CANADIAN WILDLIFE SERVICE

BEAUFORT SEA PROJECT

Technical Report #3

Thomas W. Barry

Compiler

Canadian Wildlife Service

Edmonton

1. SUMMARY

This Technical Report is a digest of four studies on birds of the Beaufort Sea:

1. A Study of Seabirds in the Coastal Beaufort Sea Area, 1972 and 1974, by G.F. Searing, E. Kuyt, W.J. Richardson and T.W. Barry. 256 pp.

2. Bird Migration Along the Beaufort Sea Coast, May-July 1975: A Radar and Visual Study by W.J. Richardson, M.R. Morrell and S.R. Johnson. 133 pp.

3. *Waterbirds of the Beaufort Sea: A Literature Review. 821 pp.

4. *The Marine Environment of the Beaufort Sea: A Textual Review of the Climatic and Oceanographic Literature Pertinent to Avifaunal Studies. 282 pp.

Approximately two million migratory birds frequent the Beaufort Sea and its littoral zone. For several species of waterbirds the shores and marshes are the principal nesting grounds. For large numbers of seabirds, the coastal bays, lagoons, barrier beaches and islands are important as nesting and molting grounds. For seabirds migrating along the coast, open-water leads in the sea ice are the traditional places for resting and feeding.

To reduce the risk of contaminating these birds by oil spills and blowouts it is important to know the critical times and places of the birds' occurrences in the Beaufort Sea Region. Such information makes possible the timing of drilling and support activities in order to minimize the danger.

The data on the spatial and temporal distribution of birds in the Beaufort Sea result from ground and aerial surveys, and radar observations. Our ground observation sites established in 1972 were for observing the movements of sea birds along the Beaufort Sea coast during spring, summer, and fall. The aerial transects flown in 1974 determined the distribution of

---

*These studies are available as supplementary reports from Canadian Wildlife Service, Edmonton.

birds 320 km out to sea between April and October. Other aerial surveys in 1974 gave a measure of birds using the coastal lagoons, bays, barrier beaches, and islands. The radar, ground, and aerial surveys of the spring migration in 1975 were to compensate for the results caused by atypical ice and weather conditions of 1974.

Altogether, those surveys showed that for birdlife the sensitive areas and times in the Beaufort Sea are:

1. The ice leads, in the spring.

2. The coastal lagoons, bays, barrier beaches, and tidal marshes, from June to September.

2. INTRODUCTION

2.1 Nature and Scope of the Study

In the Arctic most bird species are aquatic and migratory. Although relatively few species occur in the Arctic, large numbers of individual birds congregate there to summer, and many of them are economically important for native subsistence or for recreation. Nearly all of fifty-odd species occurring in the Beaufort Sea region are migratory in some respect. Some species such as glaucous gulls remain far north as long as open water permits. Others, such as Arctic Terns and jaegers, have annual migrations of approximately 40,000 km.

The Beaufort Sea is the Arctic Ocean adjacent to the north coast of Alaska and Canada, between Point Barrow on the west and Banks Island on the east. Certain species nest along the edge of the Beaufort Sea while others pass over en route to more distant nesting grounds. Nearly all species found in the region are bound to the sea at some time in their lives, whether for feeding, molting, or resting.

The birds nesting in Canada's western Arctic converge from wintering grounds in the Pacific and Antarctic oceans, and in North and South America, that is, from about one-third of the globe's surface. Of the birds nesting on the coasts of the Beaufort Sea and the Arctic Islands, approximately two-thirds migrate through the Great Plains and the Mackenzie Valley, while the rest travel through the Bering Straits and follow the coast of Alaska, Yukon, and the Northwest Territories. Waterbirds moving along the narrow leads, which usually form between shore ice and the Arctic pack in May and June, can become extremely concentrated under certain conditions.

Species using the Arctic coast migration route include Arctic terns, Sabine's gulls, and jaegers, from the Antarctic and the South Pacific; Pacific brant from coastal Mexico and California; and eiders, murres, and glaucous gulls, from the North Pacific and the Bering Sea. Some species flying the interior migration routes also use the coast, especially the whistling swans which move westward in the spring from the Mackenzie Delta and travel along the Yukon and Alaska coasts. Many snow geese follow the coast of Tuktoyaktuk Peninsula when en route from the Mackenzie Delta to Banks Island, and they use the same route again in the fall.

The discoveries of oil and gas along the rim of the Beaufort Sea and the prospect of offshore drilling have shown the need for more reliable information about the marine avifauna. In the past, population estimates of Beaufort Sea birds were casual surveys, conducted as part of other studies or reconnaissances.

Determining the number of birds, their migration routes, and the crucial dates when they are present is a complicated task with difficult logistics. The effects of ice and snow cover and of weather systems on the sea birds are variable from year to year. Unfortunately, 1974 was not a typical year, but along with 1959 and 1964, 1974 was an extremely late season with persistent snow and ice cover. The late season had disastrous effects on the reproduction and distribution of the sea birds.

Fortunately, the Canadian Wildlife Service began as early as 1959 to do long term work on a few of the bird species frequenting the Beaufort Sea. The emphasis on sea birds in those studies began in 1972 and 1973. In 1975 time and money were available to collect data for comparison with that of 1974.

The discoveries of oil and gas along the rim of the Beaufort Sea and the prospect of offshore drilling have shown the need for more reliable information about the marine avifauna. In the past, population estimates of Beaufort Sea birds were casual surveys, conducted as part of other studies or reconnaissances.

2.2 Objectives

The study is to provide information about:

1) the timing, species composition, and routes of migration of bird species that occur in the Beaufort Sea;

2) the offshore distribution of each of those species;

3) the numbers, speeds, and directions of movement of flocks of each species; and

4) the relationships between timing of migration and weather and ice conditions.

In addition, we sought to obtain:

5) a literature review and annotated bibliography of the distributions and breeding biologies of the species occurring in the Beaufort Sea;

6) a review of climatological and oceanographic literature pertinent to the avifaunal studies.

2.3 Relation to Offshore Drilling

Most of the bird species found in the Beaufort Sea region are protected by the Migratory Birds Convention between Canada and the United States.

In view of plans to begin offshore drilling in the Beaufort Sea in 1976, and along the entire outer continental shelf of Alaska in the near future, knowledge of the life histories and ecology of sea birds is essential to predict and avoid harm to them through oil spills and industrial disturbances. The wise management of these birds and their habitats requires an intimate knowledge of movements of the birds and of the areas of their concentration at various times of the year.

Of all the environmental factors affecting the lives of sea birds in the Beaufort Sea region, ice conditions are the most critical. Consideration of ice conditions have to be an integral part of the analysis of data related to the birds' distributions.

Many breeding colonies of waterfowl, gulls, and terns occur along the Beaufort Sea coastline. In addition, the coastal plain is used extensively for nesting by these species and by loons, shorebirds, jaegers, and several species of passerines. Many of these birds, both adults and young, use the sea during late summer for feeding and migration. The variety of uses the birds make of the Beaufort Sea, whether for breeding, feeding, molting, or migrating, must be considered in the event of an oil spill. Several of these uses have only been touched upon in this report. It is apparent that further studies are necessary for a complete understanding of the potential damage by human disturbance to the birds in the region.

3. CURRENT STATE OF KNOWLEDGE

Two literature reviews with annotated bibliographies are appendices to this report. One is entitled "Waterbirds of the Beaufort Sea" and the other, "Marine Environment of the Beaufort Sea." These literature reviews are to be published separately by the Canadian Wildlife Service.

4. STUDY AREA

4.1 Topography and Description

The study area includes both onshore and offshore areas from Clarence Lagoon, Y.T., to Cape Parry, N.W.T., more than 800 km east, and north to the northwest tip of Banks Island, N.W.T. The southeastern shore of the Beaufort Sea is the north coast of the mainland of Canada. Numerous small bays and several large ones, notably Liverpool Bay in the east and Kugmallit Bay and Mackenzie Bay further west, indent the coastline.

Except for the Mackenzie Delta which is a region of sparse northern coniferous woodland, the coastal area from the Yukon-Alaska border to Cape Parry and north to Sachs Harbour on Banks Island consists primarily of low-Arctic tundra. Descriptions of the southern shore of the Beaufort Sea are few, and most concentrate on the areas surrounding the settlements. In recent years, however, an effort has been made to classify in detail the environment of the Mackenzie Delta and the Yukon coast.

The portion of the Yukon coast included in the study area forms part of the Arctic Coastal Plain. This post-glacial plain is relatively flat, sloping from 300 m elevation in the south to sea level along the coast. Several large river deltas and many lakes are present. The smaller lakes are typically shallow, with emergent vegetation, while the larger ones are deep and have sedge-marsh shorelines. Riparian deposits of sand and gravel form numerous low-lying islands and spits along the coast and offshore, but the islands in the river deltas are usually low mudflats. Herschel Island, a large flat island off the Yukon coast, rises to 180 m above sea level; a long gravel spit, Avedlek Spit, extends from its southeastern corner. Habitat in the higher areas of the Yukon North Slope is predominantly dry, sedge-herbaceous tundra; in areas of low relief a tussock tundra predominates.

Although much of the Mackenzie Delta is sparse boreal forest, the northern portion is forest tundra giving way to scrub tundra, and finally to low arctic tundra near the coast. The delta itself is 160 km wide, dissected by the many channels and sand bars of the Mackenzie River. The islands of the delta are composed of inter-stratified mud, sand, and gravel, and they contain numerous large and small lakes. The fluvial deposits of the Mackenzie River have formed a chain of outlying islands of higher elevation than the rest of the delta. The eastern portion of Mackenzie Bay is shallow, and the coastline there is barely above sea level.

The coastal area east of the Mackenzie Delta is generally low, flat, and wet, but at Parry Peninsula on the extreme eastern edge of the study area low-lying sand and gravel bars give way to coastal cliffs and numerous offshore islands. Maitland Point also has steep shoreline cliffs. A series of pingoes, small raised mounds, on Tuktoyaktuk Peninsula break the flat, prairie-like appearance of the eastern Beaufort Sea coastline.

4.2 Climate

The climate of the study area is polar continental, and is characterized by long, cold winters and short, cool summers. In winter, temperatures may fall below -50°C. The humidity is low and little snow falls in the region. Summers are cloudy and wet. An extreme high of 34°C was recorded at Aklavik; offshore, however, temperatures remain cold throughout the season. The growing season is short, less than 75 days. Spring break-up typically occurs over most of the coastal area during May or June, and the country freezes again in September or October. Dates of break-up and freeze-up are more variable on the sea. Although the growing season lasts only a few months, it is effectively lengthened by continuous daylight which continues from May 25 to July 19 at the latitude of Inuvik, and from May 9 to August 4 at Sachs Harbour on Banks Island.

4.3 Oceanography and Ice Conditions

Currents in the southern Beaufort Sea follow the continental shelf in a counter-clockwise direction. Beyond the outer continental shelf, currents are primarily wind-driven and predominantly in a clockwise direction. Gale winds blow over the sea frequently, occasionally reaching hurricane force along the shores. These high-speed winds govern ice degradation and are responsible for alternations of the coast and of the bottom topography.

