FINAL REPORT

Contract: 01-5-022-2538
Research Unit: RU 341 (part)
Reporting Period: April 1, 1978 to
April 1, 1980

THE PELAGIC BIRDS OF CHISIK AND DUCK ISLANDS

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April 23, 1980

FINAL REPORT

THE PELAGIC BIRDS OF CHISIK AND DUCK ISLANDS

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Dedication

To the Pacific sand lance *Ammodytes hexapterus*
about which we know so little.

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April 22, 1980

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ABSTRACT

This is a two-year study of seabird colonies on Chisik and Duck Islands comprising the Tuxedni Wilderness in lower Cook Inlet. We compiled productivity statistics concerning black-legged kittiwakes and horned puffins through their incubation and nestling stages to fledging with major elements as follows:

Productivity of black-legged kittiwakes

	1978	1979
Nests with eggs/nest built	.748	.732
Mean clutch size	1.56	1.50
Clutches with one or more eggs hatching	25.5%	61.7%
Mean brood size at hatching	1.15	1.46
Broods with young fledging	7.7%	56. 7X
Mean brood size at fledging	1.0	1.24
Young fledged from eggs laid	1.1%	28. 9%
Mean number of young raised per pair	0.015	0.361

Productivity of horned puffins

Pairs laying eggs on sample plots	96 . 7%	69.6%
Mean clutch size	1.0	1.0
Clutches with eggs hatching	72.7%	43.7%
Broods with young fledging	92.3%	71.4%
Mean number of young raised per pair on sample plots	0.60	0.24

Implications of known kittiwake reproductive failures were considered in a population simulation model, which showed the population presently in decline. Literature review concerning a primary food fish is presented.

Observations of common murres and glaucous-winged gulls were incidental in the first year, and for the gulls in the second. In the second year, the murres made little attempt to reproduce. The gulls emerged as an important predator of kittiwakes and murres. Any disturbance sending adult kittiwakes and murres off the nest exposes the eggs or chicks to gull predation. Airplanes, particularly helicopters, create this kind of disturbance.

Two ectoparasites are reported.

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INTRODUCTION

The account which follows concerns a two year (1978-79) study of the reproductive period for three species of pelagic birds on Chisik and Duck Islands in lower Cook Inlet, Alaska (see Fig. 1). The birds, black-legged kittiwakes *Rissa tridactyla*, common murres *Uria aalge*, and horned puffins *Fratercula corniculata* nesting on these islands and adjacent mainland form the largest aggregation of pelagic birds in Cook Inlet.

Most scientific investigations in the lower Inlet have focused on its identity as a petroleum province. The presence of oil and gas seeps about 40 miles southwest of the Tuxedni Wilderness led *to* exploratory drilling as early as 1898, and a number of geologists explored the area from about the turn of the Century. William H. Dan visited the region in 1896 while investigating Alaskan coal resources, and noted the pelagic birds on Chisik Island which later became part of the Tuxedni Wilderness (Dan 1896). O.J. Murie visited Chisik in 1936, and I.N. Gabrielson visited there in 1940. Both commented on the size and importance of the kittiwake colonies, and Gabrielson noted the presence of murres (Murie 1959, Gabrielson and Lincoln 1959). In 1966 William B. Krohn, an employee of the U.S. "Fish and Wildlife Service, conducted a brief survey of the Island, and in an unpublished report *(1966)* identified the kittiwake nesting sites and noted the presence of murres and horned puffins. Finally David J. Snarski, as a graduate student from the University of Alaska conducted investigations of the main kittiwake colony on Chisik (Snarski 1970, 1971 and Unpubl. Ms.).

Our study came in the wake of the 1977 lease sale of petroleum rights to submerged lands in lower Cook Inlet. It is part of the environmental assessment associated with the expectation of changes occurring in the Inlet.

THE STUDY AREA

Chisik and Duck Islands became a bird reserve in 1909 when President Theodore Roosevelt signed Executive Order 1039. This order proclaimed withdrawal of Chisik Island (2606 ha, 6439 acres) and Egg (now Duck) Island (2.4 ha, 6 acres) from public domain to form the Tuxedni Reservation. It later became the Tuxedni National Wildlife Refuge, and in 1970 (Oct. 23, Public Law 91-504) received classification as a wilderness.

Chisik Island is 10.5 km (6.5 miles) long and about 3.6 km (2.25 miles) wide at the northern end, but narrows to less than 0.4 km (0.25 miles) at its southernmost point. It lies in the mouth of Tuxedni Bay, (see Fig. 2) and conforms in appearance to the ruggedly mountainous

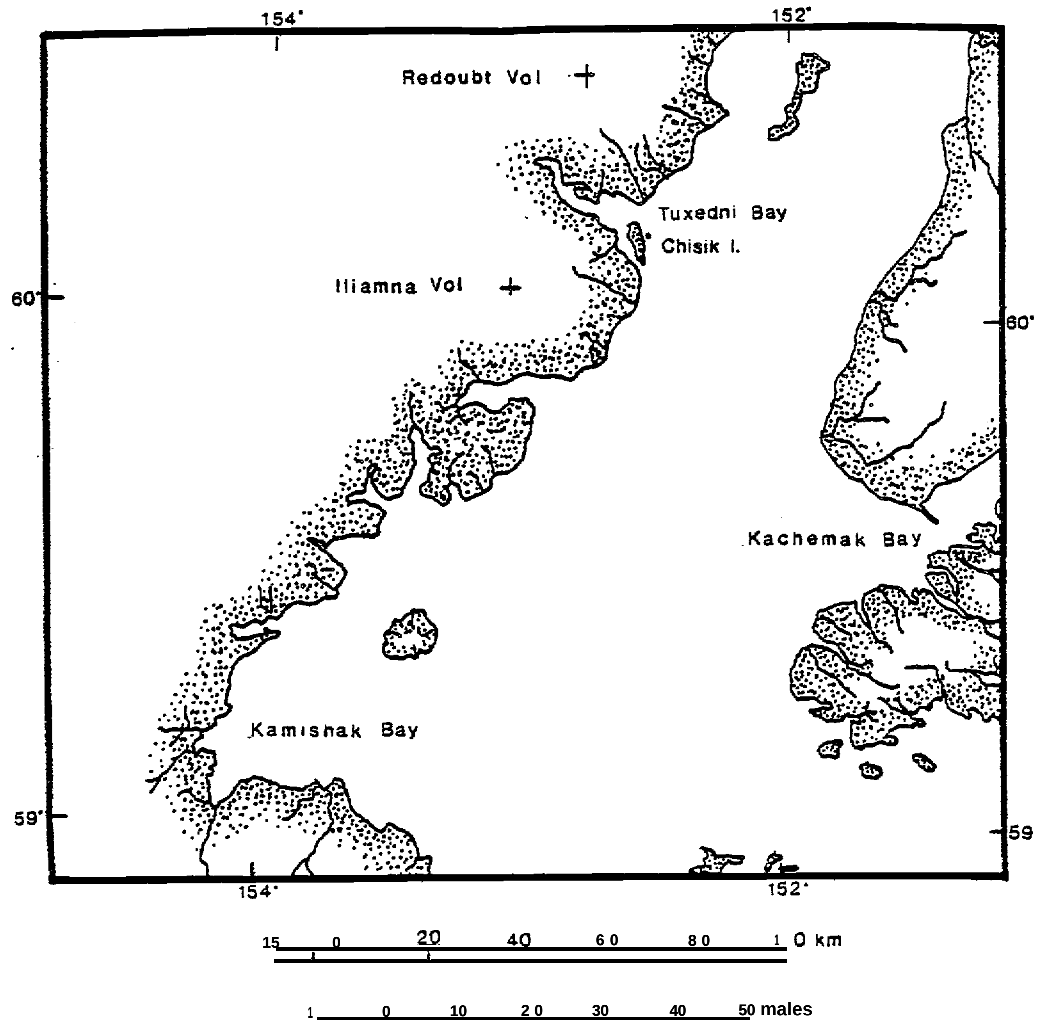

Fig. 1. Lower Cook Inlet

terrain of the region. Two historically active volcanoes, Mounts Redoubt and Iliamna, rise to slightly above 3050 meters (ten thousand feet) and dominate the view, but the surrounding mountains present an equally rugged aspect. Chisik is 815 meters (2,674 feet) in altitude at the summit in the north end of the island. From there the land dips southward along a narrow ridge to the south end of the island. Steep slopes or cliffs rise abruptly from narrow tide flats to the crest of the ridge. All streams run in short, precipitous courses, most ending in waterfalls. The exposed rocks range in age from middle to late Jurassic (Detterman 1963), and contain numerous fossils in sandstone and siltstone layers. The layered structure provides ledges on which the birds nest, but it is a physically instable formation. Continuous showers of angular stones and frequent rockslides expose fresh surfaces on the cliffs and add to the accumulating debris at their feet. Long-term residents report continual alterations to the island's facade. Whether from the earthquake shock that occurred in the Tuxedni region in late winter 1978-79 or other causes we observed greatly increased avalanche activity in the second year of field work. A large avalanche occurred in April, 1979 near the center of the kittiwake colony. Substantial amounts of rocks, soil and alders fell from the 200 meter (600 foot) level across the beach, intertidal zone and into the subtidal. This fall remained active throughout the summer, especially during rainy periods. We scurried across this section of beach, often to the accompaniment of stones pinging off the helmets we habitually wore when working the kittiwake colony. The impact zone for the larger stones and rocks lay 20 to 30 meters out from the cliff face, while a continual shower of small stones fell at the feet of the cliffs. When in late summer newly fledged chicks alighted on this part of the beach they suffered high mortality.

