Shorebird Dependence on Arctic

Littoral Habitats

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I. Summary of Objectives, Conclusions and Implications

Shorebirds (sandpipers, plovers, and their relatives) are a major and important component of the Alaskan arctic avifauna. Prior to 1975, shorebird work in the Arctic had concentrated on events on the tundra, where these birds nest, and had largely been confined to the brief breeding period. In this study we have documented seasonal, and occasionally very heavy, use of littoral (shoreline) habitats by shorebirds and other birds in the Arctic.

The ultimate objective of Research Unit #172 is the assessment of the degree and nature of dependence of shorebird species on arctic habitats which are potentially susceptible to perturbation from offshore oil development activities. Within this objective, we are identifying critical habitats, critical trophic processes, and critical areas of the Beaufort and Chukchi coasts, and estimating the relative susceptibilities of each shorebird species to potential disturbances, Quantitative data of four major categories are being gathered to meet these objectives:

1) Seasonal occurrence of birds by species, age and sex in a variety of arctic littoral and near-littoral habitats. This received major effort in 1977, consisting of repeated, intensive transect censuses of many habitats at the three main study sites (Barrow, Wales, Cape Krusenstern), supplemented by further observations at other sites in the Beaufort and Chukchi Seas.

2) Trophic relationships of shorebirds and other species foraging in arctic littoral areas. Increased emphasis on this aspect is required since we have identified major fluctuations in prey resources between seasons, and important differences in the major trophic systems for shorebirds between regions.

3) Description of habitats in littoral and near-littoral areas and determination of foraging habitat preferences by species as these change seasonally.

4) Other factors affecting the dependence of species on littoral areas, including for example, schedules of premigratory fat deposition; variation in phenology and weather patterns between sites and between years; and effects of wind conditions on zooplankton and phalarope distribution.

In general terms, most of the conclusions presented in the previous annual report (Connors and Risebrough 1977) were consistent with the results obtained during 1977 at Barrow and elsewhere in the Beaufort Sea. However, summer coastal ice conditions differed markedly from the previous two seasons at Barrow, producing a very different schedule of available foraging habitats. As a result, large numbers of post-breeding male Red Phalaropes moved to ocean shorelines, utilizing marine zooplankton as a pre-migratory food source. In previous years most males had left Barrow before this habitat opened. 1977-like phenomena greatly increase the potential susceptibility of the adult male cohort, and therefore the breeding population, to oil spills in the Beaufort. Adult Ruddy Turnstones also exhibited a heavy movement to littoral areas prior to migration.

Juvenile Red Phalaropes, and several other species of shorebirds, gulls, and terns again foraged in high densities along the shores of Barrow Spit, although the exact timing and magnitude of these population movements differed between years. These species were dependent on zooplankton along the shallow gravel shores, and the extremely high variation in species composition and density of this planktonic community, identified in 1975 and 1976, was again illustrated by our zooplankton studies in 1977. However, despite the marked difference in ice conditions between 1977 and the prior years, in some respects (Red Phalarope foraging response to wind direction, and foraging vs. roosting time budgets), 1977 can be considered intermediate between the strikingly different earlier years.

With three seasons of data, we are able to refine our estimates of the relative susceptibilities of common Barrow shorebirds to potential littoral zone disturbances associated with OCS oil development; a revised list is presented in Table 16.

During 1977 we initiated studies at two sites along the southern Chukchi coast at Wales and Cape Krusenstern. Although these sites do not border any imminent lease area, their study has relevance to potential impacts associated with development of the Beaufort Sea lease area for two main reasons. All birds using Beaufort coastal habitats are migratory, and many of them pass along the Chukchi coast; strategies of resource utilization, timing of migration, and energetics of migratory processes can be best understood by considering both coasts as a single system. Of more direct application, the development of Beaufort coast oilfields carries an attendant risk to habitats along the Chukchi coast, arising from the potential for accidents associated with the marine transport of materials to and from the oilfields.

Contrasts of habitat use and phenology between Wales and Cape Krusenstern and stations farther north are striking. Although many features of shorebird distribution and timing differ as expected, two contrasts stand out. First, species assigned low relative susceptibility ratings at Barrow (Pectoral Sandpiper, Golden Plover) because of low use of littoral habitats there, must be assigned higher ratings along the coast of the southern Chukchi, where they forage extensively on mudflats and saltmarsh margins during migration. Second, whereas marine zooplankton is the focus of shoreline feeding activity by shorebirds, gulls, and terns near Barrow and at other Beaufort sites in late summer, in Kotzebue Sound and northern Seward Peninsula shoreline zooplankton foraging by these species is minor during the same period. Instead, very high concentrations of shorebirds forage on benthic invertebrates on the more extensive tidal mudflats and saltmarsh areas of these regions. We estimate that 225,000 shorebirds were present on the beach, saltmarsh, and mudflats of the lagoon barrier strip along the north shore of Seward Peninsula in mid-August. This marked difference between areas implies corresponding differences in the expected sensitivity of bird populations to environmental disturbances. Studies of the critical elements and the flexibility within these two main trophic systems are now required.

Population density and habitat use information for individual species are presented in Parts VI and VII (Results and Discussion), In general, four periods of littoral zone use, overlapping to some extent, can be recognized.

1) In early June near Barrow, small numbers of pre-breeding or breeding adults of several shorebird species forage along beaches, around saline pools, and on mudflats near sloughs, In Kotzebue Sound, with more littoral habitat open early in the season, use of these areas is considerably heavier.

2) From late June through early July, a movement of non-breeding and post-breeding adults of several species occurs, with flocks and individuals utilizing habitats at the edges of small coastal lagoons and nearby brackish pools and on tidal mudflats.

3) In mid-July through early August, adults of both sexes of most species are released from nesting duties as young birds fledge and become self-sufficient. These flocking adults, beginning their southward migration, move into littoral areas.

4) The phase of heaviest use of littoral areas occurs during all of August, stretching into September for some species, Juveniles leave the tundra areas where they have fed before fledging and flock in littoral habitats; in many species they begin their southward movements independently of, and later than, the adults.

The post-breeding movements of adults and juveniles to the littoral zone precede migration; this phase in the annual activity cycle represents an important and possibly critical period of energy storage to meet the demands of migration. For inexperienced and presumably less efficient juveniles especially, a high level of energy reserve in the form of deposited fat may be a critical factor in determining survival during migration. Our samples of Red Phalarope juveniles foraging near Barrow during August and September indicate a significant increase in fat level during this period. Rates of fat deposition in juvenile shorebirds differed considerably between species, indicating different use of available food resources, and different strategies of energy storage. These strategies, and the flexibility of species with respect to normal variation in resource conditions, will affect the potential impact of different environmental disturbances.

In spite of year-to-year variation in timing and magnitude of movements of particular shorebird species and of differences in trophic conditions, the conclusion that the Barrow' Spit area is heavily used by many shorebirds, gulls, and terns in late summer is supported by the data from each season of this study. Other areas identified as sustaining very high use by several species in late summer include but are not limited to the Plover Islands, the muddy sloughs near Lonely, saltmarsh flats near Icy Cape and Oliktok, and the spit and islands around Peard Bay. Farther south in the Chukchi, principal sites of shorebird littoral zone activity are around Kotzebue Sound, especially in river delta areas, and along the northern shore of Seward Peninsula; coverage in these areas is scant, however.

The implications for OCS oil development from some of these results are clear. Leasing and development should be planned to minimize the threat to the most heavily used and most sensitive areas and habitats, and to avoid disturbances during periods of highest potential impact on bird populations.

Obviously, the effect of any oil spill could be quite serious, depending upon timing as well as magnitude of the spill and upon the dispersal behavior of oil under varying conditions of ice coverage. During open-water periods of August and September, oil carried to nearshore areas would probably cause extremely high mortality to juvenile Red and Northern Phalaropes and other swimming birds, including gulls, waterfowl, and alcids. Immediate effects might be almost as severe on other species of shorebirds feeding in affected habitats. Any drastic reduction in prey densities of plankton or infaunal invertebrates in areas where these shorebirds feed might reduce the foraging efficiency and survival of all these species. However, the flexibility of different species with respect to food conditions or location of staging areas is difficult to evaluate and is critical to predicting impacts.

Finally, many other kinds of oil development habitat disturbances in shoreline or nearshore tundra areas may affect the breeding success or survival of bird species using these habitats. To date, efforts in RU #172 have focused on evaluating the dependence of birds on all habitats which may be affected. In 1978 we will begin comparative studies of bird use of habitats which have already been subjected to a variety of disturbances near Prudhoe Bay, as the next step in predicting potential outcomes of oil development on arctic bird populations.

II. Introduction

Shorebirds (Charadriiformes: Charadrii; Sandpipers, plovers and their close relatives} constitute a major and prominent segment of the avifauna of the Beaufort and Chukchi coasts of arctic Alaska (Bailey 1948; Gabrielson and Lincoln 1959; Pitelka 1974: Table 1). All of these 27 species, which occur regularly in the Arctic during summer months, spend their winters in temperate and tropical regions of both northern and southern hemispheres. As a group, they are an international resource, with individual species dependent in varying degrees on summer conditions along the Alaskan arctic coast.

Prior to 1975, considerable effort had been expended on studies of the ecology of tundra nesting shorebirds near Barrow, Alaska (see

Table 1, Shorebird species occurring regularly along the Beaufort and Chukchi coasts of Alaska (from Connors et al. 1978).

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
White-rumped Sandpiper, Calidris fuscicollis
Baird's Sandpiper, Calidris bairdii
Dunlin, Calidris alpina
Semipalmated Sandpiper, Calidris pusilla
Western Sandpiper, Calidris mauri
Stilt Sandpiper, Micropalama himantopus
Buff-breasted Sandpiper, Tryngites subruficollis
Long-billed Dowitcher, Limnodromus scolopaceus
Bar-tailed Godwit, Limosa lapponica
Red Phalarope, Phalaropus fulicarius
Northern Phalarope, Lobipes lobatus
Additional Migrants
Killdeer, Charadrius vociferus
Sharp-tailed Sandpiper, Calidris acuminata
Least Sandpiper, Calidris minutilla
Rufous-necked Sandpiper, Calidris ruficollis
Curlew Sandpiper, Calidris ferruginea
Sanderling; Calidris alba
Hudsonian Godwit, Limosa haemastica

Connors and Risebrough 1977 for references). These studies dealt almost exclusively with conditions on the upland tundra, primarily during the short arctic breeding season. It had been noted, at Barrow and elsewhere in the Arctic, that densities of several species of shorebirds increase near the shoreline as the summer progresses, resulting in a net increase in use of littoral habitats (Holmes 1966; Bengtson 1970). This movement begins with non-breeders and is augmented progressively by a shoreward movement of local and also inland birds, especially after the young have fledged. However, the importance of this habitat shift in the breeding cycle of arctic shorebirds had not been adequately evaluated.

This study is attempting to provide the detailed and quantitative information necessary to assess the dependence of shorebirds and other species on littoral habitats along the Alaskan arctic coast. We wish to determine the relative susceptibilities of different species to potential impacts of oil development, and to identify sensitive species, habitats, areas, and periods to aid in OCSEAP development decisions. We are addressing several aspects of shorebird ecology essential to evaluating the significance of the littoral zone for shorebirds, gulls, and terns: seasonal occurrence of these birds by species, age, and sex, in different habitats; trophic relationships of shorebirds and other birds feeding in littoral habitats, and variability and foraging habitat preferences; and behavioral patterns and other aspects of littoral zone use by shorebirds, gulls, and terns.

The relevance of this investigation to problems of OCSEAP petroleum development is clear. To the extent that shorebirds and other birds utilize and depend upon shore and nearshore habitats, any perturbation of these habitats can affect them. Use of littoral habitats in the Arctic appears to be heaviest by juveniles moving from inland nesting areas to the coast in late summer, prior to their long-distance migrations. Since post-fledging mortality of juveniles is a significant factor in determining reproductive success, alteration of required habitat conditions for these birds could affect population levels over wide areas.

III. Current State of Knowledge

Available background information prior to RU #172 is referred to in the introductory paragraphs. The principal conclusions derived from our first two seasons of field work are discussed in sections I (Summary), VII (Discussion), and VIII (Conclusions). Briefly: we now have a good understanding of many shorebird habitat use patterns, seasonal movements, distributions, and relative susceptibilities near Barrow and in the western Beaufort and northern Chukchi; and tentative information on the same topics in the southern Chukchi. Our appreciation of trophic relationships in both areas is modest but improving.

IV. Study Area

Field activities were conducted in three primary sites during 1977: (1) Barrow (71°17'N, 156°46'W), 15 July - 17 September; (2) Wales (65°38'N, 168°08'W), 2 June - 14 September; (3) Cape Krusenstern (67°8'N, 163°43'W), 26 May - 8 September, At each site a variety of littoral and nearshore tundra habitats were studied intensively. Supplementary study areas, at Oliktok (70°30'N, 149°51'W), Prudhoe Bay (70°12'N, 148°22'W), Peard Bay (70°49'N, 158°25'W), Icy Cape (70°18'N, 161°52'W), Sesualik (66°59'N, 162°48'W), and four sites along the north shore of Seward Peninsula were visited from 1 to 3 times between 15 July and 8 September.

V. Methods

For reasons discussed in the first annual report [Connors and Risebrough 1976), the arctic littoral zone is considered to extend from lowest tide level up to the limits of the regions likely to be inundated by storms at least once every few years. Within this study, data were collected throughout this zone, on the tundra above this zone, and on the nearshore water areas beyond this zone, The discussion of methods will be divided into several sections corresponding *to* the principal classes of data gathered:

A. Shorebird seasonal habitat use. As described in Connors and Risebrough (1976 and 1977), primary effort was focused on a permanent transect method. At the three primary sites, transects were marked at 50 m intervals in littoral and in tundra areas. A listing of names and locations of transects is given in Tables 2, 3, and 4 and Figures 2, 3, and 4. Upland transects are necessary for comparison with littoral transects to assess seasonal changes in habitat use by birds. At Barrow, transect census data for tundra habitats have been provided by J. P. Myers and F. A. Pitelka, from a continuing study of tundra habitat use by birds, sponsored by the U.S. Department of Energy.

In narrow shoreline habitat areas, as along outer beach shores, stakes defined a single row of square census plots 50 m on each side, In areas of more extensive, continuous habitat, such as mudflats or upland tundra, the stakes defined a double parallel row of 50 m plots. At all sites, transect locations were selected to include the full range of available littoral habitats. Lengths of transects within single habitats ranged from .3 km to 2.9 km; almost all transects, however, were either .5 km or 1.0 km. All transect parameters for each site are listed in Tables 2, 3, and 4.

Transects were censused at least once every five days throughout the entire field season at each main study site. All birds within each census plot were recorded, as well as any birds within 200 m on the water side of shoreline transects. Transects were censused continuously between these dates: at Cape Krusenstern, 5 June 1977 through 7 September 1977; at Wales, 5 June 1977 through 12 September 1977; and at Barrow, littoral transects 19 July 1977 through

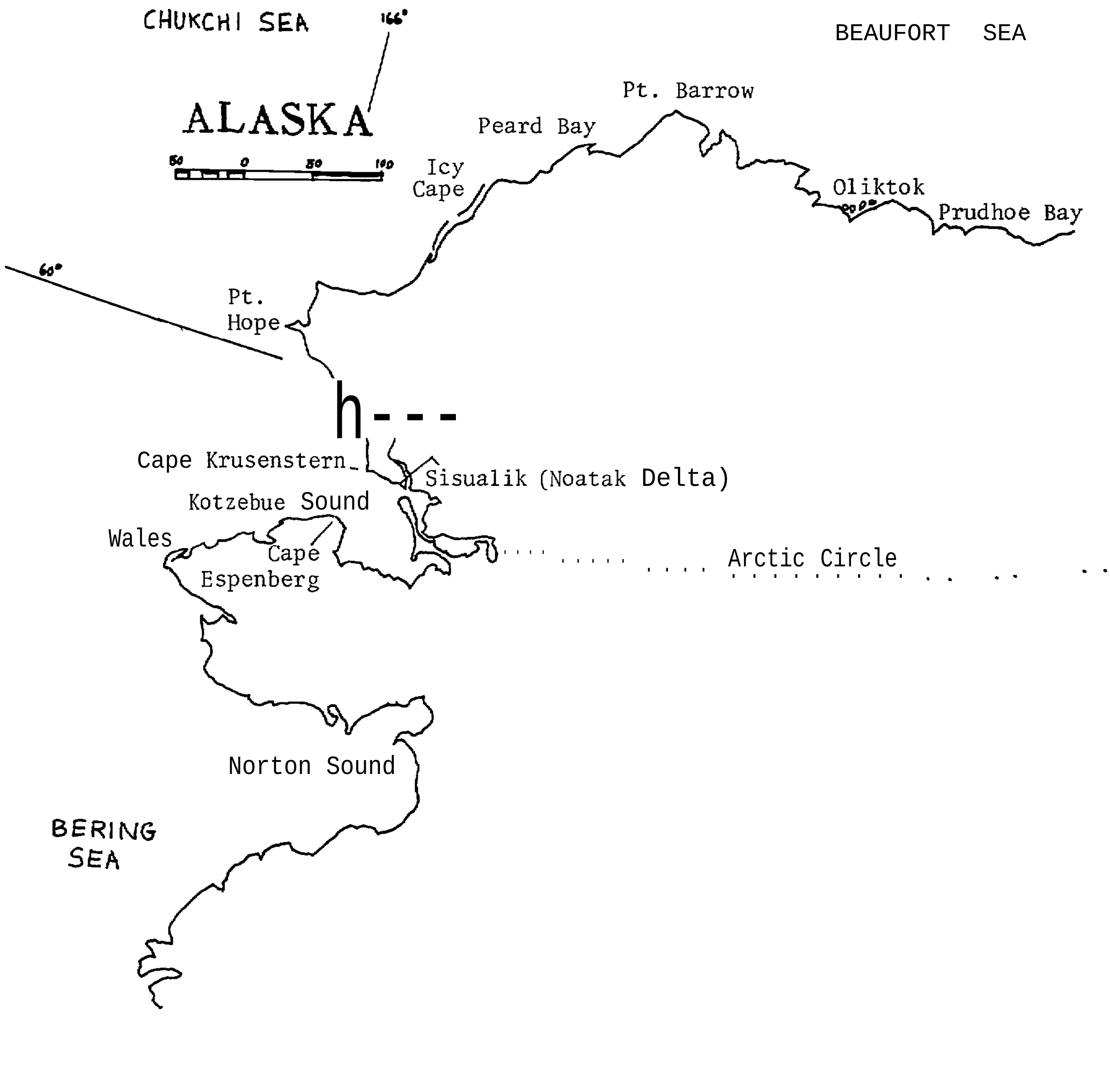


Figure 1. Map of Northern Alaska.

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

Code	Transect or station name	(Tundra or littoral)	Transect 1 ength (m)	Transect width (m)
WB1	Sea Beach 1	L	1000	50
WB2	Sea Beach 2	L	1000	50
WB3	Sea Beach 3	L	1000	50
WB4	Sea Beach 4	L	1000	50
WB5	Sea Beach 5	L	1000	50
WB6	Sea Beach 6	L	1000	50
WBB	Breeding Bird Plot	T	1000	100
WBD	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
WML	W. Lagoon 3	L	1000	50
WNL	W. Lagoon 4	L	1000	50
WNM	N. Red Mud	L	300	50
WRW	Runway	T	1000	100
WS L	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 north of B6 transect			
WBS	Sin-l-rock Sea	L	1000	50
WRL	Sin-l-rock Lagoon	L	1000	50
WRM	Sin-l-rock Mud	L	300	50

Total areas: Tundra: 60 hectares

Littoral: 73.5 hectares

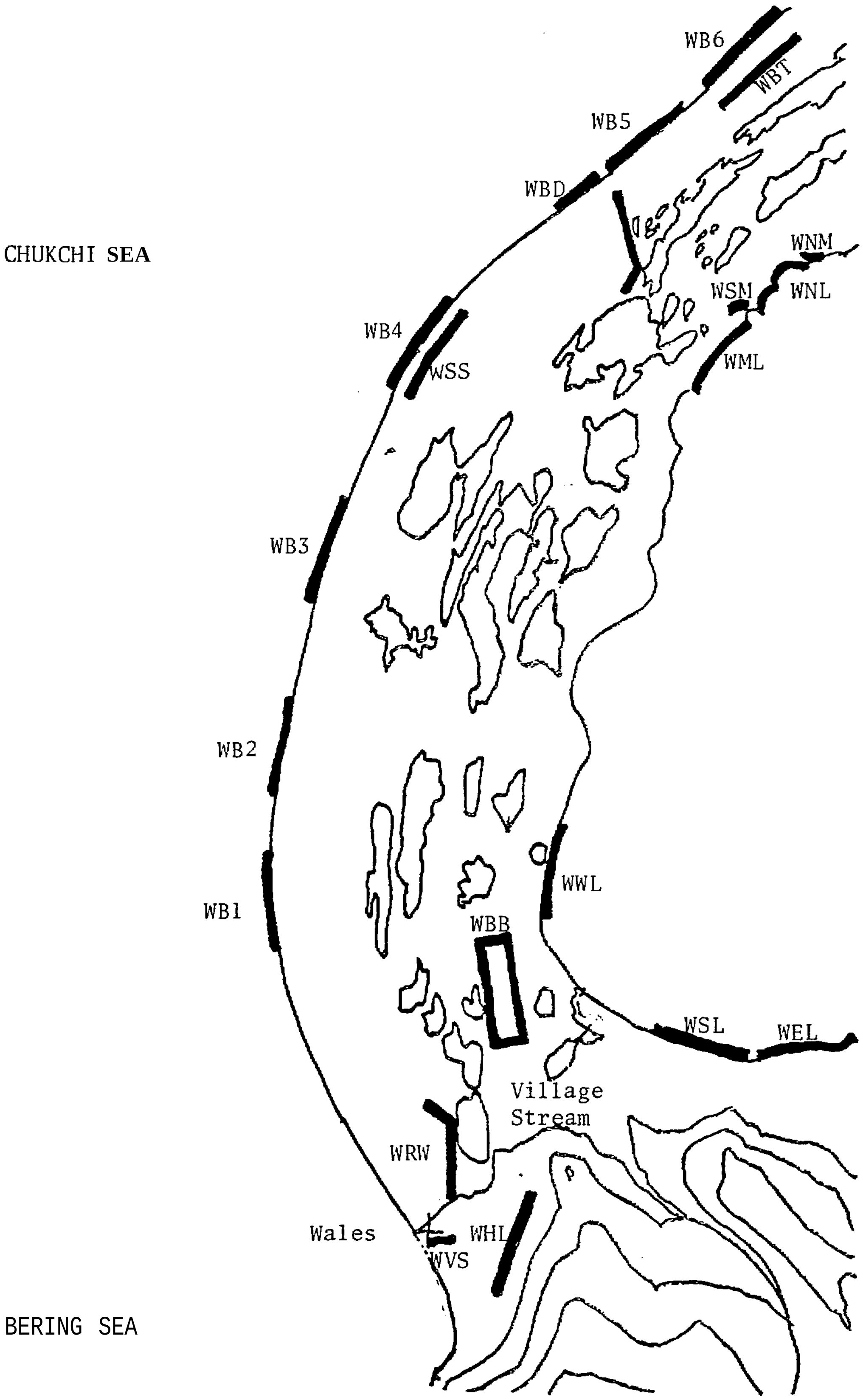


Figure 2. Locations of transects and sampling stations, Wales, Alaska.

