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Late-Summer Abundance and Distribution of Marine Birds in Kasegaluk Lagoon, Chukchi Sea, Alaska

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ABSTRACT. Oil and gas drilling programs in the Alaska Chukchi Sea were carried out on leases offshore from Kasegaluk Lagoon in 1989-91, and further exploration and development activities in this area are likely in future years. We conducted aerial surveys between late July and early September 1989-91 to determine the distribution and abundance of marine birds in the Kasegaluk Lagoon area. We hypothesized that Kasegaluk Lagoon supported an avifauna similar to that found in other lagoon systems in arctic Alaska. In fact, the richness and diversity of bird species using Kasegaluk Lagoon were greater than in lagoon systems in the Beaufort Sea. Brant (*Branta bernicla*) was the most abundant species in Kasegaluk Lagoon compared to lagoons in the Beaufort Sea, where the Oldsquaw (*Clangula hyemalis*) is the dominant species. Several other species or species groups, such as Glaucous Gull (*Larus hyperboreus*), Arctic Tern (*Sterna paradisaea*), small shorebirds (mainly *Calidris* and *Phalaropus*), and Lesser Snow Goose (*Chen caerulescens*) were also relatively abundant in Kasegaluk Lagoon.

Key words: waterbirds, aerial surveys, lagoon ecosystems, Kasegaluk Lagoon, Chukchi Sea, Beaufort Sea, Alaska

RÉSUMÉ. Des programmes de forage pétrolier et gazier ont été exécutés dans la portion alaskienne de la mer des Tchouktches, sur des concessions au large de l'étang côtier Kasegaluk de 1989 à 1991, et on prévoit que d'autres activités reliées à l'exploration et au développement auront lieu à cet endroit dans les années à venir. On a effectué des relevés aériens entre la fin de juillet et le début de septembre de 1989 à 1991, afin de déterminer la distribution et l'abondance des oiseaux marins dans la région de l'étang côtier Kasegaluk. On avait émis l'hypothèse que cet étang était le refuge d'une avifaune semblable à celle qui se trouve dans d'autres systèmes lagunaires dans l'Alaska arctique. En réalité, la richesse et la diversité des espèces d'oiseaux utilisant l'étang Kasegaluk étaient supérieures à celles des systèmes lagunaires de la mer de Beaufort. La bernache cravant (*Branta bernicla*) représentait l'espèce la plus abondante de l'étang côtier Kasegaluk comparé aux étangs côtiers de la mer de Beaufort, où le canard kakawi (*Clangula hyemalis*) est l'espèce dominante. Plusieurs autres espèces ou groupes d'espèces, comme le goéland bourgmestre (*Larus hyperboreus*), la sterne arctique (*Sterna paradisaea*), les petits oiseaux de rivage (surtout *Calidris* et *Phalaropus*) et la petite oie blanche (*Chen caerulescens*) étaient relativement abondants dans l'étang côtier Kasegaluk.

Mots clés : oiseaux aquatiques, relevés aériens, écosystèmes lagunaires, étang côtier Kasegaluk, mer des Tchouktches, mer de Beaufort, Alaska

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INTRODUCTION

This study was designed to determine the abundance and distribution of marine birds in the Kasegaluk Lagoon system in the northeastern Chukchi Sea (Fig. 1). The Inupiaq Eskimo communities of Point Lay and Wainwright are located along this section of the Chukchi Sea coast of arctic Alaska, and residents of these communities use local marine bird and mammal resources for subsistence. In 1989, 1990, and 1991, oil and gas wells were drilled on leases in the Chukchi Sea, offshore from the Kasegaluk Lagoon area. This area may be the focus of petroleum exploration and development activities in future years (Gould *et al.*, 1990; François and Gächter, 1992). As a consequence, information on the presence, distribution, and abundance of birds in and adjacent to the Kasegaluk Lagoon area may be of importance in designing management plans for the area.

Although relatively thorough ornithological research has been carried out in lagoon systems in the Alaska Beaufort Sea (Johnson and Richardson, 1981; Johnson, 1983; Brackney *et al.*, 1985; Johnson, 1985; Craig *et al.*, 1984; Johnson and Herter, 1989; Johnson and Gazey, 1992), less is known of the abundance and distribution of birds in the bays and lagoons of the Chukchi Sea (Divoky, 1978; Lehnhausen and Quinlan, 1982; Gill *et al.*, 1985). We hypothesized that Kasegaluk Lagoon supported an avifauna similar to that found in other lagoon systems in arctic Alaska. This paper presents the results of three years of aerial surveys for marine and coastal waterbirds in the Kasegaluk Lagoon area. As in other reports based on aerial survey work (e.g., Gaston *et al.*, 1986), we concentrate our discussion on those species most easily recognizable during the aerial surveys.

STUDY AREA

Kasegaluk Lagoon (Fig. 1) is situated along the Chukchi Sea coast of Alaska about 300 km southwest of Point Barrow, Alaska. The lagoon extends from about 69°16′N, 163°18′W in the southwest to about 70°30′N, 160°25′W in the northeast. Icy Cape, located at 70°20′N, 161°51′W, is a prominent coastal feature situated about two-thirds of the way north along the outer coast of Kasegaluk Lagoon. In total, the lagoon is about 200 km long — 135 km from the extreme southwest end to Icy Cape, and 65 km from Icy Cape to the extreme northeast end. The rolling foothills of the De Long Mountains are immediately adjacent to the southern end of Kasegaluk Lagoon. Virtually the entire mainland shoreline of the lagoon is backed by low tundra bluffs; vertical relief along these bluffs varies from near sea level in river deltas and creek mouths to nearly 10 m along some sections at the north end of the study area.

Five major rivers or inlets drain into Kasegaluk Lagoon: the Nokotlek River and Avak Inlet flow into the northern part of the lagoon, and the Utukok, Kokolik, and Kukpowruk rivers drain into the southern part of the lagoon. Several well-vegetated islands with high vertical relief are present in the

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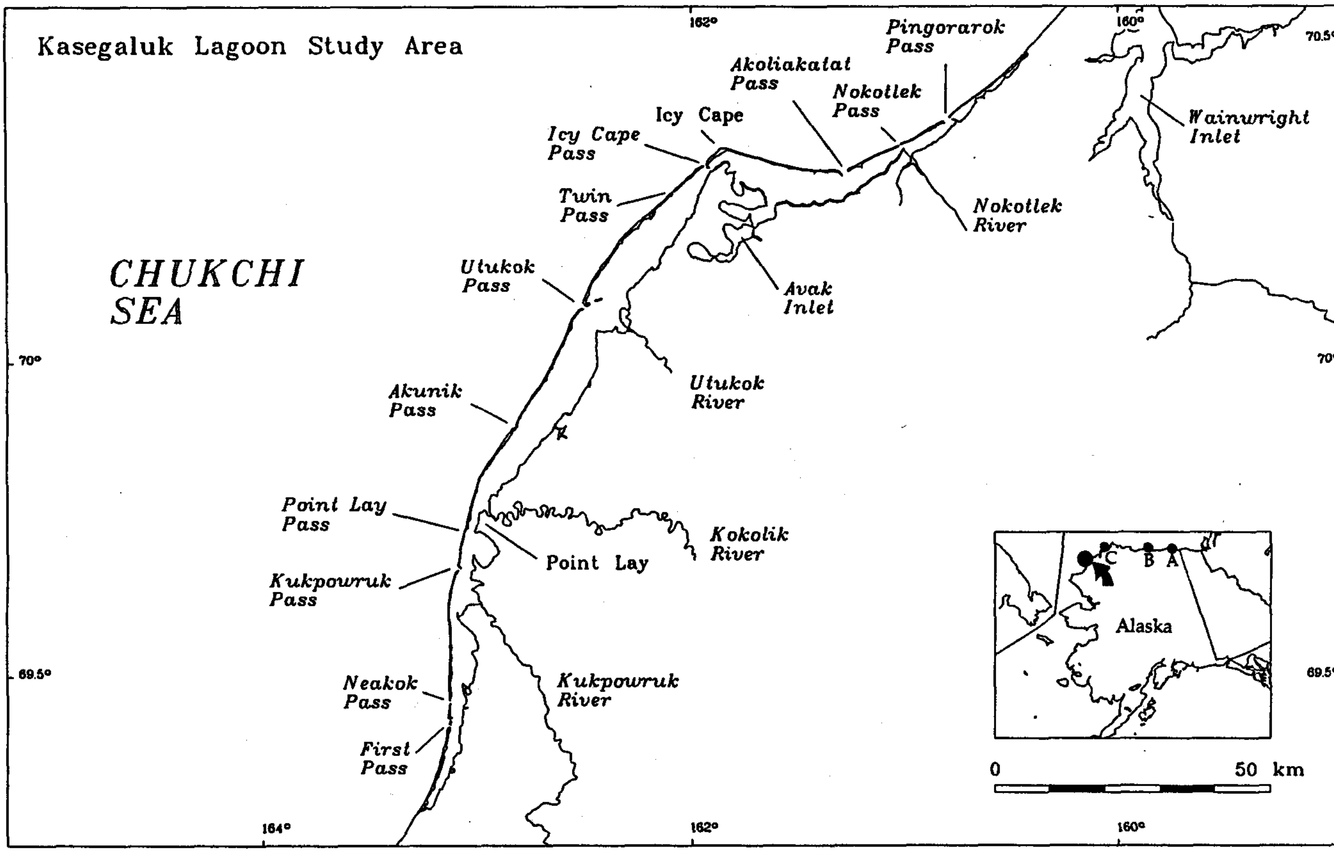

FIG. 1. The Kasegaluk Lagoon study area, Chukchi Sea, Alaska. The study area (arrow and large dot), the 11 ANWR lagoons (dot A), two central Beaufort Sea lagoons (dot B), and Peard Bay (dot C) are also shown in the inset.

deltas of the Utukok and Kukpowruk rivers. Most of these islands are covered with tundra vegetation, have extensive lakes and ponds, and are separated from the mainland by river channels and mudflats.

Barrier islands and shoals on the lagoonward sides of the islands are generally devoid of vegetation except for the region south of Utukok Pass. Barrier islands in this region, and especially in the region south of Kukpowruk Pass, are low and subject to flooding during periods of high water. Such periodic flooding has created extensive marshes with small lakes, ponds, and luxuriant vegetation on these sections of the barrier islands. The shoals and small islets adjacent to the barrier islands 5-10 km north of Point Lay are covered with patches of Lyme Grass (*Elymus* spp.).

Kasegaluk Lagoon varies considerably in width and depth. Although bathymetric data are incomplete for a large part of the lagoon, especially the portion between Point Lay and Icy Cape, the northeastern portion of the lagoon (northeast of Icy Cape) is generally deeper (3-4 m in many places) than the area southwest of Icy Cape. The northeastern portion is no wider than 8 km at its widest point off the mouth of Avak Inlet. Southwest of Icy Cape the lagoon is shallow (generally less than 2 m), turbid, and no wider than 10 km at its widest point off the mouth of the Utukok River. The most southwesterly part of the lagoon (i.e., the area southwest of the Kukpowruk River delta) is very shallow — only a few centimetres deep in many areas. Mudflats in this area are often exposed and are mostly covered with an orange/red-coloured algae. Primary production is also evident in the lagoon waters and beaches adjacent to Akoliakatat and Nokotlek passes. In this part of the lagoon, leafy green algae is visible in the water column, on the lagoon bottom, and washed-up on beaches, especially in late summer.

Kasegaluk Lagoon is ice covered for about 7 months, from early November through late May or early June. The nearby Chukchi Sea freezes in late November, and in some years ice may remain in the Icy Cape area until early July.

