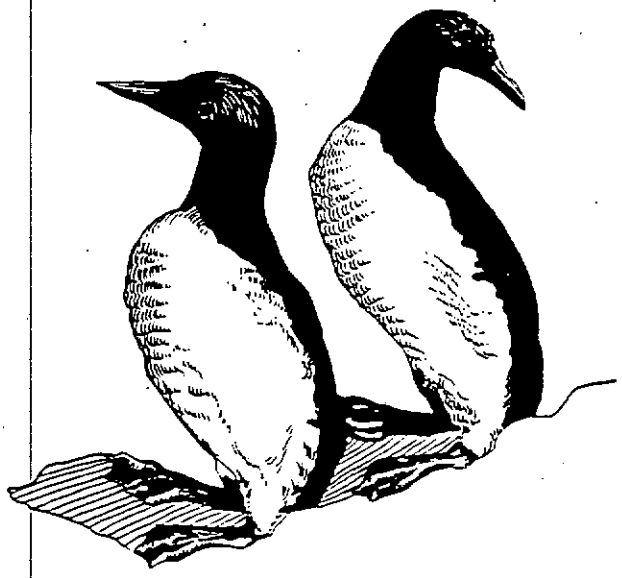
OCS Study
MMS 95-0025

Monitoring Seabird Populations in Areas of Oil
and Gas Development on the Alaskan Continental Shelf:

MONITORING POPULATIONS AND PRODUCTIVITY OF SEABIRDS

AT COLONIES IN LOWER COOK INLET, ALASKA, IN 1993 AND 1994



FINAL REPORT

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Alaska Maritime National Wildlife Refuge
Homer, Alaska

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By

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EXECUTIVE SUMMARY

As part of the Minerals Management Service's program to monitor seabird populations in areas of oil and gas development on the Alaskan continental shelf, surveys were made of breeding seabirds at colonies in lower Cook Inlet, Alaska, in 1993 and 1994. Survey efforts were devoted to all of the most common species including cormorants, kittiwakes, gulls, murres, and puffins. The primary study areas were Chisik and Duck islands near Tuxedni Bay, Gull Island and 60-foot Rock in Kachemak Bay, and Flat Islands near English Bay.

The objectives of the surveys in 1993 and 1994 were to assess population levels and reproductive success of key species. Furthermore comparisons were made with past data to assess trends. The 1993 study was more intensive and extensive than the 1994 surveys.

During the 1993 and 1994 breeding seasons, kittiwakes appeared to initiate nesting within the normal range of dates, but murres may have been slightly late. Most species of seabirds had relatively low rates of productivity in 1993 at Chisik and Duck Islands. Kittiwakes also failed at 60-foot Rock, and cormorant productivity was below normal. Reproductive success for kittiwakes at Gull Island was only slightly higher than at 60-foot Rock in 1993. In contrast, tufted puffins seemed to produce well at Flat Islands in 1993. In 1994, it appeared that reproductive success was better for kittiwakes at Chisik and Gull islands than it had been in 1993. In contrast, kittiwakes failed to produce young at 60-foot Rock in 1994.

Double-crested cormorants apparently have declined since the early 1970s at Chisik Island, but there was no indication of a decline in pelagic cormorants at Chisik and Duck or on the islands in Kachemak Bay. Glaucous-winged gulls increased or remained stable between the mid-1970s and the early 1990s at all colonies.

Black-legged kittiwake population trends varied among colonies. Apparently a slight decline occurred since the 1970s at Chisik and Duck Islands, but at Gull Island and 60-foot Rock the populations increased between the mid-1970s and the mid-1980s, stabilizing thereafter.

Common murres declined at Chisik and Duck Islands between 1970 and the mid-1980s, but the populations have remained stable since then. In contrast, numbers on Gull Island have increased since the mid-1970s. The population of murres on 60-foot Rock contained few if any breeders in 1993 and 1994, and the number of birds using the rock was lower than in the 1970s.

There were too few historical data to assess changes in populations of pigeon guillemots or tufted puffins. Furthermore, techniques have not yet been developed to assess population levels of horned puffins.

Over the past 20 years, it appears conditions have worsened for seabirds at Chisik and Duck islands while they have improved at Gull Island. In contrast, 60-foot Rock is a small, unstable colony. We could not judge trends at Flat Islands, but they currently have a substantial population of tufted puffins.

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ABSTRACT

In 1993 and 1994, we monitored the status of seabirds at major breeding colonies in lower Cook Inlet, Alaska, a region in which the U.S. Minerals Management Service (MMS) is considering offering new leases for oil development. The objective of the monitoring program was to collect information on population trends and patterns of reproductive success for selected species for assessment of potential impacts of the MMS leasing program.

Survey efforts were devoted primarily to cormorants, kittiwakes, murres, and puffins. Information was also gathered on gulls and guillemots. The primary study sites were Chisik and Duck Islands near Tuxedni Bay, the largest and most diverse seabird colonies in the area, at Gull Island and 60-foot Rock in Kachemak Bay, and at Flat Islands near Port Graham.

Our surveys and historical data that we reviewed provided a basis for evaluating changes in populations since the mid-1970s in some cases, and since the mid-1980s in most cases.

At Chisik and Duck Islands, the northernmost colonies in our survey of lower Cook Inlet, the predominant breeding species of seabirds have either declined or remained stable since the early 1970s. Double-crested cormorants, and common murres appear to have declined most. Black-legged kittiwakes may have declined slightly, and horned puffins also may have declined. There is no evidence of change for pelagic cormorants and glaucous-winged gulls.

At Gull Island, a different pattern was observed. Glaucous-winged gulls, black-legged kittiwakes, and common murres have increased between the mid-1970s and the early 1990s. Pelagic cormorants appear to have remained unchanged over the period.

Patterns of change at 60-foot Rock are less clear. At this small colony, counts of pelagic cormorants have been highly variable with no obvious pattern since the mid-1970s. Glaucous-winged gulls may have increased between the mid-1970s and mid-1980s and remained stable since. A similar increase apparently occurred for black-legged kittiwakes between 1976 and 1990, but numbers had declined by 1993 and 1994 to mid-1980s levels. Common murres have declined since the mid-1970s, but the colony is currently composed primarily of roosting, non-breeding birds, therefore it is difficult to assess trends because of high variability in attendance patterns.

The primary seabird nesting at Flat Islands is tufted puffin. We found approximately 500 nest burrows in 1993, but there were no historic data for comparison.

During the 1993 and 1994 breeding seasons, kittiwakes appeared to initiate nesting within the normal range of dates, but murres may have been slightly late. Most species of seabirds had relatively low rates of productivity in 1993 at Chisik and Duck Islands. Kittiwakes apparently had a nearly total breeding failure. Kittiwakes also failed at 60-foot Rock, and cormorant productivity was below normal there as well. Reproductive success for kittiwakes at Gull Island was also low, but they did not totally fail there in 1993. In contrast, puffins seemed to produce well at Flat Islands. In 1994, we had fewer data, but it appeared to be a better year at Chisik and Duck Islands than in 1993. In addition, black-legged kittiwakes had moderately good success at Gull Island in 1994, but they failed at 60-foot Rock as they had in 1993.

The only thing we learned about prey was that in 1993 horned puffins fed chicks mainly sand lance. The chicks grew at relatively normal rates so the amount of prey available during the chick-rearing phase must have been adequate.

Overall, it appears that conditions over the past 20 years may have worsened for seabirds at Chisik and Duck Islands while they have improved at Gull Island. Both remain substantial breeding colonies for seabirds. In contrast, 60-foot Rock is a small, possibly unstable colony. We have no basis for judging trends at Flat Islands, where the primary species of nesting seabird is tufted puffin.

INTRODUCTION

Seabird colonies in lower Cook Inlet include predominantly pelagic cormorant (*Phalacrocorax pelagicus*), double-crested cormorant (*P. auritus*), glaucous-winged gull (*Larus glaucescens*), black-legged kittiwake (*Rissa tridactyla*), common murre (*Uria aalge*), pigeon guillemot (*Cepphus columba*), horned puffin (*Fratercula corniculata*) and tufted puffin (*F. cirrhata*) (Sowls et al. 1978). These seabird populations are vulnerable to environmental disturbance and pollution that could possibly result from activities associated with oil and gas exploration and production (Snarski 1974). In light of this planned industrial activity, the Minerals Management Service (MMS) provided funding to the Alaska Maritime National Wildlife Refuge (AMNWR) to collect baseline information on the population size and reproductive performance of the most common species in the largest seabird colonies in lower Cook Inlet in 1993 and 1994. Monitoring studies enable biologists to evaluate the health of seabird populations and these studies provide a basis for assessing the effects of oil spills. Oil from the T/V *Exxon Valdez* spill did not surround colonies in lower Cook Inlet.

The primary objective of this project was to assemble past data and characterize the current status of seabirds at Chisik, Duck, Flat, and Gull Islands, and 60-foot Rock (Fig. 1).

The largest colonies of nesting black-legged kittiwakes, common murres, and horned puffins in Cook Inlet occur at Chisik and Duck Islands (Jones and Petersen 1979). Population estimates of kittiwakes were made on these islands in the early 1970s (Snarski 1970, 1971 a-c, 1974). Jones and Petersen (1979) investigated the breeding success of black-legged kittiwakes, and reproduction and feeding habits of horned puffins in 1978 and 1979. Biologists of the AMNWR have monitored populations and reproductive success of kittiwakes and murres intermittently throughout the 1980s (Jones et al. 1980, Kafka 1984, Muhlberg 1984, Beringer and Nishimoto 1988). Smaller colonies of common murres and black-legged kittiwakes have been monitored on Gull Island and 60-foot Rock by private consultants and government biologists periodically since 1976 (Erikson 1976, Nishimoto et al. 1987, Nishimoto and Beringer 1989, 1990) while little information on seabirds is available from Flat Islands (Sowls et al. 1978).

STUDY AREAS

Chisik & Duck Islands

Chisik and Duck Islands (hereinafter referred to as Chisik Island unless otherwise noted) are located on the western side of lower Cook Inlet (60° 09'N,152° 34'W, Fig. 1), and are part of the Alaska Maritime National Wildlife Refuge. Chisik Island is approximately 10.5 by 3.6 km in size, encompasses about 2606 ha, has a peak elevation of 815 m, and is located about 0.8 km from the mainland. Duck Island is 0.4 km east of Chisik, covers about 2.4 ha and reaches a maximum elevation of 49 m.

The vegetation on both islands is dominated by dense alder (*Alnus crispa*) thickets with an understory containing devil's club (*Oplopanax horridus*), salmonberry (*Rubus spectabilis*), elderberry (*Sambucus racemosa*), nettles (*Urtica Lyallii*), and several representatives of the Umbelliferae.

The islands are composed mainly of sedimentary materials such as sandstone, conglomerate, siltstone, and shale formations; surface layers are compacted fallout from volcanic eruptions of Mounts Redoubt and Iliamna (Mark

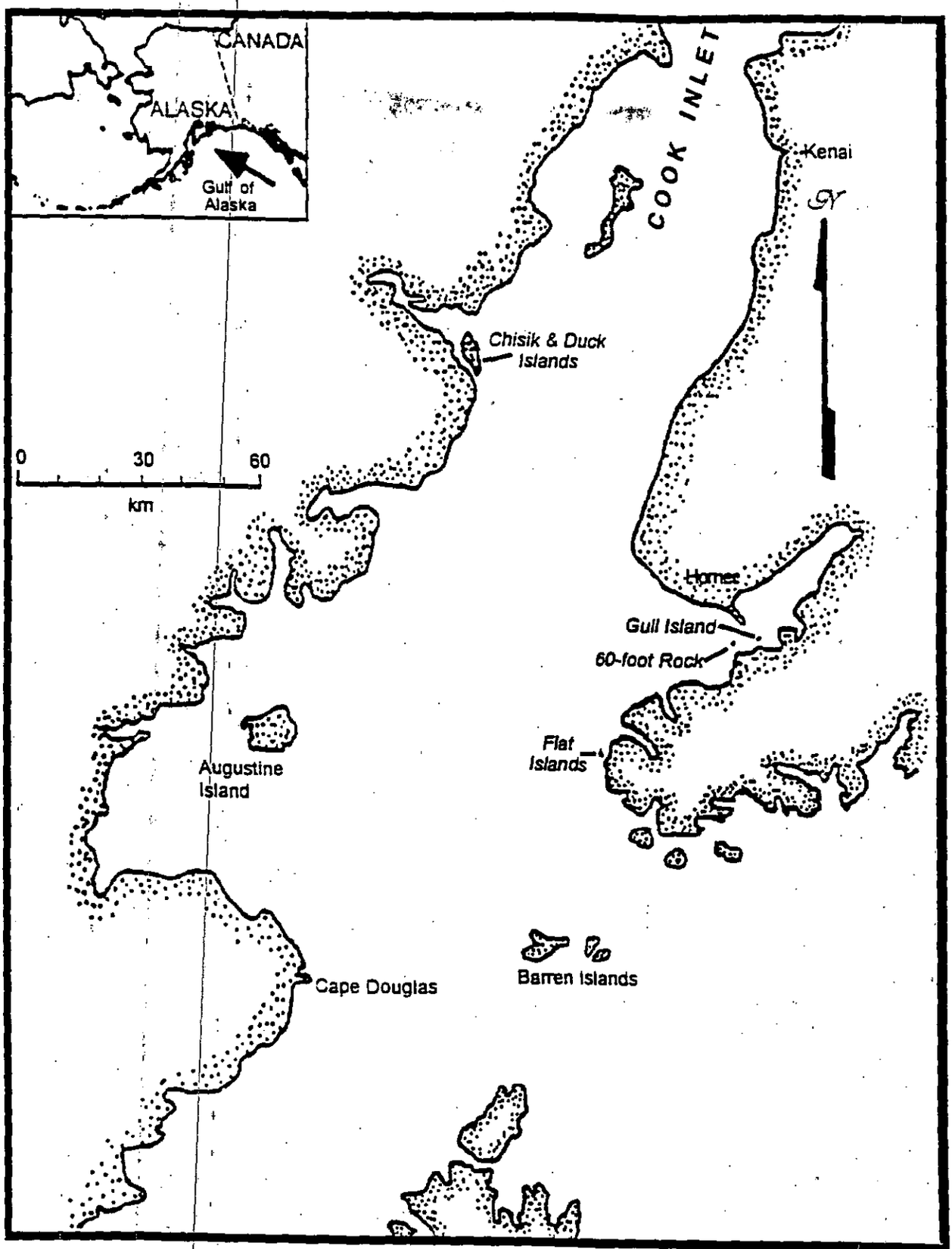

Figure 1. Study locations in lower Cook Inlet, Alaska.