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

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
KG1	Grid one	T	850	100
KG2	Grid two	T	850	100
KG3	Grid three	T	850	100
KGC	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
KNF	North Flats	L	500	100
KNL	North Lagoon	L	1000	50
KSB	Shell Beach	L	1000	50
KS L	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.			
KB1	Shelter Cabin Beach (SCB)	L	1000	50
KS1	Shelter Cabin Slough (SCS)	L	500	50

Total areas: Tundra: 45.4 hectares

Littoral: 70.0 hectares

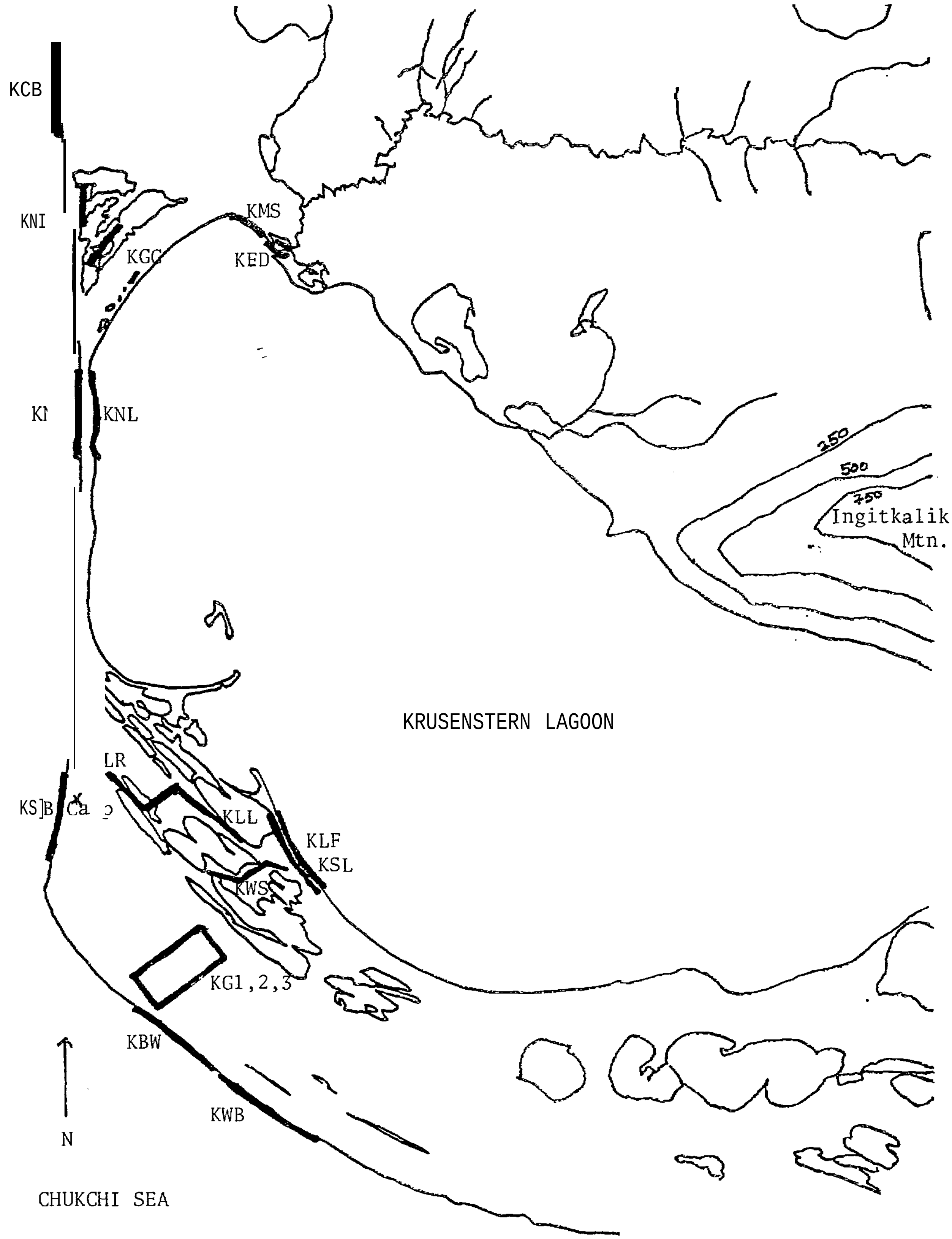


Figure 3. Locations of transects and sampling stations, Cape Krusenstern, Alaska.

Table 4 Locality codes for transects and sampling stations. Barrow, Alaska. (See Figure 4.)

Code	Transect or station name	Transect 1 ength (m)	Transect width (m)
BAP	Airport	1000	50
BBD	Barrow Dump	2900	50
BBP	Britton Ponds	300	100
BBS	Barrow Spit	1000	50
BSS	Beaufort Sea Station		
BCB	Cemetery Beach	1000	50
BCN	Chukchi Sea North	1000	50
BCS	Chukchi Sea South	1000	50
B DM	Deadman	1000	50
BGF	Graveyard Flat	500	100
BME	Middle Salt East	500	50
BMW	Middle Salt West	500	50
BNB	Nunavak Bay	1000	50
BNS -1	North Salt Lagoon-1	500	100
BNS- 2	North Salt Lagoon-2	500	50
BNT	Nuwuk Tundra	500	100
BPP	Plover Point	1000	50
BPS	Plover Spit	1000	50
BRW	Rotten Walrus	1000	50
BT-1 through BT-10 "	Tundra Transects 1-10	1000 each	100
BTW	Top-of-the-World	1000	50
BVC	Voth Creek	500	100
BWB	Whalebone Bight		
BWS	Whalebone Spit	1000	50

Total areas: Littoral transects: 10S hectares

Tundra transects of Myers and Pitelka: 100 hectares

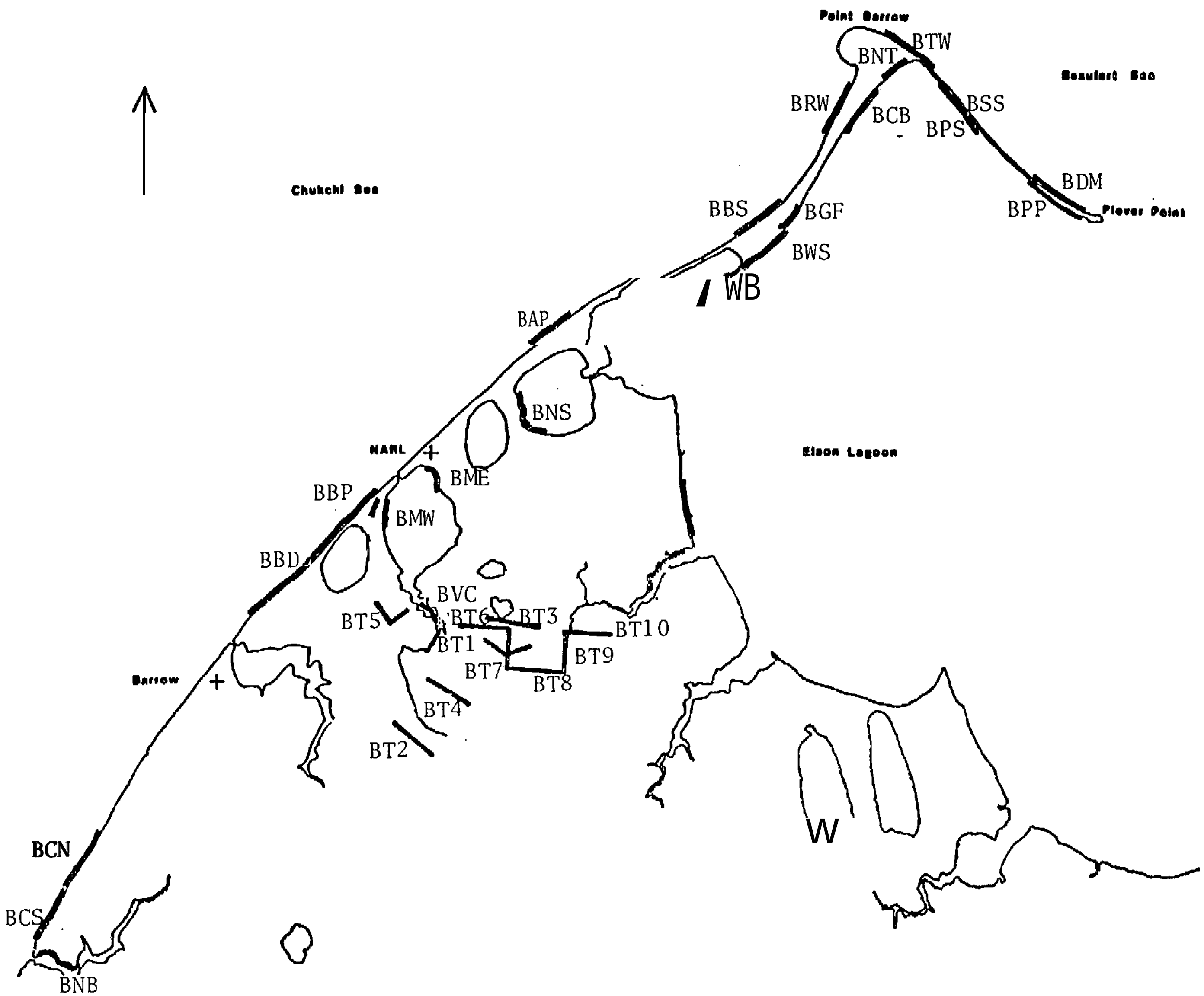


Figure 4. Locations of transects and sampling stations.

17 September 1977; Barrow, tundra transects censused by J. P. Myers et al. were censused continuously beginning in late May 1977.

The method of permanent transects regularly censused provides data which are easily analyzed to record seasonal changes in population density, as illustrated in Part VI (Results). To obtain more extensive coverage of littoral areas near the primary study sites and at other sites along the arctic coast and to increase the prospect of observing very transitory or localized phenomena, the transect method was supplemented with censuses recorded as numbers of species in a known or estimated length of shoreline or area of suitable habitat. This approach provides flexibility in treating all observations, and results can be used to explain and complement the transect results.

At three of the supplementary sites (Oliktok, Peard Bay, Icy Cape) shoreline transects of lengths from 1 to 11 km and approximate widths of 50 or 100 m were chosen, to be censused during three periods in late summer at two-week intervals. The-se transects were not marked at regular intervals, but were usually delineated by natural habitat boundaries, and were censused similarly on each visit, obtaining comparable bird density data. At other locations away from the main study sites, usually observed on only one occasion, unmarked transects were chosen in areas of representative littoral habitats, and these were censused comparably.

B. Tundra breeding bird surveys. For purposes of comparison of breeding bird communities between sites and measurement of seasonal habitat shifts in bird activities at each site, breeding bird surveys were obtained at Wales and Cape Krusenstern. (Breeding bird communities are well known at Barrow (Myers and Pitelka 1975 a, b; Myers et al. 1977 a, b)). Rectangular gridded study areas, overlapping the established tundra transects, were censused every five days; we attempted to locate all nests on the grids, Grid sizes were 29.8 ha at Cape Krusenstern and 25 ha at Wales.

C. Habitat descriptions. For all marked transects at the three primary study sites, we characterized littoral habitats, by plot, according to this outline:

A. Major landform
    1. Barrier Island, protected shore
    2. Barrier Island, exposed shore
    3. Spit, protected shore
    4. Spit, exposed shore
    5. Protected tundra shore
    6. Exposed tundra shore
    7. River inlet
    8. Closed lagoon
    9. Tidal slough

B. Habitat form
    1. Beach backed by gradual slope
    2. Beach backed by cliff-bank

3. Beach backed by sand dunes
4. Littoral flat (mudflat/saltmarsh/gravel flat)
5. Salt-burned tundra (rarely flooded)
6. Eroding tundra bank

C. Distance from shore: distance from center of 50 m plot to nearest major shoreline (ocean, lagoon, river)

D. Width of normal flood zone. From mean water level to highest level inundated during most years. Determined by recent driftwood lines and by vegetation.

E. Width of maximum flood zone. Determined by highest driftwood line.

F. Water cover. Per cent of the 50 m plot covered by water. Omitted for beach transects.

G. Salinity.

H. Exposed substrate. Classify by major type, as mud, fine sand, coarse sand, fine gravel, coarse gravel.

I. Vegetative cover. Per cent of exposed area.

J. Major plant taxa. List one to several taxa in order of abundance (area covered), to account for at least 80% of vegetative cover.

E. Trophic studies. At Barrow, Wales, and Cape Krusenstern, we collected shorebirds for stomach analysis and fat level information to complement our previous studies. Collection methods (by shotgun followed by immediate injection of formalin fixative solution in the field) were described in Connors and Risebrough (1976).

Plankton net samples were collected at several locations at each of the three main study sites in July, August and September, at 10-day intervals when shoreline conditions permitted. 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 subsequent sample analysis were also as described previously.

VI and VII. Results and Discussion

Appendix 1 provides avifaunal lists for 1977 for Wales and Cape Krusenstern. A detailed avifaunal list for Barrow has recently been published (Pitelka 1974); therefore one is not included here.

Comparative Phenologies

Phenologies for Wales and Cape Krusenstern are presented in

Appendices 2 and 3, and are compared with that of Barrow in Table 5. All three sites had temperatures average to above average and rainfall well below average during summer 1977. At Barrow, sea ice conditions were much less severe than in 1975 and 1976. Ice first moved away from shore in early July, providing shoreline foraging for phalaropes considerably earlier than in previous seasons. Snow melt and plant phenology at Cape Krusenstern preceded that of Wales and Barrow by 2 to 3 weeks, but differences in timing of bird events averaged about 6 to 10 days between Cape Krusenstern and the other two sites. Comparison of Cape Krusenstern 1977 phenology with 1976 data for Cape Espenberg (Mickelson et al. 1977), two locations which might be expected to compare closely within a season (Figure 1), suggests that in 1977 flowering events were considerably advanced, by perhaps as much as 14 days. Bird nesting, however, apparently did not advance comparably; timing of bird events may be controlled by conditions and requirements during migration as well as on the breeding grounds.

The comparative phenologies of these three coastal sites are not simply explained by latitudinal differences. The southernmost station, Wales, has temperatures similar to, and phenology slightly behind, Barrow. Coastal geography and wind directions in spring and early summer are probably important factors. The great angular exposure of Wales to winds blowing over ocean ice compared to the lesser angular exposure and resultant wind component blowing over insolated land at Cape Krusenstern probably account for the large difference between these two sites (Table 5).

Breeding Densities

Table 6 compares breeding bird densities at the three main study sites and at Meade River (Atkasook) inland on the coastal plain south of Barrow. With only a single season's data at Cape Krusenstern and at Wales (additional data are available for Barrow in other years), differences between the three outer coastal sites do not appear significant. Inland at Meade River, however, densities appear considerably higher. Contributions to this difference arise both from a greater number of nesting species and from higher densities of several species common to both inland and coastal sites.

Littoral Habitat Densities at Different Sites

In Table 7, shorebird densities measured on transects in littoral habitats at the three main study sites (Barrow, Wales, and Cape Krusenstern) are compared with densities at three supplementary sites visited during three periods July through September. Not surprisingly, densities of shorebirds on mudflats and along shores in late summer occasionally exceed by a considerable amount the densities of nests during the breeding season on the tundra. These are average densities over all littoral habitats represented at each study site. Shoreline transect densities are calculated using a 50 m transect width. Densities at all sites except Wales, the southernmost location, decreased in the final period. The higher density at Wales results from an influx of Dunlins, a species which remains late in the Arctic.

Table 5 Comparison of 1977 weather and phenology at three Alaska coastal sites.

	Cape Krusenstern	Wales	Barrow
Latitude	67°08'N	65°38'N	71°17'N
Surrounding landmass (% of compass points)	33%	21%	29%
% of winds from land, 1-15 June	14%	7%	17%
Temp: Avg. maximum °F	51.7	39.8	38.0
Avg. minimum °F	32.9	32,3	30.1
Mean °F	42.3	36.1	34.1
Relative Phenology			
Snow melt	0	+20 days	+ 16 days*
Plant flowering	0	+ 17 Days	+ 17 days*
Bird nesting	0	+ 10 days	+ 6 days*

*from data of J. P. Myers

Table 6 Comparison of breeding densities at arctic coastal tundra sites, 1977.

	Total pairs, hectare	Shorebird pairs/hectare	Number of species nesting	Reference
Barrow Plot 1	1.10	.67	10	Myers *et al.* 1978a
Barrow Plot 2	1.10	.69	11	" 1978b
Meade River	2.72	1.45	18	" 1978c
Cape Krusenstern	1.33	.48	14	Connors and Connors 1978
Wales	1.16	1.00	8	Hirsch and Woodby 1978

Table 7 Total shorebird densities in littoral habitat at study sites. Birds/hectare. ( ) = densities of Red Phalaropes.

	30 July to 8 August	14 August to 23 August	29 August to 7 September
Okiktok	6.3	9.1	3.4
Barrow	5.5	21.5 (19.2)	1.4
Peard Bay	5.4	3.7	1.0
Icy Cape	21.7 (14.2)	8.4	.9
Cape Krusenstern	4.3	1.7	.8
Wales	4.6	1.5	5.2

The two highest densities in Table 7 (Icy Cape, first period, and Barrow, second period) result from heavy shoreline populations of Red Phalaropes. Cape Krusenstern and Wales, lacking a heavy phalarope migration (see below) never attain shorebird densities comparable to some of the more northern sites. However, other sites in the Kotzebue Sound and southern Chukchi area are extensively used by large populations of shorebirds during the late summer period. Although surveys of this large area are seriously incomplete at present, the Noatak Delta, Cape Espenberg, and the regions around Shishmaref emerge as potentially very important.

Shishmaref Barrier Strip Shorebird Densities

On 17 and 18 August 1977, we conducted an aerial reconnaissance of the lagoon barrier strip on the north shore of Seward Peninsula running from Kividlo, east of Shishmaref, to the west end of Arctic Lagoon, west of Shishmaref. Areas in southern Kotzebue Sound, and especially at Cape Espenberg, have been studied by Mickelson et al. (RU #441), but we have almost no information about bird densities on the Seward Peninsula barrier strip. This strip, 130 km long by about 1 km in width, comprises an extensive area of littoral habitats of potentially high use by shorebirds and waterfowl and potentially high vulnerability to oil spills. Typically, this strip consists of a wide sand beach backed by dunes, grading to Carex and Puccinellia saltmarsh and mudflats on the lagoon (south) side. Large areas of sand or mud tidal flats occur near most of the lagoon inlets.

The aerial survey presented a rough estimate of the distribution of bird densities on the dates of the survey. Landings at four sites permitted ground identification and density estimates for 17 transects, each 100 m wide, varying in length from 350 m to 1750 m. These were distributed among four habitat classes, based principally on an intuitive estimate of the level of usefulness of habitats to shorebirds in general. Class A habitat consists of mudflats, shallow muddy pools and saltmarsh with wet mud margins. Class B habitats, usually farther from the lagoon edge, includes thickly vegetated saltmarsh with fewer ponds and less exposed wet mud. Class C consists of dried ponds, upland tundra, dunes and high beach areas, and class D refers to the ocean beach shoreline.

Table 8 lists the densities of birds recorded on these walking, transects, which permit us to estimate total numbers of birds on the entire barrier strip. We assume the 130 km long strip averages 1 km in width and is composed of equal areas of habitats A, B, and C, plus a linear strip of habitat D. Resultant populations on 17, 18 August are calculated to be approximately 300,000 total birds, of which 22S,000 were shorebirds. Note that this estimate does not include the potentially large numbers of gulls, seabirds, and waterfowl on the waters of the lagoons or the ocean, or the shorebirds on the mainland shore of the lagoons. We do not know whether this period represents peak annual densities; use by shorebirds and waterfowl may remain high from mid-July through late September. These numbers represent very significant populations of many species utilizing littoral habitats which are susceptible to oil spill damage.

Table 8. Bird densities on the Shishmaref barrier strip, Seward Peninsula, 17, 18 August 1977. Mean density (range).

Habitat	Number of transects	Shorebirds/ha	Total Birds/ha
A	7	44 (15-70)	50 (18-76)
B	4	7.5 (3-15)	12.5 (9-17)
C	2	.1 (o-.2)	5.2 (.4-10)
D	4	1.5 (o- 3)	1.5 (o- 3)

Averaging the densities in the three clearly littoral habitats (A, B, and D) to obtain a figure comparable to shorebird densities given in Table 7, we obtain an average littoral habitat density of 17.7 shorebirds per hectare on the Shishmaref Barrier Strip. This figure contains almost no phalaropes and represents by far the highest densities of mudflat and saltmarsh foraging shorebirds over any large region studied. Species present totaled 13; most common species were Golden Plover, Long-billed Dowitcher, Dunlin, Western Sandpiper and Pectoral Sandpiper.

Colony Locations

We located several small scattered colonies (five to approximately 100 pairs) of three seabird species (Glaucous Gull, Arctic Tern and Aleutian Tern) and possibly a fourth species, Mew Gull. All data have been submitted to the U.S. Fish and Wildlife Service, Alaska Bird Colony Register. Four small colonies of the Aleutian Tern at sites north and south of Cape Krusenstern represent a northward extension of the known breeding range.

Trophic System Contrasts Between Areas

For some species (Long-billed Dowitcher, Sanderling, *Larus* gulls) habitat use and population movements compared more closely between Wales and Barrow than between Cape Krusenstern and these two sites. In general, however, Wales and Cape Krusenstern are more closely allied ornithologically. Our previous studies supplemented by 1977 work near Barrow and at other sites in the northern Chukchi and Beaufort identified a heavy late summer movement of shorebirds to littoral habitats. The trophic system (entire food web) supporting the highest concentrations of shorebirds, gulls, and terns along these coasts involved marine zooplankton along shorelines, especially of spits and barrier islands. In contrast, at the study sites in the southern Chukchi, marine zooplankton contributes little to the overall energy base of shorebirds in these areas. Instead, shorebird littoral zone activity is highest on mudflats and in saltmarsh areas where the food source is benthic infauna. These habitats are also used to a considerable extent in the early summer. The pattern of heavier use of littoral habitats in late summer, especially by juvenile shorebirds, holds for both areas, however.

Shorebird Seasonal Habitat Use

We present bar graphs of bird densities recorded on transects in 5-day periods throughout the study season, to illustrate the seasonal changes in population density and habitat use for species and groups of species, contrasting the different study sites when appropriate. Open-ended bar-graphs indicate the beginning or end of the transect census season with species density greater than zero. In two previous annual reports, equivalent data were presented as actual transect census totals rather than densities. We hesitated to use densities in this case because of spatial differences in bird use between habitats: along shorelines most shorebird activity is concentrated within a narrow strip and is best calculated as a linear density. In contrast, mudflat and tundra habitats require areal densities. Because transect dimensions in both habitats at the Barrow study site remained constant throughout the season, transect census totals allowed seasonal comparisons in use of tundra and littoral habitats; at the same time they showed directly the numbers of individuals occurring along our transects.

In this report we convert all census totals to areal densities, using the standard width of 50 m to compute densities along shoreline transects. We adopt this procedure to facilitate comparisons between our main study sites, which differed in relative coverage of tundra vs. littoral habitats. This also permits easy comparison with densities reported from other studies, but only if care is taken to adjust for the effect of different transect widths used in shoreline transects. For example, 10 Sanderlings feeding at the shoreline in 1 km of an ocean beach transect may be reported as 10 per km (linear density), 200 per km2 (areal density on 50 m wide transect), or 1,000 per km^2 (areal density on 10 m wide transect).

Comparisons of bird densities in different habitats appropriately portray the differences in expected effects arising from the disturbance of equal areas of these different habitats. However, to appreciate the total population dependence on a particular habitat, we must consider the total area of that habitat relative to others. In the local Barrow study area, for example, tundra habitats cover approximately 13 times the area of littoral habitats (Connors _et al._ 1978). Thus, equal densities in both habitats imply that 93% of the population is found on tundra sites.

