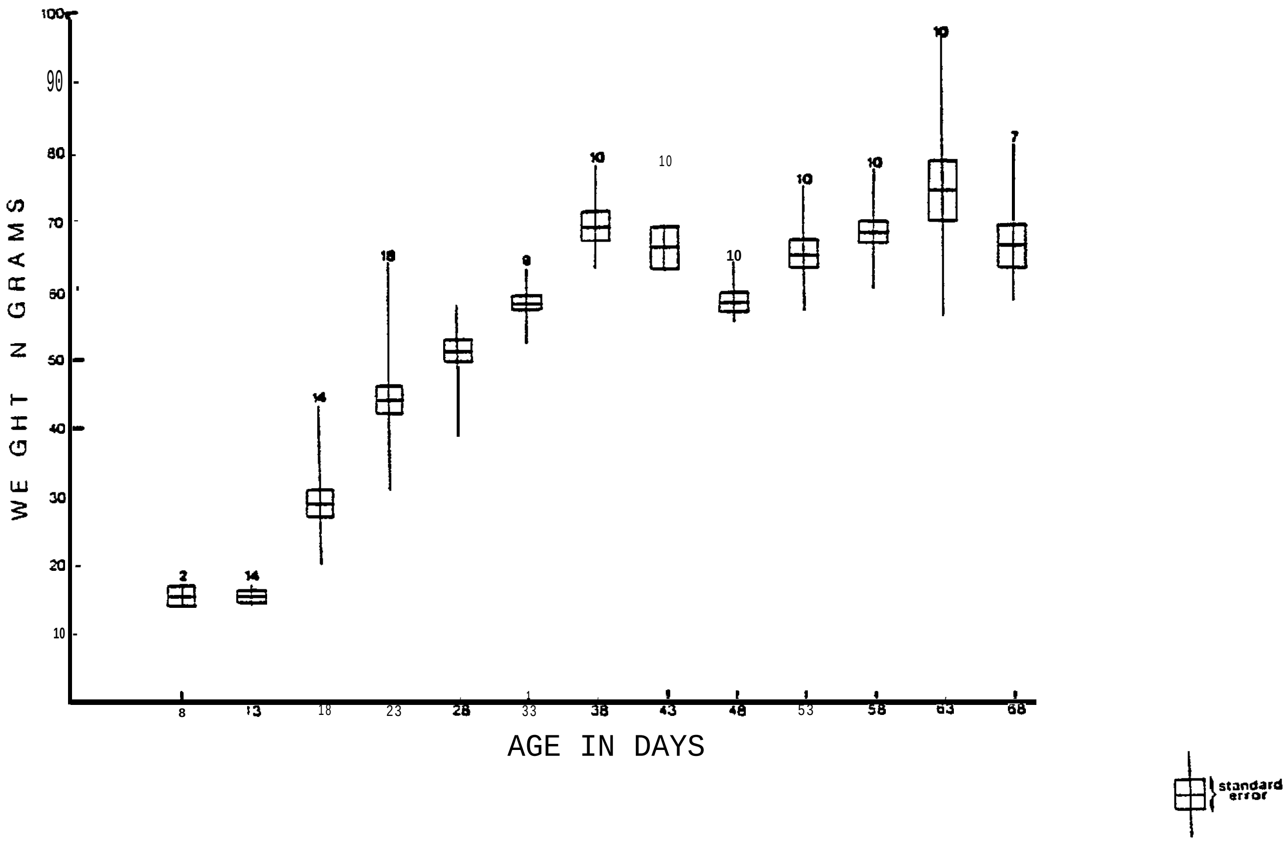


Figure 111-5. Weight gain in Leach's Storm-Petrels at the Wooded Islands. Data for 1976 and 1977 combined.

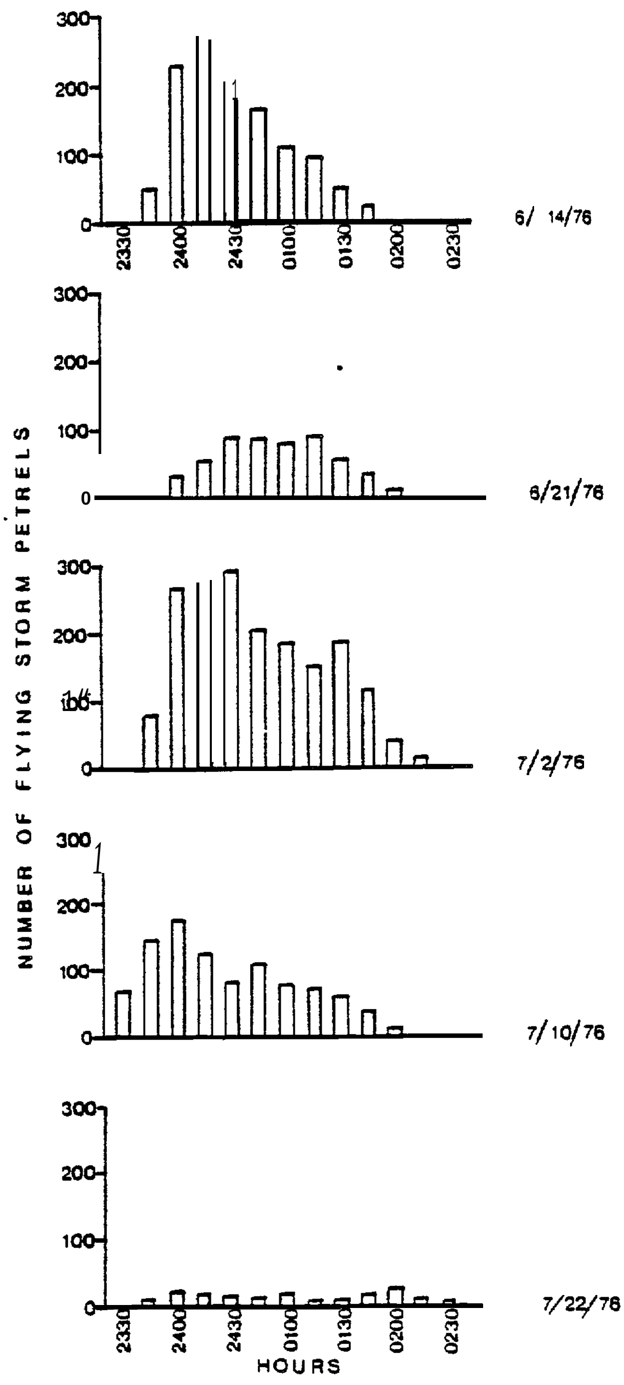


Figure III-6. Counts of numbers of Fork-tailed Storm-Petrels flying over the colony on East Amatuli Island on five nights.

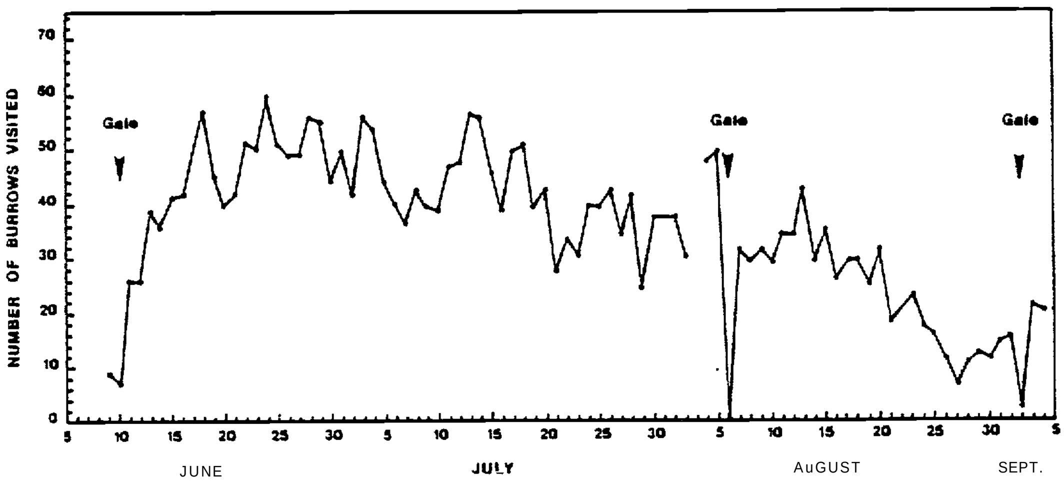


Figure III-7. Numbers of burrows visited by Fork-tailed Storm-Petrels on East Amatuli Island, Alaska in 1976.

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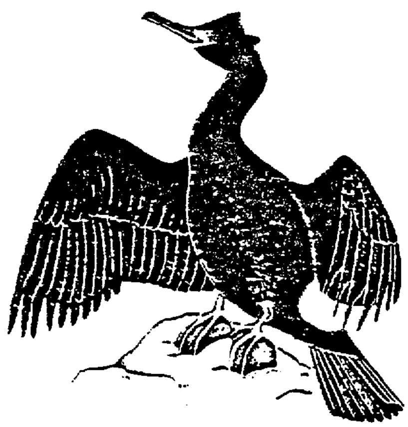
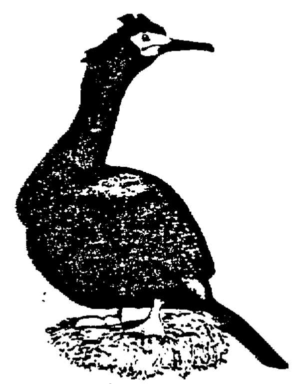
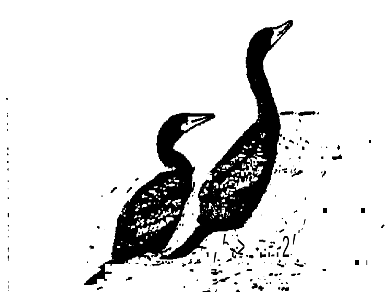
Cormorants (*Phalacrocorax* spp.)



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. resplendent*). 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 1977	(Leschner and Burrell 1977) (Hatch 1978)
Ugaiushak Island	1976 1977	(Wehle et al. 1977) (Wehle 1978)
Chiniak Bay, Kodiak Island	1977 1978	(Nysewander and Hoberg 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-la). 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-lb). 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 (Souls 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-lc). Except for a small population on the Commander (Komandorski)

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 PWS 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 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

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 O 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:

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 O 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 2977), 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 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 sticklebacks (*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

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.

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 1s.	50		0
Long 1s.	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 1s.	0	46	0
Kulichkof 1s.	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 1s.	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

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 1s.	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.

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	23 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.

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]	-	6?	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	2.8'4	3.64			2.84
Range of clutch sizes					]-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.

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
2978								
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	0.2s	0.89	a	0.19	0.20	1.58	a	0

a Unchecked even though nests vere present.

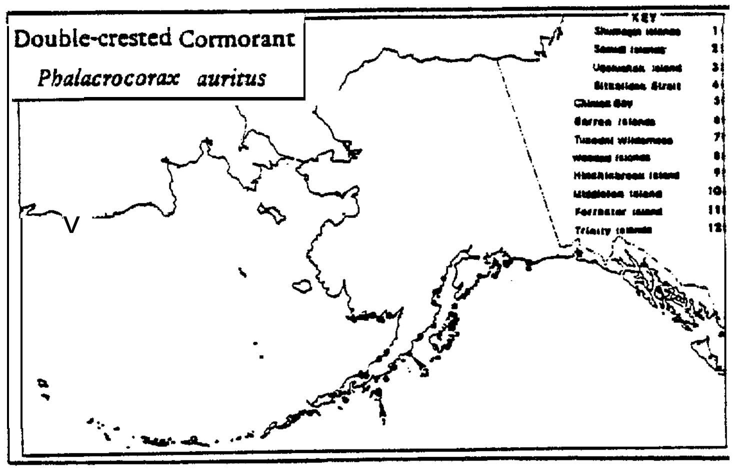
TABLE IV-11
Comparison of Productivity of Pelagic Cormorants at
Three Areas in the North Pacific Ocean.

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
Z fledging success (chicks fledged per egg hatched)	56	74	76
Breeding success[b]	1.33	1.32-1.39	1.97

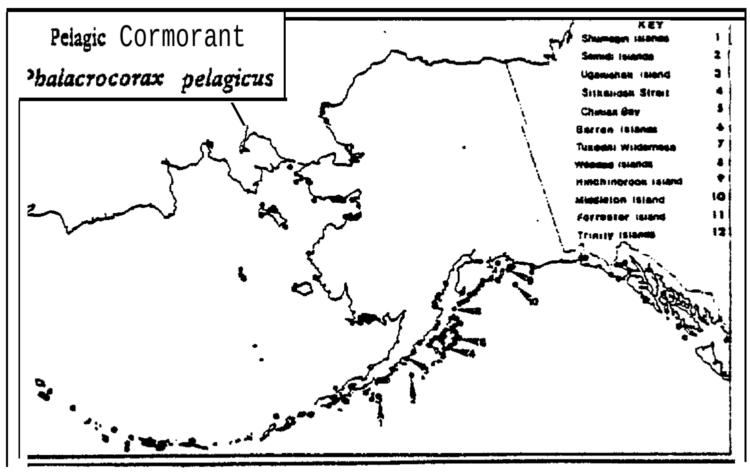
[a] Data sources are Dick (1975) and Drent et al. (1964).

[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.

(a)



(b)



(c)

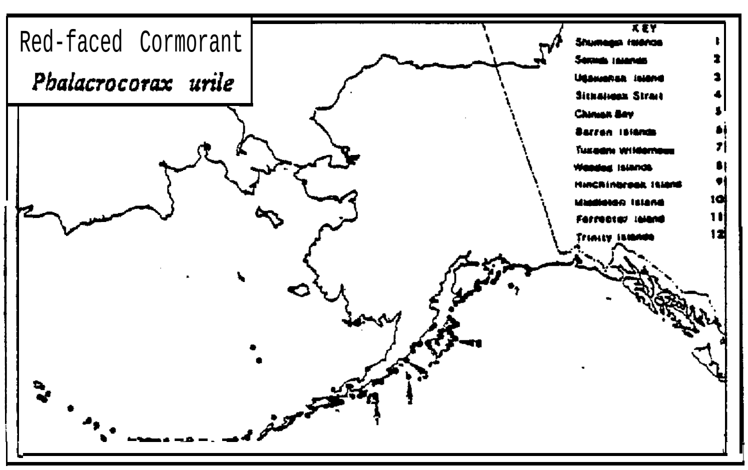


Figure IV-1. Distribution of breeding colonies of (a) Double-crested, (b) Pelagic, and (c) Red-faced Cormorants in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

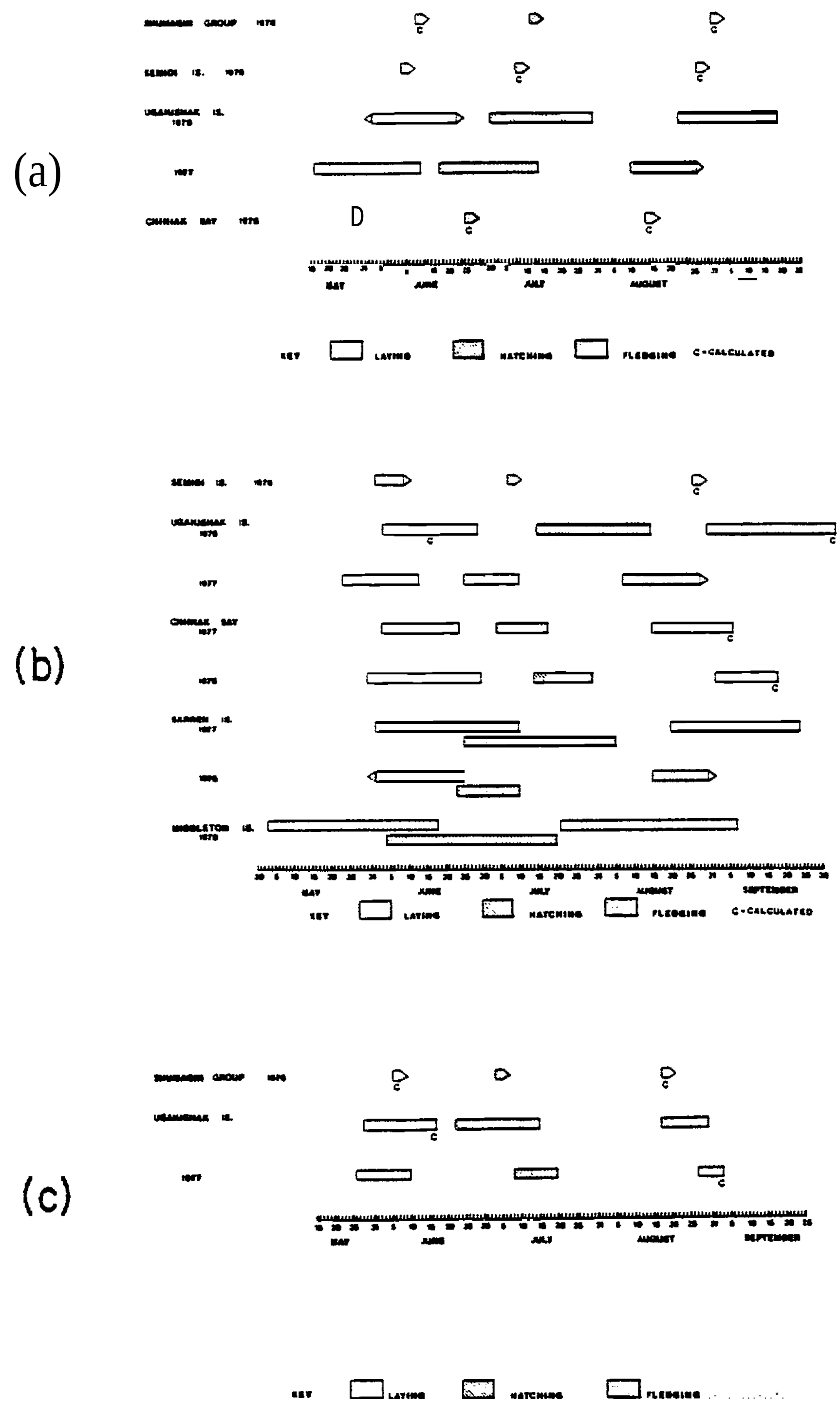


Figure ST-2. Chronology of major events in the nesting seasons of (a) Double-crested, (b) Pelagic, and (c) Red-faced Cormorants in the Gulf of Alaska.

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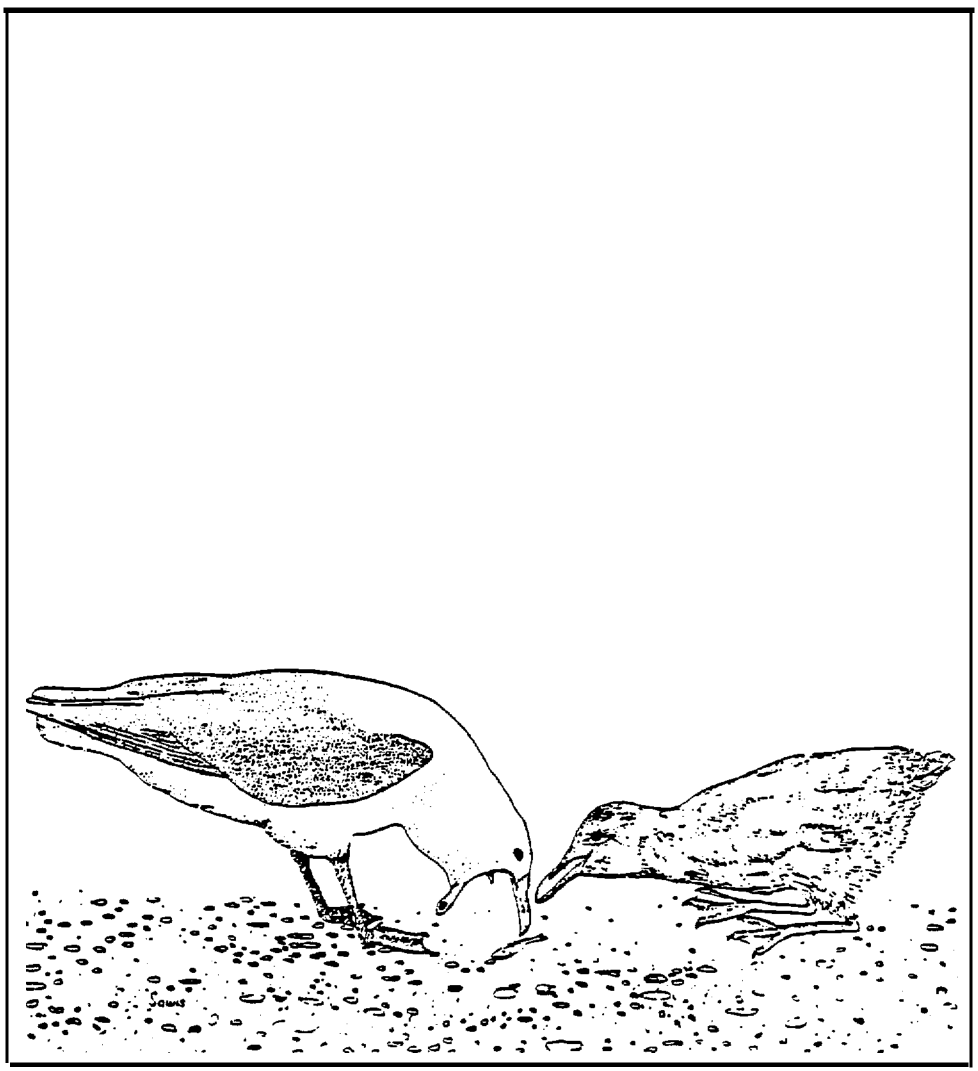
Glaucous-winged Gull (*Larus glaucescens*)



by

Patricia A. Baird

GLAUCOUS-WINGED GULL

(*Larus glaucescens*)

Gulls are one of the most commonly studied groups of birds. However, only a relatively fewof 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%

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-l). 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 impor- in recent years tance is the increased survival of fledglings over their first winter due to artificial food supplies. We may speculate that increased human population and expansionof 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 + 0.23 SE) and high (3.07 +

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 outcropping. 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 over-all 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 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 S 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 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) 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*) fish of the family Clupeidae were delivered most frequently to chicks whereas Pacific sand lance (*Ammodytes hexapterus*) and capelin (*Mallotus villosus*) were most important at also brought to chicks at these study sites. The types of urev 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 trophies 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 Sitkalidak Strait (Table V-9). Limpets were was not a limiting factor for

Glaucous-winged Gulls at Ugaiushak Island in 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 did increase 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 (Lutra canadensis) were active predators and may have taken many gull eggs.

Mortality from desertion, exposure, and unknown causes during 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 wide-spread. 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.

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		

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 00 exposed bedrock along edge of cliffs, vegetated with beach rye (Elymus arenarius) and cow parsnip (Heracleum lanatum).
Sitkalidak Strait	0.83 (high)[a] 0.]8 (low)	5.3 ±0.6	Highest densities on steep (17" slope), unvegetated cliffs of Little Kittiwake Rock and an Amee Rock, a gently sloping (4°) aea 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)	3.350.2	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; moat 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 Sod 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] Wean 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 1a. in 1976, within entire colony on Sud Is. in 1976, and within the entire colony on E. Amatuli In 1977, respectively.

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)	2a July>[a]
	77		23 May-15 June (peak 4 June)		
Ugaiushak	76		6 June>[a] (peak 15-20 June)	(peak 9-3.5 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 U July)	12 Aug-7 Sept>[a] (peak 16-20 Aug)
Chiniak Bay	75			18 June>[a] (peak 30 June)	
	?7	36	28 May-25 July[b] (peak 4 June)	25 June-n July (peak 2 July) 25-25 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 L-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 !Lsy-6 June)	25 June>[a] (peak 28 June-5 July)	3-25 Aug>[a]
	78		2S 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)	
	7a		27 April-12 June	24 May-8 July	3 July-17 Aug[b]

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

TABLE V-4
Productivity of Glaucous-winged Gulls.