Clark, Soil Conserv. Serv., pers. comm.). Substrate configuration results in continuous surface erosion and unsafe climbing conditions.

In the recent past the islands have supported breeding seabirds at the following approximate population levels:

double-crested cormorant: 150 birds
pelagic cormorant: 25-30 birds
glaucous-winged gull: 1000 birds
black-legged kittiwake: 18,000-20,000 birds
common murre: 3000-5000 birds
pigeon guillemot: 13 birds (on Fossil Point near Chisik)
horned puffin: 5000
tufted puffin: 1000

Kittiwakes nest primarily along cliffs located on the southwest side of Chisik Island, extending to the southern tip (Fig. 2). Smaller numbers of kittiwakes and the majority of murres have historically nested along the central portion of the eastern coast. Murres also nest at suitable ledges along the entire perimeter of Duck Island, and horned puffins nest in crevices found over much of Duck Island.

Gull Island & 60-foot Rock

Gull Island, owned by the Seldovia Native Corporation, is about five km southeast of the tip of the Homer Spit (59° 35'10"N, 151° 19' 45"W), and 60-foot Rock, part of the Alaska Maritime National Wildlife Refuge, lies about six km south of the Spit (59° 33'N, 151° 28'W) (Fig. 1). Both islands erupt sharply from the water and are composed primarily of fractured bedrock. Gull Island has three portions which are rarely connected at low tide (Fig. 3). Herbaceous and some woody vegetation grows on the plateau area of Gull Island while 60-foot Rock is mostly unvegetated.

Recent population estimates for seabirds occupying these islands follows:

Gull Island

pelagic cormorant: 250-300 birds
red-faced cormorant: 30-60 birds
glaucous-winged gull: 700-800 birds
black-legged kittiwake: 7000-8000 birds
common murre: 5000 birds
pigeon guillemot: 12-15 birds
horned puffin: 10
tufted puffin: 500

60-foot Rock

pelagic cormorant: 30-50 birds
glaucous-winged gull: 80-100 birds
black-legged kittiwake: 300-400 birds
common murre: 150-230 birds
pigeon guillemot: 2 birds
tufted puffin: 50 birds

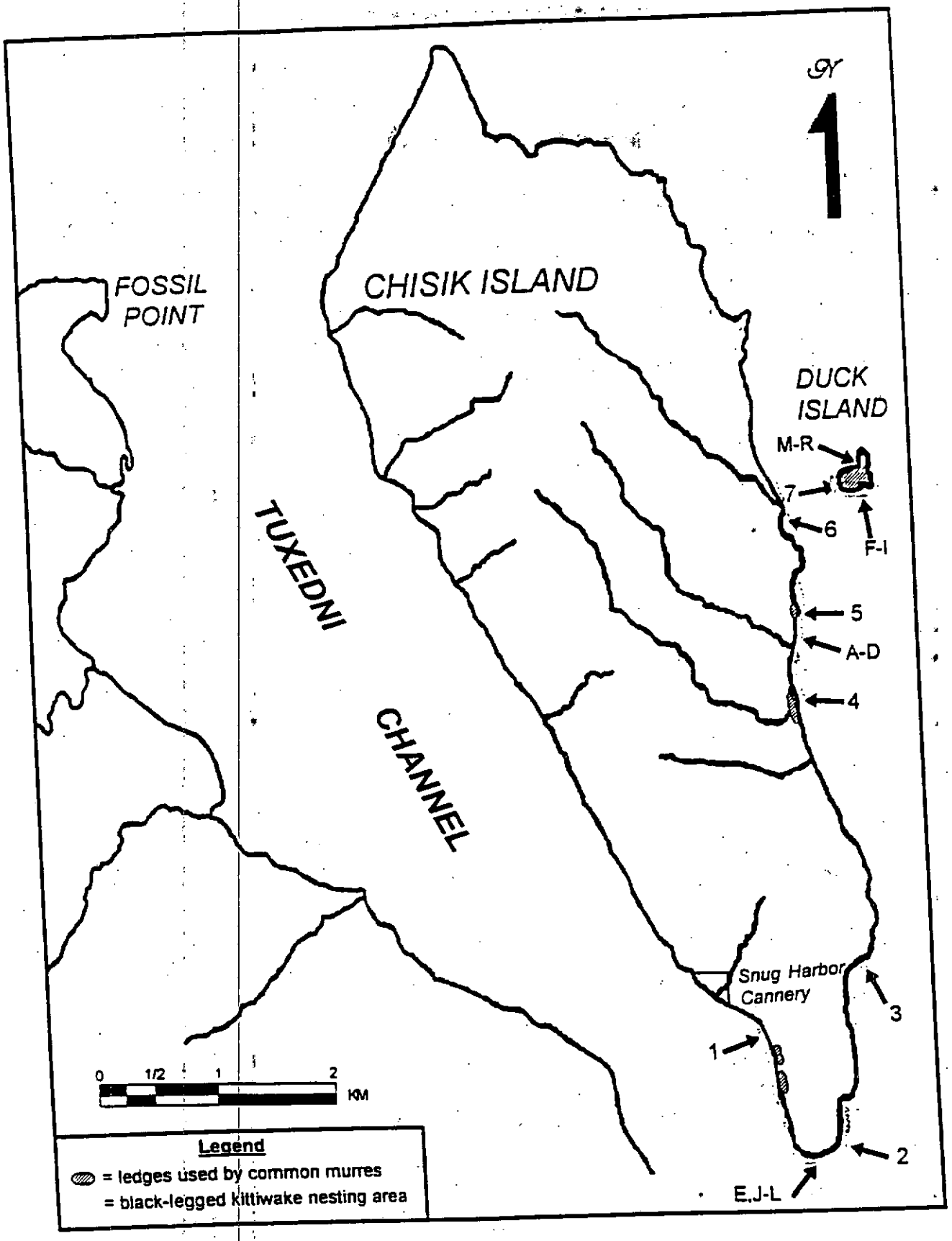

Figure 2. Nesting distributions of black-legged kittiwakes and common murres, and plot locations on Chisik and Duck Islands, lower Cook Inlet, Alaska.

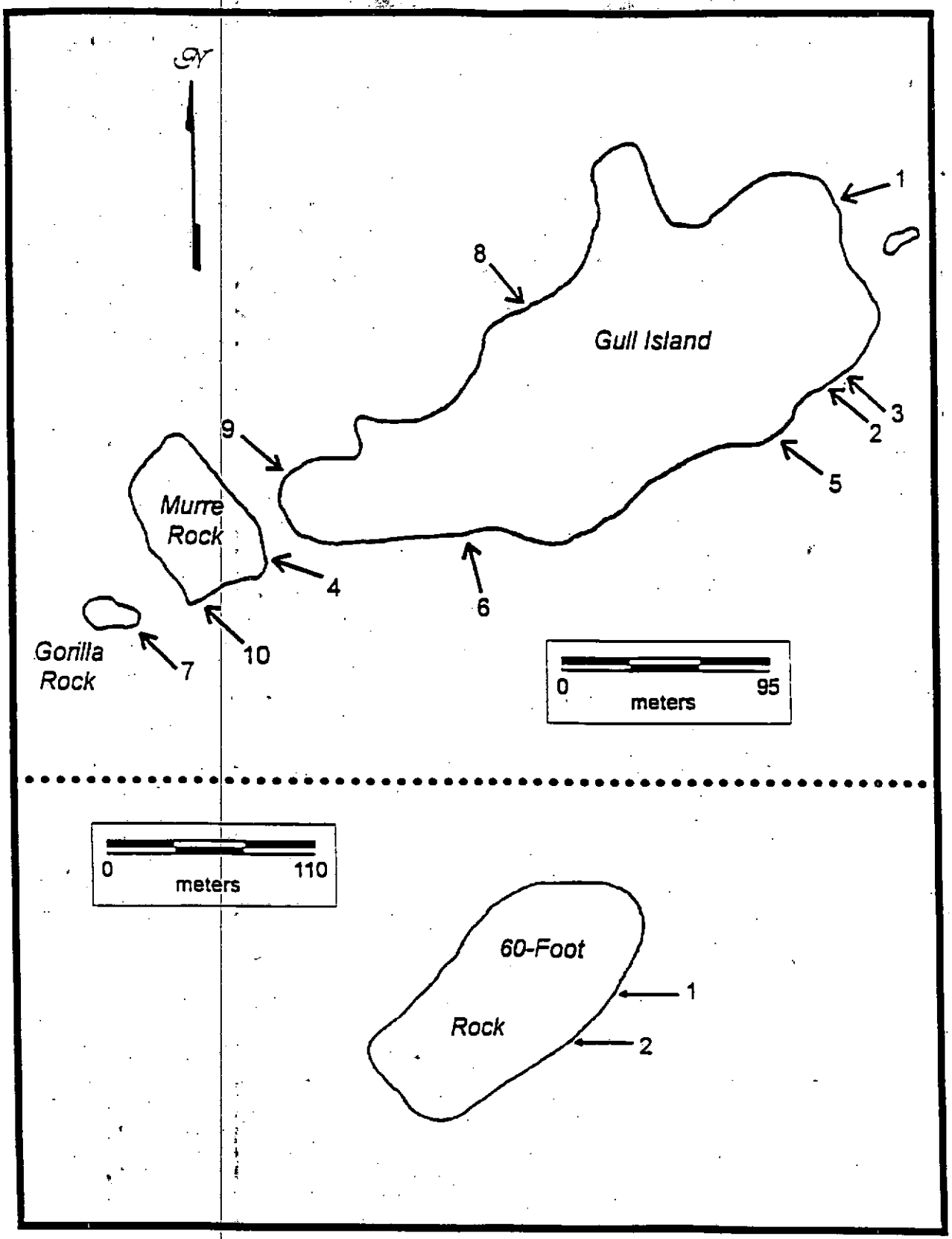

Figure 3. Seabird monitoring plot locations on Gull Island and 60-foot Rock, Kachemak Bay, Alaska.

Gull Island, and to a lesser extent, 60-foot Rock, are frequently visited by tour and charter boats throughout the breeding season. It is not uncommon for boats to approach within 25 m of nesting birds (pers. obs.).

Flat Islands

Flat Islands, a small cluster of islands occupying 2.78 ha and owned by the English Bay Native Corporation, are located in Cook Inlet about 21 km southwest of Seldovia (59°19'45"N, 151°59'45"W; Fig. 1). The main island is divided in north and south halves connected by an isthmus that is submerged at high tide (Fig. 4). The shoreline consists of cobbles and bedrock, and the island is vegetated by a dense cover of herbaceous plants with *Elymus mollis* and umbels dominating. Tufted puffins' burrows are found around the entire perimeter of Flat Islands except in areas where topography prohibits puffins from taking flight or soils are too shallow to accommodate burrows.

Recent population estimates for seabirds occupying these islands follows:

double-crested cormorant: 2 birds
glaucous-winged gull: 2 birds
pigeon guillemot: 15-20 birds
horned puffin: 4 birds
tufted puffin: 1000 birds

METHODS

More resources were applied to the project in 1993 than in 1994. Two people collected data on a daily basis at Chisik Island from 16 June to 14 September 1993, and additional observers helped complete population counts in mid-June (one observer), and late July and early August (two observers). Crews of three or four people counted ledge-nesting seabirds on plots (Fig. 2) during four visits to Gull Island (9 and 23 July, 11 and 31 August) and three visits to 60-foot Rock (20 July, 13 and 17 August). Two trips on 1 July and 17 August were made to Flat Islands to monitor burrow-nesting tufted puffins.

In 1994, Chisik Island was visited twice by two observers (5 to 13 July and 17 to 22 August). Gull Island and 60-foot Rock were surveyed by two to three observers on 30 June, 1 and 19 July, and 17 August. Flat Islands were not visited in 1994.

Population Counts

Population estimates were made using two methods. The first consisted of counting all birds on an island repeatedly and calculating a mean number of birds attending colonies. This method was used on Chisik and Duck Islands and 60-foot Rock.

A second method, also employed on Chisik, Duck and Gull Islands, and 60-foot Rock, used a series of plots to provide an index to population trends (Figs. 2 and 3). The number of seabirds using an island or a series of plots was estimated by counting birds within permanent study plot boundaries established during, or prior to, this study. Plot boundaries were delineated on photographs taken of cliffs located on each island. Plot size and location were chosen to monitor a proportion of the total population (e.g., five percent on Chisik Island) and to subdivide the colony into easilyidentifiable units. Counts were typically made by two biologists in a watercraft kept within 100 m of the plot. Using binoculars (8- or 10-power) and reciprocating counters to tally individuals, the observers made repetitive counts until the difference between their totals was ten percent or less. Once obtained, the mean of the two counts was used as the population total for the respective plot. Population estimates were made by combining the count total from all plots located on an island.