A. Total Shorebird Densities

Our studies at Barrow have identified a clear and pronounced seasonal shift in habitat use by shorebirds, from predominantly tundra habitat in early summer to heavily littoral areas in late July, August and September. In Figure 5 we present data for Barrow, 1976; 1977 data were similar but littoral transects were not censused in the early summer. The extremely high August densities in Figure 5A represent

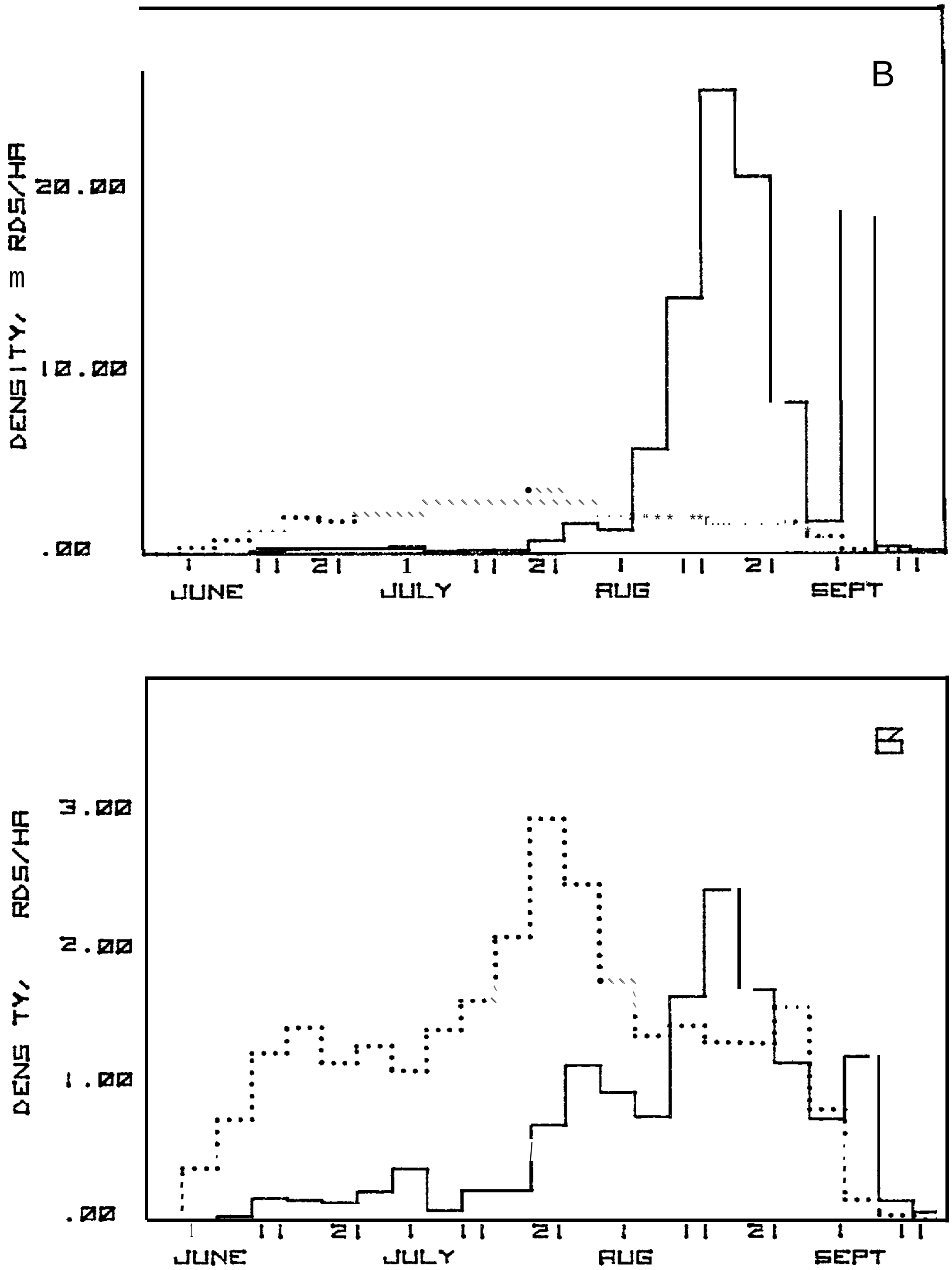


Figure 5. Transect densities, Barrow, 1976. A. Total shorebirds. Littoral (solid) vs. tundra (dotted). B. Total shorebirds excluding Red Phalarope. Littoral (solid) vs. tundra (dotted).

primarily the contribution of juvenile Red Phalaropes foraging along ocean beaches. In Figure 5B, the same transect data excluding all Red Phalaropes show the same seasonal shift in habitat use, but densities in littoral habitats of these species are comparable to densities on the tundra in *late* summer.

Figure 6A and 6B provide the total shorebird density comparisons for Wales and Cape Krusenstern, respectively. Densities at Wales show an apparent shift toward the littoral in late summer, but peak densities are less than at Barrow. Wales densities include, however, very few phalaropes; Western Sandpipers and Dunlins account for the largest contributions. At Cape Krusenstern, in contrast, the late season habitat shift did not occur. Outer coast shores with zooplankton as a food source were used very little 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 moved to areas of more extensive mudflat and saltmarsh, such as the Noatak Delta, Cape Espenberg, and the Shishmaref Barrier Strip on Seward Peninsula, as noted above.

B. Species Accounts

These results will be presented as discussions of individual species or groups of species. Since seasonal patterns for all species at Barrow in 1975 and 1976 have been presented in the two prior annual reports, only those habitat use and distributional features differing in 1977 at Barrow or at the southern Chukchi sites will be discussed. Rare or accidental species are listed in Appendix 1, and are not discussed here.

1. Semipalmated Plover (Charadrius semipalmatus). Uncommon at all three sites'. Nested at Barrow and Cape Krusenstern.

2. American Golden Plover (Pluvialis dominica). Common as a breeder and migrant at all *sites.* However, habitat use patterns differed markedly between Barrow and the two southern Chukchi sites. Figure 7A compares the seasonal census data for tundra and littoral transects at Barrow in 1976 (chosen in preference to the similar 1975 and 1977 seasons only because the 1976 data were complete for the entire season). The minimal use of littoral habitats by this species along the Beaufort coast results in a rating of low susceptibility to disturbances related to outer continental shelf oil development there (Table 16).

   However, this clear pattern of habitat use changes abruptly for the same species (and possibly the same individuals) farther south in the Chukchi. At Wales, Cape Krusenstern, and Sesualik on the Noatak Delta, non-breeding and post-breeding adults and migrant juveniles forage in high concentrations on mudflats and the muddy

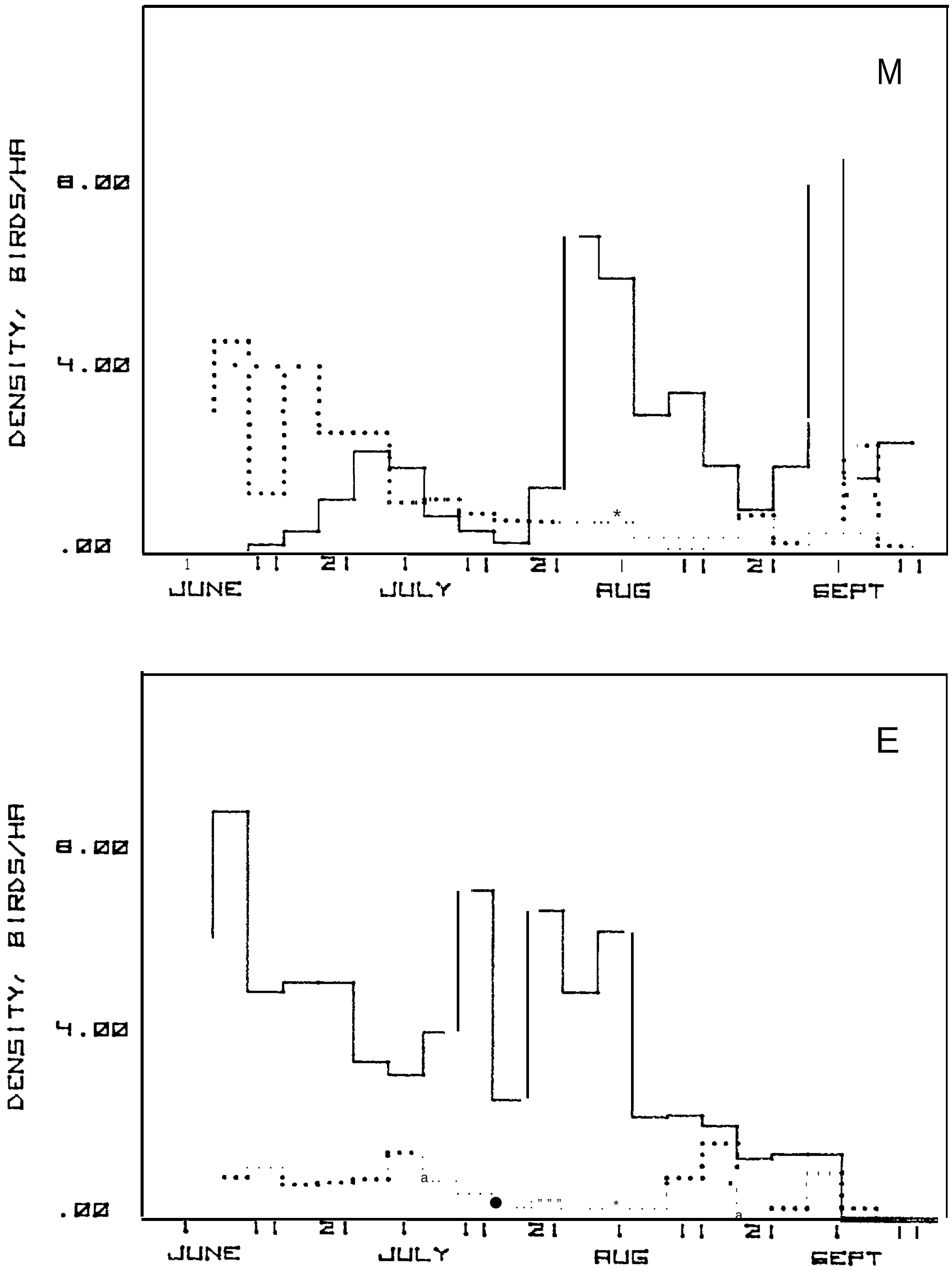


Figure 6. Transect densities, 1977. A. Wales, total shorebirds. Littoral (solid) vs. tundra (dotted). B. Cape Krusenstern, total shorebirds. Littoral (solid) vs. tundra (dotted).

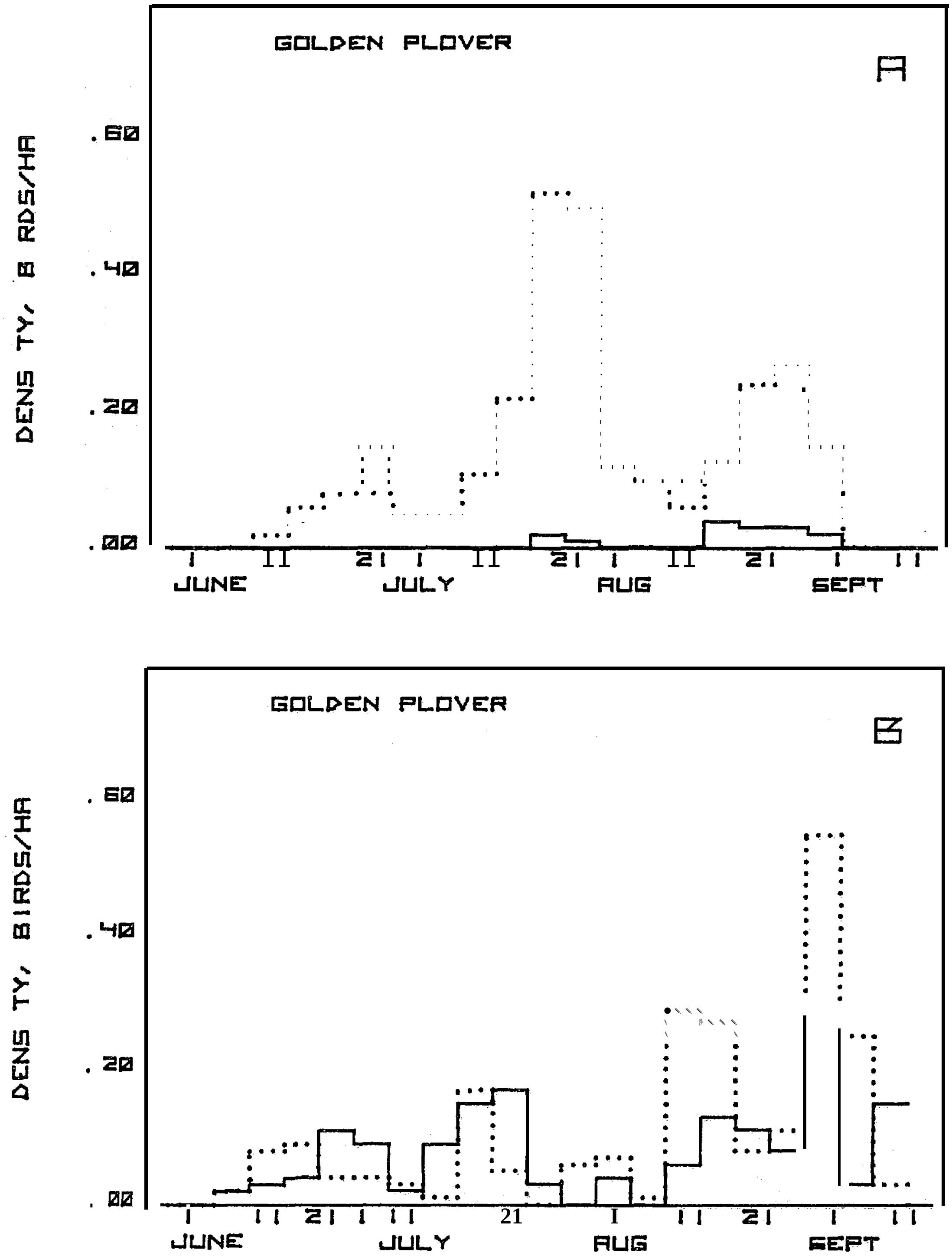


Figure 7. Transect densities, Golden Plover. A. Barrow, 1976. Littoral (solid) vs. tundra (dotted). B. Wales and Cape Krusenstern, 1977. Littoral (solid) vs. tundra (dotted).

margins of sloughs, lagoons, and saltmarshes. Figure 7B compares tundra vs. littoral habitat transect census results, combining Wales and Cape Krusenstern data. This much heavier use of habitats more susceptible to oil-related perturbations argues for a higher susceptibility rating for Golden Plovers on the southern Chukchi coast.

3. Black-bellied Plover (*Pluvialis squatarola*). Fairly common in the Beaufort east of Barrow, in littoral habitats. Rare in the southern Chukchi, although one pair rested at Cape Krusenstern.

4. Ruddy Turnstone (*Arenaria interpret*). As in previous seasons at Barrow, this species moved heavily into littoral areas in August, becoming most common on the shores of Barrow Spit (Figure 8A). Buildup in 1977 occurred earlier, however, and began declining 5 to 10 days ahead of the 1976 schedule. Figure 9B separates the 1977 peak into adult and juvenile age classes. In 1976 fewer adults used shoreline areas before migrating southward. Nevertheless the juvenile migration in 1977 was considerably earlier than that in 1976. Ruddy Turnstones were uncommon migrants at Wales and Cape Krusenstern (Figure 9B).

5. Black Turnstone (*Arenaria melanocephala*). Present as migrants at both Chukchi sites. Juveniles were fairly common in August in littoral habitats.

6. Dunlin (*Calidris alpina*). A common breeder and migrant at all three sites. Comparisons of densities on littoral vs. tundra transects at Wales, Cape Krusenstern and Barrow in 1977 are shown in Figures 10 and 11. At Cape Krusenstern tundra densities are much lower than at Barrow and Wales during the breeding season. Much of the tundra transect area at Cape Krusenstern covered a series of old gravel beach ridges and intervening moist swales, a habitat which was used very sparsely by nesting Dunlins. Older beach ridge areas closer to Krusenstern Lagoon were more densely vegetated with grasses and sedges, with some polygonization, and were favored by Dunlins as nesting areas. Dunlins used littoral habitat somewhat more heavily in early summer at Cape Krusenstern and Wales than at Barrow. In August and September, Dunlins became extremely common in large mudflat and saltmarsh areas of Kotzebue Sound and the northern Seward Peninsula, as noted above. In 1977, Dunlins remained in moderate densities on mudflats of the Noatak River Delta until about 5 October (W. R. Uhl, pers. comm.).

The comparison of 1976 and 1977 densities at Barrow in Figure 11 A and B shows a similar pattern of density on tundra transects in both years but considerable variation between years in the movement to littoral areas in late summer. In 1977, high densities were reached considerably earlier than in 1976. This pattern was also exhibited by movements of male Red Phalaropes and adult Ruddy Turnstones to shorelines in late July and may relate to the comparatively mild ice season, with shoreline habitat available at an earlier date in 1977.

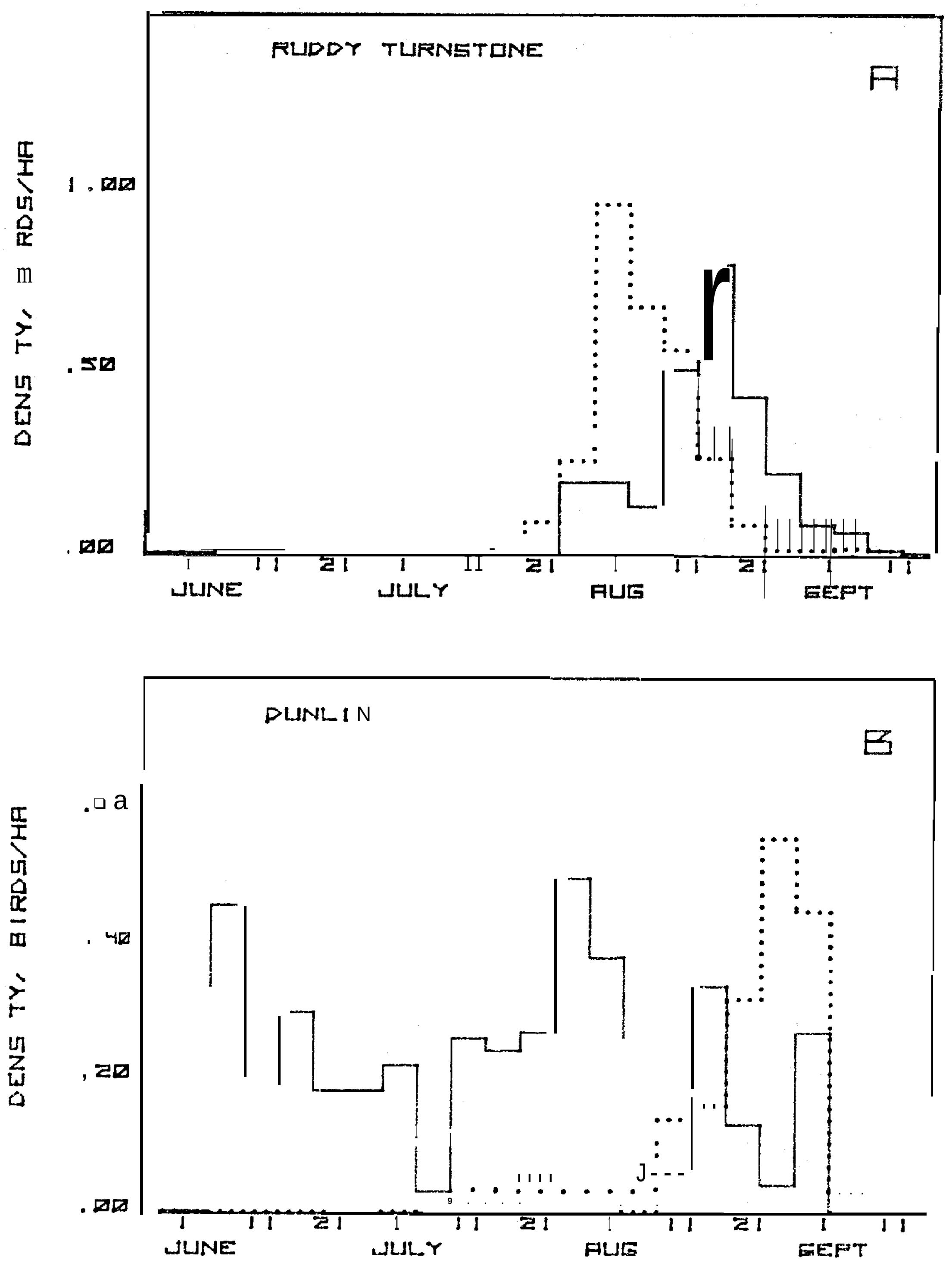


Figure 8. Transect densities, littoral. A. Ruddy Turnstone. Barrow 1976 (solid) vs. Barrow 1977 (dotted). B. Dunlin. Cape Krusenstern, 1977. Adults (solid) vs. juveniles (dotted).

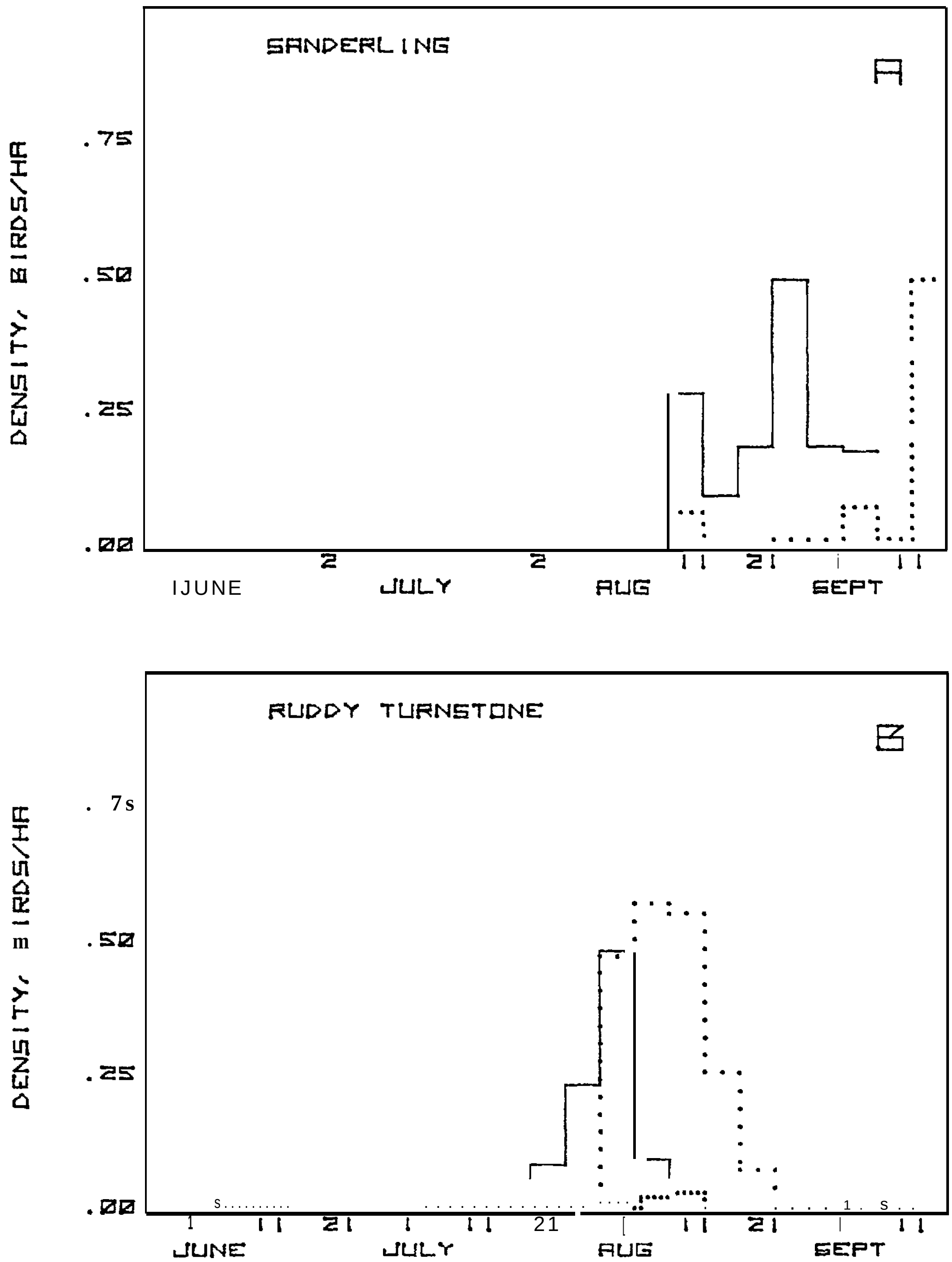


Figure 9. Transect densities, littoral, 1977. A. Sanderling. Wales (solid) vs. Barrow (dotted). B. Ruddy Turnstone. Barrow adults (solid) vs. Barrow juveniles (coarse dotted) vs. Wales and Cape Krusenstern, all ages (fine dotted).