Habitats in the study area are of four general types: 1) mainland shoreline, 2) mid-lagoon, 3) barrier island, and 4) nearshore marine. Mainland shoreline habitats consist of coastal tundra interspersed with ponds, lakes, streams, marshes, rivers, and river deltas. The lagoon margin of the mainland shoreline consists of a sand or mud beach. During low-water periods, this habitat is continuous with adjacent mud and sand flats. Mid-lagoon habitats are relatively uniform throughout the study area. Except for the shallow areas east of Icy Cape and the area at the extreme southern end of the study area, both of which are exposed during low water, this habitat consists exclusively of lagoon waters. Barrier island habitats consist mainly of sand and gravel beaches and beach ridges with little vegetation cover except for the southern sections of the barrier islands (i.e., mostly south of Point Lay). In the north, most of the barrier island chain and adjacent lagoon-side shorelines consist of gravel, sand and mud beaches, shoals, spits, and islets. The passes connecting the lagoon with the Chukchi Sea are major features of this habitat type. Nearshore marine habitats are relatively uniform along the entire length of the study area except adjacent to the passes and near Icy Cape. Near passes, seaward-flowing plumes of lagoon water may be extensive, and near Icy Cape, waters are shallow and the general orientation of the coast changes from north-south in the south to east-west in the north.

METHODS

Aerial Surveys of Birds

We surveyed four separate strips of habitat in the Kasegaluk Lagoon study area. One strip was along the mainland shoreline and sampled most shoreline, coastal marsh, and river delta habitats used by geese and some ducks and tundra habitats used by a variety of terrestrial birds. A second strip was through mid-lagoon habitats and sampled areas used by shorebirds, seaducks, gulls, and terns. A third strip was along the lagoon-side shoreline of the barrier islands and sampled 1) all of the major passes connecting the marine system with the lagoon and 2) barrier island shoreline habitats used by waterfowl, shorebirds, gulls, and terns. The fourth strip was located in the nearshore Chukchi Sea about 0.5 km seaward of and parallel to the barrier islands and sampled marine habitats used by seabirds and marine waterfowl. Each of these survey strips was approximately 200 km in length and was subdivided into six shorter transects that partitioned the area into smaller sections. Each transect was further subdivided into 1 min time intervals that corresponded to about 3 km at a survey speed of approximately 175 km/h. Each complete survey of the study area lasted 4-5 h, including the time needed to fly between transects.

Survey Techniques

Most aerial surveys for this study were conducted from a float-equipped Cessna 206 with an ARNAV-50 long-range navigation (LORAN) system for determination of transect start and end points. Five surveys were conducted in 1989 (24, 26 August; 3, 4, 11 September), eight in 1990 (27, 28 July; 11, 12, 22, 23 August; 8, 10 September), and three in 1991 (30 July; 1, 26 August). Most surveys were conducted in the afternoon (between 14:00 and 19:00 ADT). Surveys were conducted using the same flight procedures and the same prime observer in all three years. In 1991, two surveys (on 30 July and 1 August) were conducted in an Aero-Commander Shrike with the same type of navigation system used in the Cessna. Surveys in all three years were conducted with the prime observer in the front right seat of the aircraft and a second observer in the rear left seat.

All surveys were conducted at an altitude of approximately 45 m above sea level and at a ground speed of approximately 175 km/h, which is a standard procedure for accurately surveying marine birds from the air (Bradstreet, 1979; McLaren, 1982). Observers dictated into portable tape recorders all sightings made both on-transect (within a 200 m strip on each side of the aircraft) and off-transect (beyond the transect strip). Information recorded included systematic details about the transect and each sighting. The floats on the Cessna 206 aircraft obstructed downward visibility and precluded observation directly under the aircraft, so the inner edge of each transect strip was about 50 m to the side of the flight track and the outer edge was 250 m to the side.

A timer with an audible signal was used to divide all transects into 1 min time periods that corresponded to transect segments of approximately equal length (assuming constant ground speed by the survey aircraft). This procedure enabled the calculation of bird densities on a per-time-period basis as well as on a per-transect or per-habitat type basis. On-transect observations were used to calculate the numbers of birds seen per km^2 and on- plus off-transect observations were used to calculate the numbers and densities of birds seen per km (Table 1). This latter measure was used for species (e.g., Brant, Greater White-fronted Goose) that typically took flight at the approach of the aircraft and were thus often observed beyond the 200 m transect limits. Weather conditions during surveys were generally good, but on 28 July and 11 August 1990 and 26 August 1991 fog prevented surveys of some transects (Table 2).

In the Discussion we used two indices of species abundance and diversity to compare results from studies in Kasegaluk Lagoon, Peard Bay, and several Beaufort Sea lagoons (Table 3). All of these lagoons border the coastal plain of the North Slope of Alaska (Fig. 1). The timing, surveys procedures, levels of effort, and experience of the aerial surveyors in these different studies were very similar (Peard Bay and 11 ANWR lagoons in 1983) or were identical (Beaufort Sea Lagoons in 1990) to those used in Kasegaluk Lagoon in 1990. The timing and number of surveys in Kasegaluk Lagoon in 1989 and 1991 were markedly different from those in 1990 and were not used in the quantitative comparisons.

"Species richness" is the total number of identifiable species recorded by the prime observer during the aerial surveys. Small and large shorebirds were the only species groups included in this measure. The Shannon-Wiener diversity index (H) is a useful measure for comparing species diversity when sampling procedures are comparable and when the number of species is not small (≥ 20). The Shannon-Weiner "H" is computed as follows: $H = -\Sigma$ (p)(log p), where p is the proportion of sightings of a particular species relative to sightings of all other species recorded during systematic surveys (Pielou, 1974:290).

RESULTS

Comparisons of data collected during the three years of surveys are made difficult by the uneven survey efforts. Consequently, patterns of distribution and abundance are based mainly on 1990 data when eight surveys were conducted during the period 27 July through 10 September. Ancillary information is also available from the five surveys in 1989 and the three surveys in 1991.

Pacific Loon (*Gavia pacifica*)

The overall mean densities and numbers of Pacific Loons recorded in 1989, 1990, and 1991 were similar (Tables 1

TABLE 1. Mean densities (no/km²) of waterbirds recorded on transects in the Kasegaluk Lagoon study area in 1989, 1990, and 1991[1]

	Waterbird Density					
	1989 (n = 120)		1990 (n = 168)		1991 (n = 60)	
Species	Mean	s.d.	Mean	s.d.	Mean	s.d.
Yellow-billed Loon	0.01	0.04	0.01	0.04	<0.01	0.02
Pacific Loon	0.06	0.12	0.05	0.08	0.06	0.11
Arctic Loon	<0.01	0.03	—	—	—	—
Red-throated Loon	0.06	0.14	0.11	0.20	0.09	0.11
Black Guillemot	0.01	0.04	<0.01	0.01	—	—
Thick-billed Murre	—	—	<0.01	0.01	—	—
Pomarine Jaeger	—	—	<0.01	<0.01	—	—
Parasitic Jaeger	<0.01	0.01	0.02	0.08	0.04	0.07
Long-tailed Jaeger	<0.01	0.04	<0.01	<0.01	0.02	0.08
Black-legged Kittiwake	—	—	0.10	0.52	0.95	4.10
Glaucous Gull	0.67	0.97	2.89	7.54	2.80	4.38
Herring Gull	<0.01	0.01	<0.01	0.01	—	—
Sabine's Gull	—	—	0.02	0.13	0.08	0.23
Arctic Tern	0.01	0.04	3.29	9.06	6.39	26.53
Aleutian Tern	—	—	<0.01	0.02	—	—
Northern Fulmar	—	—	<0.01	0.01	—	—
Red-breasted Merganser	0.66	3.81	1.34	6.24	0.55	3.66
Green-winged Teal	—	—	0.02	0.12	0.02	0.08
Northern Pintail	0.36	1.64	2.34	7.88	2.69	6.74
Greater Scaup	0.04	0.40	0.02	0.30	—	—
Oldsquaw	5.82	14.07	11.45	32.31	21.59	78.04
Steller's Eider	—	—	—	—	0.04	0.17
Common Eider	2.45	4.76	2.27	4.98	3.04	7.79
King Eider	—	—	<0.01	<0.01	0.04	0.20
Black Scoter	0.01	0.09	—	—	—	—
White-winged Scoter	0.04	0.25	<0.01	0.03	—	—
Surf Scoter	1.01	4.89	0.10	0.37	0.27	1.62
Lesser Snow Goose*	0.04	0.20	0.15	0.69	0.09	0.38
Greater White-fronted Goose*	0.31	1.19	2.07	7.16	3.95	14.28
Canada Goose*	0.01	0.09	0.02	0.15	0.02	0.11
Black Brant*	32.99	123.71	12.90	36.88	27.05	161.04
Tundra Swan	0.04	0.18	0.04	0.14	0.01	0.07
Lesser Sandhill Crane	—	—	0.01	0.06	0.01	0.04
Red Phalarope	—	—	0.02	0.23	0.01	0.03
Red-necked Phalarope	—	—	<0.01	0.04	—	—
Unid. Phalarope	0.02	0.13	1.42	11.91	0.17	0.61
Long-billed Dowitcher	—	—	<0.01	0.04	—	—
Dunlin	<0.01	0.03	0.14	1.28	0.04	0.24
Bar-tailed Godwit	—	—	<0.01	0.01	<0.01	0.03
Whimbrel	<0.01	<0.01	—	—	—	—
Black-bellied Plover	0.02	0.10	0.04	0.34	0.05	0.16
Lesser Golden Plover	<0.01	0.04	0.10	0.70	0.05	0.27
Small Shorebird	4.38	21.63	17.10	71.31	45.54	188.73
Large Shorebird	<0.01	0.02	2.36	15.17	1.35	5.12

[1]For those species marked with an asterisk (*), linear densities (birds/km) are presented. With the exception of several groups of shorebirds, unidentified species have been excluded. The numbers of transects sampled are in parentheses.

and 2). In 1990 and 1989, the highest densities were recorded in the Kokolik River delta, in the Icy Cape area, and in the northeastern part of the study area. In 1991, the highest densities were recorded in the Icy Cape area and near Point Lay. Figure 2 shows the overall distributions of Pacific Loons in the three years of study.

Red-throated Loon (*Gavia stellata*)

The densities of Red-throated Loons were also similar during all three years of surveys (Table 1). Based on surveys in 1990, when extensive sampling was conducted, Red-throated Loons were most common in the study area in late July (Table 2). In 1989, the highest densities were recorded on nearshore marine and barrier island transects, mainly in the southwestern part of the study area (i.e., southwest of Icy Cape). In 1990, the highest densities were recorded on nearshore marine transects in the southwestern part of the study area (Fig. 3), especially on early surveys. Later in the season, high densities were also recorded on barrier island and mid-lagoon transects. In 1991, the highest densities were recorded in nearshore marine and barrier island transects (Fig. 3).