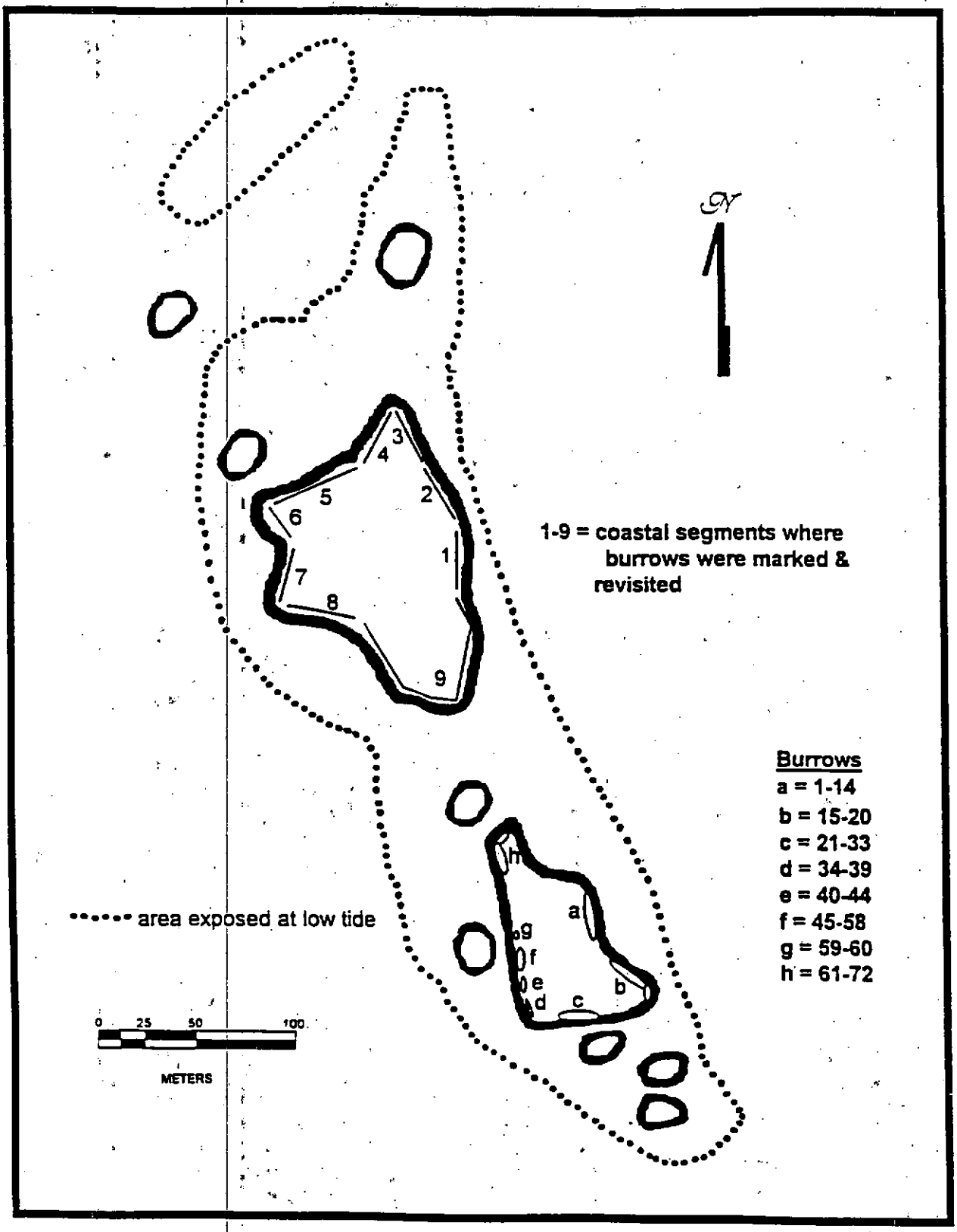

Figure 4. Tufted puffin nesting distribution on Flat Islands, Kachemak Bay, Alaska.

Population counts were made in late-June to mid-July when the maximum number of breeding birds was present (i.e., before failed breeders left), and between 1000 and 1800 hrs when within-day variability in nest-site attendance was lowest (Dragoo et al. 1991).

Using the procedures outlined above, counts of black-legged kittiwakes, pelagic cormorants, and common murres were made on seven previously-established permanent plots on Chisik Island (Nishimoto et al. 1987) and on an additional plot established in 1993 (Fig. 2). The additional plot was established in the only area where adults remained throughout the breeding season. Counts of all ledge-nesting seabirds on Gull Island and 60-foot Rock were made on permanent plots previously established by AMNWR personnel.

Total island counts of nesting tufted puffins occurred for the first time on Flat Islands as a part of this study. We recorded the number and status of all tufted puffin burrows located along the perimeter of Flat Islands in early July. All active burrows (i.e., those with fresh excavation, shell fragments, feathers or droppings) were uniquely flagged on the north half of the island and rechecked during a second visit in mid-August. An estimate of breeding success was determined by dividing the number of burrows still active during the second visit by the total number of burrows initially marked.

We used a different procedure to count pigeon guillemots. Observers anchored within 100 m of the guillemot colony at Fossil Point on the northwest side of Tuxedni Channel, Chisik Island (Fig. 2) to count adults during incubation and early chick rearing. Adults show territorial behavior during incubation (mid-June to mid-July at other colonies), which optimizes counts of successfully breeding guillemots. Tide state also influences adult presence near colonies, so we attempted to conduct surveys near high tide (Andres 1993).

Phenology

Twelve land-based plots were used to follow breeding events and productivity of black-legged kittiwakes and common murres on Chisik Island. These plots were visited every 2-3 days to record reproductive status (e.g., clutch size, hatch, and fledging) of each nest until the birds departed. Since the eggs and chicks of common murres are difficult to see, observers relied on behavioral cues to indicate reproductive status (after Mendenhall et al. 1991). Birds exhibiting incubating postures during three consecutive visits were considered to have an egg, and birds showing brooding posture (see Byrd 1989 for description of behaviors) were assumed to have a chick. We used direct observations of eggs or young for kittiwakes. Phenology of horned puffins was determined by examining occupied crevices to record the presence of eggs or chicks about once every five days. In cases where the reproductive status of a site changed between visits, we used the intermediate date between the two visits.

Productivity

Procedures for estimating productivity varied among species depending on access of sites for observation. Cormorant productivity was determined by counting the number of chicks produced per nest on each plot where cormorants attempted to breed. Active nests were defined as those having vegetation added during the current breeding season. Crude estimates of glaucous-winged gull productivity were made by counting maximum numbers of chicks on plots.

For black-legged kittiwakes productivity was determined on Duck and Chisik Islands in 1993 by monitoring active nests within designated plots throughout the breeding season. We defined active kittiwake nests as we did for cormorant nests, i.e., those containing vegetative material added in the current breeding season. Twelve land-based plots (Fig. 2) were established, eight on Chisik and four on Duck, where nest contents could be viewed with binoculars and spotting scopes, or a six m pole with a mirror attached to the top. From each plot, we counted: 1) the total number of nests, 2) the number of nests with one or more eggs, 3) the total number of eggs, 4) the number of nests with one or more chicks, 5) the total number of chicks, 6) the number of nests where one or more chicks fledged, and 7) the total number of chicks that fledged (after Dragoo and Sundseth

1993). Using plots as the sampling unit for analyses, we used a ratio estimator (Byrd 1989) to estimate the following parameters: 1) clutch size, 2) nesting success, 3) hatching success, 4) chick success, 5) egg success, 6) fledging success, 7) reproductive success, and 8) overall productivity. The final two parameters are defined as the number of nests where $\geq$ one chick fledged/number of nests with $\geq$ one egg, and the number of nests where $\geq$ one chick fledged/total nest starts, respectively. The reproductive parameters listed above are commonly used in other studies of seabirds and allow inter-year comparisons within a colony and within-year comparisons among colonies to be made easily.

At Gull Island and 60-foot Rock we also used plots to monitor kittiwake productivity (Fig. 3), but visits were less frequent and observations were made from the water.

For common murre productivity, observers recorded: 1) the number of sites with one or more egg, 2) the number of sites with a chick, and 3) the number of sites where a chick fledged (after Dragoo and Sundseth 1993). Data were used to estimate hatching success, fledging success, and reproductive success (as defined above). Chicks were assumed to have fledged if they were 11 days or older when sighted last.

Productivity of horned puffins was estimated on Duck Island in 1993 by monitoring a sample of nesting crevices that could be examined consistently (i.e., crevices into which a light beam could reach the end). Crevices were checked once per week from late June through mid-September for the presence of eggs, chicks, and adults. Since each crevice contained an egg when the study was initiated, estimates of productivity were limited to hatching and fledging success. Horned puffins do not nest on any of the other islands included in this study.

Chick Growth & Diet

Growth rates and diet of horned puffin chicks were monitored at crevices on Duck Island from mid-July to mid-September 1993. Chicks were removed from uniquely flagged crevices twice per week, weighed and measured for right wing chord length before being returned to the proper crevice.

To obtain estimates of size and species composition of food eaten by chicks, we collected prey brought to crevices by adults. Crevice entrances were blocked by squares of hardware cloth (about 25 x 1 cm mesh) after adults had departed to feed and were typically rechecked after 3-5 hours. Adults sometimes drop their prey at the crevice entrance when access to their chick is blocked. Prey were measured, weighed, and returned to the chicks in most cases. Prey that could not be identified were collected, labelled, and preserved in formaldehyde. We also collected prey samples opportunistically when found at an unflagged crevice entrance. On one occasion, prey samples were taken from five crevices where chick growth was also being monitored. Although this may have minimally affected chick growth, we assumed that the absence of one meal would not affect the overall growth rate.

RESULTS & DISCUSSION

Chisik and Duck Islands

Double-crested Cormorant

Populations.--In 1993, double-crested cormorants were observed occasionally on the cliffs of both islands. Although they were not present on established population plots on Chisik Island in 1993 or 1994 (Table 1), a nesting colony of about 60 adults was found 300 m north of the Snug Harbor cannery and a colony of about 100 individuals was on the northeast cliffs of the island. The latter figure is only approximate because the colony is located approximately 600 m above sea level and is difficult to observe.

Table 1. Summary of double-crested, pelagic, and red-faced cormorant population estimates on plots in lower Cook Inlet colonies.

Location	Year	Estimate[a]				Source	Comments
		DCCO[b]	PECO[c]	RFCO[d]	Unknown species		
Chisik Island (plots 1-7)	1986	1 (1)	0	0	4 (2)	Nishimoto et al. 1987	
	1987	1 (1)	0	-		Beringer & Nishimoto 1988	
	1993	0	0	0	0	this study	
	1994	0	0	0	0	"	
Gull Island	1986	0	55(20)	0		Nishimoto & Thomas 1991	plots 1-8
	1987	0	44(15)	0		"	plots 1-8
	1988	0	43(21)	0		"	plots 1-8
			49(22)			"	plots 1-10
	1989	0	30(16)	0		"	plots 1-8
			33(16)			"	plots 1-10
	1990	0	38(21)	0		"	plots 1-8
			39(21)	1(1)		"	plots 1-10
	1992	0	6(5)	0		Erikson, unpubl. data	plots 1-8
			6(5)	1(1)			plots 1-10
	1993	0	39(25)	0		this study	plots 1-8
			41(26)	0		"	plots 1-10
	1994	0	43(26)	0		"	plots 1-8
			44(27)	0		"	plots 1-10
60-foot Rock (plots 1-2)	1985	0	0	0		Nishimoto et al. 1987	
	1986	0	0	0		"	
	1987	0	0	0		Nishimoto & Beringer 1989	
	1988	0	0	0		"	
	1989	0	(2)	0		Nishimoto & Thomas 1991	
	1990	0	0	0		"	
	1993	0	3(0)	0		this study	
	1994	0	0	0		"	

[a] estimate is the mean of counts pooled for plots, nests in parentheses
[b] double-crested cormorant
[c] pelagic cormorant
[d] red-faced cormorant

Roosting double-crested cormorants were seen on and near murre productivity plots 5 and 6 on Duck Island on an irregular basis. The number of roosting birds peaked in the late afternoon, with a maximum of 155 birds observed on 21 August. Some of them may have been young-of-the-year that hatched on Chisik Island.

Although double-crested cormorants were more abundant than pelagic cormorants at Chisik Island, less is known of their breeding activities because they tend to breed on higher, less accessible and less visible cliffs. Counts of double-crested cormorants on Chisik and Duck in 1993 (160 birds) were similar to counts in 1983 (150), but lower than estimates in the early 1970s (Appendix 1).

Pelagic Cormorant

Populations.--Pelagic cormorants did not use any established plots, and fewer than 30 adults constructed nests in the vicinity of our plots in 1993. This nesting area appeared to have undergone significant physical changes resulting from rock slides prior to our visit in July 1994. Consequently, there was no evidence that cormorants used this area in 1994. In fact, only two pelagic cormorants were seen during the two brief visits to Chisik in 1994.

Colony numbers were similar to counts in the early 1970's (Appendix 1). It appears that Chisik Island has been used fairly consistently by pelagic cormorants over time with a maximum of about 30 nesting birds. Strong conclusions regarding the breeding population are difficult to make, however, because cormorants show variable site fidelity.

Breeding Phenology.--Twelve nests were built between 16 June and 12 July 1993 on cliffs between plots 3 and 4. We had no vantage point to view nest contents, so status could not be determined until chicks grew large enough to be seen from the water. There are no data to compare time of nest building or other phenological events.

Productivity.--Despite daily monitoring of nests near productivity plots, no young were observed in 1993 and all 12 nests were abandoned by 13 September, suggesting complete failure. No pelagic cormorant nests were found in 1994.

Cormorant breeding activities have not been studied rigorously on Chisik Island, so productivity data are limited, but it does not appear that pelagic cormorants have successfully produced young in any years of study (Nishimoto et al. 1987, Beringer and Nishimoto 1988, this study).

Glaucous-winged Gull

Populations.--In 1993, an average of nine adult glaucous-winged gulls was counted on plot 3 (SD=7.3; n=9), and adults roosted in very low numbers but did not nest on plot 4 (i.e., <5). In 1994, plot 3 had a mean of ten adults (SD=2.4, n=7; Table 2). Our counts indicate that consistent numbers of gulls used the plots in both years of this study but higher numbers were recorded in 1986 and 1987 (Table 2).

We could not accurately count gulls on Duck Island because of dense vegetation but fewer than 100 gulls appeared to be present. About 224 breeding glaucous-winged gulls were also present in a colony about 300 m north of the Snug Harbor cannery on Chisik Island. Here, too, dense vegetation precluded an accurate count. An unknown number of gulls nested near the top of the high cliffs on the southwest tip of Chisik.

The glaucous-winged gull population at Chisik and Duck Islands appears to have declined since 1978 when numbers were estimated at 1500-2000 (Jones et al. 1980, Muhlberg 1984). Muhlberg (1984) estimated that about 300 adults used the area north of the cannery in 1983; 75% more than we counted in 1993. We estimated that fewer than 1000 glaucous-winged gulls probably used Chisik and Duck Islands in 1993 and 1994 (Appendix 2).

Table 2. Summary of glaucous-winged gull population estimates on plots in lower Cook Inlet colonies.

