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APPENDIX IV

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THE BREEDING BIOLOGY AND FEEDING ECOLOGY OF MARINE BIRDS  
IN THE SITKALIDAK STRAIT AREA, KODIAK ISLAND, 1977

By

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## I. INTRODUCTION

The purpose of our study at Sitkalidak Strait, Kodiak Island, Alaska was to collect information on the breeding biology and feeding ecology of five major species of birds: Black-legged Kittiwakes, Tufted Puffins, Arctic and Aleutian Terns, and Glaucous-winged Gulls. This information is necessary in order to assess the pre-drilling avian ecology at Sitkalidak. Areas of the Outer Continental Shelf nearby are soon to be drilled and until this study, there had been no ecological assessment of the avifauna in the area.

Specifically, the long-range goals of all the OBS field studies are to determine abundance and distribution of important species of seabirds in strategic areas and to try to determine natural variation in numbers of their populations; to monitor the phenology of these populations so that critical time periods in the breeding cycle can be fully assessed; to learn preferred or critical breeding habitat of these species in case the physical environment may somehow become altered; to learn the average productivity and normal mortality of these species, to be used as a baseline against which studies in future years may be compared; to find the average growth rates of the chicks in the pre-drilling time period as a partial indicator of the health of a population, to be used as baseline again for future comparison; and finally to discover the trophic relationships of these species so that in the OCSEAP integrated studies plan, their place in the ecosystem can be determined and these relationships can then be monitored throughout all oil and gas activity to see if they change. In addition, in our study, we wanted to see if any one factor in the Sitkalidak Strait area, especially nest-sites and food tended to be in short supply.

Except for the surface nesters (Glaucous-winged and Mew Gulls, Aleutian and Arctic Terns) which suffer heavily from egg-gathering activities by the local residents, the seabird species breeding in the Sitkalidak Strait region are at present relatively undisturbed by human activities. Offshore oil and gas development will bring more people, tanker traffic, and potential pollution such as human wastes and oil to this region. Therefore, the assessment of the pre-drilling avifauna ecology is essential.

## II. METHODS

### Distribution and Abundance:

The census techniques we used in the Sitkalidak area were basically those outlined by Nettleship (1976) with some variations according to our particular situation. We censused cliff nesters, such as Black-legged Kittiwakes and cormorants by counting each nest individually from a zodiac 30-50m from the colonies during the last part of the



incubation period. We censused Tufted Puffins by estimating number of burrows from a zodiac and then ground-truthing this estimate. We censused gulls and terns also from a Zodiac by counting the number of birds on or above the colony and then comparing this number with our nest estimates extrapolated from transect counts.

The population estimates of birds that nested in small numbers in the area, such as Horned Puffins, Pigeon Guillemots, and Red-breasted Mergansers, were based on counts made at various times during the breeding season. These counts, in some cases, were then applied to the extent of the nesting habitat available, for an estimate of the size of the breeding population.

#### Nesting Habitat and Breeding Biology

We used the transect method to study the breeding biology and nest-site selection of all five species studied: Glaucous-winged Gulls, Tufted Puffins, Black-legged Kittiwakes, and Arctic and Aleutian Terns. Specific procedures and methods are outlined in each species section.

#### Feeding Ecology

The distribution of the birds on the water, their use of this habitat for feeding activities and the trophic relationships of these birds was more difficult to assess than was the nesting habitat. We undertook several approaches to acquire this information. Transects were run seaward from Cathedral Island aboard the Yankee Clipper, a vessel chartered by the USFWS for pelagic studies of seabirds in the Kodiak area. These were made on 22 June, 12 July, 11 and 12 September. Continuous observations were made of the movement of birds in and out of the strait from 1030 on 11 July to 1500 on 12 July from Lagoon Point (Figure 1). The location of feeding flocks, their composition, size, and time of occurrence were recorded whenever we encountered them. Likewise we collected three birds of each of the following species: Black-legged Kittiwakes, Tufted Puffins and terns of both species, every five days whenever possible, and subsequently analyzed their stomach contents. We also collected regurgitations of chicks opportunistically. As described later, we conducted continuous watches of selected nests of Arctic and Aleutian Terns, Black-legged Kittiwakes and Tufted Puffins in order to determine chick-feeding effort and nest-site attentiveness of the adults. From these observations, to be fully described later, we tried to determine a baseline of feeding rates of the chicks and correlate this with their growth and mortality.

## TUFTED PUFFIN

### Distribution and Abundance

#### Methods:

We estimated the number of Tufted Puffin burrows on Amee, Nut, Granite and Cathedral Islands on 16 July, which was during the initial stages of hatching. We feel confident that our estimates were good because on Amee and Cathedral Islands we had marked all the burrows in selected sample plots, of known numbers of burrows, with flags one meter high which could easily be distinguished from offshore. These gave us accurate visual indices of the burrow densities in the various habitats which we could use in censusing the entire colonies.

Because the daily cycles of attendance at the colony by Tufted Puffins severely limits a population estimate based on counts of adults at any given time (Wehle, 1976, Amaral, 1977), we did not rely on such counts for the estimates, but we did count the number of puffins in the air, on the colony and rafting offshore for both Amee and Cathedral Islands to correlate with our estimates based on burrow counts. On 19 July we censused Sheep Island using the same methods.

In order to ground-truth the offshore census, on 5 September we divided the habitat on Cathedral Island into three major categories based on density: type one with approximately 1 burrow/m<sup>2</sup>, type two with .6 burrows/m<sup>2</sup>, and type three with .08 burrows/m<sup>2</sup>, and measured the extent of each habitat type on the colony. From this we obtained a more accurate estimate of the total number of burrows on the colony.

#### Results: Censusing

The estimate of burrow numbers based on visual assessment of the colonies from offshore was within 3.6% of the census based on the direct field census of Cathedral Island (Table 1). Of the 93 burrows in all the sample plots, 30.0% did not contain eggs. This percent varied from 18.8% on the Amee Island plot to 42.1% on Amee Rock. Using the mean percent for unoccupied burrows, the inner Sitkalidak Strait area supported 4,950 breeding pairs of Tufted Puffins in 1977 (excluding Table Island).

By far the greatest concentration of Tufted Puffins was on Cathedral Island which supported 85.3% of the total Sitkalidak Strait population (Figures 2 and 20). Here, as on the other colonies, the birds were nesting in a doughnut-shaped colony with the highest densities along the immediate edge and decreasing toward the island's center.

This island was more precipitous than the others and had extensive sod-covered slopes in which the puffins nested in high numbers. The altitude of the other islands was much lower and they had less slope. On these, the puffins nested only along the immediate perimeters.

#### Results: Distribution of birds away from the colonies

The movements of Black-legged Kittiwakes and Tufted Puffins in and out of Sitkalidak Strait on 11-12 July are summarized in Figures 3-8 and Table 2. The puffins were in late incubation, and thus were not engaged in feeding chicks at this time. The most striking feature of these movements is the continued exodus from the strait on both days by both species, with a very low rate of return. Unfortunately, the entire width of the strait was not in view (Figure 1) so birds could have been moving out of the strait along the southern shore and returning via the northern side. The weather during the transects was mild (Table 4).

Both the kittiwakes and puffins were moving out with coincident peaks and the outward movements were usually correlated with feeding flock activity, at least in the morning (Figures 7,8). From a preliminary analysis, feeding flock activity was correlated with the tides. We cannot determine whether or not birds are continuing seaward once the feeding flocks dissipate. There were no feeding flocks observed beyond the mouth of Sitkalidak Strait during the shipboard transect on 12 July, although they were abundant near the mouth of the strait and farther in (Figure 14).

The ship-based transect, run seaward from Cathedral Island on 22 June, shows that the puffins were concentrated within 2-3 miles of the island, near the mouth of McDonald Lagoon with the eastern mouth of Sitkalidak Strait being of secondary importance (Figures 9 and 13). On 12 July the numbers of puffins steadily increased from the mouth of the strait to Cathedral Island as did the numbers of feeding flocks (Figures 10 and 14). The transects were not run farther seaward than the mouth of the strait on either day, but general observations were that the puffins were much more abundant within the strait itself.

We suspect that the puffins were obtaining food for the chicks reasonably close to the colony because of the number of times per day the chicks were fed (up to 6 feedings per day). To be able to make so many daily food trips the adults would have to obtain this food close to the colony.

#### Phenology

##### Methods and Results:

The surveys of the bays and fjords in the Ugak Bay and Sitkalidak Strait regions of Kodiak Island showed that the puffins were moving into

the inshore waters during late May so that by mid-June the densities of puffins in these waters far surpassed those in the shelf waters (Figure 16). This indicates a movement from the pelagic situation onto the colonies. We did not observe first arrival of the birds on the colonies. By the time we arrived they had already begun to lay eggs. When we first examined the burrows in the sample plots on 3 June, 23.1% had eggs, and by 12 June 90.4% of the burrows had eggs. The first chick hatched on 7 July, and by 24 July, 84.6% of the chicks had hatched. The peak of hatching occurred between 20-24 July when 43.6% of the chicks hatched (Figure 17). The last chick hatched on 8 August. The first chicks fledged between 22-26 August and by our last visit to the colonies on 6 September 86% of the chicks had fledged. By 11 September, most of the puffins had left the area (Table 3, Figures 9-15).

We observed slightly varying chronologies on different sample plots representing different types of habitat on Cathedral Island (Figure 18). The densest plot, plot 7, had 92.9% of its chicks hatched by 24 July while plot 5 had 60.0% hatched by this date and plot 4 only 50.0%.

Non-breeding birds began to come into the Sitkalidak Strait area after the first week of July, roughly coincident with the onset of hatching. At this time we observed increased activity on the colony (i.e., excavation of vacant burrows, large numbers of birds on the colony and rafting offshore) and began to collect birds with no brood patches and undeveloped gonads.

The departure of the puffins from Sitkalidak Strait coincided with the fledging of the young, which began around 25 August. By late August the puffins had almost completely left the bays and fjords, and by the later part of October they had vacated the waters of the shelf as well.

### Nesting Habitat

#### Methods:

We set up seven transects on Cathedral Island, one on Amee Island, one on Amee Rock and two on Sheep Island in mid-June, 1977 (Figure 20). All plots began at the outer perimeter of each island and ran towards the island's center, terminating with the last burrow that we could find. In most cases, the plots included only those burrows within one meter on each side of the transect line, but in areas of light density, such as on Amee Island and Sheep Island, the plots were wider to include a reasonable sample size. We reached the nest chambers in all the burrows and made "windows" whenever necessary, which we plugged with clumps of dirt.

At each nest site we measured the slope, nearest neighbor distance, distance from the edge, the height and percent cover of each species of vegetation at laying and at hatching, and the soil depth. We considered the depth of the soil to include the mouth of the burrow itself and the slope to be the original slope before the burrow was excavated.

### Results:

The vegetative cover was considerably less on the densest puffin plot, but this is probably a result of the density, not the cause of it. Nettleship (1972) found the angle of the slope to be positively correlated with both the burrow density and higher productivity of Common Puffins in Newfoundland, and Amaral (1977) found the density of Tufted Puffin burrows to increase with the slope in the Barren Islands. A similar correlation was apparent with the Tufted Puffins at Sitkalidak. In addition to slope, soil depth was important, and it was often inversely correlated with the angle of the slope. We calculated a measure of what we call "effective depth", the horizontal distance available to the puffins for their burrows. This gave us the limit to the maximum burrow length. We used the following formula:

$$\text{Effective depth} = \frac{\text{soil depth (cm)}}{\tan \text{ slope (deg.)}}$$

We then grouped the effective depths observed into classes. The numbers of burrows in the different classes of effective depths (Table 8) varies considerably between the sample plots and it is interesting to note that the two plots that had the greatest number of burrows with effective depths greater than 150 cm (Cathedral Island plot 7 and Ameer Rock plot) also had the highest productivity and the earliest hatching dates. It would seem then that the birds are selecting these sites first, possibly using the criteria of effective depth for this selection.

## Reproductive Success

### Methods:

We monitored 67 burrows on our disturbed transects every four days. We determined laying, hatching, and fledging dates as best possible. We also determined cause and time of chick and egg mortality. In addition, we monitored the growth rate of chicks.

### Results and Discussion: Productivity and Mortality

The mean number of young fledged per nest with eggs for all plots was 0.537 (SD 0.171, range 0.286 - 0.750) (Tables 5, 6).

We also excavated 54 burrows in an undisturbed area on Cathedral Island which we did not go near till mid-August, and these had 0.742 fledglings per all nests (including those that never had eggs). Any differences in the productivity of these two areas might be because of our own disturbance with a subsequent nest abandonment. To test this, we analyzed the fledging success on a heavily disturbed plot versus the undisturbed plots and did not include the abandoned burrows from the disturbed plot in this analysis. The productivity of the heavily disturbed plot then becomes 0.786 fledglings per burrow, which is in close agreement with the undisturbed plots (Table 5).

Mortality at the egg stage accounted for 80.6% of the total mortality. Certainly some of this is directly related to our disturbance. Not including the abandoned eggs in this assessment, 76% of the total mortality occurred before the chicks hatched (Table 7).

The greatest mortality factor for eggs was their disappearing or rolling from the burrows. However, this mortality was not correlated with the effective depth of the burrow (Table 9).

