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Waterbird Migration Near the Yukon and Alaskan Coast of the Beaufort Sea:

I. Timing, Routes and Numbers in Spring

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ABSTRACT. Radars, systematic visual observations from the coast, and aerial surveys were used to study migration near the Yukon (1975) and Alaskan (1977-78) coasts of the Beaufort Sea. Conspicuous eastward migration of loons, brant, seaducks, jaegers and glaucous gulls occurs along the icebound coast, and in the Yukon some eastbound species (especially brant) concentrate coastally. Overall, however, eastward migration is predominantly broad-front with little coastal concentration. Most eiders and perhaps most oldsquaws, the commonest waterbirds, fly east offshore where there is more open water. Westward migration is much less conspicuous visually; swans, geese and pintails are the main groups seen. However, radar shows extensive broad-front westward flights, probably largely of shorebirds. Most spring migration, both east and west, is from 15 May to 20 June, with the coastal peak (25 May-15 June) apparently being later than that offshore. Some coastal migrants land on river water that overflows onto nearshore ice in early June. Some waterbirds bypass the largely ice-covered Alaskan Beaufort by flying northeast across interior Alaska and/or northwestern Canada from the Pacific Ocean to the Canadian Arctic. These overland migrants include some yellow-billed and arctic loons, brant and jaegers; probably most Thayer's gulls; and probably some oldsquaws, Sabine's gulls, arctic terns and other species.

Key words: waterbirds, migration, Beaufort Sea, Alaska, Yukon, radar, aerial surveys, seawatches, leads, leading lines

RÉSUMÉ: "Waterbird Migration Near the Yukon and Alaskan Coast of the Beaufort Sea. I. Timing, Routes, and Numbers in Spring", par W. J. Richardson et S. R. Johnson.

Les radars, les observations visuelles de la côte et les reconnaissances aeriennes furent utilisés afin d'étudier des migrations près des côtes yukonienne (1975) et alaskienne (1977-78) de la mer de Beaufort. Les migrations vers l'est d'outards, de bernache, de canard de mer, de jaegers et de goéland glauque se présentent le long de la banquise et, dans le Yukon quelques espèces (surtout la bernache) vont vers l'est en longeant la côte. Cependant, cette migration orientale prend la forme d'un front étendu qui se concentre peu sur les côtes. La plupart des eiders, et peut-être des canards "oldsquaw", les espèces d'oiseaux aquatiques les plus communs, volent vers l'est tout en demeurant éloignés de la côte. La migration vers l'ouest est moins apparente visuellement; les cygnes, les oies et les pintails sont les principaux groupes aperçus. Cependant, le radar montre un front large et extensif de vols orientaux vraisemblablement composés d'oiseaux côtiers. La plupart des migrations printanières se prouduisent entre le 15 mai et le le 20 juin, indépendamment de leurs directions. Par contre, le maximum de la migration côtière 25 mai-15juin) semble plus tardif que celui des vols marins. Certains oiseaux côtiers se posent sur les eaux des rivières qui débordent en début juin sur la glace près de la côte. Quelques oiseaux aquatiques évitent la mer de Beaufort alaskienne, couverte en grande partie de la glace, en volant vers le nord-est à travers l'arrière-pays de l'Alaska et/ou vers le nord-ouest du Canada à partir de l'océan Pacifique jusqu'à l'Arctique canadien. Ces oiseaux qui survolent la terre ferme incluent les ouards de bec-jaune et arctique, la bernache et les jaegers; probablement la plupart de goéland de "Thayer", quelques "oldsquaws", les goélands sabins, les sternes arctiques et d'autres espèces.

INTRODUCTION

Large numbers of waterbirds that nest in and east of the Beaufort Sea area migrate through this area in late spring, summer and early autumn. In spring, observers at coastal vantage points often see conspicuous eastward migrations of loons, brant, oldsquaws, eiders, jaegers, glaucous gulls, Sabine's gulls (*Xema sabini*) and arctic terns (Murdoch, 1885; Brooks, 1915; Dixon, 1916, 1943; Anderson, 1937; Johnson, 1971; Schamel, 1978; see Table 3 for scientific names not given in text). These populations winter in the Pacific Ocean or Bering Sea and most individuals migrate north through the Bering and Chukchi areas before flying east over the Beaufort Sea or northern Alaska. Their routes through the Beaufort Sea area are poorly known, but eiders, in particular, appear to be more numerous far out over the pack ice than near the icebound coast. Thousands of oldsquaws and eiders sometimes concentrate in the few leads and polynyas present offshore in spring (Searing *et al.*, 1975).

Numbers of waterbirds that migrate east over the Beaufort Sea in spring have not been estimated reliably, but the westward return migration past Point Barrow during mid and late summer includes at least 50 000 loons, 240 000 oldsquaws and 1 000 000 eiders (Thompson and Person, 1963; Johnson, 1971; Timson, 1976). These figures underestimate total Beaufort Sea populations because many birds bypass Point Barrow or depart later in the year (Flock, 1973). Significant fractions of the total North American populations of yellow-billed and arctic loons, oldsquaws and eiders are believed to migrate through the Beaufort Sea area (Palmer, 1962, 1976; Bellrose, 1976).

Other species of waterfowl and shorebirds migrate northwest through the interior of North America to the southeastern Beaufort area (Cooke, 1915; Salter *et al.*, 1974). Some, most notably snow geese, continue north to Banks Island (Barry, 1967). Others, including some whistling swans, white-fronted geese (*Anser albifrons*), Canada geese and pintails, continue northwest near the coast to the arctic coastal plain of the Yukon and Alaska (Brooks, 1915; Schmidt, 1973; Salter *et al.*, 1980).

This paper provides systematic data about the timing, routes and amount of spring migration over the southern Beaufort Sea and the adjacent coastal plain of northern Alaska and the Yukon. It combines the results of two migration studies done for impact assessment purposes —

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along the Yukon coast in 1975 (Johnson *et al.*, 1975; Richardson *et al.*, 1975) and along the Alaskan coast west of Prudhoe Bay in 1977-78 (Johnson and Richardson, 1981). In both studies, continuous radar monitoring and occasional aerial surveys provided broad-scale data, and systematic daily migration watches from the coast provided more detailed but localized information about species, numbers, flock sizes, flight altitudes, etc. Here we emphasize the timing, routes and quantities of migration of the common species. Information about flight behaviour and weather effects in spring, and about moult and autumn migration, will be published elsewhere. Rare species encountered in the Yukon and Alaskan components of this study are noted in Salter *et al.* (1980) and Johnson and Richardson (1981), respectively.

STUDY AREAS AND ICE CONDITIONS

In 1975, the study was based at the Komakuk, Y.T., Distant Early Warning (DEW) site (Fig. 1). Another crew observed visually from Clarence Lagoon, 23 km west of Komakuk. The tundra-covered coastal plain is narrowest in this area; the foothills of the British Mountains begin only 10 km inland. There are no barrier islands in this area.

In 1977-78, we studied migration in the Oliktok Point-Simpson Lagoon area, 30-55 km WNW of Prudhoe Bay, Alaska (Fig. 1). The coastal plain consists of tundra and ponds, and is much wider than in the northern Yukon. The Brooks Range is over 150 km inland. A chain of low tundra- or gravel-covered barrier islands 3-7 km offshore forms Simpson Lagoon, most of which is only 2 or 3 m deep. The Colville River, the largest river in northern Alaska, discharges about 20 km WSW of Oliktok. In 1977, visual observations were made from the tip of Oliktok Point and from two sites on Pingok Island, both 12 km northeast of Oliktok. In 1978, visual observations were from Milne Point, 15 km east of Oliktok (Fig. 1, inset).

