SHOREBIRD LITTORAL ZONE ECOLOGY
OF THE SOUTHERN CHUKCHI COAST OF ALASKA

by

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I. SUMMARY

Our studies of shorebird ecology at several coastal sites along the southern Chukchi and Kotzebue Sound coasts in 1977 and 1978 identify several contrasts as well as a number of similarities with shorebird littoral zone use along the Beaufort and northern Chukchi coasts (see Connors et al 1981 for results of Beaufort coast studies). In general, the same seasonal habitat shift is evident in both regions. Shorebirds nest on the tundra during June and July, with post-breeding adults and newly fledged juveniles shifting to littoral zone habitats during late July and August, where they forage before migrating southward to wintering areas. At the southern Chukchi study sites, however, the degree of this shift is not so marked as at Beaufort sites, and the expression of this habitat shift varies considerably at different local sites along the southern Chukchi coast. This difference arises from a greater availability and therefore heavier use of littoral habitats during the early migration and nesting period at southern Chukchi sites; the much lower levels of shorebird activity along southern Chukchi ocean beaches compared with the heavy concentrations of zooplankton-foraging shorebirds at many Beaufort sites; and the extensive areas of saltmarsh and mudflat which draw littoral zone foraging shorebirds away from some other sites after nesting activity is finished.

Differences in phenology among regions and among local sites account for some of the differences in relative habitat use, with some littoral habitats available much earlier at southern Chukchi sites than along the Beaufort coast. Differences in tundra phenology did not, however, affect dates of nesting activities as strongly as might be expected. Instead we believe bird nesting dates are set partly by requirements such as conditions at other sites during migration or hormonal schedules, and therefore do not fluctuate as severely as for example, melt-off dates from year to year at each site. During spring melt-off we observed a surprising phenomenon of shorebirds foraging on ice-lifted sediments above the ice over shallow lagoons near Kotzebue Sound. At this time (late May) shorebirds are still migrating or just beginning to nest. We recorded extremely high densities of birds on the lagoon ice, approximately ten to fifteen times the densities on nearby salt marsh transects and fifty times the densities on adjacent tundra transects. Shorebirds of several species were foraging principally on chironomid fly larvae, the same prey which they take in late summer from lagoon mudflats. We present a hypothesis for the occurrence of these food-rich sediments above the ice. The phenomenon may be quite variable from year to year, depending on a sequence of primarily meteorological events. Shorebirds probably take advantage of this rich resource opportunisti-

tally. Oil spilled during the previous open water period or released in the ice during winter might therefore attract large numbers of spring shorebirds because its appearance would mimic this natural phenomenon. We do not know how birds of various species would respond to such an encounter, or as discussed in this report, whether such encounters would be lethal.

Shorebird littoral zone prey identified at southern Chukchi sites are very similar to foods which shorebirds take at Beaufort and northern Chukchi sites, but the importance of different habitats and different prey systems to the shorebird community varies between these regions. Along the Beaufort coast, largest concentrations of littoral zone foraging shorebirds are associated with a coastal zooplankton trophic system. Large numbers of Red and Northern Phalaropes together with Dunlins, Sanderlings, Ruddy Turnstones and occasionally other species, as well as some gulls and terns, forage in late summer along sand and gravel beach shorelines, especially near spits and barrier islands of the Beaufort and northern Chukchi coasts. The zooplankton community is quite variable, but densities are frequently high, providing an excellent food source for large numbers of shorebirds. Important prey items include amphipods, euphausiids, copepods, mysids, and decapod zoea as well as other species. At Cape Krusenstern, Wales and other Chukchi sites, we did not encounter comparable concentrations of shorebirds, although the smaller numbers of phalaropes foraging in these areas were taking similar prey species. The alternative trophic system is based principally on chironomid fly larvae as well as on other insect larvae, oligochaetes, beetles, spiders, amphipods and seeds. These occur in good densities in saltmarshes, on mudflats, around saline pools and sloughs. These habitats are generally small and scattered along the Beaufort coast, where they are important to many species of shorebirds. At southern Chukchi sites, however, such habitats are much more extensive and support much larger numbers and a greater proportion of shorebirds. Most common species include Dunlins, Western and Semipalmated Sandpipers, Pectoral Sandpipers, Long-billed Dowitchers, and Golden Plovers.

These regional differences in importance of trophic systems and habitat areas may be important in determining the extent of effects on shorebirds produced by oil development disturbances. Oil slicks along Beaufort gravel beaches in late summer would have much greater immediate affects than along southern Chukchi beaches. However, a large spill in one of the extensive saltmarsh areas of the southern Chukchi could affect much greater numbers of several species than a similar spill along the Beaufort coast. Effects of spills in these two habitats will also differ in degree and duration. Spills on gravel beaches may have an immediate devastating effect because of the swimming habits of both Phalarope species, but the zooplankton prey base associated with the water column will likely recover in subsequent seasons after the oil precipitates or is removed. In saltmarsh and mudflat areas, in contrast, the immediate direct effects on shorebird plumages will be less severe because of the non-swimming habits of most of the species which forage there, but secondary effects on the prey base may last for many seasons.

The main shorebird concentration areas of importance along the southern Chukchi coast are those areas with extensive saltmarsh and mudflat habitat. Prime among these are the lagoon and island system of the Noatak Delta-Sisualik area and the lagoon barrier strip along the north shore of Seward Peninsula east and west of Shishmaref. Densities and total numbers of shorebirds in both these areas during August and early September are extremely high compared with most arctic sites.

Seasonal habitat use patterns of most species are similar in southern Chukchi areas to those measured along the Beaufort coast. Among the most important differences however, Golden Plovers along the southern Chukchi spend much more time in littoral habitats than do these birds farther north. The same is true of Pectoral Sandpipers, another species relatively restricted to tundra habitats at Barrow. These changes increase the sensitivity of both species to coastal oil development effects in the southern Chukchi compared to their relatively low sensitivity at Beaufort sites. Phalaropes of both species retain their high sensitivity in both regions but the seasonality of their exposure and the habitats in which they are exposed differ between regions. Compared with Beaufort sites, phalaropes are much less common along August shorelines in the southern Chukchi but more common in southern littoral habitats in early summer.

II. INTRODUCTION

In a companion report to this one (Shorebird Littoral Zone Ecology of the Alaskan Beaufort Coast, Connors et al (1981),we reported on the distribution, densities, seasonality, habitat use patterns, trophic relationships? and behavior of shorebirds along the Beaufort coast and northern Chukchi coast of Alaska. That report, based on field studies from 1975 to 1980, provides detailed information about the dependence of shorebirds of many species on resources in arctic littoral areas. The present report is based on studies in only 2 field seasons, 1977 and 1978, and is meant to extend the earlier observations to the southern Chukchi coast and Kotzebue Sound area, between Cape Thompson and Bering strait (Figure 1). It also addresses those aspects of shorebird littoral zone ecology which contrast between the southern Chukchi and the Beaufort coasts. However, since much of the ecology of the shorebirds studied is similar in both regions and because many details have been reported in previous annual reports (Connors and Risebrough 1978; 1979) we will not repeat all this basic descriptive material, choosing instead to concentrate on those aspects of southern Chukchi shorebird ecology which differ from more northern areas and particularly those which alter the susceptibility of shorebird species to oil development effects.

The list of 28 shorebird species occurring regularly along the southern Chukchi coast (Table 1) differs only slightly from a comparable list of Beaufort coast shorebirds (Connors et al 1981), but the relative abundance or breeding status of many of these species differs markedly between the two regions. All are migrants, many to and from areas as remote as the southern hemisphere, and collectively they comprise a major segment of the avifauna of the Chukchi coast. Their migratory habits make them an international resource dependent for part of each year on conditions along the Alaskan arctic coast.

Most arctic shorebirds nest during the summer months in tundra habitats where they are relatively free from immediate impacts of offshore oil development. However, it is well established (Connors et al 1979; 1981) that many arctic shorebird species depend during part of each year on resources and conditions in littoral habitats along beaches, on mudflat, and in saltmarshes. As we have reported previously and will expand in this report, this dependence on littoral habitats varies among species by season, age, and sex and by geographic location across the arctic.

Table 1. Shorebird species occurring regularly along the Southern Chukchi coast of Alaska.

Regular Breeders
Semipalmated Plover, *Charadrius semipalmatus*
American Golden Plover, *Pluvialis dominica*
Black-bellied Plover, *Pluvialis squatarola*
Ruddy Turnstone, *Arenaria interpres*
Black Turnstone, *Arenaria melanocephala*
Common Snipe, *Capella gallinago*
Whimbrel, *Numenius phaeopus*
Red Knot, *Calidris canutus*
Pectoral Sandpiper, *Calidris melanotos*
Baird's Sandpiper, *Calidris bairdii*
Dunlin, *Calidris alpina*
Rock Sandpiper, *Calidris ptilocnemis*
Semipalmated Sandpiper, *Calidris pusilla*
Western Sandpiper, *Calidris mauri*
Long-billed Dowitcher, *Limnodromus scolopaceus*
Bar-tailed Godwit, *Limosa lapponica*
Red Phalarope, *Phalaropus fulicarius*
Northern Phalarope, *Phalaropus lobatus*
Additional Migrants
Killdeer, *Charadrius vociferus*
Sharp-tailed Sandpiper, *Calidris acuminata*
Least Sandpiper, *Calidris minutilla*
Rufous-necked Sandpiper, *Calidris ruficollis*
Curlew Sandpiper, *Calidris ferruginea*
Stilt Sandpiper, *Micropalama himantopus*
Buff-breasted Sandpiper, *Tryngites subruficollis*
Sanderling, *Calidris alba*
Wandering Tattler, *Heteroscelus incanus*
Hudsonian Godwit, *Limosa haemastica*

III. METHODS

Study areas. Following the definition in Connors et al (1981), we consider the arctic littoral zone to extend from the lowest tide level up to the limits of the area which may be flooded by storms at least once every few years. This zone can be recognized by brackish water in flood pools, by the presence of salt-tolerant vegetation, and by the distribution of storm drift material. It includes the habitats most susceptible to coastal oil pollution.

We established permanent marked transects at two main study sites: Cape Krusenstern (67° 08'N, 163°43'W), censused in 1977 and 1978; and Cape Prince of Wales (65° 38'N, 168° 08'W), censused only during 1977 (Figure 1). At each study site we established transects in a wide variety of littoral and near-littoral habitats (Tables 2 and 3; Figures 2 and 3). Observations at the principal study sites were supplemented in both years with brief visits to census transects and assess shorebird densities and habitat use at sites in the Noatak Delta lagoon system near Sisualik (Figure 1) and at several sites along the lagoon barrier strip of the north shore of Seward peninsula, east and west of Shishmaref (Figure 6).

Transect censusing. Permanent transects at study sites were marked with stakes at 50 meter intervals. In relatively uniform habitats such as mudflat, saltmarsh or tundra, transects 'were straight and 100 meters in width, with stakes running along the center line of a double row of 50 by 50 meter square plots. Transect distances varied from 300 meters to 1000 meters. Shoreline transects along lagoon edges or ocean beaches consisted of single rows of 50 meter by 50 meter square plots following the shoreline. These transects varied from 500 meters to 1000 meters in length.

We censused at least once every 5 days throughout the entire field season at each of the principal study sites, recording all birds within each censused plot. Study seasons at Cape Krusenstern included 5 June 1977 through 7 September 1977 and 26 May 1978 through 6 September 1978; at Wales transects were censused from 5 June 1977 through 12 September 1977.

This method of permanent transects, regularly censused, provides data which are easily analyzed to reflect seasonal changes in population density; it is especially well suited to habitats with marked seasonal changes in bird use, such as arctic littoral areas. To determine the more stable breeding densities on tundra at the main study sites we established rectangular gridded study areas and censused these every 5 days, recording locations of all birds as well as display territories and nest locations. Grid sizes were 29.8 ha at Cape Krusenstern and 25 ha at Wales. These breeding bird surveys allow us to compare local shorebird communities at these sites with other arctic coastal areas.

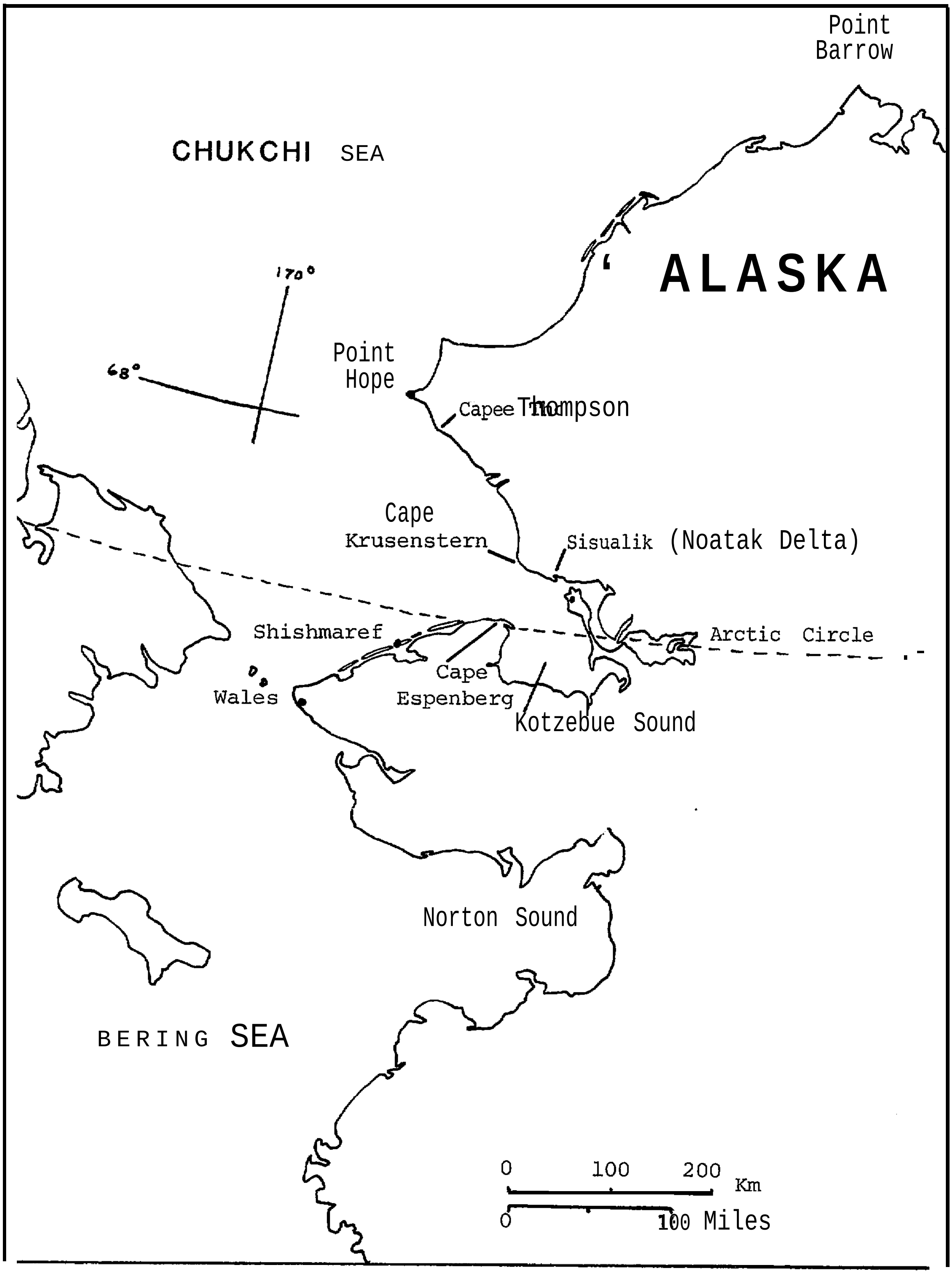


Figure 1. Map of northwest Alaska.