We do not know why so many eggs were disappearing or rolling out from the burrows. There were a few cases where they had obviously been accidentally rolled out by a panicking bird, but more often an egg would be gone from or found below a burrow from which it would be difficult to roll out on its own. At times obvious recent digging did coincide with an egg's disappearance so perhaps adult puffins contributed to eggs rolling out. Of the 13 eggs that disappeared or rolled out, four (30.8%) of these did so after 15 July. Beginning with the first part of July some non-breeders were arriving in the area and there were signs of activity at burrows formerly vacant. It is plausible that these birds were at times entering burrows not well-defended, claiming them for their own, and digging out the egg during their renovation activities. A similar situation was recorded for two species of tropic birds by Stonehouse (1962), but the intruders here were adults with full reproductive capabilities, and not immature birds. Certainly before we can make any statements on this matter we need many more behavioral observations on the colonies themselves, especially during the period of influx by non-breeders.

Fifty percent of the chick mortality could be attributed to starvation. Starvation was closely linked with hatching time, for of the three chicks that starved, two hatched after the first week of August, which is well after the modal hatching period.

The highest productivity was in plot 7 of the Cathedral Island colony. Of the plots on Cathedral Island, this plot also had the greatest density and the earliest hatching. This plot may be preferred for some reason by the puffins because it is the first selected (based on the earlier hatching) and the most heavily used.

### Feeding Ecology

#### Methods:

We collected 44 Tufted Puffins between 8 June and 4 September, 1977 (Figure 28). Immediately following collection, we poured 100% formalin down the esophagus of the birds. Within an hour of collection we removed the upper digestive tract of the birds and placed them in labeled plastic bags with a 10% formalin solution. We identified the food contents in the laboratory after we returned from the field camp in September.

Obtaining samples of chick food proved a problem. Other workers (Wehle, 1976, Amaral, 1977) have collected bill loads from incoming adults by capturing them in mist nets. While this method has the advantage of obtaining data on the specific delivery times and the amount and species in each delivery, it does not provide information on the total amount of food brought daily to a particular chick and it often causes nest abandonment. Mainly because of this latter problem, we chose not to use this method in the Sitkalidak study.

To procure data on the amount of food brought daily to burrows containing chicks of known age, we taped the chick's bill shut with masking and filament tape (Figure 19) so they could not eat any food brought in by the adults. The chicks were still able to move around freely.

Because the feeding activity was heaviest in the morning and evening, we found the best procedure was to tape the chicks at noon on one day and return the following noon to collect what food was left in the burrow during the interval. At this time, we untaped the chicks and fed them canned tuna to compensate for the fish we took. Because a considerable variation in individual feeding rates was evident, in some cases we re-taped the chicks for an additional 24 hours to see if the feeding patterns were consistent from day to day. In all, 30 chicks were taped for 24 hours and 12 were taped for 48 hours.

## Results and Discussion:

Capelin (Mallotus villosus) was by far the most important prey species for the Tufted Puffins at Sitkalidak Strait during the 1977 breeding season (Tables 10-12). It occurred in 77.8% of the samples, provided 79.5% of the total numbers of food items taken, accounted for 58.5% of the total weight of food brought back for the chicks and made up 97.9% of the stomach content weight of the adults. Sand Lance (Ammodytes hexapterus) was second in importance, accounting for 12.6% of the total numbers of food items taken. It was of more importance as chick food and made up 23.0% of the total weight of their diet, while it only accounted for 2.1% of the total weight consumed by the adults.

The diets of the adults and the chicks were similar although some prey species, such as Pacific Sandfish (Tricodon tricodon) and Sockeye Salmon smolt (Oncorhynchus nerka), were found only in the diet of the chicks, while others, such as polychaetes and shrimp, were eaten only by the adults. The size of the prey items probably is important in this difference. The Pacific Sandfish and the Sockeye Salmon smolt were slightly larger than the other fish species taken and therefore more economical as chick food rather than as adult food.

The lengths of the Capelin taken by the puffins increased with the season (Figure 29). In June 84% of the Capelin in the stomachs were between 60-80mm long but in August only 22% were of this length. The chicks were eating Capelin predominately in the 80-100mm size class in August, and 55% of the Sand Lance brought in for the chicks at this time had a range of 90-100mm.

Based on percent frequency of occurrence, the availability of Capelin to the Tufted Puffins changed little as the season progressed although it appeared to decline slightly beginning in mid-August (Table 12). In August, other fish were taken by the adults, but only occasionally, and earlier in the season only invertebrates were taken along with Capelin. The data on chick food only adequately cover the latter part of August and early part of September, but they show that Capelin were consistently fed to the chicks throughout that period but became less important in terms of food mass provided as the other species, such as Pacific Sandfish and Walleye Pollock, became more important as the summer progressed (Figures 30 and 31). The loads that were exclusively Capelin became fewer while those exclusively Sand Lance increased, suggesting a possible increase in the availability of the latter species (Table 14).



### Chick Feeding:

There was much variability in the frequency with which the adults brought in food for their chicks (Tables 15, 16, and 17). For the 30 chicks that did not lose their tape during the day, the weight of food brought in by the adults ranged from 0-113.5g. An average of 21.4% of the chicks were not fed in a 24-hour period. The mean daily load per chick was 28.0g (SD 31.7). For the 12 chicks that were monitored for two consecutive days, the total weight of food brought in by the adults for both days ranged from 0-180.5g. In this 48-hour period, only 8.3% of the chicks were not fed. The mean load for two consecutive days was 62.2g per chick per 48 hours (SD 55.6). The mean weight of food per feeding was 19.3g (n=10; SD=6.3) and the loads ranged from 13.5-35.0g. From this we estimated that each adult makes an average of 0.65 feeding trips per day, based on the entire population of chicks from 19-40 days of age. Age of the chick dictated how much it received. Chicks 19-30 days old received a mean of 28.9g per day (SD 37.8; range 0-113.5g; n=15) while chicks 31-40 days old received a daily mean of 15.9g (SD=12.1; range 0-39.5g; n=13). This difference is significant ( $P=.048$ ). We do not know if the puffins reduce the number of feeding trips as the chicks approach fledging or if the amount of food brought in each trip becomes less, because we did not monitor the nests that well.

We monitored the daily weight change of two puffin chicks of about the same age for eight consecutive days. One chick went through three days during which it received no food, followed by a day in which it gained 91 grams (23.6% of its body weight Table 18). The other chick was not fed for two days during the eight-day period, but these two days were not consecutive. Wehle (pers. comm.) found that a captive Tufted Puffin chick would alternately gorge itself one day and refuse fish the next, suggesting that the chicks are adapted to irregular feeding patterns.

The food supply for the Tufted Puffins in Sitkalidak Strait seemed to be consistent in 1977 because almost all of the 41 chicks monitored had steady growth rates (Figures 21-27). However, 50% of the chicks that hatched after 25 July (n=6) died of starvation, suggesting a possible decline in food resources at the end of the breeding season.

The ability of the puffins to obtain enough food for their chicks did not seem to be affected by storms. The last part of July and much of August was plagued by severe storms, but when these storms are compared with the growth curves of puffin chicks (Figure 32) there seems to be no correlation. Perhaps this is because the chicks are adapted to sporadic feedings.

During the last third of August, most of the feeding of the puffin chicks took place in the early morning, with a second surge of feeding activity beginning in the evening and continuing until dark. On 22-23 August, 66.7% of the food samples were left in the burrows between 0700-1300 (Table 15). On 23 August counts were made throughout the day of Tufted Puffins returning to the colony with bill loads, and the results show a peak of activity between 0700-0800, with a lesser peak beginning at 1800 (Table 19). Very few birds were seen bringing food to the colony between 0900-1800.

## BLACK-LEGGED KITTIWAKE

### Distribution and Abundance

Methods: We censused the Black-legged Kittiwake population at Sitkalidak Strait on 3 July by counting all nests on the Cathedral and Nut Island and Amee Rock colonies. We defined "nest" as a structure with sufficient nesting material to retain eggs. None of the chicks had hatched at this time, and in our sample plots, all clutches had been completed. We took Polaroid photographs of the entire shoreline of Cathedral Island and outlined each sub-section of the island directly onto the photographs. The other large colony was at Ghost Rocks (Figure 33) which we did not census until 15 August, so the nest count from this census may be lower than the actual number of nests originally built. We made sketch maps of the Ghost Rocks colony, indicating the location of the nests on each. All photographs, maps, and data sheets are filed with the OBS Colony Catalog and are not included in this report.

At-Sea distribution. The movements of the Black-legged Kittiwakes in and out of Sitkalidak Strait are discussed in the section on Tufted Puffins and the data indicate that the birds are concentrating their feeding efforts within Sitkalidak Strait (Figures 34-37).

Results: There were 2380 pairs of Black-legged Kittiwakes breeding in inner Sitkalidak Strait in 1977. Most of this population (86.4%) was on Cathedral Island with three much smaller colonies on Nut Island and Amee and Ghost Rocks (Figure 33). Of the birds nesting on Cathedral Island, 63% (or 54.7% of the total inner Sitkalidak population) were concentrated on three rocks just off the island's eastern tip, while 19% were on two islets off its western end. Only 18% of the Cathedral Island population was on the main island.

### Phenology

Results and discussion: The Black-legged Kittiwakes began moving into the bays and fjords in late May so that by late June their numbers there were at a peak. Birds were on the colonies when we arrived on 28 May and by 3 June nest construction was well underway. By 13 June the first egg was laid, and the peak of egg-laying occurred between 15-19 June during which time 55.3% of the nests in the sample plots on Cathedral Island contained eggs (Figure 39). The last clutch was initiated on 1 July. Second clutches were undertaken by approximately 10% of the birds and these were laid between 3-9 July.

The breeding chronology varied between sample plots. The plot on Lesser Kittiwake Rock, a rock just offshore from Cathedral Island had nests with eggs before any of the other plots did. By 14 June, 33.3% of the birds had begun to lay in this plot and by 19 June, 83% of their clutches had been started. On the other plots, none of the birds had begun clutches by 14 June and by 19 June only 54.8% had started laying (range 47.4%-63.6%).

The first chick in the Sitkalidak Strait area hatched on 9 July and the last chick, a relay, hatched on 9 August (Figure 40). The first chick fledged on 13 August and most of the chicks had fledged when we last visited the colony on 9 September. Although most of the chicks had fledged in early September, some adults were still at the nest sites and were participating in behavior such as billing that looked like pre-laying behavior.

Black-legged Kittiwake adults remained in high densities in the Sitkalidak Strait region throughout the breeding season, but by the end of October they had almost completely vacated these areas (Table 20, Figure 38). Fledglings began rafting up in single age-class groups by late August, and tended to remain in these groups. A few kittiwakes of all age classes probably remain in the Kodiak area throughout the winter.

Coulson and White (1959) found that age and experience of the adults only partially accounted for the time of breeding of Black-legged Kittiwakes in Great Britain. More important, they felt, was the density within a 5-foot radius of the nest, and those birds with the highest density of neighbors laid their eggs earlier. This density was usually determined by rock structure and the dates of breeding correlated with ranges in nesting densities rather than ranges in age of the breeding adults. Although we had no way of determining the ages of the breeding birds in this study, the birds in the plots with the higher mean nesting density (plots LKWR 1 and CI 2, Table 21) had earlier mean clutch initiation dates than those with lower mean nesting densities.

On 22 June we visited the Boulder Bay kittiwake colony, a large colony of ca. 50,000 pairs nesting densely on the cliff faces. Although the visit was hurried, we made quick egg counts in various sections of the colony and found 49 (43.4%) of the nests empty, 39 (34.5%) with one egg, and 25 (22.1%) with two eggs. Several pairs of birds were copulating and many were carrying nest material. One adult and two immature Bald Eagles were seen at the colony when we arrived, and there was some sign of predation on the eggs. More work must be done with this colony in future field seasons to compare the productivity and phenology of large colonies with smaller ones such as those of Sitkalidak Strait.

## Habitat Selection

Methods: We set up four plots on the Cathedral Island colony. Three of these were in small sub-colonies on the main island and one was in a large sub-colony on an offshore rock (Figure 41). Two of the plots on the main island (1 and 2) included every nest in the sub-colony. In the third plot the nests were more-scattered and we used a sharp bend in the cliff as the plot boundary, although nests continued beyond it. To define the offshore rock plot we also used natural topographic barriers. During the breeding season with the aid of a rope and an upper belay we were able to reach every nest in the plots on the main island. This was not possible with the offshore rock plot without excessive disturbance to the nests, so here we made a detailed map showing the location of each nest and obtained chronology and productivity data by viewing the nests from above. However after the chicks had fledged we reached all these nests using an upper belay in order to determine habitat selection. We obtained growth measurements on a few chicks that we could reach near the top of the colony. To determine habitat selection we measured the height above water, distance from the top of the cliff ("top" being defined as any slope less than 45°), horizontal distance to water, nearest neighbor distance, amount of overhang above the nest, the ledge width, and the size of any ledges adjacent to the nest. We then attempted to correlate these independent variables with the hatching and fledging success of each nest by using a multiple regression analysis.

Results: We did not analyze differences in habitat selection between plots. These will be included in the 1978 report. However, we did determine correlations between habitat and reproductive success, and these will be discussed in that section.