Location	Year	Estimate [a]	Source	Comments
Chisik	1986	18	Nishimoto et al. 1987	
Island [b]	1987	33	Beringer & Nishimoto 1988	
(plots 1-7)	1993	9	this study	
	1994	10	this study	
Gull Island	1988	30	Nishimoto & Beringer 1989	
(plots 1-10)	1990	24	Nishimoto & Thomas 1991	
	1992	22	Erikson, unpublished data	sgl cnt on 8/15
	1993	20(1)	this study	
	1994	2	this study	
60-foot Rock	1987	10	Nishimoto & Beringer 1989	
(plots 1-2)	1988	15	Nishimoto & Beringer 1989	
	1989	18	Nishimoto & Beringer 1990	
	1990	16(2)	Nishimoto & Thomas 1991	
	1993	20(12)	this study	
	1994	17(4)	this study	

[a] estimate is the mean of counts pooled for plots, nests in parentheses
[b] includes Duck Island

In 1978, the nesting distribution of glaucous-winged gulls included the coasts of about the southern two-thirds of Chisik Island and all of Gull Island (see Jones et al. 1980). We found similar distributions but could not reliably estimate the number of birds breeding along the high cliffs and beneath vegetation.

Breeding Phenology.--In 1993, two active nests were observed on plot 3 on Chisik Island on 28 June. Three nests were counted one month later at the colony north of the cannery, and chicks were seen there in mid- to late August during beached bird surveys. Phenology was not assessed in 1994.

Productivity.--Nest contents on plot 3 could not be determined from our observation location on the water and it is possible that vegetation obscured chicks near the nests. No fledglings were seen in 1993, and only one chick was observed on two occasions in 1994.

Glaucous-winged gulls used both plots 3 and 4 in 1986 and 1987, but only plot 3 in 1993 and 1994. Mean numbers of adults have declined on plot 3 since 1986 when it was calculated at 18; the average number of adults counted in 1993 was nine and ten in 1994.

The low numbers of nests on plots (i.e., three on plot 3 in 1993) and our inability to see and follow chicks yielded little information on productivity. In 1983 Muhlberg (1984) first observed chicks in late June. Our arrival at Chisik Island in mid-June in 1993 could have coincided with the end of incubation so that the number of active nests on plots may have been low.

Our periodic counts of gulls at the colony north of the cannery in 1993 indicated at least 20 young were present. This number is undoubtedly low because chicks are easily overlooked. They are cryptic, hide in vegetation and are difficult to observe from the beach.

Black-legged Kittiwake

Populations.--Index plots were set up at Chisik in 1986 to provide a basis for monitoring population trends without having to census all the birds on the island. Counts of kittiwakes on these index plots in 1993 and 1994 were lower than the totals for 1986 (Table 3). Nevertheless, it appears there may have been unusually high attendance of kittiwakes at the colony in 1986 based on other counts in the early 1980s (Appendix 3).

The earliest counts of kittiwakes reported for Chisik were in 1936 when Murie (1959) estimated 25,000 birds were present. Most counts and estimates in the 1970s ranged from 20,000 to 28,000 kittiwakes (Appendix 3). An exception was in 1971 when Snarski (1974) counted over 47,000 kittiwakes at Chisik, but he apparently included chicks making that count incomparable. Since 1983, counts have generally been 20,000 or less except for 1986 which was particularly high, as indicated above. Counts in 1993 and 1994 were slightly lower than previous counts, and there appears to have been a slightly declining trend at Chisik in numbers of kittiwakes since 1970 (Fig. 5).

Breeding Phenology.--Kittiwake nests were already constructed and some eggs were laid by the time observers arrived at study plots on 16 June 1993. In 1993 egg-laying and hatching occurred on dates similar to those previously recorded for the islands (Table 4). All eggs hatched between 9-15 July 1993. In 1994 young chicks were present on plots by 6 July when we first visited Chisik; all chicks fledged on or before 18 August.

In almost every year where breeding phenology data were collected, the breeding effort largely failed (Table 5). Reproductive failure has usually occurred during the incubation period. This may be due to reduced parental care resulting from food stress which, in turn, is induced by insufficient prey near the colonies (Snarski 1974, Jones et al. 1980, Kafka 1984, and Muhlberg 1984). Consequently, adult kittiwakes must forage far from breeding sites. In contrast to 1993 when few kittiwakes were seen feeding near land, cannery caretakers reported seeing kittiwakes feeding upon schools of sand lance in the southern entrance of Tuxedni Channel in mid-June 1994.

Table 3. Summary of black-legged kittiwake population plot counts at lower Cook Inlet colonies.

Location	Year	Estimate[a]	Source	Comments
Chisik[b]	1986	1498(1201)	Nishimoto et al. 1987	completed in July
(plots 1-7)	1987	(626)	Beringer & Nishimoto 1988	completed in July
	1993	919(569)	this study	completed in July
	1994	1045(996)	this study	completed in July
Gull Island	1984	145(80)	Nishimoto et al. 1987	plots 1-3
	1985	149(56)	Nishimoto et al. 1987	plots 1-3
	1986	224(158)	Nishimoto et al. 1987	plots 1-3
		993(769)		plots 1-8
	1987	213(101)	Beringer & Nishimoto	plots 1-3
		725(300)	1988	plots 1-8
	1988	240(189)	Nishimoto & Beringer	plots 1-3
		1289(949)	1989	plots 1-8
		1454(1071)		plots 1-10
	1989	234(164)	Nishimoto & Thomas	plots 1-3
		1082(875)	1991	plots 1-8
		1219		plots 1-10
	1990	218(164)	Nishimoto & Thomas	plots 1-3
		1156(817)	1991	plots 1-8
		1301(929)		plots 1-10
	1992	191(135)	Erikson, unpub. data	plots 1-3
		1027(600)		plots 1-8
		1165(685)		plots 1-10
	1993	222(94)	this study	plots 1-3
		909(515)		plots 1-8
		1025(571)		plots 1-10
	1994	204(138)	this study	plots 1-3
		926(751)		plots 1-8
		1067(847)		plots 1-10
60-foot Rock	1985	(35)	Nishimoto & Beringer 1989	
(plots 1-2)	1986	96(75)	Nishimoto & Beringer 1989	
	1987	71(31)	Nishimoto & Beringer 1989	
	1988	112(82)	Nishimoto & Beringer 1989	
	1989	98(90)	Nishimoto & Thomas 1991	
	1990	101(88)	Nishimoto & Thomas 1991	
	1993	65(47)	this study	
	1994	103(89)	this study	

[a] estimate is the mean of counts pooled for plots, nests in parentheses
[b] includes Duck Island

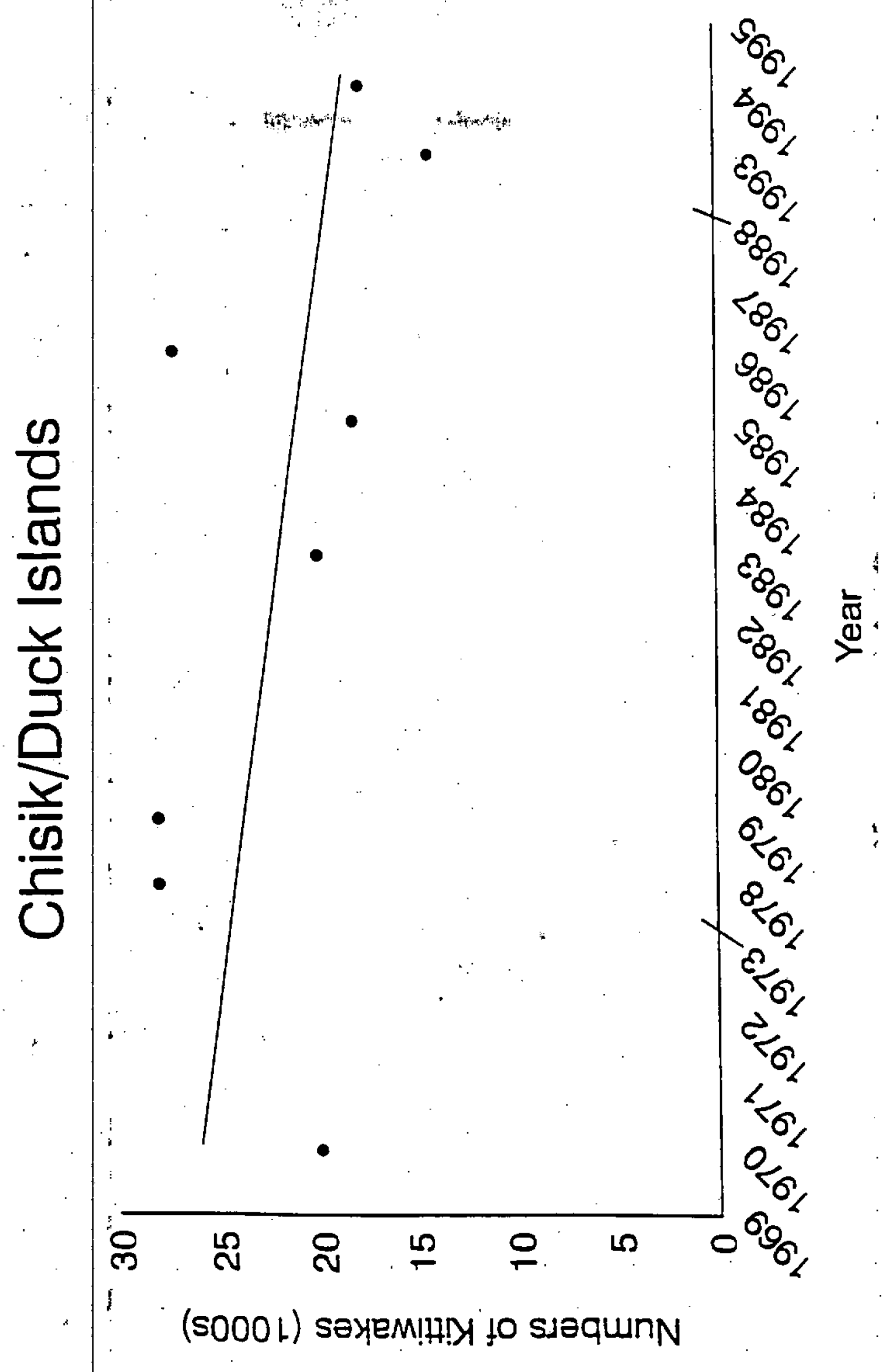

Figure 5. Population trends of black-legged kittiwakes based on whole-island counts at Chisik Island, lower Cook Inlet, 1970-1994.

Table 4. Summary of nesting phenology of black-legged kittiwakes at lower Cook Inlet colonies.

Location	Year	Egg-laying	Hatching	Fledging	References
Chisik Island	1966	early-mid June[a]	---	unquantified, but presumably "good"	Krohn 1966
	1970	19 Jun -5 July	18 July - ?	none	Snarski 1971b
	1971	27 June -10 July[b]	26-29 July		Snarski 1974
	1973	late May-early June	<27 June>	< August>	"
	1978	10-30 June	6-25 July	23 August	Jones & Peterson 1979
	1979	14 June-6 July	10 July-4 Aug	19 Aug-8 Sept	Jones et al 1980
	1983	18-22 June	---	none on plots; 11 juveniles seen in water 8/27	Muhlberg 1984
	1993	≤ 17-26 June	9-15 July	none	this study
	1994	---	---	chicks last seen in nests on 18 Aug	"
Gull Island	1971	early-mid June	---	no data; "good nesting success" on 9/2	Snarski 1974
	1984	early June	---	---	Nishimoto et al. 1987
	1985	early June	---	---	"
	1986	early June	---	---	"
	1987	18 June-?	---	<10 August>	Beringer & Nishimoto 1988
	1988	---	---	<26 July>	Nishimoto & Beringer 1989
	1990	---	early-mid July	---	"
	1993		began ~23 July	most fledged by 31 Aug	this study
	1994		mid-July	all fledged by 23 Aug	"

[a] Chick age estimated from photographs by Krohn (1966) (Snarski ca 1974)
[b] Chick age estimated by Snarski during brief visit to colony (Snarski ca 1974)

Table 5. Summary of black-legged kittiwake productivity on plots at lower Cook Inlet colonies.

Location	Year	# Nests[a]	Productivity[b]	Comments	References
Chisik	1970	---[d]	0.0		Snarski 1970
Island[c]	1971	74	0.0		Snarski 1971b
	1973	---	"very good"	~1.5 young/nest	Snarski 1974
	1978	115	0.02	in sample area	Jones & Peterson 1979
	1979	60	0.36		Jones et al. 1980
	1983	90	0.0	no chicks on cliffs, but 11 fledglings seen later with adults	Muhlberg 1984
	1986	1201	0.25	plots 1-7	Nishimoto et al. 1987
	1987	626	0.0	"	Nishimoto (*&*)&%(
	1993	341	0.0	"	this study
	1994	---	---	plots 1-7; fledging mostly done by 2nd visit; 31 fledglings:1,624 adults seen near the SW cliffs	"
Gull	1984	80	0.80	plots 1-3	Nishimoto et al. 1987
Island	1985	428	0.33	plots 1-8	"
	1986	769	0.69	plots 1-8	"
	1987	300	0.03	plots 1-8	"
	1988	1071	0.63	plots 1-10	Nishimoto & Beringer 1989
	1989	985	0.53	"	Nishimoto & Thomas 1991
	1990	929	0.47	"	"
	1992[d]	685	0.36	"	Erikson, unpublished data
	1993	608	0.10	"	this study
	1994	847	0.21	"	"
60-foot	1985	35	0.16		Nishimoto et al. 1987
Rock	1986	75	0.61		"
(plots 1-2)	1987	31	0.00		"
	1988	82	0.63		Nishimoto & Beringer 1989
	1989	90	0.01		Nishimoto & Thomas 1991
	1990	88	0.02		"
	1993	47	0.02		this study
	1994	89	0.04		this study

[a] determined from the mean of counts pooled for plots
[b] calculated from the mean number of chicks/nest (using the max number of chicks during replicate counts) unless otherwise noted
[c] includes Duck Island
[d] single count of nests on 15 August
--- counts not made for productivity

Productivity.--In 1993, we monitored the fate of 341 nests. Eggs were laid in 60% of the nests: average clutch size was 1.47 (35% had one egg, 32% had two eggs, and 3% had three eggs). Of the 305 eggs laid in our study area, only two hatched. Neither chick survived to fledging, and we saw only about five fledglings on the entire island. Clearly, in 1993 there was nearly total reproductive failure, based primarily on egg loss to predation by bald eagles and common ravens. Predation may have been exacerbated by irregular incubation by adults which was observed in early July. Presumably temporary nest abandonment was due to food stress. Most of the kittiwakes had left the colony by 6 August.