Brant (*Branta bernicla*)

The Brant was the most abundant species of bird recorded during aerial surveys in all three years (Tables 1 and 2). About

TABLE 2. Numbers of individual waterbirds seen on+off transect during aerial surveys in Kasegaluk Lagoon, Chukchi Sea, Alaska, 1989-91

	1989					1990								1991		
Species	24 Aug.	26 Aug.	3 Sep.	4 Sep.	11 Sep.	27 Jul.	28 Jul.*	11 Aug.*	12 Aug.	22 Aug.	23 Aug.	8 Sep.	10 Sep.	30 Jul.	1 Aug.	26 Aug.*
Pacific Loon	45	43	28	45	42	24	10	14	42	10	17	24	25	32	9	20
Red-throated Loon	2	14	41	48	17	88	5	21	67	26	57	31	16	33	32	18
Brant	63 256	53 135	15 854	8 998	2 675	1 238	1 361	10 834	13 535	6 596	10 530	25 683	13 129	851	995	54 626
White-fronted Goose	396	422	386	95	30	993	1 432	1 282	887	3 047	2 445	11	1	1 389	4 205	905
Lesser Snow Goose	96	70	0	0	0	303	41	186	168	81	35	180	120	102	41	95
Tundra Swan	23	30	5	2	11	8	10	13	12	17	32	25	21	4	2	29
Oldsquaw	1 907	2 077	5 690	7 441	7 564	2 833	1 499	6 593	6 776	3 906	9 052	1 082	1 343	6 872	9 093	1 130
Common Eider	873	1 728	1 125	2 031	1 289	641	323	193	950	695	1 077	1 263	1 398	1 238	757	998
Red-breasted Merganser	716	2	228	217	1 076	234	13	1 043	2 070	711	413	20	51	61	77	450
Surf Scoter	155	179	142	387	292	33	0	9	63	8	136	51	48	4	136	0
Northern Pintail	162	191	162	392	60	501	1 101	2 509	2 037	380	370	49	42	712	1 661	326
Small Shorebirds	380	3 996	1 675	176	368	4 906	2 992	5 147	2 460	4 627	8 011	106	2 190	2 762	5 364	29 070
Glaucous Gull	364	592	521	386	384	6 064	2 423	974	822	1 716	951	1 141	1 399	2 483	3 248	767
Arctic Tern	3	15	2	0	0	735	747	1 829	3 105	3 878	961	20	19	3 717	3 343	150

*All 24 transects, i.e., 778 km (311 km^2), were surveyed except on 28 July and 11 August 1990 and 26 August 1991, when only 12 transects, i.e., 399 km (160 km^2), were surveyed.

TABLE 3. Comparison of avian diversity in barrier island-lagoon systems in the Chukchi Sea and Beaufort Sea, Alaska

		Central Beaufort lagoons[a] Beaufort Sea (1990)		11 ANWR lagoons[b] Beaufort Sea (1983)		Peard Bay[c] Chukchi Sea (1983)		Kasegaluk Lagoon[a] Chukchi Sea (1990)	
Characteristics		Species	%	Species	%	Species	%	Species	%
Relative abundance	1	Oldsquaw	90.20	Oldsquaw	78.87	B-1. Kittiwake	27.63	Black Brant	39.51
(%) of top five	2	Common Eider	3.00	Sm. Shorebird	13.92	Oldsquaw	27.13	Oldsquaw	15.76
ranking species or	3	Glaucous Gull	1.70	Black Brant	2.18	Arctic Tern	19.13	Sm. Shorebird	14.51
species groups	4	Black Brant	0.70	Glaucous Gull	2.04	Glaucous Gull	12.59	Glaucous Gull	7.38
	5	Surf Scoter	0.63	Arctic Tern	1.25	Black Brant	4.97	Arctic Tern	5.38
Species richness[d]		29		24		37		48	
Shannon-Wiener "H"[e]		0.17		0.34		0.77		0.84	

[a] Central Beaufort lagoons and Kasegaluk Lagoon data are from 7 and 8 aerial surveys respectively during 27 July–10 September 1990.
[b] Arctic National Wildlife Refuge (ANWR) data are from aerial surveys during 4 August–8 September 1983 (Brackney *et al.*, 1985).
[c] Peard Bay data are from aerial surveys during 15 July–25 August 1983 (Gill *et al.*, 1985).
[d] "Species richness" is the total number of identifiable species recorded by the prime observer during the aerial surveys. Small and large shorebirds were the only "species-groups" included in this measure.
[e] Shannon-Wiener Diversity Index, $H = -\Sigma$ (p)(log p). See Pielou (1974:290).

40%, 15%, and 49% of the estimated total Pacific Flyway populations of Brant (based on mid-winter counts) were present in the Kasegaluk Lagoon study area during peak periods (late August through early September) in 1989, 1990, and 1991 respectively. A more thorough treatment of the abundance and distribution of this species in Kasegaluk Lagoon is presented in another paper (Johnson, 1993).

Greater White-fronted Goose (*Anser albifrons frontalis*)

White-fronted Geese constituted a large proportion of all waterfowl in 1990 and 1991, years when some surveys were conducted in late July and early August. This is in contrast to 1989, when only late-season surveys were conducted. Similarly, the numbers recorded on surveys and the overall mean densities of white-fronts were markedly greater in 1990 and 1991 compared to 1989 (Tables 1 and 2). The peak of migration out of the Kasegaluk Lagoon area during 1990 appeared to be in the last week of August and first week of September.

The distribution of Greater White-fronted Geese (Fig. 4) was quite different during the three years of surveys. In 1989 the highest densities were in the northeastern part of the study area, northeast of Icy Cape. In contrast, the markedly higher densities recorded in 1990 and 1991 were in the coastal marshes at the extreme southwestern end of the study area.

Lesser Snow Goose (*Chen caerulescens caerulescens*)

Lesser Snow Geese were seen in the study area in all three years of surveys, with markedly more recorded during 1990, when eight surveys were conducted (Tables 1 and 2). Only fully fledged Snow Geese were recorded in 1989, when surveys began in late August, but some individuals were clearly recognizable (grey plumage) as young-of-the-year. In 1990 and 1991, however, when some surveys were conducted earlier, molting adults with half-grown goslings were recorded during July. The presence of goslings indicated that Snow Geese nested in the Kasegaluk Lagoon area. Point Lay residents confirmed that Snow Geese often nested on islands in the outer Kukpowruk River delta. Our surveys suggest a population of approximately 35-50 pairs of adults in that area. Several smaller groups, including some goslings, were also seen in 1990 and 1991 in a thermokarst marsh complex near the entrance to Avak Inlet (Fig. 5).

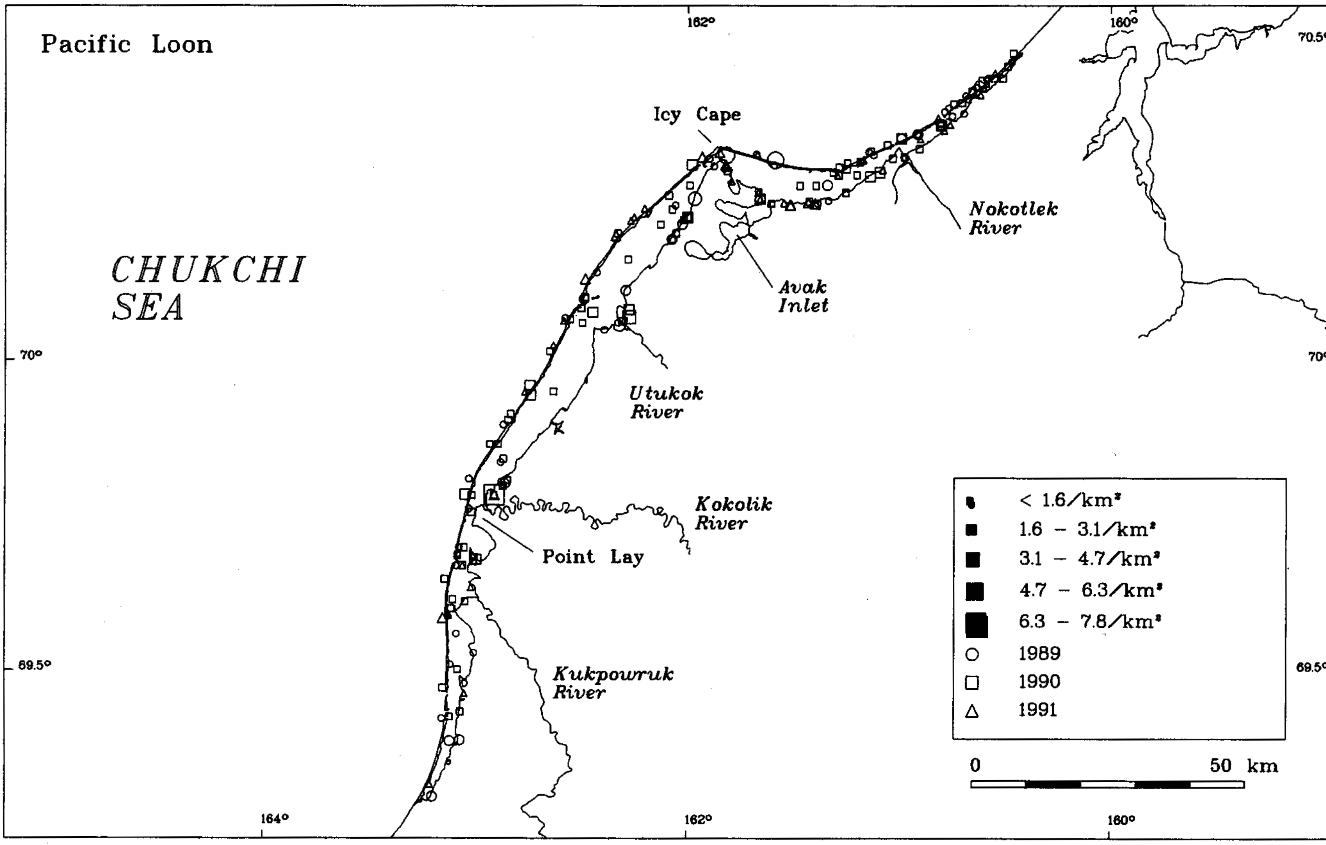

FIG. 2. Summary of Pacific Loon densities in the Kasegaluk Lagoon study area, 1989-91. Different **sized** symbols designate varying densities of birds, and different **shaped** symbols designate densities in the three years of surveys.

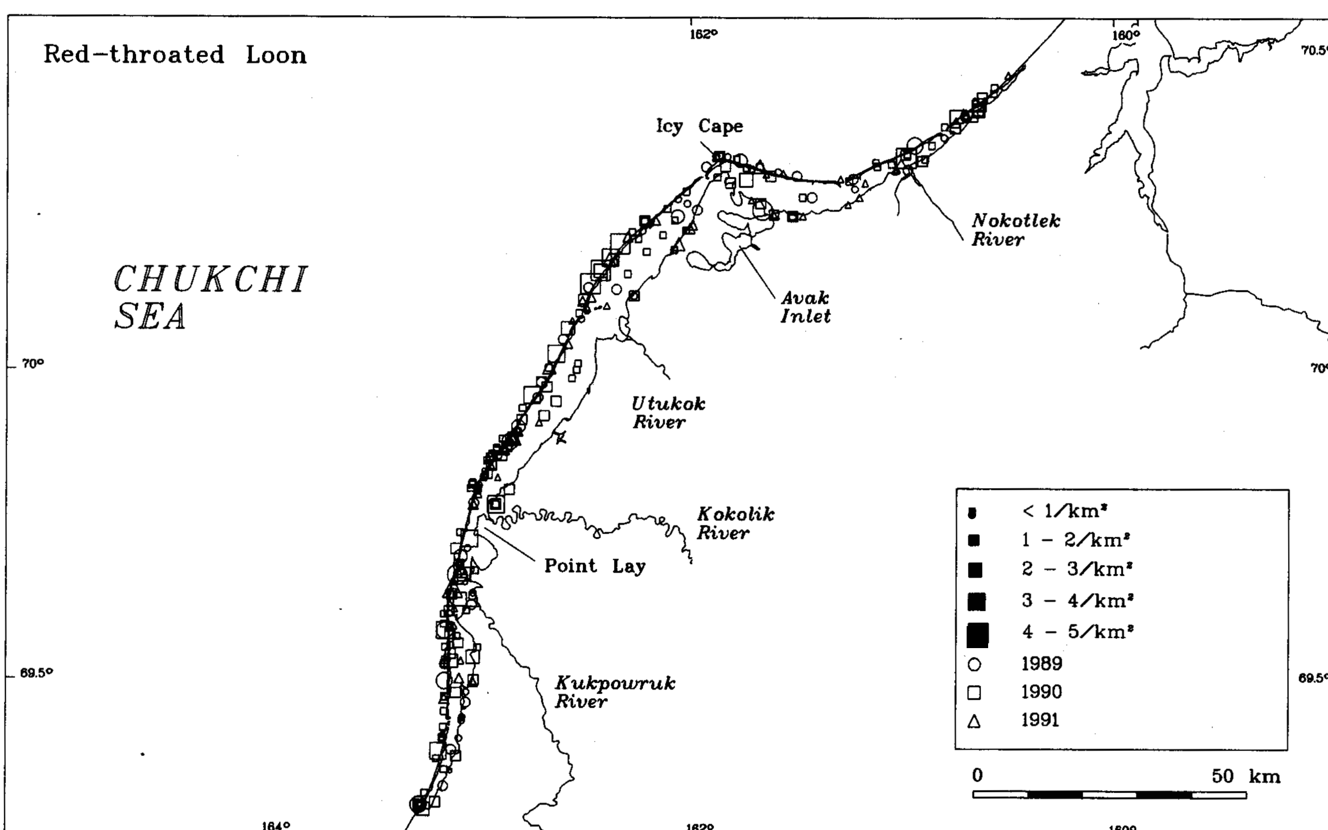

FIG. 3. Summary of Red-throated Loon densities in the Kasegaluk Lagoon study area, 1989-91.