Table 2. Locality codes for transects and sampling stations. Wales, Alaska. (See Figure 3).

Code	Transect or station name	Tundra or littoral	Transect length (m)	Transect width (m)
WB 1	Sea Beach 1	L	1000	50
WB 2	Sea Beach 2	L	1000	50
WB 3	Sea Beach 3	L	1000	50
WB 4	Sea Beach 4	L	1000	50
WB 5	Sea Beach 5	L	1000	50
WB 6	Sea Beach 6	L	1000	50
WBB	Breeding Bird Plot	T	1000	100
WB D	Beach Ditch	L	500	50
WBT	N. Beach Tundra	T	1000	100
WEL	S.E. Lagoon 2	L	1000	50
WHL	Hill Transect	T	1000	100
WM L	W. Lagoon 3	L	1000	50
WN L	W. Lagoon 4	L	1000	50
WNM	N. Red Mud	L	300	50
WRW	Runway	T	1000	100
WSL	S.E. Lagoon 1	L	1000	50
WSM	S. Red Mud	L	300	50
WSS	S. Beach Tundra	T	1000	100
WSW	Swan	T	1000	100
WVS	Village Stream	L	300	50
WWL	West Lagoon 1	L	1000	50
	Not included in map-transects located 2 km northeast of B6 transect			
WB S	Sin-l-rock Sea	L	1000	50
WR L	Sin-l-rock Lagoon	L	1000	50
WRM	Sin-l-rock Mud	L	300	50

Total areas: Tundra: 60 hectares
Littoral: 73.5 hectares

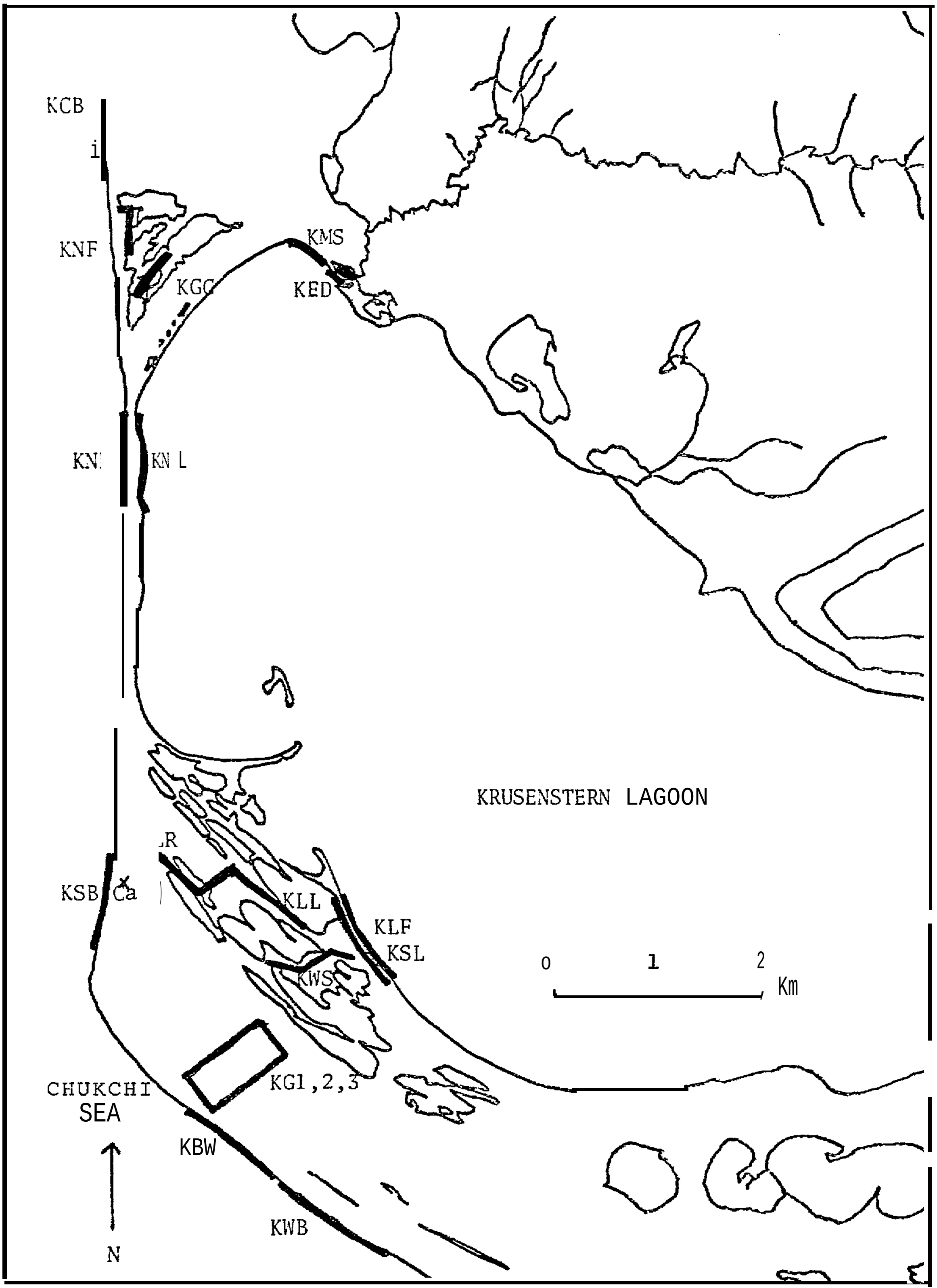


Figure 2. Locations of transects and sampling stations, Cape Krusenstern, Alaska.

Table 3. Locality codes for transects and sampling stations, Cape Krusenstern, Alaska. (See Figure 2).

Code	Transect or station name	Tundra or littoral	Transect length (m)	Transect width (m)
KBW	Baby Walrus	L	1000	50
KCB	Cliff Beach	L	1000	50
KED	Evelukpalik Delta	L	500	100
KG 1	Grid one	T	850	100
KG 2	Grid two	T	850	100
KG 3	Grid three	T	850	100
KG C	Gull Colony	L	500	100
KLF	Lagoon Flood	L	1000	50
KLL	Lagoon Lake	L	1000	50
KLR	Lake Ridge	T	1000	100
KMS	Moon Snail	L	500	50
KNB	North Beach	L	1000	50
KN F	North Flats	L	500	100
KN L	North Lagoon	L	1000	50
KSB	Shell Beach	L	1000	50
KSL	South Lagoon	L	1000	50
KWB	Whimbrel Beach	L	1000	50
KWS	Whistling Swan	T	1000	100

Not included in map: Transects located 4 km north of CB transect.

KB 1	Shelter Cabin Beach (SCB)	L	1000	50
KS 1	Shelter Cabin Slough (SCS)	L	500	50

Total areas: Tundra: 45.4 hectares
Littoral: 70.0 hectares

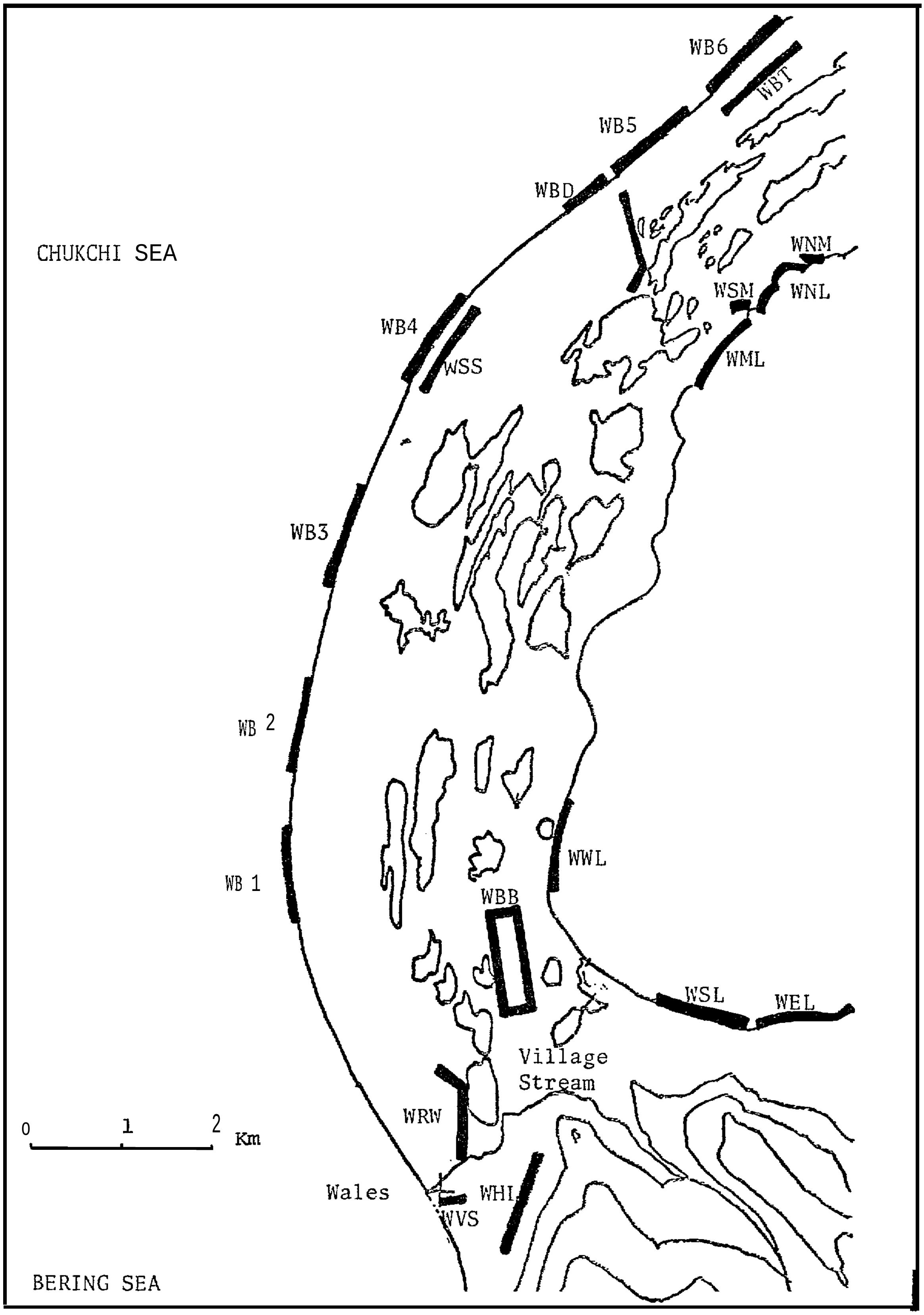


Figure 3. Locations of transects and sampling stations, Wales, Alaska.

Trophic studies. At Wales, Cape Krusenstern, Sisualik and Shishmaref we collected shorebirds of several common species for diet analysis and fat condition. Collection methods (by shotgun followed by immediate injection of formalin fixative solution in the field) were described in Connors and Risebrough (1976).

We collected plankton net samples at Wales and Cape Krusenstern in July, August and early September 1977. The surface net, towed parallel to shore in very shallow water to sample the phalarope foraging zone, was described in Connors and Risebrough (1977). Sampling procedures and sample analysis were identical at these sites and at Barrow, permitting comparison of plankton resources at the three sites (Connors and Risebrough 1978).

IV. RESULTS AND DISCUSSION

Seasonality of Habitat Use: An Overview

The transect census data can be analyzed to provide a phenology of shorebird habitat use at each site, as presented in Connors et al (1979; 1981). Our data from Barrow have shown a pronounced and consistent shift in habitat use from tundra to littoral habitats occurring in late summer for most shorebird species. In June and early July, almost all shorebird activities are centered on the tundra where shorebirds nest. As the season progresses, adults of one or both sexes, followed by fledged young, forage increasingly along shorelines as these habitats melt and become available. The degree of this shift is shown in Figure 4 for Barrow. These data are a composite of the patterns displayed by a large number of shorebird species differing in the timing, sequence, and degree of interhabitat movements. At Barrow, the late summer habitat used most heavily consists of shoreline areas along gravel beaches, where high densities of marine zooplankton provide a food source for phalaropes and several other shorebird species, as well as for gulls and terns. Areas of saltmarsh, mudflats and edges of lagoons and sloughs also attract high densities of many shorebird species. This general pattern of seasonal shift in habitat use also characterizes several other sites along the Beaufort and northern Chukchi coasts (Connors et al 1981).