In 1994, we got only indirect evidence of reproductive success, but it appeared productivity was higher in 1994 than in 1993. On 7 July we checked 333 nests; 23% were still active compared to only 5% still active at this date in 1993. Of the 77 active nests, 23% had one egg, 13% had two eggs, 27% had one chick, 22% had two chicks, and the remaining 14% had one egg and one chick. During our second visit to Chisik in mid-August 1994, most kittiwake chicks had fledged, and we counted 31 fledglings in a group of about 1,600 adults near the southwest cliffs. In addition, we regularly saw fledglings elsewhere (Table 5).

Although the quality of information about productivity of kittiwakes varied, data are available for ten different breeding seasons at Chisik (Table 5). Kittiwakes had nearly complete breeding failures in at least six years, and productivity was 0.25 or more in three years. As indicated above 1994 was not a year of failure, but the rate of success cannot be estimated.

Common Murre

Populations.--The number of murres counted on index plots at Chisik was similar in 1986, 1987, and 1994; but fewer birds were present on these plots in 1993 (Table 6). The reduction in 1993 likely did not represent a population decline, but instead, it probably reflects reduced levels of colony attendance due to low food availability and poor reproductive success (see below). In spite of the lack of evidence of a trend since 1986, it appears there was a substantial reduction in numbers of murres at Chisik between 1970 and 1978, and another decline between 1978 and 1983 (Appendix 4, Fig. 6).

Further supporting the suggested decline was evidence of a reduction in nesting distribution of murres at Chisik. Approximately 150-200 murres were counted in 1971 (Snarski 1971c) among the kittiwakes on the southwest cliffs. Fewer than 100 murres briefly visited this area in 1993, but did not return to breed. Furthermore, no murres were seen in this area in 1994.

Breeding Phenology.--Because land-based plots on Duck Island were established late in 1993, phenological events were ascertained from anecdotal information. Common murres were congregated near and on cliffs when observers arrived in mid-June. Most murres never attended cliffs regularly on Chisik Island, but birds continued to visit Duck Island cliffs inconsistently through early September. Although eggs were first observed on 8 July away from study plots on Duck Island, egg-laying did not take place until mid-July within study plots. Common murre chicks began to hatch on 23 August within our study plots, with the average hatch on 29 August (SD=4.2, n=6). The mean fledging date was 11 September and ranged from 7 to 13 September (SD=2.1, n= 17).

In 1994 we found one common murre egg on productivity plot 4 on 6 July. It was gone the following day and no other eggs were seen until 12 July. Thus, it appeared that breeding phenology began similarly to that observed in 1993.

Productivity.--Common murre productivity was estimated by monitoring six plots on Duck Island (Fig. 3) from 15 August to 14 September 1993. In 1993, 80% hatched of 41 eggs present in our plots in mid-August, and 55% (18) of the chicks fledged (Appendix 6). Overall productivity was about 44%, slightly lower than the normal range for this parameter in Alaska (Byrd et al. 1993). This estimate is probably too high because most eggs were within ten days of hatching when they were first observed, so egg loss prior to that

Table 6. Summary of common murre population plot counts for lower Cook Inlet colonies.

Location	Year	Estimate [a]	Source	Comments
Chisik Island [b]	1986	337	Nishimoto et al. 1987	
(plots 1-7)	1987	392	Beringer & Nishimoto 1988	
	1993	173	this study	
	1994	342	"	
Gull Island	1985	49	Nishimoto & Thomas 1991	plots 1-3
	1986	67		plots 1-3
		107	"	plots 1-8
	1987	103		plots 1-3
		158	"	plots 1-8
	1988	84		plots 1-3
		227	"	plots 1-8
		228		plots 1-10
	1989	112		plots 1-3
		184	"	plots 1-8
		202		plots 1-10
	1990	136		plots 1-3
		236	"	plots 1-8
		250		plots 1-10
	1992	196		plots 1-3
		327	Erikson, unpublished data	plots 1-8
		334		plots 1-10
	1993	60		plots 1-3
		315	this study	plots 1-8
		328		plots 1-10
	1994	201		plots 1-3
		324	"	plots 1-8
		333		plots 1-10
60-foot Rock	1985	23	Nishimoto & Beringer 1989	
(plots 1-2)	1986	33	"	
	1987	34	"	
	1988	20	"	
	1989	25	Nishimoto & Thomas 1991	
	1990	18	"	counts done between 19 June & 7 July
	1993	23	this study	non-breeding aggregation
	1994	11	"	non-breeding aggregation

[a] estimate is the mean of counts pooled for plots
[b] includes Duck Island

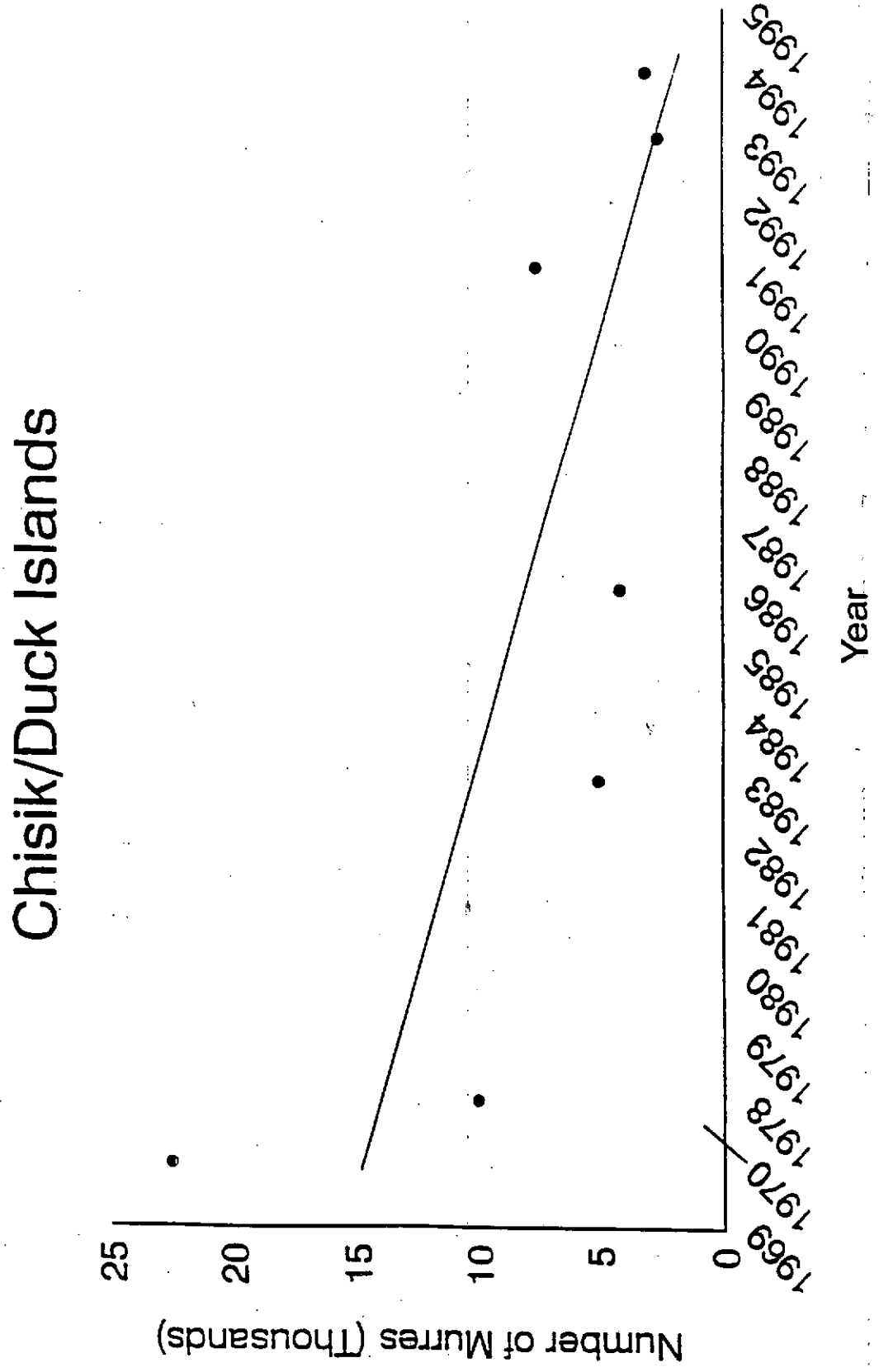

Figure 6. Common murre population trends based on whole-island counts at Chisik and Duck Islands, Alaska.

date would not have been observed. Additional evidence of reduced success in 1993 was that most murres on Chisik never settled into the normal nesting routine. Birds remained flighty throughout the summer, and even within the middle of the nesting period, major sections of the nesting area there were devoid of birds.
We did not measure productivity of murres in 1994, but during our counts, birds seems to be acting more normally (i.e., most birds remained on cliffs when we approached) than in 1993. There are no prior data on murre productivity at Chisik or Duck for comparison.

Pigeon Guillemot

Populations.--The only site believed to be used for breeding by pigeon guillemots in both years was at Fossil Point, on the west side of northern Tuxedni Channel. We completed five counts in early July and obtained a median of 13 adults (range 1-19) in 1993; 13 were observed during the only count made in 1994.

Nesting colonies of pigeon guillemots are relatively small in comparison with other seabirds, but range from about 4-48 individuals (Sanger and Cody 1994). Colony size may be limited by nesting habitat availability, access by predators, and proximity to adequate food sources. Because counts were made in early July, some of the adults present may have been failed or non-breeders. Our counts may reflect 50-75 percent of all breeders attending the Fossil Point colony (Katherine Kuletz, Migratory Bird Manage., pers. comm.).

Previous information on pigeon guillemots in the Chisik Island area is anecdotal. Krohn (1966) suspected that guillemots nested along the east shore of Chisik and stated adults were "very abundant." Gabrielson and Lincoln (1959) found guillemots nesting among black-legged kittiwakes and common murres on Chisik in 1940 (no details on the exact locations were given). We found no evidence of breeding on the east shore of Chisik. In fact, guillemots were seen infrequently throughout the summer near the southern tip and northwest shore of Chisik Island. Low rock faces at the latter site, similar in composition to Fossil Point, may provide nesting sites but were not investigated thoroughly in 1993 or 1994.

Horned Puffin

Populations.--A total of 30 crevices was monitored on Duck Island in 1993. Crevice surveys represent only a portion of the total breeding population based on the presence of about 700 adults loafing on the water adjacent to Duck Island during the incubation period. Concentrations of horned puffins were also noted along the southwest coast of Chisik Island, where about 40-50 adults were frequently seen in 1993.

We did not attempt to estimate the current breeding population, but our casual sightings (see above) may indicate a decline in the number of horned puffins using Duck Island. Jones et al. (1980) estimated that 6000 horned puffins bred at Duck Island in 1978 and 1979; Muhlberg (1984) estimated 5000 in 1983.

Breeding Phenology.--Adults with eggs were found in 67% of the crevices we examined during initial surveys on 23 and 25 June. The remaining 33% of the crevices contained only adults. The mean of hatch occurred 27 July (SD=6.1, n = 14), and the mean date of fledging was 2 September (SD=5.7, n = 12; from Table 7). Timing of these events fell within the ranges recorded during previous studies except that hatching began one day earlier in 1993 than in other years (Table 7).

Productivity.--About 53% of the 30 eggs we monitored hatched and 69% of the eggs that hatched fledged young (Table 8). We estimated that, overall, 37% of the pairs fledged young.

Hatching success was within the range recorded in other years, but chick mortality may have been higher than usual at Duck Island (Table 8). Overall, the number of young fledged per pair fell within the ranges calculated in 1978 and 1979, but the average for horned puffins in Alaska is higher at 57% (Byrd et al. 1993).

Table 7. Breeding phenology of horned puffins at Duck Island, lower Cook Inlet, Alaska, 1978-1993.

Year	Egg-laying	Hatching	Fledging	Source
1978	5-29 June	18-27 July	28 Aug-19 Sept	Jones et al. 1980
1979	15 June-4 July	25 July-4 August	30 Aug-11 Sept	Jones et al. 1980
1983	$<$10 June-?	16 July-11 August	---	Muhlberg 1984
1993	$\leq$ 23 June-?	15 July-7 August	3-$\geq$ 13 Sept	this study

Table 8. Summary of horned puffin productivity at Duck Island, lower Cook Inlet, Alaska.

Year	Hatch success	Broods with fledged young	Mean # of young raised/pair	Source
1978	0.73	0.92	0.60	Jones et al. 1980
1979	0.44	0.71	0.24	Jones et al. 1980
1993	0.53	0.69	0.37	this study

Chick Growth and Diet.--Sixteen chicks were weighed and measured an average of 12 times from late July to mid-September. A regression equation representing body condition follows: weight=2.719 (wing chord) + 16.249 (r^2=0.90, n = 109). Figure 7 shows average chick mass change per day (9.4 g).

Chick growth in horned puffins in 1993 was similar to results obtained in 1978 and 1979. Two chicks in 1993 attained greater masses prior to fledging than weights recorded in other years at Duck Island.

Diet samples (n=30) consisted primarily of Pacific sand lance but included an additional six fish whose identification is pending. The average total length of fish was 87.9 mm (SD=24.0, n=105, Appendix 6). No data are available for direct comparisons of the sizes of fish fed to horned puffin chicks at Duck Island. However, in all years Pacific sand lance comprised the majority of feedings (Jones et al. 1980, this study). Jones et al. (1980) observed only two instances in which identified fish were not sand lance; three capelin (*Mallotus villosus*) and two pink salmon (*Onchorhynchus gorbuscha*) comprised those samples.