### Reproductive Success

#### Methods:

We checked all kittiwake plots every four days (136 nests) noting dates of laying, hatching, and fledging, as well as hatching and fledging success. In addition, we monitored growth of the chicks on all of the main Cathedral Island plots and on reachable nests on the Lesser Kittiwake Rock plot. We also noted causes and dates of mortality of chicks and eggs.

#### Results and Discussion:

The mean clutch size for Black-legged Kittiwakes was 1.66 (Table 28). Two of the plots (CI 1 and 3) suffered heavy predation. The mean clutch size without these plots was 1.79, which is close to that recorded by other workers, e.g. 1.85 (Maunder and Threlfall, 1972), 1.84 (Swartz, 1966), 2.05 (Coulson and White, 1958), 1.96 (Belopol'skii, 1961), 1.94

(Cullen, 1957). In these plots (CI 2 and LKWR 1), the frequency distribution was 20% with one egg, 79% with two, and 1% with three, which is similar to that found by other workers, e.g. 16% (1), 82% (2), and 2% (3) in Newfoundland (Maunder and Threlfall, 1972).

Of the 114 nests with eggs in all the sample plots, 36 (31.6%) hatched one chick, 48 (42.1%) hatched two chicks, and 30 (26.3%) hatched none. Of the nests with chicks, 51 (60.7%) fledged one, 26 (31.0%) fledged two, and 7 (8.3%) fledged none. The mean number of young fledged per nest with eggs was .849.

Of the 191 eggs laid, 59 (30.9%) failed to hatch. Nearly half of this loss was due to predation, presumably by Bald Eagles. The remaining eggs lost were equally accounted for by exposure to storms, disappearing or being infertile (Table 29).

Thirty-one (23.5%) of the chicks failed to fledge. The greatest cause of chick mortality was exposure to storms, which accounted for 48.4% of the chick mortality. The second greatest cause was their disappearing which accounted for 32.2% of the chick mortality. Most of this mortality occurred in nests with two chicks. This may be due to the difficulty that brooding adults may have in protecting more than a single chick from severe storms and the possibility of chicks' falling out of overcrowded nests.

Bald Eagles were often seen at the Cathedral Island colony during June either flying over the colony or roosting on offshore rocks near the island's eastern end. They are probably responsible for the heavy predation which occurred between 18-25 June on plots 1 and 3 of the main island. On 25 June all but one of the eight nests with eggs in plot 3 were empty and all of the 6 nests with eggs by 19 June were empty in plot 1. This predation continued until 25 June, after which time eagles were not seen in the vicinity of Cathedral Island. It is likely that their feeding efforts were then directed to the salmon that were beginning to spawn. Of the 13 nests that lost their full clutches to predation, 9 relaid, and of these, 7 (77.8%) fledged chicks. The other two plots (Cathedral Island 2 and Lesser Kittiwake Rock 1) were little affected by such predation. What predation did occur on the Lesser Kittiwake Rock plot was that by Glaucous-winged Gulls which were nesting in very close proximity to these kittiwakes.

While the egg mortality was highest in plots 1 and 3 on Cathedral Island, the chick mortality was greater in plot 2 on Cathedral Island and the Lesser Kittiwake Rock plot. Both of these plots had their chicks hatching earlier than the other two plots (Figure 40) and by 25 July almost all of the chicks in these plots had hatched while only

33.3% of the chicks in plot 1 and 50.0% of the chicks in plot 3 had hatched by that date. Beginning on 21 July the weather began to deteriorate, and on 27 July 6.85 inches of rain fell in 24 hours. Much of the kittiwake chick mortality was caused by this storm. Lesser Kittiwake Rock was particularly vulnerable because these nests were on an exposed east-facing cliff with little protection from the prevailing winds. Also, the chicks in this plot were older than those in the other plots at this time and less able to get full protection from the adult, especially in 2-chick nests. Gordon (1928) found two weeks of continuous bad weather when the chicks were young to completely eliminate chicks in a kittiwake colony in Scotland. But most other workers have found that during seasons of less severe weather, deaths by falling are the main cause of chick mortality (Coulson and White, 1958, Maunder and Threlfall, 1972, Swartz, 1966).

The results of the multiple regression analysis (Tables 22-26) are reviewed by each plot as follows:

Cathedral Is. 01: The densest part of this plot was in the area with the least slope. This was midway between the top of the cliff and the water. Eggs were laid earlier in the steeper part of the plot near the top, yet these nests hatched fewer chicks. Avian predation accounts for the lower hatching success of these nests with earlier laying dates.

Cathedral Is. 02: The densest part of this plot was near the bottom, and was not correlated with slope. Birds on nests with less slope laid earlier, hatched more young, and had larger clutches. This plot did not suffer from avian predation.

Cathedral Is. 03: The densest part of this plot was in the area with the greatest slope. The eggs here were laid earlier, and the clutch size was larger. In spite of heavy predation, the adults in these nests also hatched more chicks and fledged more young. Predation was heaviest on the scattered nests on wide ledges.

Lesser Kittiwake Rock 01: Nests in this plot were denser nearer the top than the bottom. Birds on nests with greater slope laid more eggs, hatched more chicks, and fledged more young. However, eggs were not laid earlier in nests with greater slope.

The multiple regression analysis (Table 22) does not show any strong correlation between the week laid and any of the independent habitat variables measured. Cathedral Island plots 1 and 3 suffered heavy predation and had many re-lays which greatly complicates the interpretation

of the results. For this reason, these two plots are not considered in this analysis. Ledge width is inversely correlated with the week of egg-laying in both CI plot 2 and LKWR plot 1, but this is likely a result of its positive correlation with nearest neighbor distance (Table 22). The number of eggs per clutch increased slightly in those nests whose clutches were initiated later in one plot (LKWR1) (Table 24).

No single component of the nesting environment was correlated with productivity in all of the plots. The slope was positively correlated with productivity in both the Lesser Kittiwake Rock plot and Cathedral Island plot 3, but it was negatively correlated with productivity in Cathedral Island plots 1 and 2.

Productivity is apparently influenced by the interactions of the entire matrix of environmental parameters at each nest site, and the range of these interactions is determined by the variance of each parameter within a given plot.

### Feeding Ecology

#### Methods:

Food samples. We collected 33 Black-legged Kittiwakes between 8 June and 4 September, 1977. We removed their upper digestive tracts and subsequently placed them in a labeled plastic bag with 10% formalin. We obtained regurgitations easily from the chicks at all stages of their development and we collected, weighed, and fixed these in 10% formalin for later identification in the laboratory. Usually we collected regurgitations during our routine monitoring of the sample plots, but occasionally we made specific trips for such collections. Chicks from which we obtained regurgitations were fed tuna in compensation. We collected 150 regurgitations between 10 July and 9 September.

Foodwatches. On 11 August from a rock 50m from the colony we watched the activities of six marked kittiwake nests on Lesser Kittiwake Rock from 0600-1500. We recorded the time of the arrivals and departures of each adult and the times chicks were fed in order to determine nest attentiveness and feeding rates. At 3-hour intervals we weighed the chicks and collected regurgitations to correlate weight change with observed feedings. This procedure had to be suspended after 1500 because of bad weather.

On 22 and 23 August between 0630-2100 we watched the activities of seven kittiwake nests on a rock off Cathedral Island from a vantage point 40 m away. We recorded the same information as on 11 August, but the chicks were only weighed three times during each day.



Results: Capelin (Mallotus villosus) was the most important component of the kittiwakes diet at Sitkalidak Strait during the 1977 breeding season (Tables 30, 31 and 32). It occurred in 60.0% of the food samples provided 43.7% of the total numbers of food items taken and 55.2% of the weight taken by adults. Sand Lance (Ammodytes hexapterus) approached Capelin in importance, occurring in 43.1% of the samples and accounting for 37.9% of the total numbers taken. It played a much more significant role as chick food than it did as adult food for it only made up 3.7% of the total numbers taken by the adults yet accounted for 43.6% of the numbers of prey items eaten by the chicks. Part of this difference between chick and adult food may be because the adult sample covers 1 June-11 September while the chick sample only covers 10 July - 8 September and this may be biased towards a period when Ammodytes was most abundant.

There seemed to be a change in the ratio of Sand-Lance to Capelin in the kittiwake diet as the summer progressed (Figure 42). The frequency with which Capelin appeared in the regurgitations steadily decreased in August while that of Sand Lance increased. Not only did the consumption of Sand Lance increase during August but other food items, such as Walleye Pollock and the eggs and milt of Sockeye Salmon (which were scavenged at the spawning streams) also began to increase in frequency in the diet of the kittiwakes at this time. Further, the frequency of mixed-prey species regurgitations steadily increased in August (Table 13) suggesting that food may have begun to be more difficult to obtain with the decrease in Mallotus villosus. Such a change in the types of prey items may reflect an alteration in the availability of certain prey species.

A very similar feeding situation apparently occurred in Newfoundland where Maunder and Threlfall (1972) found Capelin also to be the most important food source for kittiwakes with Sand Lance and offal from a fish-meal plant taking on greater importance toward the end of the breeding season.

The marked surge of Pandalopsis dispar at Sitkalidak in September coincided with shrimp fishery activity in the waters within 1-10 km of the colony, and the birds would obtain this prey by following the fishing boats.

The lengths of the Capelin taken generally increased as the season progressed (Figure 43). In June, 58% of the Capelin were between 70-90 mm long, but by August only 21% were of this length. The lengths of the Sand Lance taken approximated those of the Capelin.

Chick feeding. The following observations support the hypothesis that the food supply was not limiting the productivity of the Black-legged Kittiwakes nesting in the Sitkalidak Strait area during 1977: First, there were no observations of a chick's starving to death because of

the inability of the parents to secure enough food. There were two cases where one of the chicks of a two-chick brood starved to death but both of these were out of the nest itself and unable to reach the adults bringing in food to the nest. Second, food was sufficiently abundant to support a breeding population not in tight synchrony because there was little difference in the growth rates of chicks hatching over a 32-day period ( 7 July - 9 August) (Figure 44). And finally, chicks reared with another chick did not have growth rates below those reared singly (Figures 45 and 46).

Based on the results from the three all-day watches of selected kittiwake nests (Tables 33 and 34), the adults brought food to single-chick nests an average of 2.3 times a day (SD 1.1, range 1-4), while they brought food to nests with two chicks an average of 3.8 times daily (SD .46, range 3-4). This difference is statistically significant ( $P < .05$ ). One of the chicks (chick #21 of the 11 August watch) was considerably younger than all the other chicks, and so was not considered in the analysis because of the possibility of its age influencing the number of times it was fed.

The amount of food brought to each chick was estimated by the weight gain of a chick during a three-hour interval in which it was observed. Chicks from single-brood nests received a mean of 11.3 g (SD 6.1), while each individual in nests with two chicks received a mean of 15.0 g (SD 7.3). This difference is not significant ( $P > .05$ ).

These results demonstrate that the adults do not respond to an increased brood size by bringing in more food each time but rather by making more frequent trips. We found that the adults usually respond to the chick that is more aggressive in its pecking, and that such behavior probably is caused by greater hunger. The feeding pattern for all three of the broods in the two-chick nests observed on 22-23 August was for one chick to receive more food the first day while the other chick received more the following day.

In addition to a variation in feeding patterns caused by the number of chicks in the nest and possibly by their age, it appears that there is individual variation in the ability of a breeding pair to supply the young with food as well. On 11 August one chick (#19) was fed only once and suffered a loss of 9 g between 0600-1500 while all the other chicks gained weight during the same period. Examining the growth rates of these chicks (Figures 45 and 46) shows that this pattern probably occurred consistently throughout the nestling period of this chick. This situation may be a reflection of an adult's inexperience (Coulson and White, 1958).

## GLAUCOUS-WINGED GULLS

### Introduction

Glaucous-winged Gulls are probably the most ubiquitous species in Sitkalidak Strait but they are nowhere abundant. In some places they were truly colonial and in others they were solitary nesters.

Glaucous-winged Gulls are considered a trash bird by the local people and they are often shot for crab bait or for target practice and their nests are often egged. Despite this disturbance, the gull population seems to have a healthy replacement rate when 1976 and 1977 figures are compared (Table 47). In some areas with islands more accessible to humans, nests are egged numerous times, so that all relayings are unsuccessful. In general, a greater number of gulls attempt to nest than actually are successful so that the nesting density decreases markedly as the season progresses. Likewise, there is an ever-increasing population of non-breeding gulls. This population reaches a peak in mid August when the adult non-breeders are joined by the first, second, and third year immatures which have been residing outside the Inner Sitkalidak Strait area during the earlier summer months.

The main obstacle in studying Glaucous-winged Gulls was human interference. The eggs of the gulls were gathered by natives from early June through July. The islands nearest the native village of Old Harbor were egged the most intensely even though the gull populations there were not as large as on the far islands. The islands were also used intensively for recreation. All easily accessible areas in the Sitkalidak Strait area were visited at least once by eggers.

### Methods

One of our goals in this study was to compare nesting success of truly colonial type Glaucous-winged Gulls and the more solitary or scattered nesters to see if human disturbance influenced them. Likewise we wanted to see if there were any differences in habitat selection between these populations. We also wanted to discover the prey lengths and types taken by the gulls in order to try to determine the gull's position in the food web.