In contrast, Figure 5 presents the equivalent results for all shorebirds combined from our transect census data for Wales and Cape Krusenstern. Densities at Wales showed an apparent habitat shift toward the littoral zone in late summer but peak densities were less than those recorded at Barrow. However, phalaropes, which accounted for the bulk of August littoral shorebirds at Barrow, were uncommon at Wales, where Western Sandpipers and Dunlins accounted for most of the late summer littoral zone activity. Cape Krusenstern, however, contrasts markedly with patterns at Barrow and Wales, showing instead moderately heavy use of littoral habitats throughout June and July, decreasing in August, while tundra densities remain low and constant. At Cape Krusenstern, outer coast shores with zooplankton as a food source were very little used by shorebirds in late summer. Saltmarsh and mudflat areas with shallow saline pools, open in late May at this phonologically early site, were heavily used by migrant shorebirds of several species, as well as by species nesting on the nearby tundra. Northern Phalaropes, Western Sandpipers, Semipalmated Sandpipers, Pectoral Sandpipers and Long-billed Dowitchers were common in these habitats in June and July. Species remaining in the arctic during August and September, most notably Dunlin, apparently move to areas of more extensive mudflat and saltmarsh such as the Noatak Delta, Cape Espenberg, and the Shishmaref barrier

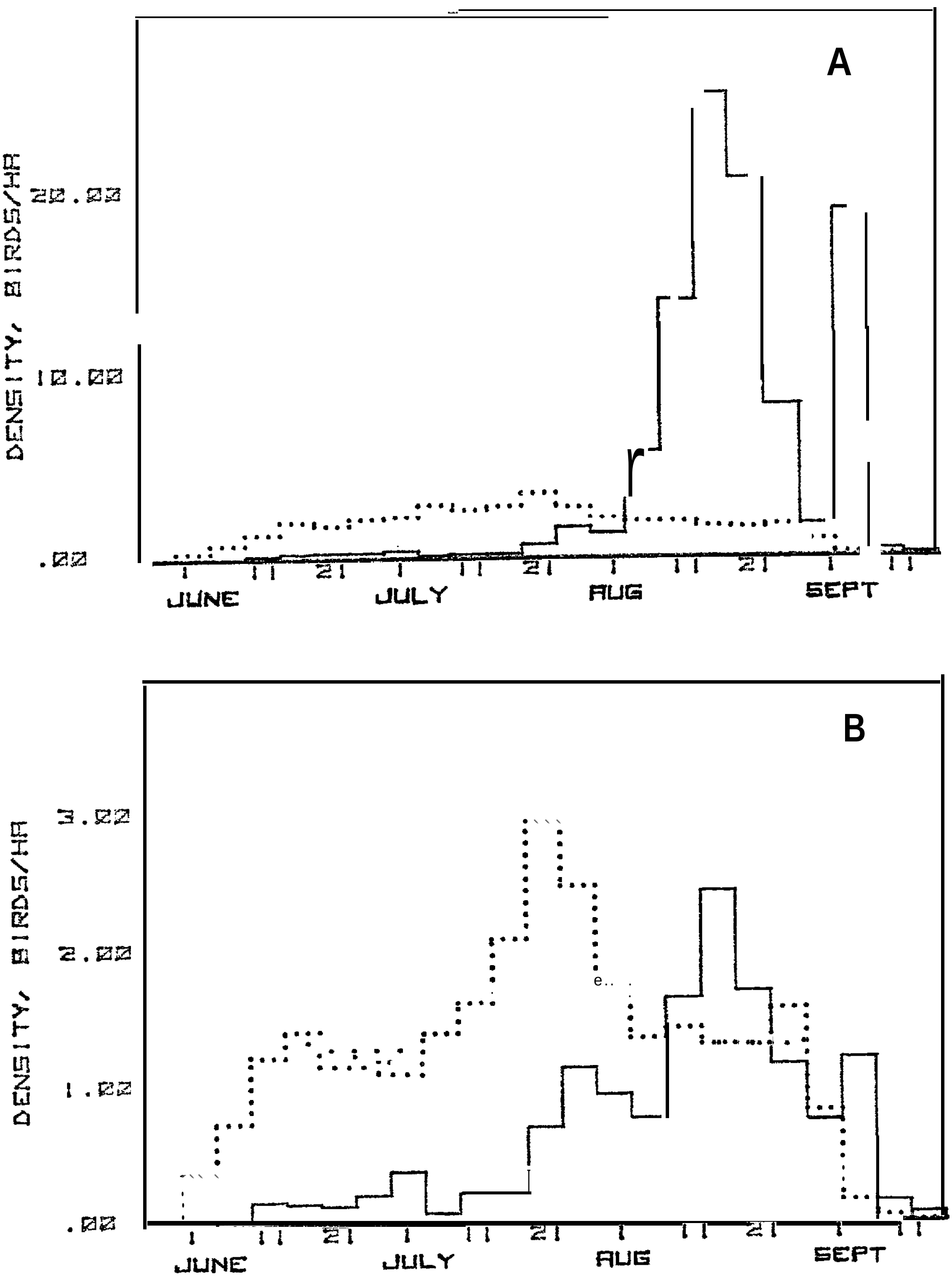


Figure 4. Transect densities, Barrow, 1976. A. Total shorebirds. Littoral (solid) vs. tundra (dotted). B. Total shorebirds excluding Red Phalarope. Littoral (solid) vs. tundra (dotted).

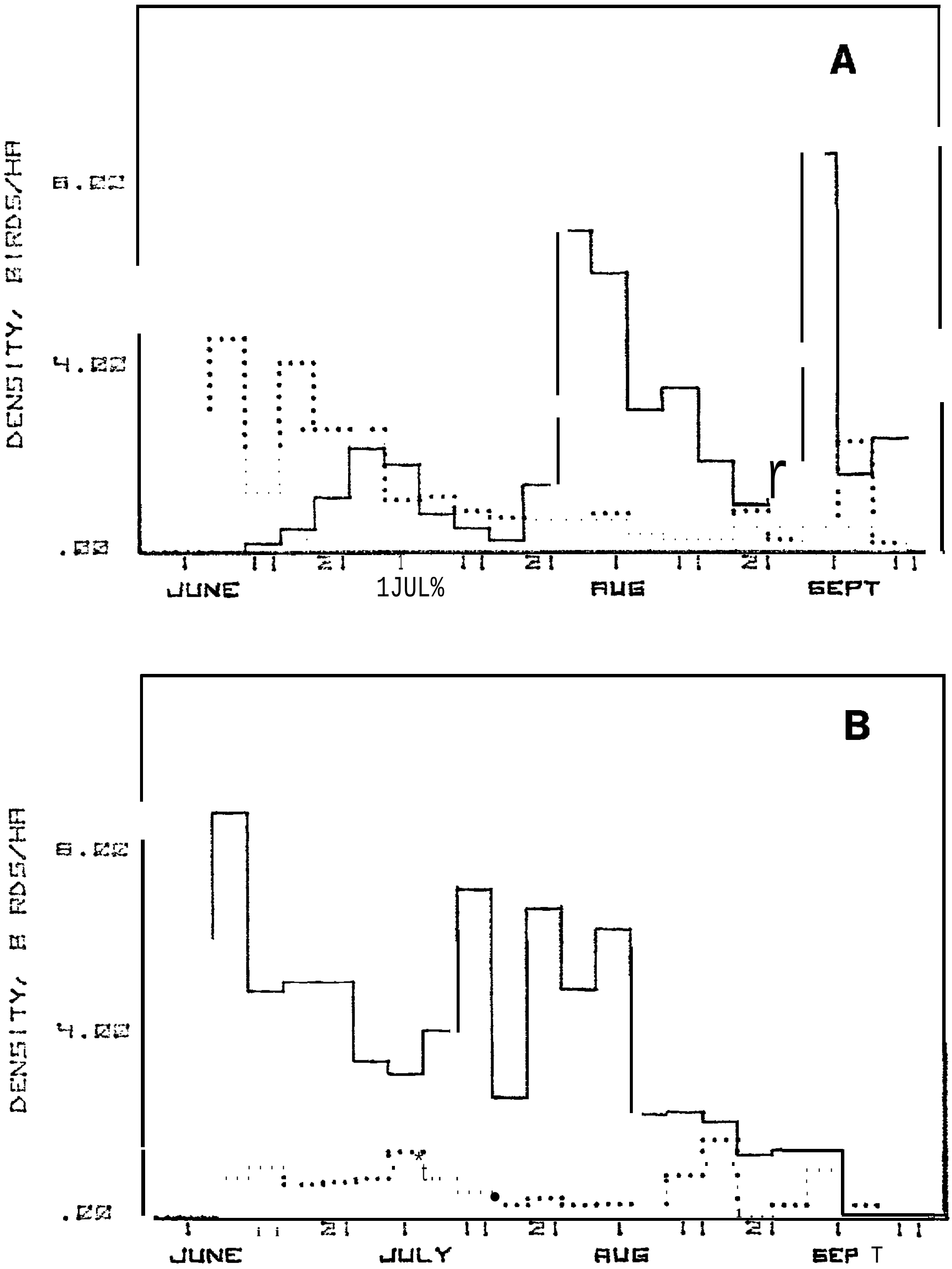


Figure 5. Transect densities, 1977. A. Wales, total shorebirds. Littoral (solid) vs. tundra (dotted). B. Cape Krusenstern, total shorebirds. Littoral (solid) vs. tundra (dotted).

strip on Seward Peninsula (see below) . Thus the general pattern of heavier use of littoral habitats in late summer seems to be widespread in the arctic but its expression at any particular site depends upon the mixture of habitats available at that site. The discontinuous distribution of prime littoral zone foraging areas along the coast results in concentration areas where environmental disturbances would exert heavy influences on the populations of migrant shorebirds.

Geographic Variation in Habitat Use

The general differences among areas described above result from several factors, including differences in shorebird species distributions, seasonal phenologies, food resource differences and differences in littoral habitat availability on a local and regional scale. The most important incidence of this latter factor is the difference in relative availability of mudflat and saltmarshes compared with gravel shores of spits and barrier islands. In the southern Chukchi, south of Cape Thompson, the former habitats are common but gravel spits are infrequent. At Barrow and elsewhere along the Beaufort coast gravel spits and barrier islands are common coastal features, but areas of saltmarsh and mudflats are limited in extent. Gravel spits along the Beaufort coast frequently support very high densities of phalaropes in late summer, foraging on marine zooplankton. The attraction to phalaropes and other shorebirds may be the high densities of zooplankton available or features of the local geography which provide protected foraging conditions in a variety of wind conditions (Connors et al 1981). As a result the charcteristic gravel shoreline species (Red and Northern Phalaropes, Sanderlings, Ruddy Turnstones, Arctic Terns and Sabine's Gulls) are common at Barrow and many other sites along the Beaufort coast but occur in much lower densities at the study sites along the southern Chukchi. In contrast the northern shore of the Seward peninsula east and west of Shishmaref, and the Noatak Delta near Sisualik, as well as a few areas on southern Kotzebue Sound, provide much more extensive areas of mudflat and saltmarsh than occur along the Beaufort coast. In late summer these support large numbers of many species of shorebirds, primarily Western, Semipalmated and Pectoral Sandpipers, Dunlins, Long-billed Dowitchers and Golden Plovers. Thus a regional difference in the occurrence of important shorebird habitats corresponds with differences in relative abundance of species which forage in these habitats. On a local scale, habitat distribution sets limits on the numbers of birds of different species at a site. Differences in shorebird occurrence are also affected by interactions with the phenology of habitat availability and changes in prey availability within habitats.

Differences in Phenology

Among the contrasts between the Southern Chukchi shorebird environment and that of the Beaufort coast, the apparent differences in phenology affect shorebird use of littoral habitats to some extent. Relative phenologies of Wales, Cape Krusenstern, and Barrow were discussed in Connors and Risebrough (1978). Except for the western tip of Seward Peninsula near Wales, the areas of southern Chukchi and Kotzebue Sound coasts experience earlier dates of tundra melt-off, shoreline ice-breakup, plant growth and insect hatching than do similar habitats in areas farther north along the Chukchi and Beaufort coasts. Fall freeze-up occurs somewhat later in the southern coastal areas. The full season of shorebird occurrence in southern Chukchi littoral areas is therefore somewhat longer than on the Beaufort coast.

The different phenology of littoral habitat availability produces some additional contrasts in shorebird use between the areas. In late May and early June near Barrow, most littoral habitats are frozen and unavailable. At Cape Krusenstern and Kotzebue Sound however, many species forage on edges of mudflats and saltmarshes as well as on ice-lifted sediments (see below) that are available while shorebirds are still migrating and beginning to establish territories. The same thing can be true of ocean shorelines, although early summer conditions at Cape Krusenstern are apparently quite variable. In 1977 shore-fast ice at Cape Krusenstern in late May and early June precluded foraging by shorebirds in that habitat. During 1978, in contrast, the shoreline was free of ice, and we recorded the highest densities of Red Phalaropes seen at that site along outer coast shorelines at any time during our 2 year study. At Beaufort sites the shoreline waters were never available for foraging by Phalaropes in early summer and high densities of Phalaropes were only seen in late summer and early fall. As a result of these differences in phenology, oil introduced into littoral habitats during late fall or winter might affect shorebirds beginning in spring along the southern Chukchi coast but not until later in the summer along the northern Chukchi and Beaufort coasts.

Differences in phenology between Cape Krusenstern and Beaufort study sites were even greater in 1978 than in 1977 (Connors and Risebrough 1979). Areas near Kotzebue experienced one of the earliest springs within memory (W.R. Uhl, pers. comm.) while North Slope areas faced an extremely late melt-off. Differences between Cape Krusenstern and Prudhoe Bay melting dates and flowering dates averaged three to four weeks, and other sites along the Beaufort coast were even later than Prudhoe Bay. However, dates of bird nesting events differed by much less, averaging only 5 to 10 days earlier (and less for some species) at Cape Krusenstern. This delay was similar to that observed in 1977 in spite of a much greater difference in melt-off dates in 1978. Birds apparently did not respond simply to differences in melt-off dates between sites. Instead, we believe bird nesting dates are set partly by other requirements (conditions at other sites during migration, hormonal schedules, etc.) and are adjusted by local breeding ground conditions. In 1978 Beaufort coast birds were delayed in nest initiation but apparently began quickly when conditions improved. At Cape Krusenstern the early spring allowed some individuals to nest very early but many delayed nesting until nearer the normal dates in spite of the habitat conditions. This resulted in a less synchronous nesting season for some species. of 20 Western Sandpiper nests discovered in our study area, the earliest clutch completion was 24 May, the latest 24 June, an unusually large spread of dates among arctic shorebirds.

These differences in phenology between years apparently had little affect on the nesting densities at coastal sites (Table 4). Nesting densities at Barrow and Cape Krusenstern

Table 4. Comparison of breeding densities at arctic tundra sites, 1977 and 1978.

	Number of species nesting		Total pairs per hectare	
	1977	1978	1977	1978
Barrow Plot 1	10	10	1.10	1.09
Barrow Plot 2	11	12	1.10	1.29
Meade River	18	16	2.27	1.88
Cape Krusenstern	14	13	1.33	1.55

References: Myers et al 1978a,b,c; 1979a,b,c.

Connors and Connors 1978.

Connors et al 1979.

were very similar on study plots in 1977 and 1978 in spite of differences in phenology between years. At an inland arctic coastal plain site at Atkasook on the Meade River, densities were higher in both years and differed primarily because of differences in densites of 2 common species - Semipalmated Sandpipers and Lapland Longspurs (Myers and Pitelka 1980)

Shorebird Species Distributions

The nesting and migrational distributions of each shorebird species determine to a great extent the potential mix of shorebirds occurring within any habitat at different sites across the Alaskan arctic. Table 1 lists species which occur regularly along the southern Chukchi coast. Since these are all long distance migrants there are few differences between this list and a similar one constructed for the Beaufort coast (Connors et al 1981) but the relative abundance of many of the species in these tables varies across that extensive range. The principal contrasts between areas are the much lower abundances in the southern Chukchi area of Ruddy Turnstone and Baird's Sandpiper and the absence as nesting birds of White-rumped Sandpiper, Stilt Sandpiper and Buff-breasted Sandpiper. Conversely, Rock Sandpiper and Black Turnstone nest on Seward Peninsula but not along the Beaufort Coast, and Common Snipe, Western Sandpiper, Bar-tailed Godwit and Sharp-tailed Sandpiper are all much more common along southern Chukchi coasts than in areas farther north and east. However, many species such as American Golden Plover, Pectoral Sandpiper, Dunlin, Semipalmated Sandpiper, Long-billed Dowitcher, and Red and Northern Phalarope are common throughout both regions.