	Shumagin Island 1976	Semidi Island 1976	Semidi Island 1977	Ugaiushak Island 1976	Ugaiushak Island 1977	Sitkalidak Strait 1977	Sitkalidak Strait 1978	Chiniak Bay 1975	Chiniak Bay 1977	Chiniak Bay 1978	Barren Island 1977	Barren Island 1978	Hinchinbrook 1976	Hinchinbrook 1977	Hinchinbrook 1978	Wooded Island 1977	Middleton 1978	Forrester 1976
Number of nests built			90[a]			84	Ill	62	40	38						43		
Number of nests w/eggs	1 on	117	63	128	126	51	. 53	41	13	35	32	25	35	68	37	21	m (52)[b]	21
Number of eggs laid	242	295	160 (18)[b]	254	114	134	124	84	87	al	19	63	88	112	92	12	202 (150)[b]	
Number of eggs hatched	196		143 (15)[b]		168	101	59		75	41	48	22		96			(121)[b]	
Number of chicks fledged			(7)[b]			90[d]	¼		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	2.41	2.52	2.51	2.53	2.49	2.67	2.89	2.511
X̄ brood size @ hatching			2.38 (2.50)[b]			1.87	2.in		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	0.40		0.86 (0.92)[c]	0.54	0.61	0.15	0.70	0.56			(0.82)[b]	
Chicks fledged/chicks hatched (fledging success)			(0.47)[b]			o. 89[d]	0.73		0.61	0.60	0.60	0.18		0.65				
Chicks fledged per nest w/eggs			(1.17)[b]			1.58[d]	0.81		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	0.14								
% 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 unt I Ju st be fore 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%

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

Age in Days	N	Weight in grams $\bar{X}$	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)
o-1,	$\bar{X}$	80.31	18.49	28.89	2.60
	SE	4.42	0.47	.59	0.05
	N	16	13	13	17
2-3,	$\bar{X}$	133	20.85	33.25	3.18
	SE	14.25	1.22	1.37	0.17
	N	4	4	4	4
4-5,	$\bar{X}$	188.4	22.98	35.07	3.68
	SE	32.01	1.38	3.10	0.28
	N	5	6	6	6
6-7,	$\bar{X}$	186.83	23.13	37.68	3.87
	SE	23.35	1.01	1.43	0.15
	N	6	6	6	6
8-9,	$\bar{X}$	337.89	28.72	47.11	5.54
	SE	25.77	0.97	1.41	0.53
	N	9	9	9	9
10-11,	$\bar{X}$	402.17	30.40	49.78	6.20
	SE	27.35	1.00	1.75	0.56
	N	12	13	12	12
12-13,	$\bar{X}$	476.56	32.49	52.14	6.33
	SE	26.79	1.15	1.63	0.40
	N	9	7	7	9
14-15,	$\bar{X}$	562.11	34.53	58.46	9.47
	SE	39.83	1.33	1.64	0.84
	N	9	10	10	10
16-17,	$\bar{X}$	658.27	37.29	61.33	10.95
	SE	12.13	0.98	0*86	0.53
	N	11	11	11	11
18-19,	$\bar{X}$	815	39.93	66.98	14.34
	SE	25.88	1.42	1.99	1.72
	N	5	5	5	5
20-21,	$\bar{X}$	812.29	39.91	66.16	14.19
	SE	41.69	0.65	1.03	0.65
	N				
22-23,	$\bar{X}$	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,	$\bar{X}$	942.57	42.57	70.14	19.30
	SE	32.09	11.20	0.83	0.78
	N	7	6	7	7
26-27,	$\bar{X}$	1012	45.99	70.28	21.62
	SE	33.16	0.85	1.46	0.58
	N	9	9	9	9
28-29,	$\bar{X}$	1140	47.37	74.47	24.00
	SE	100.67	3.82	3.38	0.51
	N	3	3	3	3
30-31,	$\bar{X}$	1182.33	48.57	74.97	24.43
	SE	63.89	0.84	.50	1.39
	N	3	3	3	3
32-33,	$\bar{X}$	1110.83	49.44	74.82	26.22
	SE	51.64	1.44	1.53	0.42
	N	6	5	5	6
34-35,	$\bar{X}$	1236.67	49.60	71.25	28.53
	SE	76.23	2.80	5.75	0.92
	N	3	2	2	3

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			

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	(loo)	295	(100)	160	(loo)	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.

Glaucous-winged Gull (*Larus glaucescens*)

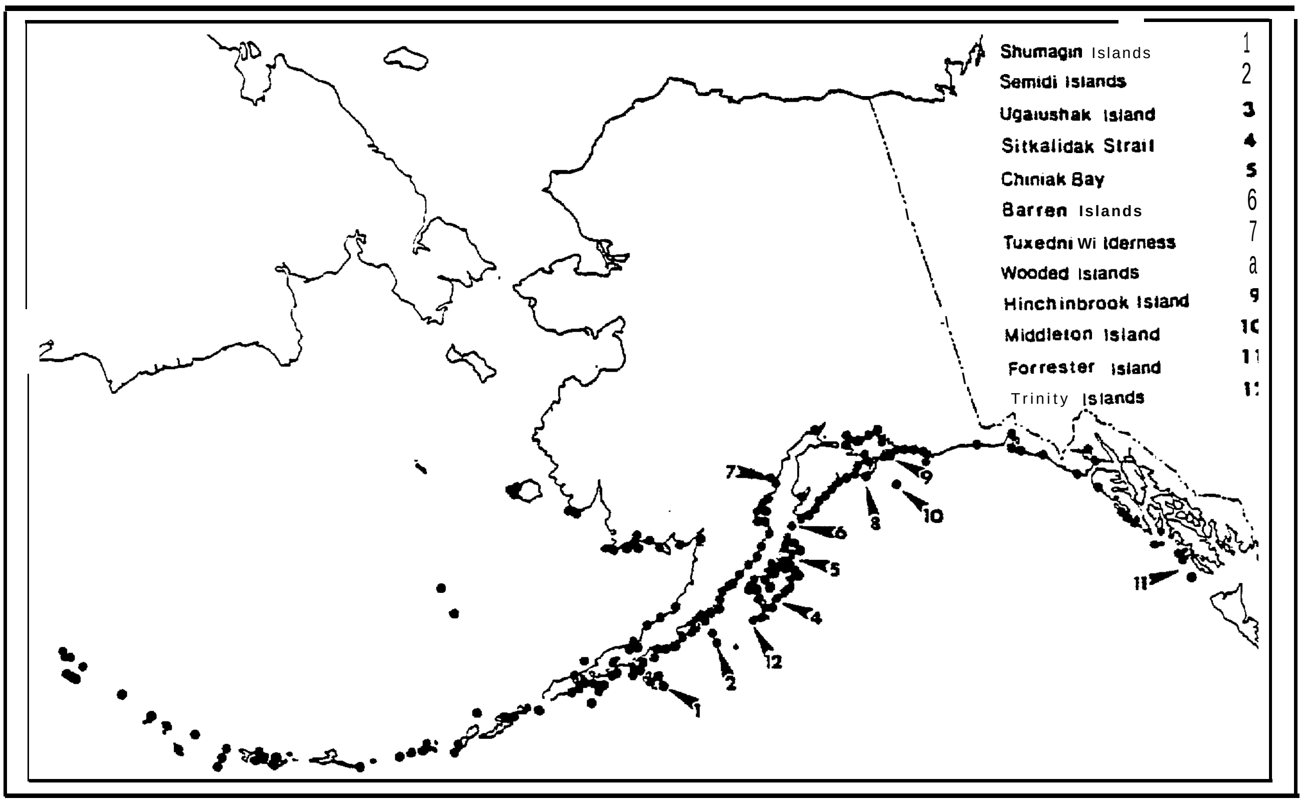


Figure V-1. Distribution of breeding colonies of Glaucous-winged Gulls in Alaska. Sites where Intensive colony studies were conducted are indicated by arrows.

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

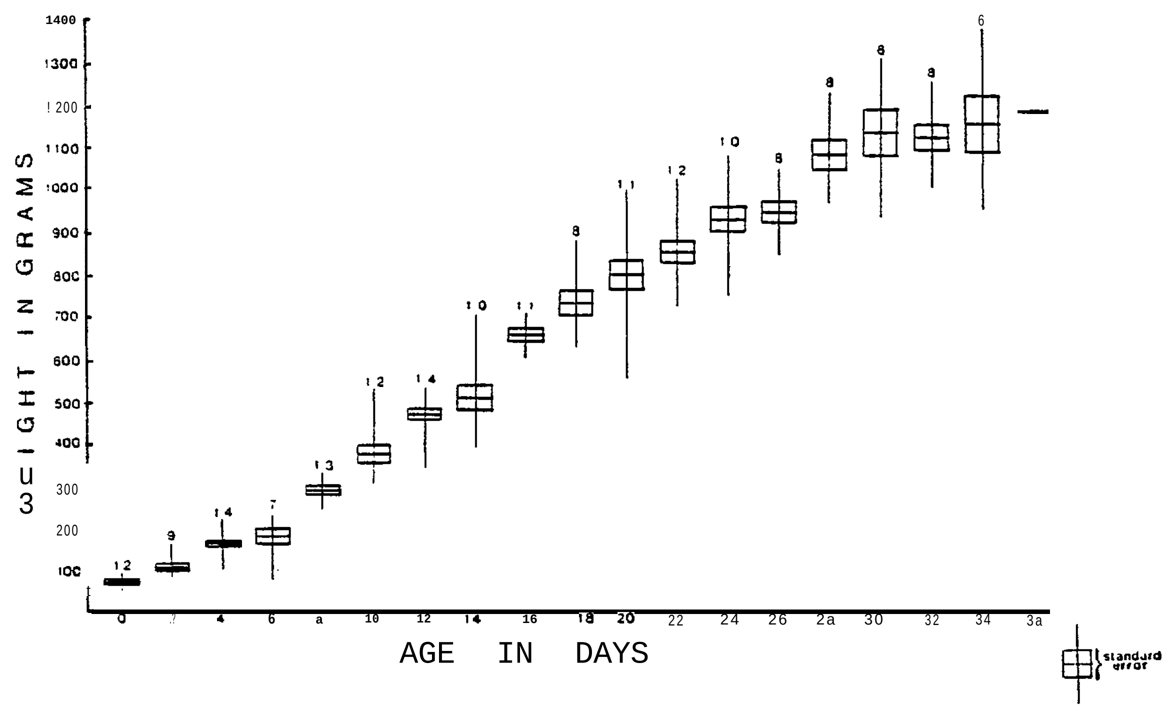


Figure V-3. Weight gain in Glaucous-winged Gull chicks at Sitkalidak Strait (1977 and 1978 data combined).

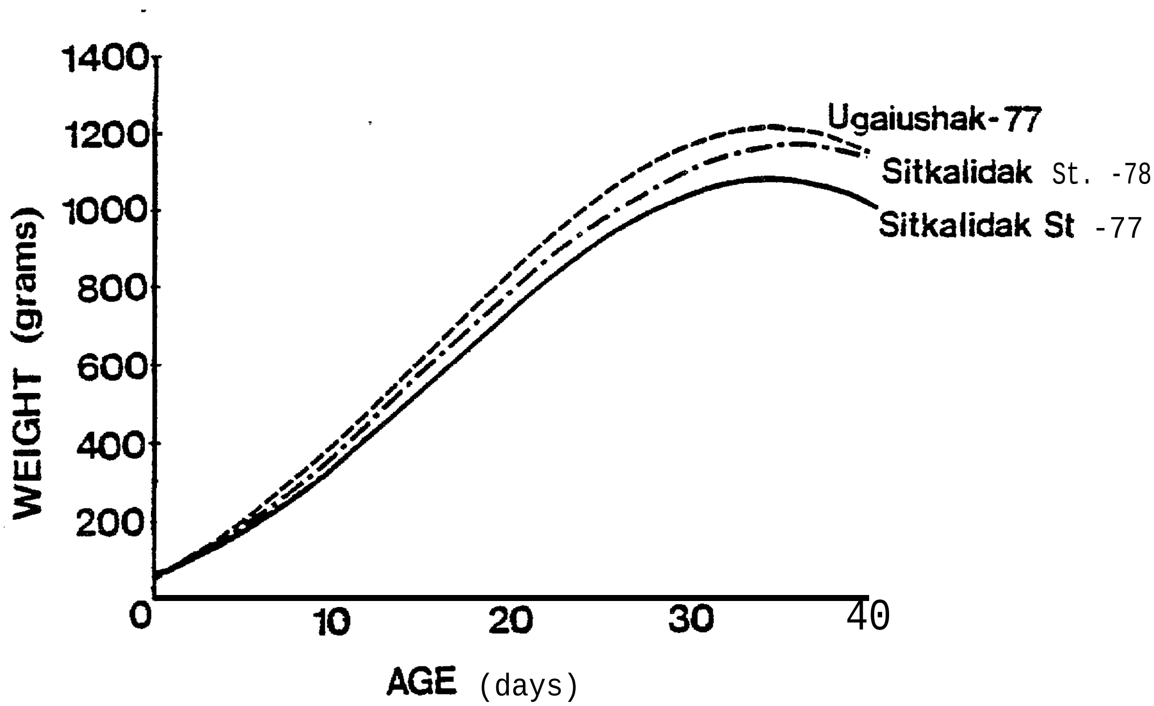


Figure V-4. Comparison of regression curves for growth of Glaucous-winged Gull chicks in the Gulf of Alaska, 1977-1978.

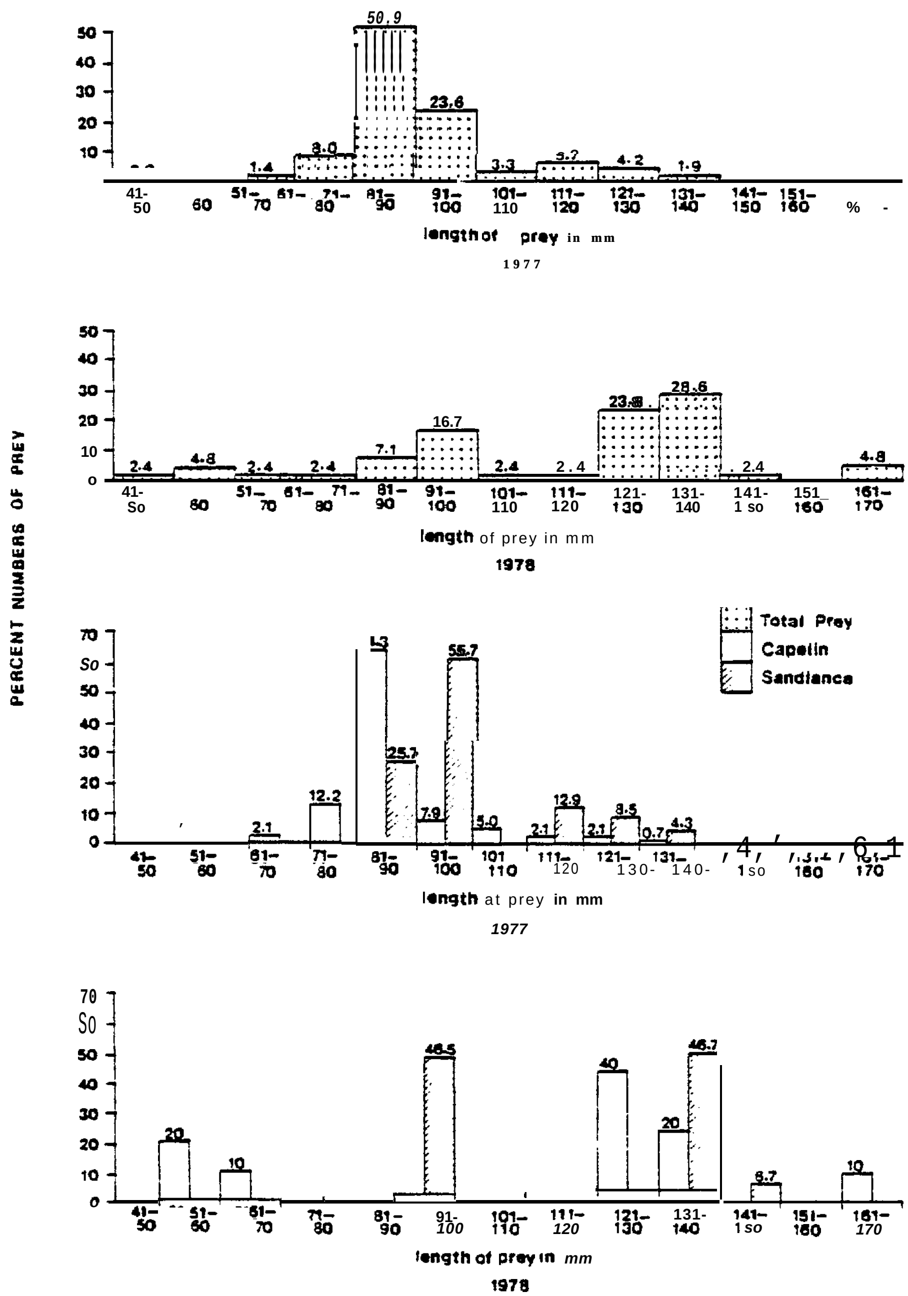


Figure V-5. Distribution of lengths of prey of Glaucous-winged Gull chicks, Sitkalidak Strait, 1977-1978.

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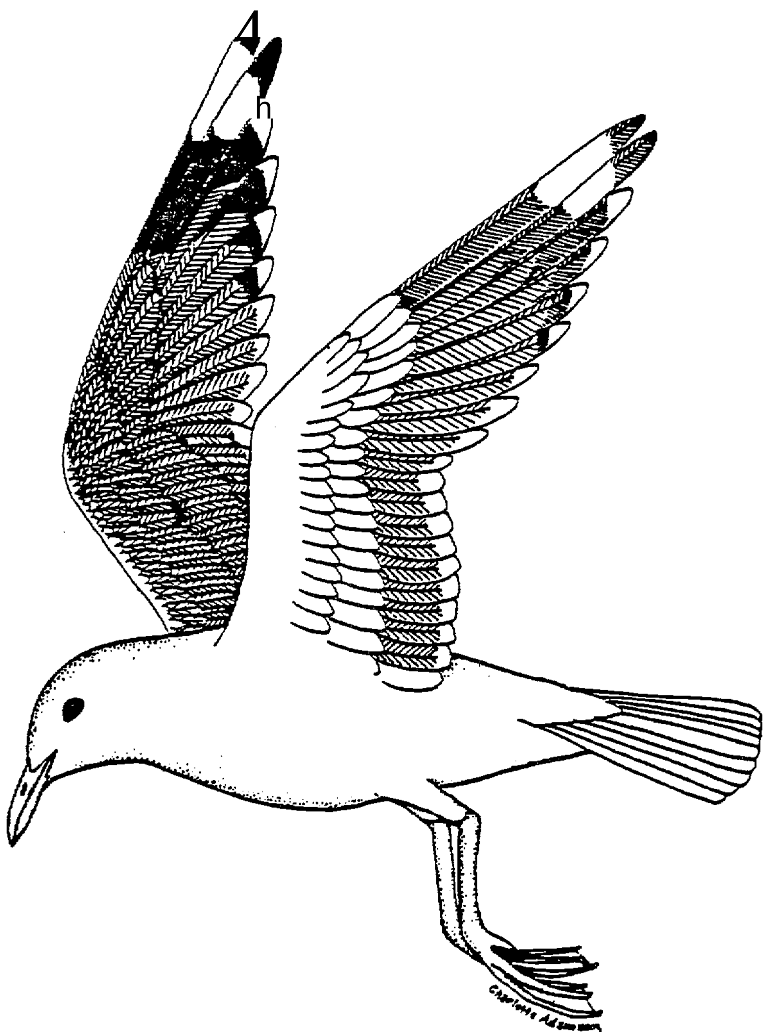
Mew Gull (*Larus canus*)



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. Bairdand 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-l). 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 pair 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

100-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 fewin 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 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 determined.

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

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 (Elegimus gracilis) was most often found in both stomach contents and pellet remains, although flounder (Pleuronectes) and nine-spined sticklebacks (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 injested 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. Al though 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).

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 1s., Chiniak Bay (Kodiak)	400	Nysewander and Hoberg (1978)
Alsek River mouth	600	S. Patten, pers. comm.
Amee Is., Kodiak	200 1976 60 1977-78	G. Sanger, pers. comm. P. A. Baird, pers. comm.

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.

TABLE VI-3
Reproductive Success of Mew Gulls.

	Chiniak Bay 1977	Chiniak Bay 1978	Anchorage 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]	28a	2o[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 Gull (*Larus canus*)

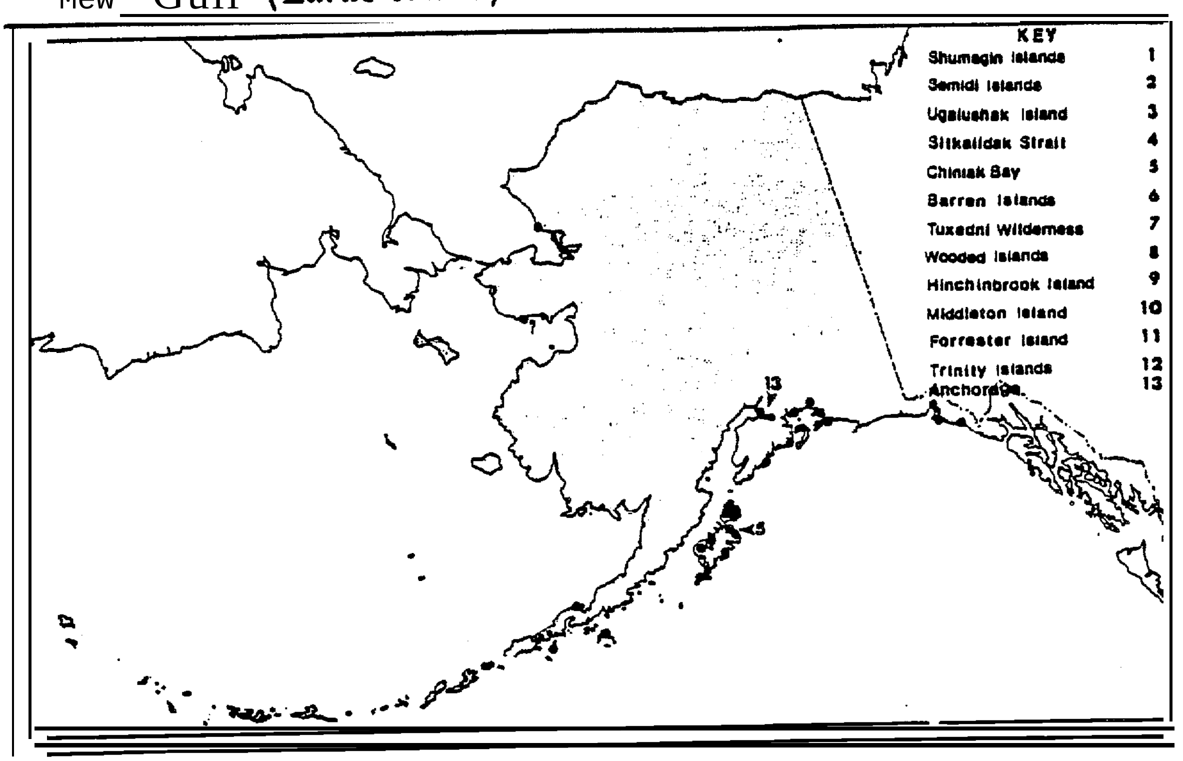


Figure VI-1. Distribution of breeding colonies of Mew Gulls in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

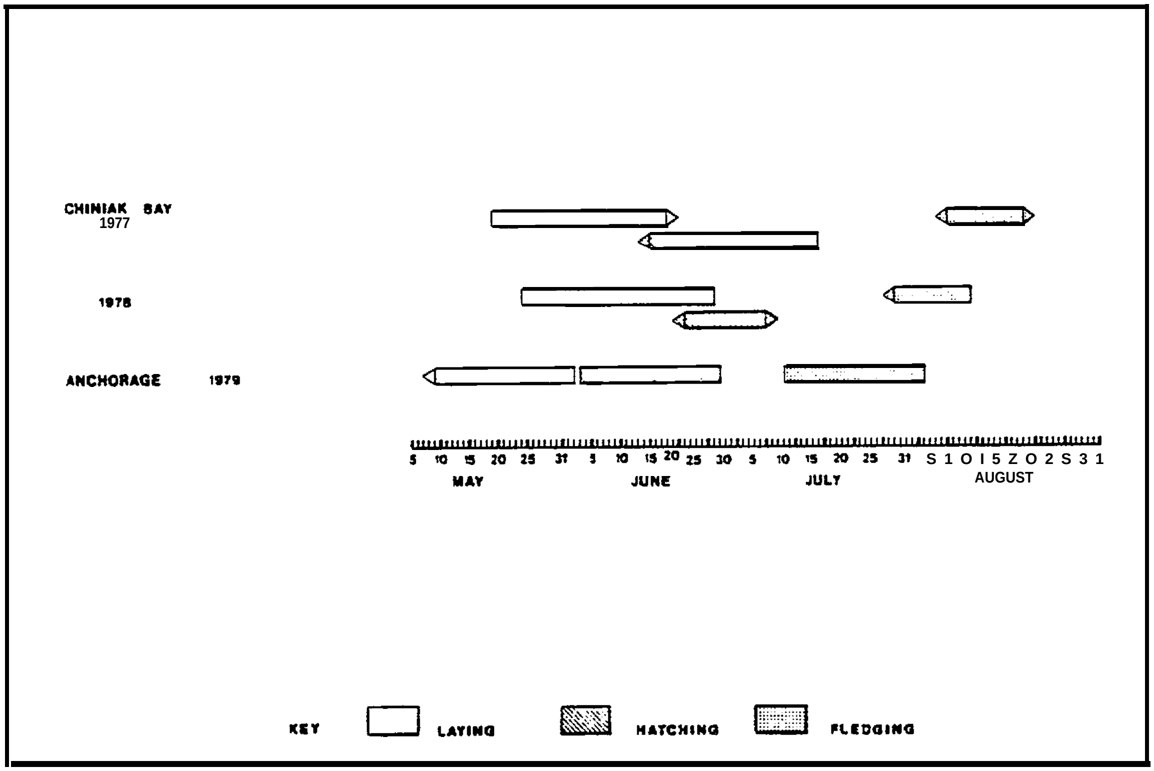


Figure VI-2. Chronolgy of major events in the nesting season of Mew Gulls in the Gulf of Alaska.