During the period of peak spring migration from late May to mid-June, major leads or polynyas are almost

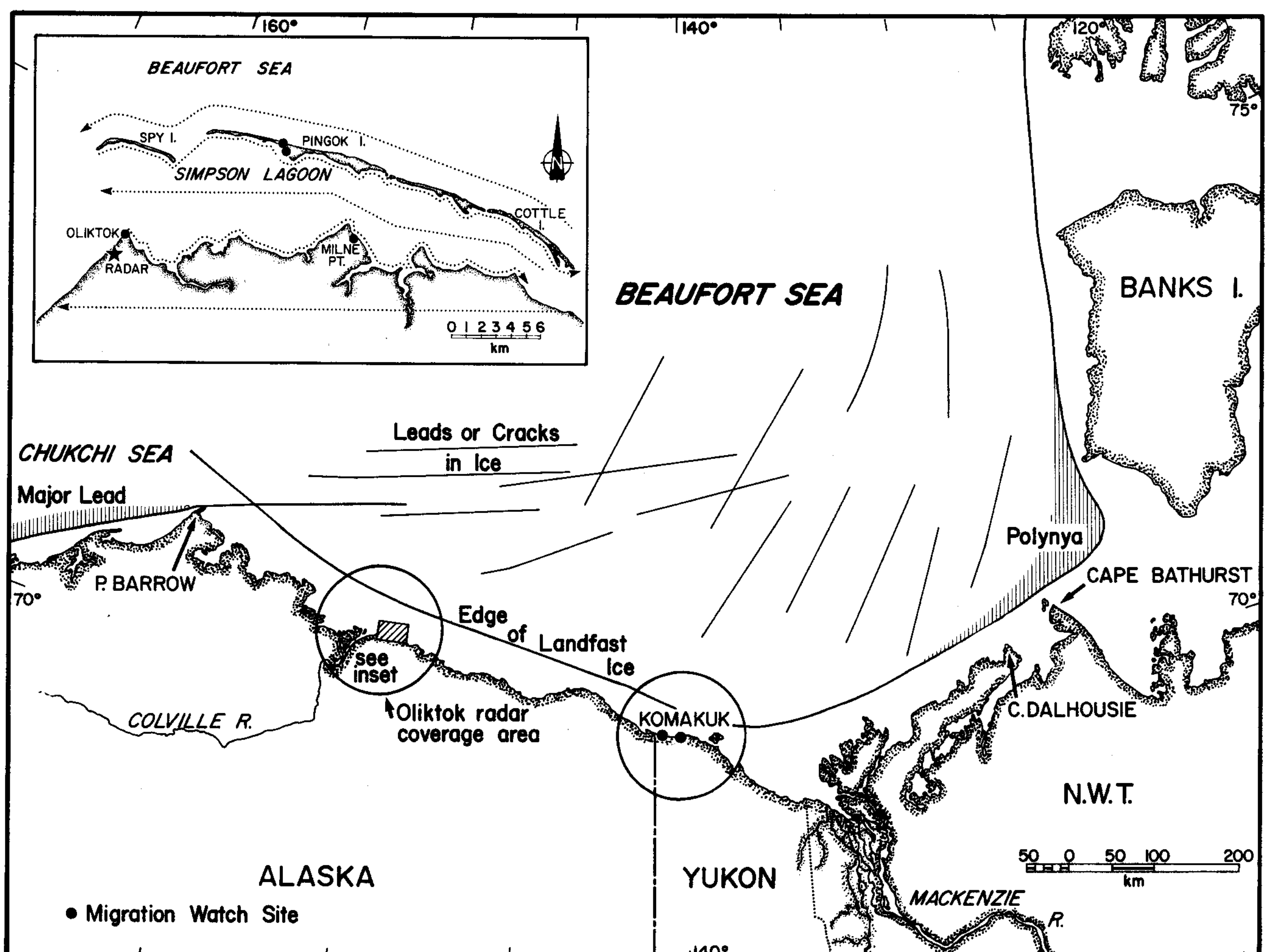

FIG. 1. The Beaufort Sea area, showing locations where there is typically open water around 1 June (cross-hatched), the two radar coverage areas (circles of radius 75 km), and details of the Simpson Lagoon-Oliktok area of Alaska (inset). Dotted lines on inset are the five standard aerial survey transects.

always present in the Chukchi Sea along the northwest coast of Alaska, and in the eastern Beaufort Sea west of Banks Island and off Cape Bathurst (Fig. 1; Marko, 1975). The intervening offshore area (about 800 km wide) is >90% covered by pack ice, with only occasional cracks and leads of open water. Satellite photos of ice conditions in May-June 1975 and 1977 appear in Richardson *et al.* (1975) and Fraker (1979).

In winter and spring a continuous sheet of landfast ice covers nearshore waters out to 20-75 km offshore (Barry, 1979). River water flows out upon or below the landfast ice at the mouths of rivers in late May or early June (Walker, 1974; Dey, 1980), but most nearshore areas remain ice-bound until late June or July, after spring migration ends. Simpson Lagoon is flooded by the Kuparuk River and other streams in early June, but within a week most water drains through holes in the ice, leaving only pools of water and small shoreleads.

The mean temperatures in May and June are −5 and 3°C, respectively, at Komakuk, Y.T. (Burns, 1973), and −6 and 2°C at Oliktok, AK (Brower *et al.*, 1977). Winds are predominantly from the east and northeast (i.e. opposing for the eastbound migrants). The land remains largely snow-covered until late May. Most snowmelt occurs in late May and early June. Snowmelt begins earlier on inland portions of the coastal plain than along the coast (Benson *et al.*, 1975; Holmgren *et al.*, 1975). There is continuous daylight throughout spring migration in May and June.

METHODS

Radar

Radar data were obtained from military surveillance radars at Komakuk, Y.T., from 9 May to 9 July 1975, and at Oliktok, AK, on 18 May and 26 May - 17 June 1977. Flock (1973) documented the suitability of DEW radars for migration studies. Time-lapse film of the PPI display was obtained almost continuously at 75 frames per hour with display radius 75 km. Polaroid photos of the PPI (durations 1- and 6-sweeps) were obtained three times per day.

Preliminary examination of films showed consistent eastward and westward broad-front migrations at both sites. In addition, northeastward migration was often evident near Komakuk. Hence, for each of the two or three main directions of migration (E, W, NE), we estimated numbers aloft and flight directions every three hours at sampling locations 20-30 km inland, along the coast, and 20 km offshore. In the Oliktok study, numbers and directions at sampling locations 50 km inland and offshore were also estimated from the films, but at that range only the larger and higher-altitude flocks would be detectable. All film analysis was by WJR.

Numbers of bird echoes moving east, west and northeast at each sampling location were estimated at 3-hour intervals on a widely used 0-8 ordinal scale (Richardson, 1972). This scale was calibrated in 1975 by counting bird echoes (Table 1).

The modal flight directions (tracks) of the east, west and northeast groups were estimated by eye to the nearest 10° for each 3-h interval and sampling location. Flight paths of individual echoes were occasionally traced from time-lapse film for detailed analysis of flight directions, routes and speeds.

TABLE 1. Calibration of the 0-8 ordinal scale of migration densities[a]

Migration density (0-8 scale)	Echoes/10km•h Mean	SD	n[b]
0	0	0	118
1	5	3	215
2	14	3	115
3	22	4	91
4	35	10	63
5	83	32	43
6	204	13	3

[a]Based on counts of bird echoes crossing a 10-km line oriented perpendicular to the modal track at Komakuk in 1975.

[b]n = number of counts with each density category.

Visual Watches

Systematic daily watches were conducted from vantage points along the coast and, for part of the 1977 season, on a barrier island (Table 2). At each site, one observer (occasionally two at Komakuk) using binoculars and a telescope (usually 20-45X zoom) conducted watches on a regular schedule. In 1975 at Komakuk, 3-h watches were conducted twice a day at ~10:00-13:00 and 17:00-20:00 YST, and occasionally also at 05:00-08:00. In 1975 at Clarence Lagoon, four 3-h watches were conducted, usually between 01:00 and 18:00. On most days in 1977, watches at each of the three sites (Table 2) were conducted for three 2-h periods: 09:00-11:00, 13:00-15:00 and 19:00-21:00 AST. In 1978, there were usually two 2-h watches at ~09:00-11:00 and 13:00-15:00, plus occasional watches at 19:00-21:00.

TABLE 2. Locations, dates and durations of systematic migration watches in May and June

Location[a] and year	Extent of observations: Period	Hours	Height of observer (m ASL)
Northern Yukon, 1975			
Komakuk	9 May - 30 June	193	8
Clarence Lagoon	9 May - 30 June	473	3
Simpson Lagoon, 1977-78			
Oliktok Pt., 1977	17 May - 15 June	141	7
Pingok Isl., 1977	3-14 June	48 + 43[b]	6, 2[b]
Milne Point, 1978	6-30 June	78	6

[a]See Fig. 1 for locations.

[b]Two observers on the north and south sides of Pingok Isl. recorded migration over the sea and lagoon, respectively.