Ice conditions, although generally correlated with season, are largely governed by wind, and as a result are variable from day to day. The Beaufort Sea includes three zones of ice conditions: (1) fast ice, (2) seasonal pack ice, and (3) polar pack ice. Although shore-fast and pack ice typically break up during the summer, onshore winds may move the polar pack ice near the coast, severely limiting the extent of open water even during the height of the summer season. In 1974, ice cover during the summer was more extensive than usual. Much of the Beaufort Sea remained ice-covered throughout the entire season.

5. METHODS

5.1 Surveys in Early Spring

Aerial surveys of the ice-free portions of the southern and southeastern

Beaufort Sea were conducted from April 21 to May 31 in 1974. These flights were essentially random searches for open water leads which were then surveyed according to normal transect techniques, that is, in strips 0.8 km wide.

A Cessna 337 aircraft was used for five surveys each of which required three days of flying. The dates were April 21-24, May 1-5, May 13-15, May 21-27, May 29-31.

The surveys were flown at a speed of 160 km/hr at an altitude of 45 m above sea level. Two observers recorded all birds seen, and a third observer acted as navigator and recorded ice and weather conditions.

The date, time, weather and ice conditions were recorded for each 8 km segment of each aerial transect. When birds were seen either on or off transect, the observers recorded the species or species group, the number of individual birds or the estimated number in the flock. Whenever possible, they recorded the sex and age of each bird and the birds' activities.

5.2 Surveys During June-October

Twelve aerial surveys were conducted between June 6 and October 17 in 1974, each survey requiring several days to complete. Bad weather prevented the aircraft from covering more than 13 of the 15 defined transects, although at least four transects were flown on each occasion. Each transect was divided into 8 km segments. Figure 1 is a map of the transects. Survey methods and techniques of recording data were the same as for the early spring surveys.

Table 1 presents a monthly summary of the sampling efforts. The variability of results is largely due to weather conditions and insufficient manpower. The impossibility of standardizing survey methods reduces the reliability, not only of month-to-month comparisons of the distribution and relative numbers of birds in the Beaufort Sea, but also the estimates of absolute numbers of birds there. Moreover, the number of surveys conducted during the fall migration period was insufficient to permit a reliable estimate of the volume of the offshore migration at that time.

5.3 Tabulation and Analysis of Data

During each aerial survey, the date, time, transect and segment number, ice and water conditions, and the meteorological and ornithological data were recorded on tape. When the aircraft was covering areas other than the regular transects, compass coordinates were recorded at specific checkpoints for birds. At the start of each transect segment and at each checkpoint the time was noted.

After the survey, all data were transcribed onto coding forms. As the coding forms arrived at LGL Limited, the staff key-punched and key-verified the data, checking for impossible or implausible notations by means of a validation program. After the correction of errors, the data were tabulated, on a species by species basis, for each 8 km segment of each transect and each survey. In all tabulations, birds were counted regardless of whether they were at rest or flying when sighted.

5.4 Coastal Surveys

A complete census of water birds was attempted on 90 bodies of water between Nunaluk Spit, Y.T., and the eastern tip of Tuktoyaktuk Peninsula, N.W.T. The sites were censused six times from a Cessna 185 aircraft. The counts were flown from 15 to 45 m above the ground. The flight was in a

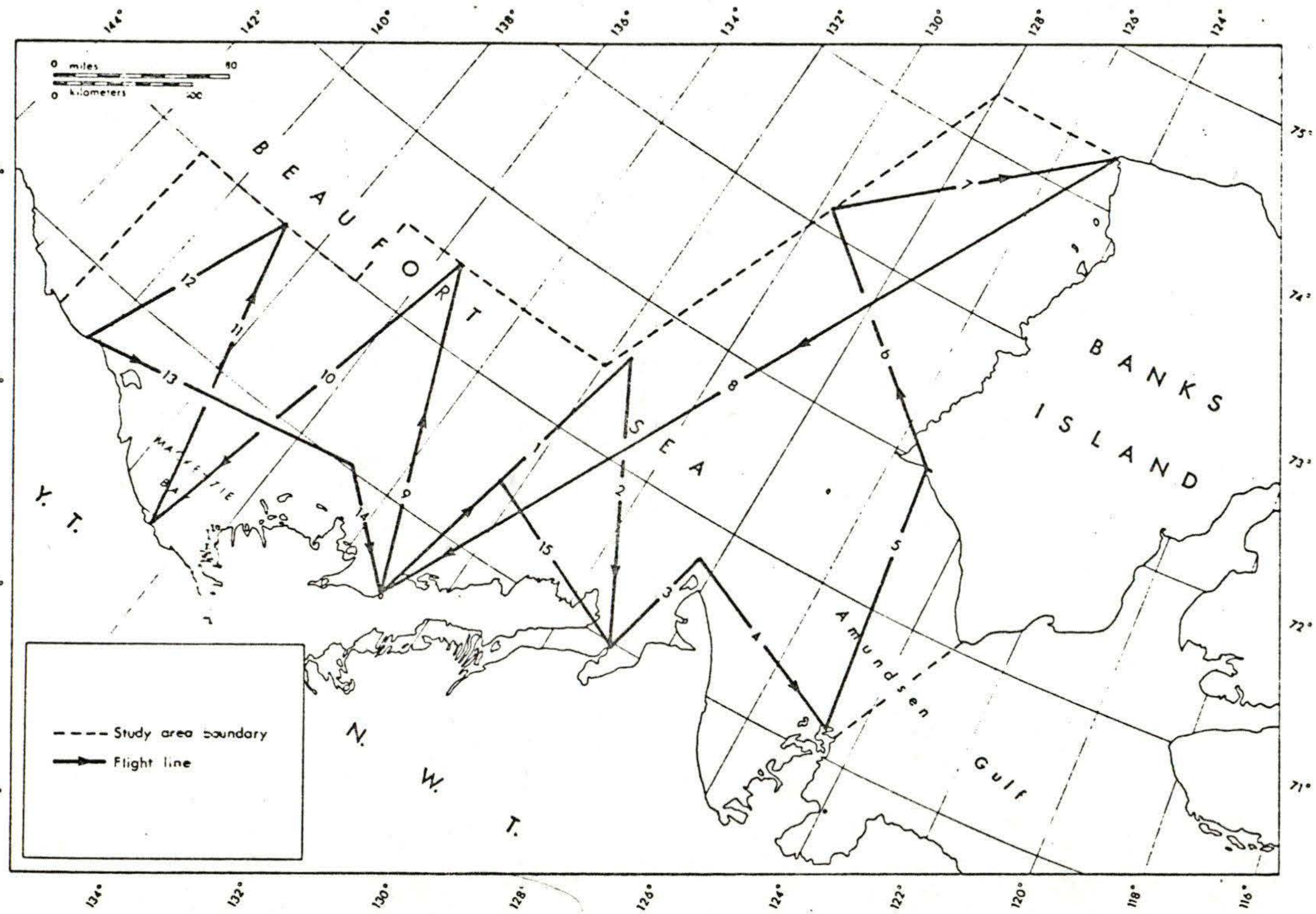

FIGURE 1. Map of the Beaufort Sea Showing Transects Flown in 1974.

TABLE 1. Area and Percent of Study Area Surveyed During Each Month.

Month	Number of Segments Surveyed	Area Surveyed (km^2)	Percent Surveyed
June	737	2383	1.3
July	967	3108	1.7
August	553	1787	1.0
September	420	1360	0.7
October	118	389	0.2

*Total study area = 186 480 km^2.

circular pattern to count all the birds on or over the water and up to 16 km inland from the shore.

5.5 Migration Watch

During 1972, migrating birds were observed from fixed locations along the coast, both from the shore and from motor vessels. The observation sites were at Liverpool Bay, Cape Dalhousie, and Toker Point on Tuktoyaktuk Peninsula; at Hansen Harbour, Pelly Island, and Moose Channel on the Mackenzie Delta, and at Nunaluk Spit on the Yukon coast. Counts of birds continued at Nunaluk Spit during the breeding season and the period of fall migration, at Cape Dalhousie only during the spring, and at other locations during late July, August, and September.

At Nunaluk Spit, observations were made daily from June 8 to 13, and from July 10 to August 18; and on every second day from August 19 to September 17. The daily observations were made during five evenly spaced, one hour periods from July 10 until August 1, and then during seven similarly timed periods from August 2 until August 15. From August 16 to September 17, daily observations were made continuously from first daylight until dark. Whenever birds were seen, the time, species, flock size, and flight direction were noted.

5.6 Spring Migration Study, 1975

Because the summer of 1974 was atypical in ice and weather conditions, the spring migration was resurveyed in 1975, this time using radar, ground, and aircraft observations.

5.6.1 Radar

Radar data were recorded through time-lapse and still photography of the Plan Position Indicator display (PPI) of the surveillance radar station at Komakuk Beach, Y.T. ($69^{o}36'N$, $140^{o}11'W$). A PPI is the standard map-like display upon which surveillance radar data are normally presented.

Detailed specifications of the Komakuk radar are classified as secret. In general terms, however, it is a medium-powered L-band surveillance radar. The angular and range resolution are typical of those of most air-surveillance radars. Moving Target Indicator circuitry (MTI) was used to permit detection of birds in the presence of echoes from stationary objects. Except for the MTI, no special circuits were used; hence, the data obtained were stable and of high quality compared to those obtained in other radar studies of bird migration. Occasionally, however, radar performance was imperfect, and the data produced in such periods were either labelled poor or else omitted from consideration.

An almost continuous time-lapse film of the PPI display, at one 35 mm frame per 48 seconds, was obtained for the period May 12 to July 8, 1975. During time-lapse filming, the PPI displayed an area of 74 km radius centred at the radar site.

There was no difficulty in identifying bird echoes. The only other kinds of echoes came from stationary objects, aircraft, and precipitation, all easily distinguished by their size and speed.

Polaroid photographs made of the PPI once or twice each day from May 9 to July 9 allowed an immediate assessment of the numbers, directions, and locations of migrating birds. The photos also provide back-up information for the time-lapse record.

5.6.1 a) Movements and Times Sampled

The time-lapse films show that the radar detects bird migration not only along the coast and along the North Slope but also over the British Mountains, 25 to 55 km or more inland, and over the Beaufort Sea to the limits of the radar's range. In each of these directions eastward, westward, and northward or northeastward movements of birds were common. As a result of a preliminary examination of the films, the characteristics of bird movements in each of these four directions were recorded separately for each of three locations: about 30 km inland over the British Mountains, over the North Slope and coast, and approximately 20 km offshore over the Beaufort Sea. The characteristics of bird movements detectable by radar were recorded from the time-lapse films at three-hour intervals: 00:00, 03:00, 06:00, and at 18:00 and 21:00 YST.

5.6.1 b) Quantification of Numbers Aloft

1) Ordinal Scale

The standard zero-to-eight ordinal scale of migration volumes, the customary scale for Canadian radar studies, was used to record the volume of migration for each class of migrating birds as distinguished by the direction of their flight. Most of the data came from the time-lapse films of the PPI display. For gaps in the films, densities of birds were estimated from such Polaroid photographs as were available.