The truly colonial areas of the Glaucous-winged Gulls at Sitkalidak Strait were all inaccessible to humans; one was on a sea stack (Ameo Rock) which we could only reach by climbing ropes; the other was on a

precipitous wave-beaten sea rock (Lesser Kittiwake Rock) (Figure 49).

The solitary nesting areas were all on easily accessible islands: Cathedral, Amee, and Sheep. The latter two islands were 5 and 2 1/2 km from the native village of Old Harbor while Cathedral was 8 1/2 km from it. We chose two plots of 22 nests each on the two colonial areas, which composed the entire two colonies from cliff edge to cliff edge, and we established seven transects on Cathedral Island for the solitary nesting areas (N=45 nests). We followed the fate of fourteen nests on the two islands nearest the village, but since the gull nests on these islands were heavily egged, the breeding and productivity data were rather inconclusive.

Since egging was such a large cause of egg mortality in Glaucous-winged Gulls, we decided to set up accessible and less accessible transects among the solitary nesters to see if accessibility influenced this type of nester also. We chose three pairs of transects that had one horizontal and one vertical transect within each pair. We also chose one very steep vertical transect for comparison. Our reasoning was that the horizontal transects had easier access and would have a greater chance of being egged, while the vertical transects were on steep slopes reaching to the cliff edge and were not conducive to egging searches by natives.

Each of the solitary transects started at the cliff edge and continued inland steeply away from the cliff. The horizontal plots formed a "T" with the vertical plots.

#### Habitat Parameters

When the nests were first constructed, we measured the distance along the transect and the distance from the midline of the transect for each nest in our study areas. At time of laying we measured the height and cover of the various species of plants within a 50 cm radius around the nest, we measured the slope of the nest, the distance to the nearest neighbor, and distance to the edge of the cliff. For nests without eggs, we measured these parameters at peak laying of the birds on the plot. At first hatching, we again measured the height and cover of the vegetation within a 50 cm radius of each nest. We visited each plot on the average of once every four days. We later will attempt to correlate habitat parameters and nesting success.

#### Chronology and Reproductive Success

We kept a log of the choronology for each nest, noting when it was first constructed, when the eggs were laid, when the chicks were hatched and if possible, when the chicks fledged. We also noted when chicks

or eggs disappeared or died and the causes of this mortality. We noted number of nests started, number of eggs laid, number of chicks hatched and fledged. During the chick stage we measured the culmens, tarsi, wings and weight of the chicks at each visit to determine growth rates.

### Feeding Ecology

We collected regurgitations opportunistically from the chicks on our transects. The chicks would often regurgitate whenever we picked them up, so the prey items were easily obtained in this way. We placed the regurgitations in a labeled plastic bag and added 10% formalin within four hours after the collection. We performed all the above measurements and collections for all nests, eggs and chicks on the transects and also on the plotless nests on Amee and Sheep Islands.

### Phenology

We did not arrive in time to observe the setting up of the Glaucous-winged Gull nesting areas so we do not know the preferred nesting sites. However, we did arrive before most of the gulls had begun to lay. The earliest clutches were laid at the colonial sites, and extrapolating back from hatching dates, we found that the first eggs laid there were on 15 May. On 30 May we found the first scrapes of Glaucous-winged Gulls along the crests of the hills on Cathedral Island and especially on the steep mixed-meadow slopes. Outside our transects we found a nest with one egg on this date. A few immature (first through third year) gulls were present at this time.

On 3 June, in the Cathedral Island colonies, copulation was still occurring and the gulls were becoming much more nest-site tenacious. The adult gulls nesting on the accessible islands, Amee, Cathedral, and Sheep, were not as nest-site tenacious as were the ones nesting on the sea stacks and sea rocks. The approach-flight distance for those on the main islands was 50 meters while the distance for the gulls on the sea stacks was 10 meters. Perhaps gulls that are not so site-tenacious are in less preferred nesting habitat. If this is true, it may correlate with better nesters choosing preferred sites with inferior (less nest-site tenacious) nesters choosing marginal habitat.

On 6 June on our transects we found the first nests with eggs on the near-town islands: Amee and Sheep ( $\bar{x}$  = 2.5 and  $\bar{x}$  = 1.0 eggs/nest respectively). By 9 June, both the nests on Amee had been egged but the one on Sheep was still undisturbed. We met or saw natives on the

islands at almost every visit through the month of June. They collected both Mew and Glaucous-winged Gull and also tern eggs.

The eggs of the solitary nesters both on the horizontal and vertical plots were first laid on 12 June. Eggs that were laid earliest on the horizontal plots were taken by natives so that if a clutch were started later in the season it had a greater chance of surviving. The steep vertical plots remained untouched by the eggers. The sea rocks and stacks also remained untouched by the eggers.

By the tenth to twelfth of June, egg laying by the gulls was well underway on all islands. On Cathedral, there was still a lot of eggging by natives, and this activity was most evident in the comparative horizontal plots.

Because of storms, we could not climb Amee Rock for a week and a half, and when we finally did have access to it on 28 June, we found that chicks had hatched in the ten days we had been absent, and that three of these chicks were older than a week and weighed over 300 grams, which means they hatched about 17 June (Figure 51). The nests at Cathedral Island followed those on Amee Rock, and we saw the first starring of eggs on 2 July. On 9 July, chicks were hatching on the vertical plots. Due to eggging, only the eggs on the vertical solitary plots hatched early in July (9th). The first eggs to hatch on the horizontal plots did so on 21 July, two weeks after those on the vertical plots. The majority of chicks on the vertical plots had hatched by 18 July and on the horizontal plots by 25 July. On the other three islands, Cub, Amee, and Sheep, no chicks had yet hatched. By the third week in June, the only nest remaining active in our study plot on Sheep Island was one hidden under a 70 cm Heracleum plant. All the others--Mew and Glaucous-winged--had been egged (Table 35).

Mid-July was a peak for hatching of chicks for all colonies (Figures 50-53-58). On 14 July we found two large chicks (830g and 610 g: 19-22 days old) on Cormorant Head (Figure 49), a colony that we did not study but which was also rather inaccessible, and was advanced chronologically. These weights compare with a 93 gram average on Cathedral Island, a 210 gram average on Lesser Kittiwake Rock, and an extrapolated 460 gram average on Amee Rock on this date.

On 20 July we saw the first fledglings, and by 5 August on Amee Rock we saw fledglings still being fed at the nesting area. At Lesser Kittiwake Rock on the same date, a near-fledging chick slid off the cliff into the water and an adult, presumably the parent, flew down

immediately and sat next to it in the water. The adults seem more attached to their chicks at fledging time than do birds of other species. However, once the chicks had been flying for a few days, the adults no longer fed them even though the chicks would food-beg and often would fly after the adults.

One of the disadvantages to the gull chicks of the nest sites on the sea stacks or cliff edges of the islands was the height of these stacks or cliffs. We found three chicks near fledging ( $\bar{x}$  wing=22.3 cm) that had died from falling. Likewise, some chicks fledged before they were strong fliers and were not able to get back up on the colony. We did not learn the fate of these chicks.

In the first week of September, the fledglings began to raft up in large numbers. We observed flocks of only fledglings flying in the straits and this grouping by age class was also true of Black-legged Kittiwakes. When we departed the Sitkalidak Strait area on 14 September, there were still many gulls, both adults and immatures of all age classes in the area.

### Nesting Habitat

#### Results

Solitary-type Colonies. The nesting sites the gulls chose varied widely within the nesting area of the more solitary nesting gulls. There was a significant difference in the habitat parameters between horizontal and vertical plots (Table 36). The horizontal plots had a greater vegetation volume around the nests than did the vertical plots (68 cm, 72% cover vs 26 cm 31% cover). The vegetation volume however was correlated with distance from the cliff edge and also with slope. The vegetation was lower and less dense near the seaward edges of the plots and these two parameters also varied inversely with slope--the greater the slope, the less vegetation. Vertical plots of course had significantly greater slope. The steepness ( $16^\circ$ ) and lack of vegetation on the vertical plots were comparable to that of the sites on Lesser Kittiwake Rock whereas the steepness ( $8^\circ$ ) and high dense vegetation of the horizontal plots were comparable to that of the sites on Amee Rock.

Colonial - type Colonies The greatest densities and least nearest neighbor distances of all the gull nesting areas were on Amee and Lesser Kittiwake Rocks, the two colonial areas. Yet, the only consistency in habitat between the truly colonial areas was their inaccessibility. Other than that, there was no similarity in habitat. There was a marked

difference in vegetation height and cover (vegetation volume) between them.

The one sea stack, Amee Rock, had a substrate and vegetation virtually identical to that of the "typical" gull colony--umbels and mixed meadow vegetation on not much of a slope. It had a lot of umbel type vegetation which was high ( $\bar{x}$  = 65 cm) and dense  $\bar{x}$  cover = 80%). The mean slope of the colony was low ( $4^\circ$ ). The sea rock, Lesser Kittiwake Rock, was as densely covered with gull nests as was Amee Rock, but the habitat was atypical of Glaucous-winged Gulls. In fact, it was almost Kittiwake-like in that the slope was steep and there was little vegetation. It had very little vegetation ( $\bar{x}$  height = 18.3 cm,  $\bar{x}$  cover = 20%) and the slope was steep ( $\bar{x}$  =  $17^\circ$ ). The mean nearest neighbor distance ( $\bar{x}$  = 250 cm) was not significantly different from that on Amee Rock ( $\bar{x}$  = 310 cm respectively) and the nest density was the same.

Near Islands The nesting habitat of the Glaucous-winged Gulls on the near islands (Amee and Sheep) was varied within each island but it also was very different from the habitat on any of the other more productive study sites. Both Sheep and Amee Islands tended to have more of a grassland cover with few woody plants or few umbels.

#### Discussion - Nesting

Glaucous-winged Gulls seem to be non-selective with respect to vegetation volume or species of vegetation in their choice of nest sites. In the non-colonial situation, slope of the nesting habitat is important in nest site selection with respect to productivity. The vertical steeper plots had more nests per hectare and the nearest neighbor distances were smaller perhaps indicating preference for the vertical habitat. However, in the two relatively inaccessible colonial-type areas, there was no difference in density or in nearest neighbor distance. This suggests that some other environmental factor, perhaps predator accessibility to the nests, is acting on the nest site preference of these gulls. There is more variation between the two dense colonial areas with respect to nest-site parameters than there is between the colonial and solitary nesting situations. It is imperative that we observe the setting up of these nesting sites, both colonial and solitary because then we can make sounder judgements about which factors in the habitat are most important for the gulls. Are the colonial sites preferred for their inaccessibility to predators (especially human) and thus become colonial sites with as many gulls packing into an area as possible, or do all areas start out at the same time with the same



density and packing and only later do the colonies fill up? Likewise, does egg-laying commence first on the colonial plots due to social facilitation or to some undetermined environmental factor? Answers to these questions in part will help explain the mechanism underlying the breeding biology of Glaucous-winged Gulls.

### Reproductive Success

#### Mortality-Results

The mortality in the three major groupings of nesting areas varied considerably. The colonial areas averaged 18.2% at Amee Rock and 23.8% at Lesser Kittiwake Rock (combined=20.9%). In the solitary areas, the vertical plots averaged 20% and the horizontal plots averaged 27.3% (combined=21.9%). Eggging was the major cause of mortality in the very accessible horizontal plots of the solitary-type nesters. Only the vertical plots had any avian predation. Likewise the chicks that died pipping were in the vertical plots (Table 37).

In the colonial areas there was a variety of mortality factors, but eggging was not one (Table 38). Mortality occurred more in the chick stage for the colonial nesters than for the solitary ones. This mortality at the chick stage, 30% of the mortality at Amee Rock and 20% at Lesser Kittiwake Rock was due to chicks' falling off the cliff edge. Steepness of slope at Lesser Kittiwake Rock also accounted for at least 20% of total mortality (29% of egg mortality) due to eggs' rolling out of the nest.

The islands nearest the town of Old Harbor, Sheep and Amee, were heavily egged so that only one Glaucous-winged Gull nest per plot (8000 m<sup>2</sup> on Sheep, 2000 m<sup>2</sup> on Amee) was successful on each island. Two natives related to us that the Mew Gull populations on Amee Island five years ago were in the hundreds, but in 1977 we found a population under fifty birds. The natives stated that this decline was because of eggging and that one year they had gleaned over 200 eggs from the Amee Island Mew Gull nests. This kind of decline shows how great an effect on gull populations that human disturbance can have.

#### Productivity-Results

The mean clutch size of Glaucous-winged Gulls on all colonies was approximately the same (Tables 39-40-42-43) ( $p > 0.05$ ). However, since there was differential mortality at various stages for the three main colony types, the hatching success varied among them. For solitary-type

nesters, hatching success was lowest on the horizontal plots (64%) and highest on the vertical plots (80%) ( $p < 0.001$ ). The colonial nesters had an intermediate hatching success (76%) which was not significantly different from that of the nesters on the vertical plots ( $p > 0.05$ ). The mean number of chicks hatching on the colonial plots and vertical plots was approximately the same ( $\bar{x} = 1.9$  and  $2.0$  chicks per nest respectively) while the mean number of chicks hatching per nest on the horizontal plots was significantly lower ( $\bar{x} = 1.4$ ,  $p < 0.01$ ).