Shorebird Use of Ice-lifted Sediments

We have observed a surprising phenomenon of shorebirds using littoral habitats during spring migration in the southern Chukchi. During melt-off in late May and early June, ice covering the shallow lagoons and sloughs of the western Noatak Delta and Sisualik area frequently supports a surface layer of mud. We believe these are ice-lifted benthic sediments and describe a possible mechanism of formation below. Beyond its geophysical interest, this phenomenon is apparently of biological importance because of its strong attraction to foraging birds of many species. On 24 and 25 May 1978, we recorded very high densities of 10 species of shorebirds in two different areas of ice-lifted sediments on a lagoon behind the Sisualik spit (Tables 5 and 6). Densities were 10 to 15 times those on nearby saltmarsh transects and 50 times the densities on adjacent tundra transects. The sediments did not occur on all areas of lagoon ice but were widespread in the Sisualik area. During at least this brief period of spring migration therefore, most of the shorebirds present apparently foraged on this surprising substrate in preference to nearby tundra or other littoral areas. The phenomenon raises several questions: What process is responsible for the formation of the sediment layer above lagoon ice? What food resource is available in

Table 5. Shorebird densities in 3 habitats, Sisualik, 24-25 May 1978.

	Total transect area (ha)	Shorebird species	Total shorebirds	Total other birds	Density of shorebirds (#/ha)
Tundra	17.5	4	30	20	1.7
Saltmarsh	15.3	8	104	4	6*8
Ice-lifted sediments	5.6	10	501	0	90.3

Table 6. Densities of common species in 3 habitats, Sisualik, 24-25 May 1978 (birds per ha).

	Semipalmated Sandpiper	Western Sandpiper	Red Knot	Bar-tailed Godwi t
Tundra	1.1	0	0	0
Saltmarsh	2.1	.1	0	0
Ice-lifed sediments	15.0	31.5	12.4	13.2

sediments to attract such high densities of foraging birds? To what degree do migrating shorebirds depend on this resource? How consistent is the sediment layer as a shorebird resource from year to year? To what extent might this phenomenon expose shorebirds to the effects of oil pollution?

Mechanism of formation: an hypothesis. Mechanisms for the puzzling occurrence of sediments in nearshore sea ice along the arctic coast have attracted the interest of geophysicists in recent years (see review by Larson 1980). Proposed explanations for the occurrence of layers of sediment on the under surface of sea ice include floating of bottom-frozen sediments and incorporation of sediments suspended in the water column or scraped from the bottoms of lagoons into forming slush ice or frazil ice. The occurrence we describe in this report, however, is very different in character from those discussed by Larson. We have observed it only in protected areas of the lagoon and delta system; it consists of much greater concentrations and amounts of sediment; it is underlain by hard ice rather than incorporated as the bottom layer of soft ice; and it contains plant material characteristic of bottom sediments.

We also feel certain that the sediments observed on lagoon ice are not carried there directly by spring river runoff over the ice, a possibility which could be suggested by the close proximity of the Sisualik lagoon system to the mouth of the Noatak. Several factors lead us to reject this possibility:

(1) The phenomenon was observed principally in the shallow areas at the west end of the lagoon system, behind the Sisualik Spit rather than farther east in the Noatak Delta system where the river flow is greater.

(2) The thickness of mud deposits is variable over distances of tens of centimeters; the surface looks lumpy. Sediment deposition by over-ice currents would probably be relatively uniform on this fine scale and show current patterns on a scale of meters.

(3) Shorebirds collected while foraging on sediments over the ice were taking almost exclusively chironomid larvae, which are also the common prey taken from lagoon mudflats in the same areas during summer (Tables 7 and 11).

(4) During May, as melt-off began, water covered the ice in the same lagoon areas. At this time Pintails (*Anas acuta*) foraged over the ice by taking plant tubers from the mud. These same tubers are a favorite waterfowl food common in the lagoon in late summer (W.R. Uhl, pers. comm.) .

These last observations in particular indicate strongly that the deposits found on the lagoon ice surface in spring consisted of the benthic sediments from the same lagoon rather than sediments carried down the river by flood waters.

Table 7. Diets of shorebirds foraging on ice-lifted sediments, Sisualik, 25 May 1978.

Species	Number of stomachs	Contents (in order of decreasing average % volume)
Bar-tailed Godwit	1	plant matter
Red Knot	1	plant matter adult diptera seeds
Long-billed Dowitcher	4	chironomid larvae plant matter seeds
Dunlin	2	chironomid larvae seeds
Semipalmated Sandpiper	4	chironomid larvae seeds
Western Sandpiper	4	chironomid larvae seeds

Another method of incorporating sediments into ice was described by Ugolini (1975). From observations of small ponds and patches of sediments deposited on islands in the Noatak Delta he suggested that sediments covered by shallow water were frozen during the winter and lifted by flotation when flood waters over-ran delta islands. These sediments were then ice-rafted to new locations and deposited as flood waters receded. Our observations, and particularly those of W.R. Uhl (pers. comm.) , suggest a slightly different mechanism for the more extensive areas of sediments we observed in the lagoon system. Uhl states that the sediments freeze during storm conditions in autumn when benthic sediments in the lagoon normally covered by water are exposed during a negative storm surge. As atmospheric conditions subsequently change, water returns to the lagoon system, floating the frozen benthic sediments to the surface where they are incorporated into the ice forming over the lagoon. The ice sheet continues to thicken below the lifted sediment.

In early spring as the Noatak River breaks up, water flows over the ice throughout the lagoon system, both from the river and from local runoff. The lagoon ice begins to melt from the top down. At this time a cross-section through the lagoon would show undisturbed benthic sediments at the base of the lagoon, covered by water, then hard ice, next lifted sediments and finally a covering of water on which dabbling ducks can feed. As the melt proceeds, surface water drains from lagoon ice into Kotzebue Sound and holes melt through the lagoon ice. Lagoon ice begins to break up and is freed in patches to float to the surface of the water. At this time (late May), large areas of melted mud are exposed on the surface of the lagoons above the ice where they are available for foraging shorebirds. Eventually the ice sheet supporting these sediments melts and the sediments return to the lagoon in the approximate locations from which they were lifted the previous fall. Different areas of the lagoon system melt at different times, so migrant shorebirds concentrate in different areas in subsequent days or weeks.

Significance of the phenomenon. The foods taken by shorebirds from the ice-lifted sediments (principally chironomid larvae and plant matter) are substantially the same as the main prey taken by these species foraging on the lagoon mudflats during late summer (Tables 7 and 11). In spring however, the lagoon mudflats are not accessible to foraging birds; the ice-lifted sediments provide a uniquely rich foraging resource for many species. The extremely high densities of shorebirds foraging on ice-lifted sediments on our study plot (90 birds per hectare) suggest that large numbers of total shorebirds might use these areas in seasons when sediment areas are extensive at this and other lagoon systems. For example the same phenomenon may occur in the extensive lagoon system on the north shore of Seward Peninsula, but this is not yet known. It may also occur in certain areas along the Beaufort coast but except for our observation of a similar phenomenon of shorebirds foraging on sediments or algal mats above the ice of North Salt Lagoon at Barrow in 1976, we know of no reports of this. Southern Chukchi mudflats are more heavily used than the similar but less extensive Beaufort areas by shorebirds in late summer and the same may be true in spring.

The occurrence of this phenomenon may be quite variable from year to year since it depends on a sequence of primarily meteorological events, which certainly varies. We do not, however, know how sensitive the mechanism is to variation in these events. Assuming that the extent and precise location of ice-lifted sediments, as well as the timing of availability, varies from year to year, shorebirds which use this resource for spring foraging must be flexible and opportunistic, characteristics which apply to migrant shorebirds in many other areas. In the event of oil spilled during the previous open water period or released in the ice during winter, the resultant patches of dark surface ice occurring in lagoon areas in spring would probably attract large numbers of shorebirds to investigate. Without experimental evidence of shorebird reactions to an encounter with oil deposited on ice, we can only guess at the outcome. We predict that many species would be attracted to the oil, probably even to the extent of landing and probing its surface, but that most shorebirds would quickly abandon these efforts after finding no food. The only experimental study relevant to the question was done with Red Phalaropes foraging on water covered with a thin film of oil (Connors et al 1981). Even in the presence of available food these shorebirds quickly learned to avoid contact with the oil surface. In that case, however, even brief contact was potentially very damaging to the birds' survival. However, in the case of shorebirds walking on, rather than swimming in the oil, the brief learning contact is unlikely to be lethal. If, however birds wade at body depth in water covered by an oil film, plumage effects may be severe.

Shorebird Concentration Areas.

Our studies at Cape Krusenstern and at Wales describe the seasonal changes in densities of each of the shorebird species at these 3 southern Chukchi sites. For a general comparison of sites, Table 8 presents total shorebird

Table 8. Total shorebird densities in littoral habitat at study sites. Birds/hectare.

	30 July to 8 August	14 August to 23 August	29 August to 7 September
Oliktok	6.3	9.1	3.4
Barrow	5.5	21.5	1.4
Peard Bay	5.4	3.7	1.0
Icy Cape	21.7	8.4	.9
Cape Krusenstern	4.3	1.7	.8
Wales	4.6	1.5	5.2

densities recorded on all our littoral habitat transects at 6 study sites for 3 different late summer periods in 1977. Except for the latest period at Wales, shorebird densities at the 2 southern Chukchi sites were somewhat lower than densities at northern Chukchi and Beaufort sites during the same periods. Each of these southern Chukchi sites has areas of littoral habitat which are heavily used by some species during periods of the summer, as do many other locations along that coast. However, the regions supporting the largest numbers of shorebirds foraging in southern Chukchi littoral habitats are the regions with the most extensive saltmarsh and mudflat areas. From our aerial and occasional ground surveys we judge the two most important of these to be the Noatak Delta - Sisualik area and the lagoon barrier strip along the north shore of Seward Peninsula/ east and west of Shishmaref (Figures 1 and 6). Less extensive but also heavily used areas include mudflat areas near Cape Espenberg (see Schamel et al 1979) and in southern Kotzebue Sound.

During July, August and early September the saltmarshes and mudflats of these 2 major areas support large flocks of Western and Semipalmated Sandpipers, Dunlins, Pectoral Sandpipers, Long-billed Dowitchers and Golden Plovers, and both Phalarope species forage on ponds within the saltmarsh. Individual flocks number in the hundreds and occasionally thousands. Lesser numbers of several other shorebird species are present also. Densities of total shorebirds on a series of saltmarsh transects near Sisualik were high compared to

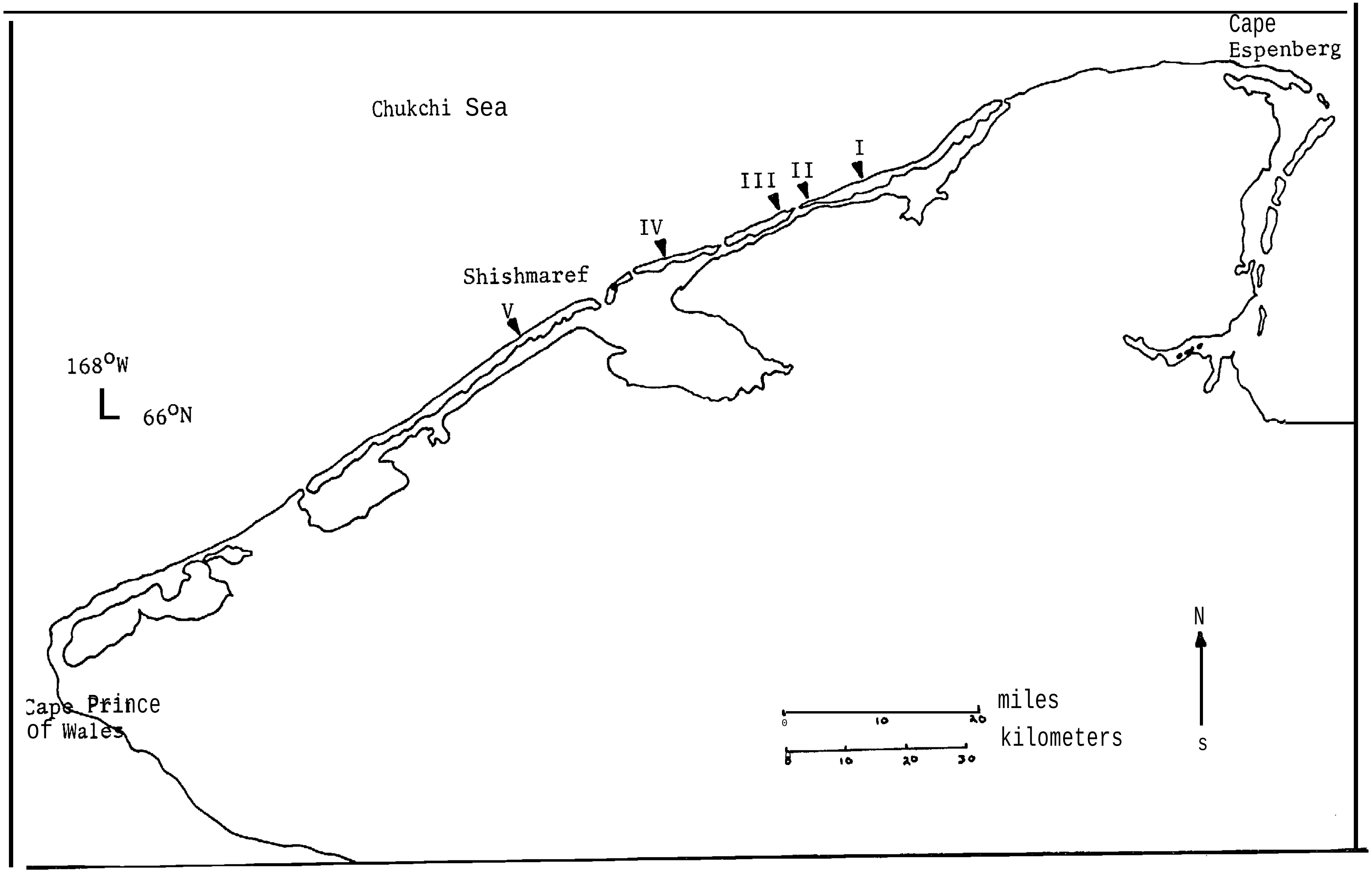


Figure 6. Locations of census sites, Shishmaref coast, Alaska.

tundra densities throughout the nesting season but peaked in August at approximately 15 birds per hectare (Figure 7B). Shorebird densities on transects crossing the Shishmaref barrier strip in August were similar (Figure 7A).

The Shishmaref lagoon barrier strip comprises the largest area of productive saltmarsh and mudflat habitats used by shorebirds north of Bering Strait in Alaska. The barrier strip is approximately 160 km in length, averaging 1.12 km in width (see Figure 6). Typically the ocean beach is backed by irregular dunes grading to sandy tundra and then to saltmarsh, pools, and occasional mudflats. The saltmarsh consists of Carex and Puccinellia flats with interspersed brackish pools. Few species nest in these habitats, and densities during June probably remain quite low, but waves of post-breeding adults and juveniles forage here in late July, August and September. Figure 7A presents the results of 5 visits to sites along the barrier strip in 1977 and 1978. These data are sketchy because we were able to visit only a few sites, and periods between visits were longer than we would wish. However, they do indicate the striking increase in densities of shorebirds in these habitats. Average densities increased more than 10-fold between late June and late August. The peak densities during both years extrapolate to total shorebird populations for the northern Seward Peninsula barrier strip alone of 250,000 to 350,000 shorebirds. Other bird species noted on the transects showed the same seasonal patterns, with densities averaging about 20% of shorebird densities during each period. In late August and September the area was heavily used by flocks of Brant (Branta bernicla) which are not often recorded on our walking transects. Our estimate from an aerial survey of 6 September 1978 was of at least 15,000 Brant on the barrier strip.