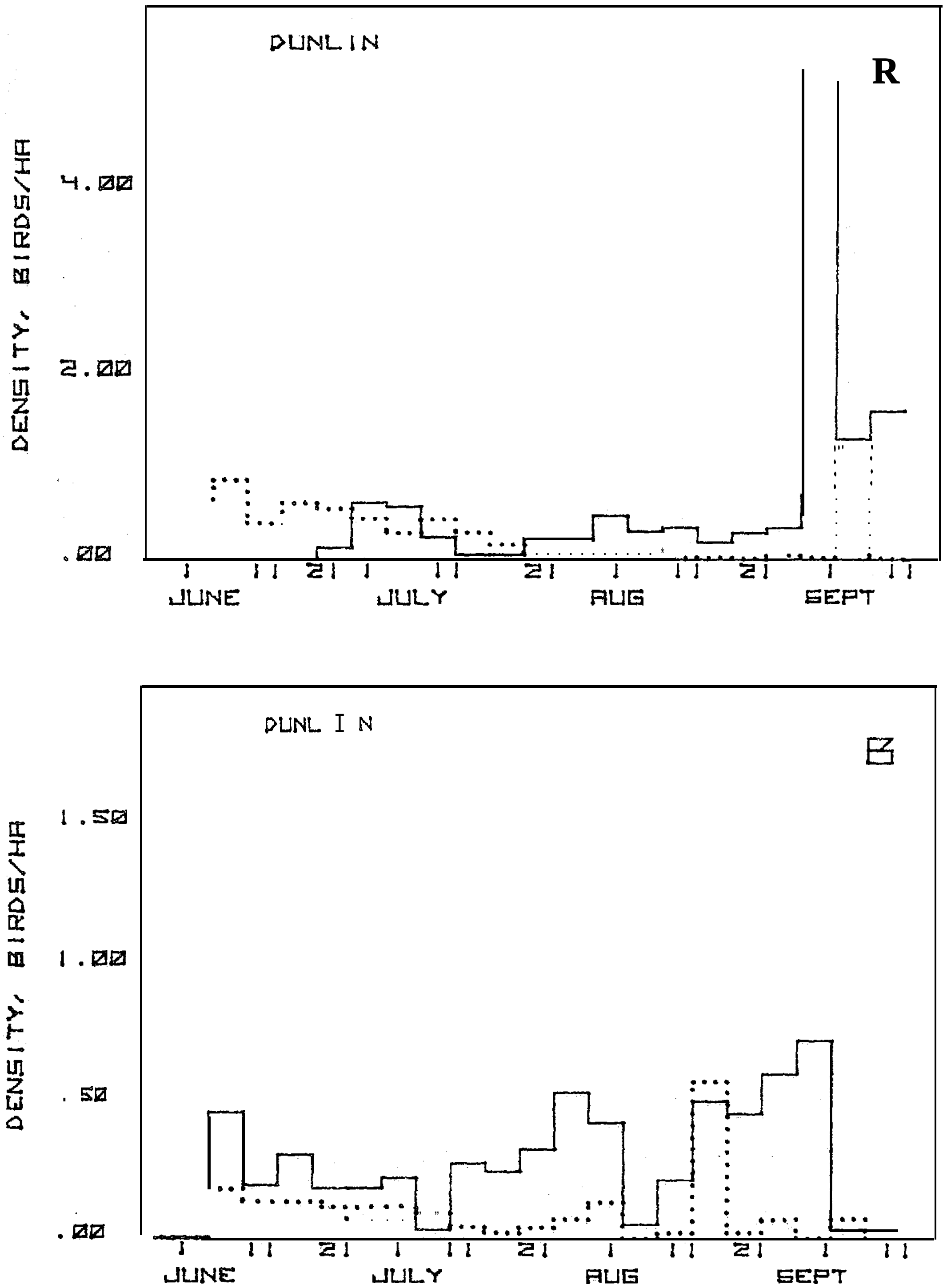
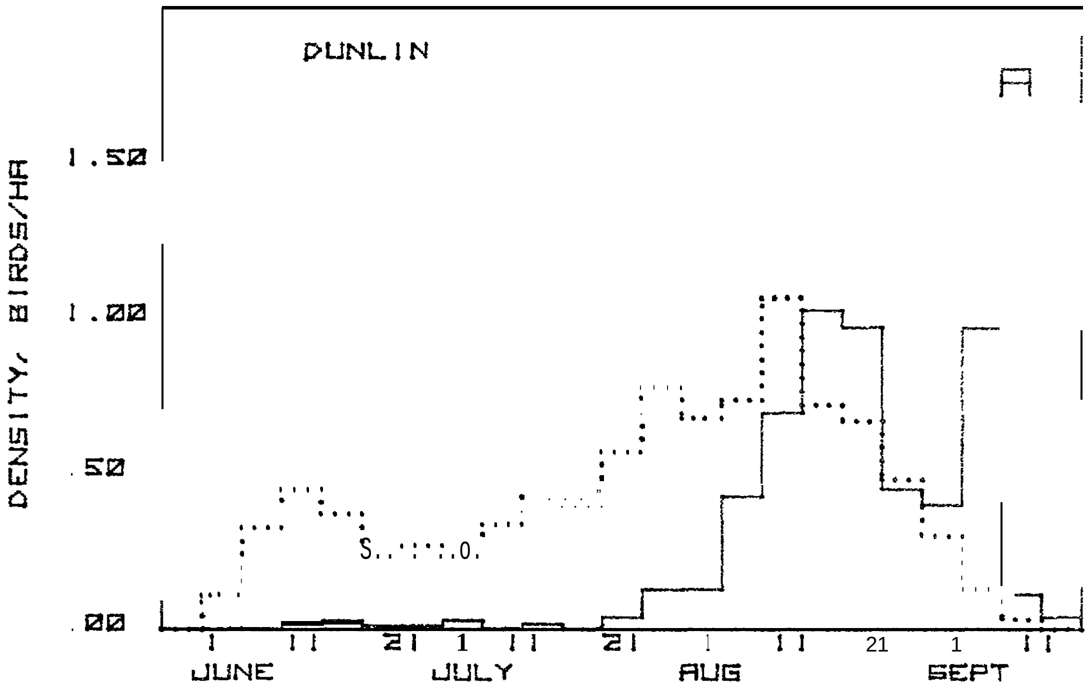


Figure 10. Transect densities, Dunlin. A. Wales. Littoral (solid) vs. tundra" (dotted). B.. Cape Krusenstern. Littoral {solid) vs. tundra (dotted).



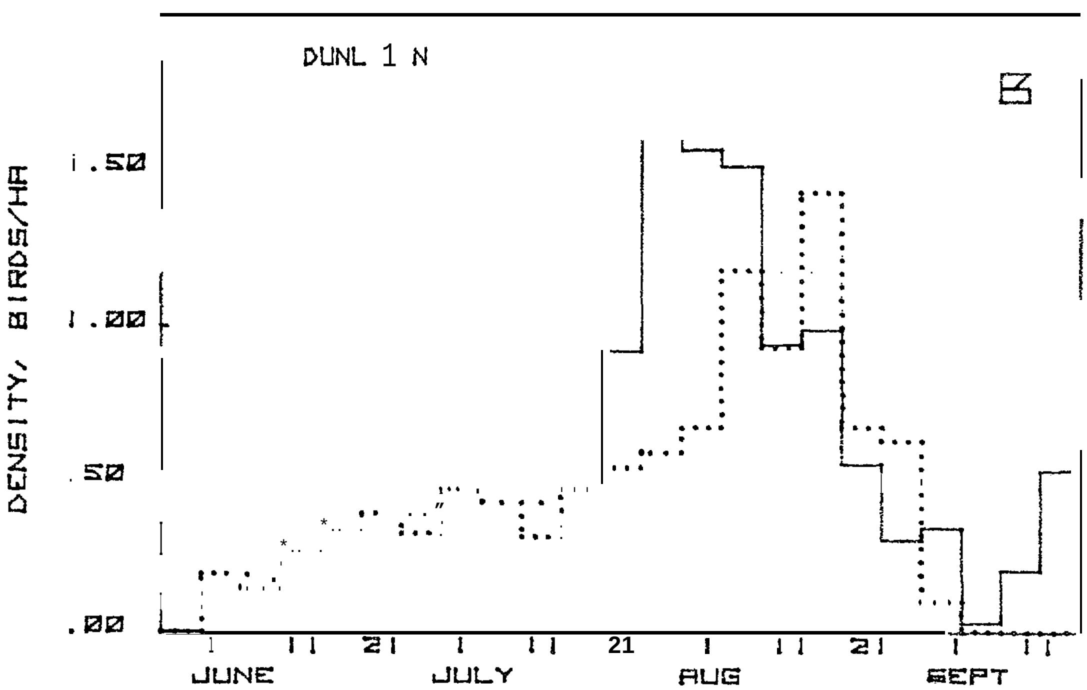


Figure 11. Transect densities, Barrow. A. 1976. Littoral (solid) vs. tundra [dotted). B. 1977. Littoral (solid) vs. tundra (dotted).

7. Red Knot (C. canutus). Adult and juvenile Red Knots were present in low densities as southbound migrants in late July and August on beaches of Cape Krusenstern and Wales. During this period no individuals were observed on tundra sites (Figure 12A).

8. Rock Sandpiper (C. ptilocnemis). Rock Sandpipers breed in low densities at Wales and move into littoral habitats in late summer prior to southward migration. One bird was seen at Cape Krusenstern in early summer .(Figure 12A).

9. Sharp-tailed Sandpiper (C. acuminate). A fairly heavy movement of juveniles of this species was evident at Wales at the end of August and first week of September. Birds foraged on tundra and in littoral areas. A few birds were seen during this period at Cape Krusenstern and moderate numbers were present on mudflats of the Noatak River Delta on September 2. This species nests in Siberia and winters in the central and eastern Pacific, but many juveniles apparently migrate eastward to forage on mudflats of Kotzebue Sound and Seward Peninsula before migrating southward (Figure 12B).

10. Pectoral Sandpiper (C. melanotos). Figure 13A gives the comparison of Pectoral Sandpiper densities on tundra and littoral transects at Barrow in 1976. The extremely low use of littoral habitats shown by these data results in our classification of this species as having low susceptibility to OCS disturbances (Table 16). The equivalent data for Wales and Cape Krusenstern 1977 (Figure 13B) contrast strongly, with very low densities on tundra throughout the season and occasional high densities in littoral areas. The contrast may not be as sharp as first appears, however. Figure 14A compares littoral transect densities for 1977 at Barrow vs. 1976 at Barrow and shows extremely heavy use of some littoral habitats by adult Pectoral Sandpipers during migration in July of 1977. It is clear that habitat use patterns for particular species can be quite variable from year to year, depending on interactions of resource conditions, habitat availability and timing of migratory movements.

11. Western Sandpiper (C. mauri). Western Sandpipers were fairly common at Barrow and very common at Wales and Cape Krusenstern. At all three sites relative use of littoral habitats by this species is high. Adults forage on mudflats and saltmarsh pool margins and the edges of littoral sloughs during the nesting season and prior to southward migration after breeding activities are completed. Juveniles move into these habitats in high densities in late July after most adults have left the Arctic (Figure 14B). Patterns of habitat use, age class movements, and densities in littoral habitats were quite similar at Wales and Cape Krusenstern sites (Figures 14B, 15A, 15B).

12. Semipalmated Sandpiper (C. pusilla). This species is also heavily dependent on littoral areas, using habitats similar to those of the Western Sandpiper. At Cape Krusenstern (Figure 16B) densities were higher on littoral transects throughout the season but the juvenile pre-migratory peak in late July reached densities only

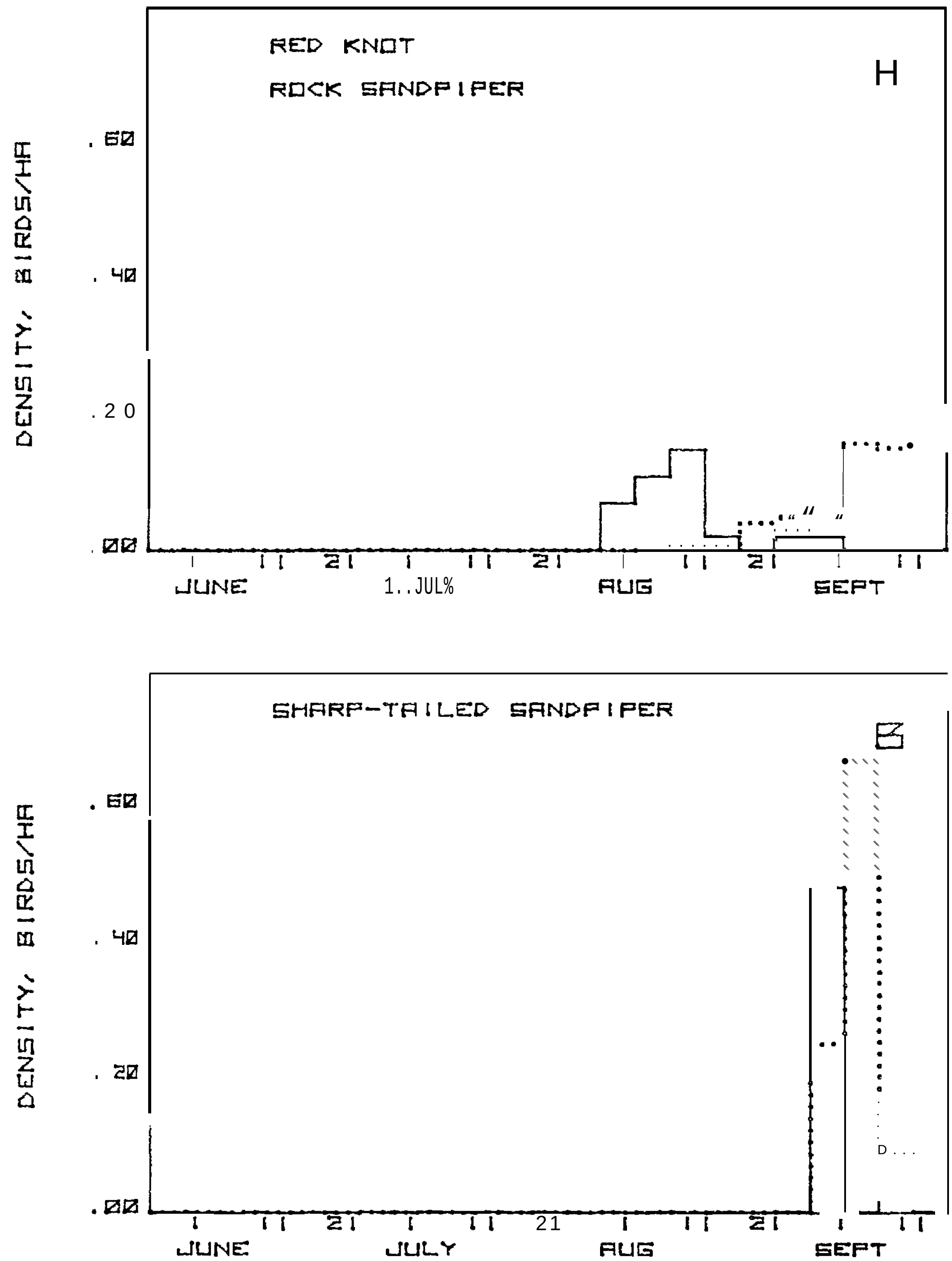


Figure 12. Transect densities, Wales. A. Red Knot, littoral (solid). Rock Sandpiper, littoral (dotted). B. Sharp-tailed Sandpiper. Littoral (solid) vs. tundra (dotted).

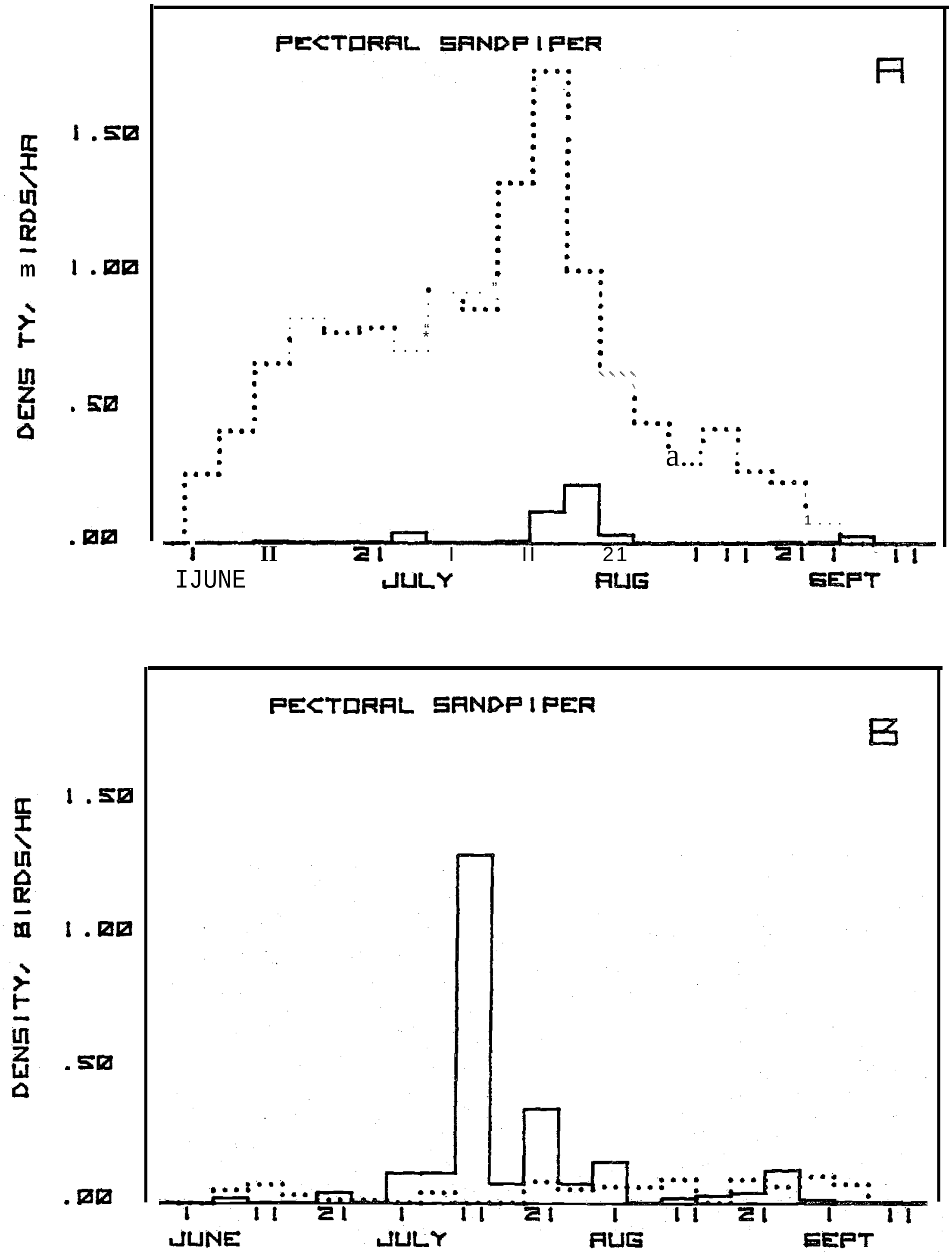
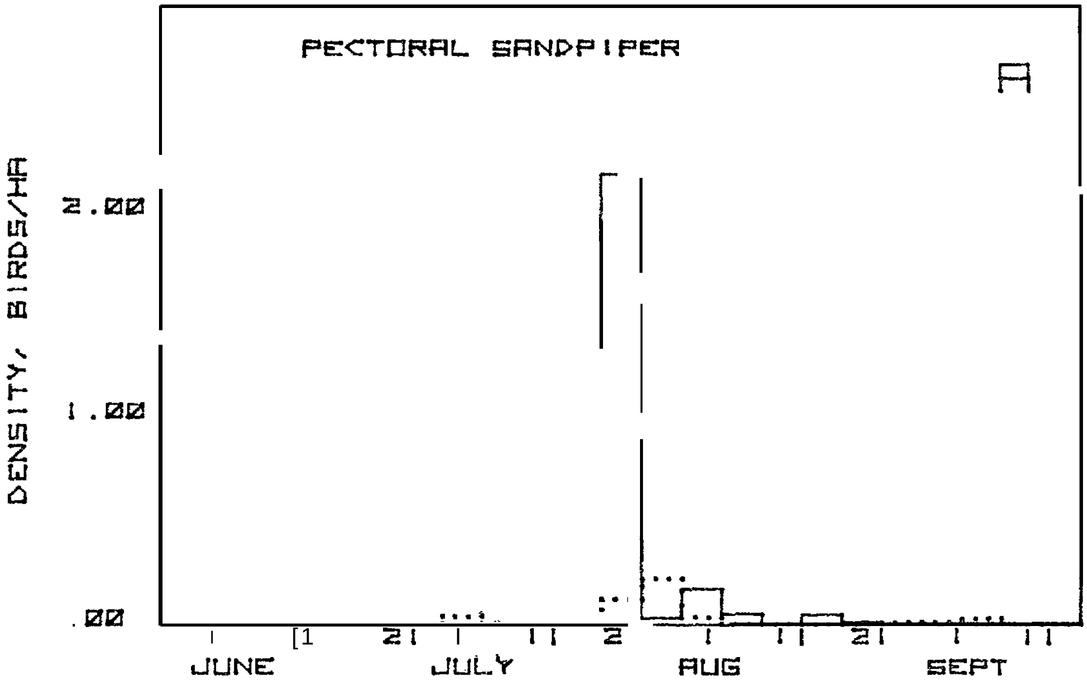


Figure 13. Transect densities, Pectoral Sandpiper. A. Barrow 1976. Littoral (solid) vs. tundra (dotted). B. Wales and Cape Krusenstern 1977. Littoral (solid) vs. tundra (dotted).