Fledging rates were almost impossible to obtain for the solitary nesters because the chicks disappeared into the 60-80 cm high umbels after about two weeks of age. On the colonial areas, fledging rates were easier to obtain but they were also inaccurate. Many chicks ran from us and to keep them from jumping off the cliff edges, we would not pursue and recapture them. We assumed, as in the terns, that any chick that survived through the first two weeks after hatching would fledge. As for the terns, we determined a minimum and a maximum fledging rate. For the minimum rate we assumed that every chick we did not recapture died. For the maximum rate we assumed that every chick we did not recapture lived.

Because we had only a few recaptures on Cathedral Island, in the solitary nesting area (Table 43, 45), a discussion of the growth rates of these chicks are meaningless. In comparison, the chicks on the two sea rocks, Amee and Lesser Kittiwake Rocks in the colonial areas were more easily recaptured. The growth rates for the chicks in these two colonies were similar both by date (Table 44) and by age of chick (Table 43, (Figures 60, 61).

#### Mortality and Productivity--Discussion

The reproductive success of Glaucous-winged Gulls varied with type of colony and type of plot. Likewise, the stage at which this success was affected varied with colony and with plot.

The reproductive success in the horizontal plots was affected at the egg stage in June. Eggs disappeared mainly due to egging and this egging also occurred on the less dense, easily accessible colonies on island as close to the native village. We only compared statistically the transects on Cathedral Island and on the sea rocks. The horizontal plots which were very accessible to eggers had a higher egg mortality--due mainly to egging--than did the less accessible vertical plots and relatively inaccessible sea rocks. Once, however, the chicks made it through the egg stage, the reproductive success between accessible and

inaccessible colonies was not significantly different. The mortality in the colonial areas was due primarily to eggs' rolling out or chicks' falling over the cliff.

Thus, the Glaucous-winged Gull colonies with the highest reproductive success occurred in areas relatively inaccessible to humans. It seems as if human predation is one of the biggest mortality factors on gulls. Not only are their eggs taken by natives, but also the more accessible nests are constantly disturbed by eggers or picnickers. This disturbance can entail stepping on eggs or simply flushing the adult off the nest. The latter exposes the chick or egg to weather which is a mortality factor in both the chick and egg stages. Likewise, human disturbance may prevent an adult from bringing in food to the chick, and this may influence mortality and growth rates of the chicks. Thus, the nests that are least accessible to humans would have fewer mortality factors to contend with and thus have a greater reproductive success. On highly accessible areas we found that cover was an important factor in a clutch's not being egged. Nests that were hidden from view had a higher egg survival than did more exposed nests. On relatively inaccessible areas such as the sea stacks, cover made no difference in survival rate.

On the more accessible Cathedral Island, slope also was important in minimizing human predation. Eggs that were laid in steeper areas nearer the cliff edges had a higher survival rate at the egg stage than did those farther from the edge in flatter areas probably because native eggers did not cover that area. Thus these factors all are correlated with accessibility.

We do not know if being in a true colonial situation is more conducive to reproductive success than being in a solitary nesting situation. Environmental factors such as slope and vegetation obscure the picture at present because we do not know how the various nesting areas are first set up.

If being in an inaccessible area is the main factor for reproductive success among Glaucous-winged Gulls at Sitkalidak Strait, there are some important genetic questions we should start asking about the future direction these populations are going to take.

## Feeding Ecology

### Introduction

Since Glaucous-winged Gulls were such a dominant part of the feeding flocks at Sitkalidak Strait, their feeding ecology was important to study. However, with respect to other species in the area, their numbers were few. Thus we did not collect any adults for analysis of their stomach contents.

Glaucous-winged Gull chicks, like most Larid chicks, regurgitate when frightened, so we found it opportunistic to collect their regurgitations on each visit to the study sites and by doing this, develop some idea of how the Glaucous-winged Gulls fit into the ecosystem trophically. Opportunistically we also collected pellets or dropped food that was from adults only.

### Results and Discussion

We found that a greater variety of food was being taken by the adults than was being fed to the chicks and that this variety was greatest in early June and in late August through mid-September. During these months we found sea urchin, crab, mussel, chiton, and limpet remains, and in August and September we found these plus salmon, shrimp, and starfish remains. During the height of the chick stage in July, we did not find these food items at the nest sites. However, in order to determine if the adult diet indeed changes, we would have to collect adult gulls.

The switch to a more varied food supply by the adults may indicate a decrease in the numbers of the regular prey fish frequenting the Sitkalidak Strait area. This switch qualitatively was also true for Aleutian Terns and for Black-legged Kittiwakes. Since the salmon were running in the streams around Sitkalidak in late August and early September we occasionally found their remains near the gull nests or their eggs in the kittiwake regurgitations. The whole salmon were too large for the gull chicks to eat and we never observed the adults tearing off chunks of the larger fish and feeding them to the chicks. It is rather common for birds like Larids to be opportunistic when an abundant food source like salmon appears. However, this temporary source may not have been adequate. We have indirect evidence that food may have been limiting in late August because one chick that was laid very late (16 August) in the season (it was a relay), died from starvation during a time when there were no storms. Its fat content was "1" the lowest category for the amount of fat in a bird. This coincides in time with our finding a dead Aleutian Tern fledgling which was at 62% of Adult weight.

Chick food. Glaucous-winged Gulls fed their chicks fish, a majority of which was Mallotus villosus (Capelin), averaging 102.4 cm in length (Table 46). These fish are significantly larger than were the fish the terns of both species were feeding themselves or their chicks ( $p = 0.001$ ). Since we did not collect Glaucous-winged Gull adults, we have no comparison between adult and chick prey as we do with other species in this study.

## ARCTIC AND ALEUTIAN TERNS

### Introduction

Arctic and Aleutian Terns are recent additions to the fauna of Sitkalidak Strait, Kodiak Island, Alaska. Older Natives in the area relate that terns were not present in the early part of this century. Likewise, there is no native word for either of the two species. At Sitkalidak Strait there were two mixed species tern colonies and one monospecific Arctic Tern colony during the breeding season of 1977 (Figures 62 A & B, Table 67). It appears that there were fewer terns of both species in 1977, due mainly to a decrease in numbers on Amee Island. Cub Island had no terns on it in 1976 but was colonized by Arctics in 1977.

### Objectives

We wanted to study the comparative ecology of Arctic and Aleutian Terns and to determine the ways in which they fit into the ecosystem. We compared nestsite preference and nesting success on two mixed species colonies: Sheep and Amee Islands. We also compared the habitat on the monospecific Cub Island colony with that on the other islands to see if nestsite preferences differed in this situation, and if so, if this different habitat influenced nesting success.

We also compared feeding ecology of the two species to see if they were somehow segregating the prey resource. We also wanted to try to determine where the terns fit into the broad trophic ecosystem of the Sitkalidak Strait area.

### Methods

We set up random transects on each of the three islands. These transects varied in length, starting at the edge of the nesting area usually in the island's center and continuing to the water's edge. They were all five meters wide. We studied all nests of both species that fell within these transects.

### Nesting Habitat

In order to determine nesting habitat, we measured the following parameters at time of nest construction: vegetation height and cover within a 30 cm radius of each nest, slope, and nearest neighbor distance. We also obtained data via plotless points of the habitat available to

terns on the islands to determine if the terns were preferentially selecting a certain habitat type. These data have not yet been analyzed. We also wanted to see if type of habitat influenced reproductive success. At hatching we again measured the vegetation height and cover.

#### Chronology and Reproductive Success

Every four days we monitored each transect and noted date of nest construction, dates of egg laying, hatching and chick fledging. We noted times and causes of mortality as well as clutch size, and numbers of chicks hatched and fledged. We also measured weights, tarsi, culmens, and wings of the chicks each time as indices of growth of the chicks.

#### Feeding Ecology

We attempted to collect three adults of each species every five days. We also collected regurgitations as they occurred. Tern chicks regurgitate readily when handled. Regurgitations were placed in labeled plastic bags and 10% formalin was added within four hours of collection. We also made detailed observations on the feeding behavior of the two species both on and off the colony.

#### Phenology

Terns of both species were well into the courtship stage when we arrived 27 May. On this date we found no nests on any of the islands, and saw courtship feeding in many of the paired Arctics but in few of the Aleutians. There was also much intraspecific aggression at this stage. It is interesting to note that there was great diurnal variation in number of birds on the colony from late May through the first week in June.

On 30 May there were no nests completed of either species on all islands but by 2 June, on our transects on Sheep Island, we found five Aleutian nests with eggs ( $x=1.4$  eggs/nest) which means the first eggs in the transect were probably laid 31 May (Figures 63-67). By 6 June, the first Arctic nests on our plots had been constructed: twelve on Amee Island ( $x=1.7$  eggs/nest) and one on Sheep Island (2 eggs) and nine on Cub Island (0.66 eggs/nest). Earliest laying dates for Arctics were thus 31 May for Amee, 2 June for Sheep and 4 June for Cub. At this point, the Arctic adults were becoming very aggressive and nest-site tenacious. They often dive-bombed us. A few Aleutians attacked us also but not with the aggression of the Arctics. They

were also less nest-site tenacious.

By 9-10 June, nest building and laying by Arctic and Aleutian Terns were well underway on all islands. On 21 June the first Arctic and Aleutian chicks had hatched (thus incubation period = 21 days) and also on this date we found new nests with eggs for both species. This range of a month in laying dates was probably due to eggging by the natives, with the later clutches being relays. We found new Arctic nests being constructed through 30 June.

It is an interesting aside to note that on Amee and Cub Islands, the islands with the greatest slope, the eggs in nests of both species at the crests of the colonies were hatching first. This may indicate some preference in habitat.

The Arctic Tern chicks on Sheep Island were the first to fledge, and did so on 15 July. Because the tern chicks were difficult to locate after a week or so of age, we do not know exactly when the chicks on our transects fledged. Using 21 June, the first hatching date, gives an 18 day brooding period for the chicks, which probably is a little low.

If the Arctic Tern chicks remained in the water, they were usually dive-bombed by adult Arctics and occasionally by an Aleutian adult. Once they swam ashore or became airborne, they were no longer attacked. This attack behavior occurred at all three islands. Also at this time, the Arctic fledglings were feeding themselves.

Aleutian Terns first fledged on 16 July, giving them a similar (but probably an underestimated) brooding period. However, unlike Arctic fledglings, they remained on the colony, usually around the nest-site. Even though they were strong fliers, they were still fed by the adults at this time. They were never hassled by adults of either species as were the Arctic fledglings. The fledglings would often fly after an adult, food-begging, but would never fly more than 50 meters from the nest site.

By mid-August, most of the Arctic Terns had left the Sitkalidak Strait area. The small percentage of adults that remained at this time were carrying fish, indicating they still had chicks. By 16 August, all Arctics had left the area. All Aleutian Terns had departed Sitkalidak Strait by 30 August.

#### Nesting Habitat

#### Results

Both tern species seemed to choose different habitat sites for their nests (Table 68). On all colonies, Arctic Terns had a greater slope



of the nest site than did the Aleutian Terns ( $p < 0.05$ ). In fact, Aleutian nests were rarely found on slopes and usually they were on the flat crests of the islands. On the monospecific Arctic Tern colony, the slope was significantly greater than that on the Sheep Island Arctic Tern colony. Height and volume of vegetation did not vary significantly between species or among colonies.

On Amee Island the Arctic Tern nearest neighbor distance was significantly greater than that of the Aleutians, and on the monospecific Arctic colony on Cub Island, the nearest neighbor distance was significantly less than that on the mixed colonies. This greater tolerance in nearest neighbor distance for an aggressive species may indicate that Cub Island has some overriding beneficial factor so that Arctic Terns would choose this island on which to nest over other islands and thus pack together in greater numbers. However, as we show later on, this apparent preference is perhaps more a species-packing due to a limited habitat available for nesting, because the hatching success, numbers hatching, fledging success, and numbers fledging were lower on Cub Island than on any other island.

#### Discussion

It seems that Arctic Terns choose areas with greater slope in which to nest. At first, the possible reasons behind this choice are not apparent. A greater slope would make it easier for eggs to roll out of nests, which in fact we found was a high cause of egg mortality.

However, greater slope of an area gives an illusion of less crowding because when birds are on their nests, they are not eye to eye. In fact they would see each other less readily, and for an aggressive species like the Arctic Tern, this would mean less time spent in aggressive behavior and more time spent in attending the nest. The other way for the terns to avoid aggressive encounters would be to have greater nearest neighbor distances. As Table 68 shows, this is exactly what happened. On colonies with less slope (e.g. Sheep Island) the nearest neighbor distance for the Arctic Terns was greatest. On islands with more slope, the nearest neighbor distance decreased.

Aleutian Terns are not an aggressive species so that the nesting strategy of the Arctics would not be important for them. This is exactly what we found. On Amee Island the Aleutians had a small nearest neighbor distance but chose nest sites with greater slope than on Sheep Island. As yet we have no explanation for the large nearest neighbor distance on Sheep Island for this species.