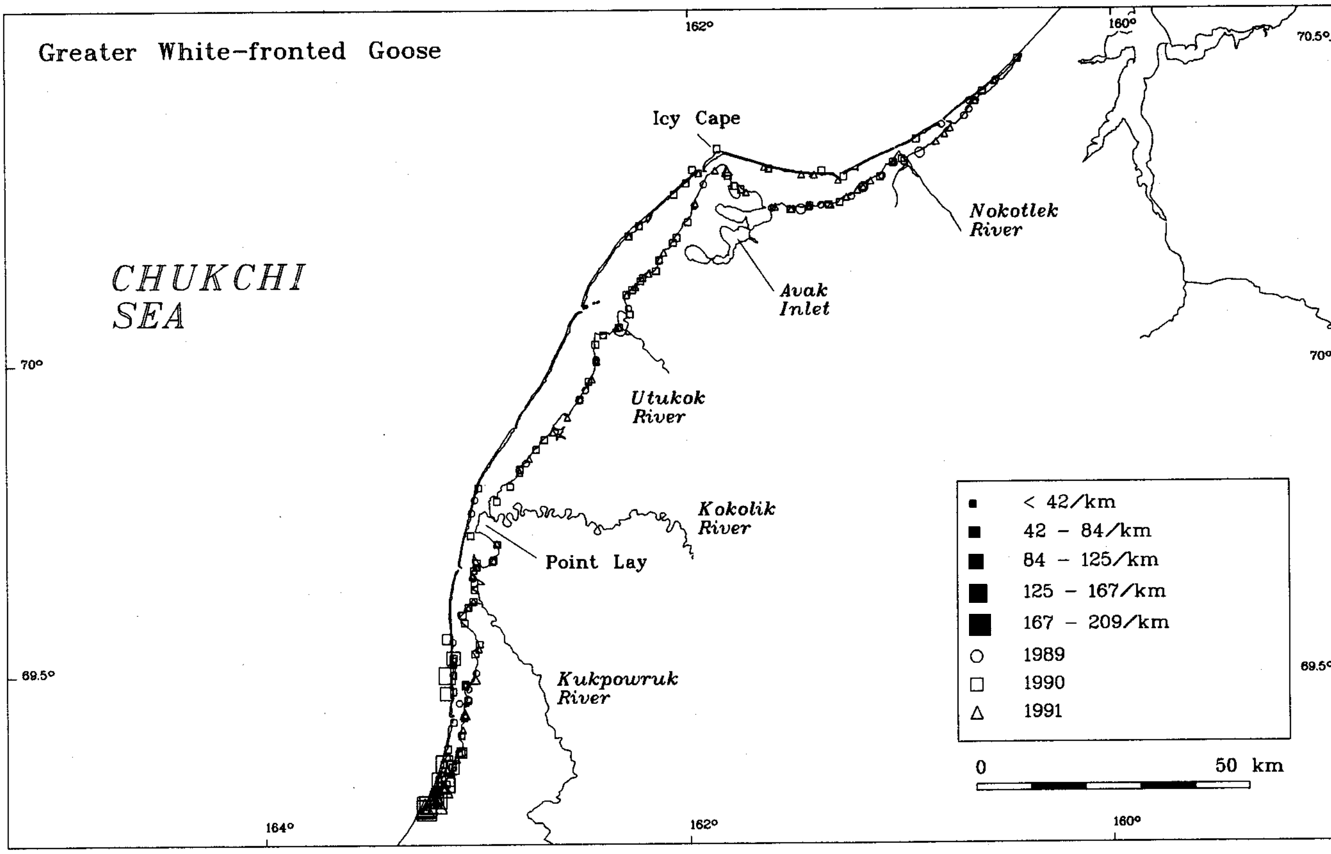

FIG. 4. Summary of Greater White-fronted Goose densities in the Kasegaluk Lagoon study area, 1989-91.

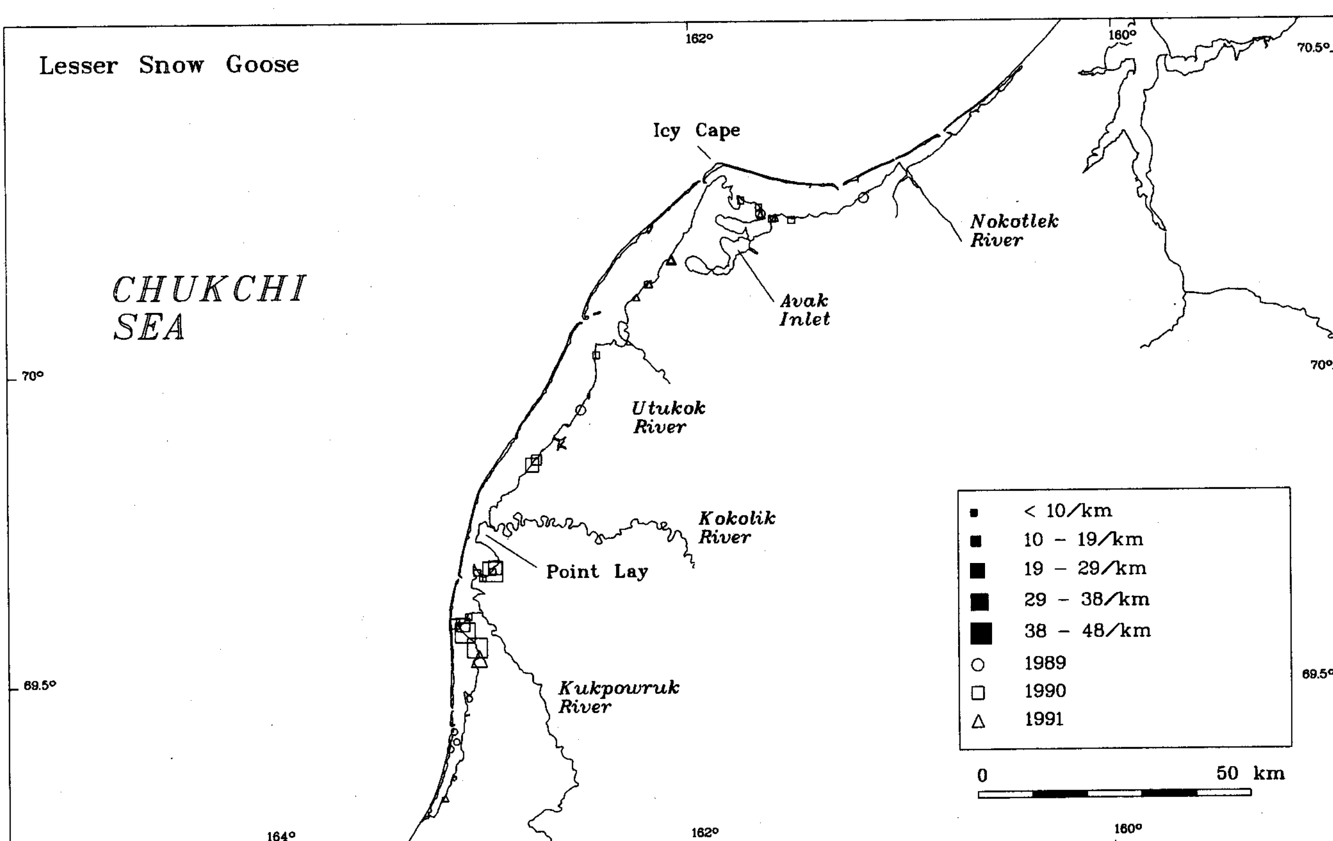

FIG. 5. Summary of Lesser Snow Goose densities in the Kasegaluk Lagoon study area, 1989-91.

Tundra Swan (*Cygnus columbianus*)

Mean densities of Tundra Swans were similar in all three years (Table 1). Family groups, including flightless cygnets, were seen during surveys in 1990 and 1991, indicating that they nested in the Kasegaluk Lagoon area in those years. In 1990, peak numbers were seen in late August (Table 2).

The distribution and abundance of Tundra Swans (Fig. 6) in late August 1990 and 1989 were similar. In these two years the densities were highest at two locations: in the marshes at the extreme southwest end of the study area and on the mainland adjacent to the Utukok River delta. In 1991, the highest densities were in the area between Icy Cape and the mouth of the Nokotlek River.

Oldsquaw (*Clangula hyemalis*)

The Oldsquaw was the second most abundant species of bird recorded in the study area in the three years of aerial surveys (Table 2). The patterns of Oldsquaw abundance were quite different in the three years of surveys, no doubt because of the uneven survey effort. During 1990, the number of Oldsquaws recorded during the final set of surveys on 8 and 10 September (7.3% of all Oldsquaws recorded in 1990) was greatly reduced from the number recorded during the previous set of surveys on 22 and 23 August (Table 2). In 1989, large numbers (30.7% of all Oldsquaws recorded in 1989) were still present in the study area during the last survey on 11 September (Table 2). The peak number of Oldsquaws recorded during the three surveys in 1991 was on 1 August; this was also the peak for the three years of study.

The distribution of Oldsquaws in all three years of study was closely tied to lagoon-side barrier island habitats, especially in the northeastern portion of Kasegaluk Lagoon (Fig. 7). The area between Nokotlek Pass and Pingorarok Pass was heavily used by Oldsquaws during all three years.

Common Eider (*Somateria mollissima v-nigra*)

The Common Eider was a relatively abundant species of waterfowl in all years of surveys. Their overall mean densities and numbers recorded during the three years of surveys were remarkably similar, despite the varied survey effort (Tables 1 and 2). This species constituted 3.4% of all individuals recorded in 1989, 3.0% in 1990, and 2.1% in 1991. We saw no evidence of Common Eider nesting colonies during the aerial surveys, but previous studies on the barrier islands (Divoky, 1978) indicated that large numbers do nest in the area.

The patterns of Common Eider abundance were similar in 1990 and 1989 (Table 2). In 1990, peak numbers of Common Eiders were observed in early September, but large numbers were also seen on 23 August and on 8 and 10 September. In 1989, relatively large numbers of eiders were seen during all surveys, with the peak number also seen in early September. In 1991, a year when no surveys were flown after 26 August, peak numbers were recorded on 30 July.