A scale value to zero represents no migration; four represents a migration of moderate density, as in a typical shorebird or waterfowl flight over southern Canada; and seven represents a migration as dense as movement of passerines over southern Canada during a night of favourable weather. Similar scales are used in European and American radar studies of migration. This method is better than counting echoes because it is quicker, and in certain situations, more accurate. Its disadvantage is that it provides no absolute numbers directly; hence, standard parametric statistical procedures are inapplicable unless their assumptions are carefully checked.

2) Counts

Standardization overcame the limitations of the ordinal scale in this study. The Migration Traffic Rate, that is the number of birds passing a 10 km "line" in an hour's time, was established for some but not all of the sampling periods; this rate was compared to the ordinal scale.

On most days, every six hours we attempted to count the number of echoes involved in the movements of the birds in various directions in each of the three sampling areas: inland, coastal, and offshore. It was not possible to count every kind of movement at every six-hour interval, especially when the impressions on the film were imprecise, when precipitation echoes were present, or when large numbers of birds were flying in different directions at the same time in one area. Nevertheless, over 600 counts were obtained.

3) Quantification of Tracks and Speeds

The direction of flight of the birds involved in each of three classes of migration was estimated to the nearest 10^{0}.

The time-lapse film allowed us to estimate to the nearest 10^{0} the direction of flight of birds involved in each of three classes of migration in each sampling area. Samples of typical paths of bird echoes were measured more precisely, as were echo paths of a special nature. While the moving film displayed the bird echoes on a screen, the viewer traced the path of an echo on a sheet of transparent plastic placed over the screen. The same segment of film was viewed repeatedly until enough echo paths had been traced to provide a significant sample. The duration of each path traced was measured with a stop watch, and this information, along with appropriate information from scaling procedures, furnished data on the speed of flight.

4) Other Information

The density of the birds moving along the coast and the maximum distance offshore at which they were detectable were recorded for each class of migration movement. Also noted were signs of unusual flight, that is, curving courses, movements far inland, echoes of great intensity, movements breaking away from or joining a concentrated stream of migrants along the shoreline, concentrations near the foothills rather than along the shores, flight patterns near areas of precipitation, and rapid changes in numbers aloft.

5.6.2 Migration Watches

Migration watches were conducted from May 9 until July 9, 1975 at Komakuk Beach, Y.T., a DEW-Line radar station, and at Clarence Lagoon, 23 km west of Komakuk. At each site, two observers shared a daily schedule of watches.

Temperature, wind speed, wind direction, extent of cloud cover, precipitation, horizontal visibility, and the extent of ice and snow cover on both the water and the land were noted at the beginning and at each hour of the watch. Significant changes were recorded as they occurred. For each individual bird or flock sighted, the following data were recorded: time, species, number of individuals, age and sex, flight direction to the nearest 10^{0}, altitude, distance inland or offshore, behaviour, and customary habitat.

Each observer used 7 x 35 binoculars, and shared a 20-45X variable power telescope with his partner. Normally, observers scanned the entire field of view every few minutes with binoculars, using the telescope only for the difficult identifications. The distance at which birds could be identified varied with the weather, the size and behaviour of each species, and the skill of each observer. The majority of birds reported were those passing within 1.4 km of the observation posts, although some flocks were seen at distances of up to 8 km.

Data were coded in the field on standard forms specially designed for key-punching. A validation program checked for coding errors. Daily tables were produced for each site which showed the rate at which birds were recorded in each of three categories: those moving east, 30^{0} - 150^{0}; those moving west, 210^{0} - 330^{0}; and those moving either north or south without marked tendencies toward east or west. From these tables, the average rate of migration of each species was calculated for each of the three classes of migration. In addition, these daily migration rates were plotted separately for each site to provide a summary description of the visual observations. Finally, the data from each site were divided into 10-day periods. Tabulations for each period show how many birds of each species and habitat type passed the observation site per hour at each period of the day; how high they were flying; how far they were from shore; how large were their flocks; and in what direction they were moving.

5.6.3 Aerial Surveys

Seven aerial surveys were conducted over the Beaufort Sea: on May 14 and 28; on June 26; and on July 3 and 9. The May 14 survey was flown between 10:00 and 13:50 YST. The rest were flown between 16:47 and 22:53 YST. A DeHavilland Twin Otter (DHC-6) was used for each survey, and an altitude of 30 to 46 m and a speed of 114 to 192 km were usual.

During each survey flight, the plane flew northward from the shore for a distance of 280 km, but in doing so it followed open leads discovered along the way. This strategy was based on the assumption that the largest numbers of birds would be found in areas of open water. The surveys were to locate concentrations of birds rather than to systematically survey a definite portion of the Beaufort Sea. Hence, the observations cannot be used as a basis for an overall estimate of desntiy or of absolute numbers in areas other than those surveyed.

The methods of conducting the survey were similar to those used in the spring of 1974. Each survey route was selected after consideration of 7- to 10-day old satellite photographs of ice conditions in the Beaufort Sea; reports of ice conditions obtained from Komakuk radar operators and British Airways pilots flying the Beaufort Sea route to Komankuk; the survey pilots' observations of ice conditions while they were flying from their base in Inuvik to Komakuk Beach; reports from other bush pilots operating in the study area; and ice conditions observed during the surveys.

After the survey flights were completed, one observer transcribed data on coding forms for key-punching and computer tabulation. Coded data were rechecked by another observer and later validated by computer. After correction of errors, a second computer program tabulated the data transect-by-transect.

6. RESULTS

6.1 Distribution and Numbers -- 1974

The total number of individuals of each bird species and species group observed during each survey appears in Table 2, Figures 2 to 6. The distribution of the major species and species groups in relation to ice-cover are as follows:

Loons

The few loons observed during aerial surveys conducted between May 27 and September 27 were distributed broadly over the eastern Beaufort Sea where they frequented small open-water leads with less than 80 percent ice cover. They showed little preference for extensive areas of open water, even after mid-July when open water had appeared along the southern coast of the Beaufort Sea.

Geese

There were few observations of geese during aerial surveys offshore during 1974. Of the 1,803 geese sighted, 1,265 or 70 percent were snow-geese. In the spring, geese were flying over country completely covered with ice, but during autumn, most of the few geese seen were scattered in coastal areas with little or no ice cover.

Diving Ducks

Although aerial surveys first reported open water in the Beaufort Sea on May 13-15, diving ducks did not appear until May 21 when 50,000 eiders, 17,000 old squaws, and 200 scoters were observed in a large lead near Cape Dalhousie and in a small lead off the west coast of Banks Island. When these leads closed again on May 20-31, fewer birds were in evidence and the old squaws and eiders had scattered widely. The aerial surveys from June 6 to July 18 found their numbers still low. Open water

TABLE 2. Number of Birds Seen Both On and Off Transect During Offshore Surveys of the Southeastern Beaufort Sea in 1974.

SPECIES	DATE														
	MAY			JUNE			JULY			AUGUST		SEPTEMBER		OCTOBER	
	13-15	21-27	29-31	6- 8	20-23	25-26	3- 7	15-18	23-24	13-22	25-30	10	26-28	6	14-18
Loons (unidentified)	0	19	0	34	11	12	17	24	5	22	22	8	1	0	0
Snow Goose	0	0	0	360	0	0	0	0	0	400	430	75	0	0	0
Scaup spp.	0	152	0	0	0	4	100	0	4	0	0	0	0	0	0
Oldsquaw	0	17454	11353	586	563	43	478	86	8	9	14	46	0	0	0
Common Eider	0	56280	1950	267	0	141	408	0	2	0	0	0	0	0	0
King Eider	0	10	140	433	66	634	249	141	40	0	0	75	0	0	0
Total Eiders (unidentified)	0	57301	7977	4844	101	815	721	201	42	15	1	75	60	212	0
Scoters	0	240	28	11	155	0	36	94	46	7	3	0	0	20	0
Diving Ducks	0	87233	40336	9285	1416	1602	2195	1124	763	605	224	654	375	240	37
Sandpipers	0	0	0	0	0	0	0	0	4	0	29	101	0	0	0
Jaegers	0	0	0	16	5	1	22	6	8	3	1	0	0	0	0
Glaucous Gulls	15	190	60	39	25	7	67	267	31	37	69	52	42	0	0
Arctic Tern	0	0	0	1	1	0	0	0	0	19	7	0	0	0	0

NUMBER OF BIRDS	SPECIES		
	LOONS	OLDSQUAWS	EIDERS
>100	▵	∘	▫
101-1000	△	○	□
1001-5000	◬	◎	▣
>5000*	▲	●	■

. .... . flight path

* Concentrations of birds that are much larger than 5000 individuals have been represented on the maps by the symbol for ">5000" with a subscript of the approximate total number of birds in the concentration.

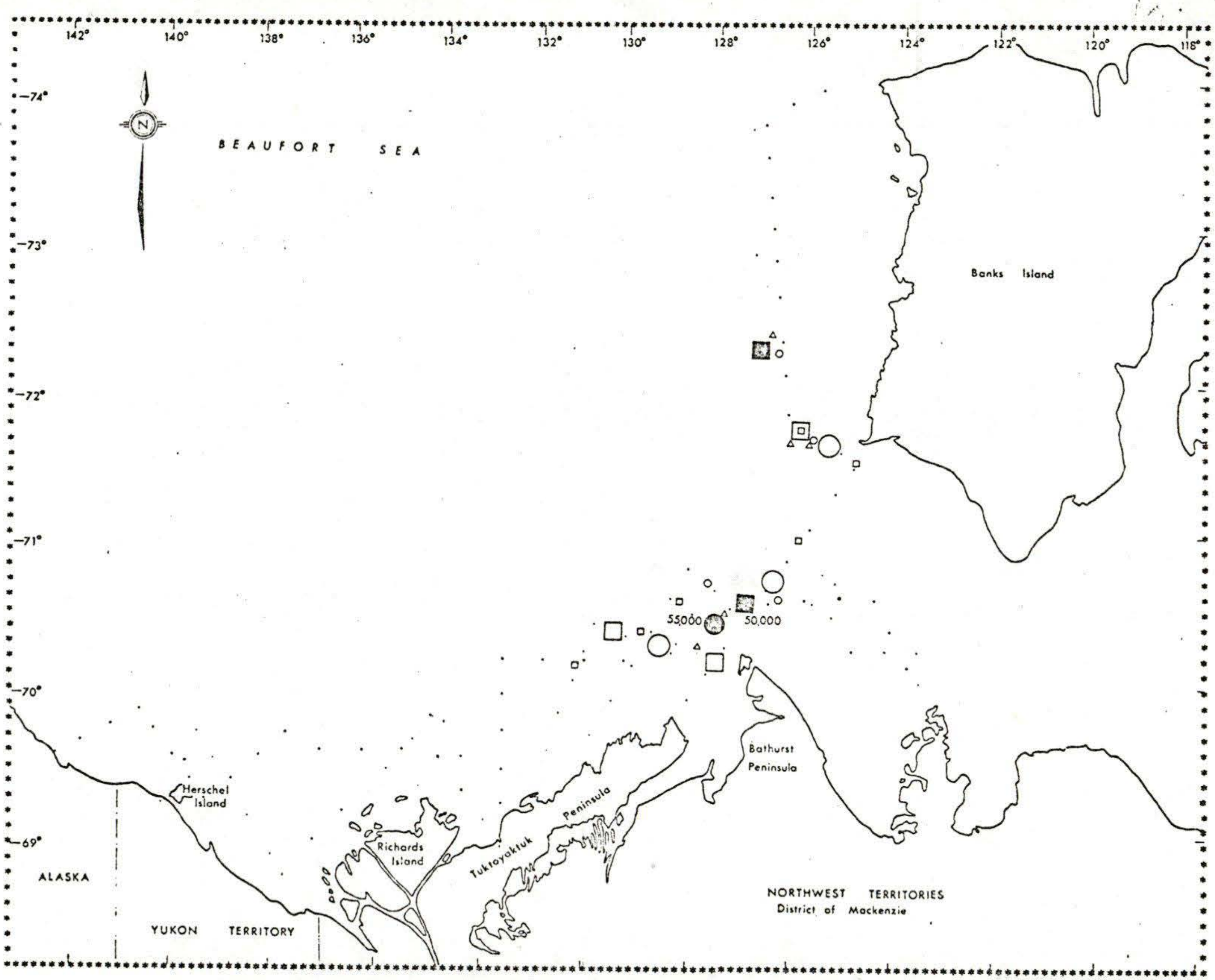

FIGURE 2. Distribution and numbers of loons, old squaws and eiders on the Beaufort Sea from aerial surveys in May, 1975.