Watches were often conducted when fog, precipitation or blowing snow restricted visibility, but in most analyses we excluded watches with visibility <3 km. To facilitate estimation of distances in 1977, stakes were positioned on the ice at 500 yard (457 m) intervals from 500 to 3000 yards north of Oliktok. In fair weather, the larger birds (but not shorebirds or passerines) were easily visible and usually identifiable up to 3 km away, and often were visible against the ice or snow at ranges of 5 or 6 km.

For each individual or group seen, we recorded number, time, age and sex composition, flight direction, height, distance from shore, behaviour (flying, circling, landing, etc.), habitat, and 'migrant status'. The last variable was our assessment of whether the bird was actively, possibly or not migrating. Richardson *et al.* (1975) and Johnson and Richardson (1981) describe the field methods in more detail.

All data were transcribed onto coding forms, keypunched, keyverified, checked by a validation program, and corrected before tabulation. For purposes of analysis, active migrants were separated from local residents and 'status uncertain' birds on the basis of the 'migrant status' and behaviour codes recorded in the field. In general, only birds that were in sustained flight on an eastward (30°-150°) or westward (210°-330°) course were treated as migrants.

Aerial Surveys

In 1975, we conducted reconnaissance surveys of the Yukon sector of the Beaufort Sea on seven dates from 14 May to 9 July. These surveys complement the more extensive surveys conducted in 1974, a heavy ice year (Searing *et al.*, 1975). A Twin Otter aircraft with two observers was flown as far as 280 km offshore, changing course to follow various leads and ice-edges that were encountered. The objective was to locate concentrations of birds, not to do systematic surveys. Thus, overall densities or numbers of birds cannot be estimated. Survey routes, ice conditions and sighting locations are shown in Richardson *et al.* (1975).

In 1977-79, we repeatedly surveyed five transects in the Simpson Lagoon area (total length 169 km; see Fig. 1, inset). In spring, surveys were conducted on 5 and 20 June 1977, 23 June 1978, and 22 June 1979. Spring surveys were conducted by two observers in a Bell 205 helicopter (1977) or Cessna 206 fixed-wing aircraft (1978-79) flown at 30 m ASL and 160 km/h. Transect width was 400 m.

RESULTS

Seasonal Timing and Species Composition

Radar data. In 1975, a few birds were migrating east and west near Komakuk, Y.T., by mid-May, but peak migration did not occur until late May (Fig. 2). In both 1975 and 1977, eastward migration became prominent on radar a few days earlier than westward migration. From late May through June eastward migration was always detectable on radar, and westward migration was almost always detectable. Surprisingly, the number of migrants visible on radar did not diminish in mid or late June of either 1975 or

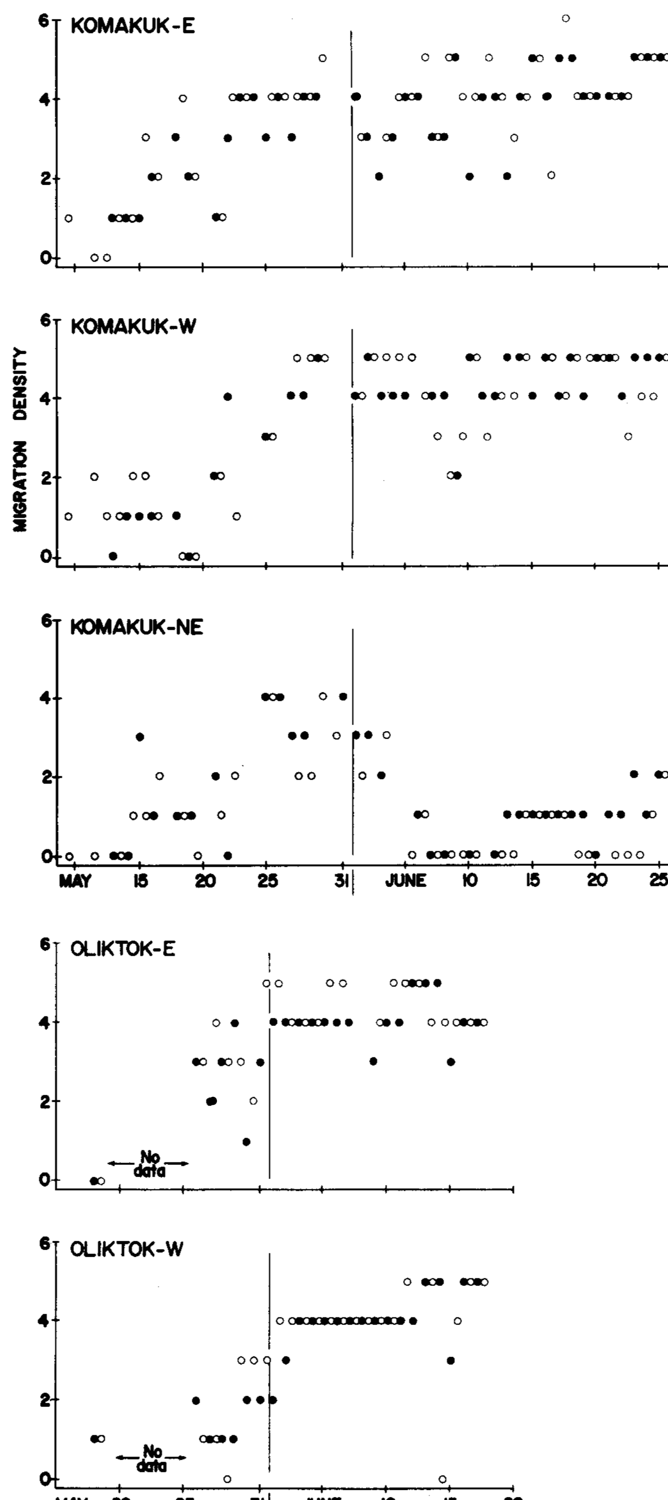

FIG. 2. Seasonal variation in amount of eastward, westward and northeastward migration detected by the Komakuk, Y.T., and Oliktok, AK, radars in 1975 and 1977. Densities near the coast at 09:00 (●) and 21:00 (○) local standard time are shown.

1977. Indeed, in 1975 when radar observations continued to 9 July, both east and west movements continued undiminished to that date (Richardson *et al.*, 1975:33).

Northeast (NE) migration from the interior of NE Alaska, across the Yukon coastal plain, and out over the Beaufort Sea was common in 1975 from 12 May onward. Peak NE migration was in late May and early June (Fig. 2), but small numbers moved NE intermittently throughout June and early July. Comparable NE flights were not detected by the Oliktok radar in 1977.

Eastbound species. Visual observations along the coast confirmed the radar evidence that a few birds were migrating east and west in mid-May, but that peak migration did not begin until late May (Fig. 3-5). Adult-plumaged glaucous gulls were the most numerous eastbound migrants in mid-May (Fig. 4), but over the May-June period as a whole the most conspicuous coastal migrants were brant, oldsquaws and eiders (Fig. 3). The aforementioned species all migrated mainly east. Very few eiders flew along the coast before early June in 1975 or 1977. Aerial surveys offshore from the Yukon also detected few eiders before June in 1975, but over 50 000 were seen in a lead NW of Cape Bathurst, N.W.T., on 21 May 1974 (Table 3). Near the coast, oldsquaws and (at least in 1975) brant were more numerous and slightly earlier migrants than eiders (Fig. 3). In 1978, observations did not begin until 6 June, but migrations of brant and oldsquaws seemed later than in 1975 and 1977, and few migrating eiders were seen. Jaegers migrated east in late May as well as June, but loons and arctic terns migrated east mainly in early and mid-June (Fig. 4, 5).