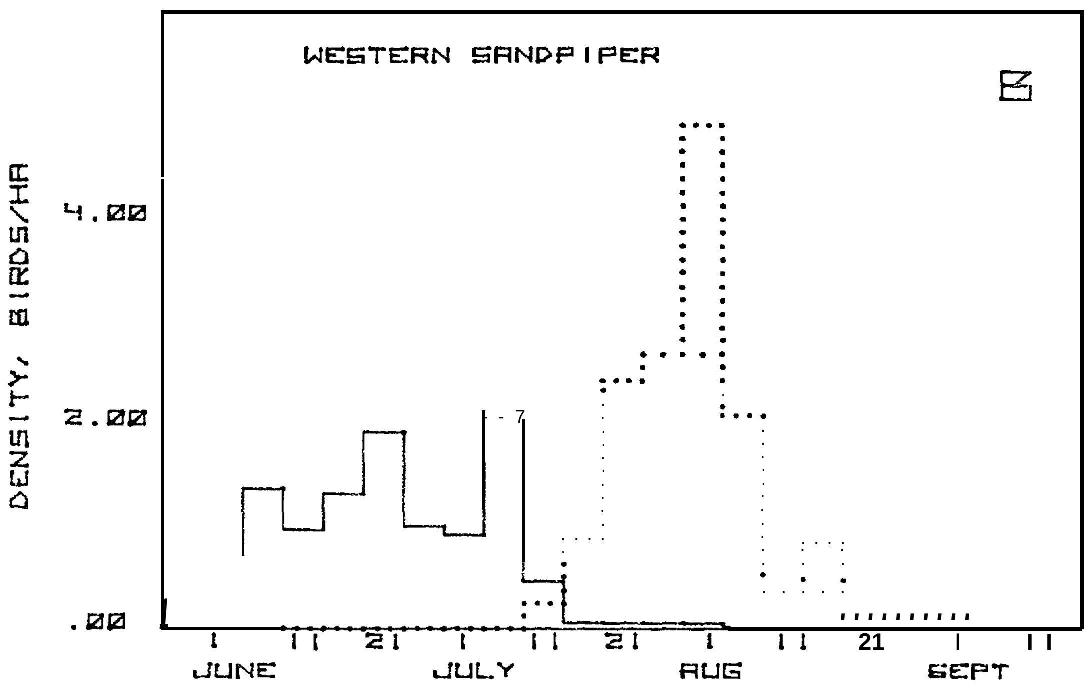


Figure 14. Transect densities. A. Pectoral Sandpiper, Barrow, littoral. 1977 (solid) vs. 1976 (dotted). B. Western Sandpiper, Cape Krusenstern, littoral, 1977. Adults (solid) vs. juveniles (dotted).

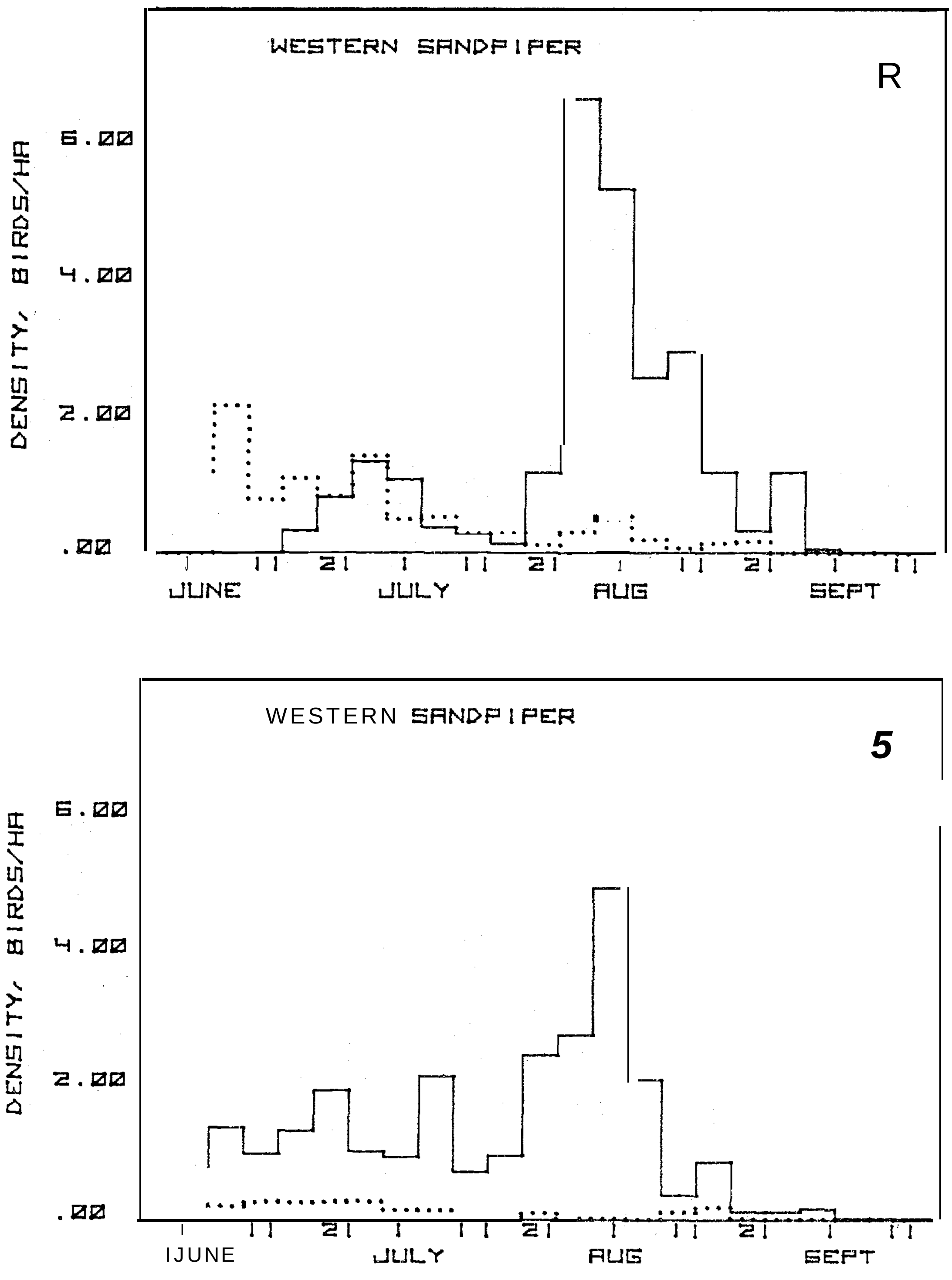


Figure 15. Transect densities, Western Sandpiper. A. wales.. Littoral (solid] vs. tundra (dotted]. B. Cap e Krusenstern. Littoral (solid) vs. tundra (dotted).

slightly in excess of adult densities in June on the same mudflats (Figure 16B, 17A). In contrast, the movement of juveniles into the littoral zone near Barrow was even heavier than in previous years (Figure 16A) and occurred 5 to 10 days later than the peak juvenile densities at Cape Krusenstern. Movements at Wales were similar to those at Cape Krusenstern but densities were much lower.

13. Baird's Sandpiper (C. bairdii). This species is common near Barrow and uses littoral habitats throughout the summer. Only two nests were found at Cape Krusenstern and few birds were seen during migration. At Wales no nests were located.

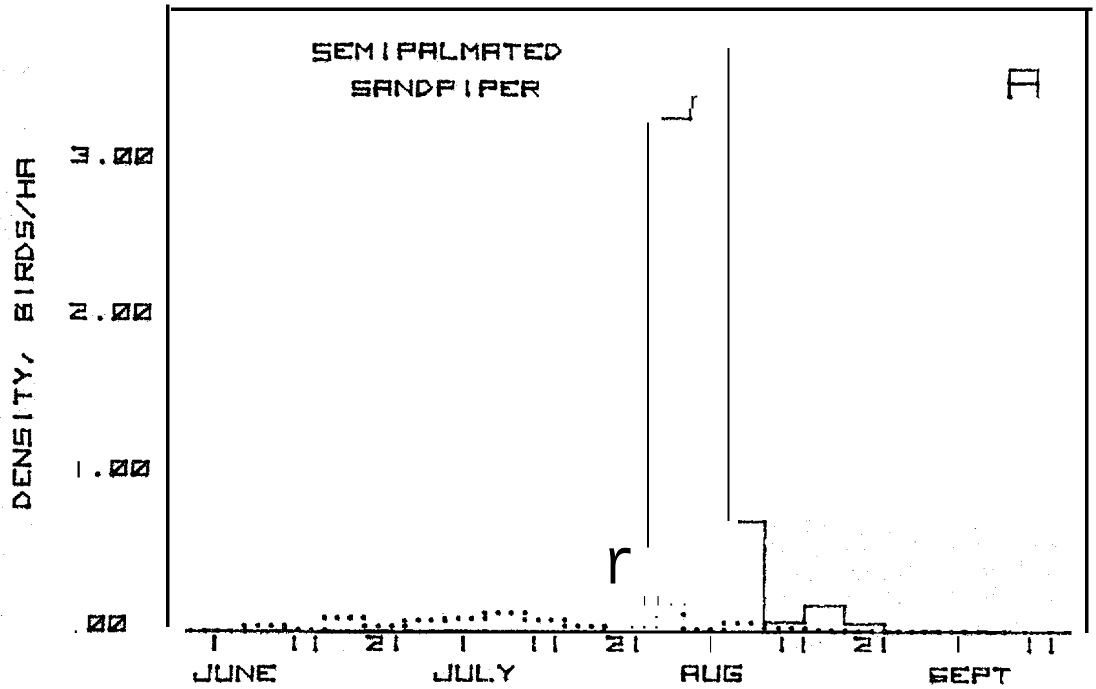
14. Sanderling (C. alba). Sanderlings have been a common late summer migrant along ocean shorelines at Barrow in all three years of this study. At Wales in 1977 one adult migrant and moderate densities of juveniles were present, with juveniles occurring considerably earlier than the late peak in Barrow in 1977 (Figure 9A). Sanderlings were uncommon late summer migrants at Cape Krusenstern.

15. Whimbrel (Numenius phaeopus). Whimbrels were rare at Barrow and Wales but common at Cape Krusenstern where migrant flocks occurred on tundra sites during late June and July. These birds seldom used littoral habitats. One nest was located at Cape Krusenstern.

16. Long-billed Dowitcher (Limnodromus scolopaceus). This species nests at all three sites. Wales (Figure 18A) and Barrow (Figure 19A) show a late August peak of migrant juveniles far in excess of densities recorded earlier in the year. At Cape Krusenstern, however, peak densities occurred with migrant flocks of post-breeding adults during July. The subsequent migration of juveniles at this site precedes in time the corresponding juvenile peaks at the other two sites.

17. Bar-tailed Godwit (Limosa lapponica). This species nested at Wales and probably did so at Cape Krusenstern, but in very low numbers at each location. Small flocks of migrants were present, however, in early and late summer, usually feeding in shallow, muddy areas.

18. Red Phalarope (Phalaropus fulicarius). On tundra transects Red Phalarope age and sex classes show a distinctly different timing of movements. Figure 19B for 1976 at Barrow shows the buildup of adult male and female nesting birds, followed by a migrational peak of post-breeding females. After nesting is completed, males migrate southward; fledged juveniles then gradually leave the tundra, moving to littoral areas before southward migration. Figure 20A compares densities on tundra and littoral transects for 1976 at Barrow, showing the extremely high densities reached by this coastwise movement of juveniles. At Wales and Cape Krusenstern in 1977, movements of this species contrasted sharply to those at Barrow in previous years (Figure 20B). In June low to moderate densities of this species occurred in tundra as well



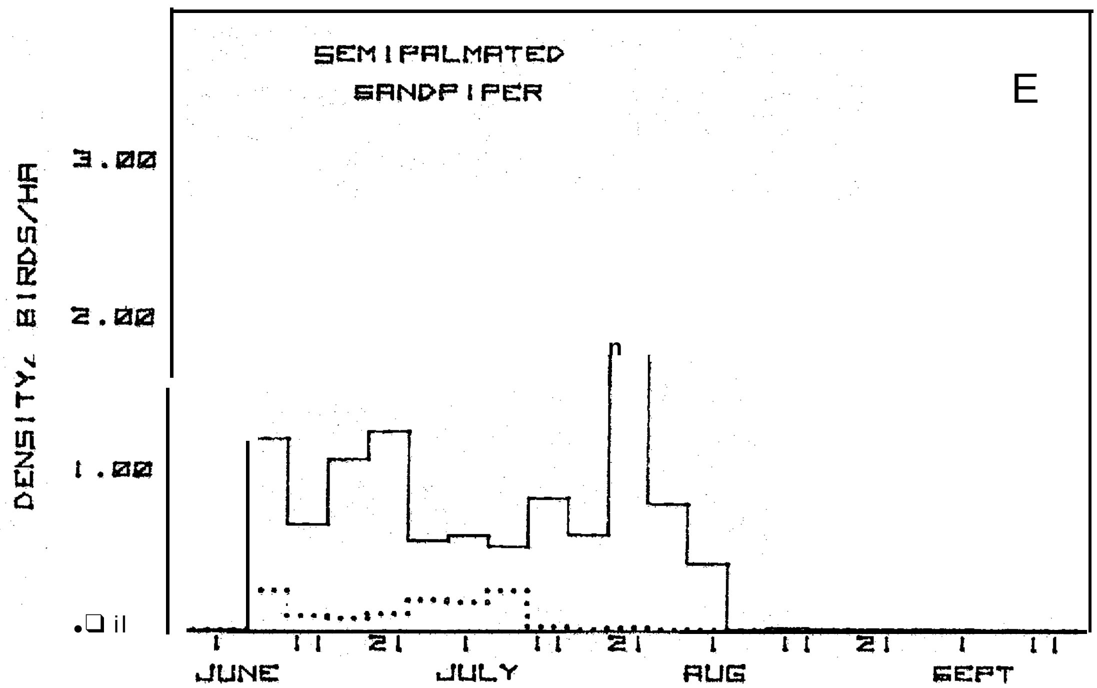


Figure 16. Transect densities, Semipalmated Sandpiper, 1977.
A. Barrow. Littoral [solid) vs. tundra [dotted).
B. Cape Krusenstern. Littoral [solid) vs. tundra (dotted) .

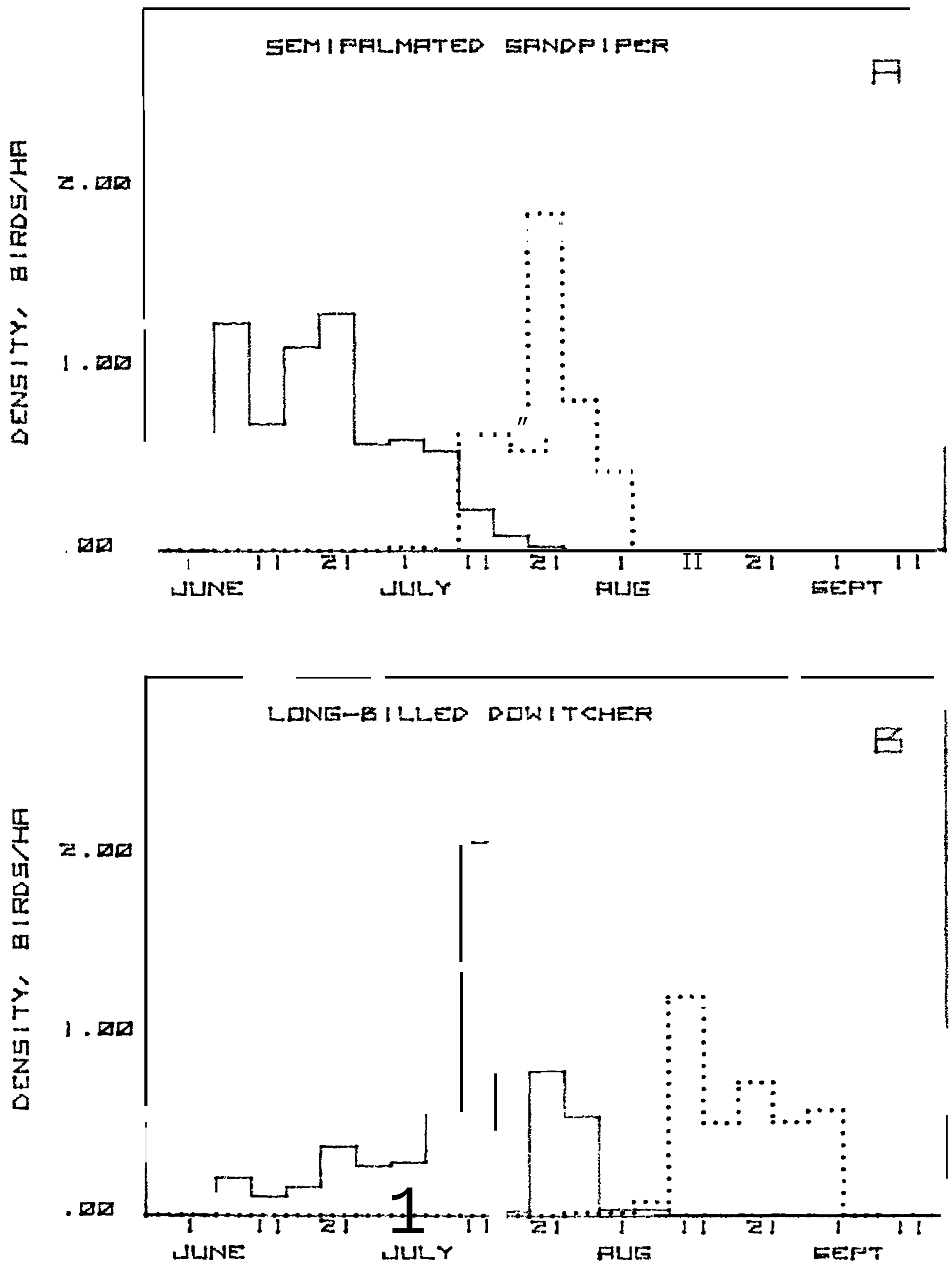


Figure 17. Transect densities, Cape Krusenstern littoral. A. Semipalmated Sandpiper. Adults (solid) vs. juveniles (dotted). B. Long-billed Dowitcher. Adults (solid) vs. juveniles (dotted).

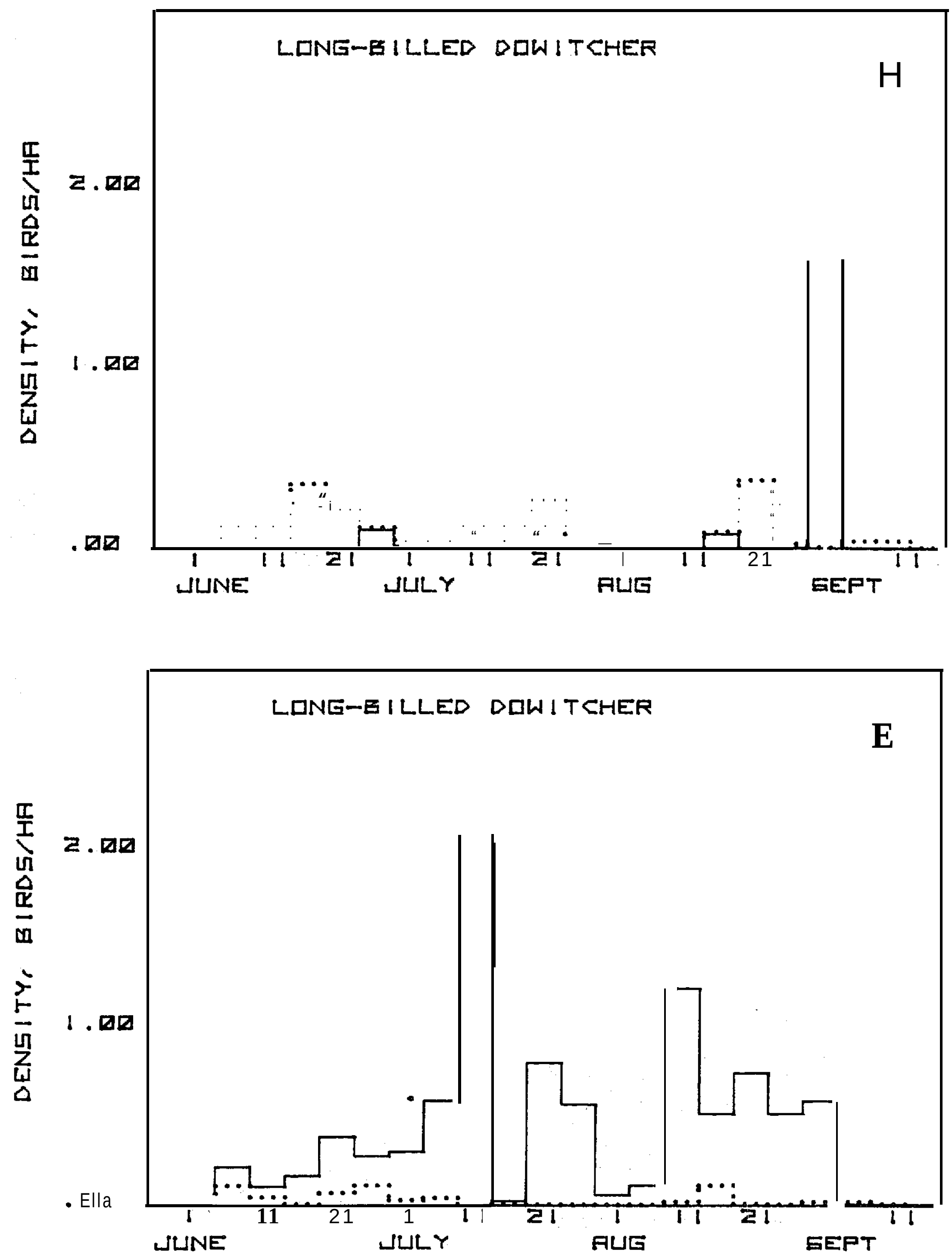


Figure 18. Transect densities, Long-billed Dowitcher. A. Wales. Littoral (solid) vs. tundra (dotted). B. Cape Krusenstern. Littoral (solid) vs. tundra (dotted).