These two saltmarsh and mudflat areas therefore represent very important foraging areas for large numbers of shorebirds as well as some waterfowl species. Oil spills or other development-related activities which affect these habitats or the food resources found within them could have important negative effects on significant populations of many species at the time when shorebirds are accumulating fat reserves prior to southward migration (Connors et al 1981).

Aleutian Tern Colonies.

During the 1977 field season we located four small colonies of Aleutian Terns (Sterna aleutica) nesting in or near littoral habitats. These colonies represented northward extensions of the known range of the species. Our censuses in 1978 indicated that three of these colonies had expanded greatly (Table 9). Observations of local residents (Carrie and W.R. Uhl, pers. comm.) suggest that this species has expanded its range into the area within the last 10 to 15 years. The marked increase in numbers between 1977 and 1978

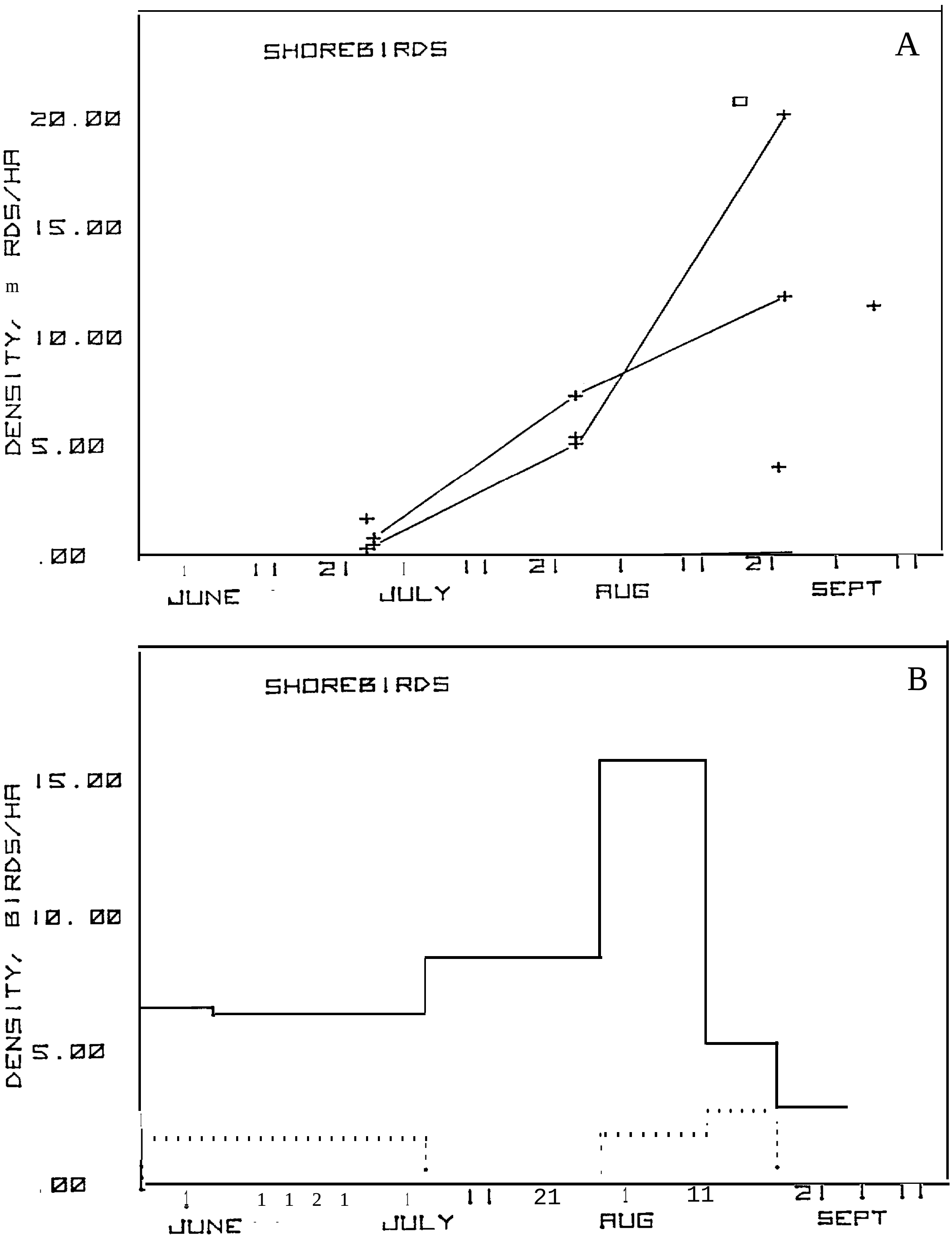


Figure 7. A. Shorebird densities at sites on barrier strip east and west of Shishmaref. (n) 1977, (+) 1978. Lines connect successive visits to 2 principal study sites.
B. Shorebird densities on transects on Sisualik Spit. Saltmarsh (solid line) and tundra (dotted line).

may be further evidence of this continuing expansion, or it may just reflect differences between years in other factors such as food supply, or predation by foxes or humans.

Table 9. Size of four northern colonies of Aleutian Terns (number of active nests).

Location Map no.[1]	Qikiqtaichaik 1s. 128-001	Uhl-Williams Camp 128-002	Krusenstern North Flats 128-005	Tasaychek Lagoon 128-006
1977	5-20	C*10	C.2	c.12
1978	C*90	?	c.29	c.38

[1]Sowls et al. 1978

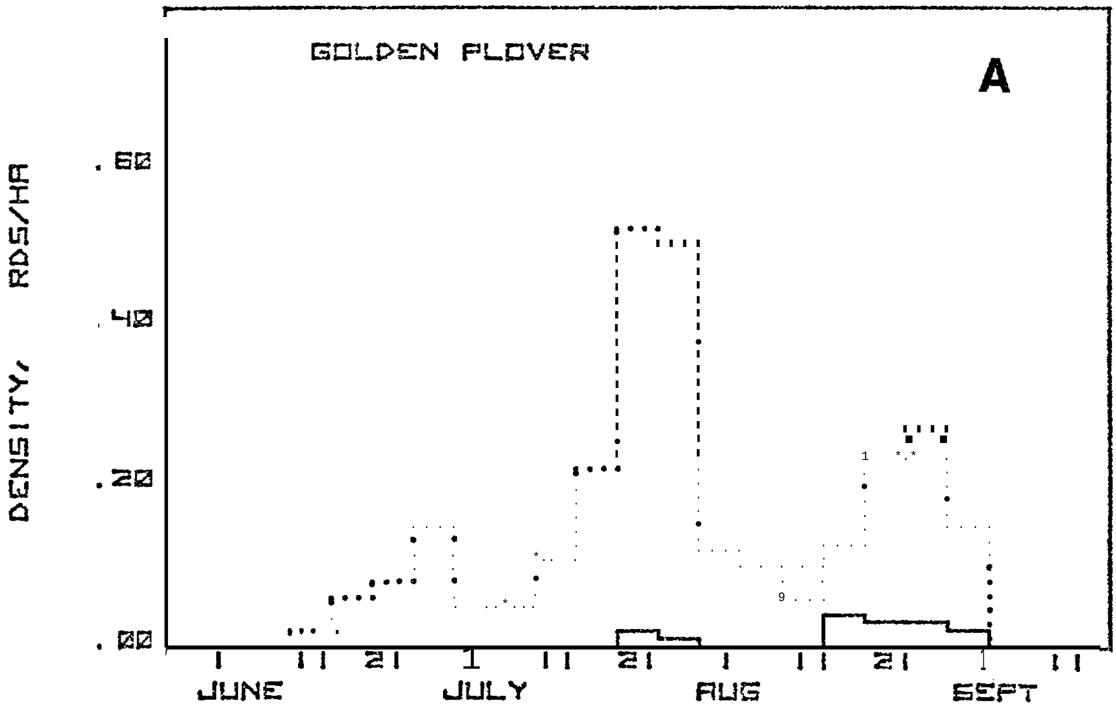
Arctic Terns (Sterna paradisaea) also nest in or near littoral habitats in small colonies at many sites along the southern Chukchi coast. They nested at several sites along the upper edge of the beach at Cape Krusenstern, on islands in the North Flats transect area and in Krusenstern Lagoon, and on the beaches near Tasaychek Lagoon north of Cape Krusenstern. They also nest at sites on the beaches of the Shishmaref barrier strip and at Cape Espenberg. Glaucous Gulls (Larus hyperboreus) also nest in some of these same habitats, especially on islands in saltmarsh and mudflat areas of the Shishmaref barrier strip and in the North Flats area near Cape Krusenstern. Colonies we noted at these sites and several other sites along the southern Chukchi coast were usually small, consisting of only ten's of nests, and some colonies are not occupied in every year. We also located one small colony of Mew Gulls (Larus canus) near Krusenstern Lagoon.

Seasonal Habitat Use Patterns of Selected Species.

Results of our transect density measurements have been presented as seasonal habitat density comparisons for all common species in Connors et al (1981); Connors and Risebrough (1978; 1979). In this report we will focus only on those common species which show the most notable contrasts between the Beaufort coast and southern Chukchi coast in relative habitat use or seasonal timing of movements.

Golden Plover. Connors et al (1979) classified common Barrow shorebirds in terms of their susceptibility to coastal oil development. This classification was based principally upon relative use of littoral zone vs. tundra habitats by each species. Golden Plovers were placed in the least sensitive category because the Barrow transect data showed very low use of littoral habitats by this species; almost all Golden Plovers seen were recorded on tundra transects (Figure 8A). We were therefore surprised to find a very different habitat use pattern by Golden Plovers in the southern Chukchi. Figure 8B compares tundra and littoral transect densities, combining Wales and Cape Krusenstern transects. Densities were comparable in both habitats at these sites. We can suggest at least two possible explanations for this surprising result. First, as mentioned above, the relative availability of different kinds of littoral habitat varies considerably between the southern Chukchi and Beaufort coasts. Habitats of saltmarsh with mud margins bordering tundra areas are much more extensive in the southern Chukchi and these are the habitats in which we observed Golden Plovers foraging in littoral areas. It is also quite possible that the types of prey available or the densities of prey differ in these littoral areas, with conditions in southern Chukchi marshes making them more attractive to foraging plovers. So our observations may actually represent a shift in habitat use within the species or by individual members of the species as they migrate through are differing in the relative availability or relative attractiveness of different habitats.

Alternatively, our observations may represent differences in habitat preference between two forms of Golden Plover. These two forms, previously described as subspecies, *Pluvialis dominica dominica* and *P. d. fulva*, differ markedly in relative abundance in the two areas of study (Connors, submitted). Almost all nesting birds along the Beaufort coast are *dominica* whereas *fulva* become increasingly more common in the southern Chukchi. Late summer juveniles can be readily identified, and these birds were almost all *fulva* at southern Chukchi sites, so the possibility exists that our observed difference in relative habitat use represents a real difference in ecological traits between the two forms. Elsewhere Connors (submitted) has argued that the two forms should be treated as distinct species because of lack of evidence of interbreeding. In this case a genetically determined difference in habitat preference would not be surprising. The environmental importance of this question arises from the much greater exposure to littoral zone disturbances associated with oil development for Golden Plovers in southern Chukchi areas. On the basis of our habitat use measurements, the relative sensitivity of Golden Plovers to coastal oil development must be rated higher in the southern Chukchi than along the Beaufort coast.



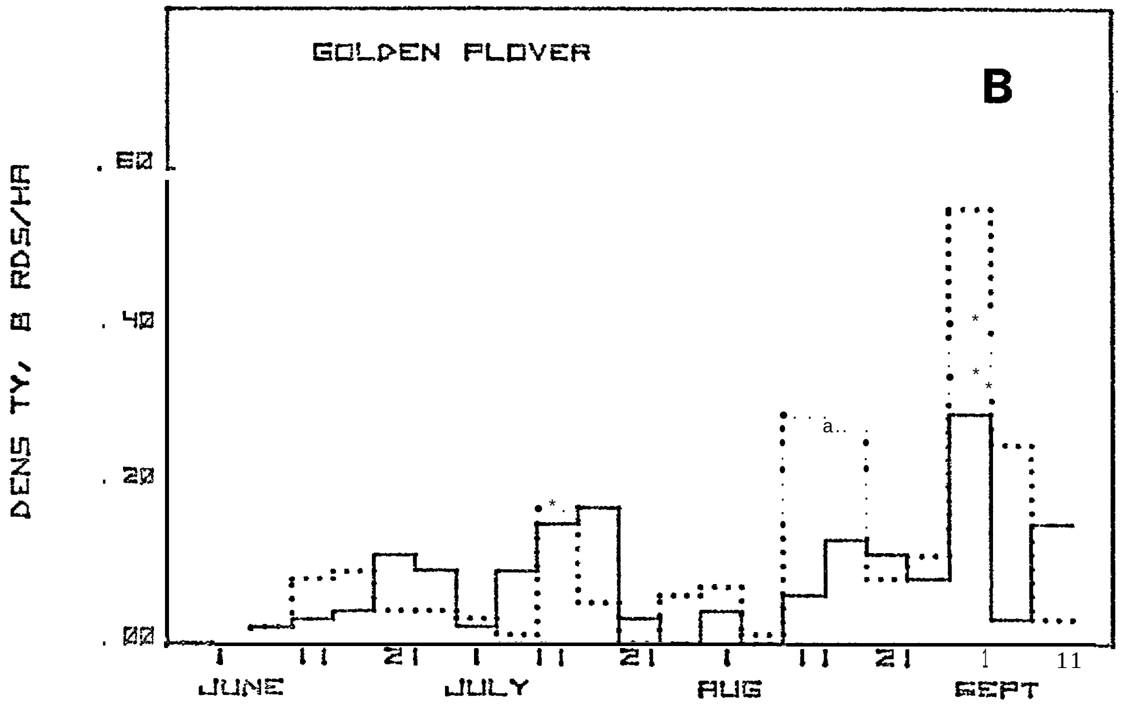


Figure 8. Transect densities, Golden Plover. A. Barrow, 1976. Littoral (solid) vs. tundra (dotted). B. Wales and Cape Krusenstern, 1977. Littoral (solid) vs. tundra (dotted).

Another aspect of the Golden Plover migrations in this region deserves comment. Our estimate of the peak species population on the Shishmaref barrier strip in August 1977 and 1978 is 13,800 birds, almost all juvenile fulva. Connors (1982) has compared that total with the production of fledged juveniles expected from the estimated nesting population of fulva occurring nearby and in all areas to the north and east. The estimate is necessarily quite rough, but the migrant juvenile population on the Shishmaref strip is about equal to the total expected production. Since juveniles also occur at other saltmarsh sites as well as on tundra, these birds may represent young produced elsewhere. We suggest that they may be Siberian in origin, crossing Bering Strait west to east in late summer to feed in the rich saltmarsh areas of Seward Peninsula, and subsequently migrating south and southwestward to wintering areas.