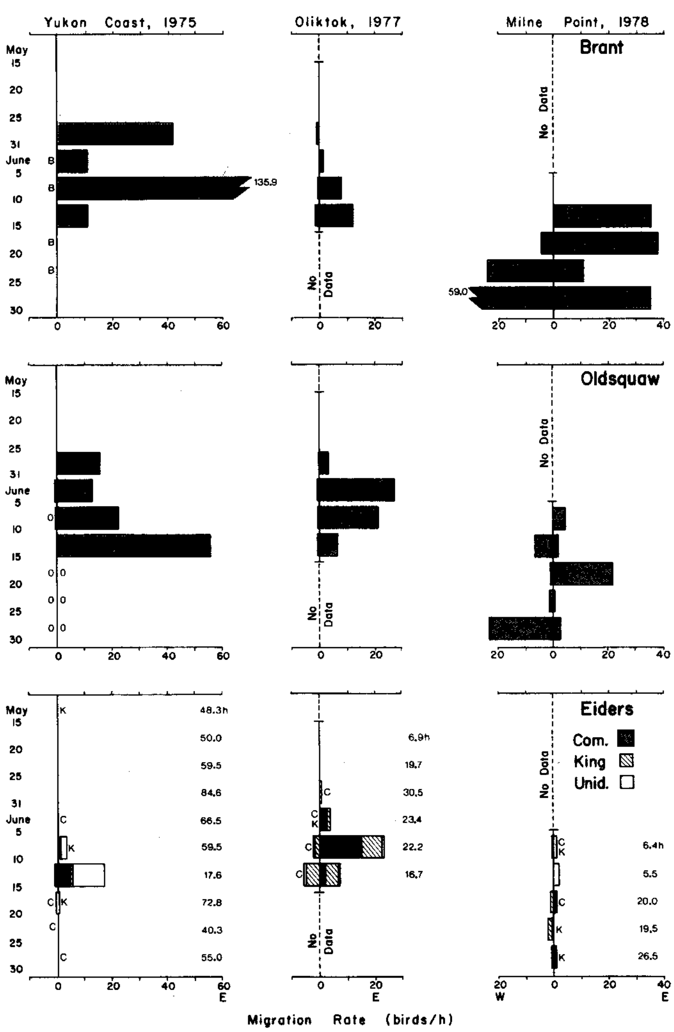

FIG. 3. Hourly rates of coastal migration of brant, oldsquaws and eiders by five-day period in spring. Eastward migration is to right of baseline; westward is to left. Birds >3 km offshore or >1 km inland not considered. Letters mean 'seen but rate too low to be plotted'. The number of hours of observations in each five-day period is given in the 'eider' section (periods with visibility < 3 km omitted).

Visible eastward migration of most species had decreased markedly by 15 or 20 June (Fig. 3-5). The radars, in contrast, showed no such decline (Fig. 2). Much of the continuing eastward movement in mid and late June must have been at altitudes high enough to preclude visual detection.

Westbound species. The main westbound migrants seen along the coast in May and June were whistling swans, white-fronted geese, pintails and, in mid-June of 1975, pomarine jaegers (Fig. 4, 5). Westward migration of the three waterfowl species was more conspicuous along the Yukon coast in 1975 than in Alaska in 1977-78, perhaps because the Alaskan study area was closer to the northwest edge of their breeding ranges. Peak westward migration of swans and white-fronted geese along the Yukon coast in 1975 was in late May, whereas the peak for pintails was in early and mid-June. White-fronts and especially pintails were both common near Oliktok, AK, in the spring of 1977, but it was often impossible to separate local from migratory flights. Pintails were unusually abundant in northern Alaska as a whole in 1977, apparently because of drought-displacement from southern areas (Derksen and Eldridge, 1980).

The westward migration of pomarine jaegers and a few parasitic jaegers along the Yukon coast on 11-21 June 1975 followed an earlier eastward migration of those species (Fig. 4). Pomarine jaegers are known to abandon parts of the nesting range soon after arrival if lemmings, their main food source, are scarce (Maher, 1974). The westward migration in mid-June 1975 was apparently an especially striking example of this phenomenon. Conspicuous return movement of jaegers was not evident along the Alaskan coast in June 1977 or 1978.

Several other waterfowl species that are uncommon along the north coasts of the Yukon and Alaska in spring were observed or suspected to be minor components of the westward migration. These included a few Canada and snow geese and several species of dabbling ducks (Salter *et al.*, 1980; Johnson and Richardson, 1981). Westward moult migration of post-breeding male seaducks began in mid to late June (Johnson and Richardson, MS), and was the most conspicuous westward migration in late June and early July.

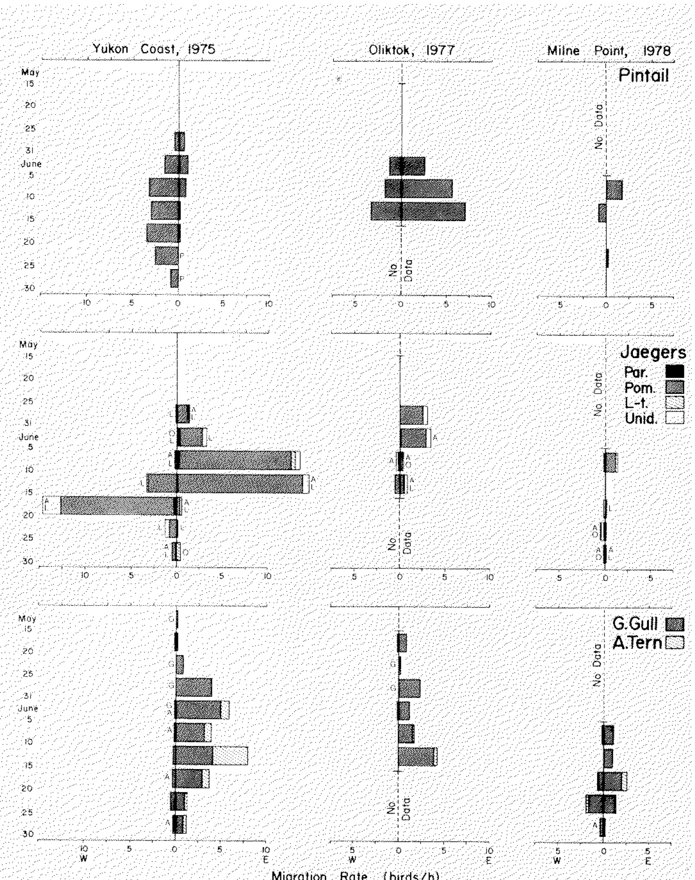

FIG. 4. Hourly rates of coastal migration of pintails, jaegers, glaucous gulls and arctic terns by five-day period in spring. Plotted as in Fig. 3 but with expanded horizontal scale.

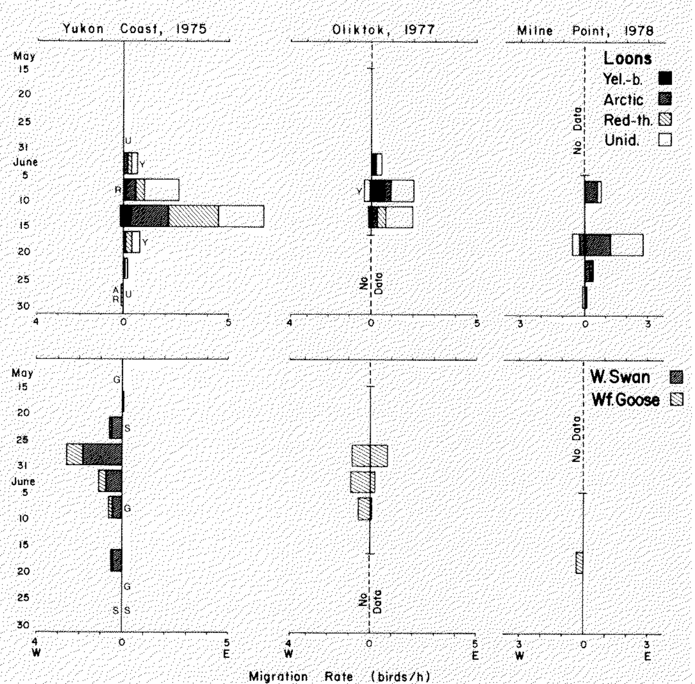

FIG. 5. Hourly rates of coastal migration of loons, whistling swans and white-fronted geese by five-day period in spring. Plotted as in Figs. 3 and 4 but with further expansion of horizontal scale.

In total, we saw much less westward than eastward spring migration near the Yukon and Alaskan coasts even though similar densities of east and west migration were detected by radar (Fig. 2). We have no definite explanation for the many westward migrants detected by radar, but suspect that shorebirds were often involved (see Discussion).

Flight Paths and Routes

Broad- vs. narrow-front migration. The radars showed that neither eastward nor westward migration was restricted to the coastal area. Migrations in both directions were detected almost continuously throughout late May and June not only near the coast, but as far as 20-75 km inland and 40-75 km offshore (Fig. 6).