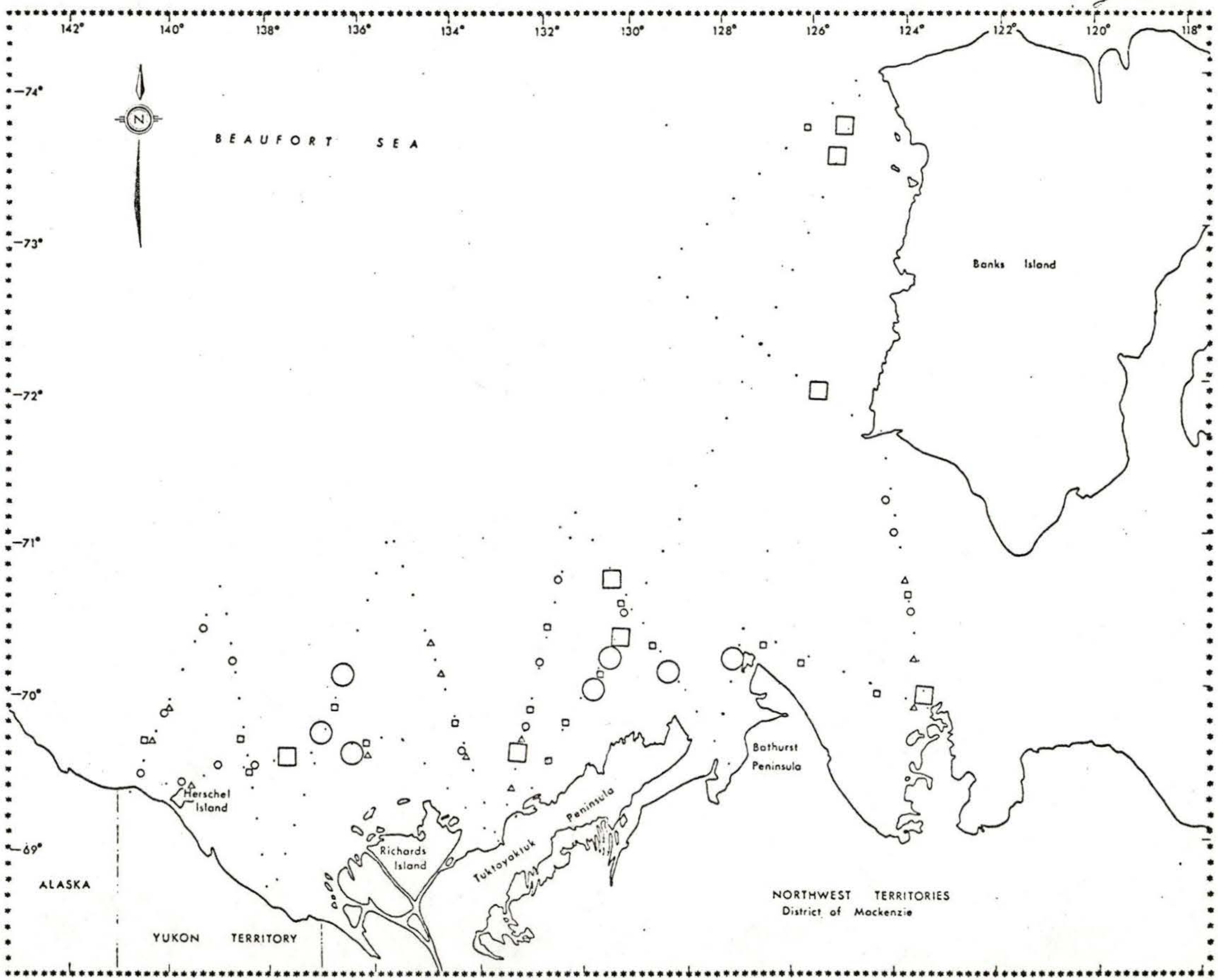

FIGURE 3. Distribution and numbers of loons, old squaws and eiders on the Beaufort Sea from aerial surveys in June, 1975.

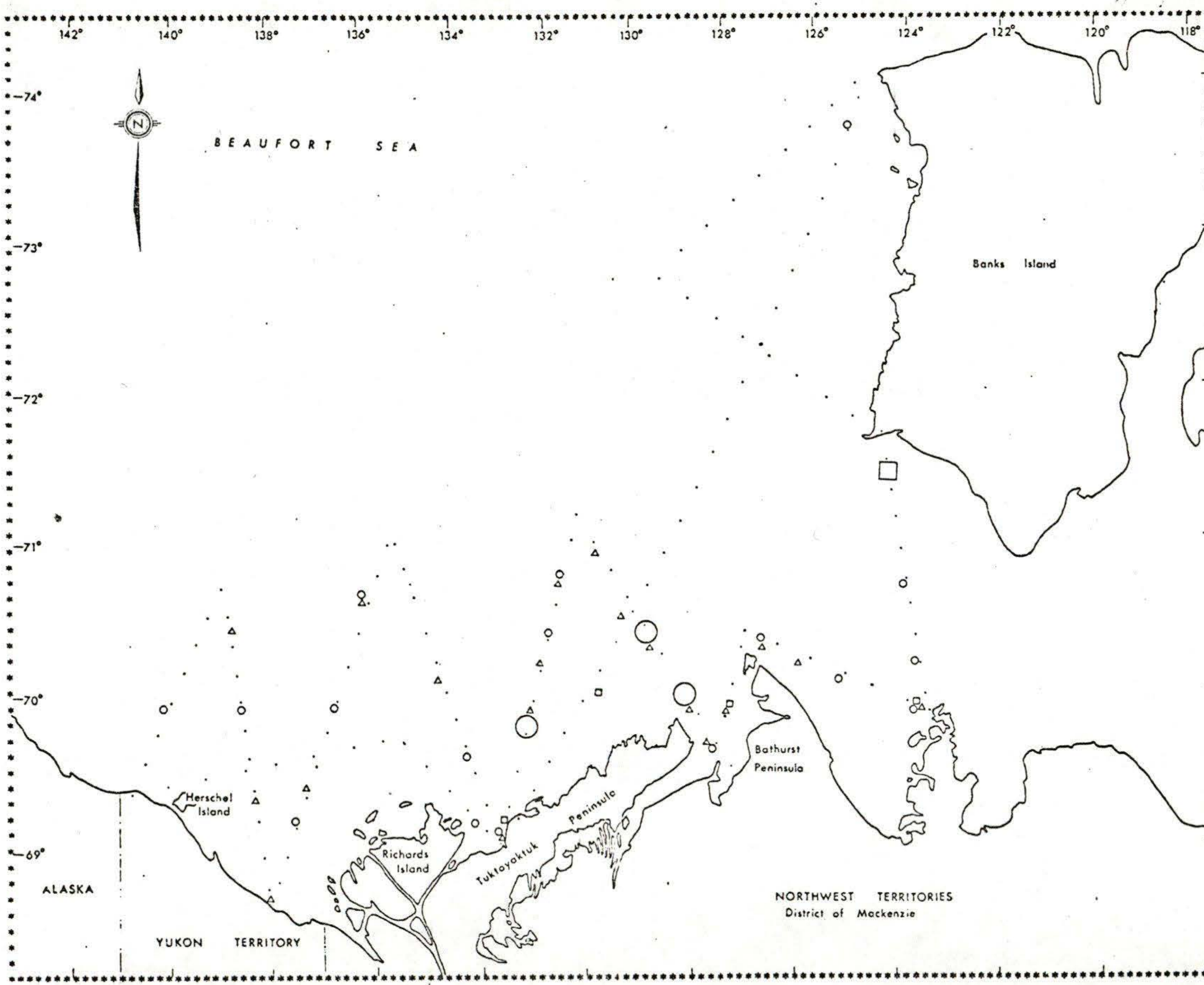

FIGURE 4. Distribution and numbers of loons, old squaws and eiders on the Beaufort Sea from aerial surveys in July, 1975.