Little is known of horned puffin diets in other parts of Alaska, particularly for chicks (John Piatt, Natl. Biol. Serv., pers. comm.). However, we compared results of chick diets from a single study completed at Hall Island, Shumagin Islands, Alaska, in 1976 (Moe and Day 1977; Table 9). Duck Island puffins were nearly exclusive in bringing sand lance to chicks between 1 and 10 August, while Hall Island horned puffins relied on three primary species (sand lance, capelin, and Pacific cod (*Gadus macrocephalus*) between 11 and 28 August. Sand lance fed to chicks at Duck Island were smaller than those delivered to Hall Island chicks (Table 9). Although prey availability at each of the sites is unknown, sand lance appear to be an important component of horned puffin chick diets.

Gull Island

Pelagic Cormorant

Populations.--Averages of 41 and 44 adult pelagic cormorants were observed on the Gull Island index plots in 1993 and 1994, respectively (Table 1). Numbers of adults and nests have remained relatively stable on plots since they were established in 1986, except for an unusually low count in 1992 (Fig. 8, Table 1). Counts of pelagic cormorants for the entire island made in 5 years between 1976 and 1990 were also relatively stable (Appendix 1).

Because cormorants sometimes use different sites for breeding from year to year, it is difficult to assess population changes. For example, Nishimoto and Thomas (1991) found that numbers of adults on plots showed a moderate increase, while total colony counts indicated a slight overall decrease.

Breeding Phenology.--In 1993, we saw no chicks at Gull Island on 9 July, but chicks were present during our next visit 23 July, and cormorants had left the island by 31 August.

In 1994, we saw no chicks during a check of the island on 19 July, but chicks had hatched by the time of our next visit on 17 August. Chicks were still present when we visited the island for the final check on 23 August 1994.

Productivity.--A total of 26 nests and 19 chicks was checked three times in 1993; on 23 July, and 11 and 31 August. All pelagic cormorants were gone from Gull Island plots by 31 August. Assuming chicks last seen 11 August fledged, productivity averaged 0.73 young per active nest in 1993.

In 1994, 27 nests observed on 19 July had 30 chicks on 17 August. Twenty-two chicks (0.81 young per active nest) were still present in nests during the last survey on 23 August.

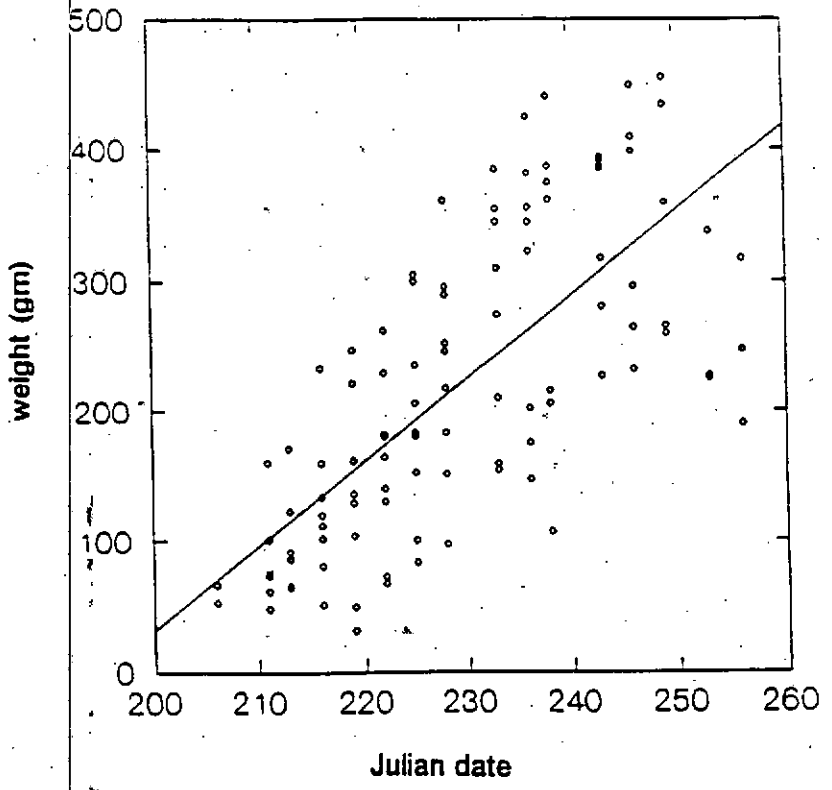

Figure 7. Mass changes of horned puffin chicks at Duck Island, lower Cook Inlet, Alaska, in 1993.

Table 9. Comparison of the relative importance of different fish species in bill loads of horned puffins at Hall Island, Shumagin Islands, 1976 [a], and Duck Island, 1993.

Species	Number Caught (%)		Total Weight in gm (%)		%Freq. of Occur.	
	Hall [b]	Duck [c]	Hall [b]	Duck [d]	Hall [e]	Duck [f]
Ammodytes hexapterus	107(66.5)	108(93.9)	211.4(70.3)	148.2(94.3)	68.8	96.7
Mallotus villosus	34(21.1)	0	62.1(20.7)		34.4	
Gadus macrocephalus	17(10.6)	0	24.9(8.3)		6.3	
Trichodon trichodon	1(0.6)	0	0.9(0.3)		3.1	
Onchorhynchus gorbuscha	0	0				
Unidentified flatfish	1(0.6)	0	0.6(0.2)		3.1	
Unidentified larval fish	1(0.6)	0	0.5(0.2)		3.1	
Unidentified juvenile fish	0	7(6.1)		9(5.7)		20.0

[a] 1976 data from Moe and Day 1977
[b] N=161
[c] N=115
[d] N=45
[e] N=32
[f] N=30

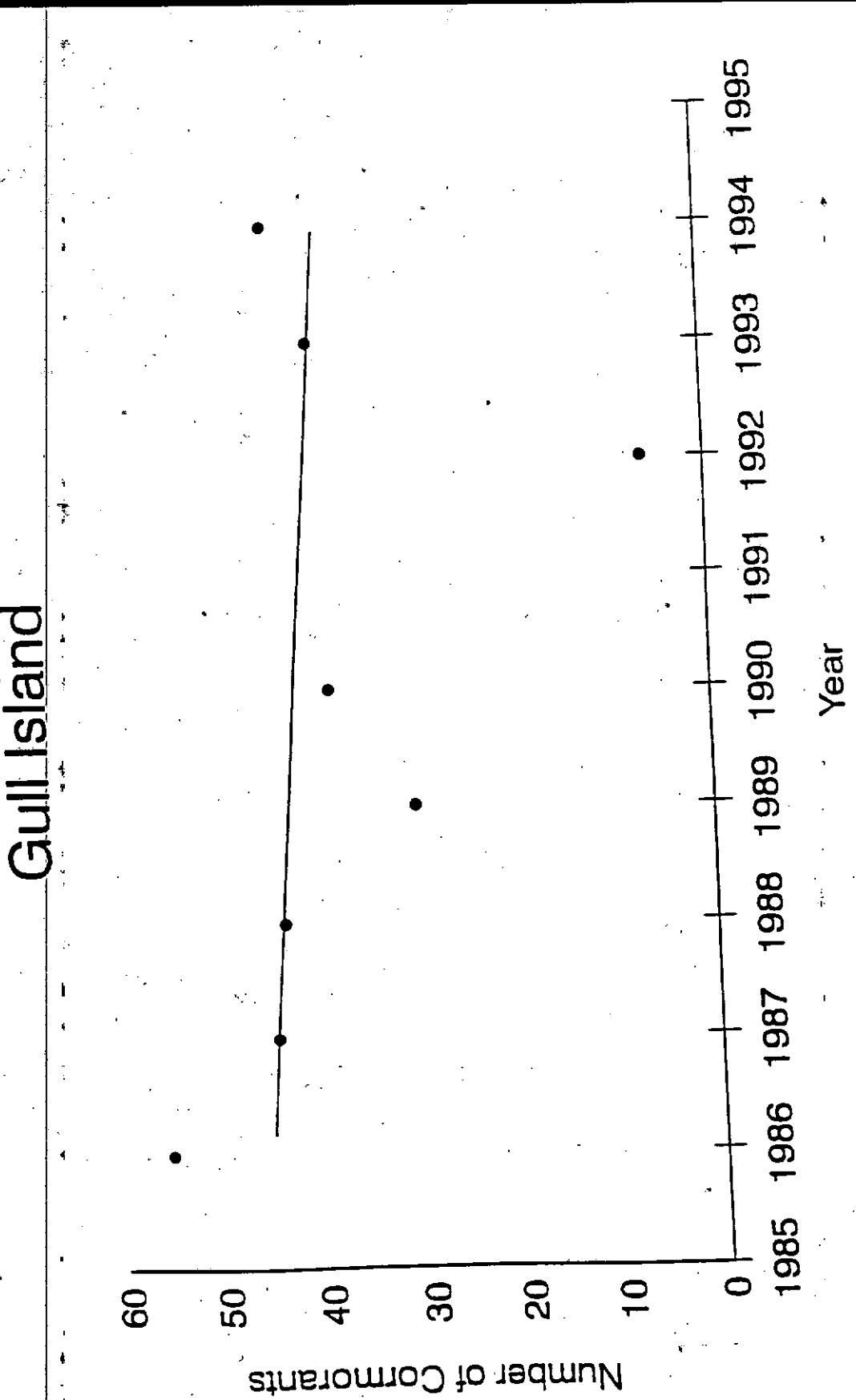

Figure 8. Population trends of pelagic cormorants on plots at Gull Island, lower Cook Inlet, 1986-1994.

Our index to productivity on Gull Island plots was similar in both years of this study and fell within the range calculated from past years (Table 10). Overall, productivity in 1993 and 1994 was lower than the mean calculated from previous years ($n=6$), a significant decline ($p=0.09$).

Glaucous-winged Gull

Populations.--We found only two adult glaucous-winged gulls on plots at Gull Island in 1994, down from 20-30 in previous years (Table 2). Nevertheless, relatively few of the gulls using Gull Island are on our cliff plots. Most occur on top of the island, and whole island counts between 1976 and 1990 suggest the population increased over that period (Appendix 2).

Productivity.--A maximum of six chicks was observed on Gull Island plots in 1993 and two chicks were seen in 1994. These numbers do not accurately assess glaucous-winged gull productivity; they only suggest that some production occurred.

Black-legged Kittiwake

Populations.--Approximately 900 adult black-legged kittiwakes were counted on plots 1-8 at Gull Island in 1993 and 1994 (Table 3). Numbers have been relatively stable on plots since 1986 when they were first established (Fig. 9). Nevertheless, whole-island counts made in 1976, 1985, and 1990 suggest kittiwakes increased at Gull Island between the mid-1970s and the mid-1980s (Appendix 3).

Breeding Phenology.--In 1993 Gull Island was visited too infrequently to calculate precise dates of breeding phenology. However, no chicks were present on 9 July, but hatching had begun by 23 July. Most successful nests had chicks on 11 August (63 chicks in five plots), and many fledglings were seen on ledges and in the surrounding water on 31 August (34 on ledges and at least 100 in the water).

In 1994, 43 nestlings were recorded on 19 July, our first visit since the beginning of the month. Most chicks had fledged by 23 August (Table 4).

Productivity.--A mean of 608 and 847 nests was constructed by black-legged kittiwakes on plots on Gull Island in 1993 and 1994, respectively. Although eggs and young chicks were not visible during observations from the water, older chicks could be counted. All nests with chicks on Gull Island contained broods with one chick in 1993, while in 1994 six nests contained two chicks each.

Although numbers of adults on plots in 1993 and 1994 were comparable, more nests were seen in 1994. Overall productivity was calculated at 0.10 chicks/nest for Gull Island in 1993 and 0.21 in 1994 (Table 5). Inter-annual comparisons of reproductive data on Gull Island plots indicated a highly significant difference in numbers recorded between 1988 and 1993 ($p<0.001$; Table 5), and similar differences were shown in comparisons of 1988 and 1994 data ($p=0.001$).

Common Murre

Populations.--Approximately 320 murres were counted on plots 1-8 at Gull Island in 1993 and 1994 (Table 6). Although numbers have been stable since 1992, there has been a significant ($p<0.01$) increasing trend in murres on plots since 1986 (Fig. 10). Furthermore, whole-island counts increased from approximately 2000 to 3000birds from the mid-1970s to the mid-1980s to over 5000 birds from 1988-1990 (Appendix 4). An inexplicably low count was reported for 1991 (Erikson 1993), the last time a whole-island survey was done.

Breeding Phenology.--Gull Island was visited too infrequently to accurately assess phenological events, but we noticed an egg as early as 30 June 1994.

Table 10. Summary of pelagic cormorant productivity on Gull Island plots, 1988-1994.