A dense tangle of alder *Alnus crispa* dominates the vegetative cover on both Chisik and Duck Islands, making overland travel difficult. This, plus the precipitous terrain and the fact that high tide covers most beaches dictates that travel is almost always accomplished in boats. A few Sitka spruce *Picea sitkensis* occur on Chisik, especially in the north end, but none on Duck Island. Cottonwood *Populus balsamifera* occur on the lower slopes of the west side of Chisik. Some of these are handsome, large trees, perhaps two or three hundred years old. The understory on both islands includes plants that complement the alder in making overland travel difficult: devil's club *Echinopanax horridum*, salmonberry *Rubus spectabilis*, nettles *Urtica Lyallii*, *Calamagrostis canadensis*, elderberry *Sambucus racemosa*, and several genera of the family Umbelliferae.

Duck Island lying about 0.4 km (0.25 miles) off the midpoint of Chisik's east side, is a steep-sided rock outcrop reaching an elevation of 49 m (160 feet). Other than rain, no water occurs on Duck Island.

Both islands produce a proliferation of flowers during the growing season, coloring the cliffs first blue and then yellow as seasonal succession occurs.

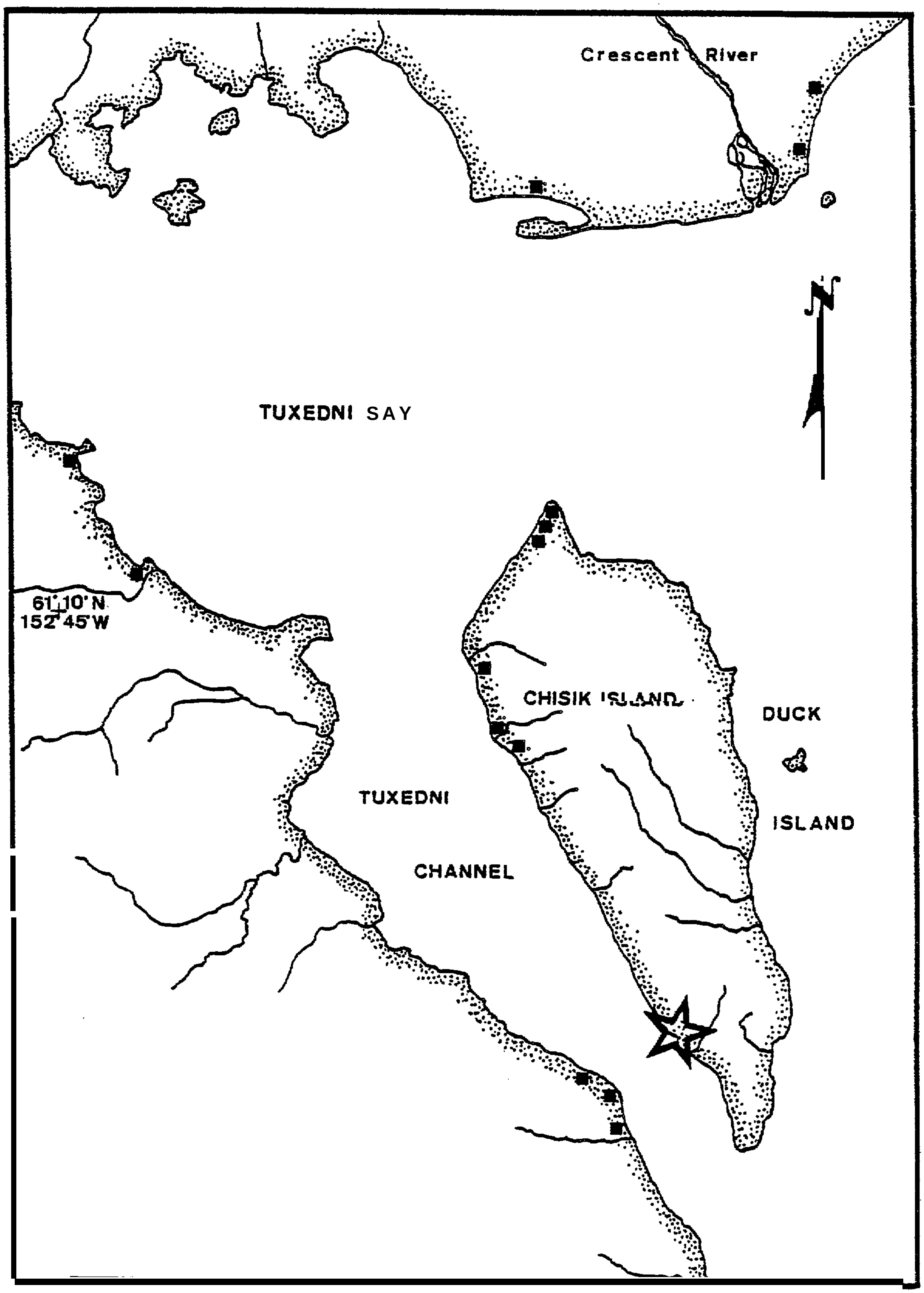

Fig. *2.* Tuxedni Wilderness study area. Squares indicate locations of cabins, the star indicates the location of the Snug Harbor Packing Co.

Because of its height Chisik Island furnishes shelter to Tuxedni Channel from storms in Cook Inlet. The deep water harbor thus formed, the only one on the west side of the Inlet, is called Snug Harbor. Its only entrance, except to vessels of very shallow draft, lies at the sourthern end of Tuxedni Channel. Any boat or ship needing shelter drops anchor there. In the early part of salmon fishing season, i.e., late June and early July, numerous fishing crews anchor their boats in Snug Harbor for the night and during periods closed to fishing.

A fish processing plant, property of the Snug Harbor Packing Company occupies a twenty acre site on Chisik Island 1.6 km (a mile) north of the entrance to the Harbor. When plant construction began in 1919 the Company processed razor clams *Siliqua patulapatula*, soon converted to salmon *Oncorhynchus spp.* and for economic reasons discontinued processing at Snug Harbor after 1970.

In addition to the packing plant, three frame houses occupy sites on the west side of Chisik toward its northern end. At the very northern tip of the island on a marine strand several shacks, and in summer, tents stand. Except for the caretaker at the packing plant the structures on the island are not normally occupied in winter. No structures exist on the east side of Chisik and none on Duck Island. There are no suitable locations there, and if there were they would be exposed to the onslaught of every storm crossing Cook Inlet.

The Cook Inlet salmon fishery, a sizeable industry, evolved into (1) a set-net fishery and (2) a drift net fishery. Both employ gill nets that are either anchored in place at pre-determined sites, or carried into the Inlet aboard very specialized boats to be set and allowed to drift with the tide. Each type occurs in or near the Tuxedni Wilderness.

In 1979 a herring *Clupea harengus* fishery developed in Tuxedni Bay. A Japanese company offered a price of $1,500 per ton of fish with certain stipulations regarding the percentage of females bearing mature eggs. A larger than usual run of herring appeared in Tuxedni Channel in May and the fishermen deployed a small-scale set-net fishery to take them. Catches not meeting the stipulations mentioned above were discarded, thereby furnishing *a* subsidy to the *glaucous-winged gull Larus glaucescens* population on the eve of nesting.

All persons who operate boats in Cook Inlet accept the problems of extreme tides. At Snug Harbor it ranges 7.65 m (25.1 feet) between extreme highs and lows. It is semi-diurnal *in* character with *considerable* difference in the level of the two lows or the two highs in any 24 hour cycle. During neap-tides the water around Chisik and Duck Islands is relatively clear and blue-green in color, but in spring-tides (Sverdrup, Johnson and Fleming 1942, p. 559) swift currents churn the bottom sediments and the water becomes muddy. Rip tides then appear in association with any abrupt change in water depth or constriction by a land mass. One encounters formidable tide rips in Cook Inlet at all times of spring tides.

No climatological data exist for the west side of Cook Inlet south of Tyonek (Evans *et al.* 1972). However, H.W. Searby, then Chief Climatologist for the National Weather Service in Anchorage (op. cit.), expressed. his opinion that for comparable latitudes, precipitation on the west side of the Inlet Is about 50% higher than on the east. Compared with Homer's 58.6 cm (23.08 inches) this means the precipitation in Snug Harbor measures about 87.6 cm (34.6 inches) on average, but subject to considerable variation. In 1978 we recorded 48.89 cm (19.25 inches) of rainfall in 110 days. We received rain in 45 of the 110 days. In 1979 we recorded 42.5 cm (16.72 inches) in 121 days. Rain fell in 51 of the 121 days.

Table 1. Summary of weather record May - September, 1978 and 1979 at Snug Harbor, Alaska.

	Temperature in C. (F)		Precip. in cm (inches)	Days of rain
	Mean low	High low		
			1978	
18-31 May	4.2 (39.6)	13.2 (55.7)	54.54 (2.18)	6
June	6.5 (43.7)	15.9 (60.6)	12.50 (4.92)	10
July	8.0 (46.4)	17.6 (63.7)	19.18 (7.8)	19
August	8.2 (46.7)	16.9 (62.5)	9.78 (3.85)	11
1-4 Sept.	5.0 (41.0)	21.1 (70.0)	1.27 (0.5)	1
			1979	
14-31 May	3.4 (38.2)	15.9 (60.6)	2.16 (0.85)	8
June	6.5 (43.8)	16.8 (62.2)	5.51 (2.17)	12
July	9.8 (49.7)	19.8 (67.6)	13.64 (5.37)	16
August	8.8 (47*9)	20.9 (69.6)	21.08 (8.30)	14
1-11 Sept.	6.9 (44.5)	19.1 (66.5)	0.08 (0.03)	1

The steep pitch to the roofs of the Snug Harbor Packing Company's buildings suggest heavy snowfall, and local residents estimate about three meters (10 feet). When we arrived at Chisik May 9, 1979 we found the island covered with snow of the crystalline sort called *firn* or *neve'* down to the high tide line. It measured about 1.2 m (four feet) deep at sea level. This generated unexpected problems in establishing camp, We judged it had been a hard winter, which Mr. Richard Baldwin confirmed. He had spent the winter alone with his dog in a nearby cabin across Tuxedni Channel. He had not planned to spend the winter, but weather conditions prevented leaving, then Tuxedni Bay froze and it was too late.