## Reproductive Success

### Mortality-Results

Overall, there was a higher percent mortality in Aleutian than in Arctic Terns (39.6% vs. 29.3%) (Table 69). However, taken colony by colony and by species, the monospecific Arctic Tern colony had the highest mortality, 54.8%. The lowest mortality, 28% for Aleutians and 10.7% for Arctics occurred at Amee and Sheep Islands, respectively (Table 70).

On all islands, each individual mortality factor accounted for about 4% (Tables 71,72). For Arctic Terns, the largest mortality factors were embryos dying, eggs rolling out, and chicks dying at pipping (Table 69). On Sheep Island, their major mortality was 3.6% from exposure at the chick stage. For Amee Island, their highest mortality, 8%, was from disappearance of the egg, probably from avian predation or egging. However, on the monospecific Arctic colony on Cub Island, eggs rolling out of the nest or dying from exposure or at pipping (usually caused by exposure also) were the highest mortality factors. The greatest mortality of Arctic Tern eggs occurred during the hotter temperatures in the season, from late June to early July. Much of this mortality was during pipping, probably from overheating.

For Aleutian Terns, the largest mortality factors were eggs disappearing, probably due to predation and egging, and chicks dying from exposure (Table 69). The greatest percentage of Aleutian Tern egg mortality occurred from 5 - 11 June in the early incubation stage (Table 48 and Figures 69,70). Some chick mortality was during the heat wave of early July but greater mortality occurred during the low temperatures and heavy rains of 10-30 July (12.5%). Greatest mortality at Amee and Sheep Islands was from eggs disappearing (14% and 22% respectively).

### Growth Rates-Results

We weighed and measured wings, tarsi, and culmens of all locatable chicks once every three to five days throughout the chick stage. The data are quite variable by date in part because the laying was spread out over such a long period of time (Figures 68-72). As mentioned before, the range in laying dates was probably due to weather and to egging. Both of these mortality factors destroyed first clutches. The last known Arctic egg was laid 30 June and the last known Aleutian egg was laid 21 June. This is a range of approximately one month for laying dates for both species. The first fledglings were seen the 16th and 15th July for Aleutians and Arctics respectively so in the growth rate means (Tables 49-53), one week old chicks (hatching around the 20th of

July) and fledglings are being combined. This gives not much meaning to the growth curves .

Comparing growth and age of chicks yields a better index of chick growth (Tables 54-56). However, the problem of range of laying dates still remains. A week-old chick for instance in June will be influenced by an entirely different set of ecological factors than a week-old chick in August, and it is these factors which in part control the growth of the chicks.

#### Mortality and Growth Rates-Discussion

The mortality factors for the terns are directly related to habitat and behavior. Arctic Terns usually chose the steeper areas of the islands in which to nest, with the most extreme example of this in the monospecific colony on Cub Island. Here the slope averaged 17° and the nests were often built up away from vegetation and thus more exposed than nests on other islands. Almost 12% of the Arctic Tern eggs laid on Cub Island rolled out while another 26.2% of the eggs were probably killed by exposure. The greatest percentages of chick or egg losses for Arctic Terns that occurred on Cub Island were at the nests which were more exposed. Many of the eggs in exposed nests addled during the heatwave of early June. (Figures 85,86)

The Arctic Tern population on Cub Island may really be a distinct population from the rest of the terns at Sitkalidak. We have reason to believe this because Cub Island was just colonized this year, and the population of Arctics that nested on it in 1976 laid a significantly greater number of eggs per clutch. However, a greater percentage of their eggs died in the embryo stage and more of their chicks succumbed at hatching than for any other population of Arctic Terns. This may somehow be related to the habitat on Cub Island, but there may also be some other factor--perhaps one regulating population size--acting here that is not immediately apparent.

Aleutian Terns usually nested near the crests of the islands and on flatter ground. Most of their loss of eggs and chicks was from disappearance of the egg (probably avian and human predation) and from exposure of the chicks to storms. This may be due to the fact that they were less aggressive than the Arctic Terns and are less apt to defend their nests as well. Most of the mortality of Aleutian Tern eggs occurred in the early incubation stage and was probably due to egg predation. This is understandable because Aleutian Terns are not very aggressive anyhow, and at this early incubation stage, the nest attentiveness of any bird is low due to reduced hormonal levels. The other period of high Aleutian chick mortality was during the storms of

late July. The mortality rates of the young of the two species of terns seem to be approximately equal during the early brooding stages in July. In late July and in August however, the mortality of Aleutian chicks, especially those 1-2 weeks old, increased while that of Arctic chicks of all ages remained the same. Chicks that were hatched late in the season were downy at this time when heavy storms occurred. Their mortality may be due in part to weather in combination with the lower nest-site tenacity of the Aleutians. Aleutian Tern adults were easily disturbed from their nests but were slow in returning--much slower than Arctics (see also Table 64 for comparisons of nest attentiveness between these two species). Because of this lack of nest tenacity, many of the downy chicks were left exposed and were quickly wetted down and subsequently died from exposure.

The mortality of chicks also may have increased during late July and August because of what we believe was a decrease in the food supply, which may incidentally be weather-correlated. This decrease, in combination with the possible difficulty of Aleutians not only in entering mixed feeding flocks but also in procuring food for their large young at this time would increase mortality of the chicks. Certainly it contributed to a slower growth rate of the surviving chicks. Partial evidence for this is our comparisons of weights of chicks at this time. We found Arctic chicks to be fledging at 106% of adult weight, while Aleutians were fledging at 82%. Also, on 14 August on Cathedral Island, we found a dead Aleutian fledgling from Amee Island and it weighed 76 grams (62% of the mean adult weight). It had no fat on it. On the colonies we found dead chicks with ages ranging from 21 to 35 days. At this time we also caught live chicks in a mist nest and found their ages to range from 21 to 26 days of age. The fledglings' weights were low, with a mean of 37.5 (71% of mean adult weight). One 34 day old chick weighed 93 grams but had a wing of 20.6 cms, indicating slow growth. This again is probably due to a poor food supply perhaps brought about in part by storms. We have reason to believe that the food supply in Sitkalidak Strait had decreased or was inaccessible at this time, and this idea will be discussed in the prey section.

#### Productivity Results

Arctic Terns had a larger clutch size than did the Aleutians in all colonies (Table 57). The monospecific Arctic Tern colony had the greatest clutch size of all ( $\bar{x} = 2.35$ ). The percent chicks hatching on Sheep Island was greater for Arctic Terns (84%,  $\bar{x} = 1.9$  chicks per nest) than for Aleutians (57%  $\bar{x} = 1.0$ ). On Amee Island, the reverse was true with 47% of Arctic eggs hatching ( $\bar{x} = 0.7$ ) and 73% of Aleutian eggs hatching ( $\bar{x} = 1.1$ ). The Cub Island Arctic Terns had the lowest hatching success, 43% ( $\bar{x} = 1.12$ ).

Fledging success varied also among the colonies. Because tern chicks are difficult to locate due to their cryptic coloration, wandering habits, and the high vegetation, we established two fledging figures: minimum and maximum. Minimum fledging rates do not include any tern that was not located again. In this case, we assumed that all terns not recaptured died. Maximum fledging rates include all terns we could not relocate. In this case, we assumed that all terns not recaptured lived to fledging. Of course, both of these figures are not correct, the one being a gross underestimate, the other, an overestimate of what really happened. For lack of a better index of success, we will use both these rates.

In all cases, Arctic Terns had higher fledging rates than did Aleutians. On Sheep Island where Arctics fledged a minimum of 0.41 and a maximum of 1.66 chicks per nest, Aleutians fledged 0.21 and 0.83 respectively. The minimum fledging rates then are 20% for Arctics and 10% for Aleutians while the maximum rates are 83% for Arctics and 47% for Aleutians. The minimum number of fledglings for Arctics and Aleutians on Amee Island was relatively the same (0.37 and 0.38 respectively) but the maximum number fledged was 0.75 for Arctics and 1.0 for Aleutians. However, the minimum fledging rate for Arctics was greater (38%) than for Aleutians (23%) while the maximum rate was equal (62%).

On Cub Island the Arctics had the least number minimum fledge (0.05 chicks per nest) and also a low maximum fledge (0.78 chicks per nest). They also had the lowest minimum fledging rates for both species (2%) and the lowest maximum rate for Arctics (52%) which was near the lowest Aleutian rate of 47% on Sheep Island.

Because there were differences in reproductive success between the two species of terns and among the three colonies, we ran a stepwise multiple regression analysis to see if any of the habitat variables strongly influenced this success.

There was a weak negative correlation between number of eggs laid and vegetation volume at laying. However, the correlation became too varied among species and colonies to compare when number of chicks hatched was the dependent variable (Tables 58-62).

On Sheep Island there is a strong positive correlation between number of chicks hatched and vegetation volume for Aleutian Terns but no correlation for Arctics. On Amee Island there is negative correlation between number of chicks hatched and vegetation volume both at laying and hatching for Aleutian Terns but no correlation for Arctics.

This apparent reversal may simply mean that some other environmental factor that is present on say Amee but not on Sheep is overriding any effect that vegetation volume may have on number of chicks hatched.

For both species it appears that there is a greater hatching rate if eggs are laid later in the season. This is probably a result of eggng by the natives. They quit eggng later in the season so that clutches laid after the first onslaught have a better chance of making it to hatching. This was true also for the Glaucous-winged Gulls.

For terns of both species on all colonies, the number of chicks hatching and the hatching rate were negatively correlated with slope. We observed a high incidence of eggs rolling out of the nests in the steeper areas of the colonies. Terns, unlike gulls, did not roll eggs back into the nest if they rolled out.

#### Productivity-Discussion

Because the Arctic Terns on Cub Island had a significantly greater clutch size than the Arctics on the other islands, and because this island was newly colonized, they may possibly be a separate population that does not interbreed with populations from the other islands. Even though the clutch size was greatest on this island, these terns had the lowest hatching and fledging success.

Arctic Terns were most successful on Sheep Island (85% hatching and 20-83% fledging success), and in terms of number of young fledged per egg laid, the Sheep Island population was highest (0.41 minimum-1.66 maximum). At this point, we have no insight into why the Arctics were so successful on Sheep.

Aleutian Terns were most successful on Amee Island (73% hatching and 23.62% fledging success) and in terms of numbers of young fledged per egg laid, the Amee population again was highest (0.38 minimum - 1.0 maximum). There was a weak negative correlation between number of chicks hatching and vegetation volume on Amee. This may be due to the Aleutians' somehow having a difficult time finding or approaching their nest sites, and possibly in being hassled by the aggressive Arctic Terns. If this is the case, then, the lower vegetation would enable the Aleutians to locate their nests more quickly and perhaps thus avoid attacks by Arctics.

## Feeding Ecology

We approached the investigation of the feeding ecology of terns in three ways. First, we made detailed observations of feeding flocks throughout the season, noting species composition, numbers of each species, and inter and intraspecific behavior within the flock. Second, we made all day food watches on a sample of active Arctic and Aleutian nests on a mixed colony on Amee Island. This consisted of watching five nests of each species all day. In addition to this we ran transects on all colonies every three to four days and monitored chick growth and fledging success. Finally, we collected food samples from adults and chicks of both species and compared these qualitatively and quantitatively.

### Foodwatches

We conducted the foodwatches at three different stages of the chicks' development: early chick (1-2 weeks old), late chick (3-4 weeks old), and fledgling stages. These foodwatches were from dawn to dusk. Data gathered were number of times and when a chick was fed, number of attempted feedings, number of visits an adult made to the nest and how long it remained, and numbers and durations of chases of the adults. The purpose of these foodwatches was to give us an insight into distance to the foraging sites and also into attendance to the chicks by the adults. The feeding rates could be related to growth rates of the chicks.

### Feeding behavior--Arctic and Aleutian Terns

Both species of adult terns foraged during daylight. Chicks were left unattended on the colony during adult foraging sorties. After the first week, the chicks did not remain at the nest but rather stayed in the high vegetation as far as 15 meters from the nest. When they were fed, it would be at a feeding station. More than one brood would share a feeding station, and there could be multiple feeding stations per nest. The feeding stations were species-specific.

### Times of feeding

We found that neither Arctic nor Aleutian terns fed their chicks at random times throughout the day ( $p < 0.05$ ) (Figures 78 - 81). Instead, feeding times were clumped, yet the feeding times of the two species did not coincide exactly. The peaks of feeding activity usually occurred one to two hours before high tide or one to two hours after low tide. The feeding of the chicks on 18 July also coincided with observed feeding flock activity in the vicinity of the colony.

### Nest-site Attendance

From our all-day food watches we found that Arctic Terns seemed to be better providers of food than did the Aleutians. They also seemed to be more nest-attentive than the Aleutians (Tables 63-64). They made a greater number of visits to both chicks and eggs than did the Aleutians in the early brooding stage, and spent a greater percent of their time brooding the chicks than did the Aleutians. Aleutians, however, spent more time on the nest incubating the egg. These behaviors may be correlated with times of mortality between the two species. Arctic chicks died more at the egg stage and more Aleutian chicks died at the chick stage. This difference may be directly related to behavior of the adult at the nest, and the change in this behavior through time.

Adult Arctic Terns were more successful in delivering food to their chicks during the early brooding stage than were the Aleutian adults. In the late brooding stage this percentage of successful feedings by the Arctics increased almost 25%. There is no comparable figure for the Aleutians at the late date. The number of feedings by Arctics increased likewise throughout the season but remained approximately the same for Aleutians. This is important with respect to growth rates of the chicks.