Although broad-front migration occurred at both study areas, results from Oliktok and Komakuk were not identical. At Oliktok, AK, where the coastal plain extends more than 100 km inland, the number of echoes (flocks) was usually quite uniform from at least 25 km inland to 25 km offshore. Apparent densities at greater ranges inland and offshore were usually less (Fig. 7), but this may have been because of radar's inability to detect distant low-flying birds. The Oliktok radar never detected a pronounced concentration of migrants along the coast, barrier islands, or elsewhere. At Komakuk, Y.T., where the coastal plain is <20 km wide, few migrants were detected over the mountains >20 km inland. Also, amidst the general broad-front migration over the coastal plain and offshore, a concentrated stream of migrants often moved east and/or west within a band of width 3-10 km centred on the Yukon coast. The degree of coastal concentration was significantly greater in the Yukon than in Alaska ($p < 10^{-5}$ and $p < 0.006$ for east and west migration, respectively; details in Johnson and Richardson, 1981).

The general predominance of broad-front migration in the southern Beaufort Sea area in spring probably occurs because at that season the coast is inconspicuous as a leading line and unremarkable as feeding or resting habitat for waterbirds. The nearshore sea is ice-covered and most of the coastal plain is quite flat and, for much of the spring migration season, at least partly snow-covered. There are probably two reasons for the greater degree of coastal concentration near Komakuk, Y.T., than near Oliktok, AK: (1) the coastal plain is narrowest near Komakuk, and both eastbound and westbound birds would be funneled toward the coast there; and (2) the coast near Komakuk is an almost linear feature, and probably is more effective as a leading line than the irregular coast with adjacent barrier islands near Oliktok.

Flight directions. Migration was predominantly east or west near Oliktok, AK, and ESE-WNW near Komakuk, Y.T. These axes are generally parallel to the broad-scale orientation of the coasts in the two study areas. Near Oliktok, the modal direction of 'eastbound' migrants was often slightly north of east (080°) far inland and south of

TABLE 3. Numbers of waterbirds seen during aerial surveys of the Canadian Beaufort Sea, May - June 1974-75[a]

	1975 (this study)					1974 (from Searing *et al.*, 1975)					
	May		June			May			June		
Species	14	28	5	15	26	13-15	21-27	29-31	6-8	20-23	25-26
Survey length (km)	700	505	410	555	365	1760	1620	1560	2660	2210	1220
Yellow-billed loon, *Gavia adamsii*	—	1	30	5	1	—	13	—	17	—	3
Arctic loon, *G. arctica*	—	—	—	6	—	—	—	—	4	1	7
Red-throated loon, *G. stellata*	—	—	—	1	2	—	—	—	—	—	—
Unidentified loons	—	—	1	8	2	—	6	—	13	10	2
Whistling swan, *Olor columbianus*	—	—	1	—	—	—	—	—	4	—	—
Canada goose, *Branta canadensis*	—	—	—	—	—	—	4	—	—	—	—
Brant, *B. bernicla*	—	40	194	30	—	—	—	—	—	—	—
Snow goose, *Chen caerulescens*	—	—	—	—	—	—	—	—	360	—	—
Pintail, *Anas acuta*	—	—	50[b]	—	—	—	—	—	—	—	—
Unidentified scaup, *Aythya* spp.	—	—	—	—	—	—	152	—	—	—	4
Oldsquaw, *Clangula hyemalis*	—	36	4274	977	104	—	17 454	11 353	586	563	43
Common eider, *Somateria mollissima*	—	—	723	120	33	—	56 280	1950	267	—	141
King eider, *S. spectabilis*	—	5	115	163	20	—	10	140	433	66	634
Unidentified eiders	—	—	25	133	1	—	1011	5887	4144	35	40
White-winged scoter, *Melanitta deglandi*	—	—	—	—	27	—	—	—	—	—	—
Surf scoter, *M. perspicillata*	—	7	—	—	14	—	—	—	—	—	—
Black scoter, *M. nigra*	—	—	—	—	30	—	—	—	—	—	—
Unidentified scoters	—	65	7	—	19	—	240	28	11	155	—
Unidentified ducks	—	2	154	—	13	—	12 086	20 978	3844	597	740
Pomarine jaeger, *Stercorarius pomarinus*	—	—	—	—	1	—	—	—	2	—	—
Parasitic jaeger, *S. parasiticus*	—	—	1	—	—	—	—	—	6	—	—
Long-tailed jaeger, *S. longicaudus*	—	—	—	—	—	—	—	—	2	3	—
Unidentified jaegers	—	—	—	1	1	—	—	—	6	2	1
Glaucous gull, *Larus hyperboreus*	40[b]	75	6	3	16	15	190	60	39	25	7
Arctic tern, *Sterna paradisaea*	—	—	—	—	1	—	—	—	1	1	—
Black guillemot, *Cepphus grylle*	—	—	—	3	—	—	—	—	—	—	—

[a]Table includes on- and off-transect sightings. Table excludes raptors, shorebirds and passerines, and surveys on 21-24 April and 1-5 May 1974 when no birds were seen.

[b]Along shoreline.

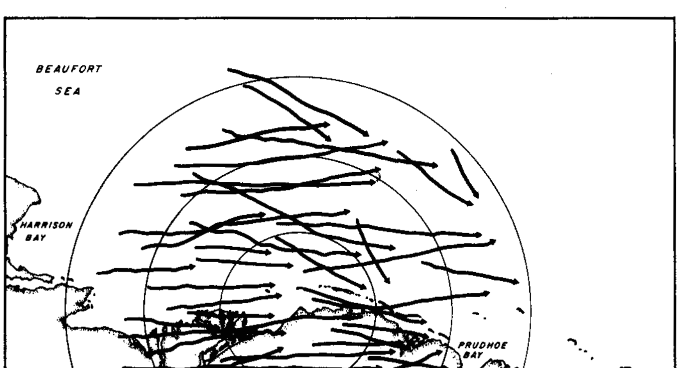

FIG. 6. Flight paths of a sample of the birds migrating east over the Alaskan North Slope and Beaufort Sea on 2 June 1977, 16:00-20:00 AST. Outer circle has radius 75 km centred at Oliktok radar. Oldsquaws were by far the most abundant migrants seen flying east at this time.

east (100°) offshore (Fig. 7). The modal direction of 'westbound' migrants was usually slightly north of west (280°) in all areas near Oliktok. Near Komakuk, Y.T., the main axis of migration was ESE-WNW near the coast and offshore (Fig. 7). Over the mountains south of Komakuk there was little ESE or E migration, and NW movement was much commoner than W or WNW migration. In addition, small numbers of birds often flew NE over the Komakuk area (Fig. 7, 8) but not over Oliktok.

Species differences. Flight paths of different species migrating east near the coast were not identical. Visual observations from Oliktok Point and Pingok Island (Fig. 1, inset) on 6-14 June 1977 showed that loons, oldsquaws, eiders and glaucous gulls flew east over the full width of the lagoon and over the frozen sea north of the barrier islands (Table 4). All these species have also been found on leads far offshore during spring (Table 3). Jaegers and arctic terns were seen over the mainland and full width of the lagoon but not seaward of Pingok Island, even though aerial surveys show small numbers of jaegers far offshore in spring (Table 3). Almost all brant flying east over the

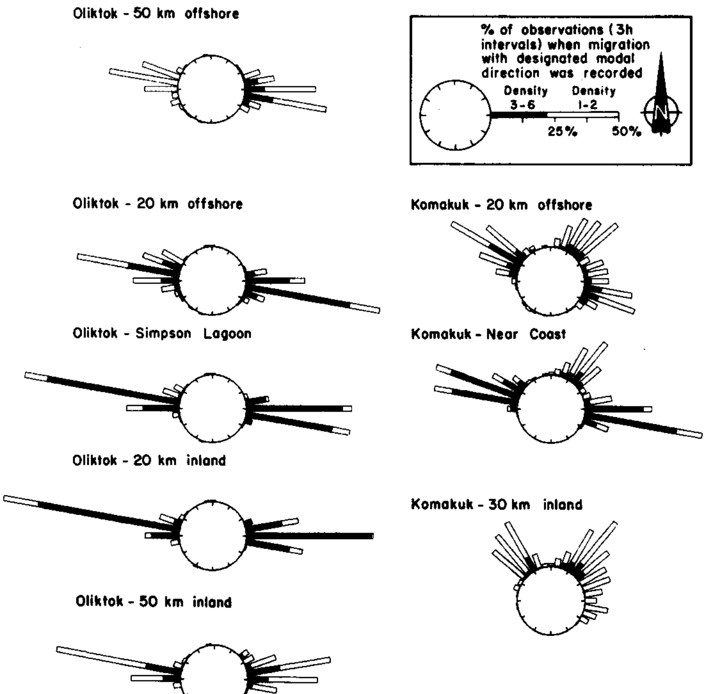

FIG. 7. Frequency of migratory movements in various directions, based on radar data from Oliktok, Alaska (1977), and Komakuk, Y.T. (1975), 9 May - 20 June.