Year	No. of chicks/nests	Source
1988	0.33	Nishimoto et al. 1987
1989	0.56	Beringer & Nishimoto 1988
1990	1.24	Beringer & Nishimoto 1988
1992	2.80	Beringer & Nishimoto 1988
1993	0.77	this study
1994	0.81	this study

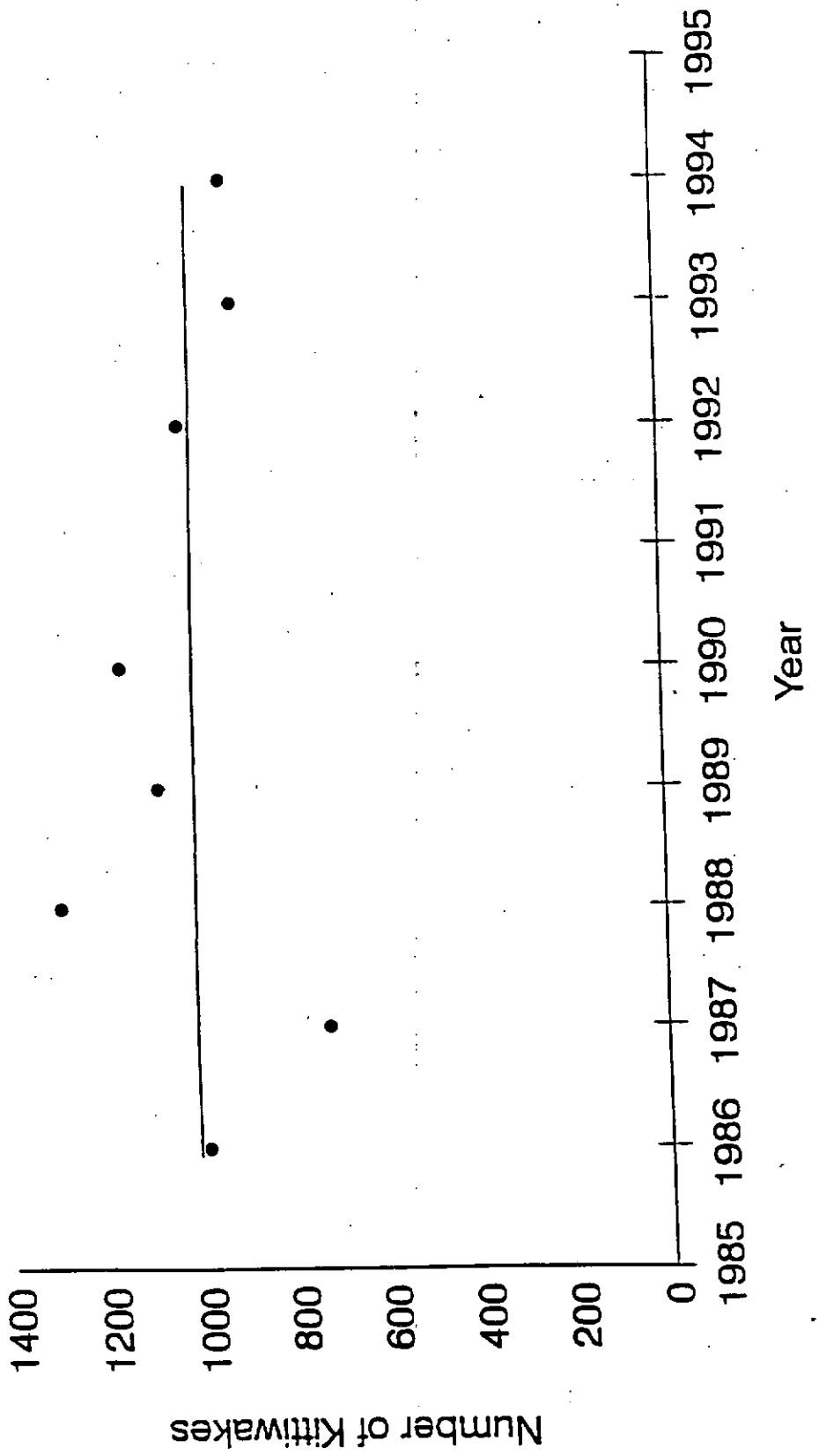

Figure 9. Population trends of black-legged kittiwakes on plots at Gull Island, lower Cook Inlet, 1986-1994.

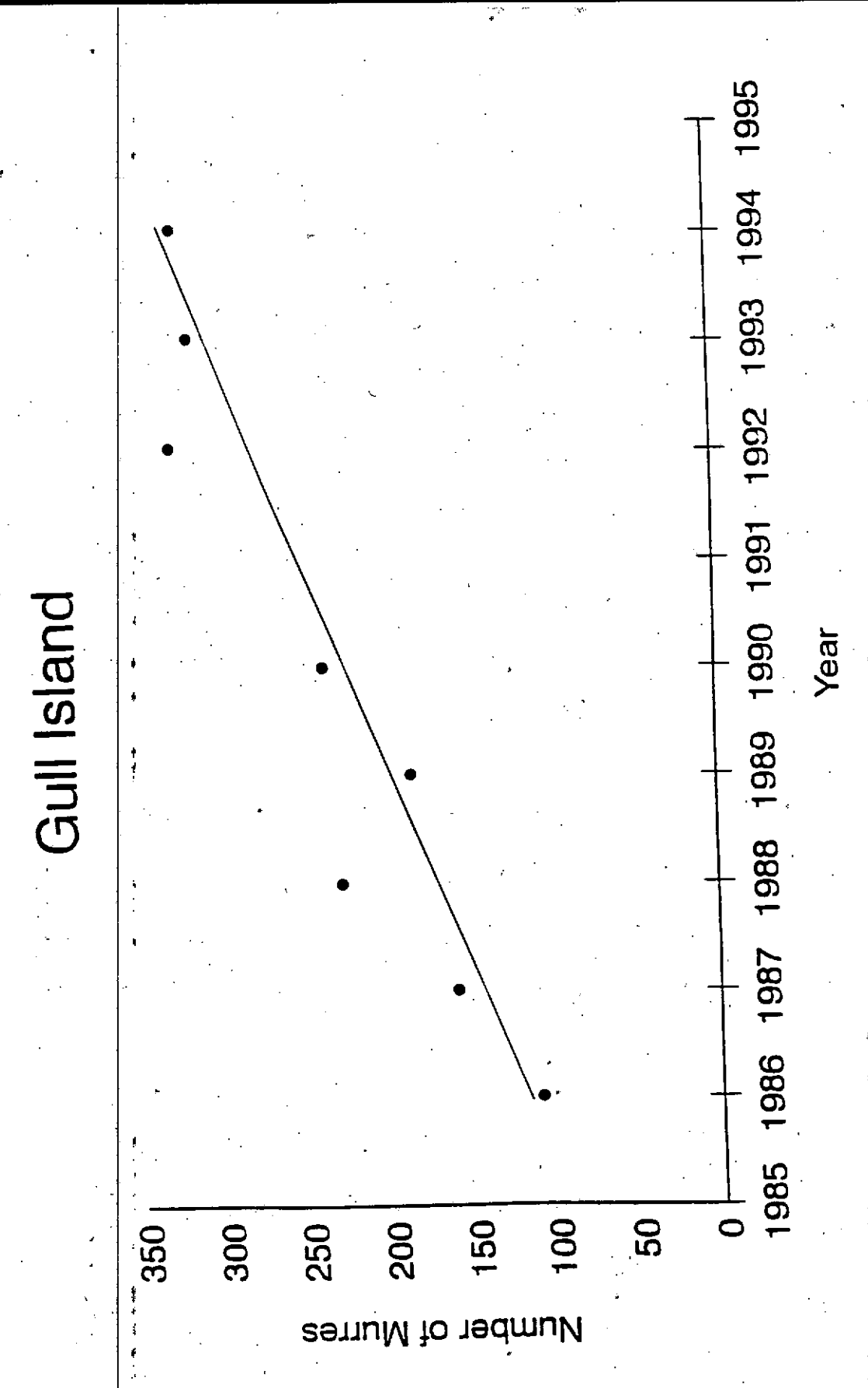

Figure 10. Population trends of common murres on plots at Gull Island, lower Cook Inlet, 1986-1994.

Pigeon Guillemot

Populations.--We did not attempt to count pigeon guillemots at Gull Island in 1993. In 1994, the maximum number of adults seen was 13 on 30 June and 1 July. Because we scheduled our surveys to observe murres when their numbers were most stable, and because pigeon guillemot activity patterns differ from the murres', our counts may have underestimated the size of the breeding population of guillemots at Gull Island.

Counts of pigeon guillemots at Gull Island included surveys directed specifically to this species and peak annual counts ranged from 24 to 42 birds in the late 1980's (Nishimoto and Thomas 1991; Table 11).

60-foot Rock

Double-crested Cormorant

Populations.--No double-crested cormorants were observed on plots in 1993 or 1994. In fact, this species has never been seen on the ledge-nesting seabird index plots since they were established in 1985 (Table 1). Nevertheless, we observed a nest that was not on one of the plots in mid-July 1993, and four roosting adults were also seen in mid-August. This species was not observed on 60-foot Rock in 1994.

Productivity.--One chick was seen on 20 July 1993 off the plots, but no information is available on a fledging date. Few double-crested cormorants have used 60-foot Rock for breeding, but occasionally it is used regularly by a few birds for roosting.

Pelagic Cormorant

Populations.--Few pelagic cormorants occurred on our ledge-nester plots (Table 1). Nevertheless, we counted 45 birds and 39 nests on 60-foot Rock in 1993 (Appendix 1). In contrast, no birds nested on the rock in 1994, but we counted 29 birds roosting there. Cormorants shift nesting locations periodically, so the change among years may represent a shift to another nesting location. Indeed, counts at 60-foot Rock since 1976 have been highly variable (Appendix 1).

Productivity.--There were no active nests on plots in either year of the study, however, some nests were observed off plots during island circumnavigations. Thirty-nine nests containing 29 chicks were observed in areas off our plots on 20 July 1993. If all these chicks fledged, the productivity rate would have been 0.74 chicks per active nest. As indicated above, no pelagic cormorants nested on 60-foot Rock in 1994.

Historical data were not available for comparisons among years of breeding cormorants on 60-foot Rock. However, productivity compared closely with nearby Gull Island (0.78) in 1993.

Glaucous-winged Gull

Populations.--Three replicate counts of plots on 60-foot Rock averaged 20 adults in 1993 and 17 in 1994 (Table 2). Whole-island counts of gulls indicated there may have been an increase between 1976 and 1986, but numbers remained relatively stable at between 80 and 113 birds through 1993 (Appendix 2). We counted 60 adults on the island in 1994.

Productivity.--A maximum of 18 chicks was observed on 60-foot Rock during three replicate counts in 1993, while a maximum of six was seen in 1994. Because boat-based counts of this species yield only a gross estimate of breeding performance, we could draw no conclusions about productivity except that gulls produced some young in both 1993 and 1994.

Table 11. Pigeon guillemot counts in lower Cook Inlet.

Location	Year	Total [a]	References
Gull Island	1976	12	summarized in Nishimoto & Thomas 1991
	1984	5	" " " " " "
	1985	13	" " " " " "
	1986	---	" " " " " "
	1987	42	" " " " " "
	1988	27	" " " " " "
	1989	24	" " " " " "
	1990	22	" " " " " "
	1994	13	this study
60-foot Rock	1976	0	summarized in Nishimoto & Thomas 1991
	1984	---	" " " " " "
	1985	---	" " " " " "
	1986	2(1)	" " " " " "
	1987	3	" " " " " "
	1988	no count	" " " " " "
	1989	0	" " " " " "
	1990	3	" " " " " "
	1994	2	this study

[a] maximum count in the particular year, number of nests in parentheses

Pigeon Guillemot

Populations.--Pigeon guillemots have not been intensively monitored at 60-foot Rock, but counts were usually completed as observers circumnavigated the island to survey ledge-nesting seabirds. We did not see any guillemots during surveys in 1993, but two birds were noticed at 60-foot Rock in 1994. Historically, numbers have been low. In 1986 two adults and one active crevice were noted (Nishimoto et al. 1987). The highest number of adults (6) on or adjacent to 60-foot Rock was recorded in 1987 when more effort was given to search for guillemots. In 1989, 1990, and 1994, two adult pigeon guillemots were noted each year near 60-foot Rock (Nishimoto and Thomas 1991).

Black-legged Kittiwake

Techniques identical to those used at Gull Island were used to study populations and productivity at 60-foot Rock.

Populations.--About 65 black-legged kittiwakes used our index plots at 60-foot Rock in 1993, and 103 was the mean count for 1994 (Table 3). In most years since 1986, approximately 100 birds and 75 to 90 nests have been present on the plots, but numbers were significantly lower in 1987 and 1993 (p's < 0.1). Whole-island counts since 1976 suggest there was a substantial increase between 1976 and 1984 (Appendix 3). It appears the population at 60-foot Rock peaked during the period 1988-1990, and declined again to mid-1980s levels by 1993-1994 (Fig. 11, Appendix 3).

Breeding Phenology.--We collected little information regarding breeding phenology at 60-foot Rock but can grossly estimate when primary breeding events took place. In 1993 we observed six and ten non-volent young on 20 July and 17 August, respectively; one fledgling was seen during the last survey as well. In 1994 two non-volent young remained on plots by 17 August after four had been seen on 19 July. Phenology appeared to be similar to that observed at Gull Island (Table 4).

Productivity.--A mean of 47 nests was constructed by black-legged kittiwakes on 60-foot Rock plots in 1993, and the mean was 89 in 1994 (Table 5). Although eggs and small chicks were not visible during observations from the water, older chicks could be counted. We did not observe any nests on 60-foot Rock that contained more than one chick in either year of the study. Overall productivity was calculated to be 0.02 and 0.04 for 60-foot Rock in 1993 and 1994, respectively (Table 5).

The kittiwake colony at 60-foot Rock consistently has lower productivity than the colony at Gull Island (Table 5). At 60-foot Rock, productivity has exceeded 0.2 young per nest in only two of eight breeding seasons for which there are data since 1985 (Table 5).

Common Murre

Populations.--The mean number of adult common murres attending plots on 60-foot Rock was 23 and 11, respectively for 1993 and 1994 (Table 6). Although the 1994 count was the lowest recorded for the index plots, there were no significant differences among years ($p = 0.15$, Table 6).

Whole-island counts suggest there were more murres at this small colony in 1976 than in later years (Appendix 4). It is unclear whether there was ever a stable breeding population here. Certainly there was little, if any, nesting in 1993 and 1994, the population being composed primarily of roosting birds.

Flat Islands

During an island circumnavigation on 1 July 1993, we observed eight species of birds (Appendix 7).