At all stages, Aleutian Terns were chased by other adult terns. During the early and late brooding stages, most of the chases were by Arctic Terns which often forced the Aleutians to the ground or made them drop their bill load. The chases by Aleutians were not as violent nor as long. Arctic Terns were never chased by Aleutians. Even without overt chases by other adults, however, Aleutian Terns would often take 20-30 minutes to approach their nests whereas Arctics would fly to the nest directly.

The chicks of the two species also exhibited very different feeding strategies at the fledgling stage. As soon as the Arctic chicks were able to fly, they went directly to the water. They started feeding themselves immediately and were often attacked by adult terns, mainly Arctics. Within a period of a few weeks after the first Arctics fledged, most of the Arctic terns--adults and chicks--were gone from the colony.

Aleutian chicks hatched about the same time as Arctic chicks and also fledged about the same time. However, they remained at the nest and were fed by their parents for about two weeks after they fledged. We have evidence also that they do not grow as fast as the Arctics. At fledgling stage, they were only 80% of adult weight while Arctic chicks were heavier than adults (106%).



### Prey Items

There was a significant difference in length of prey items between Arctic and Aleutian Terns. Within each species there was a significant difference between chicks and adults with respect to prey length. Likewise, through time, the prey length changed. It was larger in July than in June, but fell in August.

Fish was the major prey item in the tern diets, and since fish grow constantly, so that an age class of fish in any one month should be larger than the one in the previous month, we would expect there to be a simultaneous increase in the length of prey taken throughout the season or at least a leveling off once the maximum prey length had been reached. A decrease in prey length as we found in August is definitely not what we would expect.

### Arctic Terns

Arctic Terns' diet consisted of 94% fish (Table 65). Mallotus villosus (Capelin) and Ammodytes hexapterus (Sand Lance) accounted for 74% of the prey items. Chicks were always fed fish. The only invertebrates we ever found in the stomachs of adult terns were Euphausiids, and these appeared only 6% of the time.

There was a significant difference in prey length between chick and adult prey over all months ( $p < 0.01$ ). Likewise, there was a significant difference within chick or adult prey lengths throughout the breeding season.

### Aleutian Terns

Fish were the principle prey item (86%) in the diet of Aleutian Terns throughout the season (Table 66). The variety of fish prey species was large (7) but Mallotus villosus (Capelin) comprised 39% of the prey items overall. Sculpins were next in importance (17%) followed by Ammodytes hexapterus and two unidentified fish species.

The diet the adults provided for the chicks consisted exclusively of fish, whereas the adults were taking a lot of Insecta and other invertebrates such as Isopoda.

The mean prey length of food given to the chicks was 74.6 cm while that taken by the adults was 58.0 cm ( $p < 0.001$ ).

### Comparisons in prey length between Arctic and Aleutian Terns

There was a significant difference in length of prey taken over all seasons by Arctic and Aleutian Terns. Arctics took larger prey

overall. We compared prey length over the breeding season between Arctic and Aleutian Tern adults: 74.6 cm for Aleutians, 80.53 cm for Arctics (Figure 82). This was significant at the 0.05 level. We also compared the difference in prey fed the two species of chicks. The mean for Aleutian chicks, 74.57 was significantly lower ( $p = 0.02$ ) than the mean for Arctic chicks, 95.18 cm.

#### Food size by season

For both species, there was a qualitative change and a significant change in prey length over the season (Figure 83). In July, the average size of fish taken by both species was approximately the same. The species of fish taken were mainly Ammodytes hexapterus and Mallotus villosus. However, in late July and August, the size of prey fed the chicks was disproportionate between the two species. Arctic Terns were still feeding fairly large fish to their chicks, but the Aleutians had switched to more invertebrates, a greater variety of fish species, notably sculpins, and to smaller prey in general. This switch for the Aleutians but not for the Arctics may indicate not only differences in foraging strategy, but also differences in abilities to enter or remain in mixed feeding flocks due to lack of aggression. It may also reflect differences in seasonal prey availability. The choice of prey of smaller lengths for Aleutians may be by default so it is important to study Aleutian Terns in an area of allopatry.

In summary we believe that Aleutian and Arctic terns do not feed their chicks at random times throughout the day but that the times follow a tide change and may be correlated to feeding flocks that occur at these changes. The two species do not have exactly similar periods of feeding and their behavior on the colony differs markedly. The Arctics have higher percent successful feedings and the number of feedings increases throughout the season while the number for Aleutians remains the same. Arctic terns are more aggressive and are not chased when they bring in food but Aleutians are. The fledglings exhibit very different feeding ecologies with the Arctics leaving the nest immediately at fledging, and the Aleutians remaining at the nest for two weeks after they fledge.

The Aleutians are also less aggressive off the colony and do not enter readily into mixed feeding flocks. They are rarely found in these flocks and are sometimes chased by Arctics upon trying to enter the flocks.

On the whole, Aleutian terns select smaller prey than do the Arctics and this was most apparent during the late brooding and fledging periods when the prey size decreased and the variety of prey increased for the Aleutians. Rain and low temperatures may act synergistically with a decrease in prey availability and may decrease the chances for Aleutians to find food and to increase the mortality of the chicks. At fledging, the two species exhibit vastly different strategies with the Arctic chicks, at adult weight, leaving the breeding grounds immediately after fledging, often being attacked by Arctic adults. The Aleutian chicks at 80% of adult weight remain at the nest site even though they can fly, and are still fed by the adults.

## FEEDING FLOCKS

We observed feeding flocks from 02 June through 09 September. They formed usually along convergence currents especially in areas where there was a rapid change in bottom topography (Figure 84).

If the feeding flocks were composed of terns, kittiwakes, other gulls and puffins, the terns were always the initiators of the feeding assemblages. We call them the nucleus species. Kittiwakes and gulls would arrive next and the puffins and cormorants always appeared last in the flocks.

Our hypothesis for which species initiated the feeding flocks is based on observation. We believe that the strongest fliers--the ones that can fly slowly or even hover--and thus which can carefully scan an area of the water--are the nucleus species. Those species can efficiently cover a wide expanse of water, often at great heights and can thus presumably spot the fish schools more easily. If terns were not a part of the feeding flock, then the kittiwakes and gulls would initialize them. They too are strong fliers.

Evidence for visual input as a prerequisite for feeding flock formation is that whenever there was wind or rain which distorted the water, there were by far fewer feeding flocks. Thus it makes sense that species with the greatest command over the water visually--the strong slow fliers--would first locate the prey underwater.

As more birds joined a feeding flock, the feeding behavior would change. This was directly correlated with numbers of birds feeding and not with length of time the flock had been in existence.

The initial feeding behavior of terns, kittiwakes and gulls is surface plunging. The birds dive into the water from a height of 3-4 meters and sometimes completely submerge, other times only partially. They remain underwater from one to three seconds. However, when the density of birds becomes such that it blocks diving access to the water, these three species alter their feeding behavior to that of surface seizing: they sit on the water and pick up prey on the surface. Often when they switch to this type of feeding, the puffins and cormorants will have arrived although they sometimes arrive at the surface-plunging stage. If the latter is the case, the behavior soon switches after their arrival because when they land in a flock it is usually in the middle. The feeding behavior of cormorants and puffins is that of long deep dives.

Most feeding flocks lasted 10-20 minutes (n=20) and if they were of longer duration, they did not remain in one physical place but were rather dynamic, shifting over distances of hundreds of meters. Sometimes the large flocks were bimodal in structure with either one of the modes having the majority of birds at any one time.

The species departed the feeding flocks in the same order in which they arrived. Ten to twenty minutes after the feeding had stopped, Tufted Puffins would still be sitting on the water, but not diving. They would at this time, occupy the center of the area where the feeding flock had been. A few gulls and occasionally kittiwakes would remain on the fringes of this group. They too would be feeding.

We observed association between avian and mammalian feeding assemblages in 10% of the observed flocks. However, we did not make extensive enough observations to determine which class of animals was cueing in on the prey first. Marine mammals would often surface right in the center of the flocks in the area with the densest number of birds.

A feeding flock is dynamic with birds arriving and leaving constantly. One erroneous assumption that many people make is that birds leaving the flock have fed. We collected numerous birds, especially kittiwakes, leaving feeding flocks, and many of these had empty digestive tracts. Many more hours of observation must be made before the dynamics of feeding flocks are thoroughly understood.

#### Abundance and Distribution

Table 73 and Figure 84 show where most of the observed feeding flocks were located and the size of these flocks. Note that more flocks and also larger flocks occurred near Cathedral Island. In this area, the bottom of the straits changes abruptly. This change produced many convergence currents and many of the feeding flocks in this area we found at convergence lines. There seems to be no correlation between tide height or time to high or low tide and the occurrence or size of the feeding flocks. (Table 73). More systematic observations are needed in order to make sure this is true.

A simultaneous feeding flock watch plus colony foodwatch is imperative in order to fully understand the relationship between timing of feeding by the adults and delivery of food to the chicks. We observed feeding flocks and a colony simultaneously only once and found times of feeding of chicks correlated with times of feeding flocks ( $\bar{x}$  = 20 minutes lag time between feeding flocks and chick feeding).

Black-legged Kittiwakes, Glaucous-winged Gulls, and Tufted Puffins accounted for 89% of the birds in the feeding flocks (Table 74).

Ninety-five percent of all feeding flocks had adult Black-legged Kittiwakes present, 90% had Tufted Puffins present and 80% had Glaucous-winged Gulls. Fifty-five percent had cormorants and 35% had Arctic Terns. Thus, a relatively small number of species composed most feeding flocks.

#### Glaucous-winged Gull feeding behavior

Glaucous-winged Gulls were always a composite of the feeding flocks we observed. There were never very many, but they were always part of the original nucleus along with Black-legged Kittiwakes. They comprised on the average 15% of the birds in a feeding flock, but occurred in 80% of the flocks.

Glaucous-winged Gulls were one of the first arriving species, after terns, to a feeding flock. They were often dominant over kittiwakes and terns, probably because of their size. Although we did not collect any gulls, from observations it appeared that they were usually successful in the feeding flocks. Fledglings were generally unsuccessful and would often be on the periphery of the flocks, sometimes picking up floating pieces of debris or seaweed.

The adult gulls, both Glaucous-winged and Mew, and the kittiwakes, fed similarly, surface plunging at the beginning of a feeding bout. The gulls, because of their larger size, seemed to influence the feeding behavior of the Black-legged Kittiwakes. When the feeding flock grew to a certain size, the gulls first would change their behavior from surface plunging to that of surface-seizing. When they were sitting in the water feeding, the kittiwakes could no longer plunge-dive above them and would soon change their own behavior to that of surface-seizing.

All three species would then sit on the surface of the water and surface-seize any prey they could reach within about a 50 centimeter radius.

#### Arctic Tern feeding behavior

Arctic Terns were the nucleus species of all flocks in which they appeared. They arrived first and the gulls and then puffins and cormorants would follow. Terns of both species always occupied the highest stratum during the surface-plunging stage, and would dive through the gull-kittiwake stratum. Presumably their position was due to better visual acuity combined with their ability to hover. When the feeding phase changed to surface-seizing, they would sometimes sit on the surface of the water like the gulls, and seize prey, but often at this point they would leave. We would occasionally see monospecific Arctic Tern flocks and the feeding behavior would follow this same behavior.

We occasionally saw Arctic Terns feeding alone either surface-plunging or skimming along the surface. From our collection sample size of two, they were neither more or less successful than terns feeding in a flock.

Within a flock there was usually not any overt aggression between terns and other species. Occasionally we spotted deference/submission of one species to another--usually a smaller to a larger species. Aleutian terns were occasionally prevented from joining feeding flocks composed of Arctic terns, kittiwakes, Mew and Glaucous-winged Gulls, and Tufted Puffins. On one occasion we observed a single feeding Arctic Tern defending a large feeding territory 15 meters wide. This aberrant behavior may be related to prey availability and not solitary feeding, but with such a small sample size and no simultaneous prey sampling we cannot make any conclusions about it.

#### Aleutian Tern feeding behavior

The feeding strategies of Aleutian Terns are virtually unknown. Even though the Aleutian terns occupied 52% of the nesting sites at Sitkalidak Strait, we saw them in mixed feeding flocks only 5% of the time and we only observed a purely Aleutian Tern feeding flock once, close to their larger colony on Sheep Island.

When we did observe both Aleutians and Arctics in a flock, their numbers in the nesting areas were approximately equal. Likewise we observed Arctics chase Aleutians from feeding flocks but not the reverse.

It is our hypothesis that because of the absence of observations of Aleutian Terns in feeding flocks, and also the discovery of insect parts in their digestive tracts, that we believe that they must feed inland. This would be a perfect example of species coexistence and ecological segregation of the feeding niche. However, we never observed Aleutian Terns feeding inland on our three overland surveys.

Aleutians may prefer insects and thus seek out inland foraging areas or they may take them by default due to the aggression of the Arctics. In order to test this we would have to find an area where only Aleutians occurred. This would also enable us to test the hypothesis that the Aleutians align themselves with the more aggressive Arctic Terns in order for protection from predators.