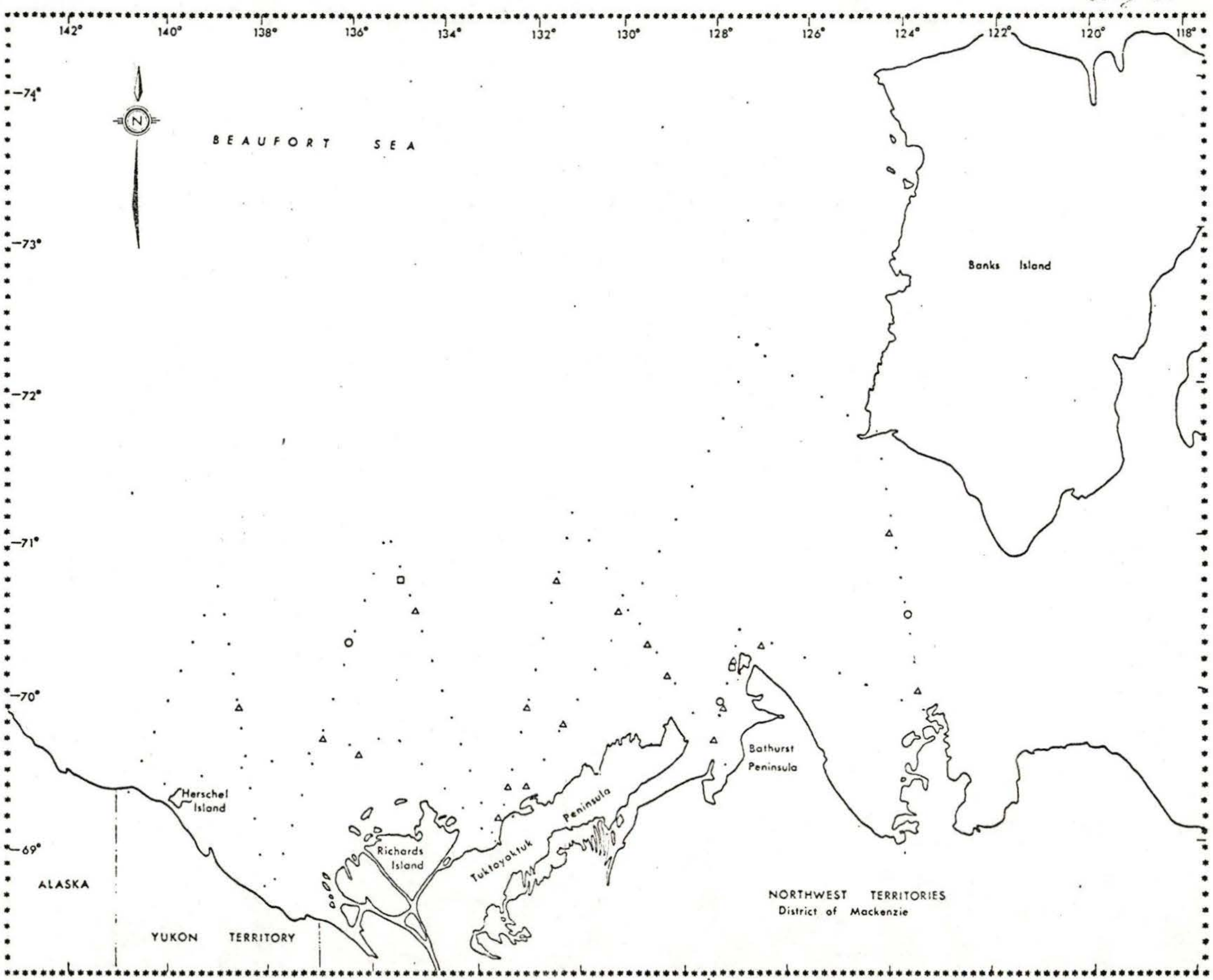

FIGURE 5. Distribution and numbers of loons, old squaws and eiders on the Beaufort Sea from aerial surveys in August, 1975.

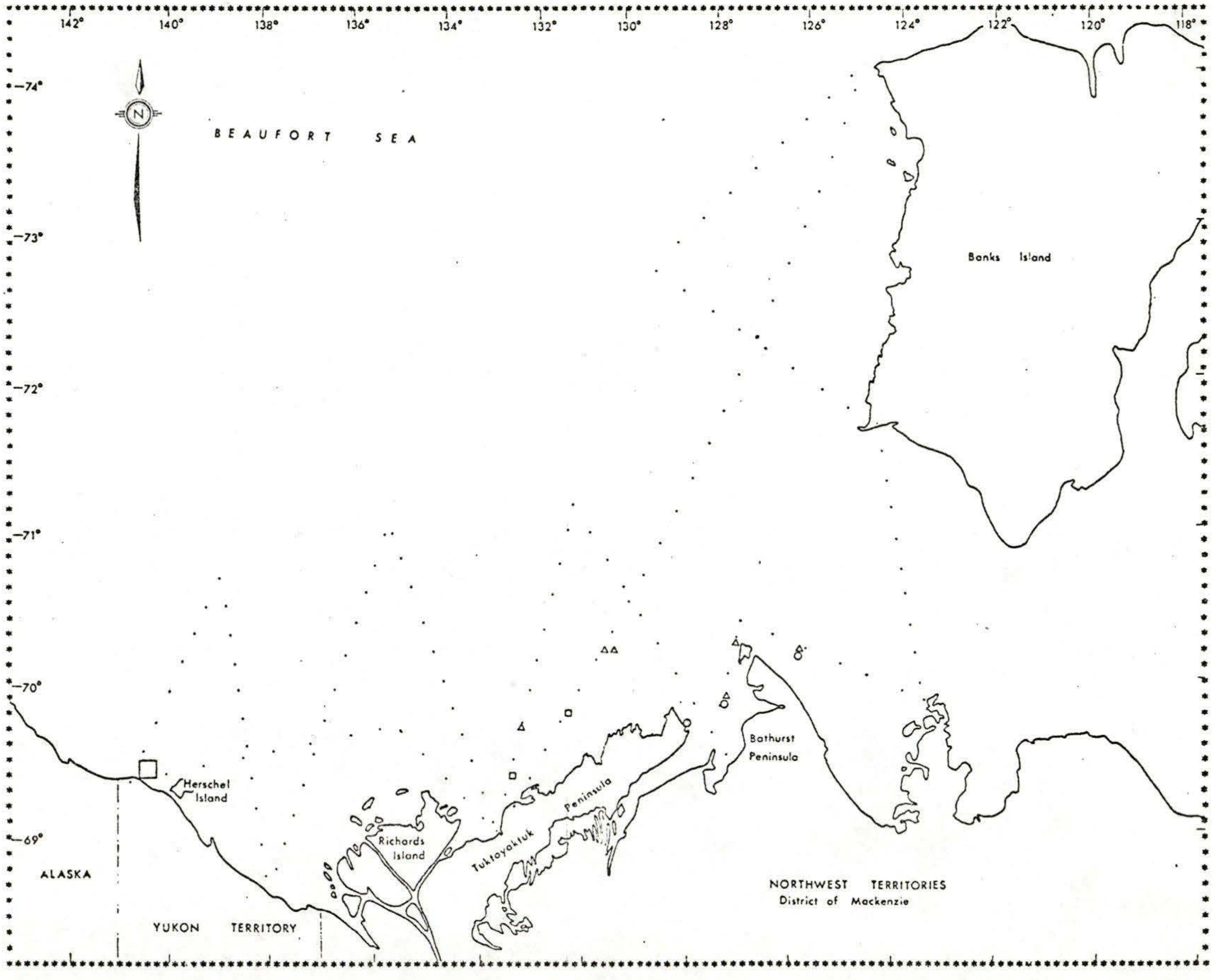

FIGURE 6. Distribution and numbers of loons, old squaws and eiders on the Beaufort Sea from aerial surveys in September, 1975.

reappeared along the shoreline in mid-July, and remained open until freeze-up in mid-September; nevertheless the numbers of old squaws and eiders continued to decline to near zero by July 23-24. These ducks remained absent from survey sightings for the duration of the study.

No large numbers of scoters were seen during any survey month. Most sightings were in the large bays of open water along the coast. Few scoters were seen after the end of July. The numbers of diving ducks in general were low to moderate from June 6 until September 10.

Jaegers

The distribution of jaegers offshore seemed unrelated to seasonal ice conditions except during June and again in mid-August when at least half the jaegers observed were more than 100 km from the coast where there was little ice; the rest of the birds were sighted from 5 to 170 km offshore.

Glaucous Gulls

Ice cover seems to have influenced the movements of glaucous gulls during the study period. Although the gulls were widely distributed across the southeastern Beaufort Sea, they were usually observed near open water. They concentrated in the large lead that formed off Cape Dalhousie late in May, and like the diving ducks, they dispersed during June with the return of heavy ice cover. At this time, the gulls frequented the ice-covered sea sometimes more than 200 km from shore. During July, nearly all sightings of glaucous gulls were in the extensive system of leads which developed along the mainland coast of the Beaufort Sea. The last gull sighting during offshore surveys in 1974 was in late September in Kugmallit Bay; the bay had already begun to freeze.

Arctic Terns

Because arctic terns were rarely observed offshore during 1974 it is difficult to evaluate the degree to which sea ice governs their movements and distribution. Whether their relative scarcity over the Beaufort Sea was a result of the heavy ice conditions in 1974 is unknown. Most of the arctic terns observed during aerial surveys were near the beaches, even after shore leads had developed in August.

6.1.1 Densities Based on Observations

Figure 7 shows the densities of waterfowl based on the numbers of these birds sighted during the surveys of June to October, 1974. The density of ducks during June was 4.9 birds per square kilometre, more than five times their density at any later time. These birds probably represent migrating or newly arrived birds waiting for the snow to clear from their nesting sites. The shift of these ducks to shore sites for the breeding season explains the rapid decrease in their densities offshore during late June and July.

6.2 Coastal Surveys in 1974

6.2.1 Movements, Distribution, and Numbers

Post-breeding activities of birds include molting, staging, molt migration, and fall migration. Depending upon the species, age, and sex of the birds, these activities begin at different times. The key to the location of these movements for molting, brood-rearing or fall staging is the lakes, bays and lagoons behind the barrier beaches near the Beaufort Sea coast. We applied multiple regression techniques to the results of bird surveys on the coastal tundra, lakes and other bodies of water

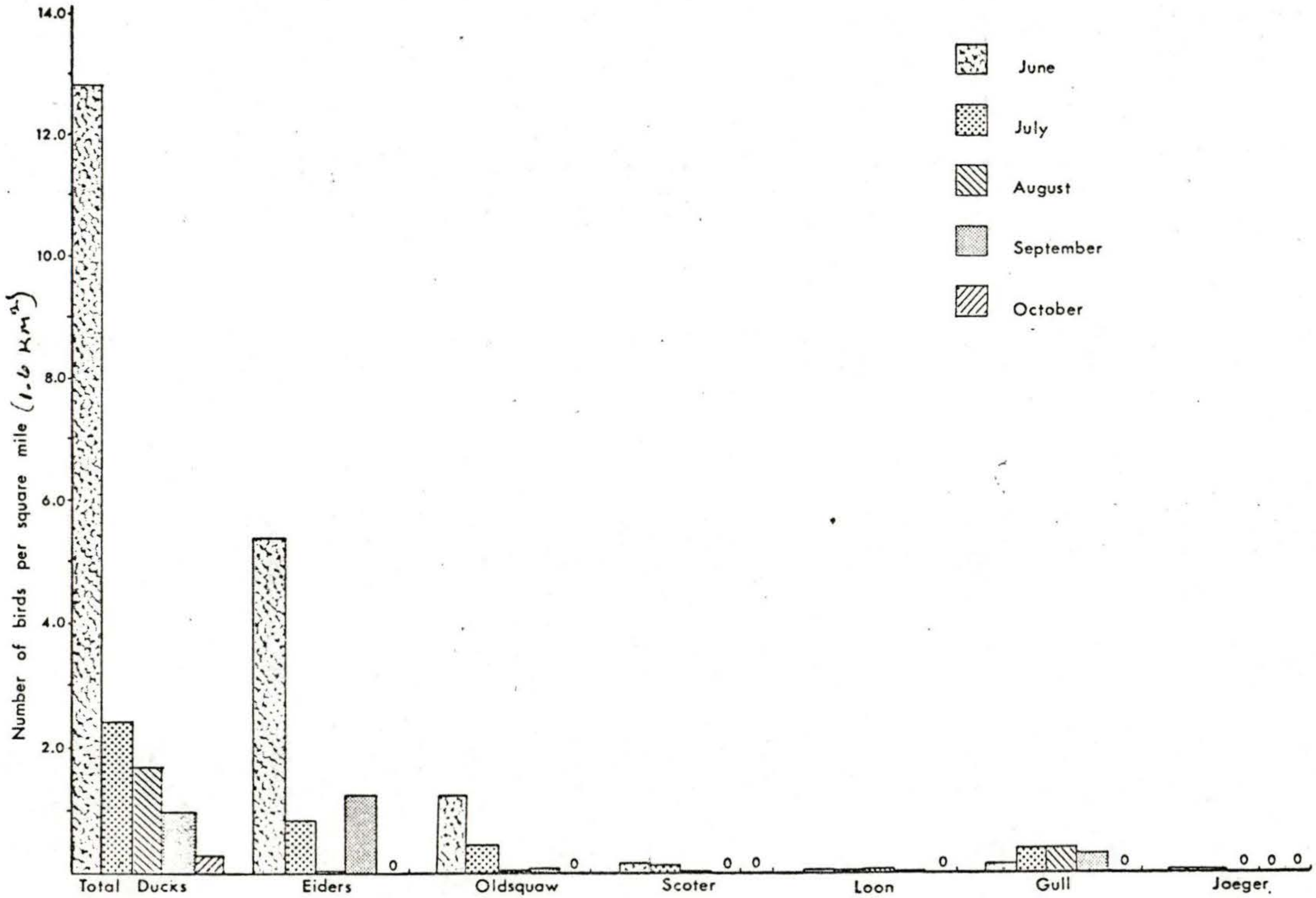

Figure 7. Observed Densities of Birds on Aerial Surveys in June through October in the Beaufort Sea