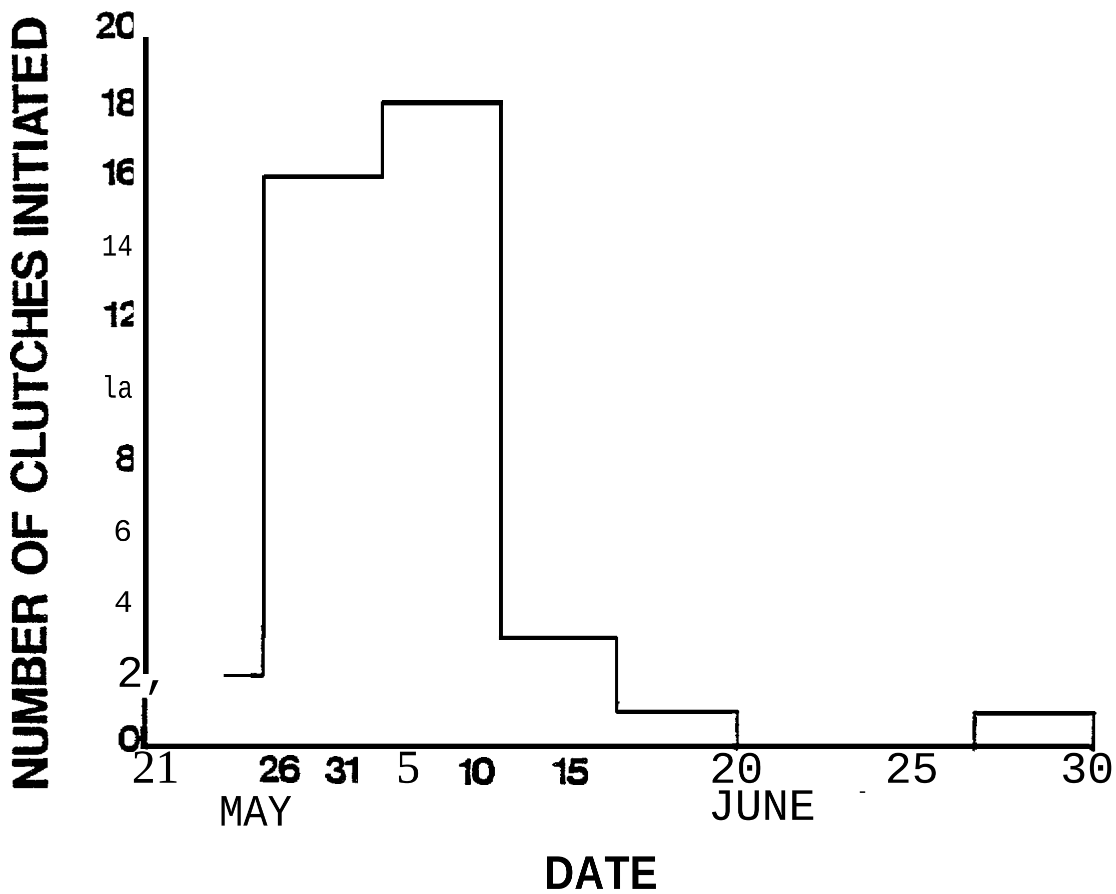


Figure VI-3. Laying chronology of Mew Gulls on south colony of Mary Island in Chiniak Bay, 1978.

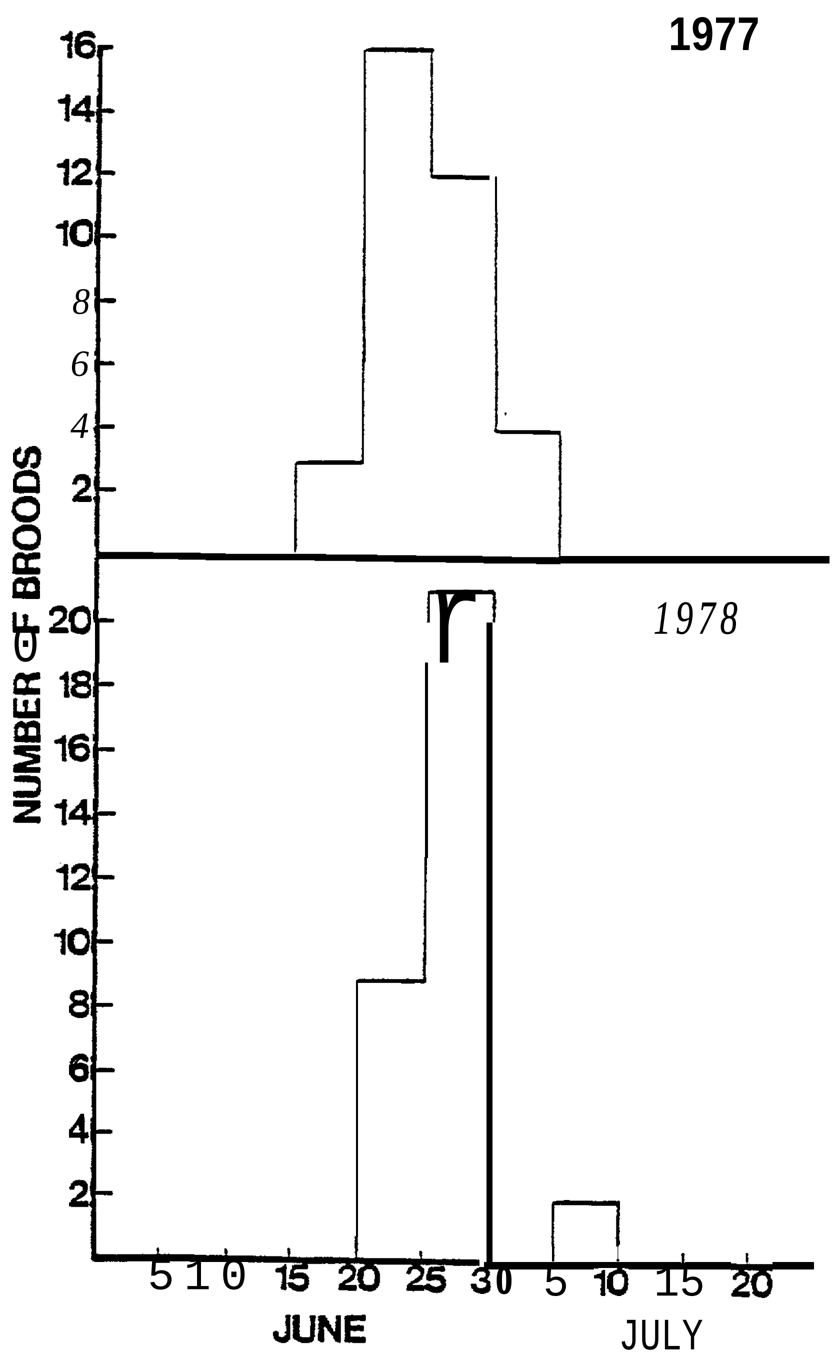


Figure VI-4. Hatching chronology of Mew Gulls on south colony of Mary Island, 1977-1978.

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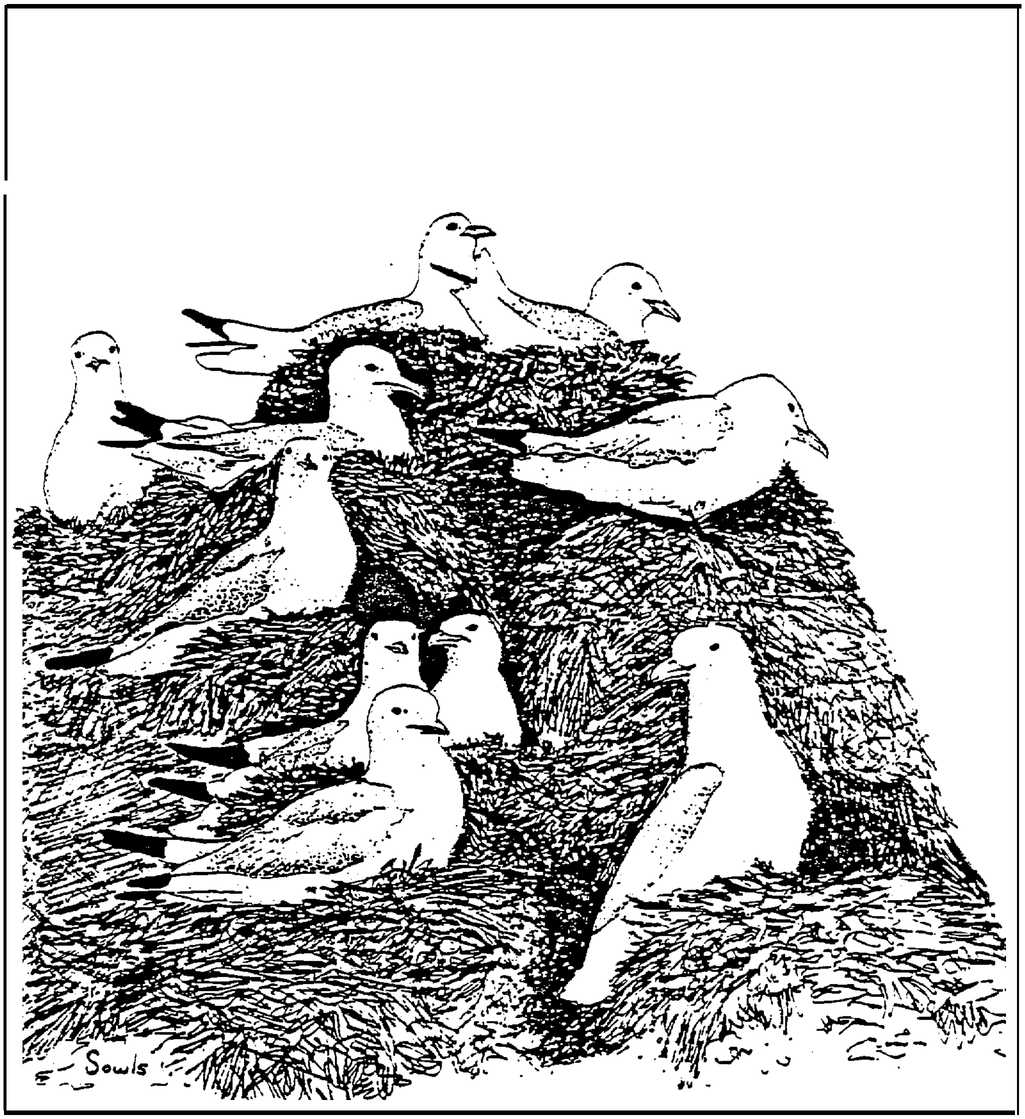
Black-legged Kittiwake (*Rissa tridactyla*)



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 (197'9)
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 (Kodiak Island)	1977	Baird and Moe (1978)
	1978	Baird and Hatch (1979)
Chiniak Bay (Kodiak Island)	1977	Nysewander and Hoberg (1978)
	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-1egged 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-l). 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 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.

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-1egged 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 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 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 O 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 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 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 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 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 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 convergence, 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. Scaly (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 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.

TABLE VII-1
Estimated Numbers of Black-1 egged 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		
Chowie t	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

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.

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

TABLE VII-4
Breeding Chronology of Black-1 egged 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 1s.			
L976	20 June-20 July		
1977	U June-28 June	14 July-25 July	22 August-31 August>
Sitkalidak Strait			
1977	12 June-L July	8 July-9 August	13 Awusc-10 September
L978	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	LO June-30 June	6 July-25 July	23 August>
Wooded Island			
1976	6 June>	3 July>	4 August>
L977	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			
L978	23 April-24 June	21 May-21 July	2 July-20 August

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

TABLE VII-5
Productivity of Black-1 egged Kittiwakes in the Gulf of Alaska, 1976 -1978.[a]

	Big Koniuji Island	Semidi Islands			Ugaiushak Island		Sitkalidak S trait		Chiniak Bay	
	-	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	1.56	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	L57
$\bar{X}$ 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)			0060	—	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	0.8s	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		Chisik Island	Wooded Island		Porpoise Rocks			Middleton Island
	1977	1978	1978	1976	1977	1976	1977	1978	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	22s	223	281
No. of eggs hatched	71	18	30				93	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
Egge 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.S1	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

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

	Weight (in grams)																			
	Middleton Island 1978				Chisik Island 1978				Chiniak Bay 1978				Sitkalidak Strait 1978				Sitkalidak Strait 1977			
Age (days)	n	X̄	S.E.	Range	n	X̄	S.E.	Range	n	x-	S.E.	Range	n	X̄	S.E.	Range	n	X̄	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	3fl-61	8	37	2.67	31-52	21	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	34-12	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	2a	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	21	235	5.38	176-285	5	132	15.67	93-174	24	248	4.94	197-2132	6	282	7.64	260-306	27	248	10.42	142-440
16-18	36	210	5.60	165-320	7	187	13. ?2	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	210-395	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	0.93	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	315-4.40	3	370	30.00	310-400	11	165	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

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.

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 ($P < 0.05$).

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

Age (day.)	Flattened Wing (mm) Chisik Island 1978 n	X̄	S.E.	Range	Chiniak Bay 1978 n	X̄	S.E.	Range	Wing Chord (mm) Middleton Island 1978 n	X̄	S.E.	Range	Sitkalidak Strait 1978 n	X̄	S.E.	Range	Sitkalidak Strait 1977 n	X̄	S.E.	Range
0					5	26	0.77	24-21	14	19	0.21	1s-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	1S-24	10	22	0.75	18-26	50	27	0.67	18-38
4-6					IS	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	0.7S	23-41	10	41	2.48	31-57	48	45	1.16	25-62
10-12					23	16	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
16-1S	6	67	5.91	50-137	27	123	2.2S	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
2S-30	1	198			17	21s	2.12	203-229	25	185	1.74	162-200	4	201	5.26	1S6-210	43	200	2.S7	105-230
31-33	3	197	4.91	1SS-205	11	234	1.38	226-240	2S	207	1.2S	194-221	5	229	6.54	207-244	29	221	1.60	201-242
34-36	1	240							14	22S	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	25S	2.96	249-265					3	254	8.76	23 S-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	0.41	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	2?	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	31	0.55	35-40	37	35	0.20	31-37
25-27	4	34	1.23	30-34	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		Chisik Island	Middleton Island
	1977 n=138	1978 n=33	1978 n=14	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		1.2.2	
Unidentified fish	5.9	27.2	4.6	45.2
Salmonid eggs and parts	2.3			
Euphausiids: *Thysanoessa spinifera* *Thysanoessa inermis* *Euphausia pacifica*			0.1	18.4
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	1623.8g	277.0g	97.2g	624.7g

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

Black-1 egged Kittiwake (*Rissa tridactyla*)

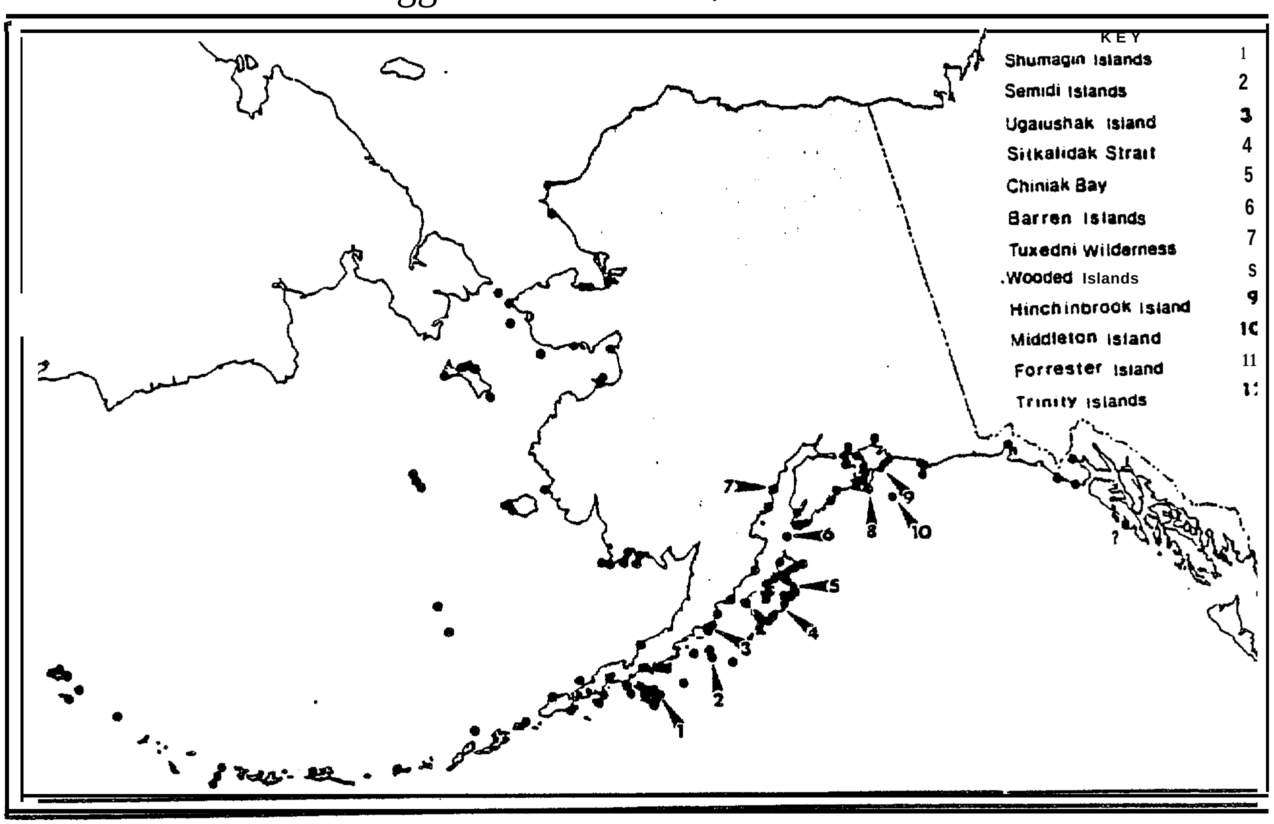


Figure VII-1. Distribution of breeding colonies of Black-1egged Kittiwakes in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

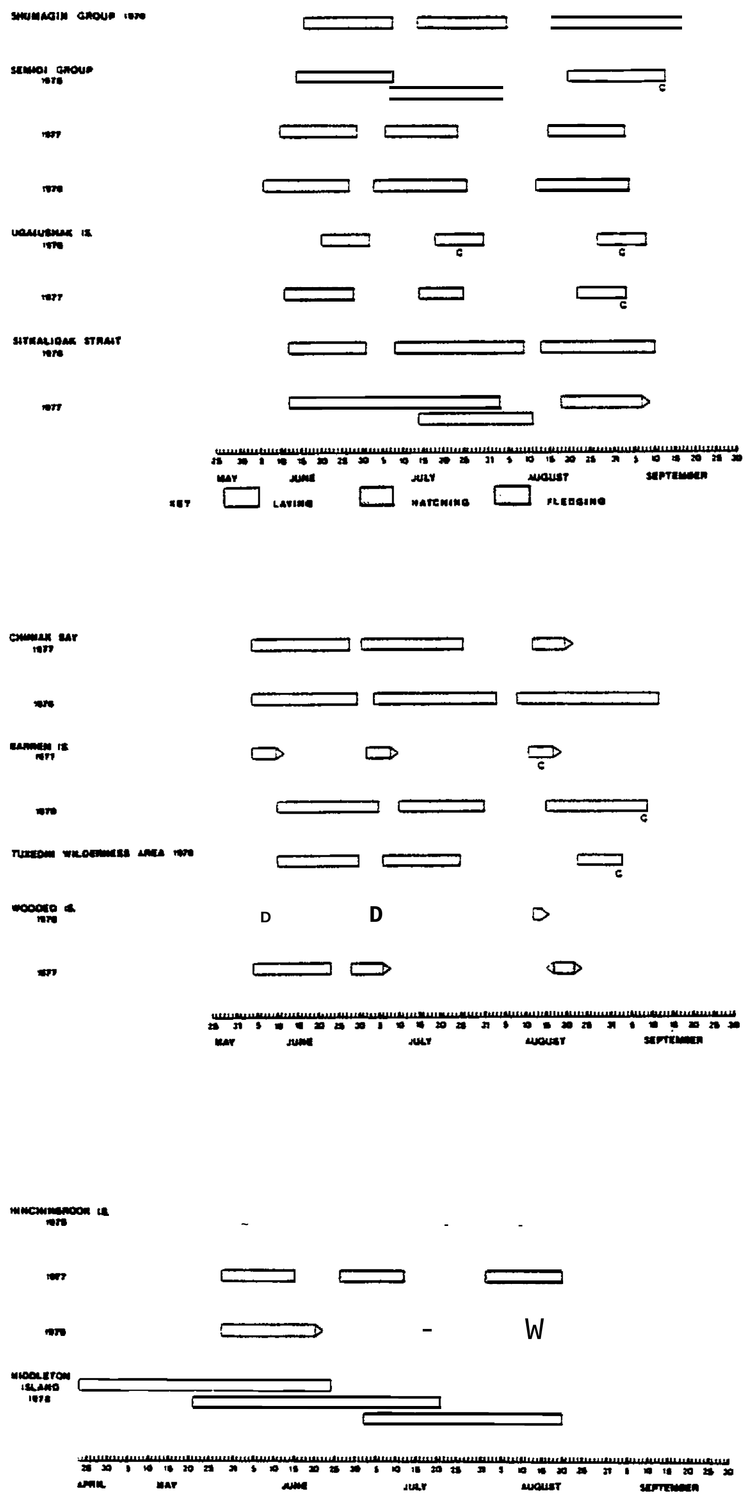


Figure VII-2. Chronology of major events in the nesting season of Black-legged Kittiwakes in the Gulf of Alaska.

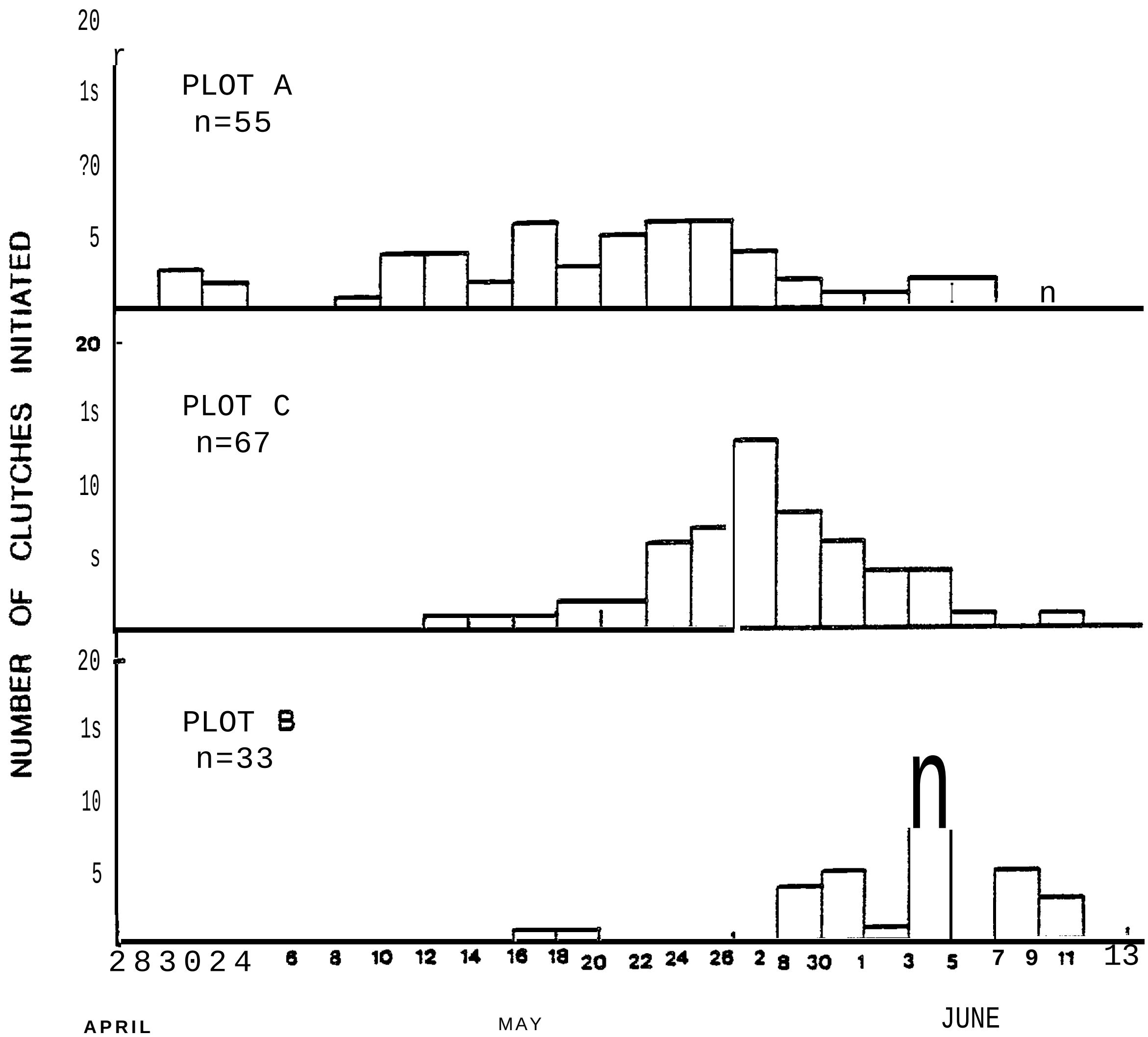


Figure VII-3. Number of clutches initiated by Black-legged Kittiwakes at Middleton Island in 1978.