The simple summary of precipitation shown in Table 1 does not quite tell the whole story. Rain tends to come in general storms rather than showers in the Tuxedni Bay region, with dry periods between storms. Thus rains usually fell for several continuous days at the end of which water poured off the island in great cataracts. It made slippery the cobblestone beach leading to the kittiwake colony, washed away exposed nests and made the cliff unsafe to climb, but solved the problem of readily available water for camp housekeeping. On the other hand, the dry spells and clear skies in such grandly scenic country touched the psyches of us all, and dried-up the water sources.

Lower Cook Inlet and Shelikof Straits have earned a reputation for stormy weather. We discussed with Dr. Edward Diemer, Chief Meteorologist for the National Weather Service in Anchorage, the probability of a summer passing in Lower Cook Inlet without winds of 30 knots or more, together with rain. After due consideration he replied that the chances seemed no better than one in twenty. Cyclonic storms moving into the region from the west produce strong northeast or southeast winds with rain. In summer 1978 the Tuxedni bird colonies experienced winds from both directions, but none from the southeast in 1979. One storm in August 1979, which produced 19.3 cm (7.6 inches) of rain in eight days with strong northeast winds, washed all kittiwake nests exposed to this wind off the cliffs, but spared many with other exposures. Some protected from the northeast wind, but exposed to the deluge pouring off the island also washed off the cliffs. Many nests in the main Chisik Island colony survived, but few did on Duck Island.

We recorded surface sea water temperatures on an occasional basis when enroute to Duck Island, about 4 km (2 1/2 miles) south of the Island. It read 7.8°C (46°F) in late May, rose to 11.1°C (52°F) by July 4 and remained at that for the rest of the season.

Fredericks de Laguna (1934, 2nd ed. 1975) studied the archeology of Cook Inlet. She reported two sites at Tuxedni Bay, one at the mouth of the Crescent River, and the other well back in the headwaters of the Bay. The latter is difficult to reach because of tidal problems, and is one of the three in Cook Inlet associated with aboriginal paintings on the cliffs. She ascribed the lack of archeological sites between the

Crescent River mouth and Cape Douglas to a scarcity of game, timber, and a lack of protection from the storms frequenting the Inlet. We queried Jack Lobdell of the University of Alaska, Anchorage campus, who recently conducted extensive investigations of sites in Kachemak Bay on the eastern side of the Inlet. He reported that ducks comprised over 50% of the identifiable avian elements, and that murres provided about 15% in all sites. Very likely the people occupying the site at the Crescent River did so during the time of salmon runs in summer. If so, they probably visited the pelagic bird colonies on Duck and Chisik Islands and varied their diet of fish and clams with alcids, eiders, gulls and eggs of all three.

METHODS

Field work extended from May 16, 1978 to September 4, 1978; and from May 9. 1979 to September 14, 1979. We devoted 213 person days in the field in 1978, Margaret Petersen 108, Robert Jones 99, Gerald Sanger and Patrick Gould each three. In 1979 Petersen spent 22 days in May, Janet Burke 109 days through the summer, Jones 107, and Claudia Slater 92 for a total of 330 person days.

We marked with painted numbers 91 kittiwake nests in the colony on the south end of Chisik in 1978. These we attempted to monitor on a three day schedule, but rain (which made the cliffs slippery and dangerous) obliged us to adjust this from time to time. Then we found we had anchored our climbing line leading to numbers 41 through 48 to loose rocks, so we abandoned these eight nests. In May 1979 we located the marked nests that survived winter and renewed the painted numbers. Most survived, but a few ledges had fallen or been knocked off by other falling rocks. We added some, so that we monitored 82 nests in the Chisik colony. In 1978 we had monitored by telescope additional territories on the Duck Island sea stack, but elected not to do this in 1979. The kittiwake nests on Duck Island and its sea stack stand so exposed to any storm in the Inlet as to offer only the most marginal opportunities for reproductive success.

Though horned puffins and a few tufted puffins *Lunda cirrhata* choose nesting sites elsewhere in Tuxedni Bay the only concentration occurs on Duck Island. There we marked nest burrows, and recorded chronology, productivity and growth rates of the chicks in each year. We marked adults and chicks with standard numbered metal bands in both years and adults with coded arrangements of colored bands in 1978.

We recorded chronological events relating to common murres and glaucous-winged gulls on Duck Island. The murres nested extensively in 1978 and we prepared to study this process in 1979 using the technique of time-lapse photography. But the murres did not nest in 1979. We employed time-lapse photography in the study of horned puffins during 1979.

In the time-lapse photography we directed an 8mm movie camera fitted with an automatic exposure meter at the desired field of view. In this application the camera exposed one frame every 60 seconds, so that a 50 foot roll of film lasted about three days. This provides a long series of spot observations without the presence of an observer.

RESULTS

BLACK-LEGGED KITTIWAKE

Nesting distribution and abundance.

Black-legged kittiwakes differ from most other gulls in that they live in the open sea, and when they come to land to breed they perch their nests on tiny ledges in the typical situation.

The center of kittiwake abundance in Tuxedni Bay lies just inside Snug Harbor on the west side of Chisik at its southern end. This, the largest colony, begins 0.8 km (a half mile) south of the buildings of the Snug Harbor Packing Company and extends 1.6 km (a mile) around the south end of the Island. Because of the horseshoe land-shape the occupants of the colony experience exposures to the west, south and east, depending on the individual nest location. The western exposure within Snug Harbor confers shelter from the strong northeast or southeast winds experienced during storms in Cook Inlet, and perhaps accounts for the concentration at that location. Smaller colonies occupy Duck Island, cliffs midway along the east side of Chisik Island, and a cliff on the mainland directly across Tuxedni Channel from the main concentration on Chisik (Fig. 3). Historically several hundred birds briefly colonized a cliff north of the present main concentration on Chisik, possibly at a time of population expansion. Estimates of numbers now indicate a total of about 28,000 birds.

Breeding chronology.

In the winter of 1977-79 the Snug Harbor Packing Company caretaker, Mr. Richard Baldwin, recorded the arrival of the first kittiwakes on March 13. That information is not available for our second year. We found them present in the colony site when we arrived at Chisik May 9th.

Nest building began May 25, 1979, three days later than in 1978 and earlier than in 1970 and 1971 (see Table 2). As in 1978 the birds gathered nest material from the cliffs and exposed tidal mud flats. The process seems rather inefficient, for the birds drop a continual shower of mud and even small stones along the course they take. It results in the removal of substantial amounts of vegetative cover from the cliffs

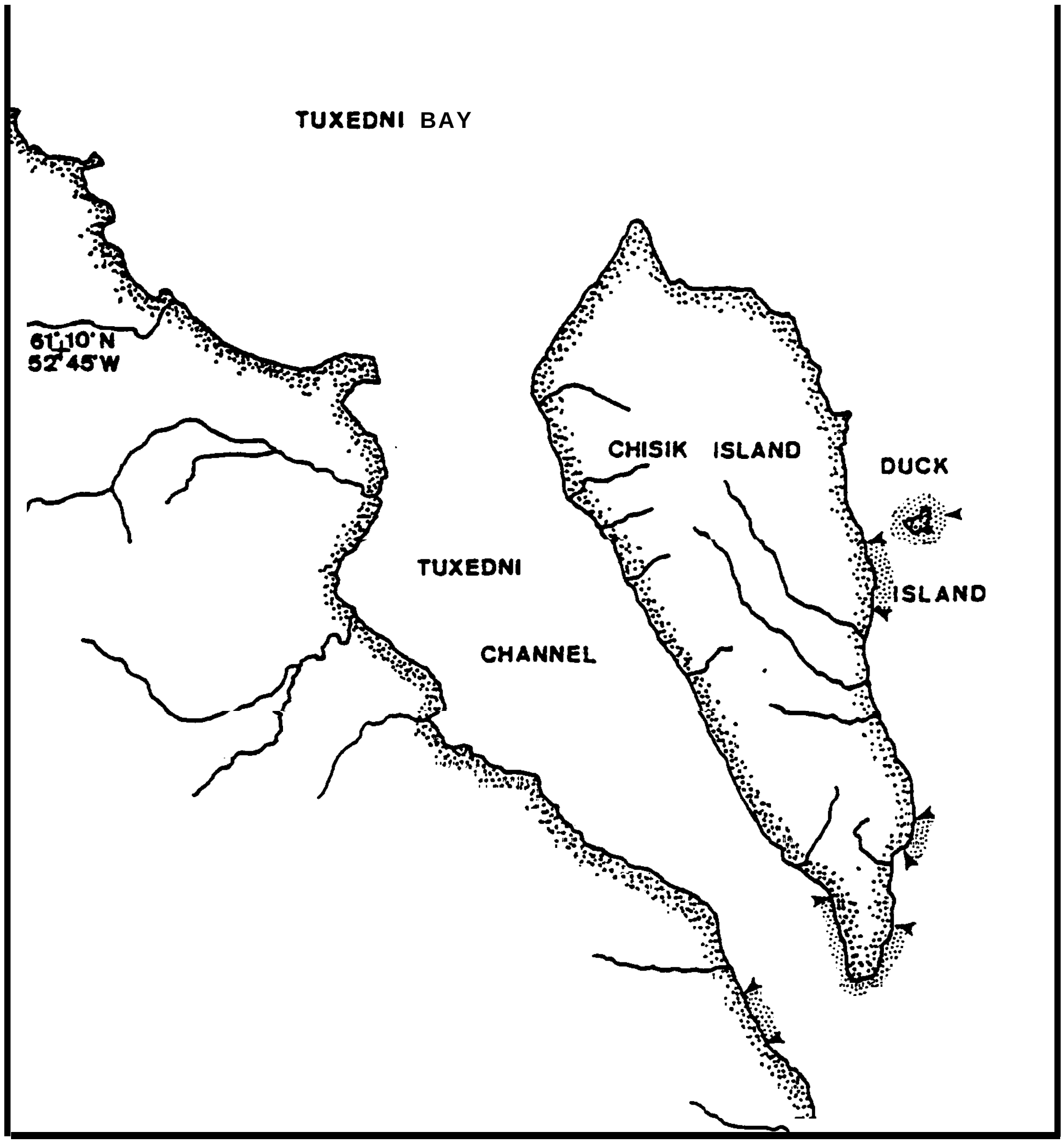

Fig. 3. Nesting distribution of black-legged kittiwakes.