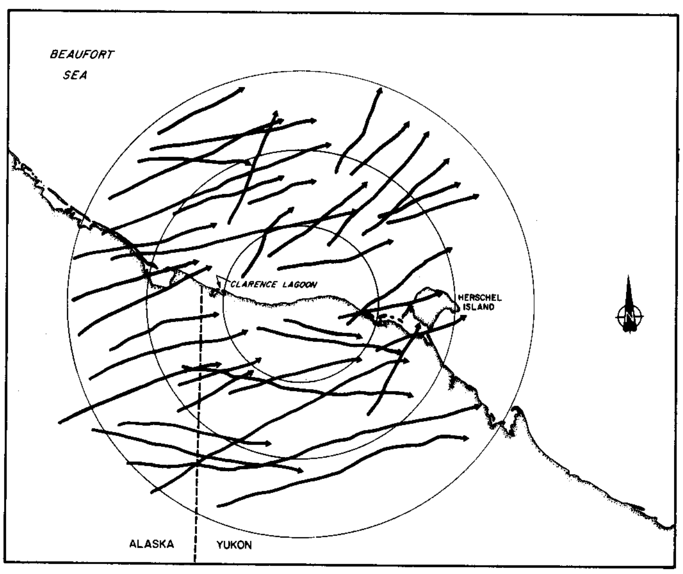

FIG. 8. Flight paths of a sample of the birds migrating northeast near Komakuk, Y.T., on 27 May 1975, 04:00-09:00 YST. The distinction between northeast and east movement was unclear on this date. Shorebirds and glaucous gulls were the species most commonly detected moving east along the coast at this time, but brant were noted later in the day. The mean ground speed of flocks shown here was 77 km/h; their air speeds would be higher, since the wind was easterly.

Simpson Lagoon area were, in contrast, over the mainland or south side of the lagoon. Again, however, aerial surveys show that, at least in the eastern Beaufort, some flocks of brant fly far offshore (Table 3; see also Barry, 1967:75).

TABLE 4. Amount of eastward migration in various parts of the Simpson Lagoon area, 6-14 June 1977[a]

Species	Birds/h over		
	S side of lagoon[b]	N side of lagoon[c]	N of barrier islands[d]
All loons	1.73	2.17	1.31
Brant	9.14	(−0.10)[a]	(−0.17)
Oldsquaw	15.16	6.21	3.39
All eiders	13.37	6.54	5.34
All jaegers	0.13[e]	0.87	(−0.02)
Glaucous gull	2.48	1.25	1.98
Arctic tern	0.27	0.18	0.00
Hours of observation [f]	37.5	39.2	40.4

[a]All rates are net values; negative values mean more birds moved west than east.
[b]Considering birds passing between 1 km inland and 3 km offshore from Oliktok Point.
[c]Considering birds from 3 km offshore (mid-lagoon) to the north side of Pingok Island.
[d]Considering birds from the north side of Pingok Island to 3 km offshore over the Beaufort Sea.
[e]Higher rates of jaeger migration occurred here earlier in the season.
[f]Excluding periods with visibility <3 km.

Numbers

Table 5 gives estimates of numbers of waterbirds that flew at low altitudes along the south coast of the Beaufort Sea in the spring of 1975 and 1977. Observations in 1978 began too late to permit meaningful estimates. Our approach was to use visual observations to (1) calculate migration rates (birds per hour) within each five-day period (Fig. 3-5); (2) extrapolate these rates to all hours in the respective periods; and (3) sum the estimates across all periods. Only the data collected during watches with visibility ≥ 3 km were used to calculate rates, and birds >3 km offshore or >1 km inland were not considered. Numbers flying over Simpson Lagoon in the 9-15 May and 16-25 June 1977 periods, when we made no observations, were taken into account by multiplying the 16 May - 15 June 1977 estimate by the ratio of the 9 May - 25 June 1975 to 16 May - 15 June 1975 estimates. The areas considered extended from 1 km inland to 3 km offshore in 1975, and from 1 km inland across Simpson Lagoon to 3 km seaward of the barrier islands in 1977.

Waterfowl, mainly brant, oldsquaws, common eiders and king eiders, accounted for most of the eastbound waterbird migrants near the coast (Table 5). However, estimated numbers passing Simpson Lagoon in 1977 were very low — 2076, 11 534, 3552 and 2226, respectively — relative to approximate numbers in the Beaufort Sea area (>10^4, 10^6, >10^5 and 10^6 respectively — Thompson and Person, 1963; Johnson, 1971; Bellrose, 1976; Timson, 1976). Estimated numbers migrating along the Yukon coast in spring 1975 were much higher in the case of brant (25 946), similar for oldsquaws (12 998), and lower for eiders (2258 total). All these values are imprecise because (1) some birds that flew by during migration watches undoubtedly were not detected, (2) birds classed as 'possible migrants' were not considered, and (3) various imprecise extrapolations were used. Nonetheless, it is clear that only small proportions of the oldsquaws and eiders that occur in the Beaufort Sea area migrated at low altitude along the coast in 1975 or 1977. Most of the brant that enter

TABLE 5. Estimated numbers of waterbirds migrating along the south coast of the Beaufort Sea in spring (9 May - 25 June), 1975 and 1977.

Species	Predominant migration direction	Estimated number[a] Yukon, 1975	Simpson Lagoon, 1977
Yellow-billed loon	E	52	187
Arctic loon	E	295	200
Red-throated loon	E	402	116
All loons[b]	E	1295	1617
Whistling swan	—	512W	12E
Canada goose	W	51	0
Brant	E	25 946	2076
White-fronted goose	W	184	176
Snow goose	—	36W	74E
Pintail	W	1318	1985
Oldsquaw	E	12 998	11 534
Common eider	E	562	3552
King eider	E	101	2226
All eiders[b]	E	2258	6060
All scoters[b]	W	1326	0
Red-breasted merganser	E	22	0
Red phalarope[c]	E	254	134
Northern phalarope[c]	E	79	~0
Pomarine jaeger	E	3632E[d] 2001W	>684
Parasitic jaeger	E	28	61
Long-tailed jaeger	E	53	23
All jaegers[b]	E	4015E[d] 2361W	>1257
Glaucous gull	E	2466	3313
Thayer's + herring gull	E	37	5
Sabine's gull	E	73	11
Arctic tern	E	787	129

[a]Estimates are net values — number in predominant direction minus number in opposite direction. Corridors considered are described in text. For detailed calculations, see Johnson and Richardson (1981:168*ff*).

[b]These lines include birds identified only to genus.

[c]Numbers of phalaropes are likely seriously underestimated because they cannot be seen at long distances.

[d]For pomarine and all jaegers in 1975, estimated numbers flying east and west are not combined into a net figure.

the Canadian Beaufort Sea apparently flew in a narrow stream along the Yukon coast in 1975, but brant were not nearly so concentrated along the coast in the Simpson Lagoon area of Alaska in 1977. Incomplete data from 1978 (Fig. 3) suggest that more brant may have passed over Simpson Lagoon that year.

Many brant are known to migrate north or northeast through interior Alaska rather than around the coast (Cade, 1955; Irving, 1960). Few eiders appear to migrate through the interior of Alaska, and the number of oldsquaws doing so is unknown. Most common and king eiders and perhaps most oldsquaws appear to migrate east across offshore portions of the Beaufort Sea rather than along the coast of northern Alaska or through the interior.

Numbers of loons migrating east along the coast in spring are of special interest because it has been suspected that a large fraction of the arctic and yellow-billed loons nesting in the North American Arctic may follow this route (Palmer, 1962). However, only about 1295 and 1617 loons did so in 1975 and 1977, respectively (Table 5). Estimates for the individual loon species are unreliable because many loons were not identified to species. Total numbers of arctic and yellow-billed loons nesting in the North American Arctic are unknown, but Timson (1976) estimated that about 50 000 loons flew west past Point Barrow, AK, on 27 August - 16 September 1975.

Many pomarine jaegers migrate east along the coast in spring, but few parasitic or long-tailed jaegers do so (Table 5). Long-tailed and apparently also some pomarine jaegers migrate north through interior Alaska (Kessel and Cade, 1958; Dean *et al.*, 1976), but the route of most parasitic jaegers to the North Slope is unknown. Our figures may underestimate the amount of eastward migration of parasitic jaegers near the coast; we saw flocks moving east too far inland (1-5 km) to be considered in Table 5.