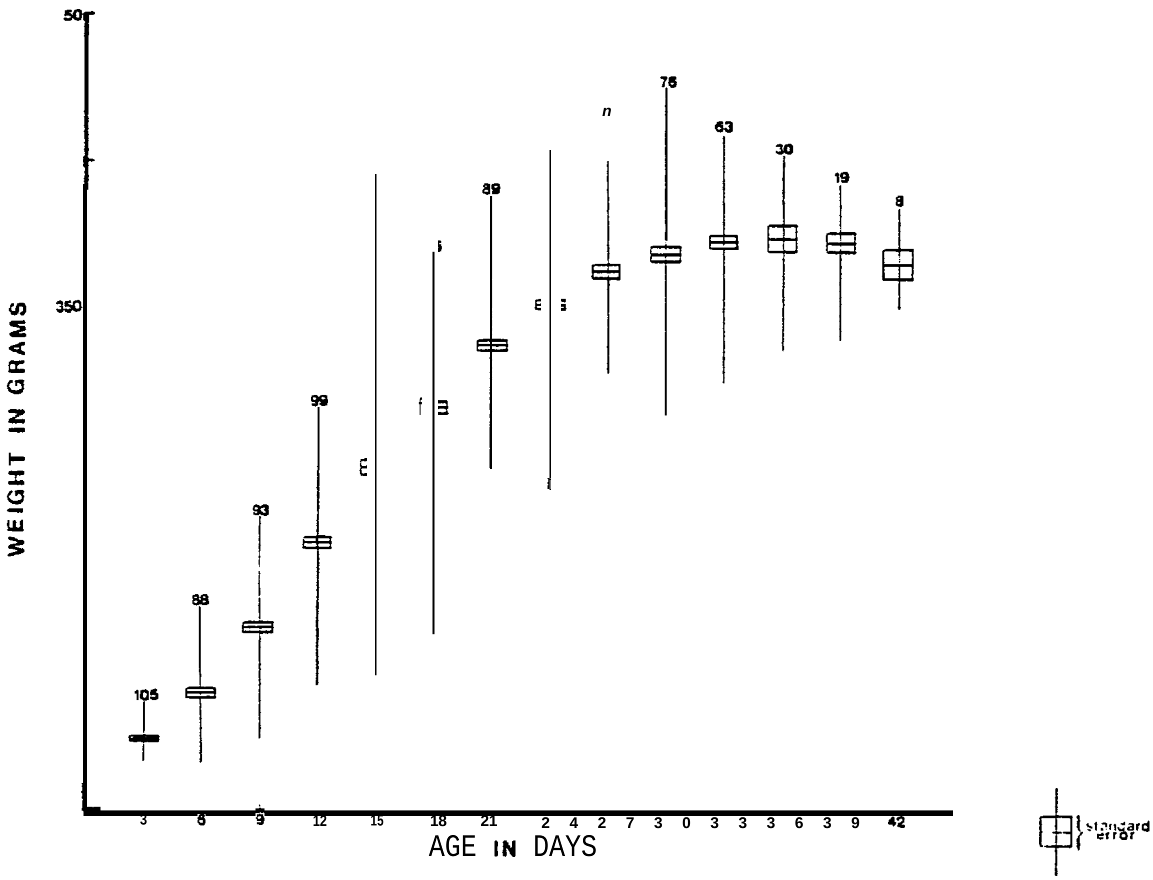


Figure VII-4. Weight gain in Black-legged Kittiwake chicks in the Gulf of Alaska, 1978.

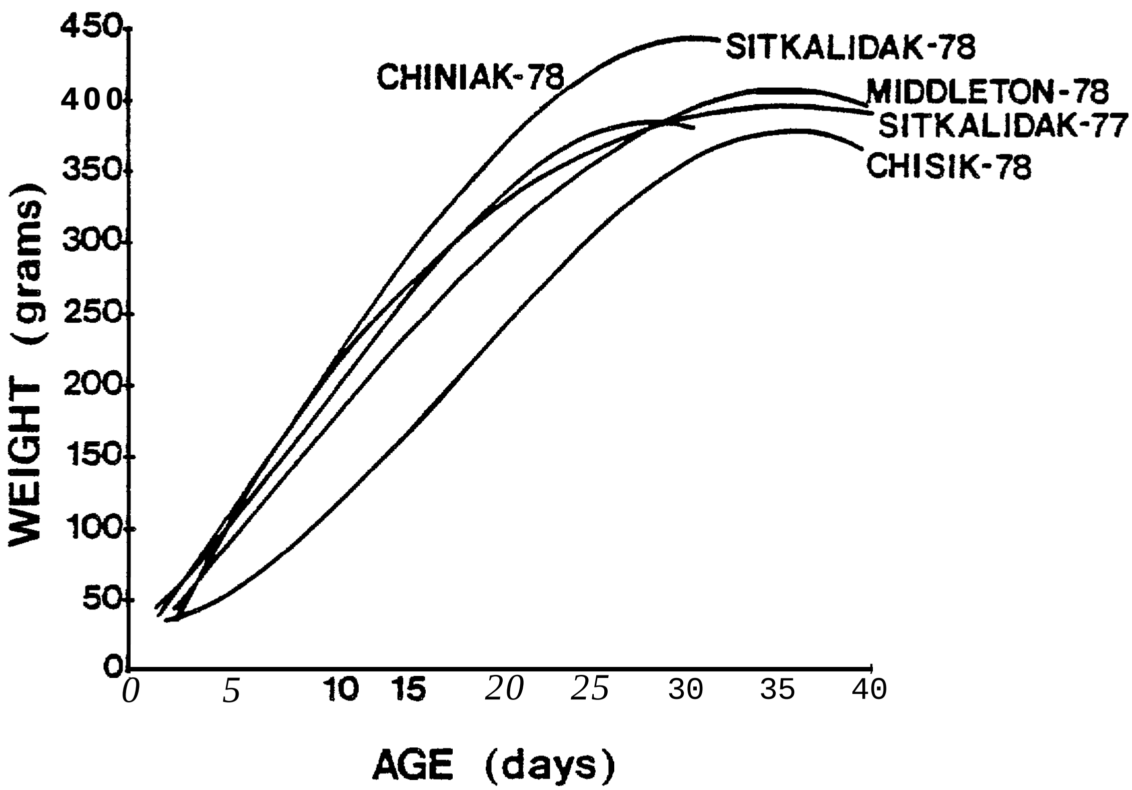


Figure VII-5. Comparison of regression curves of kittiwake chick growth at four sites in the northern Gulf of Alaska, 1977-1978.

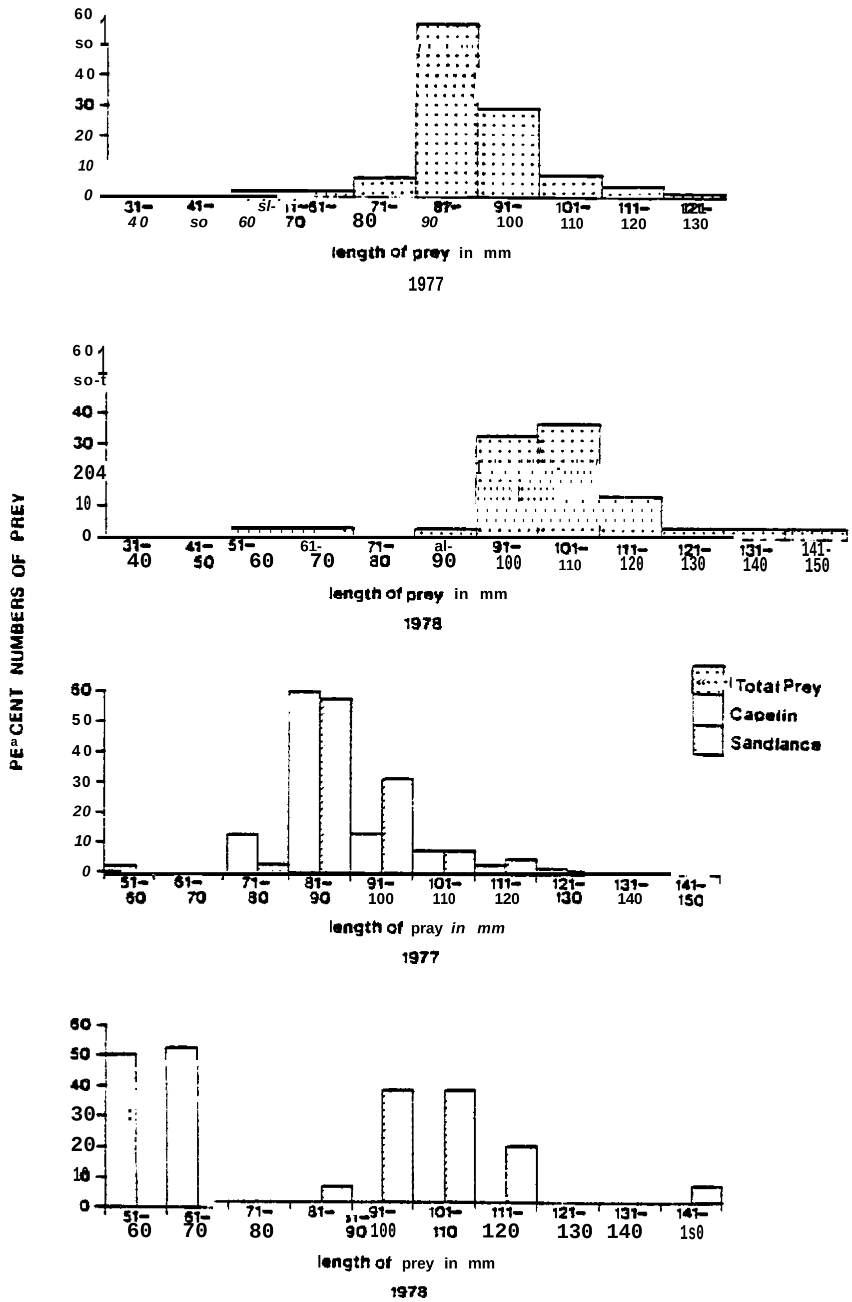


Figure VII-6. Distribution of lengths of prey delivered to Black-legged Kittiwake chicks in Sitkalidak Strait, 1977-1978.

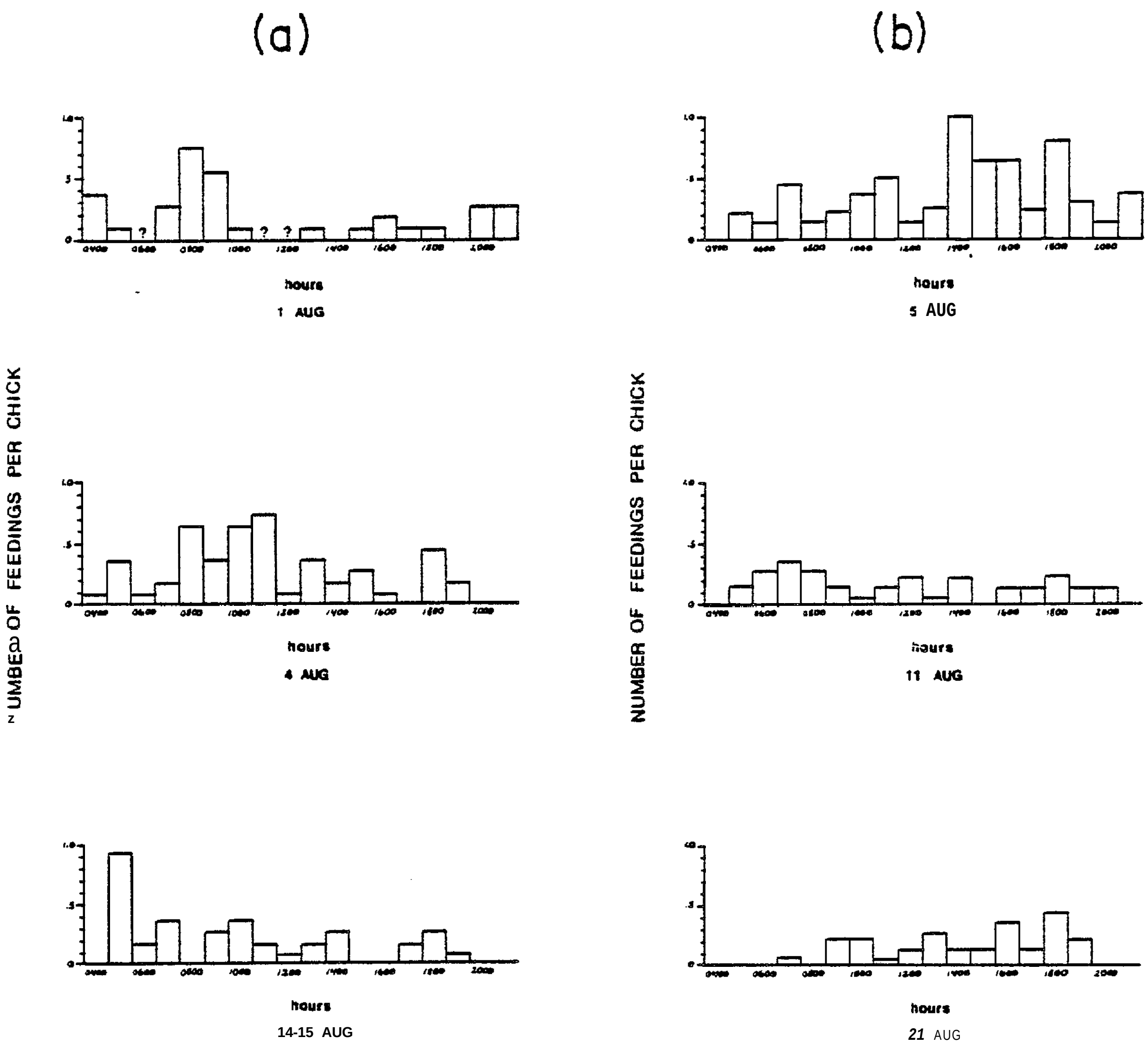


Figure VII-7. Frequencies of feedings per Black-legged **Kittiwake chick** per hour **in** (a) **Chiniak** Bay and (b) **Sitkalidak Strait** during August, 1978.

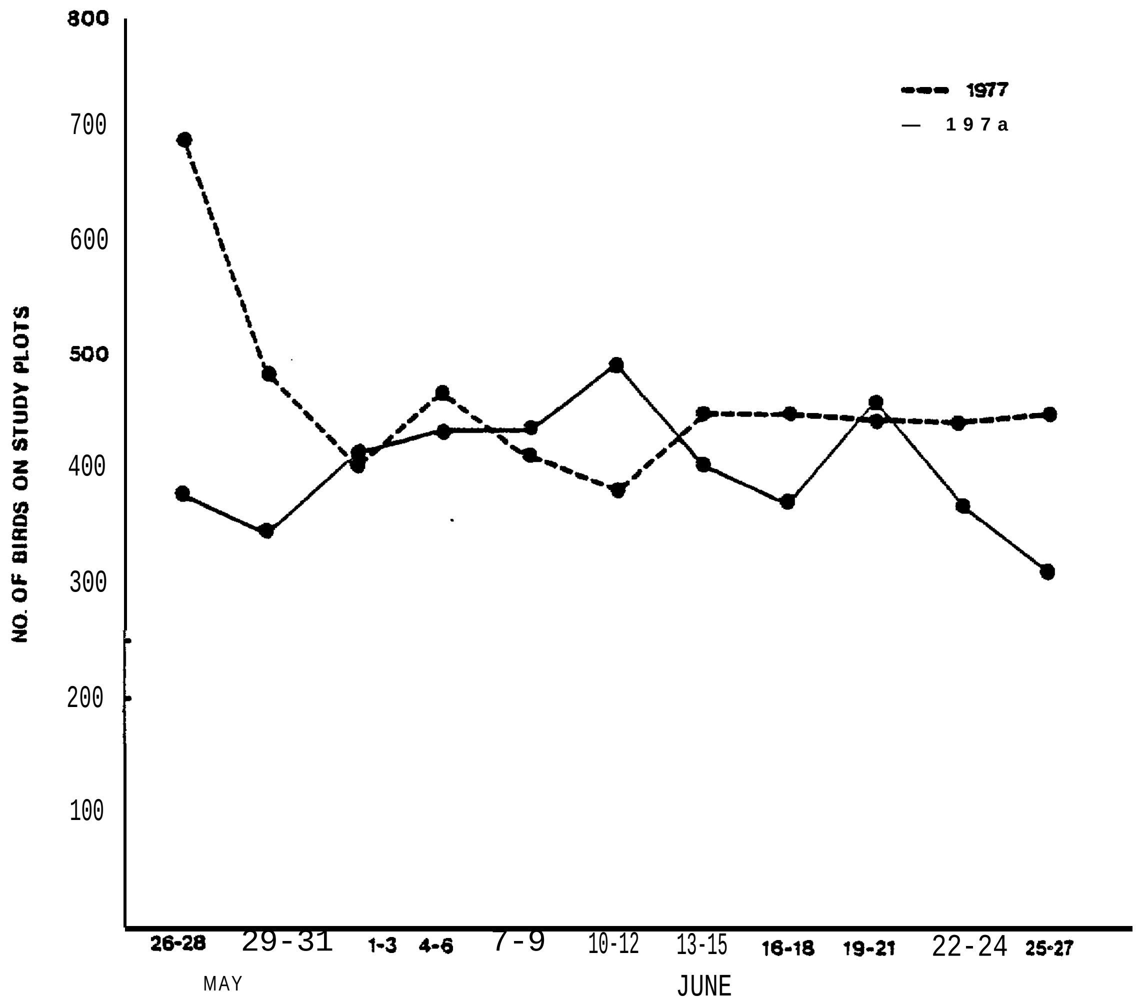


Figure VII-8. Nest site attendance of Black-legged Kittiwakes at the Semidi Islands in 1977 and 1978.

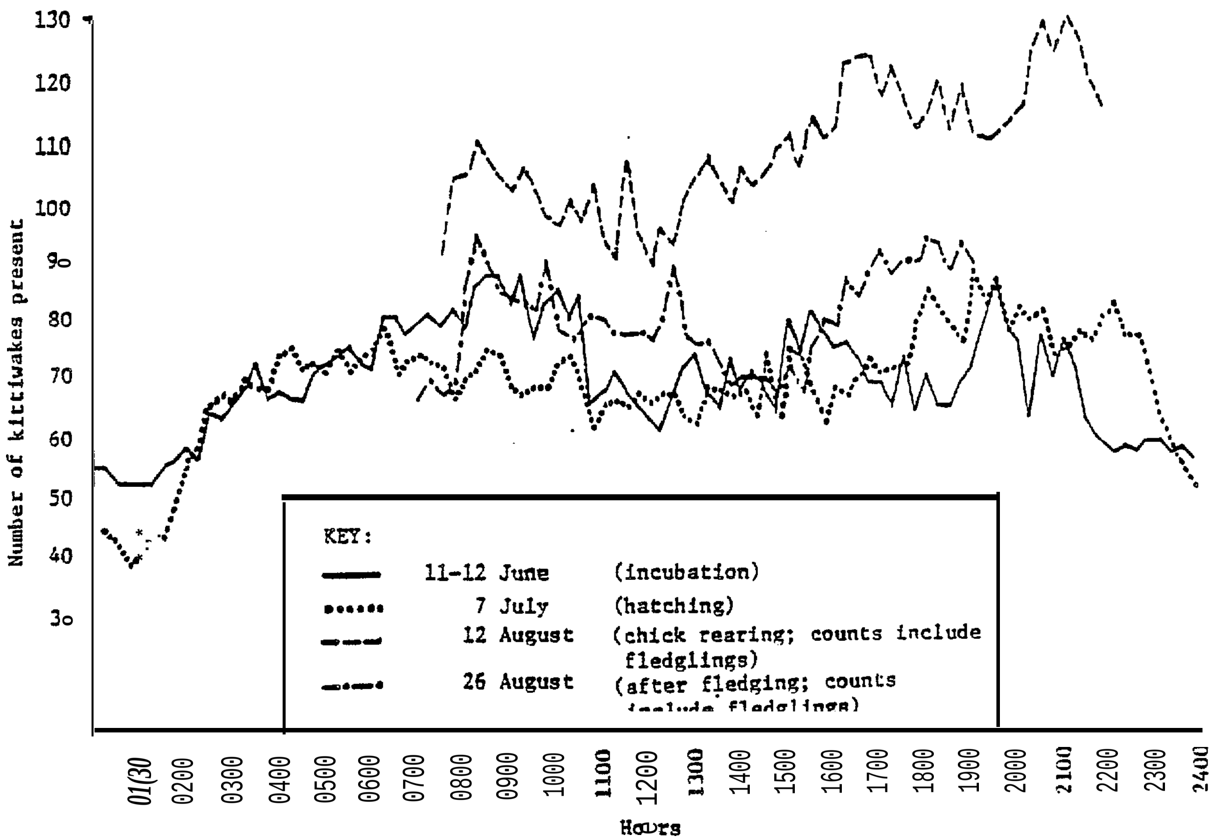


Figure VII-9. Seasonal variation in diel rhythms of Black-legged Kittiwake attendance at a sample plot (n=48 nests) on Porpoise Rocks, Hinchinbrook Island, 1977.

(a)

(b)

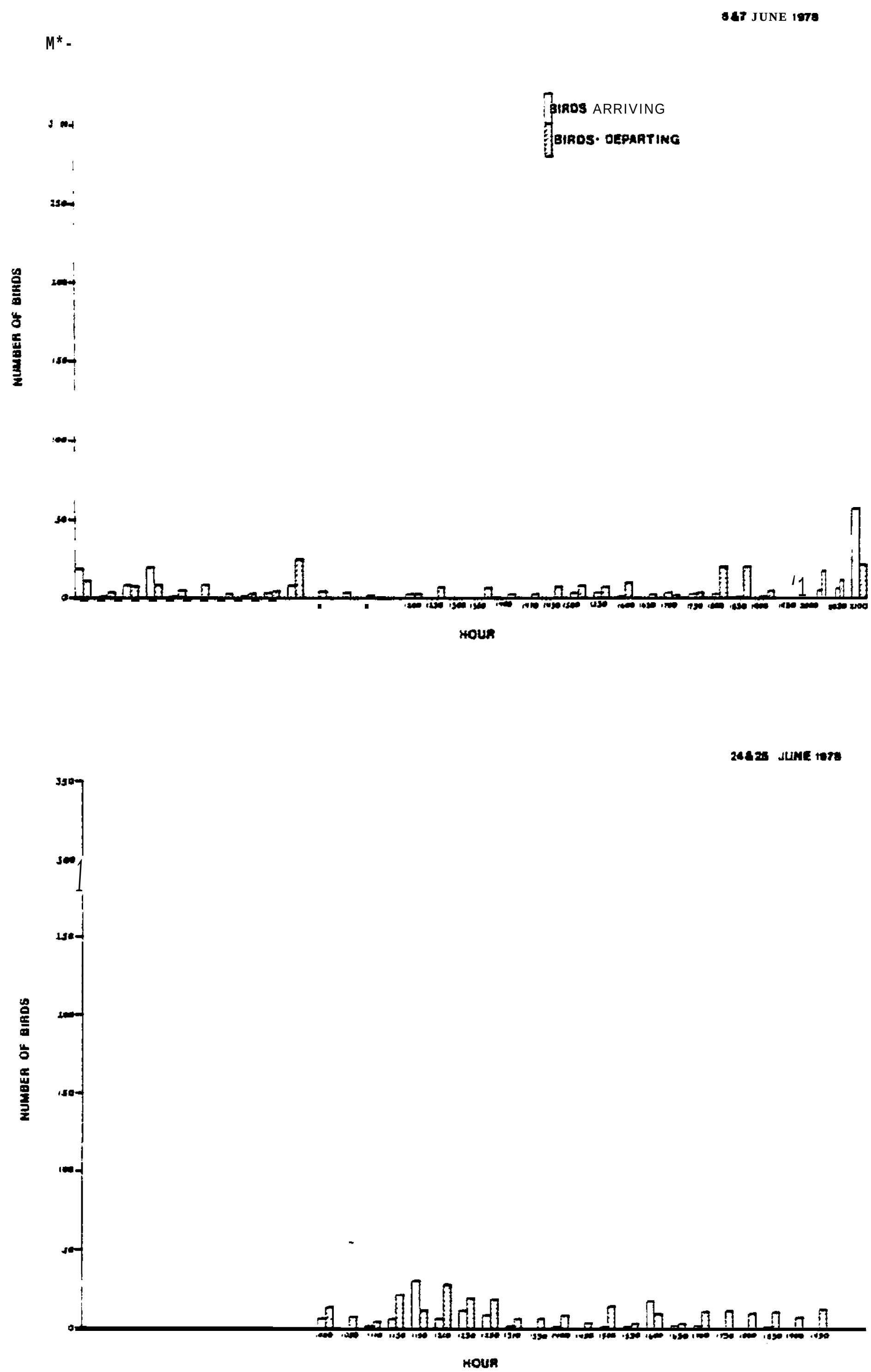


Figure VII-10. Dawn to dusk counts of Black-legged Kittiwakes arriving and departing from the colony, Sitkalidak Strait: (a) 6-7 June 1978, (b) 24-25 June 1978.