Table 2. Breeding chronology of black-legged kittiwakes.

Event	Date 1970[1]	1971[1]	1973[1]	1978	1979
Arrival	17 March	27 March		13 March	
Nest building initiated	1 June	17 June		22 May	25 May
Egg laying	19 June-5 July	27 June-10 July	<30 May>	10-30 June (n = 110)	14 June-6 July (n = 60)
Modal egg laying (2/3 pop.)				12-24 June	16-25 June
Hatching	18 July-?	26-29 July	<27 June>	6-25 July (n = 16)	10 July-4 Aug (n= 37)
Fledging	None	None	<7 August>	23 August (n = 2)	19 Aug-8 Sept (n= 21)

[1] D.J. Snarski 1979, 1971 and Unpubl. Ms.

and no doubt contributes to the maintenance of bare cliff faces. During the peak of nest-building the birds describe an elliptical traffic pattern flying from the colony site to the source of building material and return. In the process of fetching the material, mixing it with mud (which must also be carried to the site) and trampling the whole into a nest they become quite dirty. This necessitates a flight across Tuxedni Channel to a large stream to bathe. We do not know why they prefer fresh water to saline for this purpose, since they possess a salt gland and do not require fresh water to drink.

We saw kittiwakes carrying nest material throughout the summer, but on a much reduced scale when compared to that during the active nest-building period. They conduct some maintenance of the nest after egg laying commences but in general the act of carrying nest material after completion of the nest seems to be displacement activity. Their readiness to steal material from other nests leads to the requirement that one bird stay home during the building process and defend the assembled material. One of our numbered nests never reached completion, for it was undefended. Four times during the summer we observed new material deposited on the territory, only to disappear.

The first egg to appear in our numbered nests arrived June 10 in 1978, and June 14 in 1979. The last appeared June 30 and July 6 respectively in the two years. Modal egg laying, i.e., the two thirds centered about the mean, occurred between June 12 and 24 in 1978, and June 16 and 25 in 1979. Note the spread of 12 days in 1978 and 9 in 1979. No second nesting attempt following egg loss occurred in the marked nests in either year.

In 1978 mean clutch size numbered 1.56 eggs (n = 115, se. = 0.048). This sample included one nest with three eggs. In 1979 mean clutch size numbered 1.50 eggs (n = 60, se. = 0.066). In this sample thirty nests contained one egg and thirty contained two. None contained three.

Hatching in 1978 extended from July 6 through 25 (n = 16), and in 1979 from July 10 through August 4 (n = 37). Twenty-one of the 37 nests whose eggs hatched in 1979, completed hatching July 15 and 16, thus a strong modal pattern centered around these dates. The incubation period (1979) spanned 27.8 days (n= 37, s.d. = 1.37, se. = ().226).

Fledging time of kittiwake chicks can only be determined by a continuous watch at the end of the nestling period (Coulson and White 1958). On Chisik two factors, extreme tide range and falling rocks, render this impractical. At times of high tide the water stands well up the cliffs at several points, requiring that observers travel to and from the colony at the lower stages of the tide or remain over the high portion of the cycle. To accept this course means roosting in the path of an avalanche should the rocks fall at that time. We chose not to accept this risk. Fledging occurred in 1978 by August 23, and in 1979 between August 19 and September 8. The nestling period (1979) covered 43.5 days (n = 26, s.d. = 5.61, se = 1.1).

After completion of fledging birds began to leave the colony, but not in a clear-cut exodus. The emigration described a series of departures and returns of the adults and some of the juveniles over a period of several days. In this process the numbers diminished decrementally until on September 14, 1979, the day we left the Island, only a few (perhaps 1000) birds, mostly juveniles, remained.

Productivity.

Kittiwakes first reproduce in their third or fouth year, and gain success in reproduction as they gain experience (Wooller and Coulson 1977). Differential mortality between the sexes results in an estimated life expectancy after first breeding of 5.4 years for males and 7.1 years for females (Coulson and Wooller 1976). Survival rates are lowest in the first year, higher thereafter, but with a gradual decline in advancing age (op. cit.). These age related factors determine the reproductive potential of the population in any year, thus we emphasize the *age* distribution.

Productivity of kittiwakes was poor in the Tuxedni Bay colonies in 1978 when only 0.015 young per nesting pair of adults reached the point of fledging. In Table 3 we *list* data from this and earlier studies which show productivity gains in two of five years in the decade of the '70's.

We used the Leslie matrix simulation model (Leslie 1945, 1948) to estimate the effect of frequent reproductive failures on the kittiwake population in Tuxedni Bay. The model provides a mathematical system for handling parameters of recruitment and survival using different age distributions. We found that the known productivity as shown in Table 3 cannot maintain the population. If the level of productivity observed in 1979 were approximately duplicated in successive years it would provide for a very modest increase in the population; but the loss of a *year* class, which occurs in years of reproductive failure, depresses the reproductive potential for six to eight years beginning in the year that class should enter the reproductive segment of the population. Such failures occurred in 1970, 1971 and 1978 (see Table 2), and we suggest that the Tuxedni population is in decline. This population has a long history (Dan 1896), very likely marked by periods of advance and decline, but we possess only limited data, and beyond what these data tell us about the present reproductive status we can only speculate.

Food habits.

Kittiwakes are surface feeders, i.e., they catch their food in the upper half meter of the water column by plunge-diving. They swallow food whole, and later after returning to the nest regurgitate partially digested food which the chicks eat. The chicks often regurgitate food when we arrive at the nest, affording an opportunity to learn what they had eaten. We collected a few samples each year (Table 4), which indicate the importance of fish, but furnish no statistically sound comparisons. The Pacific sand lance *Ammodytes hexapterus* appeared in the samples both years and in the adults collected in 1971 (Snarski Unpubl. Ms.). Blackburn (1978) suggested this fish is the most common small fish in lower Cook Inlet, with O, 1 and 2 the predominant age classes captured in sampling gear. This fish played an important role in the ecology of the other birds we studied so we searched the literature, rather fruitlessly for this particular species. Except for distribution information regarding *A. hexapterus*, most of what we found concerns *A. americanus*, the North American Atlantic form, and *A. tobianus*, the European form. The most interesting characteristic of the sand lances is their ability to burrow into sand or gravel and remain there for long periods. Coastal sand lance may bury themselves above low-water mark and remain buried over the low half of the tide cycle. In Britain sand lance are commonly taken for bait by digging for them above low tide level (Langham 1971). We experienced this with *A. hexapterus* on exposed sandflats on the north shore of Tuxedni Bay, and Dames and Moore (1979) report the same for the Homer Spit in Kachemak Bay. The burrowing habit leads to the occurrence in greatest abundance of *A. americanus* over shallow banks offering clean sandy or gravelly substrates (Bigelow and Schroeder 1953, Meyer *et al* 1979).

Regarding the behavior of *A. dubius*, the northern sand lance, Scott (1973) draws the following tentative conclusions. (1) Copepods provide the bulk of the food source; (2) They are both filter feeders and selective feeders; (3) They are captured in relatively shallow water, generally under 100 meters where the bottom is fine sand; (4) They are captured in grabs during bottom sampling operations in sandy areas on the Nova Scotian banks; (5) They go into the sea bed during daylight hours and rise to near surface at night; and (6) Heavy catches have been made at various times of the day and all seasons. Conversely, unpredictable periods occurred when no sand lance were caught even with prolonged effort on known sand lance ground. 'Meyer *et al* (1979) warn of this problem when attempting quantitative sampling of *A. americanus*. Their divers observed successful net avoidance by these fish. Kuhlman and Karst (1967) report that *A. tobianus* remains buried at night and emerges in daylight. It seems clear to us that we need to know these things about *A. hexapterus*.

Growth.

We present comparative growth data of kittiwakes for both 1978 and 1979 in the form of growth curves in Fig. 4 and graphs in Fig. 5, but the reader should bear in mind the differences in sample size. We

Table 3. Reproductive success of black-legged kittiwakes.

	Date			
Event	1970[1]	1971[1]	1978	1979
Nests with eggs/ nest built		.50	.748 (n = 147)	.732 (n = 82)
Mean clutch size	1.71 ±0.066 (n = 49)	1.27 ±0.052 (n = 24)	1.56 ±0.048 (n = 115)	1.50 ±0.066 (n = 60)
Clutches with one of more eggs hatching			25.5% (n = 102)	61.72 (n = 37)
Mean brood size at hatching			1.15 ±0.074 (n= 26)	1.46 ±0.084 (n = 37)
Broods with young fledging	0.0%	0.0%	7.7% (n = 2)	56.7% (n = 21)
Mean brood size at fledging	0.0	0.0	1.0 (n = 2)	1.24 ±0.094 (n = 21)
Young fledged from eggs laid	0.05 (n = 83)	0.0% (n = 94)	1.1% (n = 179)	28.9% (n = 90)
Mean number of young raised per pair	0.0	0.0 (n = 148)	0.015 (n = 137)	0.361 ±0.073 (n = 72)

[1] D.J. Snarski 1970, 1971 and Unpubl. Ms.

Table 4. Foods delivered to black-legged kittiwake young, 1978 and 1979.