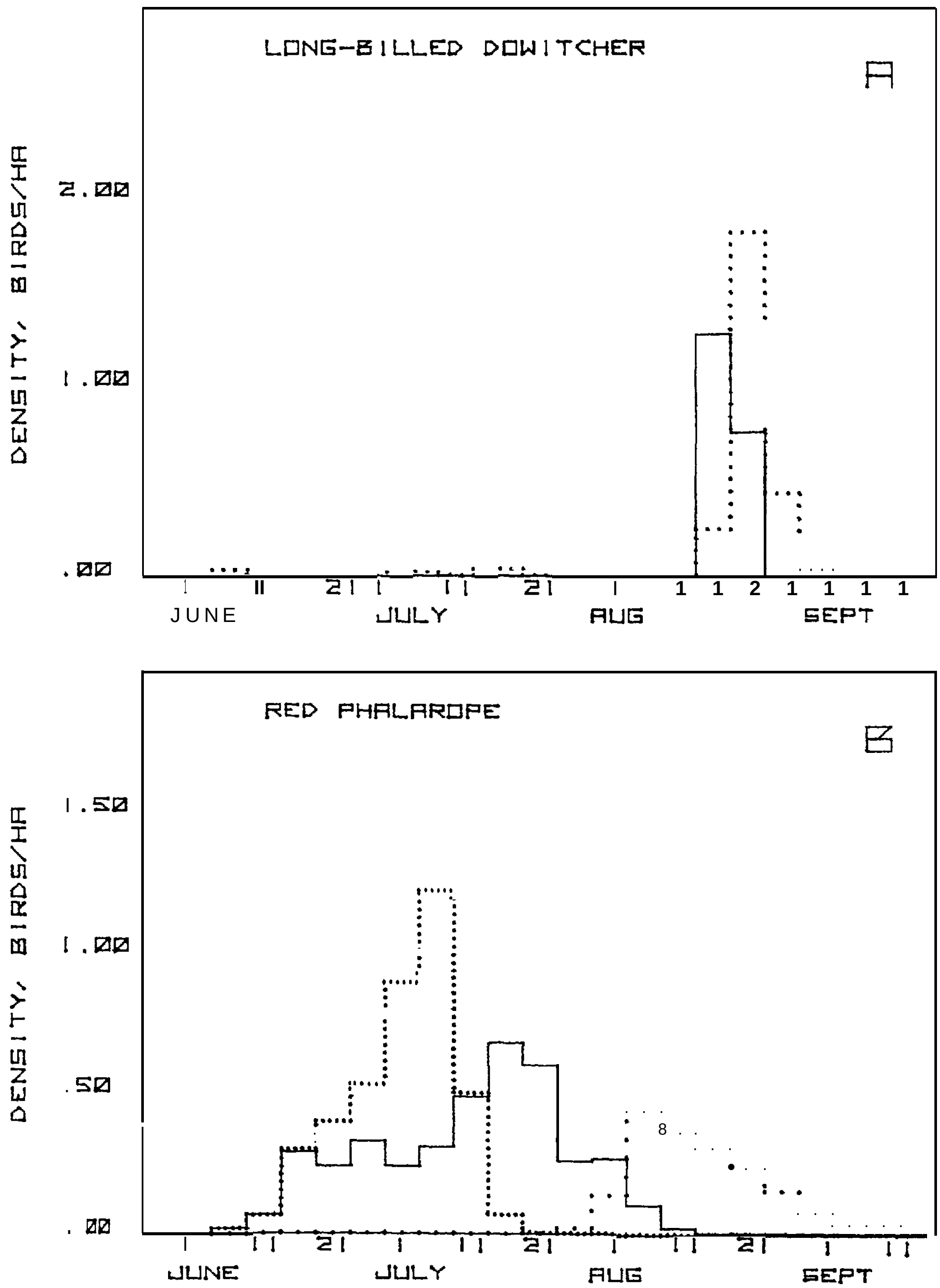


Figure 19. Transect densities, Barrow. A. Long-billed Dowitcher, 1977. Littoral (solid) vs. tundra (dotted). B. Red Phalarope, tundra, 1976. Adult males (solid), adult females (fine dotted), juveniles (coarse dotted).

as littoral sites, but no migrational peaks were evident at any time throughout the summer and densities after July 1 remained low. The dense concentrations of adult male and juvenile Red Phalaropes foraging on marine zooplankton along shorelines, which is so evident at Barrow and at other northern Beaufort and Chukchi sites, did not occur by September 7 at Cape Krusenstern, or by September 12 at Wales. Reports of local observers indicate that phalaropes can become more common in September after these dates (pers. comm.: Clarence Ongtowasruk, Wales; W. R. Uhl, Kotzebue).

Figures 21 A and B compare littoral zone densities at Barrow between 1976 and 1977 for adult males and juveniles, respectively. The juvenile movement was quite similar in both seasons. However, as discussed above, adult males moved to marine shores in heavier numbers and at an earlier date in 1977. This change probably arose from the early availability of shoreline foraging sites resulting from the mild ice conditions in 1977. The importance for OCS development of this contrast with the two previous seasons of our work arises from the potential exposure of the adult male cohort to littoral zone perturbations such as oil spills.

19. Northern Phalarope (Lobipes lobatus). Northern Phalaropes occurred at Barrow in extremely low densities in 1975 and 1976. In 1977, however, a heavy movement of juveniles occurred in mid-August, with most individuals foraging on brackish water copepods in Middle Salt Lagoon. This represents another strong contrast between seasons and leads us to add this species to the list of birds potentially affected by littoral zone disturbances in the Barrow vicinity (Table 15). Densities at Wales on both tundra and littoral transects were considerably less than the peak density at Barrow (Figure 22A). High densities in the littoral zone were recorded at Cape Krusenstern, however (Figure 22B), in early June. This pattern of early high density, progressively decreasing, is in marked contrast to the pattern of late season shoreline buildup of most other shorebird species. As noted under Red Phalaropes above, late season marine zooplankton foraging, such as is prominent in the Beaufort and northern Chukchi, did not materialize at Wales and Cape Krusenstern, and birds became progressively scarcer through the summer. The steady decline in density at Cape Krusenstern also correlates with a gradual drying of a brackish pond mudflat area on two transects and the predation-caused failure of approximately 25 Northern Phalarope nests on the borders of this pool area.

Other shorebird species occurring in lower densities are listed in Appendix 1. Some of these, occurring at Barrow, have been discussed in previous reports. Notes which follow address several species or groups of species which also use littoral habitat in our transect areas.

20. Loons (Gavia spp.). Loons, principally Red-throated and Arctic, occur at low densities at all three sites on tundra and in

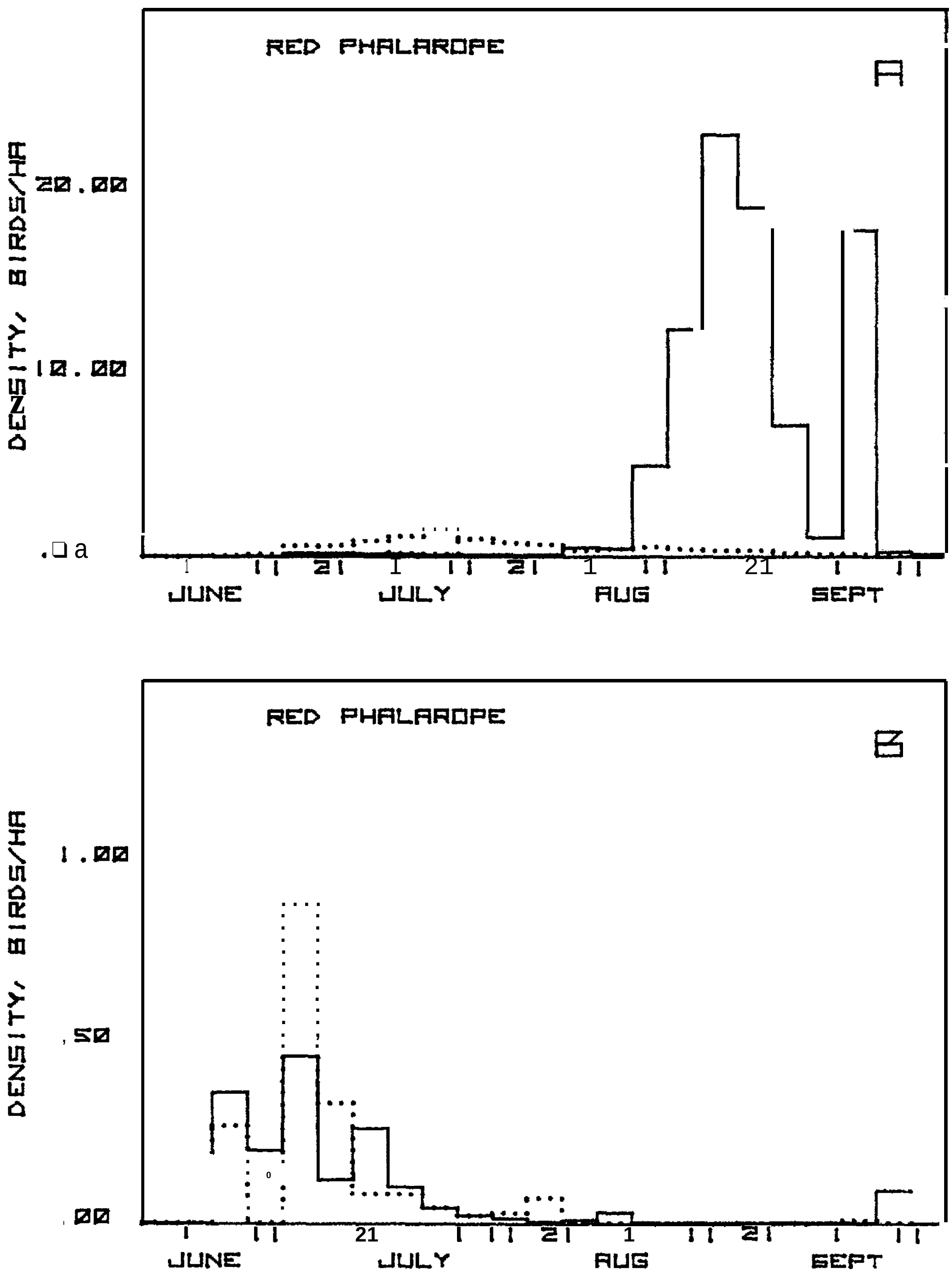


Figure 20. Transect densities, Red Phalarope. A. Barrow, 1976. Littoral (solid) vs. tundra (dotted). B. Wales and Cape Krusenstern 1977. Littoral (solid) vs. tundra (dotted).

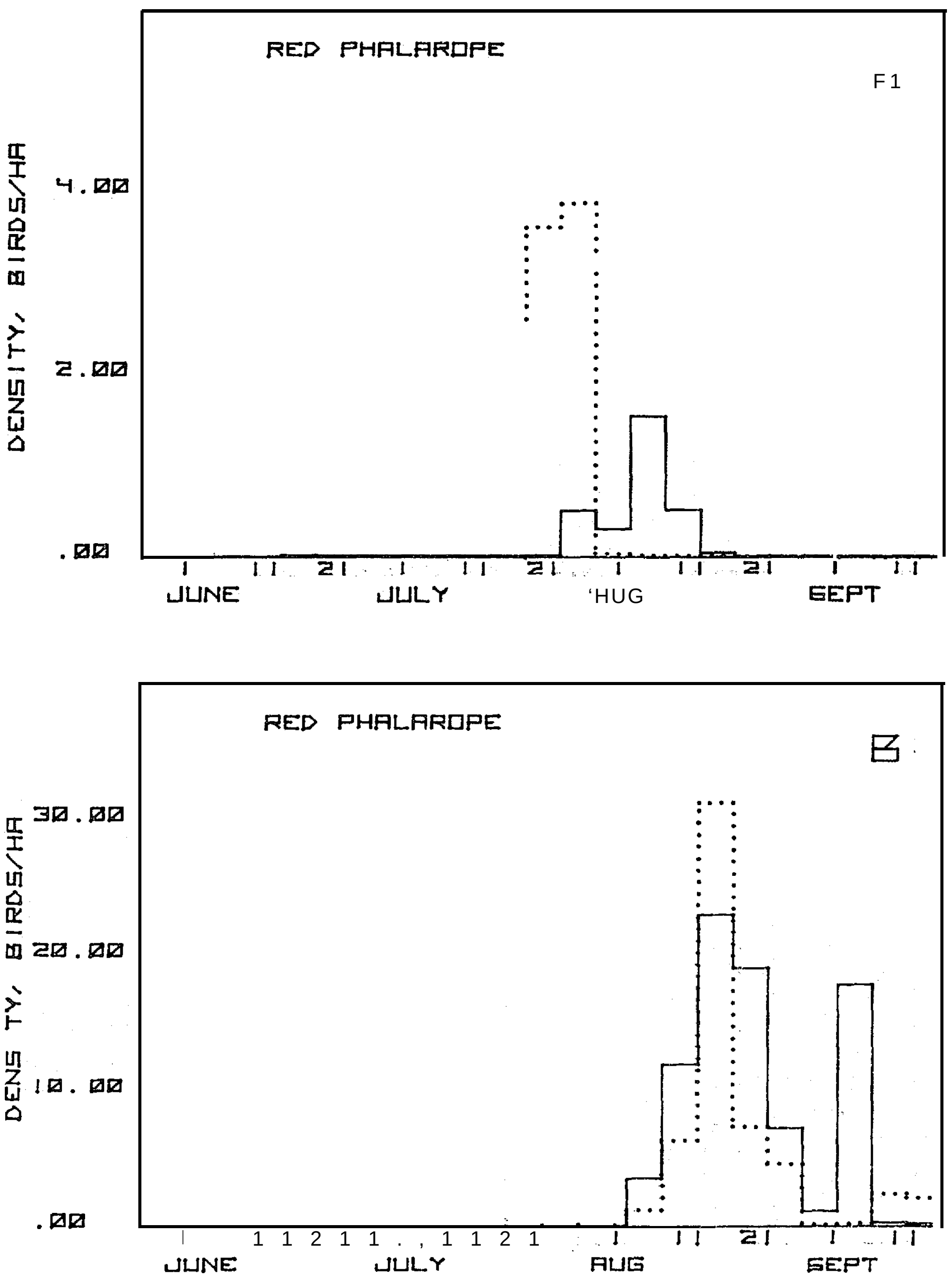


Figure 21. Transect densities, Red Phalarope, Barrow littoral. A. Males 1976 (solid) vs. males 1977 (dotted). B. Juveniles 1976 (solid) vs. juveniles 1977 (dotted).

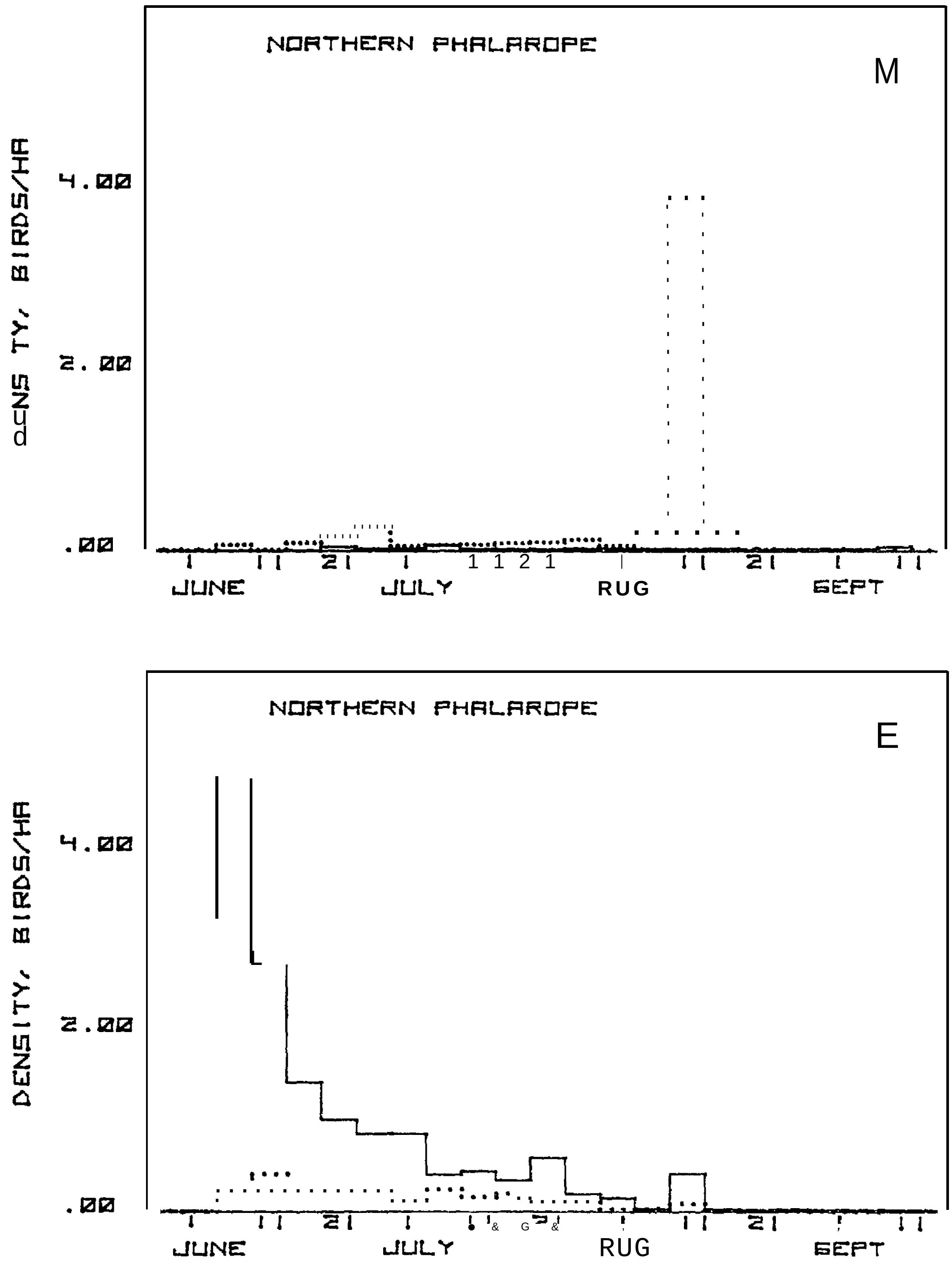


Figure 22. Transect densities, Northern Phalarope, 1977. A. Wales littoral (solid) vs. Wales tundra (fine dotted) vs. Barrow littoral (coarse dotted). B. Cape Krusenstern. Littoral (solid) vs. tundra (dotted).

littoral areas during open water conditions. Highest densities were recorded at Wales (Red-throated Loon, tundra transects, .20 per hectare).

21. Waterfowl (includes ducks, geese and swans). Moderate densities of several species of waterfowl occur at all three sites throughout the summer. Densities increased greatly in late August and early September at Barrow when large flocks of Oldsquaws occurred off Barrow Spit. Brant were most numerous at Icy Cape (Figure 23A).

22. Larus gulls (mainly Glaucous Gull, Larus hyperboreus). Moderately -densities of large gulls occurred on all ocean shorelines during the summer, but densities were consistently less at Cape Krusenstern (Figure 24B).

23. Black-legged Kittiwake (Rissa tridactyla). This species is much more common at Wales than at the other two sites; Wales is closest to nesting colonies (Little Diomede Island). Immature Kittiwakes are common near Barrow but almost absent from Wales and Cape Krusenstern (Figure 24A).

24. Sabine's Gull (Xema sabini). Sabine's Gulls are a prominent member of the group of species which forages heavily on marine zooplankton along Beaufort and Chukchi shorelines in late August and early September. Consistent with the results found for Red and Northern Phalaropes, this species was not seen in numbers prior to the end of the field season on 11 September at either site in the southern Chukchi.

25. Arctic Tern (Sterna paradisaea). Arctic Terns nest in scattered small colonies on beaches and in saltmarsh and lagoon island areas in the Cape Krusenstern region. They were present throughout the summer in densities somewhat higher than those recorded at Wales. The late season concentration of migrating terns at Barrow was much greater than densities recorded at either southern site (Figure 23B).

26. Aleutian Tern (Sterna aleutica). Present and apparently nesting at four sites between Kotzebue and Kivalina, including two areas in the Noatak Delta, one at Cape Krusenstern and one at Tasaychek Lagoon north of Cape Krusenstern. Maximum number of nests was about 10 at any of these colonies, but all colonies represent a northward extension of the known breeding range of this species.

27. Lapland Longspur (Calcarius lapponicus). This very common passerine behaved similarly at all three sites, moving into littoral habitats in late summer when juveniles foraged in flocks prior to southward migration. Figures 25A and 25B contrast the occurrence of adults and juveniles in tundra and littoral habitats at Cape Krusenstern.

28. Snow Bunting (Plectrophenax nivalis). Snow Bunting juveniles also move heavily into littoral areas at Barrow. Densities at Wales were considerably lower than at Barrow, At Cape Krusenstern Snow Buntings did not nest in 1977, and migrants were almost absent during our field season.

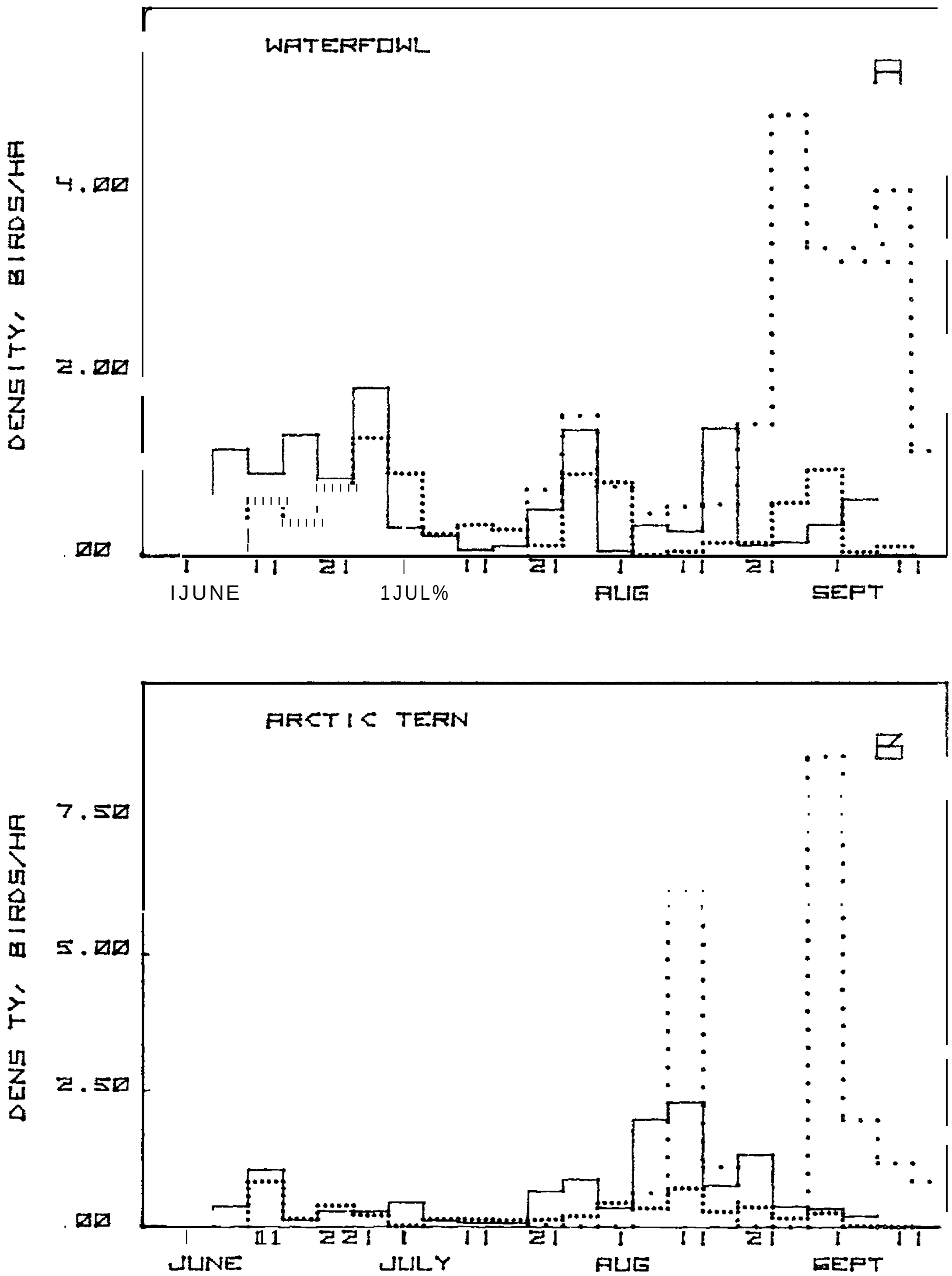
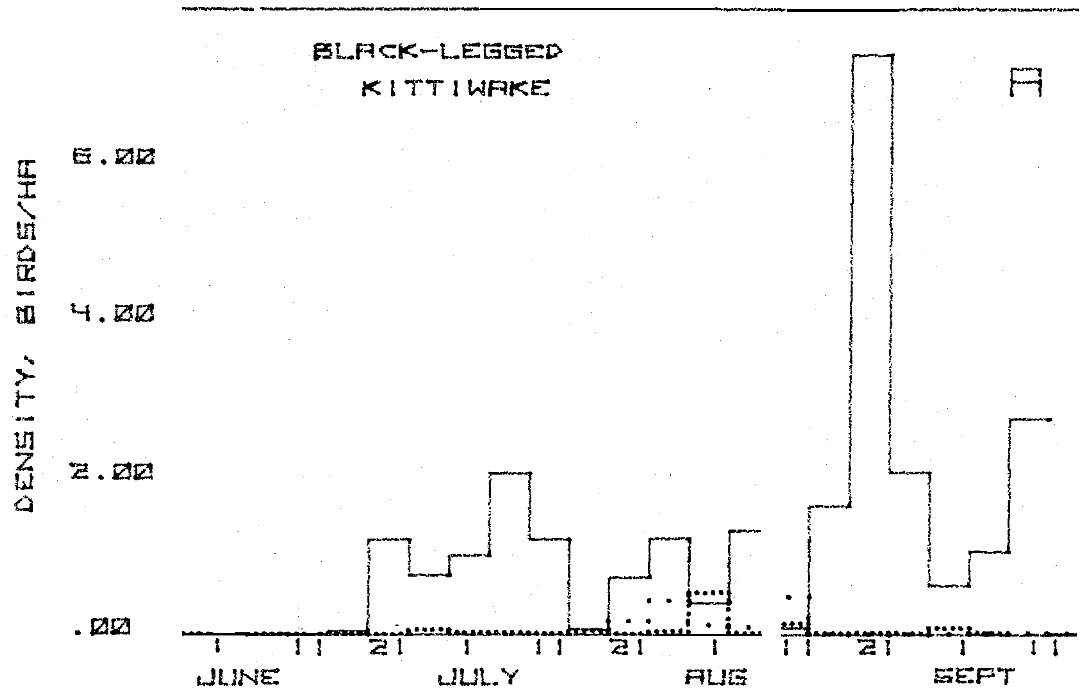


Figure 23. Transect densities, littoral, 1977. A. Waterfowl. Cape Krusenstern (solid) vs. Wales (fine dotted) vs. Barrow [coarse dotted). B. Arctic Tern. Cape Krusenstern (solid) vs. Wales (fine dotted) vs. Barrow (coarse dotted).