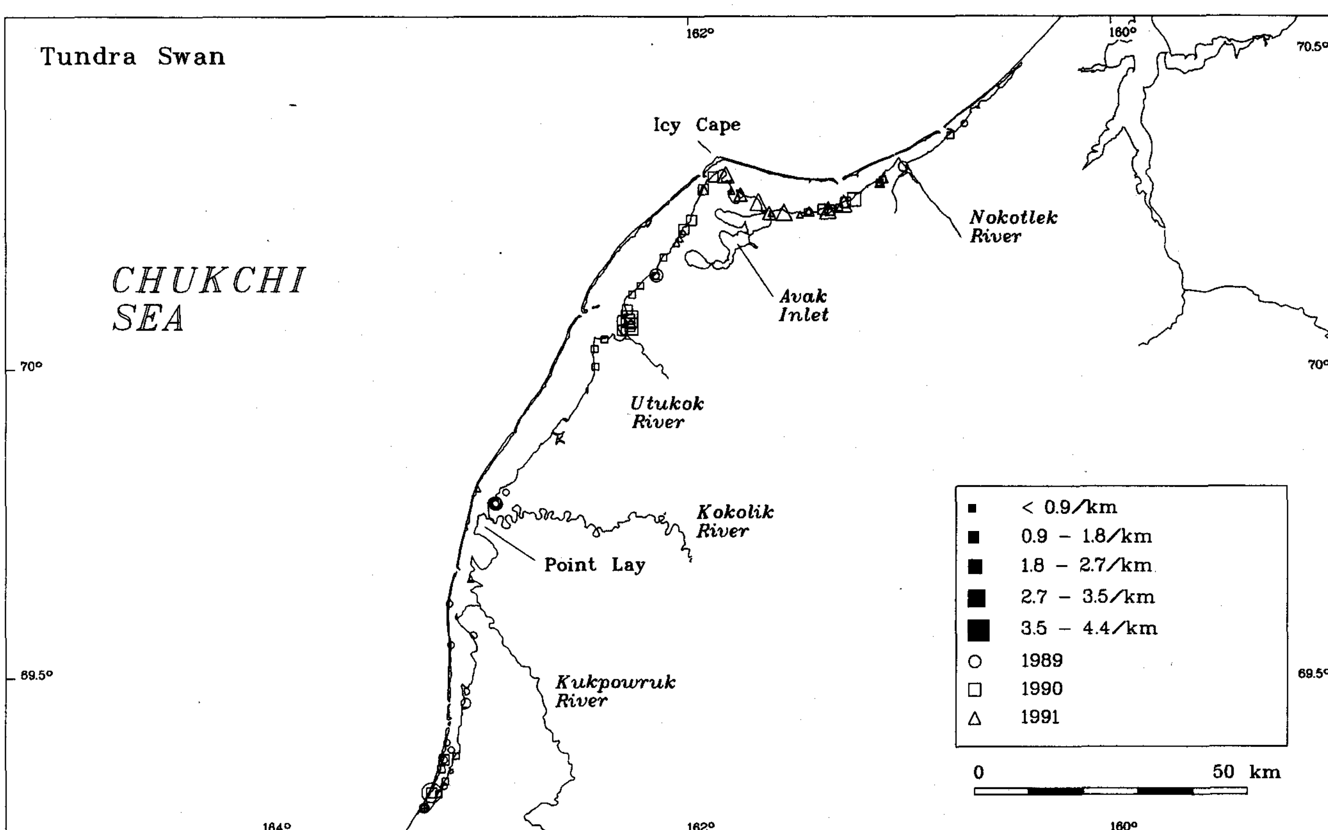

FIG. 6. Summary of Tundra Swan densities in the Kasegaluk Lagoon study area, 1989-91.

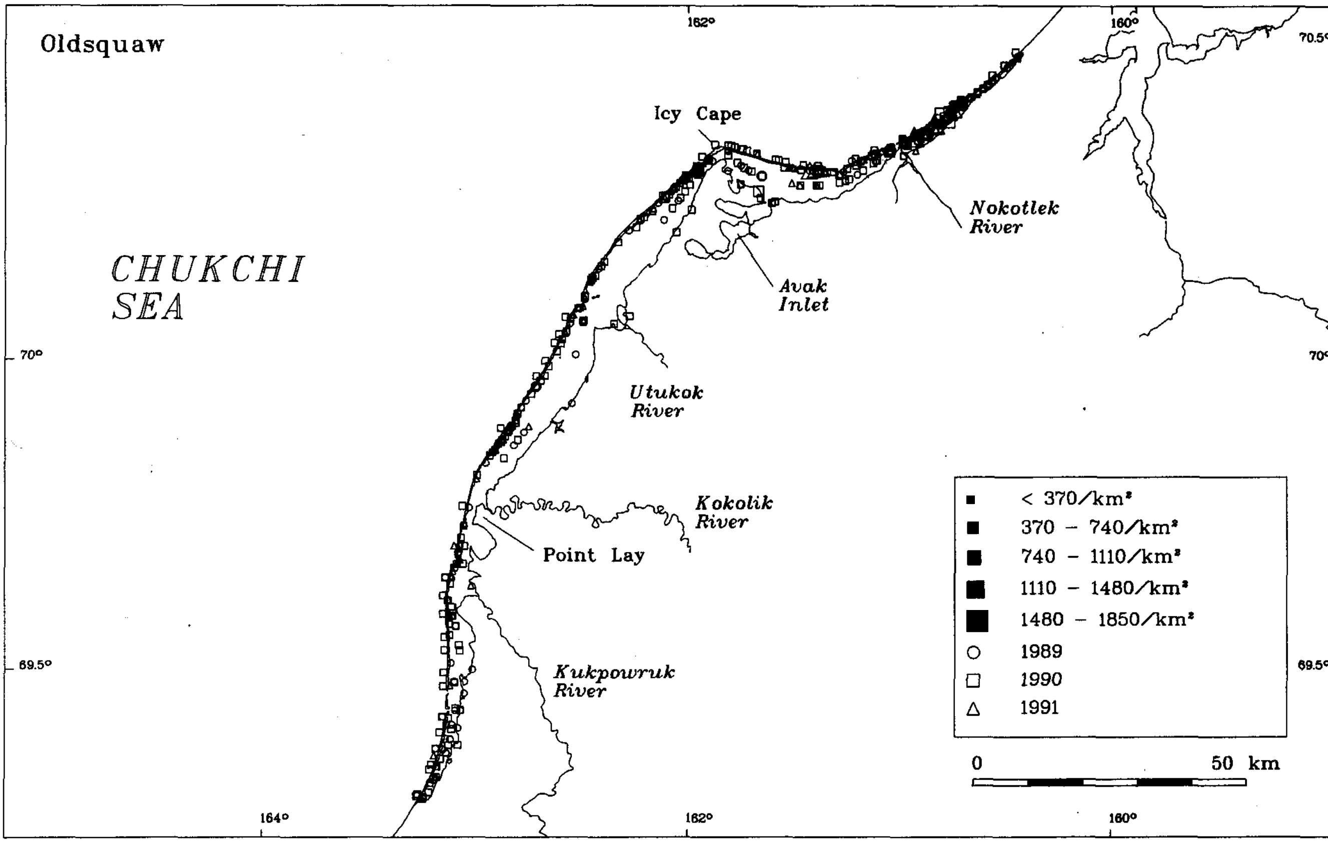

FIG. 7. Summary of Oldsquaw densities in the Kasegaluk Lagoon study area, 1989-91.

The distribution of Common Eiders, like that of Oldsquaws, was closely tied to lagoon-side barrier island habitats, especially in the northeastern portion of Kasegaluk Lagoon (Fig. 8). Areas near Utukok Pass and between Icy Cape and Pingorarok Pass were particularly heavily used by Common Eiders in 1989 and 1990. Peak densities of Common Eiders occurred near Utukok Pass in 1989, near Icy Cape in 1990, and near Akoliakatat Pass in 1991.

Red-breasted Merganser (*Mergus serrator*)

The numbers of Red-breasted Mergansers were different in the three years of surveys (Table 2), probably a result of the uneven survey effort. In 1990, the largest number of mergansers was seen on 12 August, and numbers declined markedly thereafter. In 1989, the largest number was seen during the final survey on 11 September, and in 1991, the peak number was seen on 26 August, the last day of surveys.

The distribution of Red-breasted Mergansers (Fig. 9), like that of the Oldsquaw and Common Eider, was closely tied to lagoon-side barrier island habitats, especially in the northeastern portion of Kasegaluk Lagoon. Areas near Icy Cape and between Akoliakatat Pass and Pingorarok Pass were particularly heavily used by this species in all three years. In general, the highest densities of Red-breasted Mergansers were recorded in sheltered lagoon waters along the barrier island near Akoliakatat Pass. In 1990, high densities were also seen at the entrance to Avak Inlet.

Surf Scoter (*Melanitta perspicillata*)

In contrast to Red-breasted Mergansers (and most other diving ducks), higher densities and more Surf Scoters were seen in 1989 than during either 1990 or 1991 (Tables 1 and 2). In fact, nearly three times more surf scoters were seen in 1989 relative to 1990, when more surveys were conducted over a longer period. Even fewer Surf Scoters were recorded in 1991, a year when only three surveys were conducted (Table 2).

The distribution of Surf Scoters was different from that of other diving ducks. They were seen primarily in nearshore marine habitats seaward of the barrier islands. The peak density was recorded in 1989 in nearshore marine habitats near the southwestern end of the study area (Fig. 10).

Northern Pintail (*Anas acuta*)

The Northern Pintail was the only species of dabbling duck recorded during aerial surveys in the study area in 1989, and aside from a few Green-winged Teal (*Anas crecca*), it was also the most common dabbling duck recorded in 1990 and 1991 (Tables 1 and 2). Northern Pintails were much more common in the study area in 1990 (3.2% of all individuals recorded in 1990) compared to 1989 (0.5%) and 1991 (1.9%), when sampling was restricted.

The distribution of Northern Pintails was similar during the three years (Fig. 11). In all years low densities of pintails were recorded throughout the study area, but most sightings