to analyze the habitat requirements of birds nesting on the coastal plain. After analyzing the results of the 1974 aerial surveys, two separate analyses for each of ten common species were made, one which considered all bodies of water together, and the other, fresh-water lakes only. These analyses showed that:

a) The numbers of red-throated loons, whistling swans, and glaucous gulls found on the coastal water increased slightly during July, but declined thereafter. The numbers of arctic loons and old squaws frequenting the coastal water did not change significantly during the study. Other factors being equal (P0.001 for each species), all five species were more numerous on the larger lakes and lagoons than on the smaller ones.

b) Arctic loons and whistling swans appeared more frequently on fresh water lakes than on other kinds of water (P0.001), although swans also occurred in greater numbers in coastal bays than they did near beaches or islands. On the other hand, fewer red-throated loons and glaucous gulls were seen near islands than in bays or near the shore. Old squaws were more often concentrated near beaches and in bays (P0.001) than on lakes.

c) Larger numbers of red-throated loons and glaucous gulls frequented lakes near the sea than those further inland (P0.001 and P0.01, respectively). The reverse was true for arctic loons and whistling swans (P0.05 and P0.001, respectively).

6.2.2 Species Richness

It is well known that the nature and diversity of a habitat controls the number of species which occupy it. Species richness is one measure of the importance of an area to wildlife; changes in the numbers of species from year to year may reflect changes, whether from natural or artificial causes, in habitat quality. Therefore, we documented the species richness of the Beaufort Sea coast, and assessed some factors related to the species richness of 90 different bodies of water.

Species richness was first considered by classifying lakes and lagoons as either fresh or salt with the help of maps on the scale of 1:250,000. All lakes connected to the ocean by streams only, were considered fresh.

The species richness of each body of water is clearly related to ocean access. During each survey period, the mean species richness was greater on lakes and lagoons with ocean access than on those landlocked or connected by streams. When the results of all six surveys were combined, the difference between lakes with and without ocean access was highly significant (Student's $t = 8.22$; two-sided P0.001); the average number of species per salt water lake was 6.80 ± 2.85 (Mean $\pm$ Standard Deviation; $n = 286$), while the average number of species per fresh water lake was 4.91 ± 2.00 ($n = 245$).

Next, we considered the species richness based on four classifications of water bodies. Of 90 survey sites, 41 were classified as lakes, 28 as bays, 15 as beaches and 5 island shores; one site did not fit any of these categories. When the results of all six count periods were combined, the average number of species per category was: beaches, 7.49 ± 2.81 (Mean $\pm$ Standard Deviation; $n = 90$); bays, 6.55 ± 2.76 ($n = 166$); island shores, 6.10 ± 3.49 ($n = 30$); and lakes, 4.91 ± 2.00 ($n = 245$).

We also considered the relation of species richness to the distance of an inland lake from the nearest salt-water shoreline. To increase sample sizes, we grouped the lakes as follows: (1) less than 1 km from coast, (2) 1 to 3 km from coast, (3) 3 to 5 km from coast, and (4) more than 5 km from coast.

The previous analyses were based on consideration of the effects on species richness of one factor at a time. The techniques of multi-variate analysis, however, permit evaluation of the simultaneous relationships of several environmental factors to species richness. This procedure involved a stepwise multiple regression analysis to handle the potential of nine variables. The results indicate that species richness is strongly related to two factors, the size of the water (P0.01) and the parabolic function of date. The relationships of date and the square of the date indicate that species richness on the lakes tended to increase slightly during the early part of the survey period but decreased substantially near the end. Analysis of variance indicated a high degree of difference between the number of species on different kinds of lakes.

6.2.3 Species Composition

The changing composition of the avian population in the Beaufort Sea during and after the breeding season reflects the phenology of the bird species and indicates the periods during which some of these species may be most susceptible to the effects of environmental disruptions. We calculated the relative numbers of individual birds for different species or species groups, for each category of lake or lagoon and for lakes at various distances from the coastal shoreline. Those data were separately analyzed for each of the six aerial surveys.

Most of the birds occurring near the mainland coast of the Beaufort Sea belong to one of 13 species groups. Gulls and the four species groups comprising the family Anatidae constituted more than 75 percent of the birds sighted. During four exceptional surveys, these groups of birds comprised 56 percent, 67 percent, 67 percent, and 73 percent of the birds sighted.

The bird populations sighted in beach and bay habitats were dominated by diving ducks during most of the study period. To a lesser extent the ducks also dominated in the lakes. Geese, predominantly brant and lesser snow geese, were more common both near beaches and on bays during the survey of August 24 to 28. Although populations of birds on and near islands were less strongly dominated by any one species or species group, gulls, primarily glaucous gulls were the most common birds on and near islands during July; thereafter the dominant species varied.

Comparison of species composition of the birds on various categories of water bodies indicate the relative importance of these areas to particular species groups. The results of these surveys indicate the changing importance of certain kinds of water over time to a particular species group.

Diving ducks usually dominated the lakes; however in July and early August on lakes from 1 to 3 km from the coast, geese were slightly more common than the ducks. In late August and early September, 80 percent of the birds sighted on these inland lakes were diving ducks.

6.2.4 Species Associations

The fact that different species of birds prefer similar habitat often results in strong correlations between the numbers of species present on different bodies of water. Such correlations can be assessed only after accounting for such variables as the date of observation and the characteristics of the water bodies. For example if two species did not happen to prefer similar habitats, both might occur in large numbers on large lakes solely because the size of the lake attracts greater numbers of birds.

Generally, the numbers of closely-related birds such as geese and swans occurring in the same place, showed a high degree of correlation. Gulls were often sighted with terns. Most species of diving ducks were found with other diving ducks and with loons; the strongest correlation was between the numbers of old squaws and scaup.

6.3 Migration Watch in 1972

The results of the migration watch are difficult to interpret accurately. The chance that an observer will detect a bird or flock varies with his visual acuity, with the visibility of the bird, and with its horizontal and vertical distance from the observation point. For example, a flock of geese is easier to see than a single goose or a flock of shorebirds. Moreover, migrating flocks rarely move along the coast in a stream narrow enough to allow an observer on shore to see all the birds. Nevertheless systematic migration watch can provide useful information about the direction and timing of bird migrations and about the minimum numbers of conspicuous species which tend to fly along the coasts. This technique does not provide reliable data about the actual size of bird populations or the relative numbers of several species. Aerial surveys and radar studies must furnish the supplementary information on which conclusions can be based about the concentrations of birds flying within and beyond the visual range of an observer on the ground.

Nonetheless, we feel it necessary to submit rough estimates of some of the more common species that passed Cape Dalhousie between May 29 and June 16, 1972:

Species	Numbers estimated from ground observations
Yellow-billed Loon	4,500
Arctic Loon	9,000
Red-throated Loon	200
Unidentified Loons	24,150
Pomarine Jaeger	6,200
Parasitic Jaeger	5,300
Long-tailed Jaeger	7,700
Glaucous Gull	35,400
Sabine's Gull	6,400
Arctic Tern	2,300
Old Squaw Duck	1,130,250
Common Eider	549,120
King Eider	695,115
White-fronted Goose	1,100
Canada Goose	9,350
Pacific Brant	21,885
Plovers	6,400

6.4 Spring Migration in 1975-based Radar, Visual and Aerial Surveys

Visual observations indicate that the spring bird migration along the Beaufort Sea coast takes two principal directions: eastward and westward. The radar confirmed that most of these migrants move more or less parallel to the coast; however there is a third group of migrants, those moving northeast across the British Mountains and the North Slope, and then out over the Beaufort Sea. This third direction of movement usually involved far fewer flocks than did the eastward and westward flights.

6.4.1 Eastward Migration

The radar detected eastward migrations of birds during almost every day of the study period, May 23 to July 9. However, fewer birds moved east during most days in mid-May than did during most days later in the season. Over a thousand eastbound groups of birds were occasionally detectable at one time. When observations ended July 9, the volume of this eastward migration, as detected by radar, still seemed to be increasing. The most intense and most prolonged eastward movement to be detected by radar occurred July 3 to 8.

The variations in numbers of birds observed during migration watches showed seasonal patterns. Before May 27, the maximum rate of eastward migration during any one half-day period at either observation site was the 12.5 birds per hour (counted during the afternoon of May 23 at Komakuk). These were mostly unidentified shorebirds. Often no birds were seen even though observations continued for five hours at a stretch within these half-days. To permit direct comparison between radar and visual observations, all references to migration rates in half-day intervals refer to the time periods 02:00-10:00 and 14:00-22:00 YST. Intervals with less than 60 minutes of visual observations are excluded from consideration.

At both Clarence Lagoon and Komakuk, the number of birds moving east peaked during the period May 27 to June 13. More than 100 birds per hour were observed during seven half-day periods between May 29 and June 11. The most common birds sighted were brant, old squaws and pomarine jaegers.

The highest migration rate observed visually during any one half-day period was 486 birds per hour at Clarence Lagoon during the afternoon of June 7. At the same time birds were passing Komakuk at the rate of 332 per hour. Again, brant, old squaw and pomarine jaegers were the most abundant migrants.

After June 13, the east bound migration rate observed during watches at either site never exceeded 26 birds per hour. This maximum rate occurred at Komakuk during the afternoon of July 1. Most of the birds observed were old squaws and unidentified shorebirds.

The sharp decline of the eastward migration as detected by observers on shore during the latter part of the study was not parallelled by a decline in numbers of birds detected by radar, either along the coast, North Slope or elsewhere. In the discussion that follows it should be kept in mind that visual observations apparently record an incomplete and biased sample of the flow of migrants eastward parallel to the coast.

6.4.1 a) Broad-front Migration

The radar showed large numbers of migrating birds moving eastward more or less parallel to the sea coast, not only along the shore line but also over the entire North Slope, and offshore waters, to the limits of the radar's range. Often smaller numbers of birds were moving eastward over the foothills of the British Mountains and over the mountains themselves.