(c)

(d)

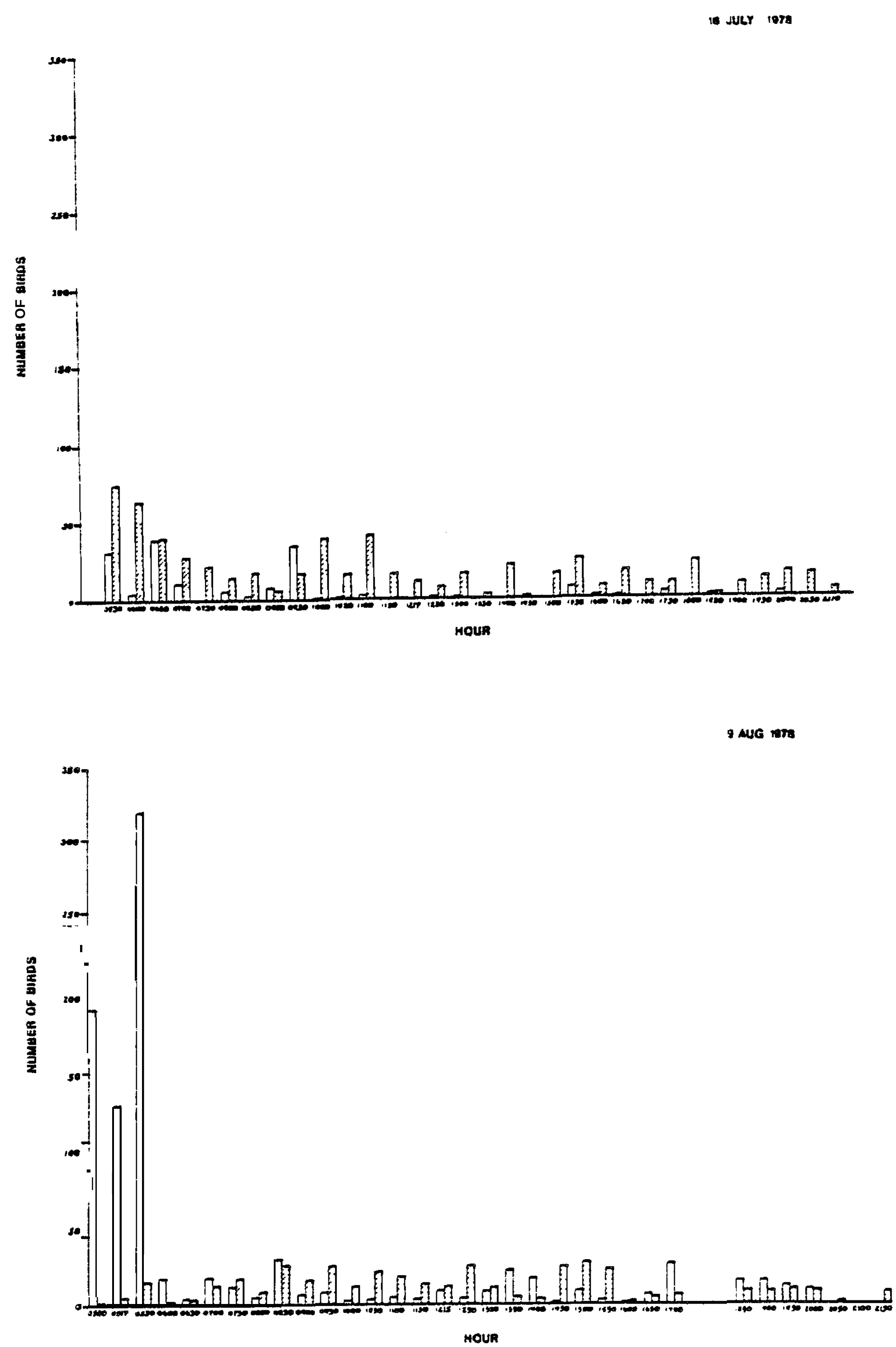


Figure VII-10 (cont.) (c 16 July 1978, (d) 9 August 1978.

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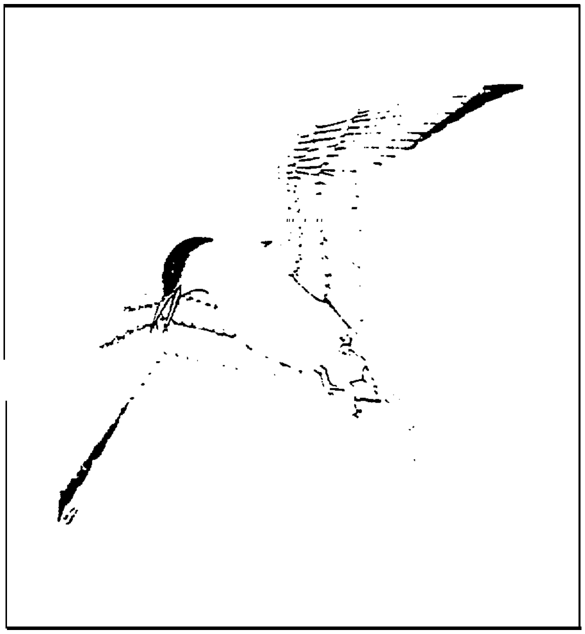
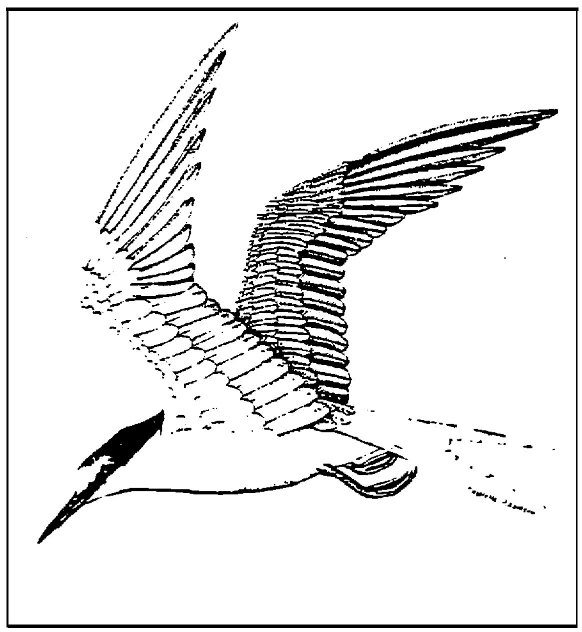
Terns (*Sterna* spp.)



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-la). 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-lb). 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 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 habitats 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, 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 mono-specific 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/m2, 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). However, the productivity of Aleutian Terns in mixed colonies was still lower than their productivity at mixed colonies on islands. 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.

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 = 2S-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 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-l). 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

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 monogenetic 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 i- 7.3 (range = 7-113 rein). 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 (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 (*Lams 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 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.

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

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

Species Location year	$\bar{X}$ Density (nests/m²)	$\bar{X}$ Nearest" Neighbor (m)[a]	$\bar{X}$ 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, Achilles, Geranium	Short grassy areas on high points of islands. Mixed or single species colony.
1978 (n-29)	0.01 (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 moat 50 m from water.
Aleutian Tern					
Sitkalidak Strait					
1977 (n-46)	0.13 (island)	3.69 (island, mixed)	5.5	Calamagrostis, Sphagnum, Achilles, Geranium	Short grassy areaa on lower parta 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 ❑ ainland, monospecific or mixed species.

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 peek 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 Hey>) (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 ' v=t-

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>)

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	23.2	223	64	24	115	119
No. of eggs hatched	48	28	181	71	56	17	6.4	35-97[b]
No. of chicks fledged	10-42[c]							
$\bar{X}$ clutch size	2.12	1.79	2.21	1.97	2.29	2.00	2.05	2.05
$\bar{X}$ 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]		Chiniak Bay	
	1977	1978	1977	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			
$\bar{X}$ clutch size	1.61	1.35	1.89	1.79
$\bar{X}$ 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.

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

Age (days)	Weight (g)											
	Arctic Terns						Aleutian Terns					
	1977			1978			1.977			1978		
	N	X̄	S.E.	N	X̄	S.E.	N	X̄	S.E.	N	X̄	S.E.
0-2	8	17.6	1.s	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-u.	-	-		2	102.0	6.0	1	85.0		-	-	
12-14	-	-		1	98.0		2	105.0	6.0	3	90.0	5.3
25-17	-	-		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.?	(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.

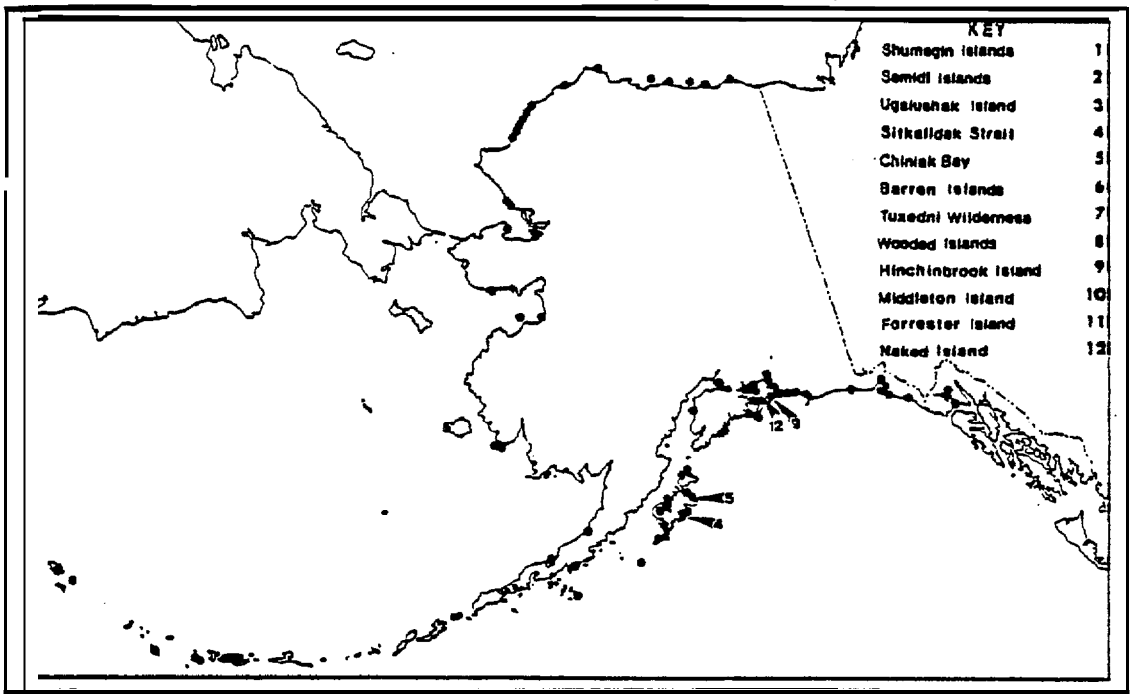
Prey Species	1977				1978			
	Frequency of occurrence N=53		Total number prey N=40		Frequency of occurrence N=12		Total number prey N=14	
	%	(N)	%	(N)	%	(N)	%	(N)
Capelin (*Mallotus villosus*)	52.8	(28)	57.5	(23)	25.0	(3)	21.4	(3)
Sand lance (*Ammodytes hexapterus*)	28.3	(15)	17.5	(7)	16.7	(2)	21.4	(3)
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)				

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%

Arctic Tern (*Sterna paradisaea*)

(a)



Aleutian Tern (*Sterna aleutica*)

(b)

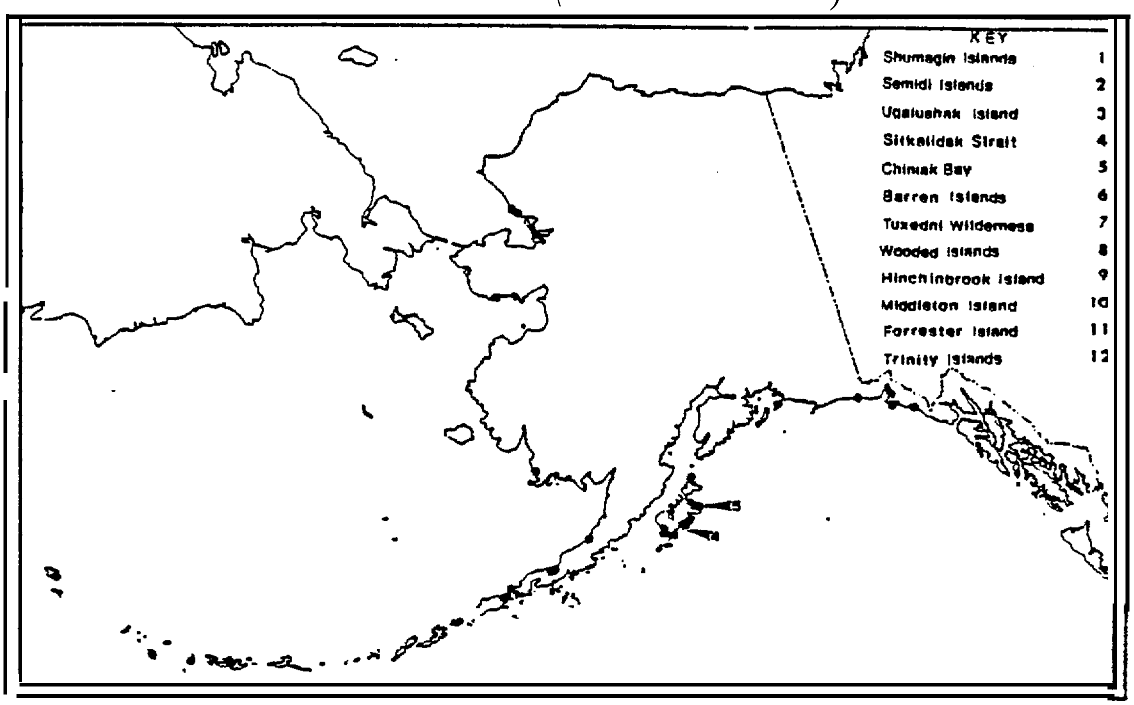


Figure VIII-I. Distribution of breeding colonies of (a) Arctic Terns and (b) Aleutian Terns in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

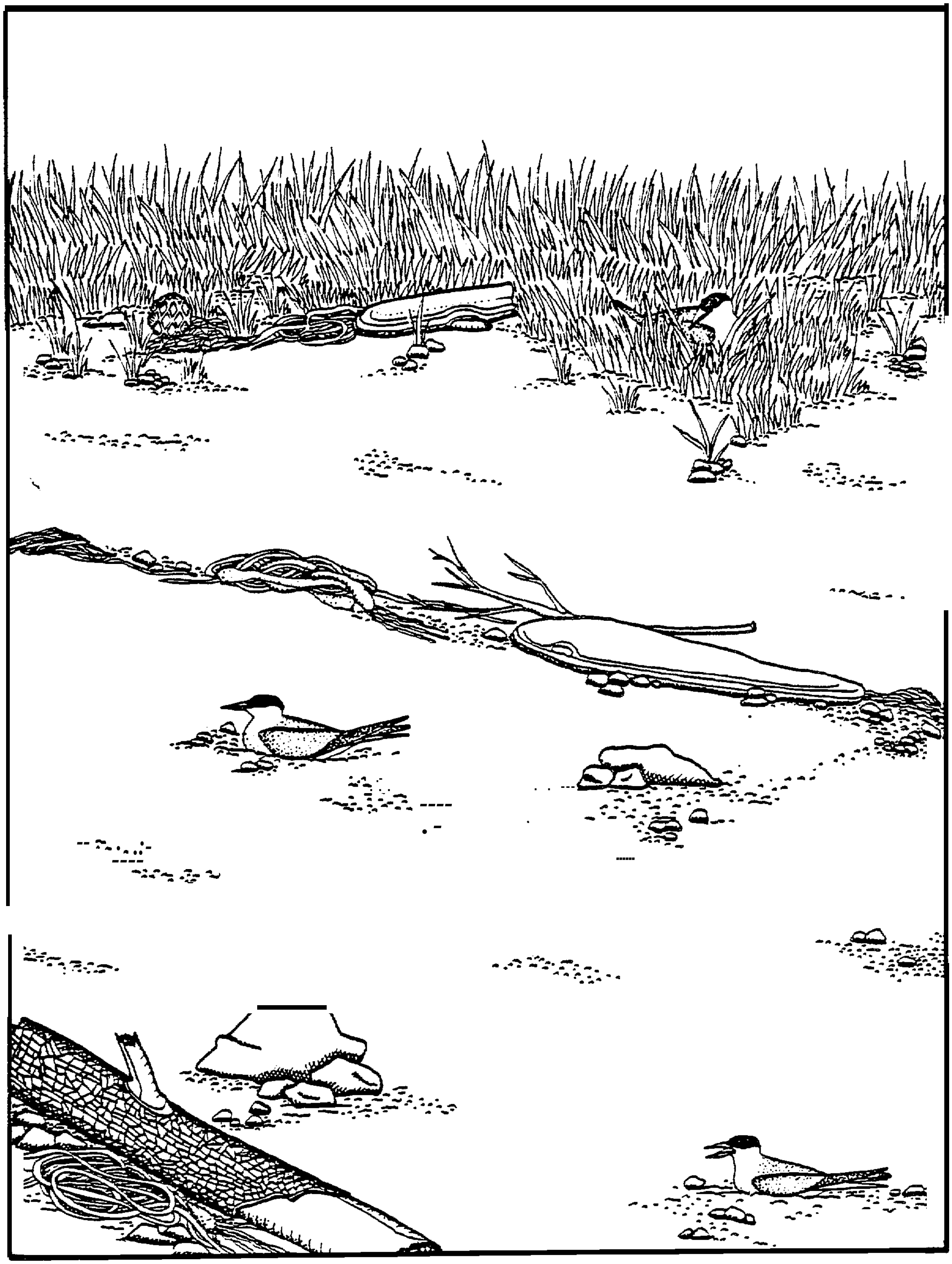


Figure VIII-2. Nesting habitat of Arctic and Aleutian Terns.

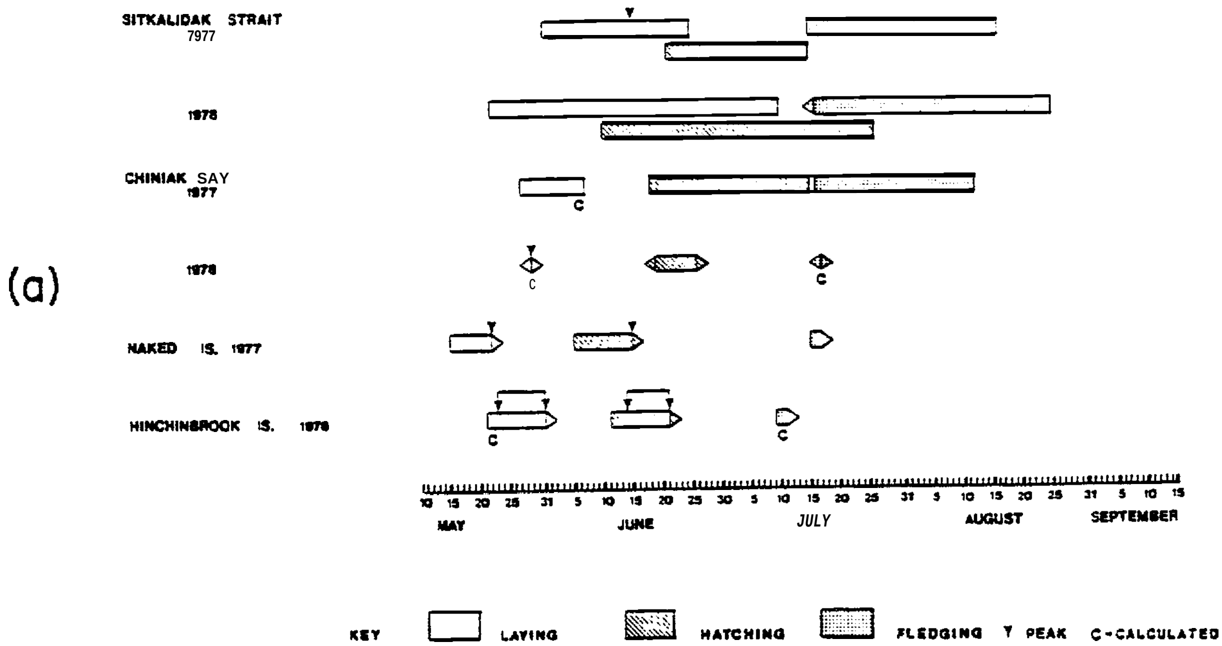


Figure VIII-3. Chronology of major events in the nesting seasons of (a) Arctic Terns and (b) Aleutian Terns in the Gulf of Alaska.

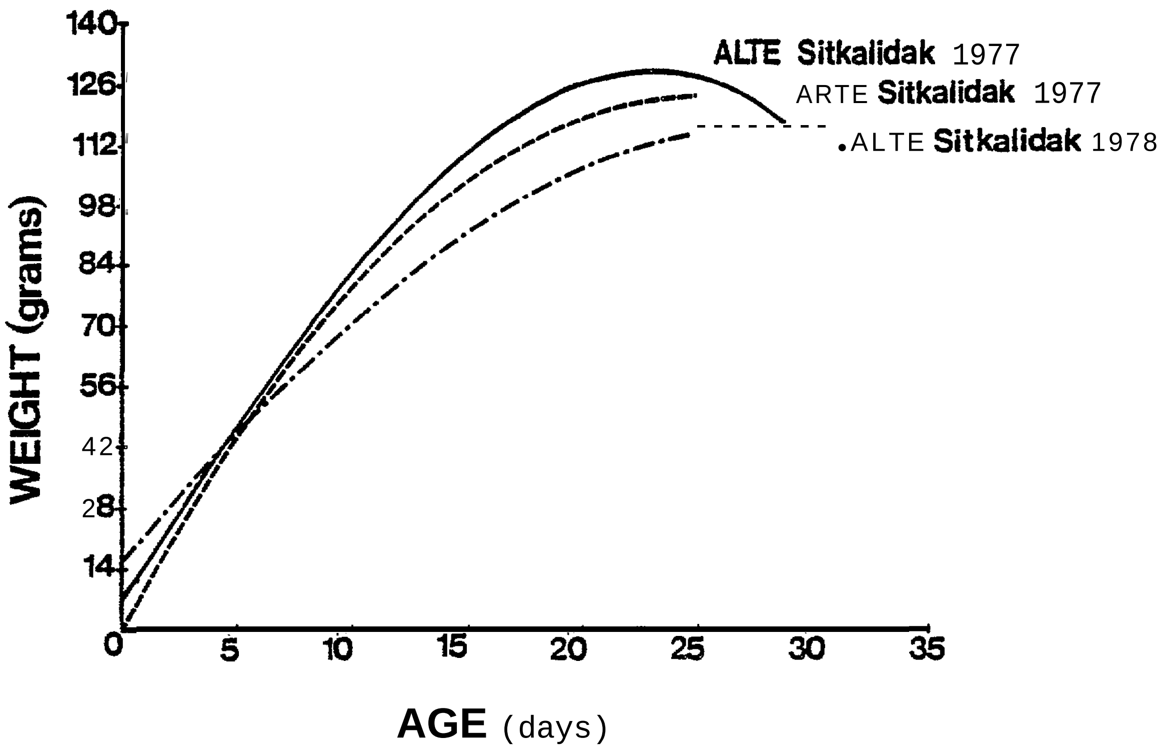


Figure VIII-4. Comparison of regression curves for growth of Arctic and Aleutian Tern chicks in Sitkalidak Strait, 1977-1978.

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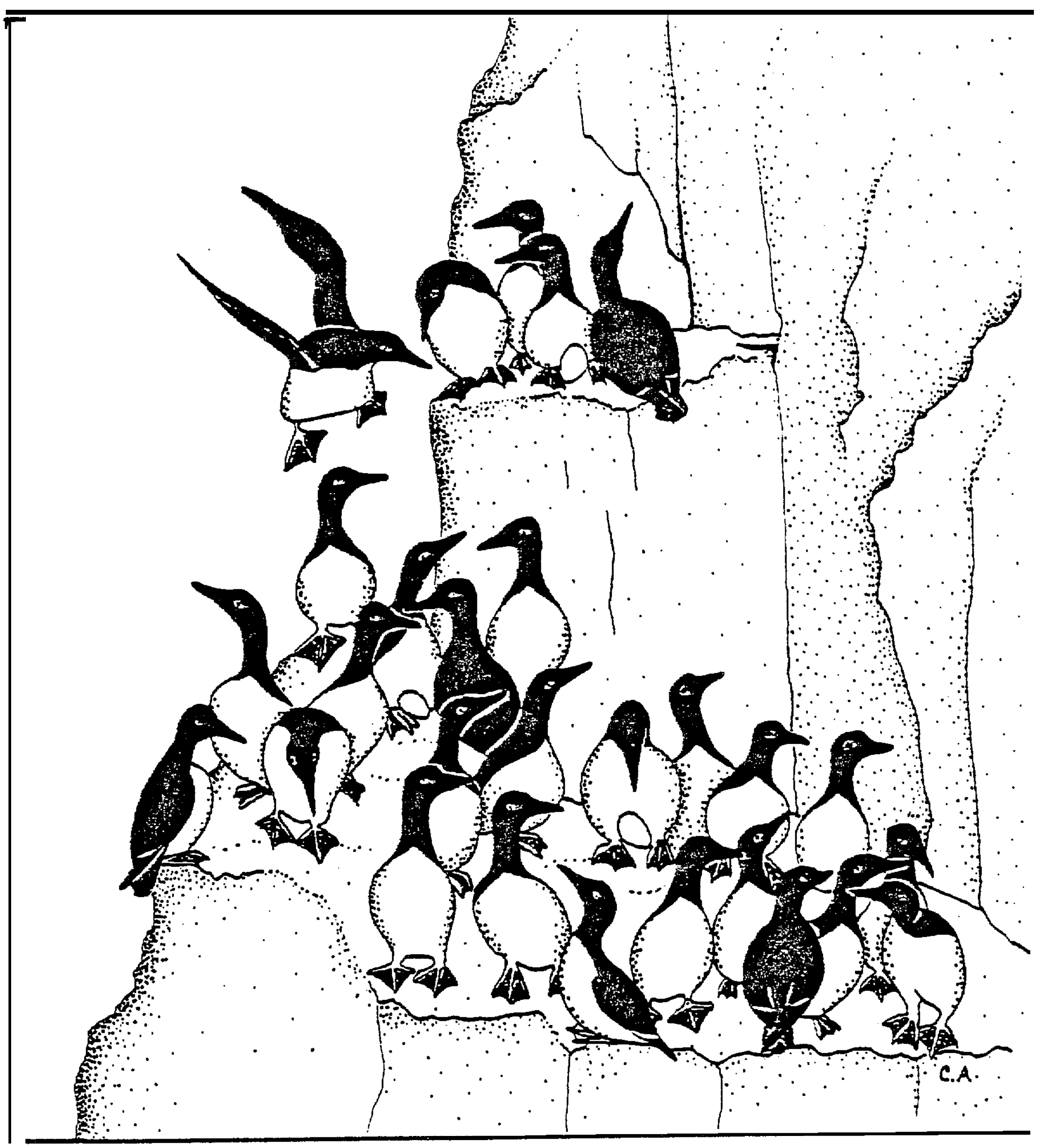
Murres (*Uria* spp.)



by

Margaret R. Petersen

COMMON AND THICK-BILLED MURRES

Uris 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-2). 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-l). 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 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 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 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.

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.

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

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-n 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 1s.			
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.