Species	1978			1979		
	Weight in grams	Percent weight	Percent frequency of occurrence	Weight in grams	Percent weight	Percent frequency of occurrence
Pisces	97.16		100.0	147.55		87.5
Ammodytes hexapterus	66.7	68.6	71.43	18.2	11.5	37*5
Mallotus villosus	13.9	14.3	14.29	0.0	0.0	0.0
Theragra chalcogramma	11.9	12.2	7.14	62.25	39.4	50.0
Mixed *A. hexapterus* and T. *chalcogramma*	0.0	0.0	0.0	36.4	23.0	12.5
Unidentified pisces	4.5	4.6	21.43	30.7	19.4	12.5
Crustacea	0.16		14.29	10.4		12.5
Thysanoessa inermis	0.06	0.1	7.14	10.4	6.6	12.5
Unidentified crustacea	0.1	0.1	7.14	0.0	0.0	0.0
		n = 14			n = 8	

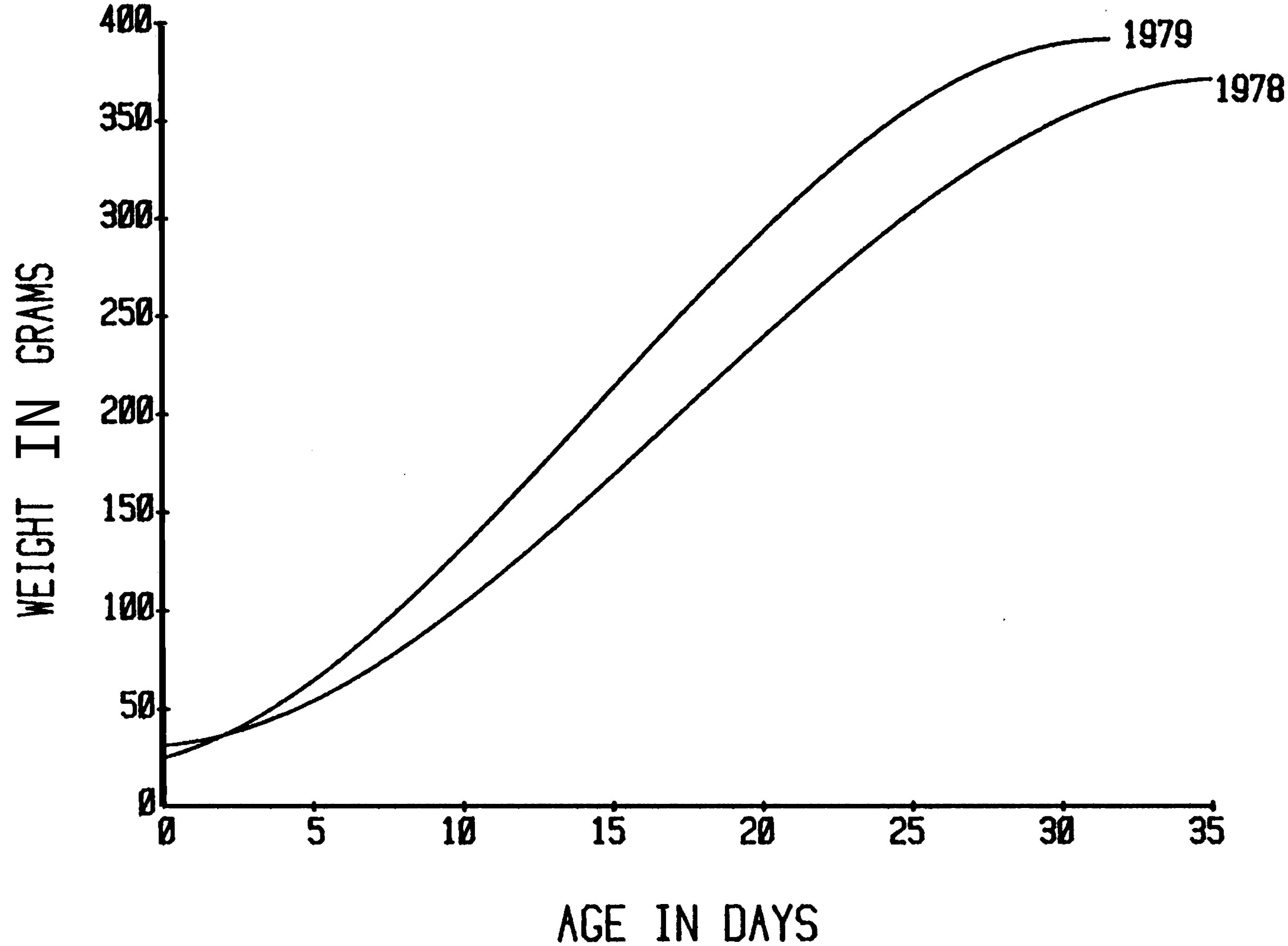

Fig. [illegible]. Comparative growth curves of black-legged kittiwakes in two years.

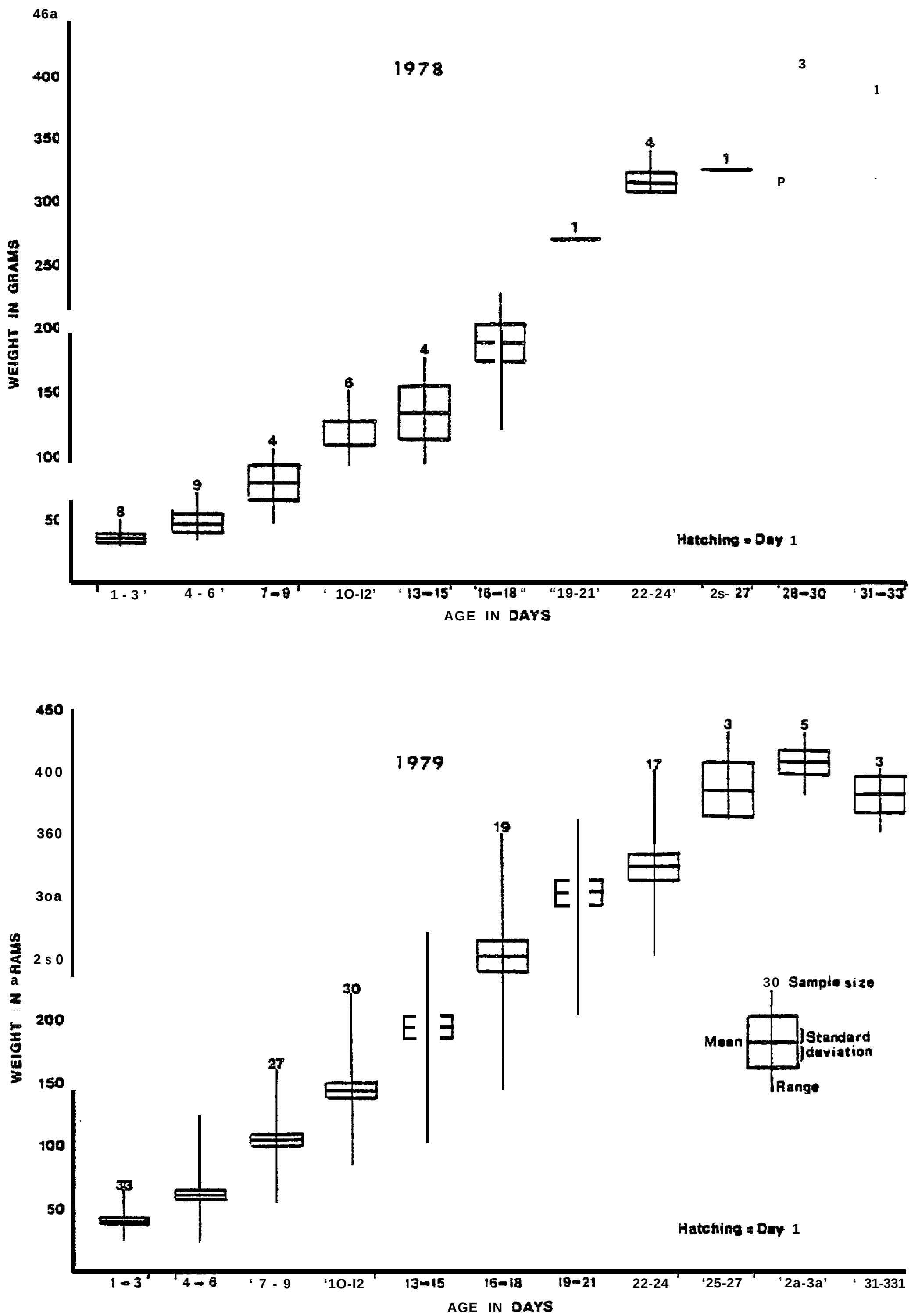

Fig. 5. Comparative growth of black-legged kittiwakes in two years.

suggested in 1978 that the reproductive failure of that year had its origin in part on an inability of the adults to secure adequate food supplies. We based that opinion on the erratic and depressed growth rates of the chicks. In 1979 we found a lag in the growth of chicks that ultimately failed to fledge, and we wish to emphasize this. We have already noted that kittiwakes gain success in reproduction as they gain experience at it, and this lag in growth bears on that point. It indicates the presence of adult birds not pursuing the goal of success as diligently as it requires. And it illustrates another point already made: the importance of the age distribution in the population. If a large proportion of the nesting adults were inexperienced birds, which appears to have been the case in 1978, the overall productivity of the colony slips perceptibly. Which in turn underscores the need for continuous long-term studies of these colonies.

HORNED PUFFIN

Nest distribution and abundance.

Horned puffins choose nest sites under ground, usually in rock cavities, where they lay their single egg on loosely scattered vegetative material brought from outside the burrow. In the usual situation they form colonies such as the one we studied on the slopes of Duck Island, but they also nest as scattered pairs along the cliffs of Chisik Island and at least one other island in Tuxedni Bay (Fig. 6). They nest in high densities in several caves formed on Duck Island by weathering and shifting of the rocks. No puffins nested in the alder covered slopes on either island, though some chose sites in the edges of the brush. Puffins propel themselves with their wings while diving, an adaptation that places severe limitations on their flight characteristics. They approach land in a stalling attitude which allows no maneuvering through brush.

In ten marked study plots we found an average of 0.18 (±0.04) burrows per square meter (range 0.04 to 0.44), but this does not appear representative of the entire colony and we prefer not to project a population estimate on this basis. We estimated the colony to number about 6,000 birds, but this must be viewed in the context of wide confidence limits.

Breeding chronology.