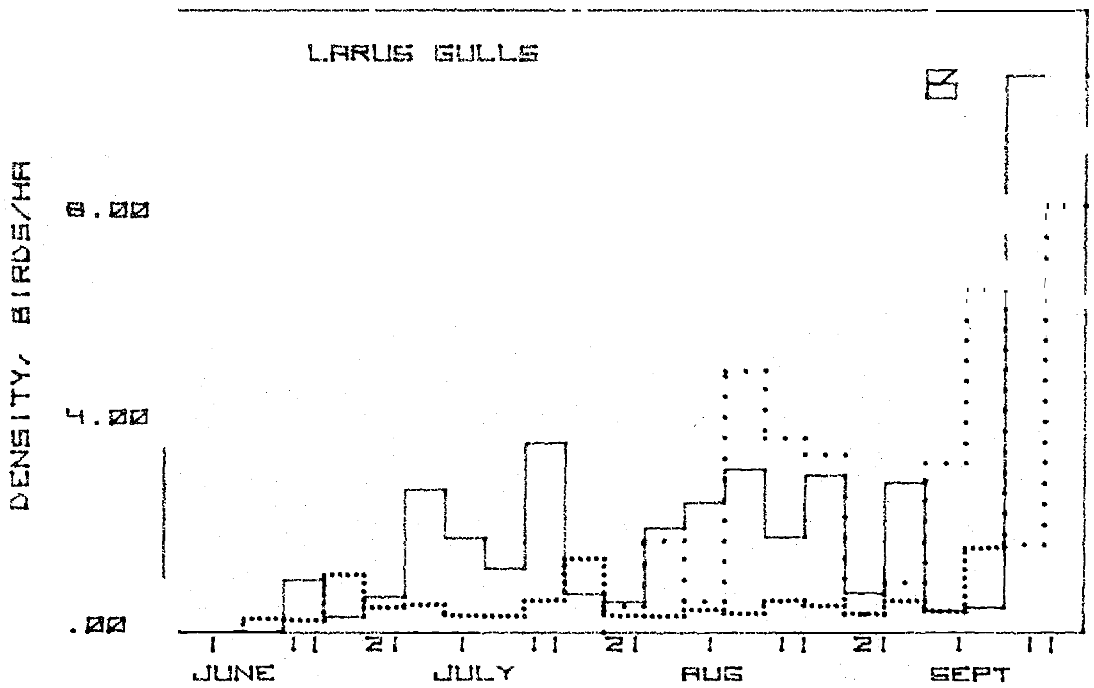


Figure 24. Transect densities, littoral, 1977. P,. Black-legged Kittiwake. Wales (solid) vs. Krusenstern (fine dotted) vs. Barrow (coarse dotted). B. Larus gulls. Wales (solid) vs. Krusenstern (fine dotted) vs. Barrow (coarse dotted).

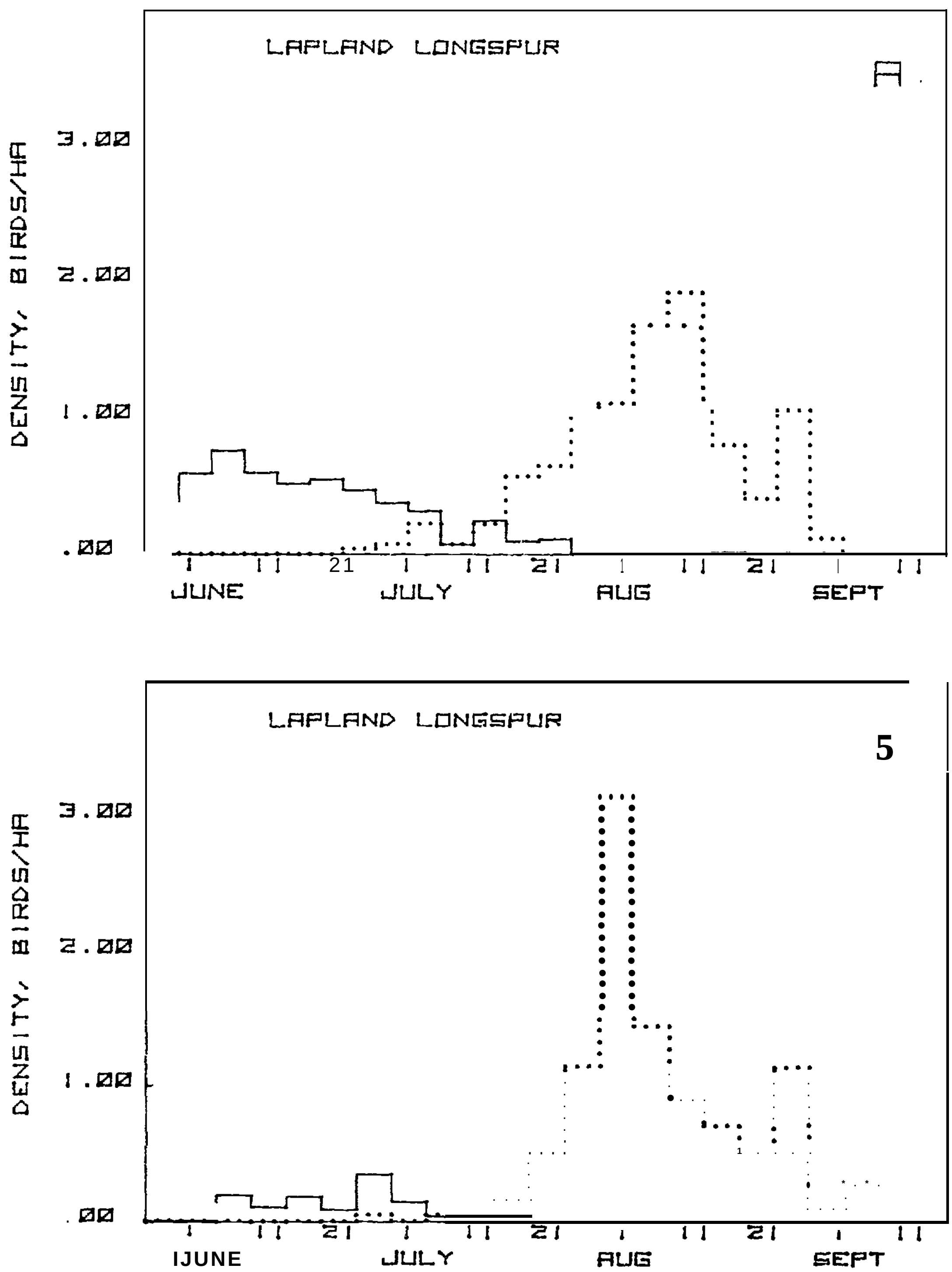


Figure 25. Transect densities, Lapland Longspur, Cape Krusenstern. A. Tundra. Adults (solid) vs. juveniles (dotted). B. Littoral. Adults (solid) vs. juveniles (dotted).

Bird Trophic Studies

In the 1977 season, 61 specimens of 17 shorebird species, were collected which had identifiable stomach contents (Table 9 and Appendix 6). The prey items taken are shown in Table 9, along with bird species, station data, and relative per cent of stomach contents. Four phyla of invertebrates (annelids, mollusks, arthropods, and chaetognaths) are represented in the stomach contents, including approximately 14 species of non-insect invertebrates. Seeds from a variety of plants comprise a minor portion of most diets, Arthropods, primarily insects, comprise the majority of prey items.

For 1975 and 1977 at Barrow and Lonely, 20 of 84 specimens (24%) of shorebirds, including 7 of 9 species (78%) had 70% or more of their stomach contents consisting of chironomid flies or larvae. Comparative figures for Wales, Cape Krusenstern, and the Noatak Delta in 1977 are 40 of S4 specimens (74%), including 12 of 17 species (71%). 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. These striking differences are related to the distinct major trophic systems between the Beaufort Sea (Barrow and Lonely) and the southern Chukchi Sea. In the Beaufort Sea, foraging shorebirds heavily use marine shoreline zooplankton, while in the southern Chukchi, closed lagoons, brackish pools, saltmarshes, and mudflats comprise the main focus of foraging birds. Specific comparisons of these habitats, both within and between sites, are shown in Table 10. The marine zooplankton system in the Beaufort is most heavily used by Red and Northern Phalaropes, Ruddy Turnstones, Sanderlings, Baird's Sandpipers, and Dunlins (as well as Arctic Terns and Sabine's Gulls), while the bulk of the foraging activity on the southern Chukchi mudflats is by Dunlins, Western Sandpipers, Semipalmated Sandpipers, Pectoral Sandpipers, Long-billed Dowitchers, and Golden Plovers. However, at any one site within a habitat, birds of several species have frequently been found to utilize the same prey (Table 11).

Plankton Studies

Large marine zooplankters were rare in our studies of nearshore plankton at Barrow, Krusenstern, and Wales, in 1977. The most common zooplankters at all three sites (Table 13) consisted of small hydromedusae and small calanoid copepods, neither of which generally has comprised a major food resource for most shorebirds in our samples. Other relatively common species, which were either localized and/or transitory in the plankton, are given in Table 13. Major descriptive distinctions between plankton stocks at the three sites concern the absence or presence of particular species that showed transitory high numbers. For example, cladocerans were present only at Cape Krusenstern in late July and early August; cumaceans were preSent only at Wales in early July, while mysids (Boreo mysis) were common occasionally at Krusenstern and Wales, but never at Barrow. As another example, Mysis relicts occurred only once in early September in relatively high numbers at Wales.

Table 9 Prey Items of Shorebirds, 1977.

Key: "B: 30, 50(2)" = Three birds from Barrow: (indicated food item composing) 30 and 50% (two birds) of relative stomach mass, respectively
B, W, K = Barrow, Wales, Cape Krusenstern
* = observation only, presumed food item collected (no stomach)
+ = present in stomach, less than 1% of contents

ANNELIDA: Oligochaeta
*Dunlin (W)
*Western SP (W)

MOLLUSCA
Bivalvia
Musculus Sp.
Rock SP (W+)
Sharp-tailed SP (W:25)
undet. sp.
Dunlin (K+)
Gastropod
undet. sp.
Red Knot (W:5)

ARTHROPODA
Crustacea
Copepoda
calanoid, undet. sp.
Red Phalarope (B:+, 100[2))
Northern Phalarope (B:100(2); K:15)
Cladocera: ephippia
Red Phalarope (B:10)
Northern Phalarope (B+; K:10)
Western SP (W+; K+)
Dunlin (K+)
Cumacea, undet. sp.
RP (W:100)
Amphipoda
Gammarus sp.
Sanderling (W:10)
Bar-tailed Godwit (W:100)
Dexaminidae, undet. sp.
Red Knot (W:10)
Calliopiidae, undet. sp.
Red Phalarope (W:100)
undet. sp.
Western SP (K:50)
Rock SP (W+)
Red Phalarope (B+, W+)
Golden Plover (W:25)
undet. sp. : amphipod tissue
Rock SP (W+)
Sharp-tailed SP (W:75)
Sanderling (W:50, 100)
Dunlin (W:100(2))
Baird's Sandpiper (K:90)
Decapoda: zoea
Western SP (W:96)
Insects: Diptera
Chironomidae: larvae
Pectoral SP (K:100(2))
Western SP (W:100(2); K:100(3), 75, 97)
Baird's SP (W:100; K:10)
Dunlin (W:100; K:100(11))
Red Phalarope (B:10)
Long-billed Dowitcher (K:100(3))
Insects: Diptera: adult flies, Chironomidae and other families
Western SP (W:4, 100; K:100(2), 49, +)
Semipalmated SP (K:100)
Least SP (K:85, 100)
Dunlin (W:100; K:9)
Red Knot (W:90(2); K:100)
Sanderling (W:50, 90)
Red Phalarope (B:10, +; W:*)
Northern Phalarope (K:75, 100, *)
Black Turnstone (K:100)
Ruddy Turnstone (K:100)
*Arctic Tern (K)

CHAETOGNATHA
Sagitta sp.
Red Phalarope (B:90)

PLANTAE: seeds
Western SP (K:+(3), 3, 25)
Least SP (K:15)
Pectoral SP (K+)
Dunlin (K:+(2), 90; W:+(2))
Long-billed Dowitcher (K:+(2))
Red Phalarope (W+; B:+(2))
Red Knot (W:+(2))
Sharp-tailed SP (W+)

Table 10 Major prey items in two habitat types (Barrow includes 1975, 1976, and 1977 data). (n) = number of birds; * = observation

	Ocean Stations			Closed Lagoons, Brackish Pools, and Mudflats		
	Barrow	Krusenstern	Wales	Barrow	Krusenstern	Wales
WESTERN SANDPIPER						
		(3) adult flies	(1) decapod zoea	(1) chironomid larvae	(5) chironomid larvae and flies	(3) chironomid larvae and flies (*) oligochaetes, chironomids
DUNLIN						
	(2) <u>Thysanoessa</u>			*(6)* chironomid larvae and oligochaetes	(12) chironomid larvae; seeds	*(4)* chironomid larvae and flies; amphipods (*) oligochaetes
SANDERLINGS						
	(10) <u>Thysanoessa, Apherusa</u>		(3) adult flies; amphipods	(1) chironomid larvae; seeds		
RUDDY TURNSTONE						
	(3) <u>Thysanoessa</u>	(1) flies		*(4)* chironomid larvae; oligochaetes		

Ocean Stations			Closed Lagoons, Brackish Pools, and Mudflats		
Barrow	Krusenstern	Wales	Barrow	Krusenstern	Wales
RED PHALAROPES					
(27) Onisimus, Apherusa, euphausiids, calanoids, Zoea, Sagitta, Spiratella, insects, seeds		(2) cumacea; amphipods	(10) calanoid copepods; chironomids		(*) chironomid flies
NORTHERN PHALAROPES					
	(*) flies		(2) calanoid copepods	(3) chironomid flies, calanoids, ephippia	

Table 11 Bird species utilizing the same prey resource at the same time and place. B, Barrow; W, Wales; K, Cape Krusenstern.

Prey Item	Location	Birds Feeding on Prey Item	Date
Oligochaeta	B: GF/CB pool	Ruddy Turnstone Red Phalarope	11 Aug 76
Bivalvia: Musculus Sp.	W: NL/SM	Rock SP Sharp-tailed SP	3 Sep 77
Copepoda: calanoids	B: MSE	Red Phalarope Northern Phalarope	8 hug 77
Amphipoda: tissue, undet. sp.	W: NL/SM	Rock SP Sharp-tailed SP Golden Plover	3 Sep 77
	K: N of SB	Baird SP Western SP	28 Jul 7"7
Onisimus litoralis	B: BD	Red Phalarope Baird SP	1 Aug 76
Euphausiacea: Thysanoessa raschii	B: WS	Sanderling Dunlin Ruddy Turnstone	17 Aug 76
	B: BSS	Red Phalarope Ruddy Turnstone	14 Aug 76
Insects: chironomid larvae	W: VS	Western SP Dunl in	23 Jul 77
	K: NF	Pectoral SP Long-billed Dowitcher	15 Jul 77
	K: Tasaychek Lagoon	Dunl in Western SP	21 Jul 77
	K: Noatak Delta	Dunlin Long-billed Dowitcher	2 Sep 77
	B: BP	Ruddy Turnstone Semipalmated SF'	29 Jul & 30 Jul 76

Prey Item	Location	Birds Feeding on Prey Item	Date
Insects, continued			
	B: NSL	Dunlin Semipalmated SP	3 Aug 76
adult flies	K: Tasaychek Lagoon	Western SP Least 5P Ruddy Turnstone Red Phalarope	1 Aug 77

Comparisons between the 1976 and 1977 Barrow seasons are difficult because of the striking differences in species composition and abundance. Table 5 (page 47) of our 1977 report (for 1976) contrasted Sagitta, Calanus, and decapod zoea for 1975 and 1976. In 1977, Sagitta and decapod zoea were present in small numbers only once each in mid-August, while small (approximately 1 mm in length) calanoid copepods occurred in consistently very large numbers (many times that of either 1975 or 1976) at Barrow from mid-August through early September. Euphausiids (Thysanoessa) were strikingly absent in our 1977 Barrow shoreline samples.

Because of limited sampling in 1977 directed to specific synchronous samples of birds with co-occurring plankton stocks, analysis of correlations between diet (stomach contents) and resources (plankton) is limited. Thus, five specimens of Red Phalaropes, Dunlins, Baird's Sandpipers, and Western Sandpipers, at Barrow, Wale's, and Cape Krusenstern show a limited correlation between prey and plankton resources (Table 12), but do not permit any analysis of prey selection by the birds.

Because of the high variability in plankton composition which we have found at each site within a season and between seasons at Barrow, and within and between stations at Barrow, comparisons between sites based on a single year's data are tenuous. Therefore we are unable to state whether the lack of a heavy late summer occurrence of zooplankton-foraging shorebirds, gulls, and terns in the southern Chukchi relates to differences in availability of zooplankton prey between northern and southern sites. In 1977 at least, simple explanations were not evident from our plankton sampling.

Premigratory Fat Deposition by Shorebirds

Fat conditions of collected bird specimens are included in Appendix 6. The OCS Fat Code can be compared to a scale similar to that of McCabe (1943) with the following definitions: Code 2, little fat; Code 3, moderate fat; Code 4, very fat; Code 5, excessive fat. Combining these data with data from 1975 and 1976 supports the trends suggested last year. Considerable variation in fat accumulation schedule exists among the species for which we have sufficient samples. Juvenile Semipalmated and Western Sandpipers have low fat levels (mean scores 2.6 and 2.0, respectively); both species leave the Arctic in late July and early August, and must replenish fat supplies at foraging sites during migration. Red Phalarope juveniles and all ages of Dunlins have low fat levels in early August, but our data show an increase in fat score with date after August 1 (Red Phalarope, $\bar{x}$ = 2.6, Spearman Correlation Coefficient rs = .40, $p < .01$; Dunlin, $\bar{x}$ = 2.5, r_S = .41, $p < .05$). This suggests strongly that the long period in which these species forage in arctic habitats is important for the deposition of fat prior to southward migration. Arrival of these species at the latitude of California occurs in middle October or later in most years, considerably delayed compared to Sanderlings and Ruddy Turnstones. These latter species apparently accumulate higher fat reserves during August (Sanderling $\bar{x}$ = 3.8; Ruddy Turnstone $\bar{x}$ = 3.3) and migrate southward more rapidly.

Table 12 Comparison of prey stomach and esophageal contents) and corresponding plankton samples.

Rare < 10/m^3

					AN			
Station, Date	Species	No.	Size (mm)	% Total Mass	Station, Date	Species	#/m^3	Size (mm)
BARROW								
(1) Red Phalarope: GF, 24 Aug 77	Sagitta	c.4	8-10	90	WS, 24 Aug	calanoid copepods	3,952	1+
	fly fragments	--	2-3	10				
	calanoid copepods	c.3	c.2	in esophagus				
WALES								
(2) Red Phalarope: BD, 2 Sept 77	Calliopiid amphipods, amphipod tissue and fragments	--	--	100	BD, 2 Sept.	calanoid copepods	124	1.0
						Sagitta	24	5-10
						echinoderm larvae	14	1.0
						rare: Calliopiidae (6/m^3) and other gammarids		
(3) Dunlin: EL, 9 Sept 77	gammarid amphipod tissue	--	-	100	SL, 9 Sept	Mysis relicta	368	10-30
						Gammarus (rare: 6.3/m^3)	--	4-6
KRUSENSTERN								
(4) Baird sp.: 1 km N of camp 29 July 77	gammarid amphipod tissue	--	-	90	SB, 27 July	calanoid copepods	24	1.0
						rare: juvenile gammarids (3.2/m^3)		

(TABLE 12 cont'd)

	chironomid larvae fragments	--	--	10			
(5) <u>Western SP:</u> (as (4))	gammarid juveniles	c.3	4-5	50	(as 4)		
	adult flies and frag-ments	c.2	5	49			
	seeds	7	1.5	1			

Table 13 Most common zooplankton at Barrow, Cape Krusenstern, and Wales, 1977 (species occurring more than once at numbers greater than 10/m^3).

( ) = station and number/m3

Species	Barrow	Krusenstern	Wales*
Coelenterata			
Hydromedusae	4 Aug (BS, 25) 24 Aug (BSS, 357)	13 Aug (NB, 12)	31 July (NB, 37; BD, 94) 19 Aug (SL, 22) 30 Aug (SL,38; NL, 14)
Mollusca			
Spiratella helicina	3 Aug (BSS, 16) 14 Aug (BS, 21)		
Crustacea			
cladocerans		23 July (NB: 794) 1 Aug (NB: 48)	
cumaceans			12 July (SB, 149; NB: 21)
calanoid copepods	14 Aug (BS: 306; WS: 101; PS:6786; BSS: 4311) 24 Aug (WS: 3952; PS: 516) 29 Aug (BS: 14; WS:7258; BSS: 54)	15 July (SB: 635) 23 July (NB: 238) 27 July (SB: 24) 1 Aug (NB: 556) 4 Aug (NB: 397) 13 Aug (NB: 36) 21 Aug (NB: 76) 1 Sept (SB:>1350; NL: 289)	11 July (SL: 190] 12 July (NB:794; NL: 476) 21 July (SL: 10, 100; SE: 190; NB: 95; NL: 1587) 30 July (SL:5630; SB:20 31 July (NL: 1138; NB: 278; BD: 556) 4 Aug (SL: 12, 640) 10 Aug (NL: 1, 110; SB: 29) 20 Aug (SB: 570) 2 Sept (NB: 124; SB: 49) 11 Sept (NL: 19)

14=

(TABLE 13, cont'd)

Species	Barrow	Krusenstern	Wales
gammarid amphipods, juvenile, unidentified		1 Aug (NB: 2[illegible]) 21 Aug NB: 19)	12 July (SB: 19, NL: 78)
mysids: <u>Boreomysis</u> sp.		23 July (NL 102) 1 Aug (NL: 12)	[illegible] Aug (SL: 205) 1[illegible] Sept (NL: 33)
Chaetognatha <u>Sagitta</u> sp.	14 Aug (WS: 20) 4 : 113)		30 July (SB: 10) 2 Sept (NB: 24)
Appendicularia <u>Oikopleura</u> sp	3 Aug (BSS:968) 4 Aug (BS:933)		

* SB, South Sea Beach
NB, North Sea Beach

Phalarope Foraging in Relation to Wind Direction

The distribution of juvenile Red Phalaropes foraging along the shores of Barrow Spit, when compared to the concurrent wind direction, showed strong contrasts between 1975 and 1976. In 1975, the correlation between per cent of birds on each shore and the number of degrees deviation from onshore wind direction was high (Spearman $r = .811$, $p<.001$). This suggested a reason for the high use of spits and barrier islands by shoreline zooplankton foraging birds: these structures offer a protected shore during more different wind conditions than do mainland shores.