This surprising, indirect migration route gains plausibility when compared with an unequivocal movement of another shorebird. Sharp-tailed Sandpipers nest only in Siberia and winter in the South Pacific (New Guinea, Australia), but juveniles are fairly common in the same saltmarshes of western Alaska in early September. Numbers are much lower than for Golden Plovers, so this is not a major migration route, but neither is it a rare occurrence of out-of-range stragglers. If Siberia is the source of many of the juvenile Golden Plovers observed, as well as all the Sharp-tailed Sandpipers, the saltmarsh areas of the Alaskan coast become even more of an international resource, with birds which breed and winter on other continents dependent to some extent on resources here.

Pectoral Sandpiper. This species shows a comparable difference in relative habitat use between the two study areas, with Pectoral Sandpipers quite common on mudflats and in saltmarshes of the southern Chukchi (Figure 9), in contrast with their greater concentration in tundra areas along the Beaufort coast (Connors et al 1979).

In this species there is no question of a taxonomic difference in forms in the two areas, suggesting that the observed differences are a response to habitat conditions differing between the two regions. Again the result is a higher sensitivity of Pectoral Sandpipers in the southern Chukchi compared to their low sensitivity to oil development at Barrow.

Western Sandpiper. This species, uncommon east of Barrow but very common along the Chukchi coast, showed a consistent use of littoral habitats throughout our study, with individuals nesting on tundra but often foraging in nearby littoral areas of saltmarsh and mudflat during the breeding season and shifting heavily to these littoral habitats in late summer. Figure 10 shows the consistency of these patterns between 2 southern Chukchi study sites (Wales

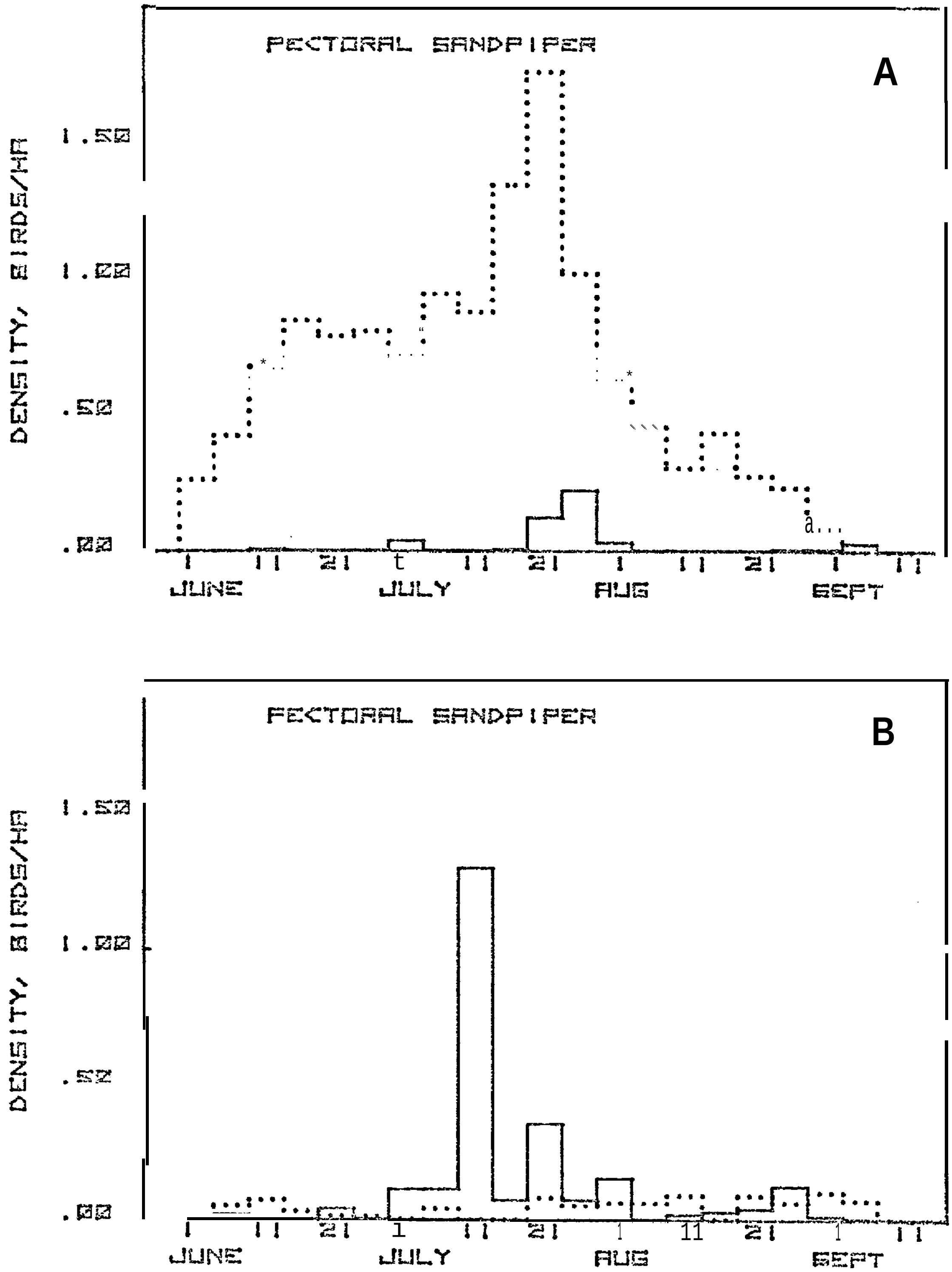


Figure 9. Transect densities, Pectoral Sandpiper. A. Barrow 1976. Littoral (solid) vs. tundra (dotted). B. Wales and Cape Krusenstern 1977. Littoral (solid) vs. tundra (dotted).

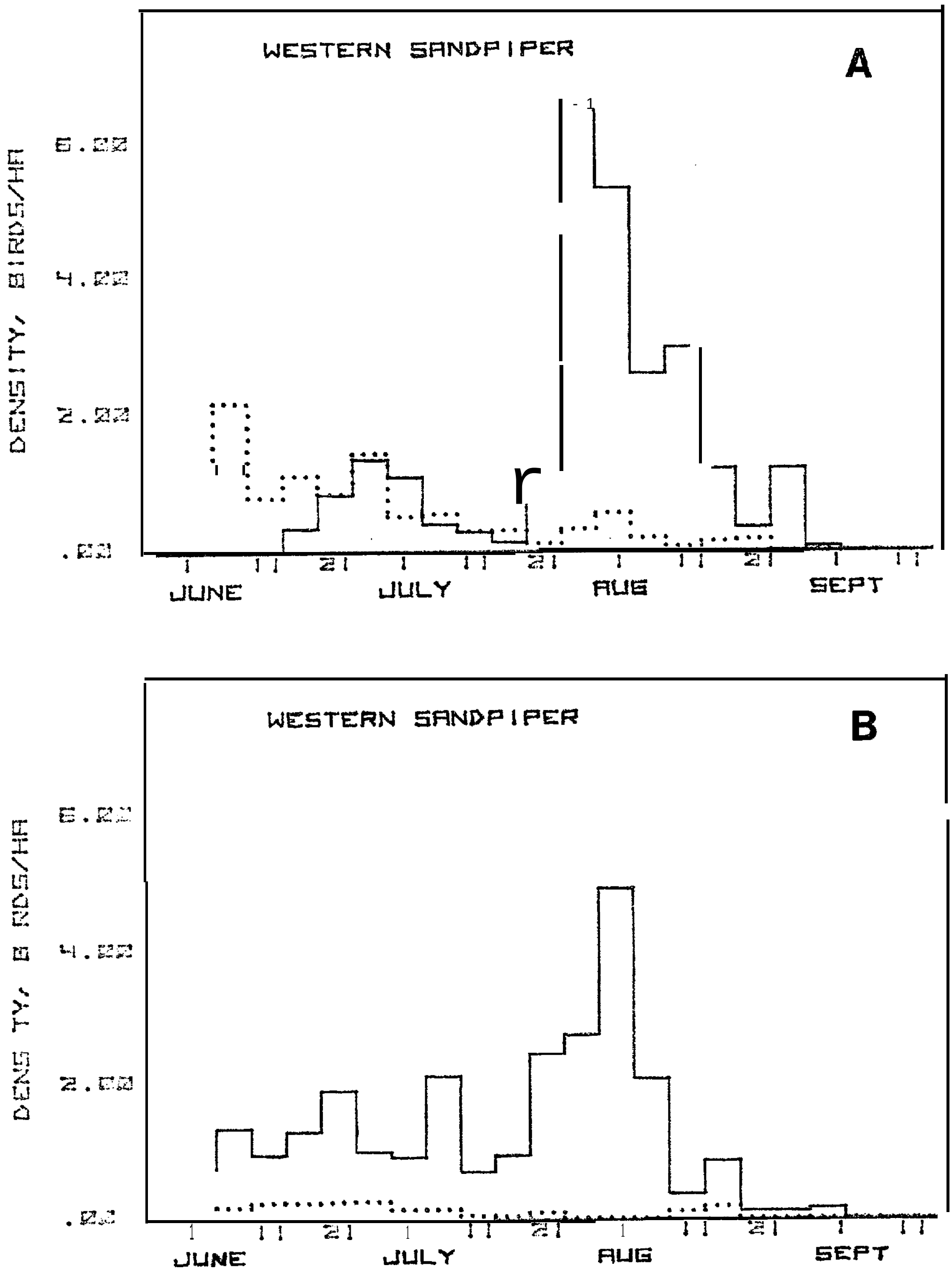


Figure 10. Transect densities, Western Sandpiper. A. Wales. Littoral (solid) vs. tundra (dotted). B. Cape Krusenstern. Littoral (solid) vs. tundra (dotted].

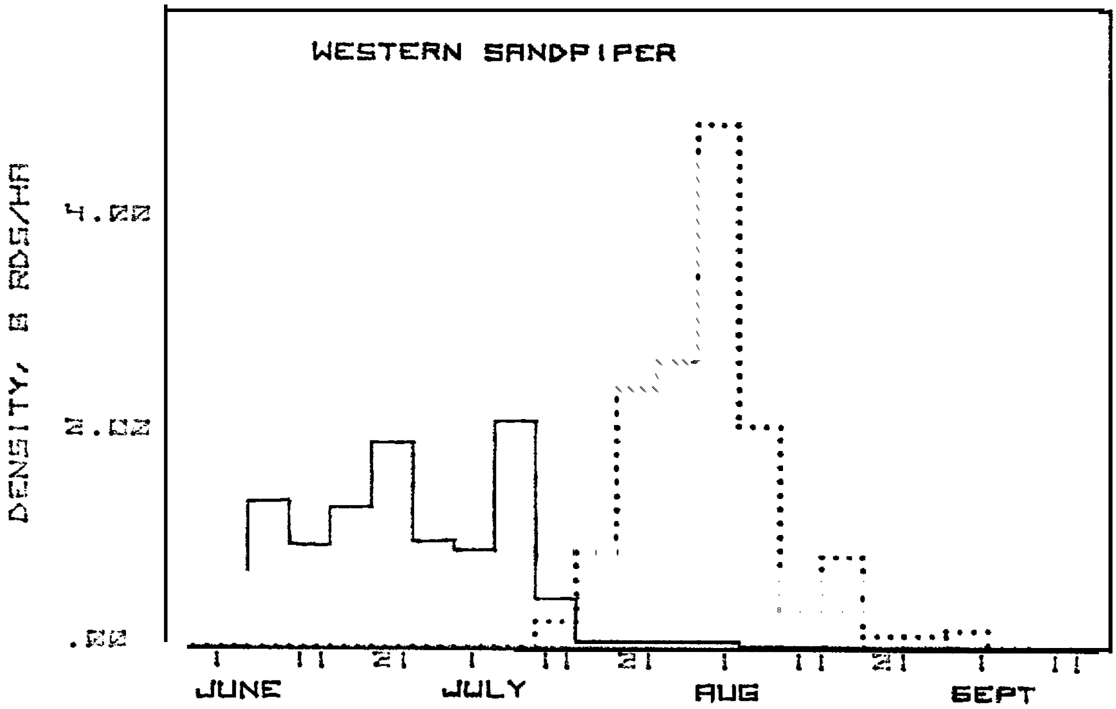


Figure 11. Western Sandpiper littoral transect densities, Cape Krusenstern, 1977. Adults (solid) vs. juveniles (dotted).

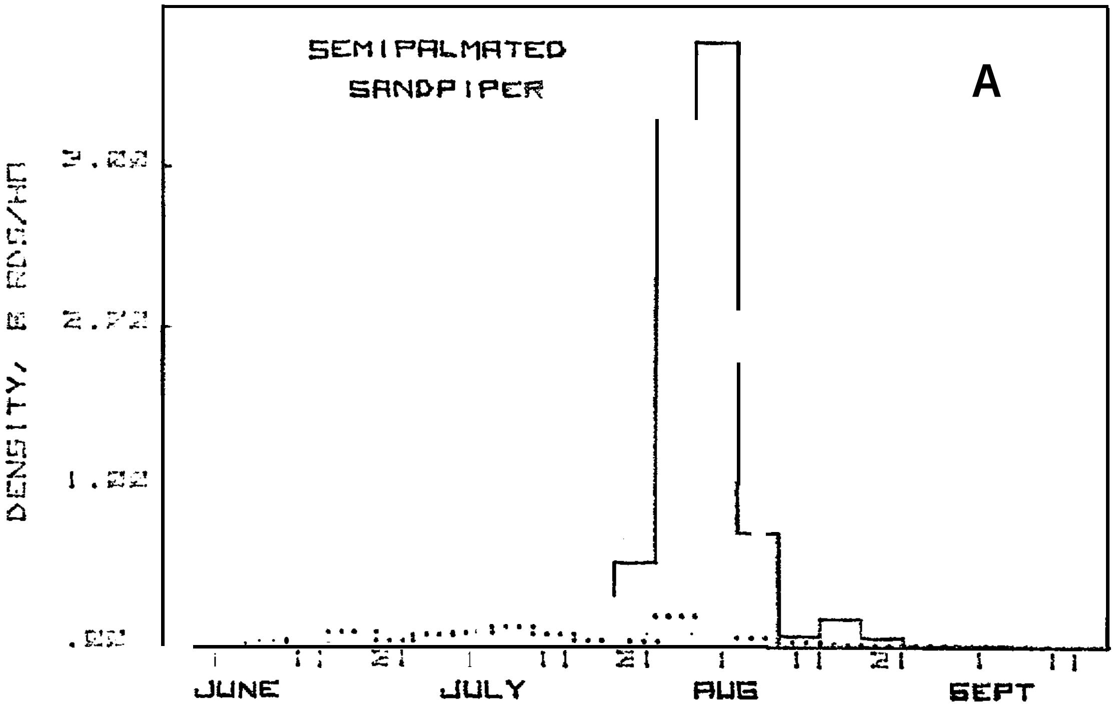
and Cape Krusenstern) in 1977. This pattern can be broken down further to show the movements of adults and young birds into littoral areas (Figure 11). Adults depart on southward migration soon after completion of nesting duties, and newly fledged young move heavily into littoral habitats in late July, where they forage prior to migration.