#### Black-legged Kittiwake:: feeding behavior

Black-legged Kittiwakes fed in a similar way to Glaucous-winged Gulls. They surface-plunged at the beginning of the feeding flock but

would change to surface-seizing when the flock became dense. They were often the nucleus species of the flocks and were also one of the first species to leave.

Tufted Puffin : feeding behavior

Tufted Puffins were one of the last species to arrive at the feeding flocks and often came from a few kilometers away. They usually landed near the middle of the flocks and then proceeded to dive after the prey. Once the feeding flock had dispersed the puffins remained in a loose aggregation, sitting on the water no longer diving. They often stayed in the vicinity for up to 30 minutes after they quit feeding.



## MAPPING

### Arctic and Aleutian Terns

#### Cub Island

The Arctic Tern plot on Cub Island begins at the benchmark on the highest point of the island and continues on a course of 273° with a width of 2 1/2 meters on either side, for 90 meters (Figure 45).

#### Amee Island

The permanent marker for all three tern plots is located 30.7 meters at 278° magnetic from the USGS benchmark which is located on the south hill of Amee Island (Figure 46). All three tern plots are five meters wide and they all start at the permanent marker. The courses are all sighted down the center of the transects so that there is a strip 2 1/2 meters wide on either side of the sighting line. Plot T-1 continues for 150 meters at 143° magnetic from the marker. Plot T-2 continues for 59 meters at 203° magnetic from the marker. Plot T-3 (which was not used by terns in 1977) continues for 30 meters at 338° magnetic from the marker. The extent of the entire tern colony is also shown in Figure 46.

#### Sheep Island

The tern transect on Sheep Island is located six meters at 156° from the permanent USGS benchmark marker on the peak of the easternmost and also highest hill (Figure 47). The transect continues from this point, 248° to the western edge and 68° to the eastern edge of the island. Terns of both species nest in all areas of the island except the indicated marsh.

### Glaucous-winged Gulls

#### Amee Island

Both Glaucous-winged and Mew Gull areas are indicated on the map (Figure 46). Glaucous-winged Gulls prefer North Head and Mew Gulls prefer the low area between the two heads, although a few scattered nests are found on South Head. Amee Island is not an important gull colony at this time, so we did not establish permanent transects.

### Sheep Island

Both Glaucous-winged and Mew Gulls were scattered throughout the island with no true colonial situation. The area that we censused is indicated on the map (Figure 47).

### Amee Rock

The Glaucous-winged Gull colony covers the entire top of Amee Rock. (Figure 46). Nests are found under the high umbel vegetation.

### Lesser Kittiwake Rock

Glaucous-winged Gulls occupy the entire sloping south side of Lesser Kittiwake Rock (Figure 48).

### Cathedral Island

Cathedral Island is the largest of the islands and is divided into four areas for mapping purposes. Each area has its own area (Figure 48).

Plots G-1 and G-2 The location stake for Plots G-1 and G-2 can be found by sighting at  $173.5^{\circ}$  magnetic, 21.5 meters from marker B. Plot G-1, the horizontal plot, begins 10.3 meters at  $155^{\circ}$  magnetic from marker B. The beginning of vertical Plot G-2 is found at 11.3 meters at  $55^{\circ}$  magnetic from the location stake.

Plots G-3 and G-4 Plots G-3 and G-4 are located near marker C. Their location stake is 52 meters at  $88^{\circ}$  magnetic from marker C. Horizontal plot G-3 is located 6.25 meters at  $23^{\circ}$  magnetic from the location stake. Vertical Plot G-4 is located 30.6 meters at  $29^{\circ}$  magnetic from the stake.

Plots G-5 and G-6 The location stake for plots G-5 and G-6 is 53 meters at  $167^{\circ}$  magnetic from marker D. The beginning of Plot G-5 is 15 meters at  $60^{\circ}$  magnetic from the stake. The beginning of G-6 is 38.5 meters at  $150^{\circ}$  magnetic from the location stake.

Plot G-7 Vertical plot G-7 is  $190^{\circ}$  magnetic and 44.3 meters from marker A. The beginning of the plot is located 30 meters at  $225^{\circ}$  magnetic from this location stake.

### Tufted Puffin

All Tufted Puffin plots are sighted from the permanent locator markers to a marked post (Figures 46, 47, 48). The beginning of the plots is at the marked post at a certain distance and bearing from the permanent locator markers. All puffin plots continue to the cliff edge and are one meter wide unless noted. All sightings are magnetic.

#### Cathedral Island

Plot 1: 355 and 41 meters from marker A.  
Plot 2: 315 and 50 meters from marker A.  
Plot 3: 315 and 50 meters from marker A.  
Plot 4: 353 and 60 meters from marker B.  
Plot 5: 211 and 92 meters from marker C.  
Plot 6: 16 and 53 meters from marker C.  
Plot 7: 63 and 78 meters from marker C.

#### Amee Island

The permanent marker to locate the Tufted Puffin transect is a large rock on South Head, next to the eastern landing beach (Figure ). The puffin transect is 148 and 5.75 meters from this marker and continues to the cliff edge.

#### Sheep Island

The beginning of Tufted Puffin transect #2 is sighted from the permanent Sheep Island marker which is at the peak of the easternmost hill. Plots are 5 meters wide and continue to the cliff edge.

Plot 2: 360 and 1575 from the marker.  
Plot 3: Begins 18 meters northeast from the beginning of Plot 2.

### Black-legged Kittiwake

#### Cathedral Island (Figure 48)

Plot 1: 128° and 88 meters from marker D.  
Plot 2: 98° and 102 meters from marker D.  
Plot 3: 188° and 88 meters from marker D.

Lesser Kittiwake Rock northeast face.

## ANNOTATED LIST OF OTHER BIRDS

### Pigeon Guillemot

Nowhere abundant in the Sitkalidak region, the Pigeon Guillemot was an ubiquitous breeder throughout the area. We make censuses of birds rafting just offshore on 9, 10, and 13 June, and found a total of 520 birds in the middle Sitkalidak Strait area. The birds at this time were displaying in pairs, so we estimated that there were 260 breeding pairs of Pigeon Guillemots in the area.

Two nests were located on Amee Island and another on Cathedral, but they were not monitored regularly so we have no data on the productivity or breeding chronology.

### Horned Puffin

Suitable Horned Puffin nesting habitat was scarce in the Sitkalidak Strait area. About 40 pairs were nesting in cracks on Cathedral Island and perhaps 10 pairs were nesting in similar situations on Amee Island. We frequently saw 5-10 birds on the waters near Sheep Island and presumed that they were nesting there, although the island is very low and offers no broken cliffs suitable for nesting. It is possible that they were nesting in small talus along the island's perimeter.

At the end of July we began to see higher numbers of Horned Puffins, especially off Cathedral Island. The maximum was 29 July when 83 birds were seen in the Cathedral Island waters. These may have been non-breeders.

### Shorebirds

Sitkalidak Strait offered little habitat suitable for shorebirds and the only one that nested there was the Black Oystercatcher. However, beginning on 30 June we occasionally saw scattered numbers of various shorebirds on the beaches and intertidal areas. A favorite site of congregation was a low, graveled spit jutting from the south side of Cub Island. The following is a synopsis of the sightings by species:

#### Western Sandpiper:

- 30 June - 10 at west end of Sheep Island.
- 10 July - 13 at west end of Sheep Island.
- 23 July - 5-10 on Cub Island spit with 10 Black Turnstones.
- 27 July - 5-10 on Cub Island spit with 10-15 Black Turnstones.
- 21 August - 35 on beach on eastern side of Sitkalidak Island.

Black Turnstone:

- 05 July - 3 on Amee Island beach.
- 23 July - 10 (8 adults, 2 immatures) on Cub Island spit.
- 25 July - 15 on Cub Island spit.
- 27 July - 10-15 on Cub Island spit.

Lesser Yellowlegs:

- 23 July - 4 feeding on tidal flat, Amee Bay.

Northern Phalarope:

- 20 July - 45 in winter plumage feeding in waters off Cub Island.
- 09 August - single bird feeding in convergence line off Cathedral Island.
- 21 August - 40 feeding in splash zone on beach on eastern side of Sitkalidak Island. 10-20 in convergence line near Cathedral Island.

Dunlin:

- 01 August - two on Cub Island spit. Molting into winter plumage.

Wandering Tattler:

- 01 August - one on Cub Island spit.
- 09 August - 5 on beach at Old Harbor.
- 13 August - two at west end of Sheep Island.
- 21 August - one along shore near mouth of Port Hobron.

Golden Plover:

- 21 August - 3 moulting into winter plumage foraging in mudflat at mouth of McDonald Lagoon.

Black Oystercatcher:

- 21 June - nest located on western side of Cub Island - apparently abandoned.
- 09 July - 20 seen at Nut Island.
- 03 July - 8 seen at Nut Island.
- 23 July - 15 seen on Cub Island spit.
- 07 September - 19 on Cub Island spit.

## ANNOTATED LIST OF MAMMALS

Marine mammals were not prevalent in the Sitkalidak Strait area. There were no breeding grounds there for any of the pinnipeds and the few mammals we did see may have been immatures passing through. The mammals appeared in only 10% of the feeding flocks which may indicate that the food available is not the preferred prey for marine mammals, hence their absence from the area.

### Harbor Seal

We saw Harbor Seals regularly throughout the summer, with the first sighting on 10 June off Sheep Island, and the last on 7 September near the Cub Island rocks. Favorite hauling areas were the rocks off the north side of Nut Island and the rocks below Lesser Kittiwake Rock. We had six sightings in June, six in July, five in August, and two in September (Table 75).

### Stellar's Sea Lion

We saw a Stellar's Sea Lion once only. It was swimming west of Cathedral Island below the Black-legged Kittiwake Plot #1 on 25 June.

### Harbor Porpoise

Harbor Porpoises were the second most common marine mammal at Sitkalidak Strait. They were the species of mammal most common in the feeding flocks we observed. We had three sightings in June, one in July, eight in August, and one in September (Table 76). Half of our sightings were when the porpoises were feeding.

### Minke Whale:

Sighting of Minke Whales was sporadic, although they were the most common marine mammal in the Inner Sitkalidak Strait area. We had a lot of sightings early in the season. These sightings decreased with time as the season progressed. In the early sightings, we observed the Minkes breaching. These sightings were always from our support vessel, the Yankee Clipper. We suspect that the act of breaching may have been in response to the vessel. Most of the other sightings were of the whales in mixed feeding flocks. We had one sighting in May, three sightings in June, fifteen in July, and four in August (Table 77).

### Sea Otter

We saw one sea otter eating a king crab at 1000 on 19 June, south-east, 100 meters off Cathedral Island.

### Beaver

We saw beavers twice, both times swimming 15 meters off our camp beach, 28 May and 18 June.

### Red Fox

We had three sightings of red foxes: 2 June, 28 June, and 17 July. Each time the fox ran from us. In the Sitkalidak area they are not tame as they are on islands such as the Shumagins.

## DATA GAPS

The most obvious data gap is that the study only covers a single season. Very few definitive statements can be made about the breeding ecology of the seabirds at Sitkalidak Strait other than what occurred during the 1977 season. Much time was spent this season orienting ourselves to the area and trying to determine how we best could efficiently obtain the most data. Hopefully other workers will have the time to fill in the gaps we have in our data, which should include:

1. A better analysis of the nesting habitat by observations of any competition by adults for the nest sites as well as an assessment of any unused habitat. This entails arriving at the study site before the birds set up their nesting territories.
2. A better record of the movements of birds in and out of the strait throughout the season by monitoring day-long sea watches from Lagoon Point at various times during the season.
3. A better record of the distances birds nesting in Sitkalidak Strait are traveling for food by making more shipboard transects throughout the season and continuing them beyond the mouth of the strait, and an analysis of the feeding effort by more monitoring of the nests in food-watches, as we did this year.
4. A better understanding of the feeding ecology by collecting more samples of chick food (especially for the puffins) throughout the season and by sampling the availability of the prey directly with tow nets.
5. A better record of the breeding ecology at the very large Boulder Bay kittiwake colony that can be compared with the colonies in Sitkalidak Strait.



## EFFECTS OF OIL SPILLS

The most obvious danger of offshore oil development in the Kodiak waters are oil spills. The vulnerability of seabirds to such spills has been well documented (Vermeer and Vermeer 1974, 1975) and need not be reviewed in depth here. One effect of oil spills in the marine environment is a decrease in the available food supply because of the depth or contamination of prey species which have succumbed to or have accumulated the toxic fractions of oil (Payne and Penrose 1974). Another is the buildup of toxic hydrocarbons in the birds themselves as a result of the ingestion of contaminated prey (Alaska OCS office 1977).

Any oil slicks in the Sitkalidak Strait area during May through September could also have a direct effect on the seabirds by oiling any birds rafting off the colonies or feeding in the strait. Convergence lines and tide rips were found to be important feeding areas for all species, and it is here that much of the oil would accumulate, presenting a serious threat.

The impact of related activities, such as the onshore development of support facilities and increased shipping activities, would be less dramatic than that of oil spills but would be severe if uncontrolled. Certainly no development should take place that directly reduces the nesting areas presently used. Onshore development and shipping activities also should not be close enough to existing colonies to cause abnormal disturbances to the nesting birds.

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