Glaucous gulls migrate east along the coast at only low to moderate hourly rates, but for a prolonged period (Fig. 4). About 3313 flew east through the Simpson Lagoon area in spring 1977, and about 2466 flew east along the Yukon coast in spring 1975.

No other gulls migrate in large numbers along the coast. Numbers of Thayer's gulls (*Larus thayeri*) and Sabine's gulls there are extremely low (Table 5). Clearly only a few individuals of these species migrate east along the south coast of the Beaufort Sea while enroute from Pacific wintering grounds to breeding areas in the Canadian Arctic. Arctic terns were not abundant at Simpson Lagoon, AK, in the spring of 1977 (129 estimated) but were more numerous along the Yukon coast in 1975 (787 estimated).

These estimates and the Oliktok radar both suggest that the north coast of Alaska forms the spring migration route of only a minority of the waterbirds using the Beaufort Sea. Farther east, where the coastal plain is narrower, the spring routes of certain species such as brant and arctic terns appear to be concentrated along the coast, but even there only small fractions of the oldsquaws and eiders follow the coast.

Use of Nearshore Habitats

Migrating waterbirds land on leads offshore in the Beaufort Sea during spring, and many may die in heavy ice years when open water is scarce (Barry, 1968). Because the nearshore area is covered by landfast ice during spring migration, few waterbirds land there. In this study, most migrating waterbirds seen near the Yukon and Alaskan coasts continued out of sight without landing. The radars showed that many flocks flew non-stop for 50-85 km (Fig. 6, 8), and perhaps much farther. However, after runoff water flowed onto the nearshore ice in late May or early June, and especially after shoreleads began to form (by mid-June), some migrant waterbirds landed. Such birds could be affected by oilspills in the nearshore zone.

A few yellow-billed and unidentified loons swam and even dived in runoff waters on top of the lagoon ice off Oliktok, AK, on 8-12 June 1977. During three aerial surveys of Simpson Lagoon on 20-23 June of 1977-79, 111 loons of all four species were seen, primarily in shoreleads. Previous studies near Prudhoe Bay (Bergman *et al.*, 1977; Schamel, 1978) indicated that during June loons concentrated in early-melting areas of the Sagavanirktok and Kuparuk river deltas (peak of 3.9 loons/km^2 near Egg Island on 16 June 1972).

White-fronted geese were overland migrants. They landed on mainland tundra and ponds near the coast during spring but rarely flew over the nearshore sea. At Simpson Lagoon none were seen on lagoon or sea ice or on runoff water, and none were seen during offshore aerial surveys (Table 3).

Some migrating brant landed at mainland ponds near Oliktok, and some of those flying along Simpson Lagoon in mid-June landed in runoff water on the lagoon ice. Of the 586 migrating brant recorded from Oliktok on 8-15 June 1977, 68 were seen to land at least briefly in the river runoff. Only a short stretch of one lagoon was in view, so a high proportion of the brant migrating during the period after river water flows onto the landfast ice may land somewhere in the series of lagoons along northern Alaska.

Dabbling ducks, mainly pintails, were present on meltwater ponds on the mainland in early to mid-June. Pintails were seen along the coast west of Komakuk, Y.T., on 5 June 1975, but not offshore (Table 3). At Oliktok in spring 1977 only five pintails and three green-winged teal (*Anas crecca*) were seen to land (very briefly) on the runoff water in the lagoon.

Thousands of oldsquaws were seen on offshore leads during late May and early June of 1974-75 (Table 3). Oldsquaws appeared on meltwater ponds on the mainland in early June. Only a few migrants (20) were seen in runoff water on the ice in Simpson Lagoon, all on 7-10 June 1977. Aerial surveys recorded few oldsquaws (24-40 per survey) on shoreleads in Simpson Lagoon on 20-23 June in 1977-79.

During spring migration, eiders sometimes concentrate in large numbers on offshore leads (Table 3), and may concentrate in smaller groups on runoff water and newly-formed leads off river mouths (Bergman *et al.*, 1977; Schamel, 1978). We saw as many as 50 common eiders on shoreleads at Clarence Lagoon, Y.T., in mid-June 1975, but <10 eiders during each aerial survey of shoreleads in Simpson Lagoon on 20-23 June in 1977-79. During migration watches from Oliktok Point in 1977, only 43 eiders (including five common, 26 king and two spectacled [*Somateria fischeri*]) were seen on the runoff water on the lagoon ice.

No jaegers, Sabine's gulls or arctic terns were seen to land on runoff water on top of the ice in Simpson Lagoon. Glaucous gulls were common along island and mainland shorelines in spring, but during watches from Oliktok in 1977 we saw only six on the runoff water.

DISCUSSION

The existence of annually recurring areas of open water (Fig. 1) and recurring patterns of ice break-up in the Beaufort Sea during spring has undoubtedly influenced the development of waterbird migration routes and timing. During the peak of spring migration, an extensive area of open water in the eastern Beaufort Sea is still separated from open water near Point Barrow, AK, by a large area where the only open water is in leads far offshore and (after late May or early June) in local areas at the mouths of rivers. Some of the characteristics of spring migration that are probably at least partly a result of these ice conditions are (1) the lack of attraction of most waterbirds to the coast, especially during May; (2) the occurrence of migration over offshore waters; and (3) the occurrence of northeast migration across interior Alaska to the eastern Beaufort Sea, bypassing the Alaskan Beaufort. The following sections discuss these three points in detail.

Eastward Migration Along the Coast and Coastal Plain

Along the northwest coast of Alaska, where open water occurs close to shore during spring, large numbers of waterbirds migrate northeast over nearshore waters (Gabrielson and Lincoln, 1959; Johnson, 1971). East of Point Barrow, eastward migration near the icebound coast is conspicuous but, for most species, the numbers are comparatively low (Brooks, 1915; Irving, 1960:275; this study). Observations from islands and points of land have suggested that much of the migration, especially in early spring, occurs too far offshore to be seen from land (Anderson, 1937:118; Schamel, 1978).

This study provides the first estimates of numbers of waterbirds migrating along the Alaskan or Yukon coasts of the Beaufort Sea in spring (Table 5). Noteworthy results included the low estimated numbers of oldsquaws, eiders, Thayer's gulls, Sabine's gulls, and arctic terns. Although imprecise, these estimates are based on a considerable volume of systematically-collected data, and are at least comparable in reliability to previous summer and fall results from Point Barrow (Thompson and Person, 1963; Johnson, 1971; Timson, 1976). Consistent with our low estimates, radar shows that eastward migration in spring is mainly broad-front in character, with some concentration along the Yukon coast but little along the Alaskan coast near Oliktok.

During spring, the Oliktok radar routinely showed eastward broad-front migration inland over the coastal plain (Fig. 6, 7; see also Flock, 1973). Eastbound migrants were usually present to the limits of radar detectability 50-75 km inland. The species involved are poorly known, but visual observation from the coast showed many brant and some jaegers flying over tundra within a few kilometres of the coast.

Farther east, along the Yukon coast, both visual and radar evidence showed more eastbound migrants narrowly concentrated along the coast. Migrants more abundant there than at Simpson Lagoon included brant (about 26 000 *vs.* 2100), arctic terns (about 790 *vs.* 130), and probably pomarine jaegers. However, loons, oldsquaws and eiders, which are abundant migrants in the Beaufort area (Johnson, 1971; Timson, 1976), were seen in only modest numbers along both the Yukon and the Alaskan coast.

Barry (1976:31) implies that much larger numbers passed Cape Dalhousie, N.W.T., on 29 May - 16 June 1972. However, his extrapolations apply to a corridor 80 km wide, and are based on several unproven assumptions. The values presented are — depending on species — 15 to 750 times the numbers actually seen (Barry, unpubl.; cf. Searing *et al.*, 1975). The uncertainties remaining after the 1972 work were one of the reasons for conducting the present study.

Thus there is an important broad-front eastward migration over the arctic coastal plain and southern Beaufort Sea during spring, but in most respects the coast itself does not form a major route for narrow-front eastward migration. The brant, however, is one bird whose Beaufort Sea population appears to concentrate along part of the coast (in the Yukon sector) during spring. The failure of most species to concentrate along the coast during spring presumably is attributable primarily to the presence of landfast ice over most nearshore waters. Even after river water overflows onto the ice, access to marine food resources is blocked by underlying ice until shoreleads form in June. Waterbirds that land on the river water present on top of the landfast ice probably find little food.