Semipalmated Sandpiper. This species is very similar in appearance and habitat use to Western Sandpiper, but shows a pattern of movements which contrasts more between regions than does the former species (Figure 12). At Barrow and at other sites along the Beaufort Coast, densities in littoral areas remain low throughout the breeding season, followed by a very sharp, high density movement of juveniles to the littoral zone at the end of July. At Cape Krusenstern, densities in littoral areas during the breeding season were higher than at Barrow but the movement of juveniles into the littoral zone was less marked (Figure 12B). However, both these species in both areas would be sensitive to disturbances of saltmarsh and mudflat habitat.

Semipalmated Sandpipers also show differences in timing of littoral zone movements at different sites across the arctic. Figure 13A shows the peak of juvenile Semipalmated Sandpipers on littoral transects censused in 1978 at Cape Krusenstern, Barrow and Prudhoe Bay. These movements differ in peak density, as described above, but also differ in peak timing by about 5 days between each site. This may represent differences in nesting phenology at each site, or it may represent to some extent a wave of coastal migration in this species which migrates eastward across Canada in autumn.

Another aspect of timing of littoral zone use which differs between regions depends partly upon the availability of ocean shoreline habitat, as discussed above under Phenology. At Beaufort sites large numbers of many species of shorebirds move to shorelines during August and early September, but in June these shorelines are ice-bound. At southern Chukchi sites shorelines are sometimes free of ice in June as in 1978 when northward migrating Phalaropes foraged along beaches at Cape Krusenstern. Figure 13B shows the resultant sharply contrasting difference in seasonal use of ocean shorelines between Cape Krusenstern and two Beaufort sites. Thus the timing of oil spills can have drastically different effects on shorebirds in different regions of the coast.

Red Phalarope. The extreme contrast in relative habitat use by phalaropes between the Beaufort and southern Chukchi coasts is further shown for all habitats in Figure 14. At Barrow Phalaropes are almost confined to tundra habitats until late July when the largest annual accumulations of shorebirds begin to accrue along ocean shorelines. This heavy build-up of plankton-foraging Phalaropes does not occur in late summer at Cape Krusenstern and Wales, and densities



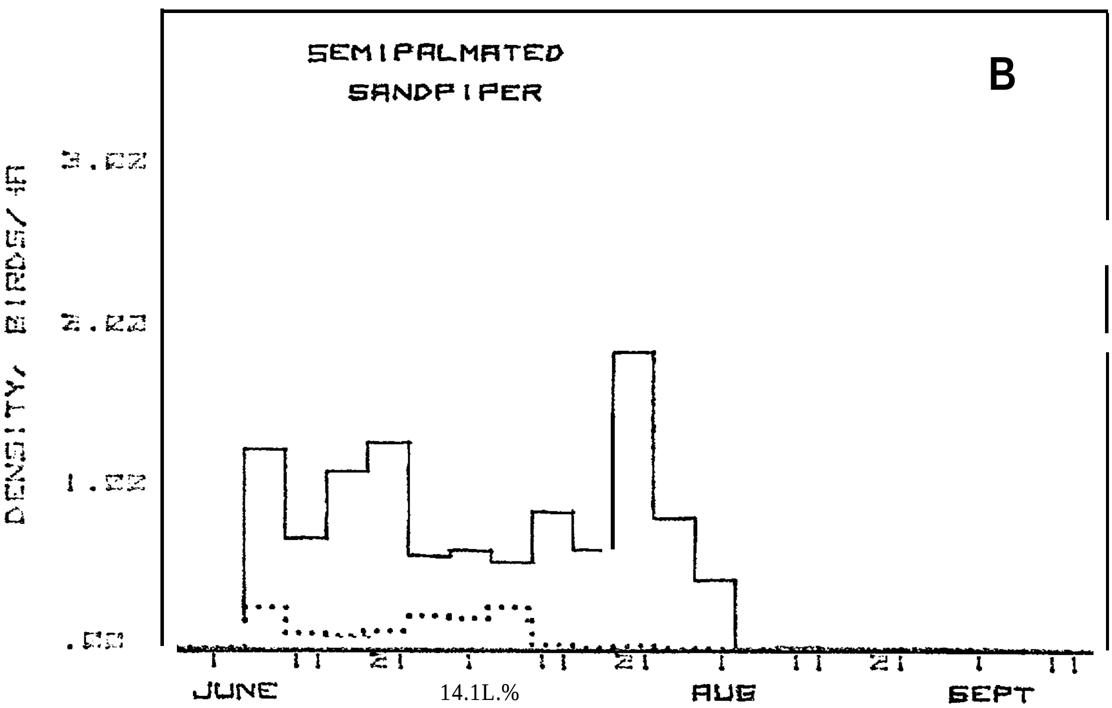


Figure 12. Transect densities, Semipalmated Sandpiper, 1'377.
A. Barrow. Littoral (solid) vs. tundra (dotted).
B. Cape Krusenstern. Littoral (solid) vs. tundra {dotted) .

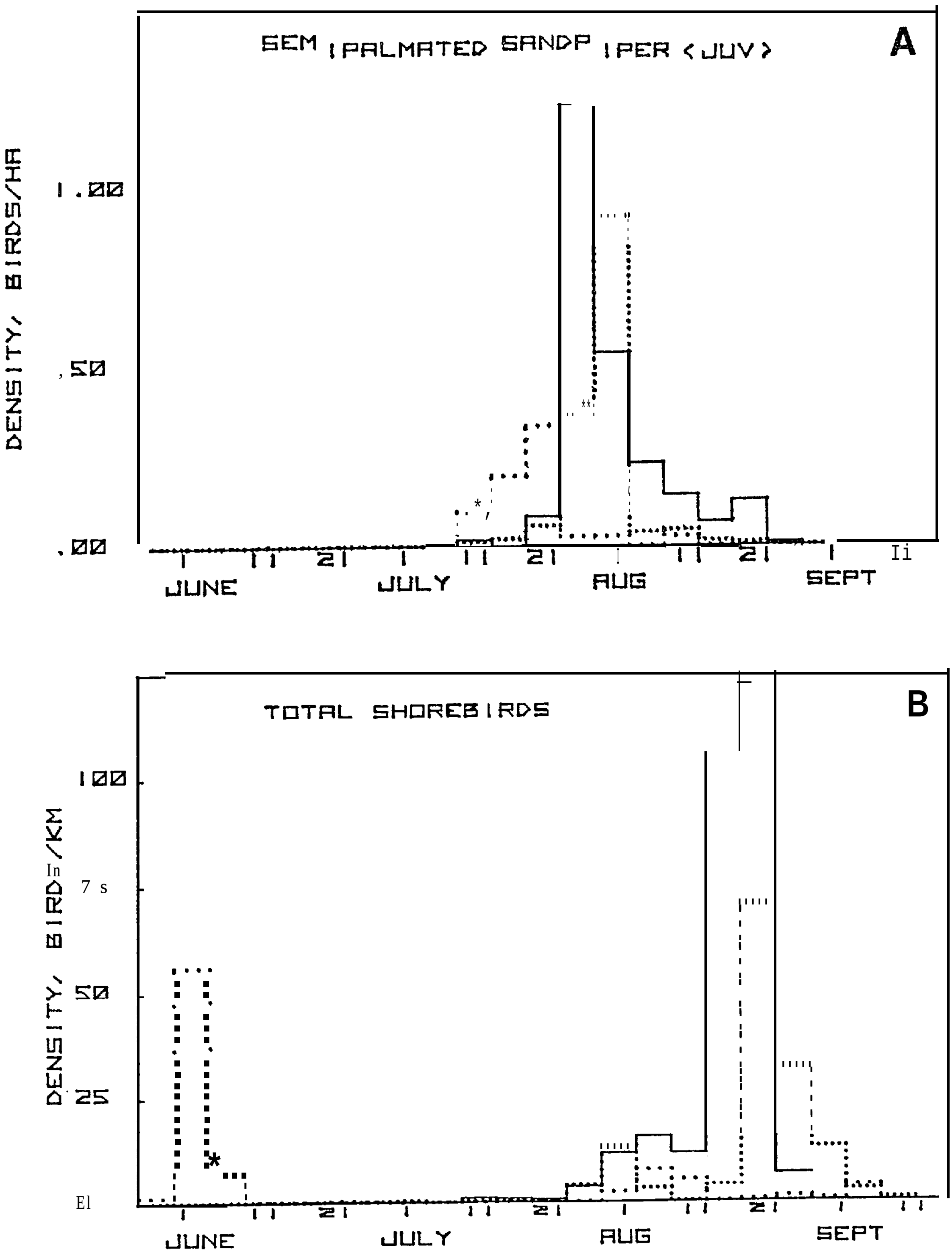


Figure 13. Shorebird densities at 3 sites: Barrow (solid line), Prudhoe Bay (short dot line), Cape Krusenstern (long dot line).
A. Juvenile Semipalmated Sandpipers on littoral transects,
B. Total shorebirds along ocean shorelines.

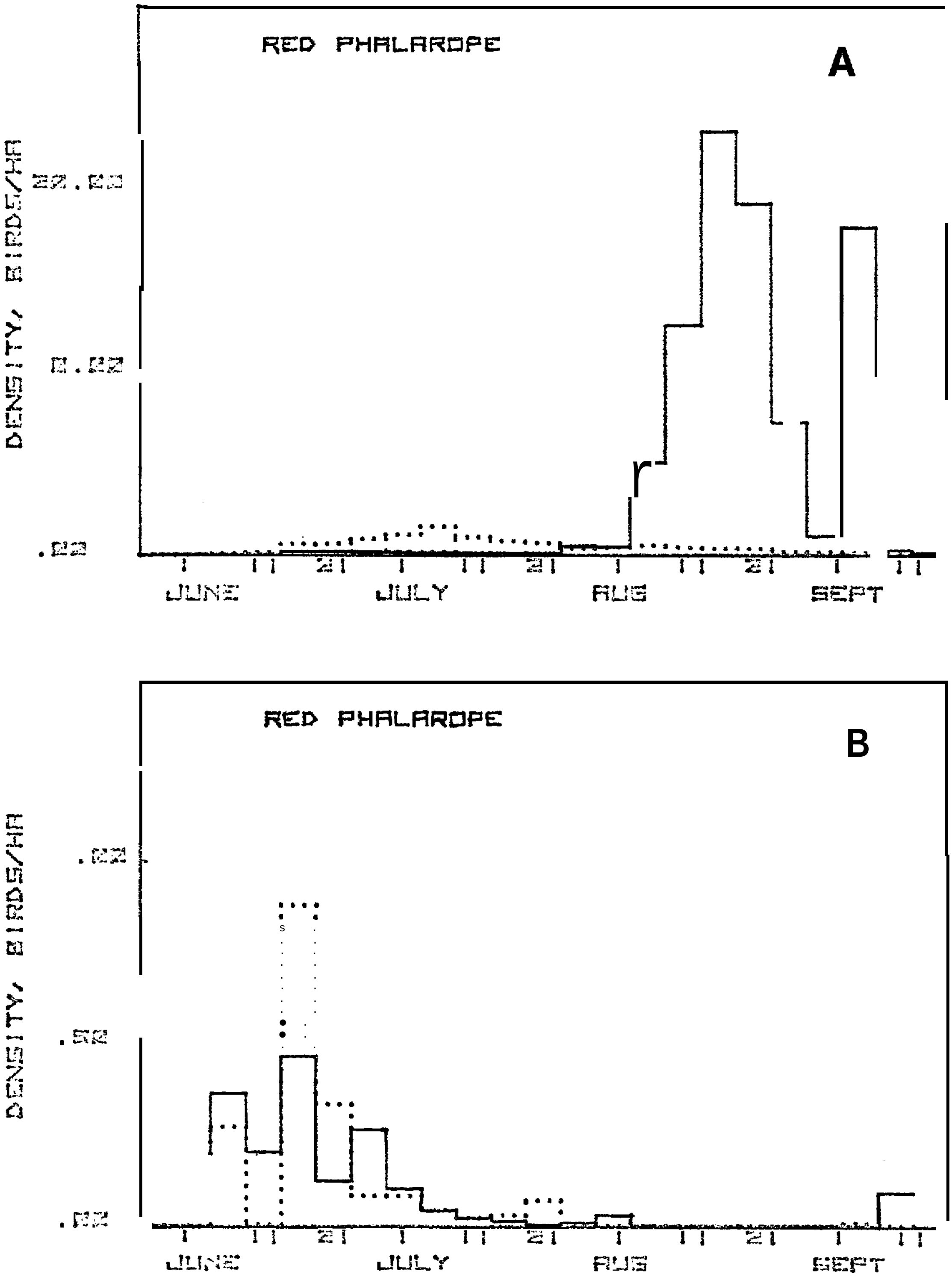


Figure 14. Transect densities, Red Phalarope. A. Barrow, 1976. Littoral (solid) vs. tundra (dotted). B. Wales and Cape Krusenstern 1977. Littoral (solid) vs. tundra (dotted].

in early summer remain low but roughly equal in littoral and tundra habitats (except 1978; see Figure 13B). Northern Phalaropes, more common as nesting birds at Cape Krusenstern than at Barrow, show a similar contrast in pattern, with birds more common in littoral habitats in early summer at Cape Krusenstern and much more common in late summer at Barrow and elsewhere on the Beaufort coast (Connors and Risebrough 1978; 1979; Connors et al 1981).

Trophic Systems.

As mentioned earlier in this report, there is a major difference in littoral zone shorebird trophies between the Beaufort coast and the southern Chukchi coast when viewed on a community level. At Barrow and elsewhere along the Beaufort coast, large numbers of several shorebird species, including principally Red and Northern Phalaropes together with Dunlins, Sanderlings, Ruddy Turnstones, and occasionally other species, forage in late summer along sand and gravel beach shorelines, especially near spits and barrier islands (Connors et al 1981, Johnson 1978). During August, the bulk of the Barrow shorebird community will be found in these habitats, where the important prey are a variety of the larger species in the zooplankton community. This zooplankton community is highly variable in time as well as space (Redburn 1974; Connors et al 1981) but densities are frequently quite high, providing an excellent food source for large numbers of shorebirds. Important organisms among these marine zooplankton include amphipods (Onisimus and Apherusa), euphausiids (Thysanoessa), copepods (Calanus), and decapod zoea, as well as other species, and along barrier lagoon shores, mysids (Mysis).

Along the beaches at Cape Krusenstern, Sisualik, Shishmaref, and Wales, we never saw comparable late summer concentrations of zooplankton foraging shorebirds. We measured shoreline plankton densities in 1977 at Barrow, Cape Krusenstern and Wales and found very little correlation in density and composition among the zooplankton communities during July and August at the 3 sites (Connors and Risebrough 1978). Densities at all 3 sites were lower than during the preceding 2 seasons at Barrow. We are not able to state whether the lower use of shoreline foraging areas by Phalaropes at southern Chukchi sites is a direct response to lower prey availability at these sites compared with Beaufort sites. Diets of Red and Northern Phalaropes collected along lagoon and ocean shorelines at Wales and Cape Krusenstern consisted of a variety of zooplankton similar to those taken at Barrow, but total numbers of Phalaropes feeding in these habitats at the southern Chukchi sites were much lower than along the Beaufort coast (Table 10).