Horned puffins began laying eggs June 5 in 1978 and continued to June 29 with 66% of the laying done between June 10 and 23. (Table 5) In 1979 laying spanned June 15 to July 4 with 66% done between the 19th

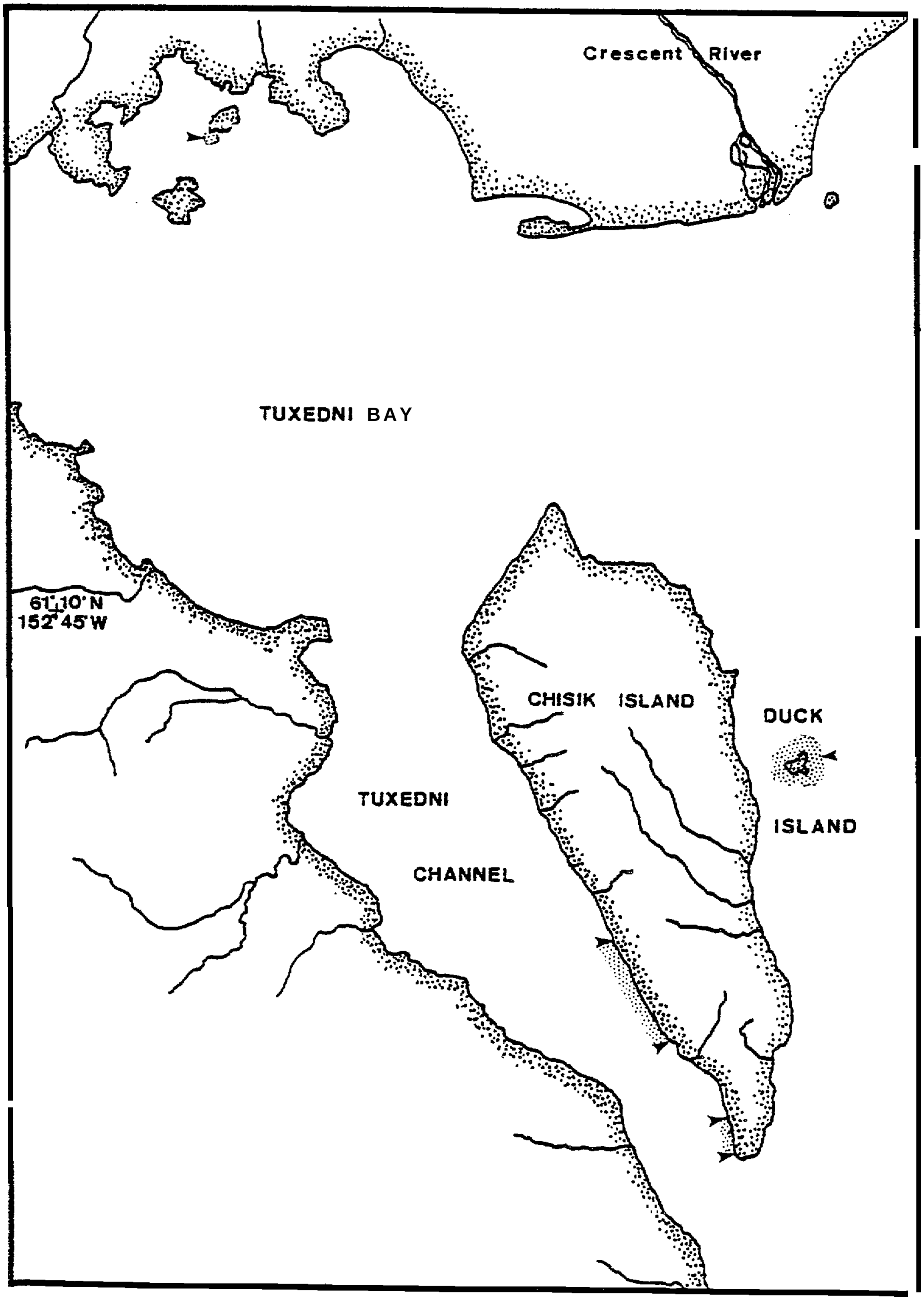

Fig. 6. Nesting distribution of horned puffins in Tuxedni Bay.

Table 5. Nesting chronology of horned puffins - 1978 and 1979.

Event	1978	1979
Egg laying	5 - 29 June (n= 29)	14 June - 2 July (n= 32)
Modal egg laying (2/3 of pop.)	10 - 23 June	19 - 26 June
Hatching	18 July - 27 July	25 July - 4 August
Modal hatching	19 - 26 July	26 July - 1 August
Fledging	28 August - 19 September (n = 20)	30 August - 11 September

and 26th of June. Fledging began at the end of August in 1978, and we left the island before completion. In 1979 fledging occurred between August 29 and September 10.

Productivity.

Most puffins that established burrows on the study plots in 1978 laid eggs (96.7%), but fewer (69.6%) did so in 1979 (Table 6). They lay a single egg, and we observed no instance of laying a replacement after losing the first one. Only slight egg loss occurred in 1978, but increased in 1979. The chicks that fledged in 1979 did so at a heavier weight than those in 1978 (Fig. 7), but we question the reality of the difference shown by such small samples.

We think our investigations caused at least part of the increased loss at all stages. Each time we approached the island large numbers of puffins flew away. The same thing happened when we went to another section of the island to reload the time-lapse camera, and the photos showed that they did not return for several hours. Evidently the presence of humans has an effect beyond the immediate moment of intrusion.

Some natural losses to gull predation may occur if the chick steps out of the burrow to defecate or stretch its wings late in the growing period. Other losses reported by us may not be real, for in some instances the chick may move to an inaccessible part of the burrow.

Food habits and feeding areas.

Puffins signalize the end of incubation by initiating food deliveries to the chick. This they do by pursuing and catching small fish underwater, then carrying them to the burrows. They carry these items clamped crosswise in their bills, usually more than one at a time. At Duck Island, while we were present they usually approached the colony and flew around in an elliptical pattern several times before landing and delivering the fish. We think this may not be typical. Once having landed, the bird disappeared into the burrow without delay, and reappeared shortly thereafter.

At Duck Island all the fish we observed being delivered in 1978 by puffins, and all those we collected from puffins were sand lance.

That pattern very nearly repeated itself in 1979. In one case a puffin delivered three capelin *Mallotus villosus*, and in another two pink salmon *Oncorhynchus gorbushka*. Other than these two exceptions all the many hundreds of fish we observed being delivered in 1979 by puffins were sand lance. We recorded numbers of fish being carried by puffins when that was possible with the results shown in Table 7. The average number of fish per delivery that may be calculated from the above data (2.3) has no meaning. These data represent a time span of 34 days, over which the demands of the chick increased, and the frequency of larger numbers per delivery increased.

Table 6. Reproductive success of horned puffins - 1978 and 1979.

	1978	1979
Pairs laying eggs on sample plots	96.7% (n = 25)	69.6% (n = 23)
Mean clutch size	1.0 (n = 29)	1.0 (n = 32)
Clutches with eggs hatching	72.7% (n = 29)	43.7% (n = 32)
Broods with young fledging	92.3% (n = 26)	71.4% (n = 10)
Mean number of young raised per pair on sample plots	0.60 (n= 25)	0.24 (n = 23)

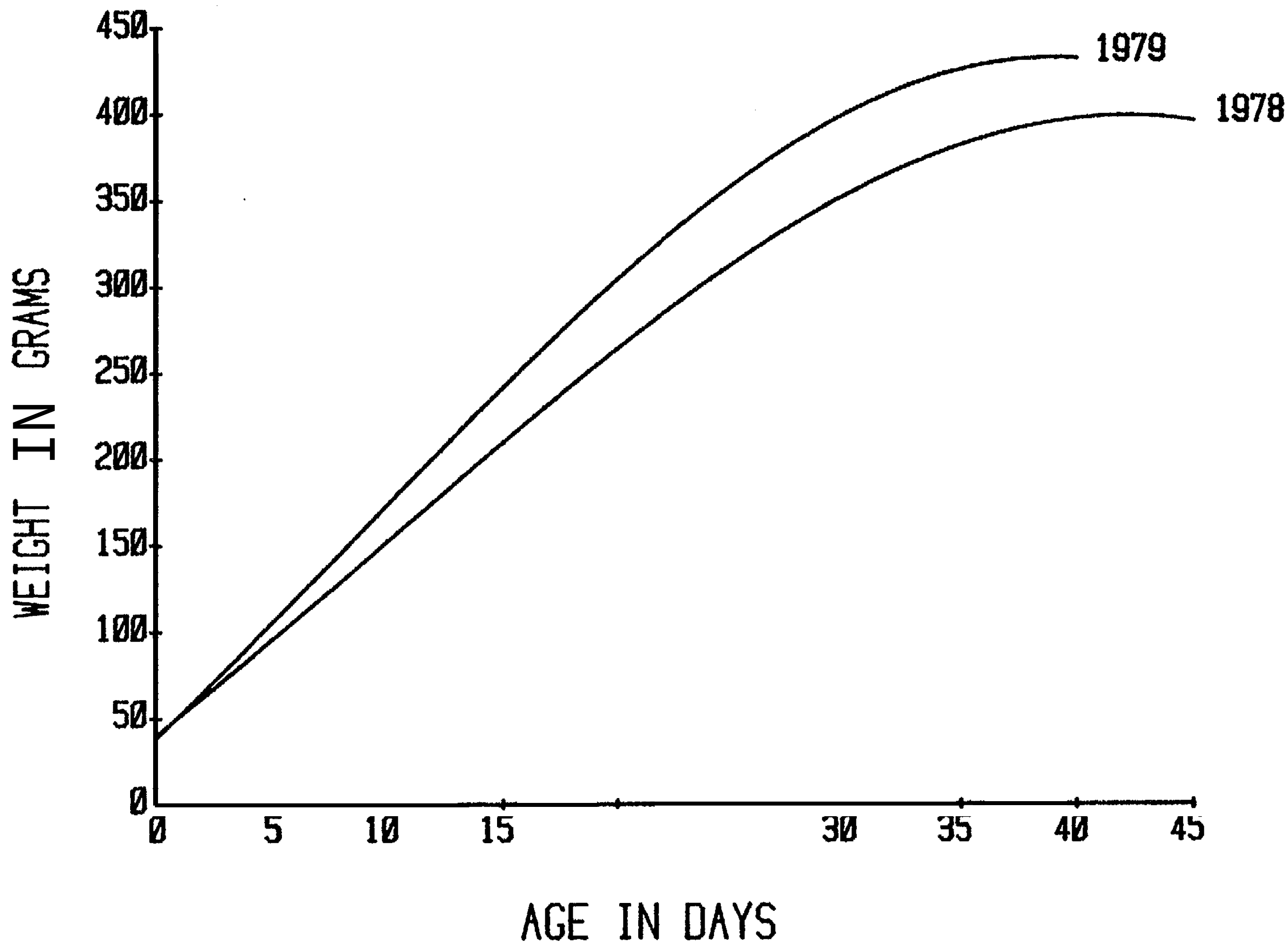

Fig. 7. Comparative growth curves of horned puffins in two years.