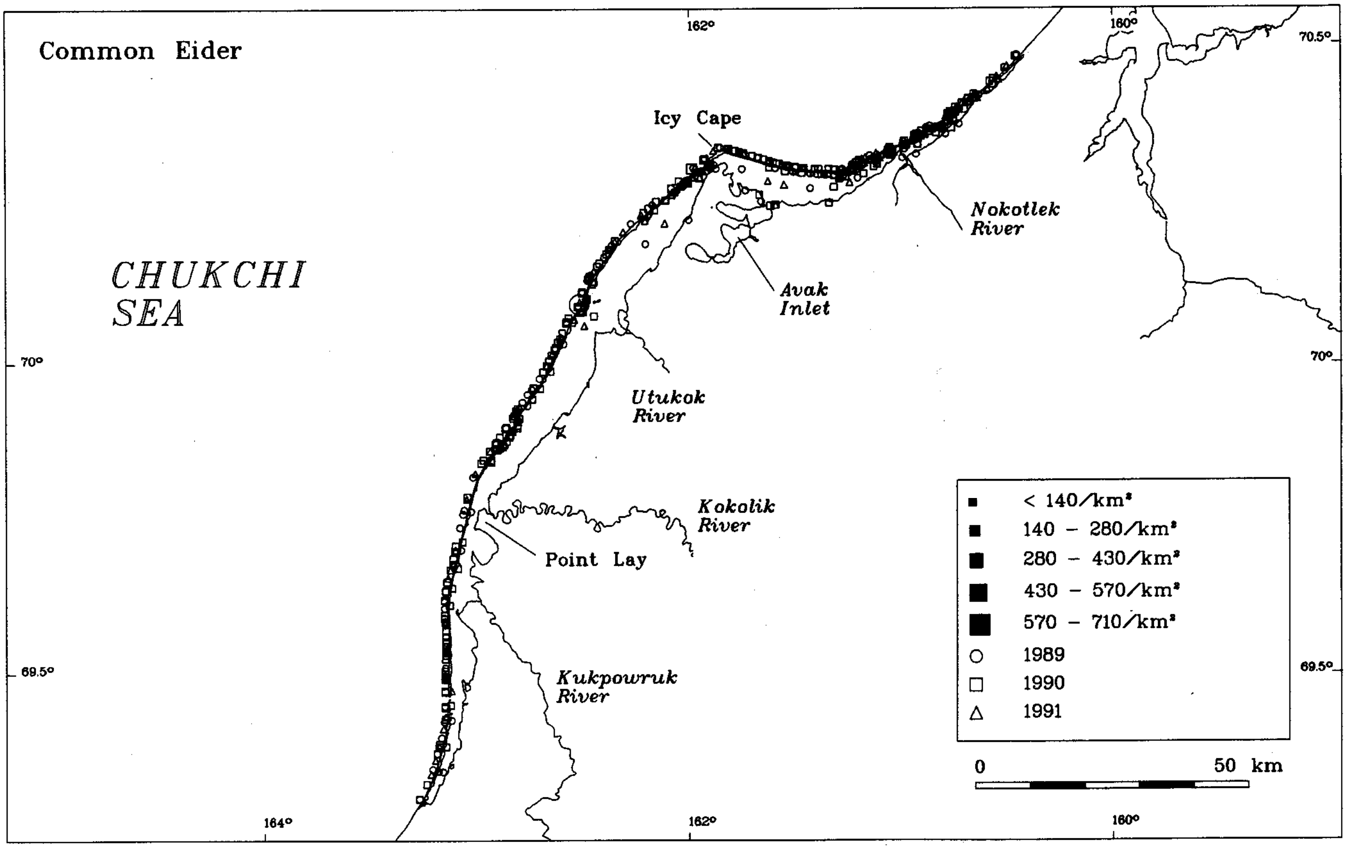

FIG. 8. Summary of Common Eider densities in the Kasegaluk Lagoon study area, 1989-91.

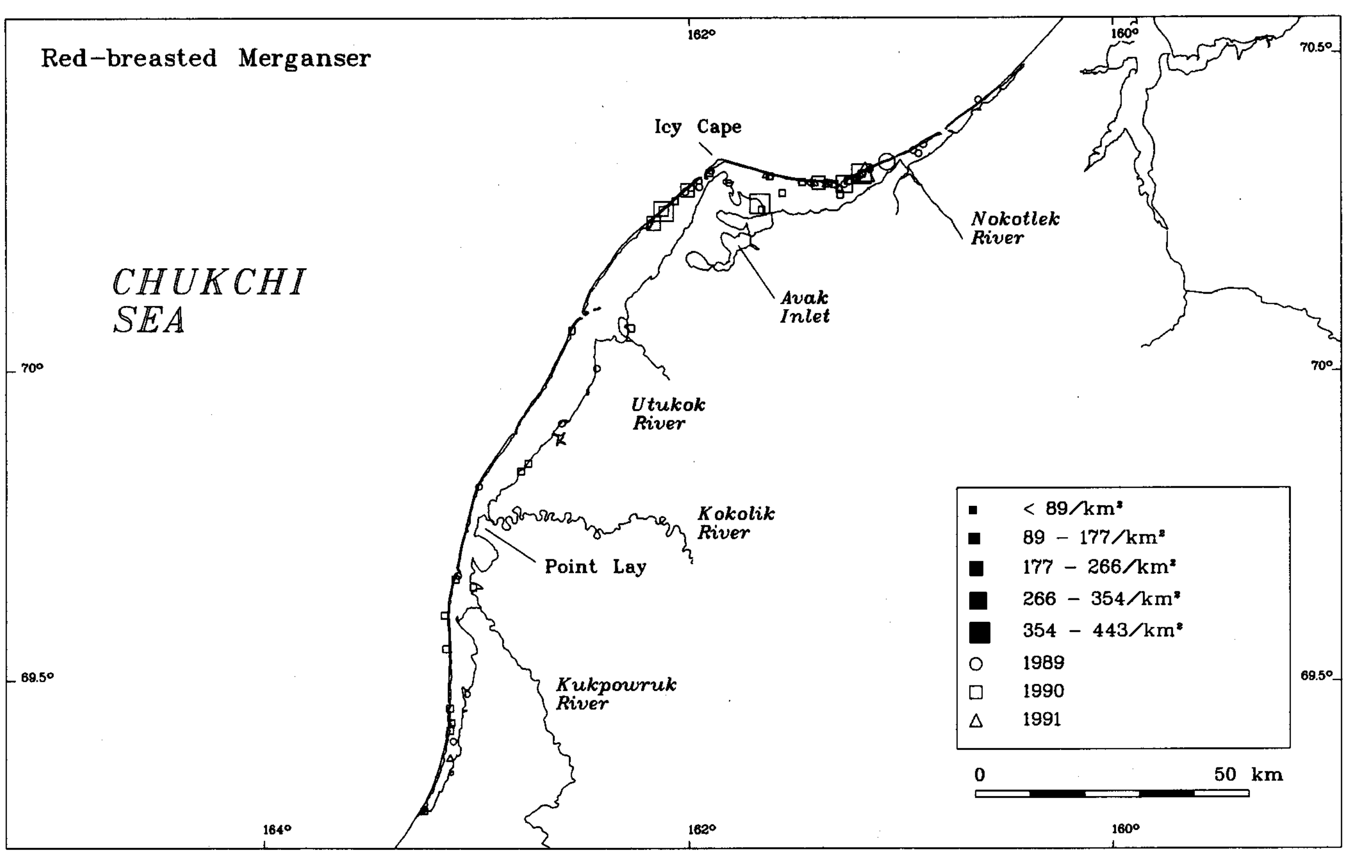

FIG. 9. Summary of Red-breasted Merganser densities in the Kasegaluk Lagoon study area, 1989-91.

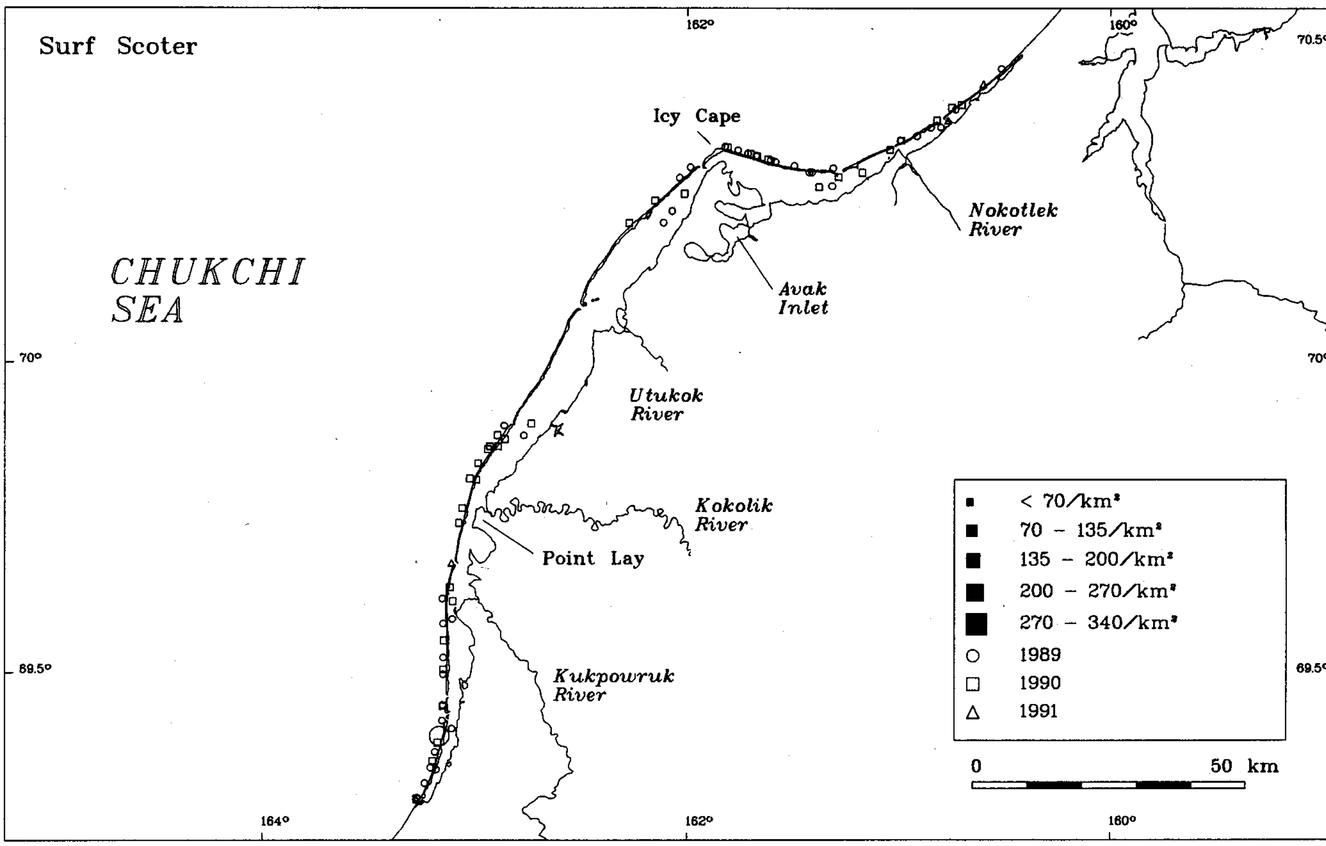

FIG. 10. Summary of Surf Scoter densities in the Kasegaluk Lagoon study area, 1989-91.

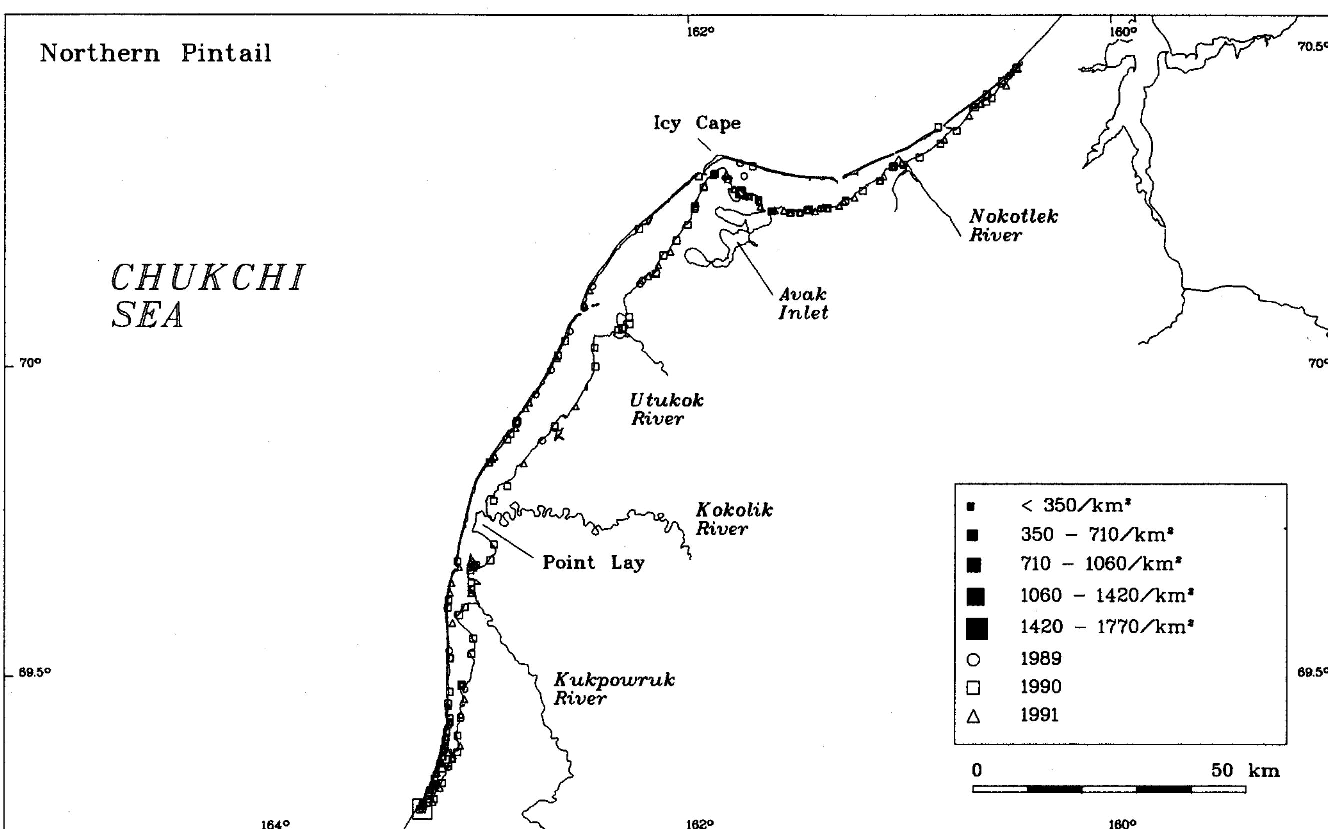

FIG. 11. Summary of Northern Pintail densities in the Kasegaluk Lagoon study area, 1989-91.

were along the margins of Kasegaluk Lagoon, mainly at the far southern end.