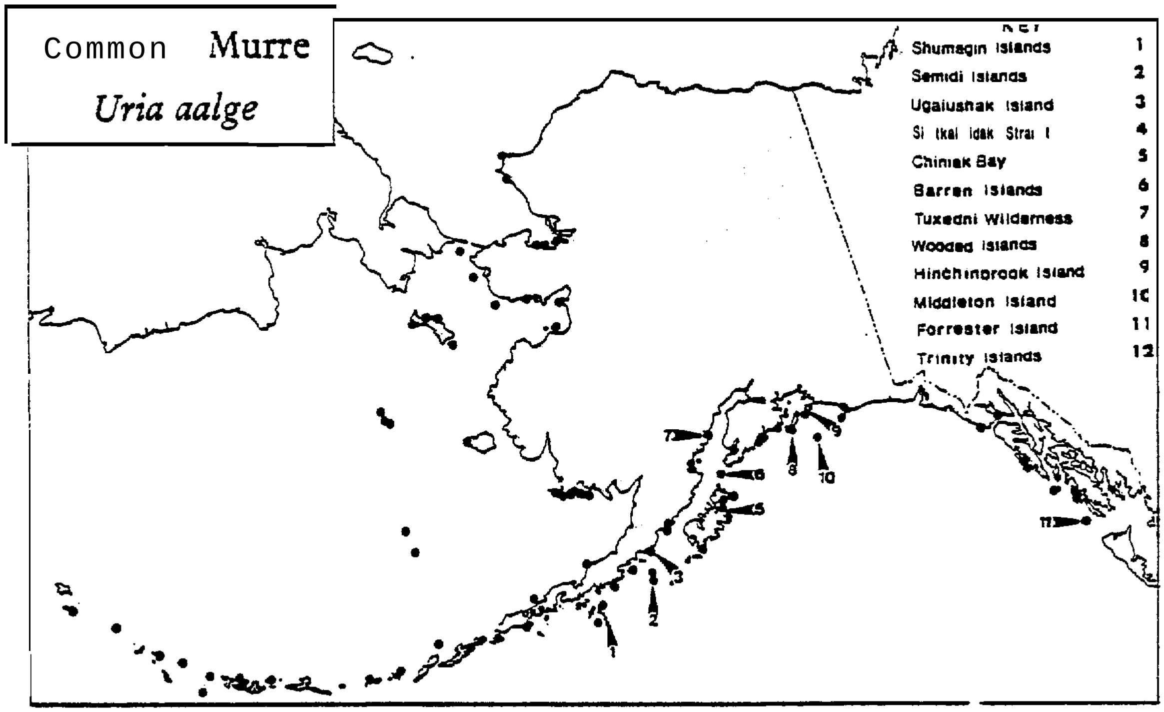
[c] From Willett (1915).

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
$\bar{X}$ 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.



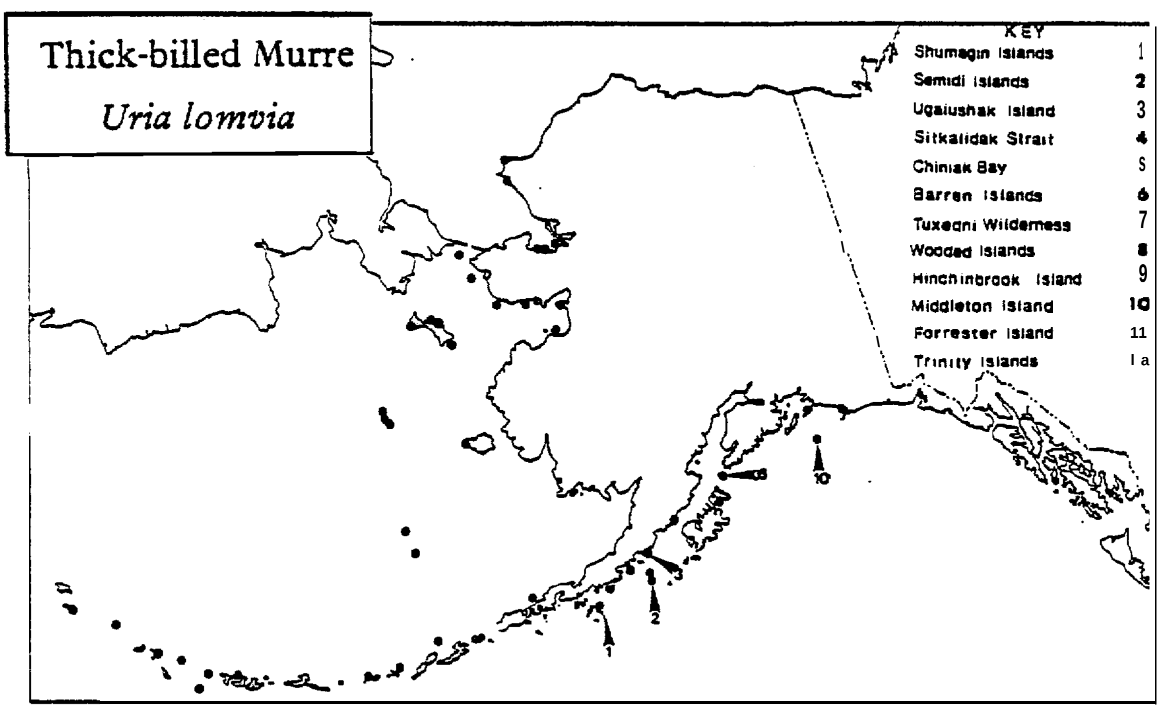


Figure IX-I. Distributions of breeding colonies of Common and Thick-billed Murres in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

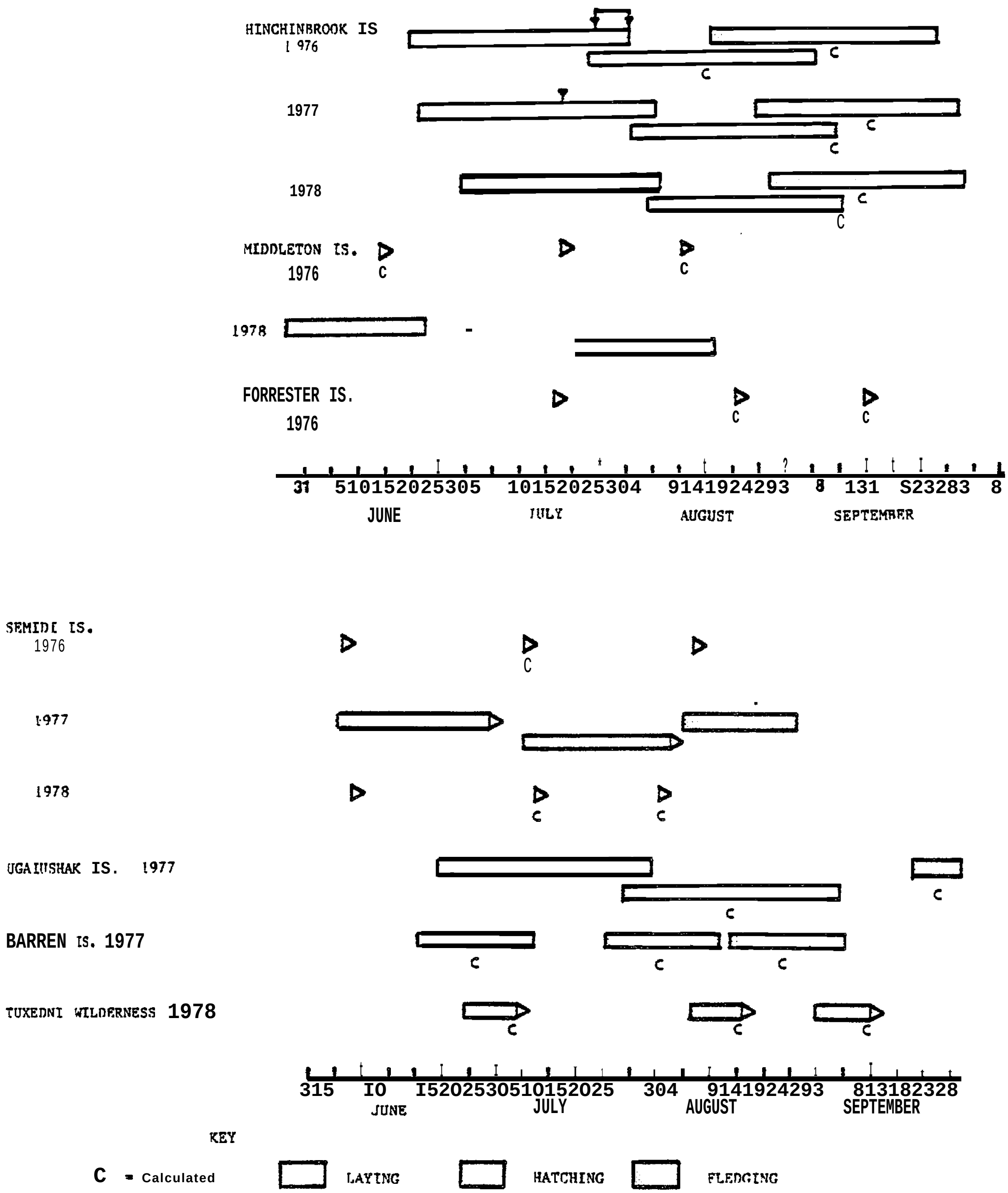


Figure IX-2. Chronology of major events in the nesting season of Common Murres in the Gulf of Alaska.

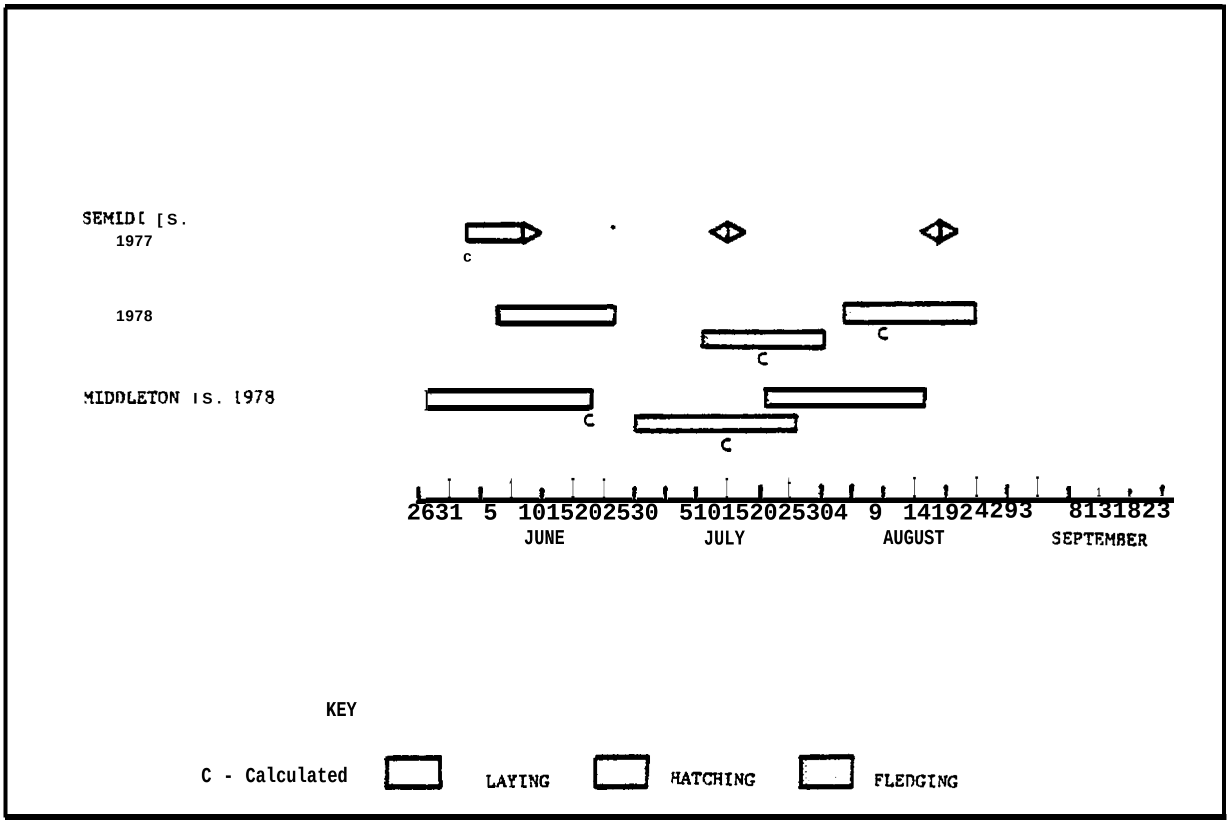


Figure IX-3. Chronology of major events in the nesting season of Thick-billed Murres in the Gulf of Alaska.

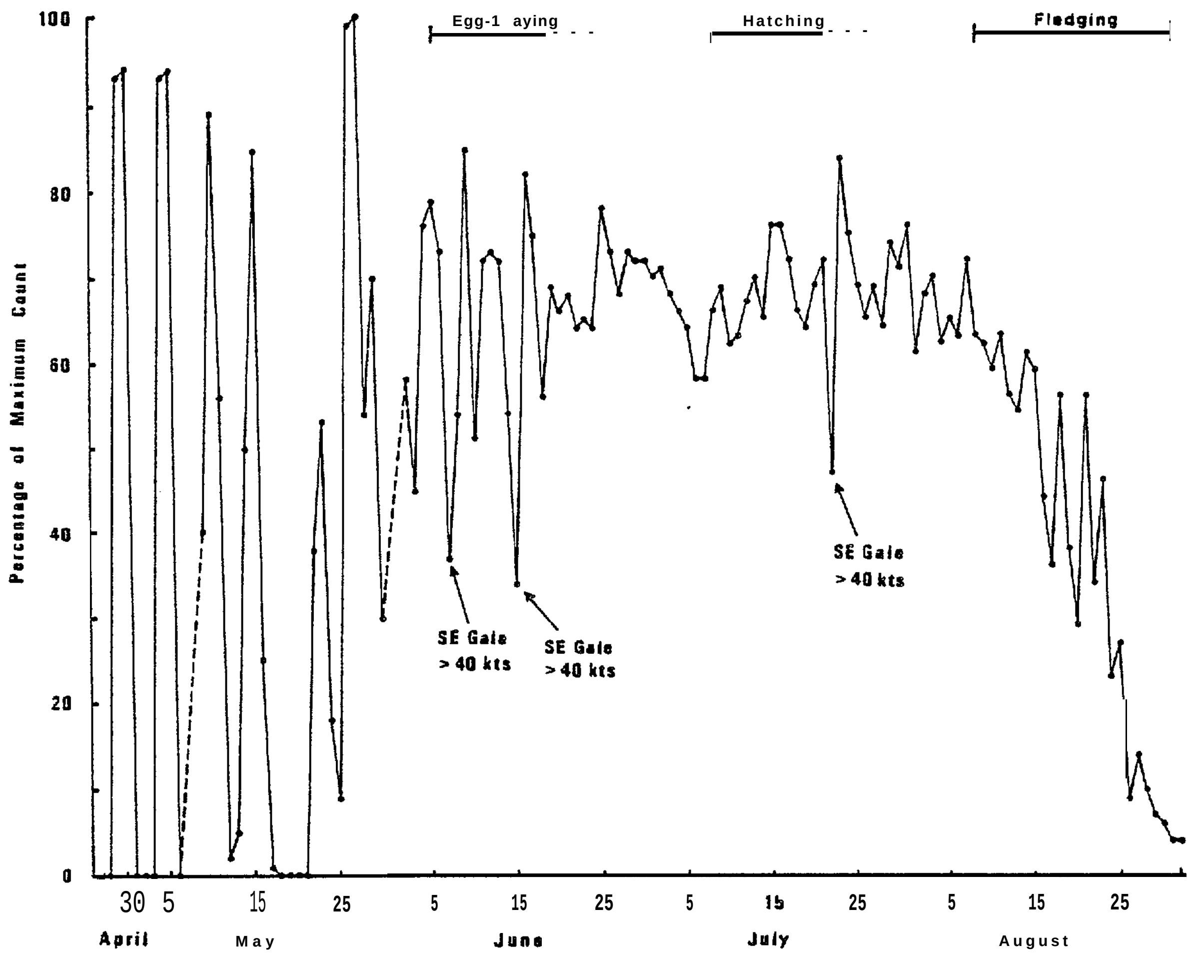


Figure IX-4. Seasonal pattern of colony attendance by Common and Thick-billed Murres at the Semidi Islands in 1977.

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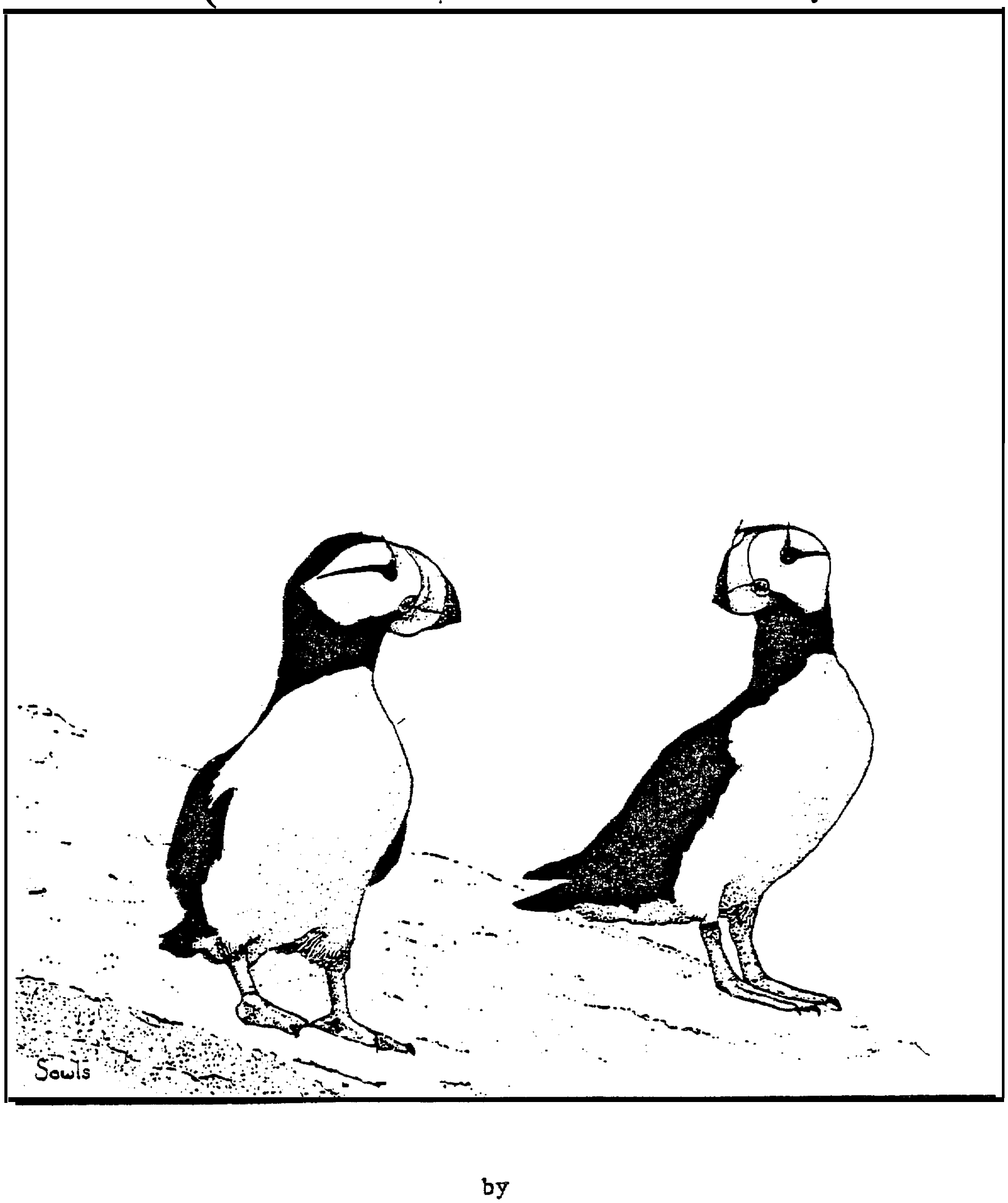
Horned Puffin

(*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 Scaly (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-l).

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. Di s tances between nests were similar in rock-sod slope habitats. On cliff-face and boulder slope habitats, birds on the Shumagins nested significantly closer together then 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 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, X=41.2$\pm$0.77, range=38-49 days) and a nestling period of 42 days (N=12, X=42.3$\pm$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 (Scaly 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 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 ± 1.0 g per day, 8 chicks at the Shumagins gained 12.6 ± 1.4 g per day, and 12 chicks at Chisik Island gained 10.7 ± 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 ± 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).

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, Scaly (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-89. 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 may not have died, mortality may be overestimated.

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 N	Shumagin Islands Nearest Neighbor (m)	Semidi Islands N	Semidi Islands Density (per m^2)	Semidi Islands Nearest Neighbor (m)	Tuxedni Wilderness Area N	Tuxedni Wilderness Area Density (per m^2)	Tuxedni Wilderness Area 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-gratis slopes		--	9	0.01	2.89+0.60		--	--

[a]Mean + SE

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.)
Semid i 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 -u-. 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.-n 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.

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	1.977	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..S0	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		

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%

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 16. 1976(N=14)	Barren 16. 1977(N=14)	Barren 16. 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%	12.5X	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%
'POTAL MORTALITY (Eggs & Chicks)	31.8%	60.4%	43.2%	30.9%	71.4%	28.6%	27.8%	50.0%	42.5%

Horned Puffin (*Fratercula corniculata*)

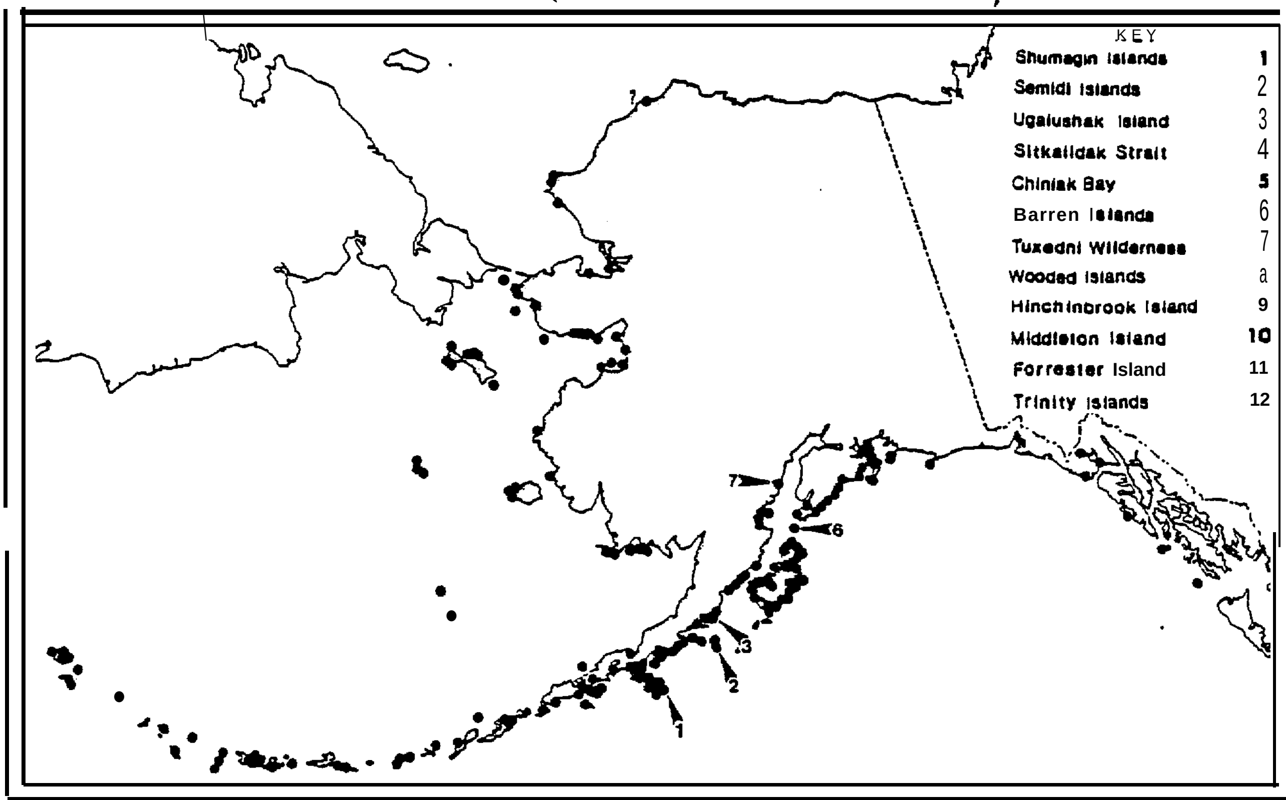


Figure X-1. Distribution of breeding colonies of Horned Puffins in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

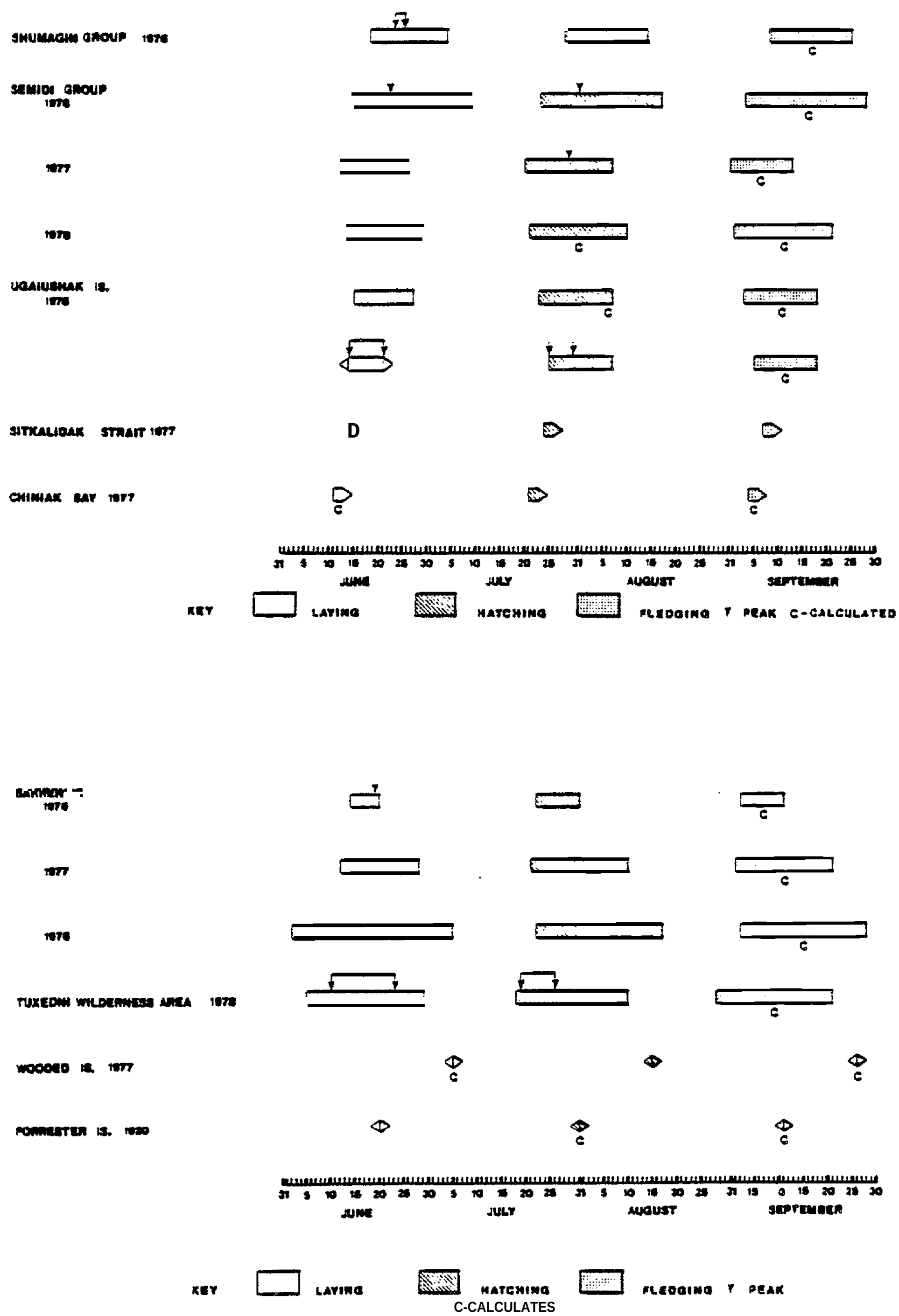


Figure X-2. Chronology of major events in the nesting season of Horned Puffins in the Gulf of Alaska.