Table 7. Numbers of fish delivered by 199 horned puffins - 1979.

Numbers of fish	1	2	3	4	5
Numbers of deliveries	54	66	48	28	3

In Newfoundland Nettleship (1972) observed cleptoparasitism (piracy or robbery) of food-carrying common puffins *Fratercula arctica* by herring gulls *Larus argentatus*. We watched for this, and on August 17, 1979 observed a glaucous-winged gull make six attacks on food-carrying puffins at Duck Island. In one of these instances the puffin dropped the single fish it carried, but without the gull obtaining it. We did not observe this activity on any other occasion.

Adult puffins did not appear to forage for food near Chisik or Duck Island, although they frequently occurred in rafts on the water near the colony. However, they sometimes delivered living fish, indicating nearness of the foraging area. For an understanding of the major prey we refer the reader to the discussion of sand lance in the section of this report concerning kittiwakes.

Other authors, e.g., Nettleship 1972, emphasized the timing of puffin forage activitiy just after daybreak, but in the time-lapse photos of horned puffins on Duck Island a full hour intervened between daybreak and the appearance of puffin activity. We entertain the intuitive opinion that the Duck Island puffins have little difficulty catching sand lance, but we conducted no experiment to verify this.

On September 4, 1978 we crossed the Inlet by boat to a landfall at Anchor Point, and observed nine newly fledged young puffins in water depths not exceeding 100 meters. A year later we crossed September 14th, after the puffins on Duck Island had fledged, and observed no newly fledged young. This suggests they make their way promptly to the open sea, which they must do by swimming for they cannot fly. The connotation of flight associated with the term fledging does not apply to puffins. The developed chick jumps, tumbles, scrambles or walks from its burrow after nightfall to a solitary life at sea where it eventually develops the ability to fly.

Growth.

The curves we developed to represent puffin chick growth (Fig. 7) indicate comparable rates each year, except that in 1979 they reached heavier weights. Since the kittiwakes performed similarly we recognized the temptation to regard this a product of differential fish availability, but see no basis for this judgement relative to the puffins. We prefer to regard the difference in the two years as an artifact of small sample size.

COMMON -

Nesting distribution and abundance.

Murres nested on the cliffs on Chisik Island and the slopes and cliffs of Duck Island (Fig. 8). In the latter case they chose unusual sites within the dense alder stands, where they can be approached closely without disturbance.

Chronology.

We **observed murres while crossing the** Inlet in May of each year, and found them in large rafts near Duck Island. We did not attempt a close study of murres in 1978, but planned to take advantage of the unusual sites within and adjacent to the alders in 1979. Nuptial activity was in progress by June 12, 1979, both on the cliffs and in the alders. The birds in the alders landed on the cliff edge and walked *into* the vegetation with surprising agility, and no apparent reaction to moving under the canopy. Up to 200 birds gathered in one area amongst the alders at a location readily accessible for observation, and here we installed a time-lapse camera. We installed a second overlooking a cliff edge habitat. We saw the first murre egg June 26 in the alder area, and seven on July 1. On the 7th we found ten broken eggs in the same area, and observed one bird incubating an egg July 28. With the exception of two "pockets" of murres that produced less than 100 chicks, this was the *total* reproductive effort at Duck Island. The few chicks produced left the island in the first week of September.

GLAUCOUS-WINGED GULL

Nesting distribution.

Glaucous-winged gulls nested on the cliff faces of Chisik Island, the grassy slopes of Duck Island, and on small, mammal-free islands in Tuxedni Bay (Fig. *9).* Most nests were inaccessible to human observers, and densities could not be accurately estimated. We estimated a population of about 2,000 birds in Tuxedni Bay both years.

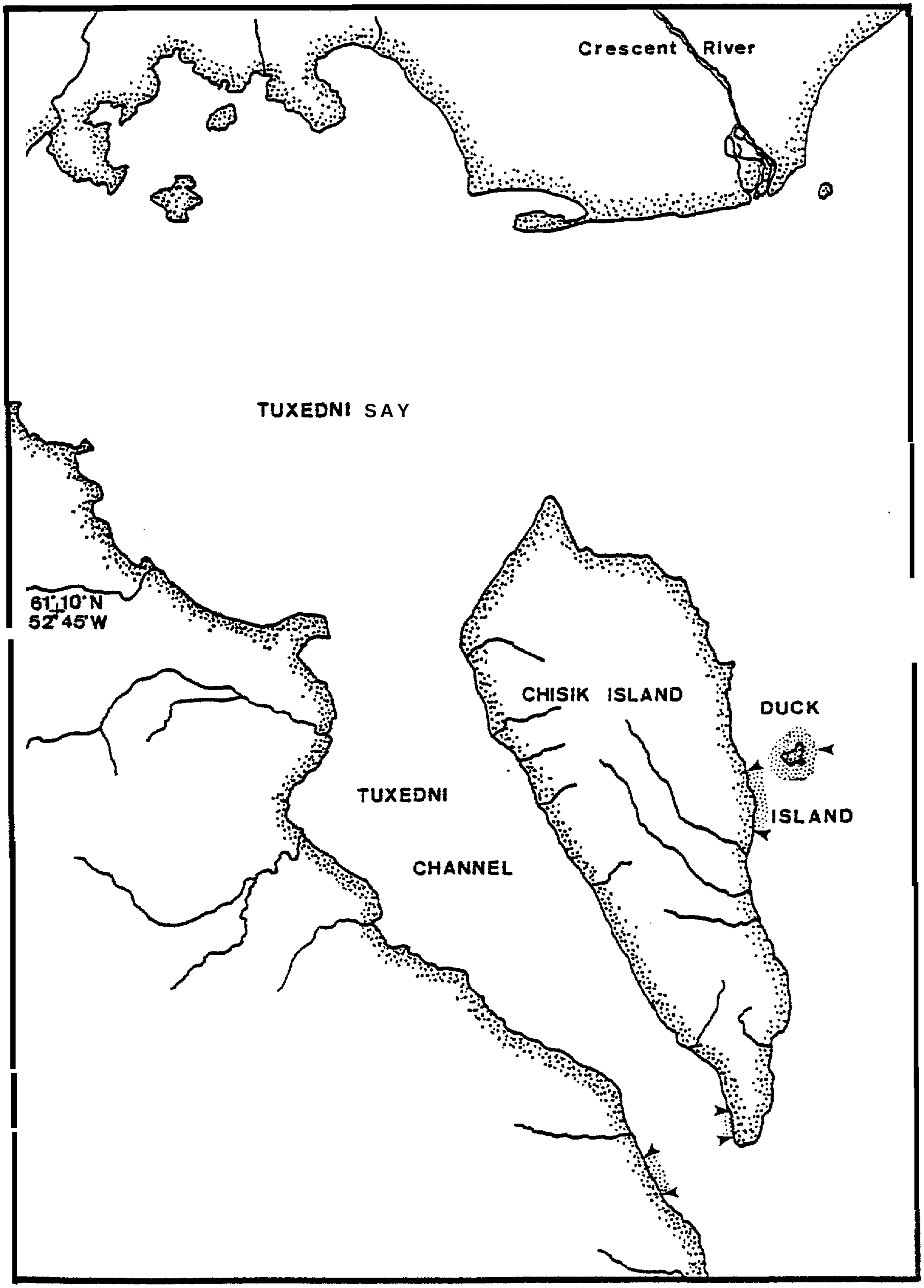

Fig. 8. Nesting distribution of common murres.