Table 10. Principal food items of Phalaropes at Cape Krusenstern (in order of decreasing frequency).

3 Northern Phalaropes Tundra marsh, 2 June 1978	3 Northern Phalaropes Lagoon shore, 12 June 1978	9 Red Phalaropes Ocean shore, 3-7 June 1978
chironomid larvae	mysids	copepods
other dipteran larvae	arachnids	amphipods
coleoptera	seeds	adult diptera
tiny eggs		arachnids
seeds		coleoptera
		seeds

The other major shorebird littoral zone trophic system includes the saltmarsh, mudflat and saline pool habitats which occur in scattered areas throughout the Beaufort coast, but comprise much larger areas along the southern Chukchi coast, as discussed above. In both regions and at all collection sites, the shorebird prey taken in these habitats were similar. Stomachs of almost all species contained insect larvae and adults, with chironomid fly larvae clearly the most important single prey item. Adult chironomids were taken frequently in some areas and larvae of other diptera were found occasionally. Other prey included principally oligochaetes, beetles, spiders, amphipods and seeds. In general, our samples at any one site were not sufficient to identify minor differences in diets among species. They do however show a very broad overlap in diet among many species, arising principally from the widespread importance of chironomid larvae and adults to almost all shorebirds foraging in these habitats. As an example, a comparison of diets of 6 species foraging in saltmarshes at 2 sites is presented in Table 11. Of 49 individuals with identifiable prey in their stomachs, 41 birds contained larvae or adults of diptera (flies). Except for seeds or other plant material no other group of prey items occurred in more than 5 stomachs. Of the 6 species sampled, only Sharp-tailed Sandpipers had most stomachs containing prey other than diptera larvae and adults.

Table 11. Diets of shorebirds foraging in saltmarsh and mudflats at two locations in late July and August 1978.

	Number of stomachs	Number containing more than trace amounts of:						
		Fly larvae, adults	Beetles	Spiders	Amphipods Isopods	Poly-chaetes	Fish	Plant matter
A. Sisualik and Noatak Delta								
Golden Plover	3	3	0	1	1	0	0	0
Dunlin	12	9	0	1	1	0	0	8
Western Sandpiper	5	5	0	0	0	0	0	5
Pectoral Sandpiper	3	3	0	0	0	0	0	1
Sharp-tailed Sandpiper	4	1	1	3	0	0	0	4
Long-billed Dowitcher	3	3	0	0	0	1	0	3
B. Shishmaref strip								
Golden Plover	3	1	2	0	0	0	1	0
Dunlin	6	6	1	0	1	0	0	2
Western Sandpiper	5	5	0	0	0	0	0	5
Long-billed Dowitcher	5	5	0	0	0	0	0	5

This broad overlap among diets of shorebirds foraging in arctic littoral habitats appears to be the general rule. In most cases when more than 1 shorebird species was collected while foraging at the same time and place the mixture of prey found in the stomachs of all species was similar or identical (Connors and Risebrough 1976 and 1977; Connors et al 1981).

Another indication of the striking difference in importance of the southern Chukchi and Beaufort coastal trophic systems can be seen by comparing diets of all shorebirds collected during 1975 through 1977. At Barrow and Lonely on the Beaufort coast, 20 of 84 specimens (24% of shorebirds collected) had 70% or more of their stomach contents consisting of chironomid flies or larvae. Comparative figures for Wales, Cape Krusenstern, and Sisualik are 40 of 54 specimens (74%). Of course, samples of this type are inevitably biased due to the habitats sampled for shorebirds. Nonetheless, these results correspond with the bird habitat use data discussed earlier in this report and indicate in a rough way the relative importance of insects vs. marine zooplankton between the 2 regions.

Oil Development Effects Through Trophic Systems.

These differences between trophic systems may be important in determining the extent of effects on shorebirds produced by oil development disturbances. An oil slick along Beaufort gravel beaches in late summer will likely have an immediate and powerful adverse effect on large numbers of Phalaropes (Red and Northern) and a lesser effect on several other species of beach foraging shorebirds. The same oil slick along the beaches of the southern Chukchi in August would have a much reduced initial effect. Furthermore, after removal or precipitation of the oil, zooplankton communities, which are associated with the water column, may recover quickly, providing adequate foraging for shorebirds in the following season. In contrast, pollution of saltmarsh, mudflats, and brackish pools caused by on-site development or by oil slicks carried by storm surges may affect the prey densities of benthic infauna for several seasons to come. The prey base in these habitats may not recover quickly, and oil spills will therefore have a many season affect on shorebirds foraging in these habitats.

The initial, direct effect of an oil spill, however, is likely to be less severe in saltmarsh habitats because of differences in foraging modes of many species. Shorebirds walking on mudflats and in saltmarshes will not have their plumage coated with oil as readily as Phalaropes swimming on oil covered waters. There may, however, be some direct contact effects since many of these species wade in shallow water to probe for invertebrates in the mud beneath the water. In any event, the numbers of shorebirds potentially affected by pollution in saltmarshes and mudflats in the southern Chukchi is greater than that along the Beaufort coast. Thus an oil spill or other environmental disturbance will affect different species depending on whether it occurs along gravel shorelines or in saltmarshes and sloughs and its effects will differ in degree and duration depending on whether they are direct (oiling of plumage) or indirect (through prey resource) and will also differ in the extent of shorebird populations affected in different regions of the coast.

V. CONCLUSIONS

Many of the detailed conclusions of our studies have been presented in the preceding section. We summarize here our rankings of relative sensitivity to oil development for species, habitats, and seasons.

Relative Sensitivity of Shorebird Species.

Connors et al (1981) classified the common Beaufort coast shorebirds with respect to each species' relative sensitivity to littoral zone disturbances associated with oil development. The principal disturbance considered in the assessment was the threat of oil spills along the coast, and the factors employed in making this assessment included primarily habitat use patterns of the various species. Primary weight was given to the relative use of tundra vs. littoral habitats but this was modified with information on type of littoral habitat, choice of foraging microhabitat within these habitats and individual species foraging methods and behaviors. In Table 12 we present a reclassification of the relative sensitivity of common species which applies to the southern Chukchi. The several changes in this table compared with that in Connors et al (1981) take into account differences in shorebird distributions and abundance between regions as well as the differences in habitat use and behavior described above.

Relative Sensitivity of Habitats.

Since the most effective method of managing bird populations is frequently the approach of managing habitat, Connors et al (1981) summarized their results in terms of the littoral habitats studied along the Beaufort coast. We repeat this classification in Table 13 since it applies equally well to the southern Chukchi coast, although the relative amounts of these habitats in the 2 areas differ.

Sensitive Seasons.

Shorebirds are present along the southern Chukchi coast from mid-May through early October. Peak numbers of shorebirds in littoral areas are probably reached during August, but densities in some littoral habitats are also high in early summer, in marked contrast to the relative absence of shorebirds from littoral areas during the same period at Beaufort sites. Most habitat disturbances, regardless of the time of initiation, will last through many seasons. Nevertheless, the winter period, when shorebirds are absent from the arctic, is also the period when these frozen habitats are least sensitive to alteration. We therefore recommend that, whenever possible, development take place during winter months.

Table 12. Relative sensitivity of common shorebirds to littoral zone disturbances on the southern Chukchi coast.

HIGH	MODERATE	LOW
Red Phalarope	Golden Plover	Common Snipe
Northern Phalarope	Western Sandpiper	Whimbrel
	Baird's Sandpiper	
	Pectoral Sandpiper	
	Dunlin	
	Long-billed Dowitcher	
	Bar-tailed Godwit	

Table 13. Relative sensitivity of arctic littoral habitats. (Listed in order of decreasing sensitivity).

1. Littoral mudflats and saltmarsh
2. Sloughs and small lagoons (water surface and shorelines)
    1. with broad muddy margins
    2. with narrow margins
3. Spits and barrier islands
4. Mainland shorelines with broad beaches
5. Mainland shorelines with narrow beaches

VI. APPENDIX

Birds of Cape Krusenstern, Alaska, 1977-78

The following list presents the status of bird species observed in the vicinity of Cape Krusenstern, Alaska (see map, Figure 1) in 1977 between 26 May and 7 September and in 1978 between 26 May and 4 September.

RB, rare breeder: 1 or 2 nests (or broods) located in one year.
CB, common breeder: 3 or more nests or territories located in one year.
PB, probable breeder: breeding suspected, but no nests located.
CM, common migrant: present on at least 5 days; at least 10 individuals.
V, visitor: includes less common migrants and stragglers.
*: nested near Krusenstern Lagoon on Ingitakalik Mountain

The second column lists additional species reported as nesting occasionally at Cape Krusenstern in other years (W.R. Uhl and C.K. Uhl 1977).

	1977-78 Status	Additional breeders Other years (Uhl 1977)
Common Loon, *Gavia immer*	v	
Yellow-billed Loon, *G. adamsii*	v	
Arctic Loon, *G. arctica*	CB	
Red-throated Loon, *G. stellata*	CB	
Horned Grebe, *Podiceps auritus*	V	
Red-necked Grebe, *P. grisegena*	V	x
Pelagic Cormorant, *Phalacrocorax pelagicus*	V	
Whistling Swan, *Olor columbianus*	RB	
Canada Goose, *Branta canadensis*	CM	x
Brant, *B. bernicla*	CM	x
Emperor Goose, *Philacte canagica*	V	
White-fronted Goose, *Anser albifrons*	CM	x
Snow Goose, *Chen caerulescens*	CM	
Mallard, *Anas platyrhynchos*	CM	x
Pintail, *A. acuta*	CB	
Green-winged Teal, *A. crecca*	CM	x
American Wigeon, *A. americana*	CM	

Northern Shoveler, A. clypeata	CM	
Redhead, Aythya americana	V	
Ring-necked Duck, A. collaris	V	
Canvasbacks, A. valisineria	RB, CM	
Greater Scaup, A. marila	CB	
Oldsquaw, Clangula hyemalis	CB	
Harlequin Duck, Histrionicus histrionics	V	
Steller's Eider, Polysticta stelleri	V	
Common Eider, Somateria mollissima	CB	
King Eider, Somateria spectabilis	V	
Spectacle Eider, S. f *	V	
White-winged Scoter, Melanitta deglandi	CM	
Surf Scoter, M. perspicillata	CM	
Black Scoter, M. nigra	V	x
Red-breasted Merganser, Mergus serrator	CM	x
Osprey, Pandion haliaetus	V	
Sharp-shinned Hawk, Accipiter striatus	V	
Red-tailed Hawk, Buteo jamaicensis	V	
Rough-legged Hawk, B. lagopus	V*	
Marsh Hawk, Circus cyaneus	CM	x
Gyrfalcon, Falco rusticolus	V	
Peregrine Falcon, F. peregrinus	V*	
Willow Ptarmigan, Lagopus lagopus	CB	
Sandhill Crane, Grus canadensis	CB	
Semipalmated Plovers, Charadrius semipalmatus	RB	
Killdeer, C. vociferus	V	
American Golden Plover, Pluvialis dominica	CB	
Black-bellied Plover, P. squatarola	RB	
Ruddy Turnstone, Arenaria interpres	V	
Black Turnstone, A. melanocephala	CM	
Common Snipe, Capella gallinago	CB	
Whimbrel, Numenius phaeopus	RB, CM	
Bristle-thighed Curlew, N. tahitiensis	V	
Wandering Tattler, Heteroscelus incanus	V	
Red Knot, Calidris canutus	CM	
Rock Sandpiper? C. ptilocnemis	V	
Sharp-tailed Sandpiper, C. acuminata	V	
Pectoral Sandpiper, C. melanotos	RB, CM	

Baird's Sandpiper, *C. bairdii*	RB	
Least Sandpiper, *C. minutilla*	V	
Rufous-necked Sandpiper, *C. ruficollis*	V	
Dunlin, *C. alpina*	CB	
Sanderling, *C. alba*	CM	
Semipalmated Sandpiper, *C. pusilla*	CB	
Western Sandpiper, *C. mauri*	CB	
Stilt Sandpiper, *Micropalama himantopus*	V	
Buff-breasted Sandpiper, *Tryngites subruficollis*	CM	
Long-billed Dowitcher, *Limnodromus scolopaceus*	CB	
Bar-tailed Godwit, *Limosa lapponica*	PB,CM	
Hudsonian Godwit, *L. haemastica*	V	
Red Phalarope, *Phalaropus fulicarius*	CM	
Northern Phalarope, *Lobipes lobatus*	CB	
Pomarine Jaeger, *Stercorarius pomarinus*	CM	
Parasitic jaeger, *S. parasiticus*	CM	
Long-tailed Jaeger, *S. longicaudus*	PB, CM	x
Glaucous Gull, *Larus hyperboreus*	CB	
Glaucous-winged Gull, *L. glaucescens*	V	
Herring Gull, *L. argentatus*	V	
Thayer's Gull, *L. thayeri*	V	
Mew Gull, *L. canus*	PB,CM	x
Black-legged Kittiwake, *Rissa tridactyla*	CM	
Sabine's Gull, *Xema sabini*	CM	
Arctic Tern, *Sterna paradisaea*	CB	
Aleutian Tern, *S. aleutica*	CB	
Common Murre, *Uria aalge*)>	CM	
Thick-billed Murre, *U. lomvia*)		
Black Guillemot, *Cepphus grylle*	V	
Horned Puffin, *Fratercula corniculata*	V	
Snowy Owl, *Nyctea scandiaca*	V	
Short-eared Owl, *Asio flammeus*	V	x
Common Flicker, *Colaptes auratus*	V	
Eastern Kingbird, *Tyrannus tyrannus*	V	
Say's Phoebe, *Sayornis saya*	V*	
Horned Lark, *Eremophila alpestris*	V*	

Tree Swallow, *Iridoprocne bicolor*	RB
Bank Swallow, *Hirundo rustics*	v
Cliff Swallow, *Petrochelidon pyrrhonota*	V
Common Raven, *Corvus corax*	CM*
Gray-headed Chickadee, *Parus cinctus*	v
Swainson's Thrush, *Catharus ustulatus*	v
Gray-cheeked Thrush, *C. minimus*	v
Wheatear, *Oenanthe oenanthe*	CM
Bluethroat, *Luscinia svecica*	v
Arctic Warbler, *Phylloscopus borealis*	v
White Wagtail, *Motacilla alba*	V
Yellow Wagtail, *M. flava*	CB
Water Pipit, *Anthus spinoletta*	V
Red-throated Pipit, *A. cervinus*	V
Yellow Warbler, *Dendroica petechia*	V
Wilson's Warbler, *Wilsonia pusilla*	V
Redpoll, *Acanthis* sp.	CB
Savannah Sparrow, *Passercula sandwichensis*	CB
Tree Sparrow, *Spizella arborea*	v
White-crowned Sparrow, *Zonotrichia leucophrys*	PB
Fox Sparrow, *Passerella iliaca*	v
Lapland Longspur, *Calcarius lapponicus*	CB
Snow Bunting, *Plectrophenax nivalis*	CM
Total species recorded, 1977-1978:	113

[1]Observed only in 1980.

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