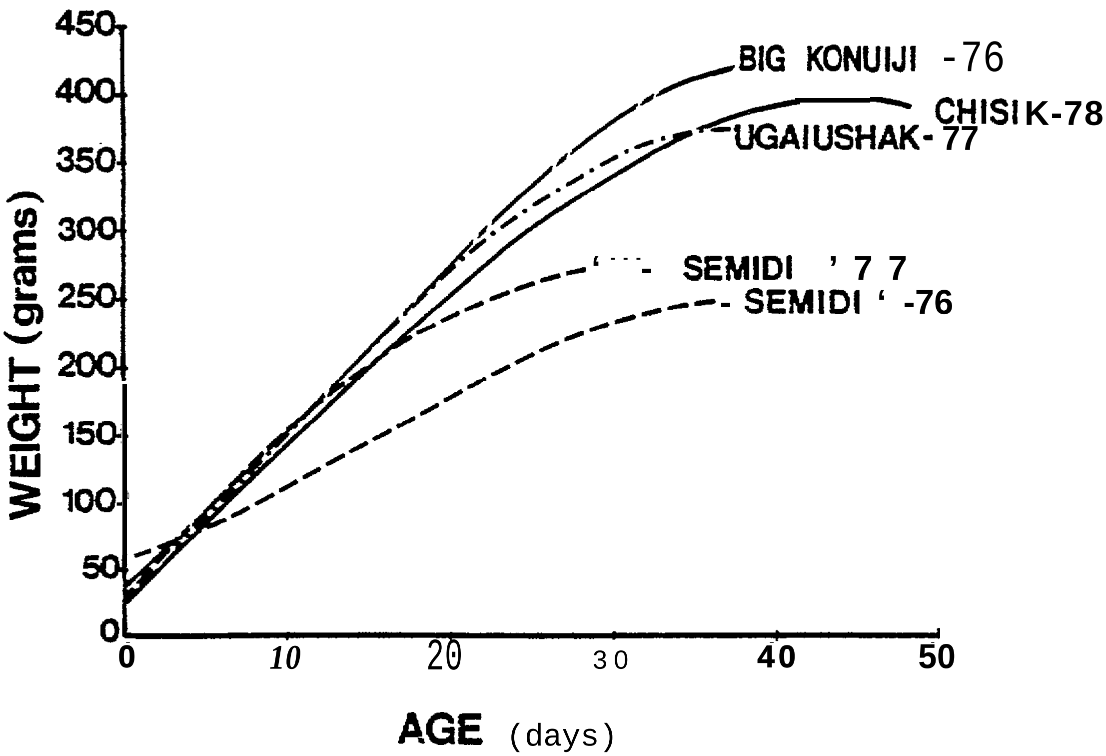


Figure X-3. Comparison of regression curves for growth of Horned Puffin chicks at four study sites in the Gulf of Alaska, 1976-1978.

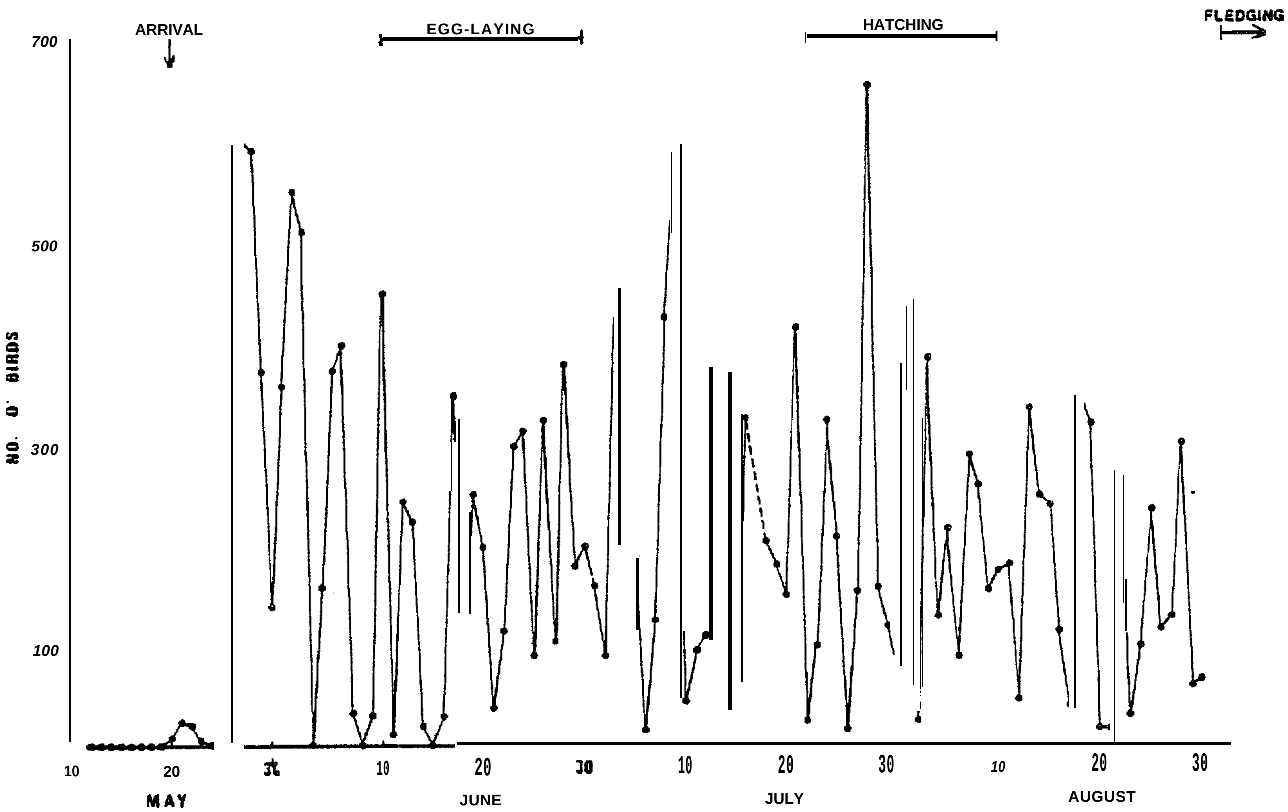


Figure X-4. Daily counts of Horned Puffins on the water made at the same time (0700-0900 h) and location, Semidi Islands, 1977.

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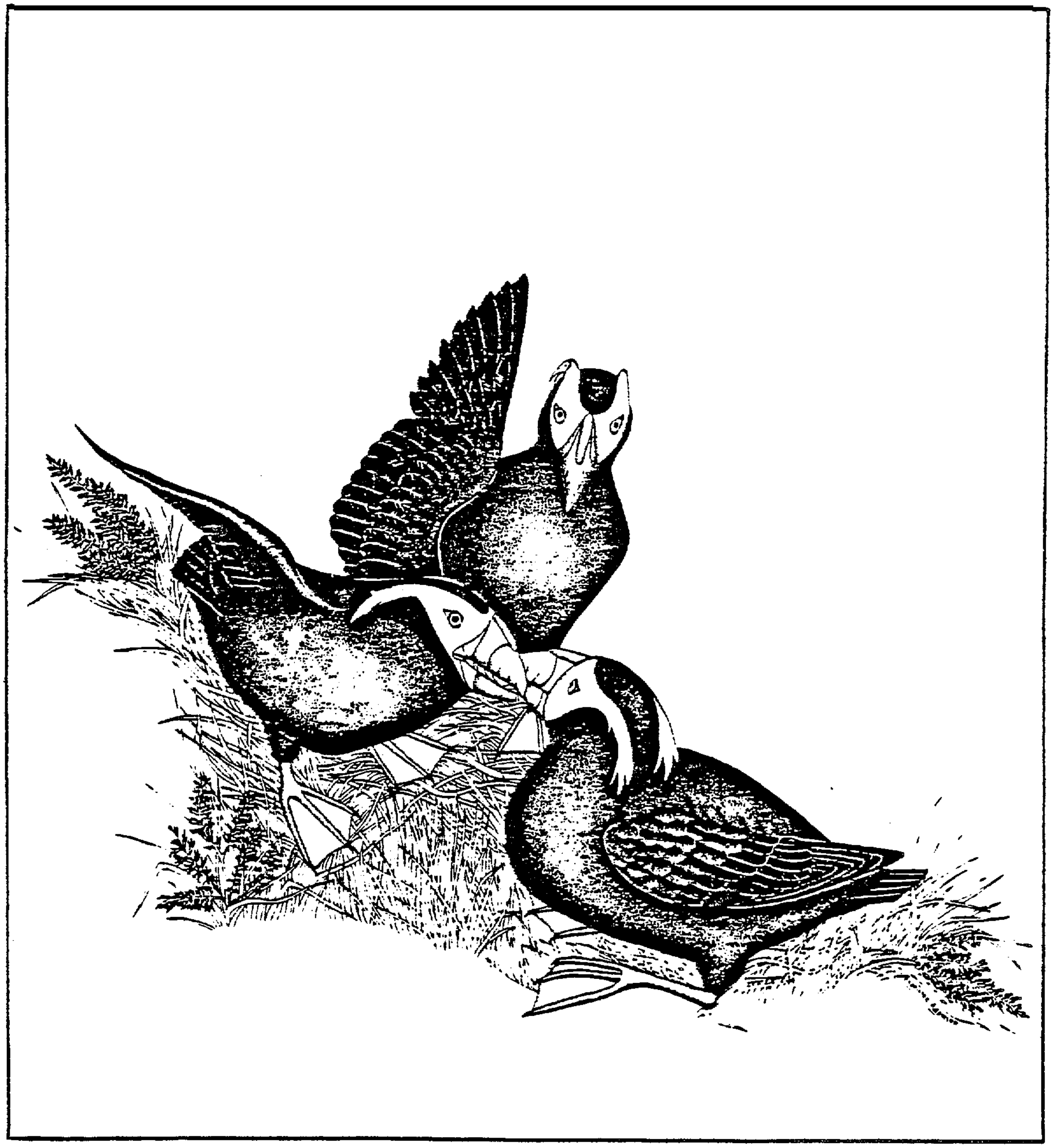
Tufted Puffin (*Lunda cirrhata*)



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 Scaly (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. X1-l):

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)

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-l). 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-l).

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 approximately 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 mof 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 XT-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-1egged Kittiwakes, also nested earlier on Middleton Island in 1978 than at other colonies (Hatch et al. 1979).

The incubation period ranged from 41-54 days ($\bar{X}$ 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 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 unweighed 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 ± 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 X1-7). 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 XZ-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 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, Scaly 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 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-1 4). 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 + 1.0 for capelin, 1.6 g + 0.1 for sand lance, 2.7 g + 0.3 for cod, and 24.5 g+ 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 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).

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 disturb- ante, e.g., from predation or from inexperience of breeders. Manuwal and

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).

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 edgee grassy slopes, rocky slopes, boulder slides, 83% of burrows w/ in 2 m of edge.		0.07 (range- 0.02-0.13)		

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.=
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 daee (>) not determined.
c Beginning date(<) not determined.

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	?.03	85	100	7a	—	—
No. burrows with eggs	51	3a	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	—	—
Retching 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 neat w/eggs	0.41[a]	0.24			0.52	0.46	0.28	0.39	0.18	—	0.22
Chicks fledged par active burrow (reproductive success)			—	—	0.38	0.31	0.13	0.22	0.08	—	—

[a] Baaed 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	9o[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.

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

	Hatching weights (g)				Fledging weights (g)			
	N	$\bar{X}$	SE	F	N	$\bar{X}$	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.

TABLE XI-8
Growth of Tufted Puffin Chicks.

Chicks at 5 sites[a]				Chicks at the Semidi Islands[b]		
Age (days)	N	Weight (g) $\bar{X}$	SE	N	$\bar{X}$	SE
o-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
IS-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	$\bar{X}$ 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 staining.

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	(-).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

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 (Cephalopod)	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)	X	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 (Cephalopod)	(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		i.7
Prowfish (*Zapora silenus*)			10.3
Squid class (Cephalopod) "	0.01	0.05	36.3
Nereid worms	0.02	0.06	

TABLE XI-14
Mean Lengths of Prey Fed to
Tufted Puffin Chicks.

Prey species	Ugaiushak Island 1977 (N) X + SE (mm)	Sitkalidak Strait 1978 (N) x + SE (mm)	Barren Islands 1977 (N) X + 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	

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.

Tufted Puffin (*Lunda cirrhata*)

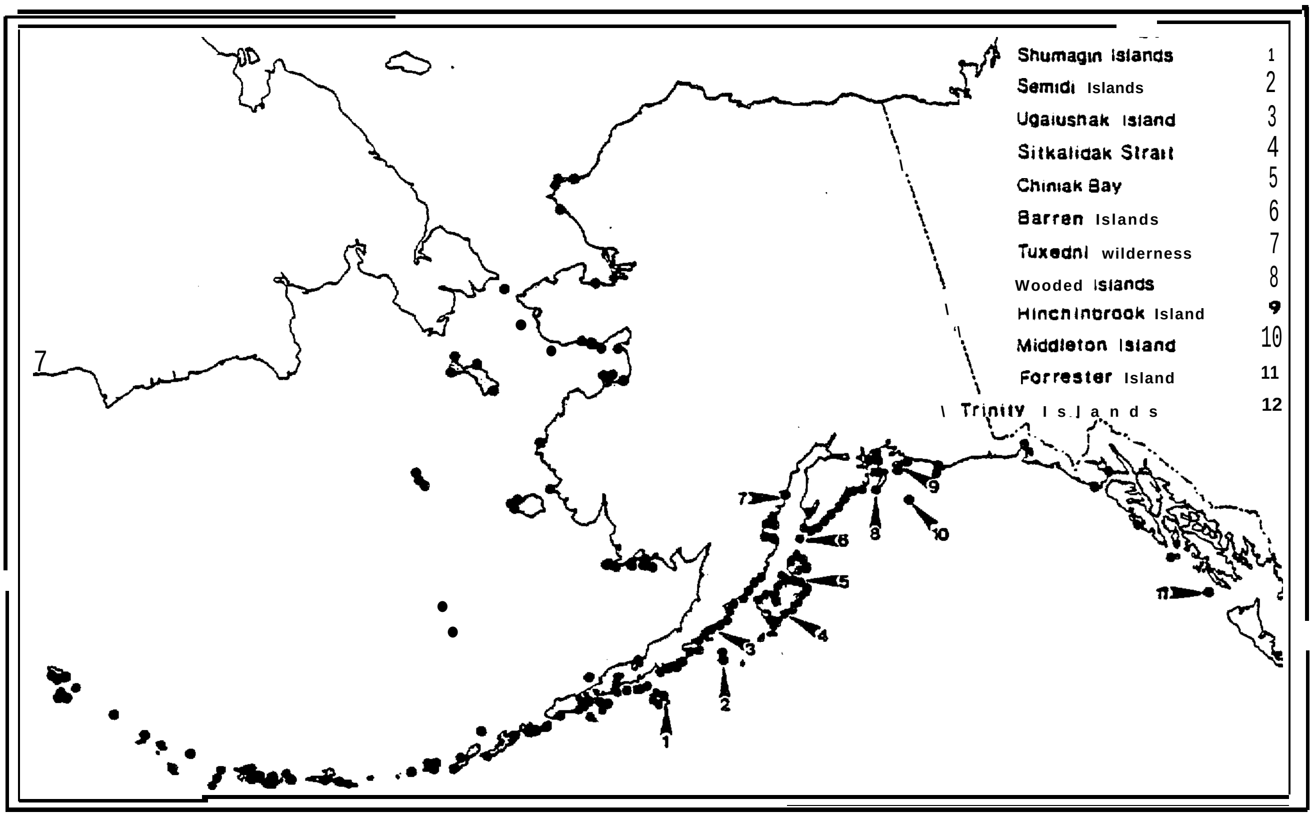


Figure XI-1. Distribution of breeding colonies of Tufted Puffins in Alaska. Sites where intensive colony studies were conducted are indicated by arrows.

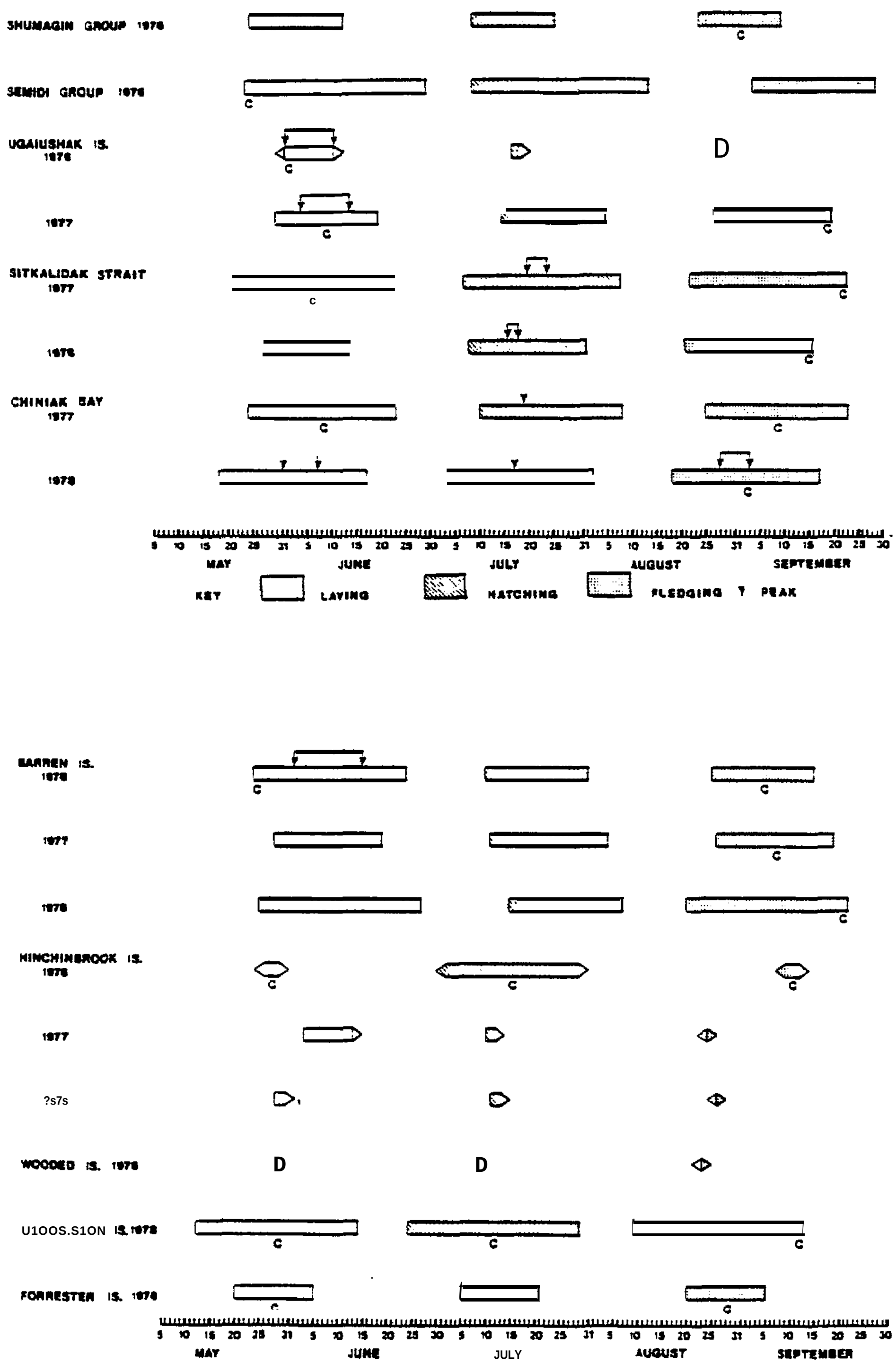


Figure XI-2. Chronology of major events in the nesting season of Tufted Puffins in the Gulf of Alaska.

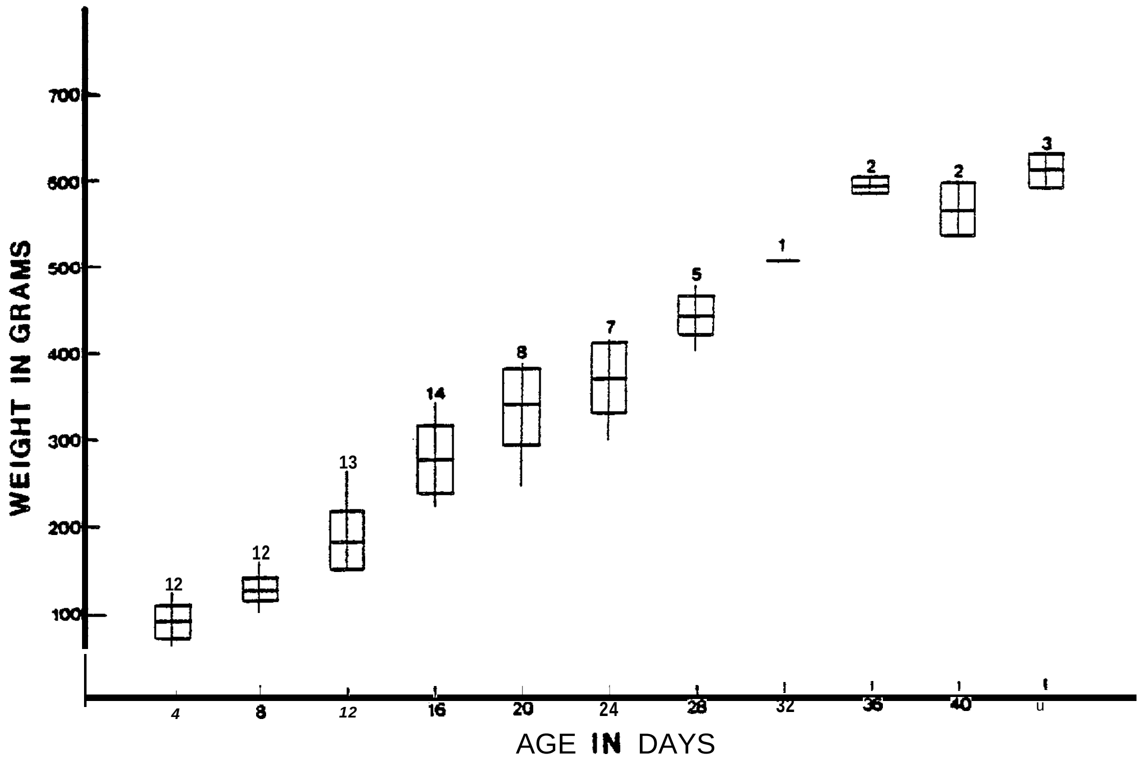


Figure XI-3. Weight gain in Tufted Puffins at Middleton Island in 1978.