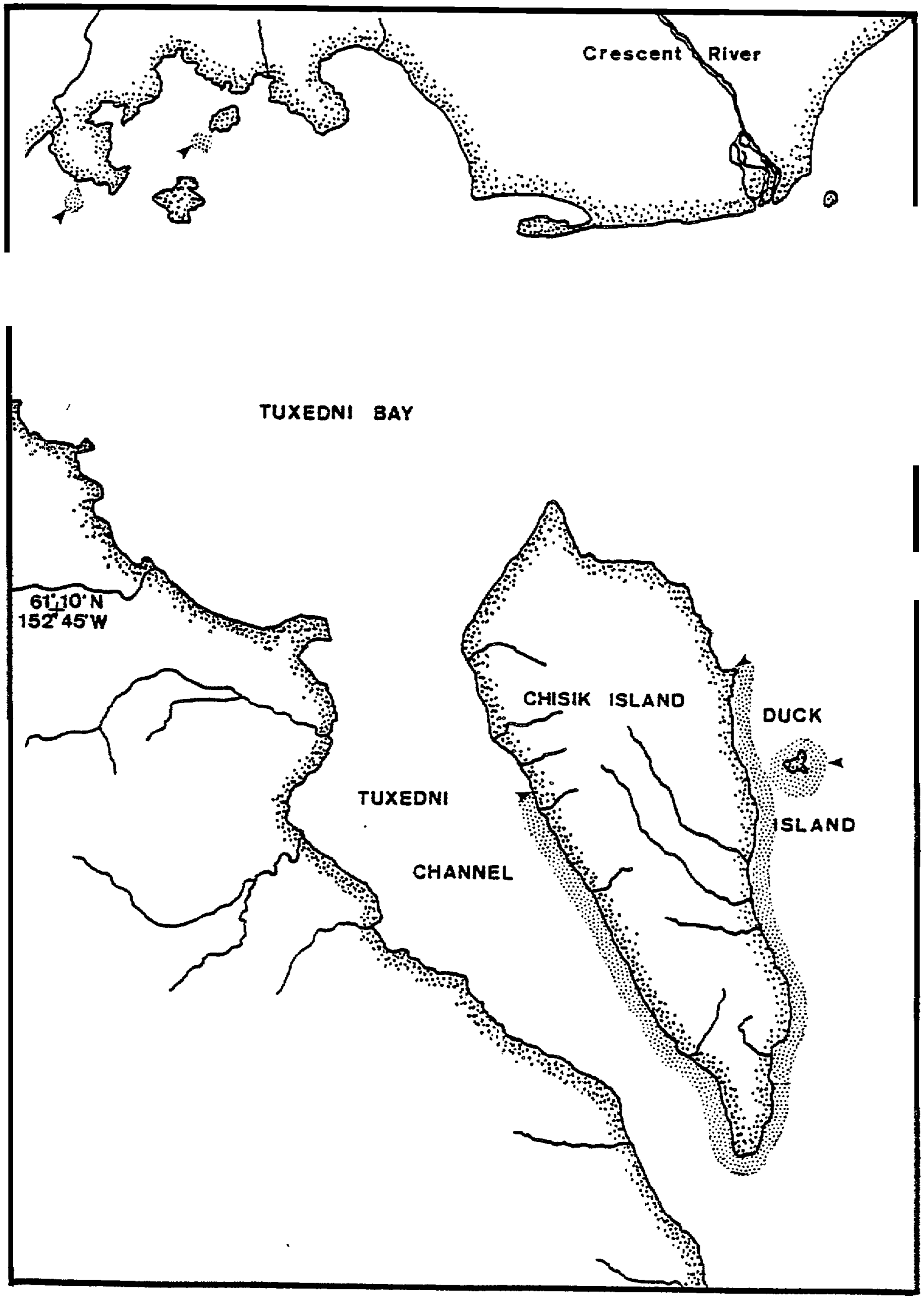

Fig. 9. Nesting distribution of glaucous-winged gulls.

MAMMALS

This study concerns birds, but we frequently observed marine mammals in Tuxedni Channel and the open Inlet and terrestrial mammals on the islands. Harbor seals *Phoca vitulina* commonly appeared as individual animals. As everywhere, their appearance evoked wrathful comments from the fishermen. Steller's sea lions *Eumatopias jubata* also appeared, though less frequently than seals, usually in the open Inlet. Beluga or white whales *Delphinapterus leucas* occasionally came in pods on a liesurely procession through Tuxedni Channel. Out in the Inlet, especially when we crossed in the boat, we encountered harbor porpoise *Phocoena vomerina* usually as single animals. To our surprise on May 13, 1979 we observed and photographed a live walrus *Odobenus rosmarus* on the east shore of Chisik Island, not far from the southern end. Equally surprisingly, we observed no sea otters *Enhydra lutris* in Tuxedni Bay either year.

Several terrestrial mammals occur on Chisik Island, but except for the little brown myotis *Myotis lucifugus* a bat, none exist on Duck Island. We did not observe bats, but detected their smell in the several caves on the Island. In 1978 we observed tracks made on Chisik Island by a small specimen of big brown bear *Ursus arctos*, and on one occasion saw a black bear *Ursus americanus* that visited the Island. Two mustelids, the marten *Martes americana* and short-tailed weasel *Mustela erminea*, and the tundra redback vole *Clethrionomys rutilus* and an unidentified shrew complete the list of mammals.

FACTORS AFFECTING PRODUCTION

Snarski (1970, 1971) reported two reproductive failures of Chisik Island kittiwake colonies, and we reported a third in 1978. He suggested poor food availability as a possible underlying cause, and our 1978 evidence led to the same conclusion. Dement'ev and Gladkov (1969) observed diminished fertility in kittiwakes as a function of reduced food availability. They recorded reduced clutch sizes in such cases: a mean of 1.6 in a year of low food availability contrasted with 2.3 in a good year. Egg production of the Chisik colonies in 1970, 1971 and 1978 yielded mean clutch sizes of 1.7, 1.27 and 1.56 respectively, and of these, few hatched. In 1979 clutch size was still low, but hatching success more than doubled and chick weight and survival improved. These differences may stem either from a real shortage of sand lance, or from a high proportion of birds inexperienced in the reproductive process and its demands (see our earlier discussion of age distribution). To date no study of sand lance in Alaska has been published, and we cannot estimate the range of natural fluctuations or underlying causes. However, what we know of *Ammodytes spp.* (reported earlier in this paper) suggests that in the absence of environmental change, such as temperature change or substantial pollution, the standing stock should be fairly stable. Regarding the effect of age distribution in the kittiwake population, we know that in 1978 it held few seven and eight year old birds (Snarski 1970, 1971), but probably substantial numbers of five year olds (Snarski Unpubl. Ms.). Five year olds are inexperienced birds (Wooller and Coulson 1977), which we suggest contributed to the reproduction failure in 1978, and a year later to be a better performance.

We have already discussed aspects of the weather, but wish to emphasize once again its importance in limiting kittiwake production. In the two years of our study an important difference occurred in the weather pattern. In 1978 strong winds with rain blew from both the northeast and the southeast. In this case only the nests on the west side of Chisik Island received protection. In 1979 storm winds blew only from the northeast, which meant that more nests were protected, contributing to higher reproductive success. We consider this especially important with relatively inexperienced birds.

In mixed seabird colonies such as those on Duck and Chisik Islands, glaucous-winged gulls exhibit marked predatory behavior (Gabrielson and Lincoln 1959). Any factor that drives the adult kittiwake away from egg or chick exposes it to the attention of these aggressive gulls. We estimate their population to number about 2,000 birds in Tuxedni Bay. They choose nesting sites among those of the kittiwakes on Chisik and Duck Islands in addition to other areas on Chisik and other islands in the Bay. During the years in which the Snug Harbor Packing Company processed clams or salmon the gull population received a subsidy of offal from the cannery. It appears that the gull population expanded in these circumstances, but has not declined since withdrawal of the subsidy in 1971. This agrees with the behavior of large-gull populations in the Atlantic Ocean off the New England States and Atlantic Provinces. There, according to William Drury (OCS Vertebrate Ecology Workshop, Oct. 17-19, 1978 Fairbanks, Alaska), though waste management has been brought under control in the last two decades, the large-gull populations have merely stopped growing but not returned to "natural" levels.

Many kittiwake chicks fall prey to glaucous-winged gulls, even after fledging. It appears that a lone kittiwake chick in its early flight experience is doomed to gull predation if it alights on the water. Nor are the gull chicks themselves immune from such attacks, though their greater size gives them more resistance.

Natural disturbances which drive the adult kittiwake off its nest include the activities of bald eagles *Haliaeetus leucocephalus*, common ravens *Corvus corax*, and occasional other Falconiformes. Of these a family of peregrine falcons *Falco peregrinus* with an eyrie across Tuxedni Channel from our campsite in 1978 proved the most disruptive. The falcons made daily forays to the colony south of the cannery. Their arrival at the south face of the cliff, the center of the colony, invariably provoked a massed flight of kittiwakes. The falcons actively pursued these birds while the glaucous-winged gulls flew along the cliff face in full view of the now exposed nest contents. Ravens also soared along the cliff face in these circumstances. The falcons appeared to have no difficulty in catching kittiwakes which they carried away in the direction of the eyrie. They probably took at least one a day. In 1979 the eyrie was not occupied and the level of disturbance was much reduced.

Our appearance on the colony beaches elicited a similar response from kittiwakes nesting on the lower cliff levels. Our presence did not produce the sustained disturbance of the falcon, and did not affect the higher levels, but for a time numerous nests were exposed. Some of the set-net fishing sites lie under the colonies, and during salmon fishing days the fishermen appear at these sites frequently, creating the same kind of disturbance. A few birds, most commonly the divers became entangled in the set-nets.

The most consistently disturbing activity on the Tuxedni Wilderness arises from its location on the flight path for all aircraft flying up or down the west side of the Inlet. Helicopters are the most disturbing of these, perhaps because of the pulsing sound they produce. Several operated in the vicinity of Snug Harbor in 1978, while others travelled up and down the coast all summer. One, Evergreen N59440, landed on the beach under the kittiwake colony August 13, 1978 and put every bird in the colony in flight. Light fixed-wing aircraft caused little disturbance unless they flew over the colony.

Ectoparasites.

We found ticks of the genus *Ixodes* abundant on Duck Island, and they infected the horned puffins, particularly the chicks. Their effect seemed negligible, but we made no determination.

In the major kittiwake colony at the south end of Chisik Island we found fleas *Ceratophyllus niger* the western chicken flea. Dr. Glenn Haas of the Alaska Department of Health and Social Services provided the identification.

These insects proved personally unpleasant since they jumped to our clothing and attacked us. We suffered multiple irritating bites until we identified the source. After that we examined our clothes carefully after each contact with a kittiwake nest, and destroyed the parasites that had transferred to us, but they showed an ability to hide in seams, hems and folds of clothing. We found that light-colored clothing made them conspicuous and easy to remove because of their dark color, and we adopted this as the uniform of the day when working the kittiwake colony.

We found no fleas on Duck Island in either kittiwake or puffin nests. We suspect exposure to weather produces this situation since all the material in kittiwake nests disappears from Duck Island, while at Chisik many survive the winter to be used a second year.

We cannot suggest just what role these pests play in kittiwake production, but it may be important to chicks in a marginal situation.

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