Shorebirds

Shorebirds were the second most abundant group of birds (after waterfowl) recorded during aerial surveys in Kasegaluk Lagoon. The group classified as small shorebirds dominated all others in overall density (Table 1). In 1990, when surveys began in late July, shorebirds constituted 17.8% of all individuals. In 1989, surveys began in late August and shorebirds constituted only 3.3% of all birds recorded. In 1991, a year when only three surveys were recorded, shorebirds were a very large proportion — 26.9% — of all individuals recorded.

Small Shorebirds

Small shorebirds were very difficult to classify to species during aerial surveys. The group classified as small shorebirds in Figure 12 and Tables 1 and 2 comprised only unidentified small shorebirds. This group represented nearly all (98.5% in 1989, 78.8% in 1990, and 97.1% in 1991) individual shorebirds recorded in the study area.

Some species of shorebirds were recognizable from the survey aircraft in all three years. The most abundant of these birds were phalaropes (*Phalaropus fulicarius* and *P. lobatus*). In 1990 and 1991, Dunlins (*Calidris alpina*) were also recognizable from the survey aircraft, but they constituted a relatively small proportion (0.7% and <0.1% respectively) of individual shorebirds seen in those two years. Although Western Sandpipers (*Calidris mauri*) were not recognized from the aircraft during aerial surveys, they were one of the most common small shorebirds seen during observations on the tundra and along the shoreline of Kasegaluk Lagoon at Point Lay during July and early August. Large shorebirds (plovers and larger) were poorly represented in 1989 and 1991, but in 1990 plovers made up most of the 11.4% of all individual large shorebirds recorded.

In 1990, the peak abundance of small shorebirds was during late August, when over 8000 were recorded. Several thousand small shorebirds were still present during the final aerial survey on 10 September 1990. In 1989, the peak of shorebird abundance was in late August, when nearly 4000 were recorded. Most shorebirds had departed the study area by early September — only several hundred were recorded during the final survey on 11 September 1989. In 1991, the peak number of shorebirds (29 070, virtually all small shorebirds) was recorded on 26 August; this was the largest number of shorebirds recorded in the study area in the three years of surveys (Table 2).

The distribution of shorebirds (Fig. 12) was similar during all years of aerial surveys. Most were recorded in mudflat habitats at the far southwestern end of the study area.

Glaucous Gull (*Larus hyperboreus*)

Glaucous Gulls were widespread and abundant in the study area in all years (Tables 1 and 2). In 1990, over half (54.8%)

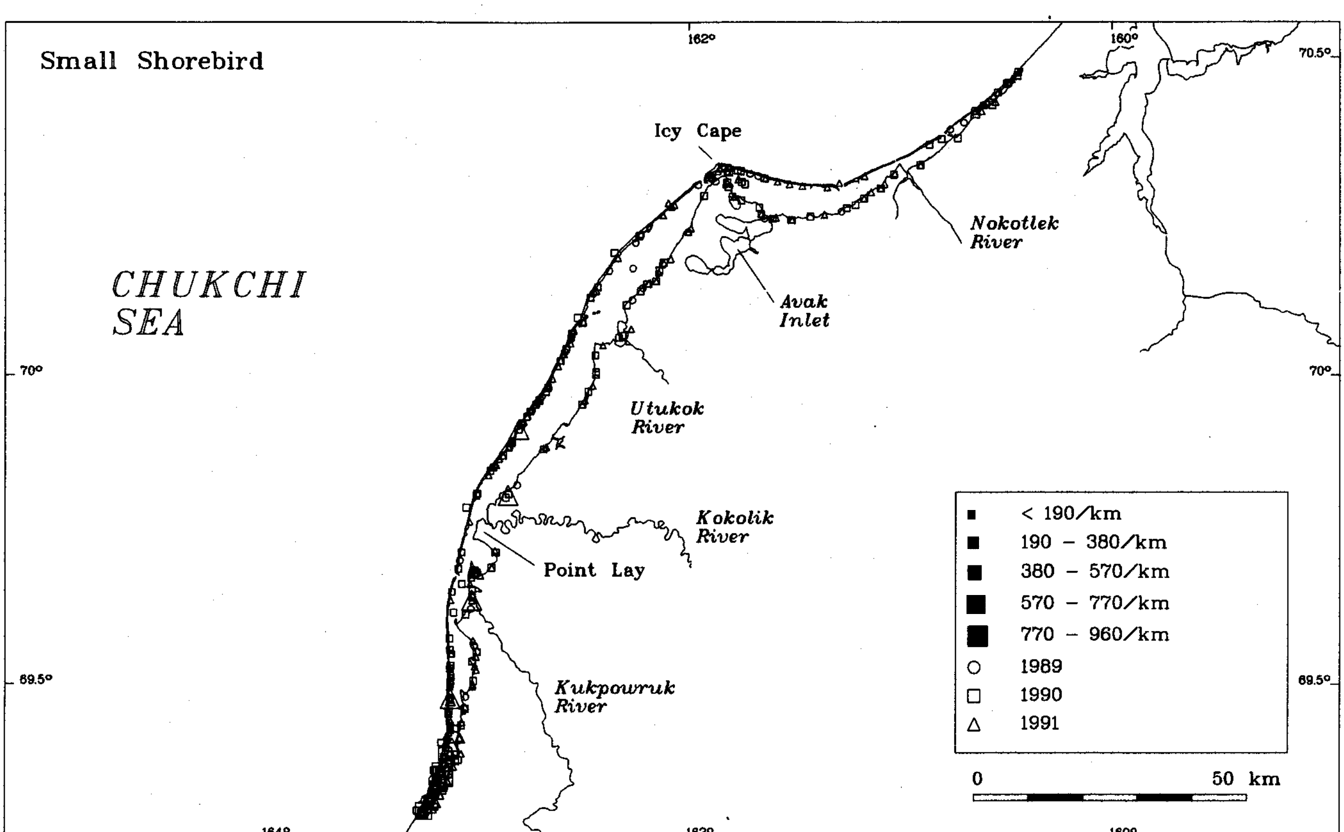

FIG. 12. Summary of small shorebird densities in the Kasegaluk Lagoon study area, 1989-91.

of all Glaucous Gulls were observed during the first set of surveys on 27 and 28 July, about two weeks after the beluga whale (*Delphinapterus leucas*) harvest at Point Lay. Overall mean densities of Glaucous Gulls during 1990 and 1991 were quite similar and were an order of magnitude greater than recorded in 1989 (Table 1).

The distribution of Glaucous Gulls (Fig. 13) was similar during the three years of surveys. A large proportion of sightings was recorded in lagoon habitats along barrier island shorelines. On 27 July 1990, an especially large number (>5000) of Glaucous Gulls was recorded on a small section of barrier island-lagoon shoreline transect adjacent to Point Lay, where several dozen beluga whale carcasses were located.

Arctic Tern (*Sterna paradisaea*)

In 1990 and 1991 aerial surveys commenced in late July and large numbers of Arctic Terns were recorded (11 294 in 1990, 7210 in 1991) (Table 2). In 1989, the aerial surveys commenced on 24 August and only 20 terns were observed. Virtually all of the terns recorded in 1990 were during the period 27 July through 23 August, i.e., the period not covered during the 1989 surveys. Similarly, in 1991, almost all terns were seen during the 30 July and 1 August surveys.

The distributions of Arctic Terns (Fig. 14) during the three years of surveys were only marginally comparable because of the drastic difference in the number of birds seen (Table 2). In 1989, when few birds were seen, most were along the barrier islands southwest of Icy Cape and in the marshes at the far southwest end of the study area. In 1990, most Arctic Terns were also recorded along the barrier islands, but peak densities were in the area around Icy Cape and at Akoliakatat Pass, Utukok Pass, and Kukpowruk Pass, and in the marshes at the extreme southwest end of the study area. In 1991, as in 1990, virtually all Arctic Terns were seen along the barrier islands, mostly near Icy Cape and Akoliakatat Pass.

In 1983, several small groups of Aleutian Terns (*Sterna aleutica*) were discovered nesting among Arctic Terns on the grassy islets and shoals along the barrier islands 5-10 km north of Point Lay (LGL, unpubl. data). Although the colonies were not visited on the ground during this study, Aleutian Terns were positively identified twice in 1990 during aerial surveys near these colonies.

DISCUSSION

The single most important result in this study was the documentation of the very large number of Brant staging in the area, especially during late August 1989 and 1991. There was strong evidence that very large quantities of green algae (probably *Ulva* and *Enteromorpha*) attracted Brant to feed in the study area. A more thorough treatment of this species in Kasegaluk Lagoon is presented in another paper (Johnson, 1993). Another important result was the confirmation of nesting Snow Geese in at least two locations in the study area (Kukpowruk River delta and near the mouth of