Arctic terns migrate east in spring along the north coast of Alaska and the Yukon. Salomonsen (1967) suggested that the 'migration divide' between those migrating over Atlantic and Pacific waters was in Alaska, but our results show the 'divide' to be somewhere in the Canadian Arctic — closer to the middle of the continent.

Eastward Migration Offshore

Visual and radar observations at Point Barrow suggest that, after passing that location, most eiders fly ENE toward offshore waters of the Beaufort Sea (Flock, 1973). There have been no systematic observations offshore in the Alaskan Beaufort during spring, but in 1974 many eiders and oldsquaws appeared in the leads and polynyas of the eastern Beaufort during May (Table 3). In 1974, 1975, or both, loons (especially yellow-billed), brant and glaucous gulls were also widely distributed in small numbers far offshore. Some individuals of these species probably migrate east through offshore portions of the Beaufort Sea. However, jaegers and arctic terns were scarce far offshore, and Thayer's and Sabine's gulls were not seen.

Radar has shown a few birds approaching the coast from the north in spring (Flock, 1973; Richardson *et al.*, 1975), and Schamel (1978) saw red phalaropes (*Phalaropus fulicarius*) doing the same. Some waterbirds that nest on the Alaskan or Yukon North Slope may migrate over offshore areas and remain offshore until snow melt occurs on land or until river runoff produces shoreleads in the nearshore landfast ice.

Northeast and North Migration through Interior Alaska

The offshore and coastal routes discussed above are not the only routes by which waterbirds wintering in Alaskan or Pacific waters reach the Beaufort Sea. Our radar data from the Yukon show that as early as 12 May some birds fly NE from interior Alaska, across the North Slope of extreme NE Alaska and the Yukon, and out over the Beaufort Sea (Fig. 8). Some brant (Cade, 1955; Irving, 1960) and jaegers (Dean *et al.*, 1976; B. Kessel, pers. comm. 1978) follow such a route, at least as far as the North Slope, during late May and June. However, it is unlikely that brant and jaegers were responsible for the NE migration detected by radar in mid-May.

Species present offshore in the Canadian Beaufort in mid to late May are oldsquaws, common and king eiders, and glaucous gulls. There is no direct evidence that members of any of these species fly NE across interior Alaska to the Beaufort Sea, but the radar evidence suggests that some must do so.

Oldsquaws seem to be the most likely possibility. They migrate through interior Alaska and the Yukon in at least small numbers (Kessel and Cade, 1958; Irving, 1960). During spring they are known to migrate overland for long distances, mostly at high altitudes and inconspicuously, in northern Europe (Bergman and Donner, 1964; Bergman, 1974, 1977) and in central North America (Bellrose, 1976).

Eiders are not known to migrate in significant numbers across interior Alaska, but they are not always confined to coastal and offshore routes. Some cross the Seward Peninsula and the tundra south of Barrow during spring (Murdoch, 1885; Myres, 1958; Johnson, 1971; Palmer, 1976). Overland migrations of common eiders do occur elsewhere (Swegen, 1972; Alerstam *et al.*, 1974; Gauthier *et al.*, 1976; Karlsson, 1976; Schmidt, 1976), and many king eiders fly overland across Baffin Island during their moult migration (Wynne-Edwards, 1952). There is also circumstantial evidence of a long (1200 km), non-stop, high-altitude (1500+ m) spring migration of common eiders from western Norway to the White Sea (Bergman, 1974:133). Thus it is possible that some eiders fly non-stop and unseen over Alaska to the eastern Beaufort Sea.

Some glaucous gulls migrate through interior Alaska in spring (Kessel and Cade, 1958; Irving, 1960). However, it is doubtful that they fly fast enough to account for the fast-moving flocks detected migrating NE in May 1975.

Some other waterbirds also bypass much or all of the Alaskan Beaufort and take a more direct overland route from the Pacific Ocean to northeast Alaska or the western Canadian Arctic. Some arctic loons, yellow-billed loons, and perhaps arctic terns fly overland along this route (Kessel and Cade, 1958; Irving, 1960; Palmer, 1962; Griffiths, 1973). Some individuals of these species nest in the interior, so it is uncertain how many of the overland migrants continue to the arctic coast. However, some arctic loons and arctic terns do undertake long overland migrations elsewhere (Godfrey, 1973; Schüz, 1974; Cramp and Simmons, 1977). Also, arrival dates of arctic loons at Hudson Bay are about the same as those in the Beaufort area (cf. Jehl and Smith, 1970); this suggests that eastern-nesting arctic loons fly overland rather than the much greater distance around Alaska. In view of their scarcity in the Beaufort Sea in spring, many Thayer's and perhaps Sabine's gulls may also fly overland.

Many other waterbird and shorebird species that are summer residents of the North Slope also fly north through interior Alaska. These include snow, Canada and white-fronted geese, pintails, scoters and various shorebirds (Kessel and Cade, 1958; Kessel and Schaller, 1960; Irving, 1960). Some of these species are common on tundra and freshwater habitats north to the Beaufort coast, but these species do not move north into the Beaufort Sea itself during spring.

Northwest Migration

Irving (1960:276) stated that "there are no reports known to me which indicate that spring migration passes westward from Mackenzie to the arctic coast of Alaska". However, recent studies in northwestern Yukon have shown that some whistling swans and pintails and small numbers of white-fronted, snow and Canada geese fly west into Alaska along the Yukon coastal plain (Gollop and Davis, 1974:161; Salter *et al.*, 1980; this study; see also Brooks, 1915; Schmidt, 1973). Many if not all whistling swans nesting in northern Alaska are Atlantic-wintering birds (Sladen, 1973), and likely migrate west and northwest from the Mackenzie Valley rather than through interior Alaska. The other four species listed above migrate north through interior Alaska as well as west along the coast. None of these species uses marine habitats significantly.

The five waterfowl species discussed above migrate west along the north coast of the Yukon and Alaska in only small to moderate numbers. (Bellrose [1976] indicates that more than 10 000 snow geese migrate west along or near the coast from the Mackenzie Delta to Wrangel Island, U.S.S.R.; we know of no recent observational evidence of such a migration.) The numbers of westbound migrants seen visually are quite inconsistent with the nearly continuous and broad-front westbound migration detected by radar during spring (Fig. 2). From mid-June onward, there is westward moult migration of seaducks (oldsquaws, eiders, scoters; Johnson and Richardson, MS), and in some years (e.g., 1975) there is conspicuous westward migration of non-breeding jaegers (see Fig. 4 and Maher, 1974). These movements may account for increased westward migration as June progresses (Fig. 2), but not for major westward migrations in late May and early June.

Shorebirds are likely responsible for much of the west and WNW migration detected by radar during spring. Of five sandpiper species listed as abundant at Prudhoe Bay, Barrow, or both by Norton *et al.* (1975), four species — the semipalmated (*Calidris pusilla*), Baird's (*C. bairdii*), pectoral (*C. melanotos*) and buff-breasted (*Tryngites subruficollis*) sandpipers — migrate to northern Alaska from the interior of the continent. American golden plovers (*Pluvialis dominica*) and long-billed dowitchers (*Limnodromus scolopaceus*) also follow that route. All six of these species are also common at Anaktuvuk Pass in the Brooks Range in spring (Irving, 1960), so only a fraction of the individuals nesting in northern Alaska likely migrate WNW or west along the North Slope. Shorebirds are normally inconspicuous during their long-distance migrations, which often occur at high altitudes (Richardson, 1979). Thus they are more prominent on radar than visually. Sandpipers and plovers do not use shoreline habitats along the Beaufort Sea in spring.

Attraction to Open Water

Marine birds depend on open water for access to food. Open water is scarce in much of the Beaufort area in spring, and migrating waterbirds can be expected to land on any available open water in nearshore areas (this study; Bergman *et al.*, 1977; Schamel, 1978). Thus, some waterbirds likely would be contaminated if oil or another contaminant were present during spring in any nearshore area with open water.

Some birds appear to be attracted to pools of oil on top of ice, presumably mistaking the oil for open water (Barry, 1970). Such pools could occur not only if oil is spilled onto the ice from above, but also when oil that has accumulated under the ice in winter migrates upward through the melting ice in spring (Lewis, 1978). The situation would be especially serious in a heavy-ice year when there is little or no open water offshore in the Beaufort Sea. Waterbirds are severely stressed in such years (Barry, 1968), and would be expected to be attracted even more than usual to any available area of open water, or to pools of oil.

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