The relative numbers of eastbound migrants detectable at different points varied considerably from time to time. Sometimes the density of birds flying eastward along the coast was not much greater than the density of those flying at various distances offshore. At other times, the relative density of eastward migrating birds along the shore was much greater than that offshore. Occasionally, the numbers of birds flying eastward along the shore and those flying inland over the North Slope were about the same. More commonly however, there were fewer flocks inland.

On rare occasions there were more birds flying near the foothills than near the coast, and even more rarely the birds were flying over the mountains in greater numbers than offshore. Characteristics of the eastward migration were so variable; on some days of heavy migration offshore and over the North Slope birds might be flying more than 45 km inland, while on other days there would be few or none beyond the foothills.

The density of eastward migration 20 km offshore was occasionally as great as that over the coast, but almost never greater. However, because of the broad expanse of the offshore movement relative to the coastal movement, the total number of flocks, and presumably the numbers of individual birds, detected 10 to 75 km offshore were often much greater than the numbers within 2 or 3 km of the coast. Furthermore, radar would have detected a larger portion of the flocks present along the coast than of those offshore. Thus, there were many days when an observer posted on the shore could not see a large fraction of the eastward migration occurring across the general area of the North Slope, Yukon coast, and southern Beaufort Sea.

6.4.1 b) Species Composition of Eastward Migration

Only visual observations could ascertain the species composition of eastward moving birds. No radar-monitoring method provides enough information to identify species, and in this study the radar rarely indicated even related groups of species.

Migration watches at Clarence Lagoon and at Komakuk provided considerable information about the species of east and west bound birds, but for a number of reasons the observations were incomplete and biased:

1) The visual observations were made at only two locations, both on the shore, while the radar showed that the migrants were by no means confined to the coastal zone.

2) The probability of detecting and accurately identifying a bird at a specific distance as well as at the maximum distance at which individuals of a species are identifiable is limited by the bird's size, coloration, the frequency and loudness of its calls, and the typical altitude of its flight, among other factors.

3) The area covered by observers posted onshore was small. Hence, it is likely that low-density movements readily detectable on the radar went unnoticed by field observers. Consequently the movement would not be identified as to species involved.

4) Only rarely was the total flow of migrants dominated by a single species, a circumstance which complicates the interpretation of radar data.

5) Visual observations provide little information about shorebirds or passerines, the more inconspicuous members of the migratory movement, or about species that rarely occur along the Beaufort Sea coast, for example, the king eider which apparently travels eastward far offshore.

For these reasons, we must interpret visual observations with caution as they do not permit a positive identification of many of the birds detected by radar.

Glaucous gulls were the only species moving east in significant numbers between May 9 and 20 when they passed ground observers at the average rate of 0.37 birds per hour. The absence of eiders, particularly king eiders, during this period is significant. From their dates of departure from Point Barrow, Alaska, bound in an east-northeast direction across the Beaufort Sea, one would expect them to be mvoing eastward at the same time as the gulls. Aerial surveys on May 14 did not report eiders in the small cracks between ice pans to a point 280 km north of Herschel Island. The eastward migrations detected by radar during this period probably consisted largely of glaucous gulls, a species reported to migrate over land as well as along the shoreline and over the sea.

From May 20 to 31, the predominant species moving east were brant (28.2 birds per hour), old squaws (10.7 birds per hour), glaucous gulls (3.6 birds per hour), and pomarine jaegers (1.1 birds per hour). The first shorebird movements begin during this period at the average rate of 3.5 birds per hour; only the pectoral sandpiper was identified in significant numbers. Many of the birds were sighted during the last three days of the period.

Of the birds involved in the late May migration eastward, the dominant species are those tending to fly close to the ground or ice, at least insofar as field observers could see. Because shorebirds migrate at moderate to high altitudes, they were probably a large fraction of the birds detected by radar.

Extensive eastward migrations were recorded both by the observers on shore and by radar during the first ten days of June. Again, the most abundant species were brant (86.7 birds per hour), old squaws (22.3 birds per hour), pomarine jaegers (9.4 birds per hour) and glaucous gulls (4.7 birds per hour). Loons, predominantly arctic and red-throated, were moving eastward at the rate of about 1.8 birds an hour. About one each of common eiders, arctic terns, and red phalaropes passed each hour; other species of shorebirds also occurred in significant numbers. Because they are relatively inconspicuous, shorebirds were probably more common than visual observations suggest.

An aerial survey over the Beaufort Sea on June 5 revealed the presence of more birds than were reported in six other surveys combined. From aerial surveys, old squaws were by far the most common species, a total of 4,274 counted. There were also 723 common eiders, 115 king eiders, and 194 brant. Most birds seen from the aircraft were travelling towards the east.

Old squaws were the most common eastbound migrants between June 11 to 20, passing at the rate of 12.3 birds per hour. Almost all the pomarine jaegers migrating east in mid-June were seen before June 12. Their numbers were sufficient to make 4.1 birds their hourly rate for the whole period. Glaucous gulls continued to migrate past ground observers at the rate of 3.3 birds per hour; eiders, mostly common, 3.1; arctic terns, 1.5; brant, 1.5, and loons 1.4.

From June 21 to 30, field observers saw many fewer birds than they had during the three previous periods of the migration. The glaucous gull was the only species to pass at the rate of more than one bird per hour. In contrast, the radar detected large numbers of unidentified birds migrating eastward. Because these unknown birds travelled at moderate or high speeds and many of them were flying at altitudes of at least 100 m, it is unlikely that they were glaucous gulls.

The old squaw was the most common species observed during the offshore aerial survey of June 26. The survey also reported a significant number of scoters, but most of them were west bound.

Small numbers of old squaws, glaucous gulls, and brant were moving east from July 1 to 9, but their numbers were few compared to the eastward broad-front migration detected by radar at this time over the Beaufort Sea and Yukon coast.

6.4.1 c) Flight Directions

As already explained, most of the migrating birds observed from shore positions moved parallel to the coast. At Clarence Lagoon, where the coast has a west-northwest by east-southeast orientation, the general direction of "eastward" migration was actually east-southeast. At Komakuk, where the coast lies west-southwest by east-northeast, the birds travelled east-northeast.

The radar often showed a concentrated movement of migrating birds eastward within 1 or 2 km of the coast, plus an eastward migration of lower density as a broad front across the Beaufort Sea and along the North Slope. The birds that followed the coastline frequently changed course according to the irregularities of the shore, but those involved in the broadfront movement offshore or inland tended to maintain straight tracks. On July 8, 1975, several flocks moving east-southeast about 25 to 40 km offshore suddenly shifted course to a track closer to shore at about 10 to 25 km from the coast; presumably the birds jogged in response to the sight of open water in a lead lying off Komakuk.

6.4.2 Westward Migration

Observers onshore saw few birds moving west before the end of May, and it was not until mid-June that they reported westward migrants in large numbers. The peak of westward flights occurred on June 21 when birds passed the observers at the rate of 127 per hour; almost all of these birds were unidentified scoters.

The seasonal pattern of the westward migration as observed from the shore did not coincide with the pattern appearing on radar. Radar monitoring detected westward as well as eastward migration nearly every day of the study.

In addition to an increase in numbers of westward moving birds to be seen from shore as the season progressed, there was a significant increase in their proportion in the total migration, with a pronounced increase in their numbers about mid-June. This pattern was significant (P0.001) both at Komakuk and at Clarence Lagoon, as well as for both sites considered together. Again, radar data show neither an increase of westward migration during the study, nor a decrease in eastward migration.

6.4.2 a) Broad-front Migration

The radar showed that many migrants moved west more or less parallel to the coast, not only along the shoreline but also over the entire North Slope and offshore to the limit of detectability. Much smaller numbers were frequently moving northwest over the northern part of the British Mountains south of Komakuk.

As was the case with eastward migration, the relative numbers of birds moving west over different parts of the study area varied considerably. The density of flocks over the coast and North Slope was never less than offshore or over the mountains, and indeed was often considerably greater. Nevertheless, the fact that the density of westward moving birds offshore was occasionally as great as along the coastline, even on those days when coastline migration was greatest, indicates that large numbers of birds were moving west far beyond the vision of observers on the shore.

6.4.2 b) Species Composition of Westward Migration

Between May 9 and 20 almost no birds were to be seen moving west. At the same time, the radar rarely showed more than a few westbound groups. Because these birds were distributed over an area of several thousand square kilometres, it is not surprising that the observers on shore saw so few.

Westbound migration increased considerably between May 21 and 31, although the numbers of birds moving in a westerly direction were still much less than the numbers moving east. Whistling swans, passing at the rate of 1.7 birds per hour, and white-fronted geese, at the rate of 1.0 per hour, were the principal westward migrants during this period. There was also some westward movement of shorebirds. Because shorebirds tend to fly high and along a broad front, they probably contributed more substantially to the westward movement detected by radar than to the migrations as observed on the ground.

During the first ten days of June, the westward movement of swans continued at the rate of 0.7 birds per hour. Pintail, (3.2 birds per hour) was the dominant species of the movement. More shorebirds of several species were seen moving west in this period than earlier.

From June 11 to 20, the westward migration of pintails continued at an average rate of 2.8 birds per hour. Relatively few whistling swans moved west after June 17. Scoters began to move west, at the rate of 1.0

per hour. Fewer shorebirds were moving west than were in early June.

The most conspicuous westward movement during mid-June was that of pomarine jaegers and unidentified jaegers. Until June 12, almost all jaegers observed were moving east. After that date they were travelling west at the rate of 14.6 birds per hour.

Between June 21 and 30, the principal birds migrating westward were scoters (5.4 per hour), unidentified ducks (3.6 per hour) and pintails (1.5 per hour). The westward movement of jaegers continued, but fewer were seen compared to mid-June.

The westward pintail movement virtually ceased between July 1 to 9, and was replaced by scoters, predominantly surf scoters (2.5 per hour) and old squaws (1.9 birds per hour). The aerial survey of July 3 was the first of the flights over the Beaufort Sea during which large numbers of scoters were seen: white-winged scoter, 137; surf scoters, 82; and unidentified scoters, 289.

6.4.2 c) Flight Direction

Most of the westbound birds reported by field observers were moving parallel to the coastline. Because of the different orientations of the coast at Clarence Lagoon and at Komakuk the directions of westward migrants observed at the two sites varied slightly.

Radar revealed more noticeable differences in the directions of westward migrations. A concentrated stream of migrants moved westward along the coastline which, within the Komakuk area covered by radar, is oriented almost due east-west. However, the broad-front movements tended to be directed west-northwest, parallel to the more general orientation of the

Beaufort Sea coastline. Birds travelling along the shore usually travelled in a direction only slightly different from those flying offshore or across the tundra. Flocks whose paths intersected the coast after a flight along part of the North Slope often changed course to join the stream of birds following the coastline.

6.4.3 Northeastward Migration

Intermittent northeastward movements of birds were detected by radar all during the study. Significant migrations of birds to the northeast occurred as early as May 12 and continued until early July. The record of the daily migration is often imprecise because it was not always possible to distinguish clearly between eastward and northeastward movements. However, there were many periods during which no northeastward movement took place at all.