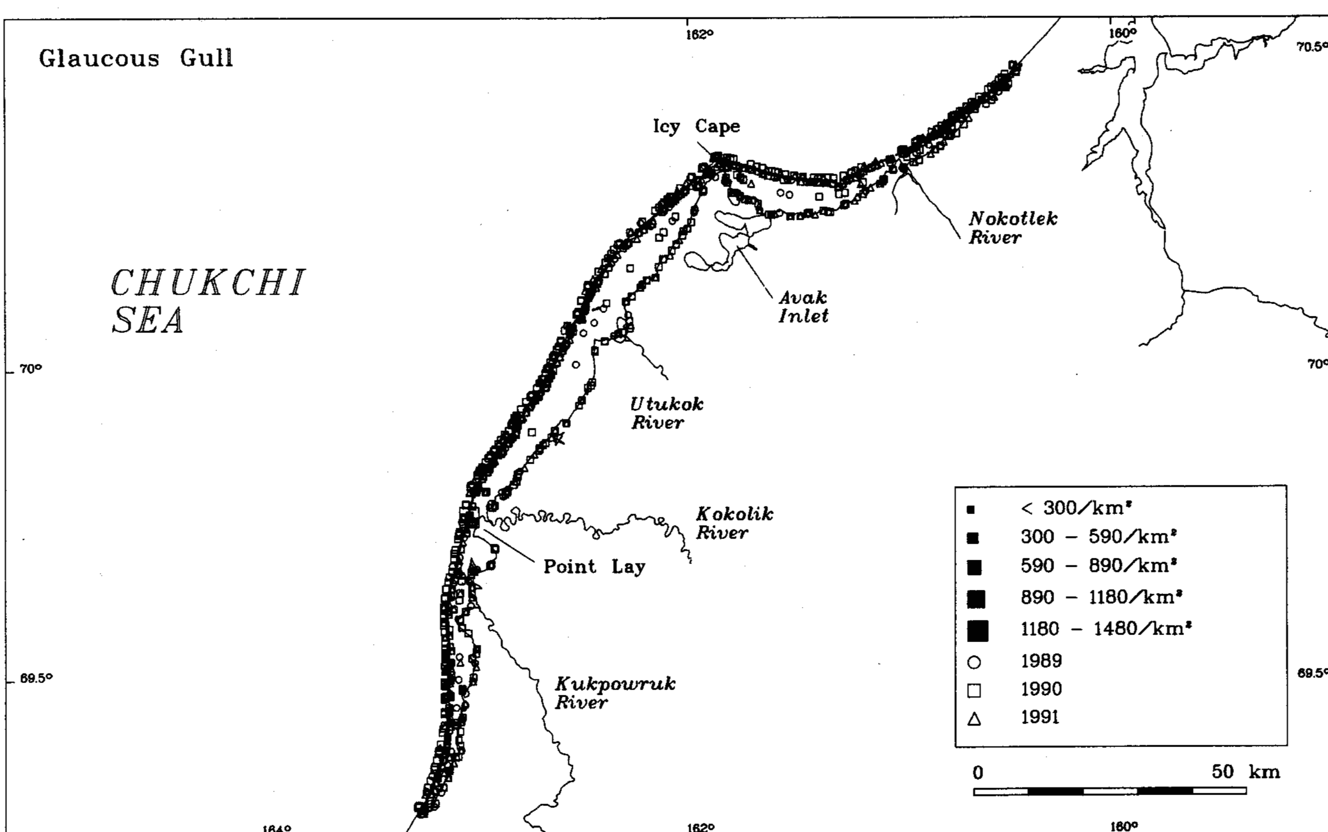

FIG. 13. Summary of Glaucous Gull densities in the Kasegaluk Lagoon study area, 1989-91.

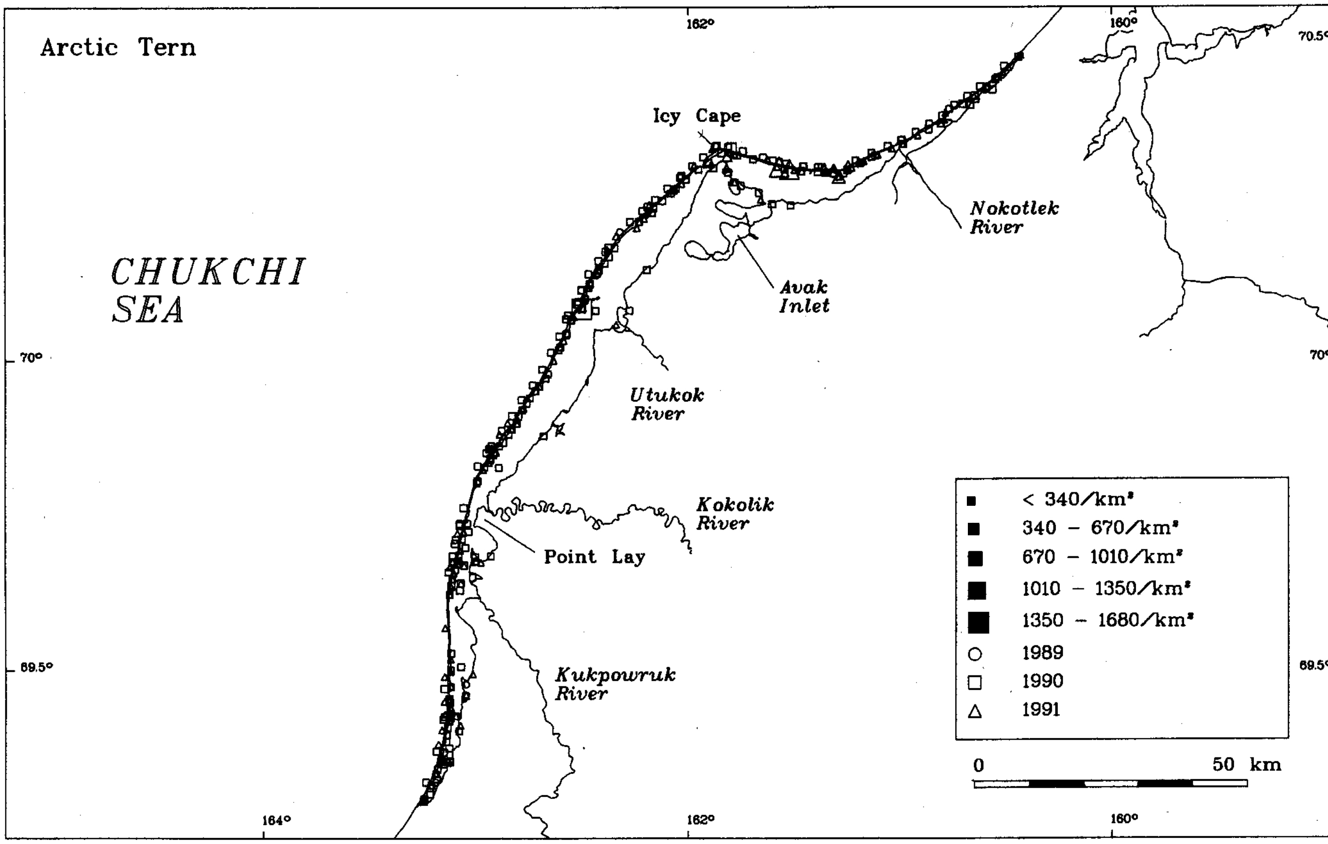

FIG. 14. Summary of Arctic Tern densities in the Kasegaluk Lagoon study area, 1989-91.

Avak Inlet). These two small nesting colonies in Kasegaluk Lagoon and the larger colony on Howe Island in the outer Sagavanirktok River delta near Prudhoe Bay (Johnson and Herter, 1989) are the only consistently used nesting colonies of Snow Geese in Alaska (and the United States).

The small nesting colony of Aleutian Terns in the study area may represent the most northerly nesting location for this species in North America. The large numbers of small shorebirds feeding on the mudflats at the southern end of the lagoon and around Icy Cape were not reported in earlier studies of Kasegaluk Lagoon, and similar large aggregations on mud flats have not been reported in other North Slope lagoon systems.

The richness and diversity of bird species in the Kasegaluk Lagoon system are much greater than we anticipated at the start of this study, and they are markedly greater than in other lagoon systems that have been studied in arctic Alaska. The most striking comparison is between Kasegaluk Lagoon and similar lagoons along the central Alaskan Beaufort Sea coast. There is a large historical base of data for these central Beaufort lagoons, but the best comparisons (Table 3) are based on aerial surveys that were conducted in Kasegaluk Lagoon and in several central Alaska Beaufort Sea lagoon systems in 1990 using the same sampling procedures and personnel (Johnson and Gazey, 1992; Johnson *et al.*, 1992). Data from studies in other arctic Alaska lagoon systems (Gill *et al.*, 1985; Brackney *et al.*, 1985) have also been reanalyzed, and although sampling procedures were not identical to ours, those results are also presented for comparison (Table 2).

Bird use of barrier island–lagoon systems in the Alaskan Beaufort Sea is dominated by one species, the Oldsquaw. Oldsquaws using lagoons in the Beaufort Sea are primarily molting and feeding males. They constituted over 90% of all birds recorded during aerial surveys conducted during 1977 through 1991 (Johnson and Gazey, 1992). Farther east, in lagoons along the coast of the Arctic National Wildlife Refuge (ANWR), Oldsquaws made up nearly 80% of all birds recorded during aerial surveys (Brackney *et al.*, 1985). Beaufort Sea shorelines are also used by phalaropes for premigratory feeding and by Glaucous Gulls, Arctic Terns, Common Eiders, and Black Brant (Craig *et al.*, 1984; Johnson and Herter, 1989). However, the overwhelming dominance of Alaskan Beaufort lagoon systems by a single avian species has a strong influence on avian species diversity in these lagoon systems (Table 3).

Species richness and the diversity of birds in the Peard Bay–Franklin Spit area, studied extensively in 1983 (Gill *et al.*, 1985), were more similar to those in the Kasegaluk Lagoon system than to those in the Beaufort Sea lagoons (Table 3). A dominant species in the Peard Bay study area was the Oldsquaw, although the Franklin Spit area also attracted large numbers of seabirds, such as the Black-legged Kittiwake. Kittiwakes observed in this area in 1983 and the kittiwakes seen near Icy Cape in the Kasegaluk Lagoon system in 1991 (Table 1) probably originated from the colonies at Cape Thompson and Cape Lisburne, located about 200 km southwest of Peard Bay. Overall, kittiwakes were equal in abundance to Oldsquaws in the Peard Bay–Franklin Spit area. Other marked differences in the Peard Bay-Franklin Spit system (compared to lagoons in the Alaskan Beaufort Sea) were the large numbers of Glaucous Gulls and Arctic Terns on Franklin Spit.

The reasons for the greater avian species richness and diversity in Kasegaluk Lagoon and Peard Bay compared to similar lagoon systems located in the Alaskan Beaufort Sea are not well understood but are probably related to productivity and food abundance, which are largely determined by weather and climate, oceanography, proximity to the De Long Mountains, and the general physiography and orientation of the coastline in the Kasegaluk Lagoon area. This region of the Chukchi Sea is characterized by a northward flow of the relatively warm Alaska coastal water mass, which is heavily influenced by discharges from the Yukon and Kuskokwim rivers (Coachman and Aagaard, 1981). Mean air temperatures in May and June are higher in the Kasegaluk Lagoon study area than along the Beaufort Sea coast (Brower *et al.*, 1977). The warm coastal waters and prevailing northeastward currents along this section of the Chukchi Sea coast cause shorefast ice to depart from this area earlier than it does in the Beaufort Sea (Brower *et al.*, 1977; Hale, 1987; Barnes *et al.*, 1989). The Kukpowruk, Kokolik, Utukok, and Nokotlek rivers, which drain runoff from summer storms in the nearby De Long Mountains, and the shallowness of Kasegaluk Lagoon probably greatly reduce the salinity of the lagoon (Pease, 1987), which is thought to be considerably more brackish than lagoons in the Alaskan Beaufort Sea (Barnes *et al.*, 1989).

The southwest-northeast orientation of the coastline in the Kasegaluk Lagoon area coupled with the prevailing northeast winds and southwest storms in the area play a key role in the mass transport of water onto and away from the coast (Pease, 1987). The predominant direction of water movement along this section of the Chukchi Sea coast is northeastward, forced primarily by Bering Sea water influx. Adjacent to some stretches of coast, a baroclinic coastal jet parallels the coast in the direction of the wind. Periodic upwelling of relatively cold and saline outer shelf water into coastal areas probably occurs under strong northeast winds (Lewbel and Gallaway, 1984); this may increase productivity in the area.

Most severe storms along this section of coast are from the southwest; longshore flow rates as high as 200 cm/s and positive rises in sea level of 1.8 to >3 m have been recorded during southwesterly storms (Lewbel and Gallaway, 1984). These factors appear to be the major forces behind the dynamic changes in water levels that affect bird habitat availability and bird abundance in the Kasegaluk Lagoon system.

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