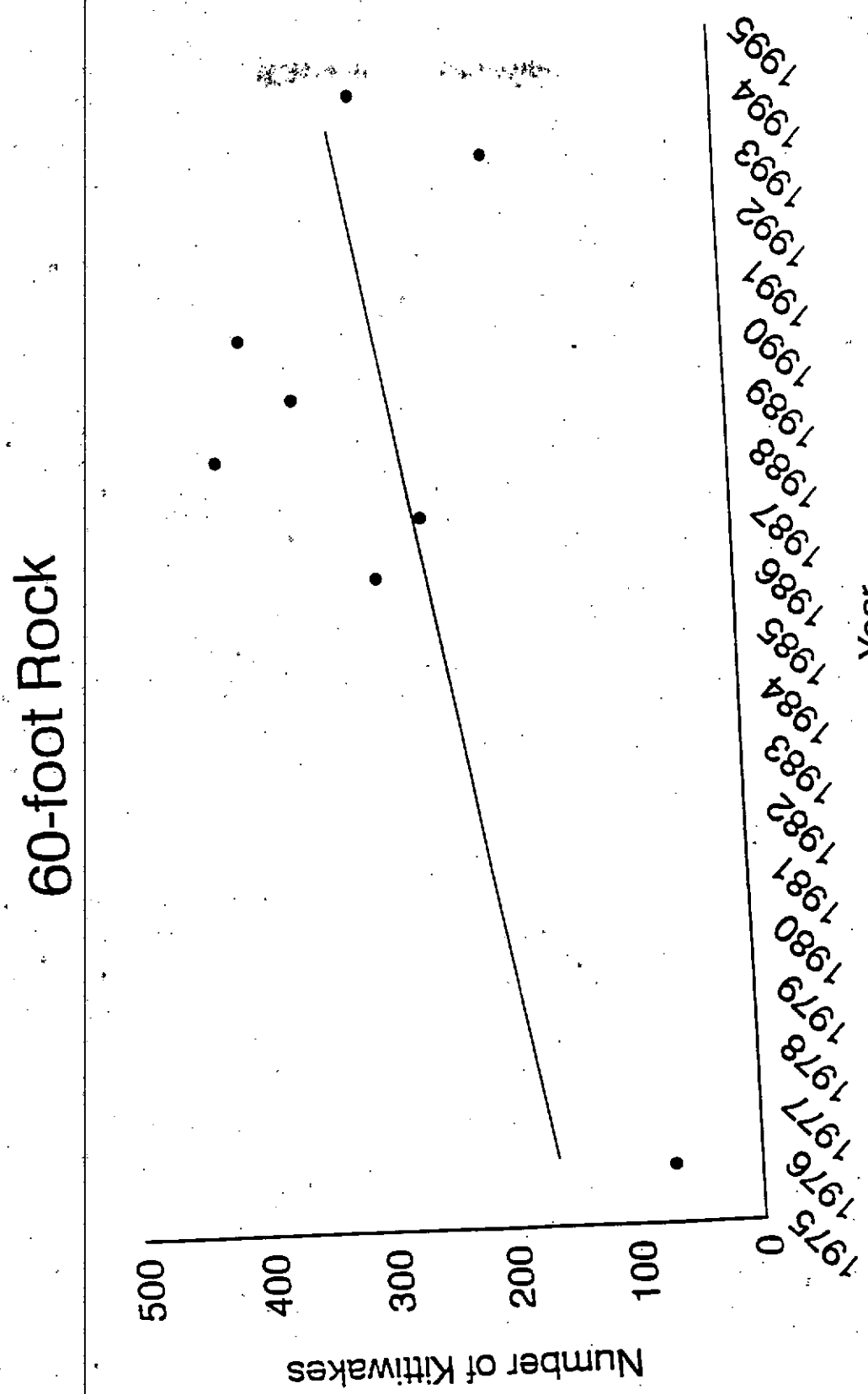

Figure 11. Population trends of black-legged kittiwakes on plots at 60-foot Rock, lower Cook Inlet, 1975-1994.

Tufted Puffin

Populations.--During our survey of all habitats occupied by tufted puffins on 1 July 1993, we found 464 burrows on Flat Islands, of which 67% (312) were active. We were able to access almost all areas along the perimeter of the island, but a small number of burrows could have been overlooked. Furthermore, a few burrows could have occurred on inaccessible nearby islets (Fig. 4). We conservatively estimate that 500 tufted burrows were present in 1993. About 15% of the land area at Flat Islands was used by nesting tufted puffins.

Productivity.--We marked all burrows found on the north half of Flat Islands in July for recheck in August. In July, 74% of the burrows in the sample (n = 73) were active (i.e., probably had an egg), but only 61% were active on 17 August. Taking the July occupancy rate as an index to the number of eggs laid, and the August occupancy rate as an indication of the number of chicks, approximately 80% of the burrows that had eggs in July had chicks in mid-August.

Byrd et al. (1993) reviewed 21 data sets of North Pacific tufted puffin colonies and found that, on average, nearly 50 percent of the eggs produced fledglings. While recognizing the limitations of our indirect methods to evaluate productivity, our result suggests productivity was normal or above this average at Flat Islands in 1993.

CONCLUSIONS

One of primary objectives of the study was to evaluate trends in seabird populations at lower Cook Inlet breeding colonies (i.e., Chisik and Duck Islands, Gull Island, 60-foot Rock, and Flat Islands). Some of the species we monitored occurred at only one of the study areas while others occurred at most. The following conclusions were reached about various species:

1. Double-crested cormorants appear to have declined since the early 1970s at Chisik Island, the only colony we surveyed where this species occurred in numbers. In contrast, there was no indication of a decline over the past 20 years in pelagic cormorant populations at Chisik and Duck, Gull Island, or 60-foot Rock.

2. Glaucous-winged gulls apparently increased or remained relatively stable at Chisik and Duck Islands, Gull Island, and 60-foot Rock between the mid-1970s and the early 1990s.

3. Black-legged kittiwake population trends varied among colonies. There was evidence of a slight decline since the 1970s at Chisik and Duck Islands, but at Gull Island and 60-foot Rock the population increased between the mid-1970s and the mid-1980s at which level it remained through the early 1990s.

4. Common murre numbers declined at Chisik and Duck Islands between 1970 and the mid-1980s, but have remained stable since then. In contrast, numbers on Gull Island have increased since the mid-1970s. The population of murres at 60-foot Rock contained few, if any, breeders in 1993 and 1994 so numbers attending the colony were highly variable. It appears fewer birds were present in the early 1990s than in the 1970s.

5. There were few prior counts of pigeon guillemots, horned puffins or tufted puffins, so population trends could not be critically assessed.

Besides population trends, we examined timing of nesting events and reproductive success for selected species, particularly in 1993. Few prior data for Cook Inlet are available, but from what we could glean, it appeared black-legged kittiwake laying dates were approximately normal, but murres may have been slightly later than normal.

In 1993 prey for seabirds may have been scarce near Chisik and Duck Islands, because cormorants, kittiwakes, murres, and horned puffins had relatively low reproductive success. Further down Cook Inlet in Kachemak Bay, cormorants had lower than average success, and kittiwakes failed at 60-foot Rock but had limited success at Gull Island. At the southernmost colony we monitored in Cook Inlet, Flat Islands, tufted puffins apparently had good success in 1993.

The 1994 survey effort was reduced from 1993, but available data suggest reproductive success for kittiwakes and murres was better in 1994 than in 1993 at Chisik. At Gull Island, kittiwake productivity was better in 1994 than in 1993, but kittiwakes failed to produce young at 60-foot Rock in 1994 just as they had in 1993.

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Appendix 1. Summary of double-crested, pelagic, and red-faced cormorant population estimates in selected lower Cook Inlet colonies.

Location	Year	Estimate			Source	Comments
		DCCO[a]	PECO[b]	RFCO[c]		
Chisik Island [d]	1970	500	20-30	---	Snarski 1971c	
	1971	500	20-30(1)	---	"	
	1973	---	(2)	---	Snarski 1974	
	1978	common	7(0)	---	Jones & Peterson 1979	
	1983	150(17)	---	---	Muhlberg 1984	+150 roosting on
Duck Island						
	1986	(16)	(2)	---	Nishimoto et al. 1987	+150 unidentified cormorants roosting on SE
	1987	50+(1)	0	---	Beringer & Nishimoto 1988	derived from partial island count
	1993	160	30(12)	---	this study	entire island
	1994	81	2	0	"	NE bluffs not in count
Gull Island	1976	0	222	62	Erikson 1976	entire island
	1984	0	(54)	(4)	Nishimoto et al. 1987	entire island
	1985	0	105	14	"	entire island
	1986	0	272(111)	45(14)	"	entire island
	1987	0	296(103)	56(17)	Beringer & Nishimoto 1988	entire island
	1988	0	(130)	(8)	Nishimoto & Beringer 1989	entire island
	1989	0	(129)	(15)	Nishimoto & Thomas 1991	entire island
	1990	0	246(111)	29(15)	"	entire island
60-foot Rock	1976	0	0	0	Erikson 1976	
	1984	0	30	---	Nishimoto et al. 1987	
	1985	0	28	0	"	
	1986	1	13	0	"	
	1987	0	9	0	Nishimoto & Beringer 1989	
	1988	0	2	0	"	
	1989	0	29(3)	0	Nishimoto & Thomas 1991	
	1990	0	62(6)	1(1)	"	
	1993	1(1)	45(39)	0	this study	
	1994	0	29(0)	0	"	

[a] double-crested cormorant
[b] pelagic cormorant
[c] red-faced cormorant
[d] includes Duck Island; numbers of nests are in parentheses

Appendix 2. Summary of glaucous-winged gull population estimates in selected lower Cook Inlet colonies.

Location	Year	Estimate	Source	Comments
Chisik Island [a]	1978	1500-2000	Jones et al. 1980	
	1983	1500-2000	Muhlberg 1984	Tuxedni Bay area
	1993	1000	this study	
Gull Island	1976	216	Erikson 1976	
	1984	200	Nishimoto et al. 1987	
	1985	442	"	
	1987	592	Nishimoto & Beringer 1989	
	1988	1054	"	
	1989	762	Nishimoto & Thomas 1991	
	1990	713	"	
60-foot Rock	1976	64	Erikson 1976	
	1984	21	Nishimoto et al. 1987	
	1986	113	"	max count, 7/31
	1987	86	Nishimoto & Beringer 1989	
	1988	96	"	
	1989	95	Nishimoto & Thomas 1991	
	1990	80	"	
	1993	98	this study	
	1994	60	"	

[a] includes Duck Island

Appendix 3. Summary of black-legged kittiwake population estimates in selected lower Cook Inlet colonies.

Location	Year	Estimate [a]	Source	Comments
Chisik Island [b]	1936	25,000	Murie 1959	may include only the SW colony
	1970	20,000		Snarski 1971a
	1971	47,690	Snarski 1974	counted in early August
	1978	28,000		Jones and Peterson 1979
	1979	28,000		Jones et al. 1980
	1983	20,000	Kafka 1984	estimate of "Tuxedni Bay area"
	1985	18,170	Nishimoto, unpublished data	counted prior to nest building
	1986	27,228	Nishimoto 1987	
	1993	14,191	this study	
	1994	17,804	"	
Gull Island	1976	3194	Erikson 1976	
	1984	(4204)	Nishimoto et al. 1987	
	1985	8202	"	
	1990	6986(5684)	Nishimoto & Thomas 1991	
60-foot Rock	1976	68	Erikson 1976	
	1984	(199)	Nishimoto et al. 1987	
	1985	(177)	"	
	1986	289	"	
	1987	250	Nishimoto & Beringer 1989	
	1988	414	"	
	1989	351	Nishimoto & Thomas 1991	
	1990	391	"	
	1993	186	this study	
	1994	294	"	

[a] estimate is the mean of counts pooled for plots; numbers of nests are in parentheses
[b] includes Duck Island

Appendix 6. Diet samples brought to horned puffin chicks at Duck Island, Alaska, in 1993.

Date Collected	Sample #	Sampling Method[a]	Species	Total Length(mm)	Mass(gm)
01 August	1	opport	sand lance	65	<1
	2a	screen	sand lance	107	---
	2b	screen	sand lance	143	---
	2c	screen	sand lance	108	---
	2d	screen	sand lance	111	---
	3	opport	sand lance	61	---
	3	opport	sand lance	61	---
03 August	4a	screen	sand lance	92	---
	4b	screen	sand lance	120	---
	5	opport	sand lance	145+	---
4 August	6a	screen	sand lance	65	---
	6b	screen	sand lance	70	---
	7a	opport	sand lance	65	---
	7b	opport	sand lance	51	---
	7c	opport	sand lance	65	---
	7d	opport	sand lance	64	---
	7e	opport	sand lance	60	---
	7f	opport	sand lance	52	---
	7g	opport	sand lance	52	---
06 August	8a	opport	unknown	114	---
	8b	opport	unknown	56	<1
	8c	opport	unknown	40	---
07 August	9a	opport	unknown	109	---
	9b	opport	sand lance	95	---
	9c	opport	sand lance	85	---
	10a	screen	sand lance	118	---
	10b	screen	sand lance	114	---
09 August	11	opport	sand lance	131	---
	12a	screen	sand lance	60	---
	12b	screen	sand lance	70	---
	12c	screen	sand lance	67	---
	12d	screen	sand lance	64	---
	12e	screen	sand lance	65	---
	12f	screen	sand lance	69	---
	12g	screen	sand lance	64	---
	12h	screen	sand lance	62	---
	12i	screen	sand lance	65	---
	12j	screen	sand lance	75	---
	12k	screen	unknown	63	---
	13a	screen	sand lance	63	---
	13b	screen	sand lance	74	---

Appendix 6. Continued.

Date Collected	Sample #	Sampling Method [a]	Species	Total Length(mm)	Mass(gm)
09 August	13c	screen	sand lance	94	---
	13d	screen	sand lance	82	---
	13e	screen	sand lance	80	---
	13f	screen	sand lance	88	---
	13g	screen	sand lance	97	---
	13h	screen	sand lance	104	---
	13i	screen	sand lance	92	---
	14	opport	sand lance	148	---
	15	screen	sand lance	86	---
10 August	16a	screen	sand lance	124	6.5
	16b	screen	sand lance	---	---
	17	screen	sand lance	139	7
	18	opport	sand lance	75	---
	19a	screen	unknown	104	---
	19b	screen	sand lance	60	---
	19c	screen	sand lance	92	---
	19d	screen	sand lance	80	---
	19e	screen	sand lance	70	---
	19f	screen	sand lance	56	---
	19g	screen	sand lance	86	---
	19h	screen	sand lance	79	---
	19i	screen	sand lance	70	---
	19j	screen	unknown	70	---
	19k	screen	sand lance	67	---
	19l	screen	sand lance	65	---
	19m	screen	sand lance	62	---
	19n	screen	sand lance	67	---

[a] opport = samples collected opportunistically at burrow entrances that may not comprise a complete bill load
[b] *Ammodytes hexapterus*

Appendix 7. Wildlife recorded during a circumnavigation of Flat Islands, Kachemak Bay, Alaska, 1 July 1993.

Species	Number of individuals
Double-crested cormorant	2
Northern pintail	1
Black oystercatcher	2
Glaucous-winged gull	2
Pigeon guillemot	~15
Tufted puffin	20
Bank swallow	50
Song sparrow	4
Steller sea lion	3