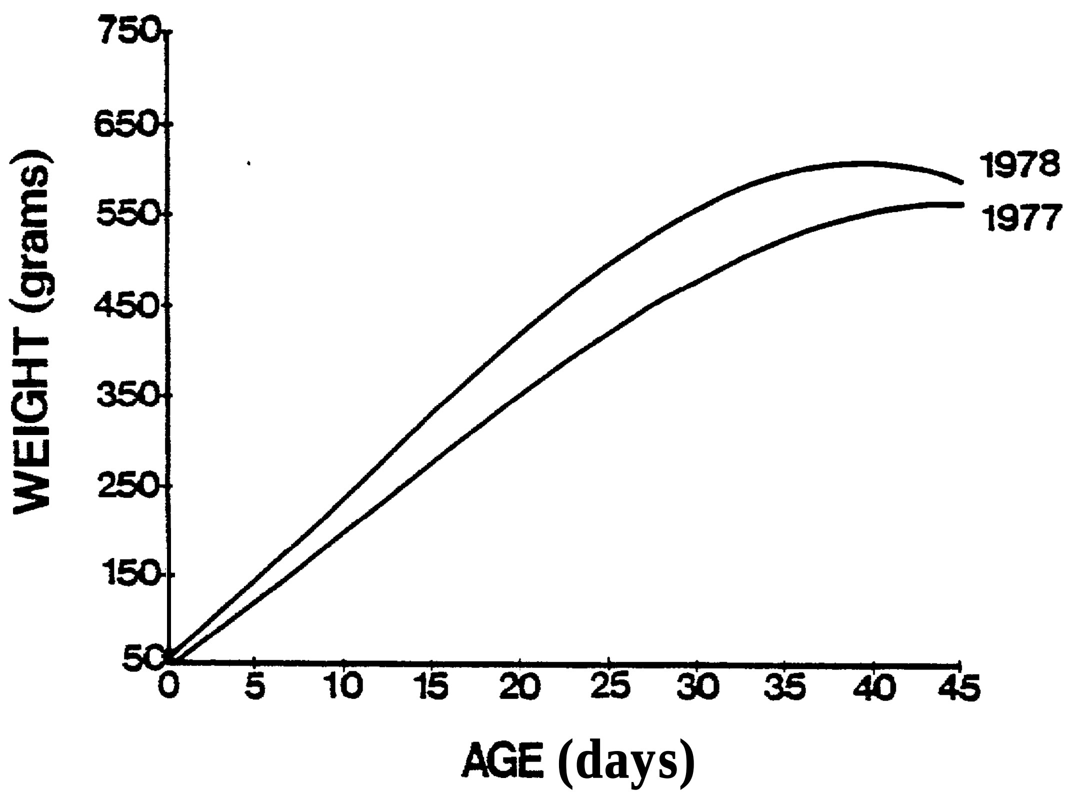


Figure XI-4. Comparison of regression curves of Tufted Puffin chick growth at Sitkalidak Strait in 1977 and 1978.

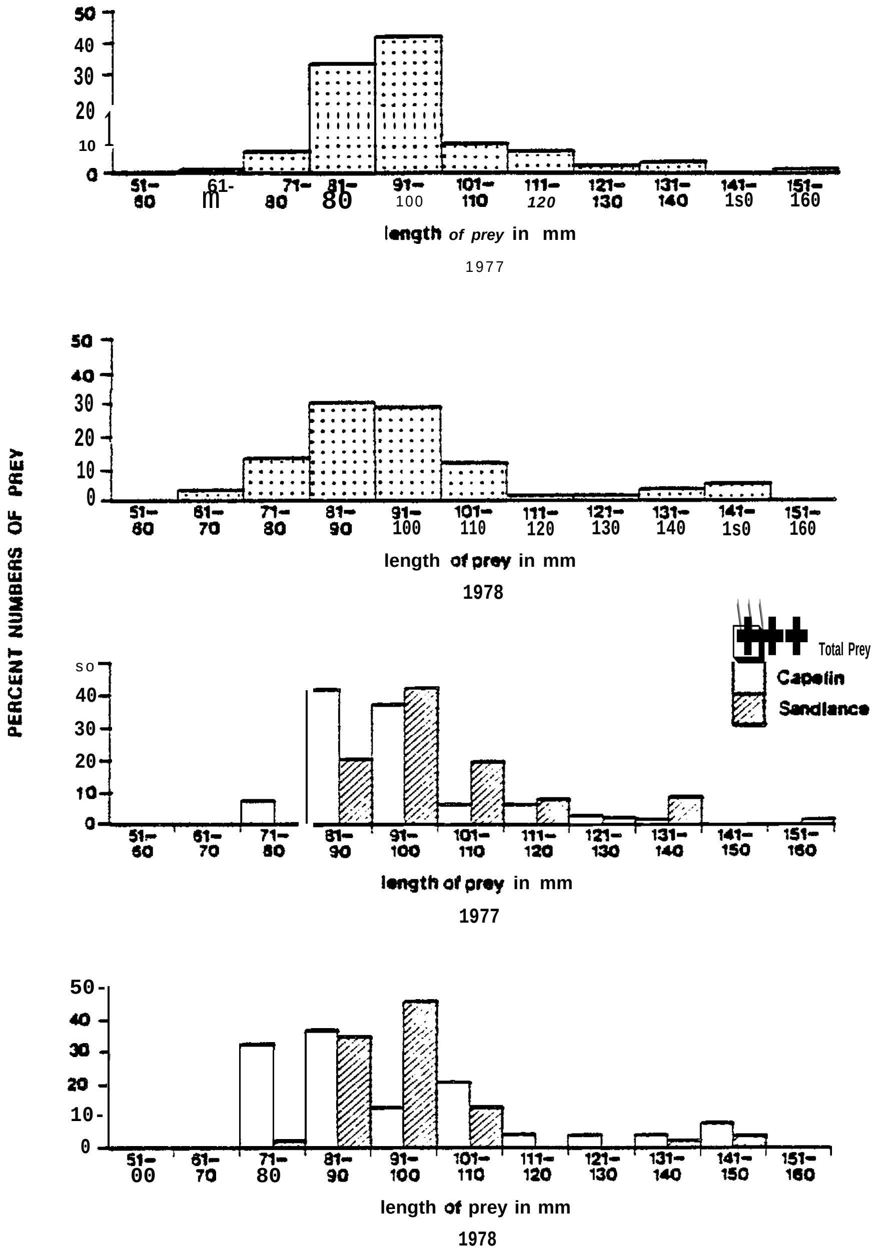


Figure XI-5. Distribution of lengths of prey delivered to Tufted Puffins in Sitkalidak Strait, 1977-1978.

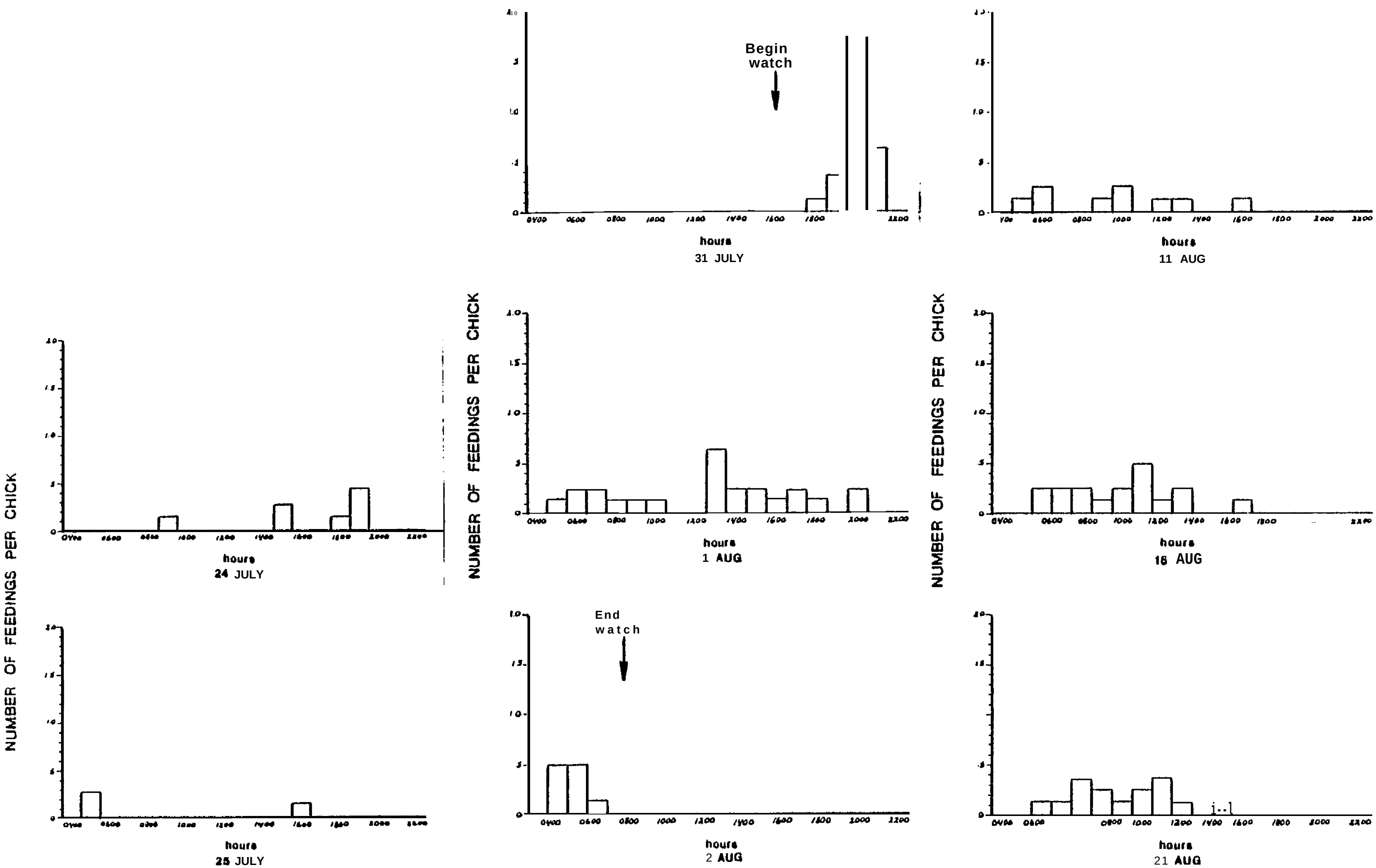
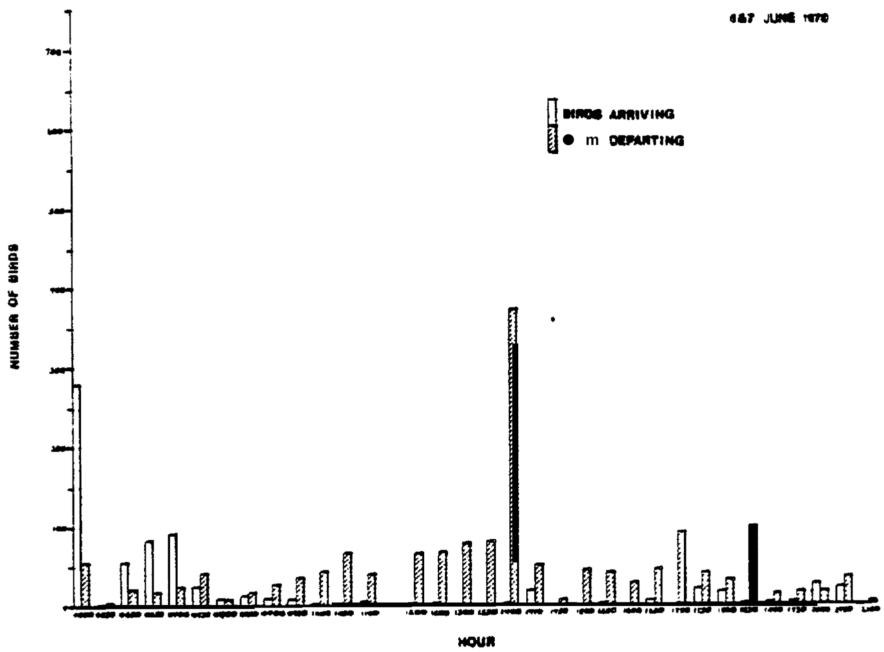


Figure XI-6. Frequency of feedings of Tufted Puffin chicks (n = 10-15 chicks) in Sitkalidak Strait, 1978.

(a)



(b)

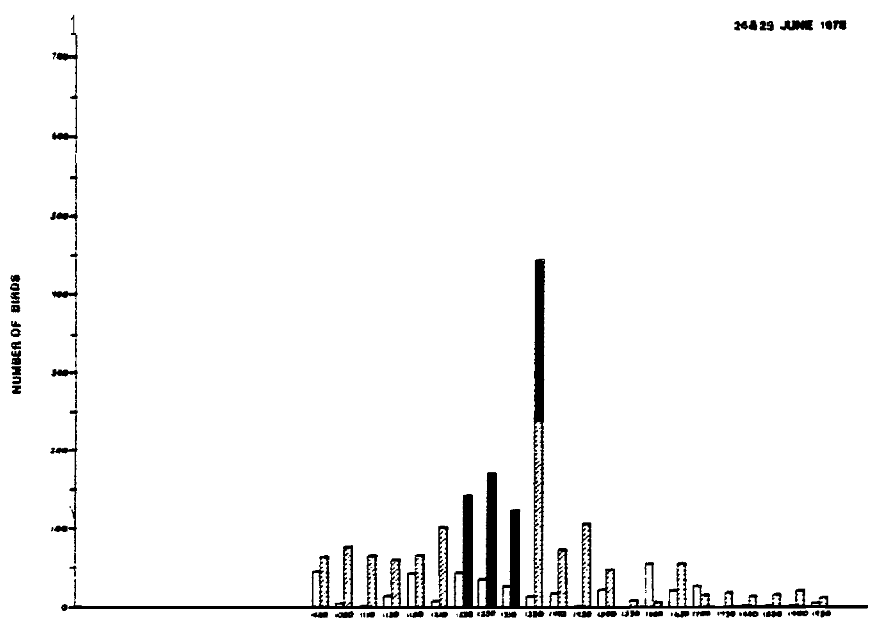
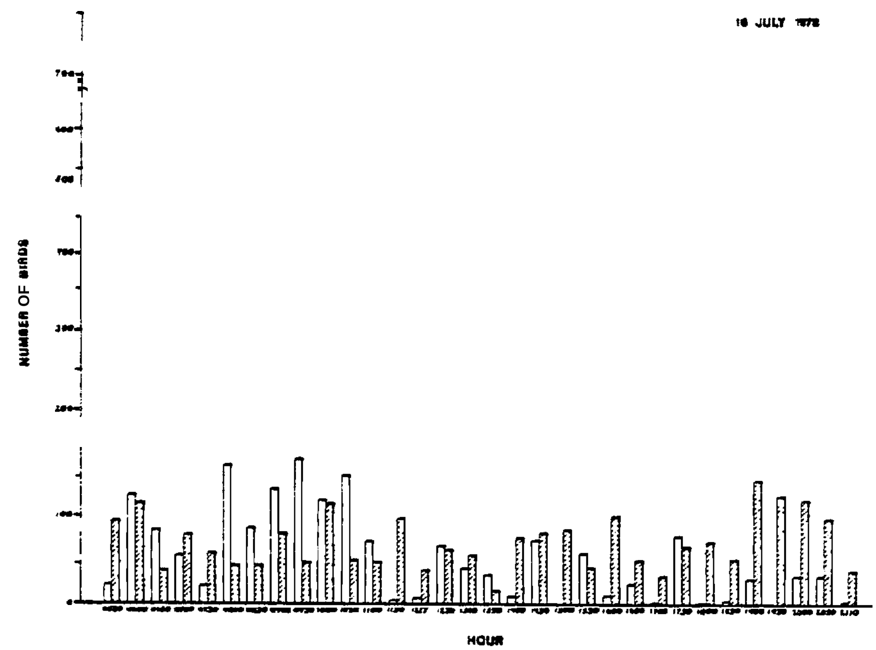


Figure XI-7. Numbers of Tufted Puffins flying to and from the colony, Sitkaldak Strait, on (a) 6-7 June and (b) 24-25 June, 1978.

(c)



(d)

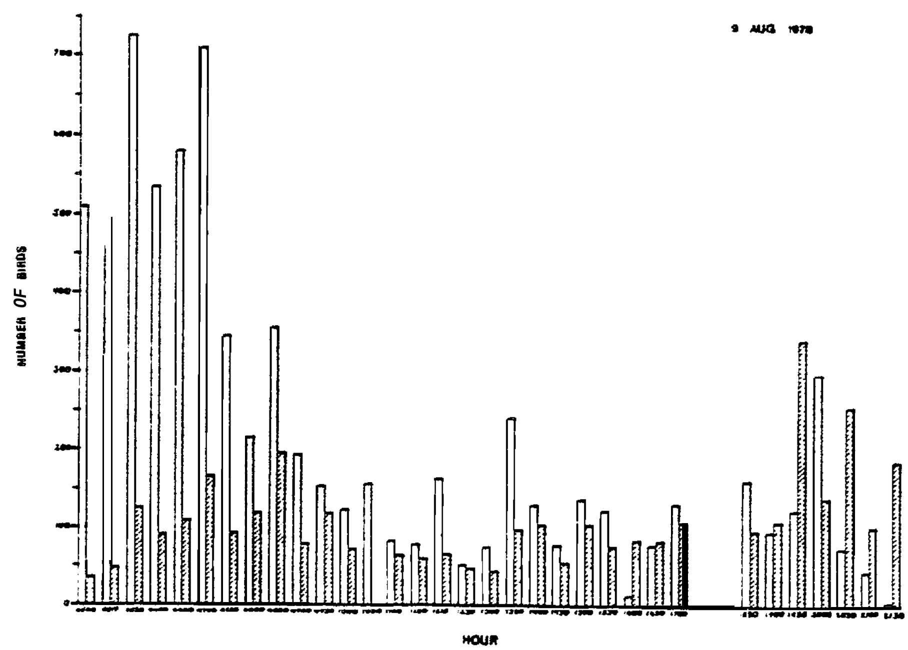


Figure XI-7 (cont.) (c 16 July and (d) 9 August, 1978.

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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-wing ed 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 abimdamat as Glaucous-wing ed 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 murr e. 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 outcropping 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 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-1egged 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 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-1egged 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 91-92X.

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-l). 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.

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-1egged 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.

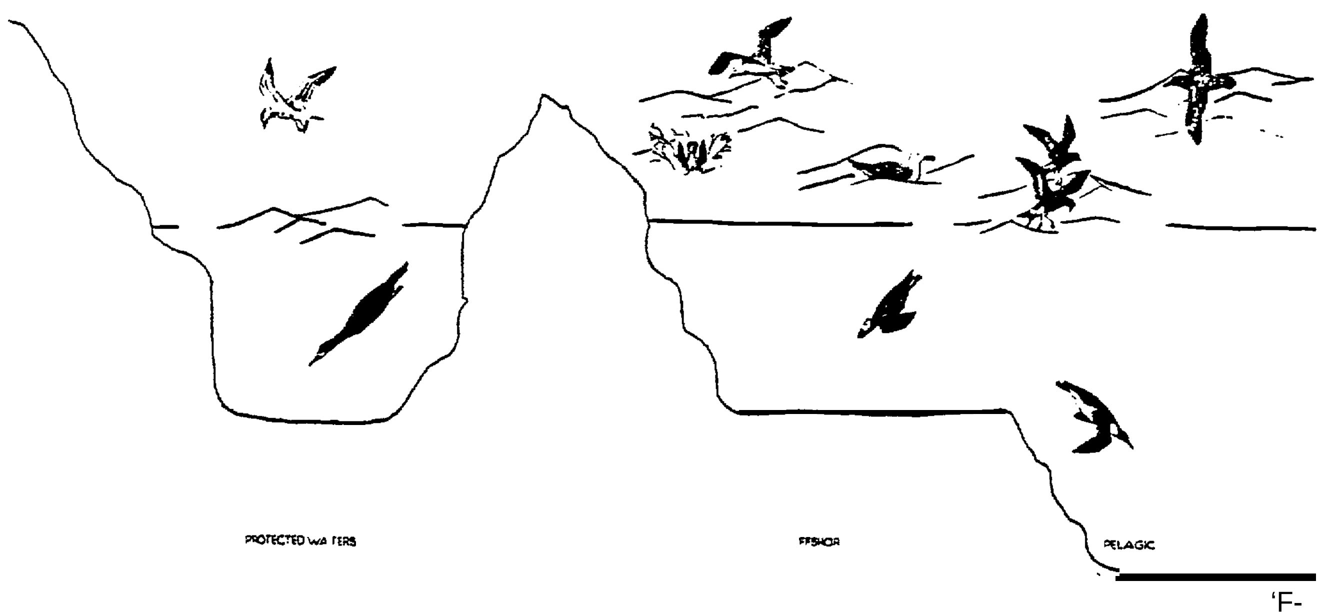

Figure XII-1. Foraging zones and feeding methods of seabirds in the Gulf of Alaska.

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-created 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 Cull	Open nests on very small to very large islands. Nests near vegetating 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 Cull	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 *Achilles* only.	Nests very close (30 cm).
Arctic Tern Aleutian Tern	Open nests on low grassy islands. Occupy grassy meadows sometimes 10 heads of bays. Arctic Terns sometimes neat on gravel bars.	*Calamagrostis*. No high vegetation; avoid mixed meadows.	Highest densities on islands. Nore 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-cod slopes or extensive burrows in sod-grass slopes.	If on slopes, then in burrows beneath mixed-meadow vegetation.	Solitary neetera 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. Nave 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	Comment a
Northern Fulmar	ca. 101 daya.	Late May to early August.	Hid-July to early October.	Early September to early October.	Little yearly variation. Predictable. Peaks within 3 daya from year to year.	Arrive on colony in mid April.
Fork-tailed Storm-Petrel	ca. 108 daya.	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'a Storm-Petrel	ca. 105 days.	Late April to late August.	Early June to lace October.	MId-August to late October.		
Double-crested Cormorant	ca. 73 daya.	Late May to mid-July.	Late Juna to early September.	Mid-August to early September.	Some variat on among sites and y ars (l-2 weeks). Relaying an reneating common.	
Pelagic Cormorant	ca. 81 days.	Early May to mid-August.	Early June to early October.	Late July to early October.	Same as Double-created 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-created 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 Middleton 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.		Fledgling 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 Way to early September.	La t e-June to early October.	Early August 10 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] daya.	Late May to late July.	Late-June to mid-August.	Late July to mid-August.		
Worried 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 weeke later tha others. Egg neglect prolongs incubation atage.
Tuf ted 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 Way. 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.

	Mean and (Range) of:						
Species	Fledglings/ neat attempt	Fledglings/ neat 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 197S 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. Heat 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 197S 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:						
Ulack-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 (.8-2.3)	--	0.75 (0.29-0.91)	--	Heavy mortality from storms.
Aleutian Tern	--	-- (0.22-0.83)	1.66 (.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)	I .0	0.81 (0.64-0.97)	0.71 (0.67-0.93)	0.68 (0.36-0.9)	
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 (0.90-0.9)	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	6S-74	1.5	Grouch 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	a		
Horned Puffin			370-410	3.4-12.6	Growth similar between yeara 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	Bo ttom-dwelling coarse fish Smelt			
Glaucous-winged Gull	Capelin Sand lance	1977=37-43% Seth 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
Hew Gull	Capelin Macoma baltica Three-spined Stickleback			Mew gulls are eclectic: eat berries, earthworms in ocher areas.
Black-legged Kitt iwake	Capelin Sand lance	1977=56% Such prey 1978-6-14% species 1977-48% 70-104% 1978=64-70%		Mean length fieh-94.9 mm-111.0 mm. The majority therefore are 2-yr-old fish. Prince William Sound: herring ware 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% 1978-30%	1977=51% Seth prey 1978-20% species 2977-29% 70-80% 2978-50%	X̄ length Eiah-111.0 mm
Aleutian Tern	Capelin Sand lance	1977-40% Both prey 1978-25% species 1977-U% 42-25% 1978-172	1977=43% Both pray 1978=21% species 1977- 9% 42-52% 1978-222	X̄ length fish - 103.9 mm
Common Murres	Capelin Saod lance Herring			
Horned Puffin	Sand Lance Capelin			
Tuft ed Puff in	Capelin Sand lance	1977-852 Both prey 1978 35% species 1977=38% 84% 1978=46%	Seth Capelin end Sand lance : Range 60-99 .5%. X̄-87%. 1978=Capelin # * e decreased from 1977 and #s of eand lance increased.	X̄ length=90.3 mm (60-150 mm). Majority of ffeh-2-yr-olds. Similarity in sizes between sites & years. Middleton Ie.: 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
Fodc-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-LO 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 1S.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 3S 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 ripe, convergence lines; 500 nt- 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-pm-egg stage in Way.	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 eights. Eggs left unattended $\bar{X}$=11 days/60. Egg chilling extends incubation time.
Black-legged Kittiwake	Lowest numbers= June	Loue9t=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 correlate 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 Puff in		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 sear 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 enclosures. Amount of egg neglect is sensitive indicator of foraging condition.
Double-crested & Pelagic & Red-faced Cormorant	Eggs: avian predation. Chicks: exposure.	Inattentiveness by adults. Stoma also destroyed nests. Poor foraging conditions bring starvation. Dispersed or asynchronous nests have 1.5-3.5 times lower productivity. Possible competition at nest sits with Black-1egged Kittiwakes. Disturbance by humane.	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, inattentive nesa.	Availability of food influences all stages of reproduction: number of adults that enter breeding kpopulation, Laying, hatching, & fledging success, greater search time for food, lees 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 MEGO, GWGU, BBMA & NWCR.	Alteration of habitat. If no human disturbance, then predation most important. Chicks: exposure from less nest attentiveness 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 co 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.	Stoma sometimes caused burrows co 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.