Although migrations toward the northeast were often conspicuous on the radar display, they usually involved only a few widely scattered flocks. But during late May and early June, up to 30 flocks moved each hour across a 10 kilometre "line" of migration front over the Beaufort Sea region. From the ground observation sites, the northeastward movements were not plainly recognizable, due to the low density of these flocks and the northeastward flights occurred at high altitudes.

6.4.3 a) Extent and Directions of Northeastward Migration

Whether over land or over the sea, the northeastward movements of birds were always on a broad front. The birds approached over the British Mountains and the Brooks Range, and were often detectable 55 km or more south and southwest of Komakuk. Usually, they continued across the North Slopes and coast with no change in direction. Once offshore, most of them continued to fly northeast until they moved out of radar range 45 to 75 km offshore or dropped below the radar horizon.

Occasionally the birds would change direction from northeast to east after they had moved out to see, where they joined the eastbound migration in progress offshore. Some birds turned east within a few kilometres of the coast; others maintained their original track until they turned at 45 km offshore. Others which moved out of radar range also may have turned eventually.

Birds moving northeast likely took off from interior Alaska. Most of them were flying in a direct line with Yukon Flats. Other birds moving due north were coming from the direction of Old Crow Flats, Y.T.

The landfall destinations of the birds observed flying northeast over the Beaufort Sea are unknown. It is debatable whether they were flying Great Circle routes or Rhumb-line courses; that is, maintaining a constant bearing, but in either case they would not have encountered land without turning until they reached the north coast of the U.S.S.R. or Greenland. Because the number of flocks flying northwest, north and northeast was extremely small compared to flocks headed in other directions, it is possible that they were disoriented and did not survive.

6.4.3 b) Species Composition of Northeastward Movements

There is little direct evidence bearing on the species of birds making northeastward flights. Some brant are known to move from the Yukon River Basin in Alaska over the mountains to the Beaufort Sea, and one flock of brant was reportedly flying northeast 480 km offshore. Old squaws are the most common ducks to move northward down the tributaries of the Colville River. Because this species also migrates eastward along the coast in large numbers we may surmise that there is also a broad-front northeastward movement over the mountains and the Beaufort Sea towards Banks Island. Shorebirds of various species may also be among the migrants flying toward the northeast; they routinely migrate non-stop for long distances and at high altitudes.

Especially puzzling is the identity of birds moving northeast in mid-May, that is, before either shorebirds or waterfowl were seen in significant numbers. The air speeds of these birds was approximately 70 km per hour, not typical of glaucous gulls. The only other birds migrating eastward in large numbers in mid-May are eiders which have been seen moving northwest and north across northern Alaska in spring. Furthermore, common eiders are known to migrate across southern Sweden at moderate and high altitudes, and are suspected of undertaking similar flights across Finland, also New England. Again, available evidence does not warrant any conclusions about early spring migrations of eiders in signficant numbers.

6.4.4 Visible and Actual Migration

We have already remarked that there was not always a close relationship between the numbers of migrants reported by field observers and those detected by radar. The radar showed an extensive eastward migration continuing to the end of the study period, while field observers saw little movement of birds after mid-June. The radar also revealed an extensive westward migration occurring over a longer period than was indicated by visual observations. It is probable that the field observers were unable to record passerine and shorebird migration with any accuracy. Few individuals of these groups of birds were reported considering the numbers of them known to occur on the Yukon North Slope.

6.5 Food Habits

The food habits of the various bird species occurring in the Beaufort Sea was not the subject of investigation. A separate study of glaucous gulls revealed food habits in an early year 1973, and a late year 1974. A comparison of regurgitated pellets taken on 22 June in each year at Anderson River Delta is summarized as follows:

	1973 % Volume	1974 % Volume
Marine Invertebrates	59	10
Fish	17	34
Birds	10	17
Mammals	8	32
Vegetation	6	7
	100	100

In the late year of 1974 ice covered the tide flats and beaches, forcing the gulls to hunt inland. Fortunately for the gulls small mammals, fresh water fish, and birds were relatively abundant.

Other birds are not so catholic in their tastes and are much more limited in food species or niches. For example eider ducks feed on blue mussels and other bottom invertebrates in water shallow enough to dive to the bottom. The combination of open shallow water off Cape Dalhousie probably explains the concentration of eiders and old squaws in May and June. Loons feed on marine fish found by diving in the areas of clear water away from the Mackenzie River plume. Most lakes where red-throated and arctic loons nest are devoid of fish, thus requiring long flights to sea for food.

In the Beaufort Sea area pacific brant are confined in their nesting and feeding to the alkali grasses and sedges that grow only on littoral areas.

In the fall staging areas of snow geese the low coastal marshes of the Mackenzie Delta are extremely important for food for developing young, especially after the higher inland areas are snow covered.

7. DISCUSSION

Foul weather and late persistent ice during the 1974 season affected the migration and reproductive success of the birds. Furthermore, because of persistent bad weather, observations of the birds and the logistics of making surveys of their numbers were even more difficult than in "normal" seasons.

Fortunately, we have two additional sources of information to supplement the atypical bird data gathered in 1974. First, we could draw upon the experience and records derived from ground observations made in 1972, although the weather that year was not particularly "good," either. More fortunately, we had opportunity in 1975, a year of fairly good weather and improved ice conditions, to conduct radar, ground, and aerial observations during May and June.

Ideal conditions for bird life in the Arctic are rare. What is good for one species or one phase of its life history may be detrimental at other times or to other birds. An early snow melt will allow early nesting, larger broods, and more time for the birds to prepare for fall migration. If the sea ice clears early in the season, it increases the chances of early storm tides which flood the coastal nesting grounds before the eggs hatch. Presumably because of weather and ice conditions, some birds, especially non-breeders, stay in coastal Alaska to molt behind coastal barrier beaches, rather than continuing east.

The open leads that parallel the coast just off the landfast ice provide a traditional pathway for spring migrants. Where the depth of water is favourable and where food species are abundant, the leads provide the only feeding grounds for such birds as eiders and loons before they begin nesting.

8. CONCLUSIONS

There are approximately 100 species of birds associated with the Beaufort Sea and its littoral zone. As a group, they present complex patterns of migration routes, and feeding, resting and nesting requirements. They range in numbers from the ubiquitous old squaw and eiders to the rare and endangered ivory gull. Some birds arrive in the Beaufort Sea as early as April and others depart as late as December.

The open leads between the landfast ice and the pack-ice are used by hundreds of thousands of several species during spring migration. But as the radar studies show, many individuals migrate on a broad front at higher levels, probably overflying the marine zone.

Those species, such as loons, which cannot take off from land and are dependent upon water for food and a place to copulate or rest are attracted to any open water in the ice. Where currents and winds usually cause open water to appear each spring, sea birds have established a traditional use of the opening. The lead system which forms nearly every year off Herschel

Island overlies water too deep to permit bottom feeding by most diving birds. Therefore, the birds use it primarily for resting and feeding on nektonic fishes. Another important lead is off Cape Dalhousie and Baillie Islands sometimes extending north to the west coast of Banks Island. Because this lead overlies shallow water at 50 m or less, it is suitable for bottom feeding on benthic invertebrates, as well as resting; large numbers of eiders, old squaws, and loons concentrate here.

Protected bays and lagoons behind barrier beaches, such as McKinley Bay on the northwest coast of the Tuktoyaktuk Peninsula, are important places for the rearing of broods and for the annual moulting of adults. These sites are especially favoured by scaup, white-wing scoters, surf scoters, and old squaws.

The littoral zone of Ellice and Oliver Islands, Moose Channel flats, Anderson River Delta, and Harrowby Bay flats, are heavily used for nesting, feeding, rearing young, and fall staging. Here, the snow geese, brant, white-fronted geese, swans, dabbling ducks, and many species of shorebirds which concentrate in these areas probably represent the densest population of birds found in any Arctic habitat except bird cliffs of the eastern Arctic.

No satisfactory estimate of the total numbers of individual birds in the Beaufort Sea region is yet possible. However, at least two million birds migrate to or through the study area each season. A firmer estimate is impossible because these birds are a highly mobile, ever-changing population.

9. RECOMMENDATIONS

Open water in the system of leads between landfast ice and park ice are attractive to seabirds. This is especially true of those species which traditionally follow the leads around Alaska and northern Canada in migrations to their nesting grounds on the Arctic islands. These birds are obligated to open water leads for food or resting (because of their anatomy, loons cannot take off from land). An example of the importance of open leads to eider ducks occurred in 1964 when due to persistent northwest winds, the leads remained closed through most of the season. This unexpected event caused an estimated 100,000 eiders and other marine birds to starve when they arrived to find no food or resting available.

The results would be similar if oil contaminated the leads. Only small quantities of oil, often a few drops, can destroy the birds' thermal protection and waterproofing; the kill of seabirds could be very great. In late May, old squaws, eiders and loons, etc., concentrate north of Cape Dalhousie. The numbers range up to 175,000 on any one day. The turnover rate could be high enough to include nearly the entire population in only several weeks.

Attempts to de-oil seabirds have proven useless, even in warmer climates. To attempt to re-oil seabirds on the edge of ice 60-100 km from land is ludicrous.

If oil-covered leads are small (depending on wind, etc.), it might be possible to cover them with white foam so that they look like snow or ice rather than water and hence not be attractive to birds. But, where else can the marine-obligated birds go? The frozen seascape would be the same as 1964 and a large number will die of starvation.

If the ice leads are large as in normal seasons, wind and brash ice would compound difficult logistics to attempt a clean-up. One can only hope that oil would be pushed against the ice edge and conventional scaring devices would effectively keep birds in wind-cleared waters. Our observations of seabirds in large leads in May and June show that they congregate in the water at the lee edge of ice, which is expected to be free of surface oil.

In the spring, with oil spills appearing in open water leads in the ice, several strategies are available, but with marginal chances of success.

1. Masking foams or similar material so that the oil doesn't look like water and attracts seabirds.

2. Scaring devices to keep birds away from wind driven comcentrations of oil.

3. Dispersants, flamings, or gathering of oil. The effects on the food chain in the benthos or nektors are another matter for study.

Once the ice has cleared, an oil spill would be driven ashore by northwest winds,--the prevailing storm winds in the Beaufort Sea. Storm tides inundate the littoral zone; that is, beaches and barrier beaches, lagoons, marshy flats and deltas. Therefore, oil carried over the littoral zone by the tide would remain as a residue, destroying prime habitat of nesting and feeding birds.

Clean-up of beaches is difficult under the best of conditions. However, there are certain patterns to storm tide currents that might tend to concentrate large amounts of oil. For example, at Atkinson Point a storm tide washes over the sandspit into Louth and McKinley Bays. The bays are shallow (less than 2 metres) but there is a network of tidal channels through which most of the water (and perhaps oil) flows on the receding tide. Craft designed to remove oil might be successful in these areas.

10. FURTHER STUDY

a) A study of near shore and littoral zone tidal currents in critical bird habitat should prove very useful in the deployment of clean-up equipment.

Most of the critical areas are somewhat protected from heavy seas so that clean-up can begin while a storm is in progress. Shallow draft vessels (1 metre or less) and barges would presumably be required.

b) Ice leads are used for feeding, resting, and copulation.

It would be desirable to study the precise use seabirds make of the leads during the spring. Such a study would require a camp on the edge of the ice and would require expensive logistical support.