In 1976, however, the correlation vanished ($r = -.015$, $p>.50$). We interpret this as arising from the generally much lower concentrations of shoreline zooplankton in 1976, combined with the presence of broken ice grounding on the beaches during most wind conditions. The grounding ice released under-ice amphipods, providing an alternate food source available only on the exposed shores. Grounding ice was present during August in 1975 and 1976. Thus the lower concentrations of marine zooplankton (copepods, euphausiids, decapod zoea, chaetognaths) in 1976 produced a change in phalarope foraging behavior, in this interpretation.

In 1977, the correlation improved considerably ($r = .443$, $p<.07$) but did not match the 1975 data. Concentrations of marine zooplankton along the Barrow Spit shorelines were low (Table 13), but grounded ice was not available during August of 1977. With no alternate food source, the birds apparently followed the 1975 pattern, which presumably optimizes foraging efficiencies on the marine zooplankton resource.

VIII. Conclusions

Many of the conclusions from this study have been presented in sections I and VII. Only the major points will be summarized here.

In the Beaufort and northern Chukchi, the general pattern of seasonality in habitat use by shorebirds, gulls, and terns was similar to that of previous years, with heavy use of littoral areas developing in August and September. Timing and magnitude of several species movements differed considerably, however.

The trophic system of principal activity in the Beaufort littoral zone involves foraging by many species on marine zooplankton along shorelines. In the southern Chukchi, the greatest activity centers on mudflats and saltmarsh areas, where high concentrations of several shorebird species forage on benthic invertebrates. This difference between areas implies corresponding differences in the sensitivity of bird populations to environmental disturbances.

In Table 14 we categorize the seasonal habitat use patterns of common Barrow shorebirds, based on 1975 and 1976 data. From these and from subsequent 1977 data, we have refined two tables (15 and 16) presented in a similar form in the 1977 annual report. These present rankings of the relative susceptibilities of Barrow shorebirds to disturbances associated with OCS development. Our studies in Kotzebue Sound and on Seward Peninsula indicate higher relative susceptibilities in those areas for Golden Plover and Pectoral Sandpiper, and possibly also for Western Sandpiper, Long-billed Dowitcher, and Dunlin.

Table 14. Habitat use patterns of common shorebirds near Barrow, Alaska. (T = Tundra; L = Littoral) (from Connors et al. 1978)

Category	Breeding	Post-breeding Adult	Post-fledging Juvenile	
I	T	T	T	Golden Plover, Pectoral Sandpiper
II	T	T+ L	T+L	Dunlin, Long-billed Dowitcher
III	T+ L	T+L	T+ L	Western, Semipalmated, Baird's Sandpipers
IV	"T	T+L	L	Red Phalarope, Ruddy Turnstone, Sanderling

IX. Needs for Further Study

In three seasons of work in the Arctic on RU #172, we have identified as a critical biological system the late summer concentrations of several species of birds foraging along gravel shorelines of spits and barrier islands in the Beaufort Sea. Both Red and Northern Phalaropes, as well as several other species of shorebirds, gulls, and terns are dependent upon a prey base of marine zooplankton for accumulation of energy reserves prior to southward migration. But the density and composition of the zooplankton community near Barrow has been extremely variable over the past three summers, with corresponding variations in the foraging behavior of some bird species. We do not yet understand the causes of this variability; nor do we know how flexible birds are to these fluctuations or to potentially greater fluctuations which may occur in the future as a result of oil development in the Beaufort. We need to increase our understanding of this trophic system in order to predict the probable effects of potential environmental insults to the system.

Table 15 Shorebirds potentially affected by oil development near Barrow, Alaska (from Connors *et al.* 1978).

COASTAL PLAIN TUNDRA		LITTORAL AND OFFSHORE
Lowland	Upland	
Red Phalarope	Golden Plover	Red Phalarope
Pectoral Sandpiper	Ruddy Turnstone	Northern Phalarope
Long-billed Dowitcher	Semipalmated Sandpiper	Sanderling
?	Baird's Sandpiper	Ruddy Turnstone
?	Dunlin	Semipalmated Sandpiper
	?	Western Sandpiper
	?	Baird's Sandpiper
		Dunlin
		Long-billed Dowitcher
		?
		?

Table 16 Relative susceptibility of common Barrow shorebirds to littoral zone disturbances (from Connors *et al.* 1978).

High	Moderate	Low
Red Phalarope	Semipalmated Sandpiper	Golden Plover
Sanderling	Western Sandpiper	Pectoral Sandpiper
Ruddy Turnstone	Baird's Sandpiper	
	Dunlin	
	Long-billed Dowitcher	

A second trophic system has emerged from our 1977 studies in the southern Chukchi (and from Mickelson et al. 1977) as parallel in importance to the Beaufort zooplankton system. Large numbers of several species of shorebirds forage during July, August, and September on tidal mud and sand flats and in saltmarshes in Kotzebue Sound and along the north shore of Seward Peninsula. Benthic invertebrates are the prey base supporting these bird populations, and the entire system is potentially very vulnerable to the effects of spilled oil. At present we know very little of the prey community structure, the trophic dependencies or energetic requirements of the foraging birds, or even the geographic or seasonal extent of this phenomenon. Although this occurs outside any presently planned lease areas, the potential interactions involving transport between the Bering Sea and the Beaufort lease area argue for continued study in the Chukchi.

Finally, in all areas where significant populations may face disturbances, we need to know specifically what the disturbances will be and how severe will be the resultant population effects. Comparison of bird use in disturbed and undisturbed habitats, as well as study of the impact of actual environmental results, planned or unplanned, and of the recovery of populations following such impacts promises to be extremely useful in meeting OCSEAP objectives.

X. Fourth Quarter Operations

1. Field Schedule.

No field activities during this quarter.

2. Scientific party.

Peter G. Connors, University of California Bodega Marine Laboratory, research coordinator.
James T. Carlton, University of California, Davis, research assistant,
Carolyn S. Connors, Bodega Marine Laboratory, research assistant.
Katherine Hirsch, University of California, Davis, research assistant.
Douglas Woodby, University of California, Davis, research assistant.
Eileen Kiera, Western Washington University, research assistant.

3. Methods.

Laboratory analysis:

(1) Summary and computer plotting of shorebird seasonal distributions.

(2) Continuing analysis of bird data.

(3) Final analysis and identification of invertebrates in stomach samples and plankton samples.

(4) Interpretation of results and preparation of annual report.

4. Sample localities.

None.

5. Data analyzed.

(1) Analysis of data from 11 bird surveys.

(2) Analysis and identification of 200 bird stomach and invertebrate samples.

(3) Analysis of 1100 transect censuses.

(4) Identifications of 60 saltmarsh specimens.

6. No serious problems encountered.

7. Total funds expended, 1 April 1975 - 28 February 1978: $105,657.

Appendix l Birds of Cape Krusenstern and Wales, Alaska.

The following list presents the status of bird species observed in the vicinities of Cape Krusenstern and Wales, Alaska (see map, figure 1) between 26 May 1977 and 11 September 1977. Status categories are:

- RB, rare breeder: 1 or 2 nests (or broods) located in 1977.
- CB, common breeder: 2 nests or territories located in 1977.
- 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,

The second column lists additional species reported as nesting occasionally at Cape Krusenstern in other years by W. Robert Uhl in Subsistence Use Patterns in the Proposed Cape Krusenstern National Monument (approximate title). Report to the National Park Service, 1977.

	Cape Krusenstern 1977 Status	Cape Krusenstern Additional breeders other years (Uhl 1977)	Wales 1977 Status
Common Loon, Gavia immer	V		V
Yellow-billed Loon, G. adamsii	V		PB
Arctic Loon, G. arctica	CB		PB, CM
Red-throated Loon, G. stellata	CB		CB
Horned Grebe, Podiceps auritus	V	X	
Red-necked Grebe, P. grisegena	V		
Short-tailed Shearwater, Puffinus tenuirostris	V		CM
Pelagic Cormorant, Phalacrocorax pelagicus			PB, CM
Whistling Swan, Olor columbianus	RB		RB
Canada Goose, Branta canadensis	CM	X	CM
Brant, Branta bernicta	CM	X	CM
Emperor Goose, Philacte canagica			PB, CM
White-fronted Goose, Anser albifrons	CM	X	RB
Snow Goose, Chen caerulescens	CM		V
Mallard, Arias platyrhynchos	CM	X	V
Pintail, A. acuta	CB		CB
Green-winged Teal, A. crecca	CM	X	PB
American Wigeon, A. americana	CM		
Northern Shoveler, A. clypeata	CM		V
Redhead, Aythya americana	V		
Canvasbacks, A. valisineria	CM		
Greater Scaup, A. marila	RB, CM		
Oldsquaw, Clangula hyemalis	CB		CB
Harlequin Duck, Histrionics histrionics	V		V
Steller's Eider, Polysticta stelleri			CM
Common Eider, Somateria mollissima	CB		CB

King Eider, *Somateria spectabilis*	V		CM
Spectacle Eider, *S. fischeri*	V		PB, CM
White-winged Scoter, *Melanitta deglandi*			V
Surf Scoter, *M. perspicillata*	CM		
Black Scoter, *M. nigra*	V	X	V
Red-breasted Merganser, *Mergus serrator*	CM	X	CM
Sharp-shinned Hawk, *Accipiter striatus*			V
Red-tailed Hawk, *Buteo jamaicensis*	V		V
Golden Eagle, *Aquila chrysaetos*			V
Marsh Hawk, *Circus cyaneus*	V		
Gyrfalcon, *Falco rusticolus*	V		V
Peregrine Falcon, *Falco peregrinus*	V		
Willow Ptarmigan, *Lagopus lagopus*	CB		V
Rock Ptarmigan, *Lagopus mutus*			PB, V
Sandhill Crane, *Grus canadensis*	CB		RB, CM
Semipalmated Plover, *Charadrius semipalmatus*	RB		PB
American Golden Plover, *Pluvialis dominica*	CB		CB
Black-bellied Plover, *Pluvialis squatarola*	RB		V
Ruddy Turnstone, *Arenaria interpres*	V		PB, CM
Black Turnstone. *Arenaria melanocephala*	CM		
Common Snipe, *Capella gallinago*	CB		V
Whimbrel, *Numenius phaeopus*	RB, CM		V
Greater Yellowlegs, *Totanus melanoleucus*			V
Tattler, *Heteroscelus* sp.			V
Red Knot, *Calidris canutus*	CM		CM
Rock Sandpiper, *C. ptilocnemis*	V		CB
Sharp-tailed Sandpiper, *C. acuminata*	V		CM
Pectoral Sandpiper, *C. melanotos*	RB, CM		CB
Baird's Sandpiper, *C. bairdii*	RB		V
Least Sandpiper, *C. minutilla*	V		
Rufous-necked Sandpiper, *C. ruficollis*	V		PB
Dunlin, *C. alpina*	CB		CB
Sanderling, *C. alba*	V		CM
Semipalmated Sandpiper, *C. pusilla*	CB		CB
Western Sandpiper, *C. mauri*	CB		CB
Stilt Sandpiper, *Micropalama himantopus*	V		
Buff-breasted Sandpiper, *Tryngites subruficollis*	V		
Ruff, *Philomachus pugnax*			V
Long-billed Dowitcher, *Limnodromus scolopaceus*	CB		CB
Bar-tailed Godwit, *Limosa lapponica*	PB, CM		RB, CM
Hudsonian Godwit, *L. haemastica*	V		V
Red Phalarope, *Phalaropus fulicarius*	CM		CB
Northern Phalarope, *Lobipes lobatus*	CB		CB
Pomarine Jaeger, *Stercorarius pomarinus*	CM		CM
Parasitic Jaeger, *S. parasiticus*	CM		CM
Long-tailed Jaeger, *S. longicaudus*	PB, CM		PB, CM
Glaucous Gull, *Larus hyperborea*	CB		CB
Glaucous-winged Gull, *L. glaucescens*			CM
Slaty-backed Gull, *L. schistisagus*			V
Herring Gull, *L. argentatus*	V		CM
Mew Gull, *L. canus*	PB, CM		V
Black-legged Kittiwake, *Rissa tridactyla*	CM		CM

Sabine's Gull, Xema sabini	V	V
Arctic Tern, Sterna paradisaea	CB	CB
Aleutian Tern, S. aleutica	CB	
Common Murre, Uria aalge	CM	CM
Thick-billed Murre, U. lomvia		CM
Black Guillemot, Cepphus grylle	V	
Least Auklet, Aethia pusilla		V
Horned Puffin, Fratercula corniculata		CB
Tufted Puffin, Lunda cirrhata		V
Snowy Owl, Nyctea scandiaca	V	V
Short-eared Owl, Asio flammeus	V	
Common Flicker, Colaptes auratus	V	
Eastern Kingbird, Tyrannus tyrannus	V	
Say's Phoebe, Sayornis saya	V	
Olive-sided Flycatcher, Nuttallornis borealis		V
Horned Lark, Eremophila alpestris	V	
Tree Swallow, Iridoprocne bicolor	RB	CM
Bank Swallow, Hirundo rustics	V	
Common Raven, Corvus corax	RB	PB
Gray-headed Chickadee, Parus cinctus	V	
Swainson's Thrush, Catharus ustulatus	V	V
Gray-cheeked Thrush, C. minimus		V
Wheatear, Oenanthe oenanthe	CM	CM
Bluethroat, Luscinia svecica	V	V
Arctic Warbler, Phylloscopus borealis	V	V
White Wagtail, Motacilla alba		CB
Yellow Wagtail, Motacilla flava	PB	CM
Water Pipit, Anthus spinoletta	V	CM
Red-throated Pipit, Anthus cervinus	V	PB, CM
Orange-crowned Warbler, Vermivora celata		V
Yellow Warbler, Dendroica petechia	V	
Northern Waterthrush, Seiurus noveboracensis		V
Wilson's Warbler, Wilsonia pusilla	V	V
Brown-headed Cowbird, Molothrus ater		V
Redpoll, Acanthis sp.	PB	CM
Savannah Sparrow, Passercula sandwichensis	CB	PB, CM
Dark-eyed Junco, Junco hyemalis		V
Tree Sparrow, Spizella arborea	V	V
White-crowned Sparrow, Zonotrichia leucophrys	PB	CM
Lapland Longspur, Calcarius lapponicus	CB	CB
Snow Bunting, Plectrophenax nivalis	V	CB
Total species recorded, 1977:	95	96

Appendix 2 Phenology. Cape Krusenstern, 1977.

Date	Observations
21 May	First Sandhill Crane egg (W. R. Uhl report).
27	Tundra snow cover less than 10%; large ponds still frozen; most shorebirds present, displaying.
29	Pintails, Lapland Longspurs with nests; some shorebirds may have nests.
2 June	Pedicularis kanei first flowering.
6	Caltha palustris first flowering.
8	First completed nests of Semipalmated Sandpiper, Western Sandpiper, Golden Plover, Whimbrel located.
10	First Chironomid adults; Potentilla villosa and Parrya nudicaulis first flowering.
14	First eggs of Arctic Tern, Oldsquaw; Lapland Longspur hatched; Myosotis alpestris first flowering.
17	Krusenstern Lagoon 70% ice covered; about 30 species flowering.
20	Ocean ice at 1 km from shore.
23-27	First chicks of Dunlin, Western Sandpiper, Semipalmated Sandpiper, Long-billed Dowitcher, Golden Plover, Black-bellied Plover; first flowering of Tripleurospermum phaeocephalum.
5 July	First heavy mosquito day.
10	First Arctic Tern chick.
18	Flocking juvenile Semipalmated and Western Sandpipers common.
20	Last ice washed up on shore.
28	First flying juvenile Arctic Tern.
10 Aug	Last annoying mosquito day.
29	First migrant Sharp-tailed Sandpiper.
8 Sept	Most of Betula, Salix, Arctostaphylos recently changed to fall colors of red and yellow.

Appendix 3 Phenology. Wales, 1977.

Date	Observations
2 June	Tundra snow cover 90%; shorebirds on open tundra patches and in flocks on mud by stream,
10	Snow cover 80%; small ponds melting; passerines and shorebirds beginning to nest,
16	First flowering: Pedicularis kanei.
20	Low tundra free of snow; 10% remains on slopes; ocean ice decomposing rapidly. Black-legged Kittiwakes, Glaucous Gulls, Murres common near shore':
25	Parrya nudicaulis first flowering,
27	Caltha palustris first flowering.
30	Lagoon free of ice; sea ice almost gone; shorebird hatching begins, Potentilla villosa first flowering.
10 July	Male Oldsquaw and eiders rafting on lagoon; passerine fledging; shorebirds mostly with chicks..
20	Semipalmated and Western Sandpipers fledged. Flocks of adult Long-billed Dowitchers; juvenile Western Sandpipers feeding on mudflats.
30	Juvenile Dunlins feeding in littoral areas. Western and Semipalmated Sandpipers gone.
20 Aug	Arctic Terns migrating offshore. Brant becoming common; Sharp-tailed Sandpipers appear in flocks; Dunlin, juvenile Golden Plovers and Long-billed Dowitchers still common.
10 Sept	Most shorebirds gone; influx of Dunlin and Red Phalaropes along lagoon shore. Cranes migrating eastward,

Appendix4 Breeding Bird Census, Cape Krusenstern, Alaska, 1977.

Wet Coastal Tundra---Location: Alaska, Cape Krusenstern, 55 km NW of Kotzebue; 67°7'11"N, 163°42'31"W; Noatak (A-4) Quadrangle, USGS. Continuity: New. Size: 29.8 ha (73.6 acres); rectangular, 350 m x 850 m, surveyed and gridded at 50 m intervals. Description of Plot: Crossed by a series of approximately 13 parallel low ridges (up to 2 m above troughs) of gravel formed as former ocean beaches. One pond (area = 1 ha), partially in plot, plus many shallow water troughs, mainly with emergent vegetation. Ridge vegetation, in decreasing order of area covered: Lichens (several species), Crowberry (Empetrum nigrum), Dwarf Birch (Betula nana), Willow (Salix, several species), moss (several species), Potentilla villosa, River Beauty (Epilobium latifolium). Dominant emergent in troughs is Carex aquatilis, with other sedges (Carex), Willow (Salix) and grasses (Arctagrostis latifolia and others). Other wet areas are mainly Dwarf Birch, willow, moss, sedges and grasses, By area, open water covers 5%, dry ridges S3%, emergent vegetation 20% and other wet tundra 22%. Plant names are from E. Hultén, Flora of Alaska, 1968. Edge: Similar beach ridge tundra continues on three sides; to the west, the present ocean beach is 200 m from the plot. Topography: Flat tundra, a series of beach ridges between the ocean and a large brackish lagoon. Maximum elevation 8 m (25 ft.); higher land (more than 100 m) beginning 7 km inland, Weather: June was unusually clear and dry. Average June temperature (mean of daily maxima and minima) was 5.2°C (41.3°F). Temperature range -3.3 to 17.8°C (26 to 64°F). Total rainfall .28 in. Snow cover less than 10% by 28 May 1977. Coverage: Censuses on 3, 8, 14, 19, 23, 28 June; 3, 9, 14, 19 July. Census periods 0400 to 1600; total person hours 31. Census: Savannah Sparrow 13 (44, 18); Lapland Longspur 8.5 (29, 12); Northern Phalarope 5 (17, 7); Semipalmated Sandpiper 2.5; Western Sandpiper 2; Long-billed Dowitcher 2; Redpoll 2; Willow Ptarmigan 1; Golden Plover 1; Pectoral Sandpiper 1; Red-throated Loon 0.5; Oldsquaw 0.5; Common Snipe 0.5; Black-bellied Plover +. Total: 14 species; 40 territorial males or females (133/km^2, 54/100 acres). Visitors: Pintail, Sandhill Crane, Whimbrel, Dunlin, Parasitic Jaeger, Long-tailed Jaeger, Raven. Remarks: Although Parasitic and Long-tailed Jaegers did not appear to nest in the area, both species were present throughout the breeding season. Mammalian predators present were Arctic and Red Foxes. No microtines were observed. P. Connors, C. Connors.

Appendix 5 Breeding Bird Census, Wales, Alaska, 1977.

Wet Coastal Tundra---Location: Alaska, 4 km (2.5 miles) N of Cape Prince of Wales; 65°38'N, 167°04'W; Teller Quadrangle (C-7) USGS. Continuity: New. Size: 25 ha = 61.8 acres (250 m x 1 km, surveyed and gridded). Description of Plot: Dominant Ground Cover (approximate percentages for vegetated area only): Sedge (Carex) 55%, moss 25%, willow (Salix) 5%, crowberry (Empetrum nigrum) 5%, and lichens 5%. Water cover = 12%, including 5 lakes averaging 30 meters width, 13 small ponds averaging 2 meters "across, and minor areas of flooding. Edge: Bordered on all sides by similar tundra. Topography: Flat, with 1 meter ridges separating 2 wet areas of low ground from 2 moist areas of higher ground. Elevation: Less than 50 ft. Weather: cool and windy. Average June temperature 3.6°C (38.4°F); Temperature range -1.7 to 12.8°C (29 to 55°F). Coverage: June 15, 20, 25, 30; July 7, 10, 15, 20. Census periods between 1100 and 1700; Total person hours 45.5. Census: Western Sandpiper 17 (68, 27); Dunlin 5 (20, 8); Lapland Longspur 2; Pintail 1; Oldsquaw 1; Long-billed Dowitcher 1; Red Phalarope 1, Northern Phalarope 1. Total: 8 species, 29 territorial males or females (116/km^2, 46/100 acres). Visitors: Red-throated Loon, Golden Plover, Pectoral Sandpiper, Parasitic Jaeger, Glaucous Gull, Arctic Tern. Remarks: Nests found: Western Sandpiper 15, Dunlin 4, Pintail 1, Oldsquaw 1, Long-billed Dowitcher 5, Red Phalarope 1, Northern Phalarope 1, Lapland Longspur 1. Reindeer (Rangifer tarandus) herds trampled or disturbed several nests in early July. No microtines were seen on the plot. We thank Polar Research Laboratories for supplying us with weather data. K. Hirsch, D. Woodby.

Appendix 6 Birds collected for fat and diet studies, 1977 (n = 3 or more) (B, Barrow; K, Cape Krusenstern; W, Wales).

Location[1]/Date (1977)	Sex/Age a-adults j-juveniles	Weight (gm)	Ocs Fat Code
Dunlin (*Calidris alpina*)			
KTL[2]/21 July	F/a	52	2
KSS[3]/10 Aug	F/j	51	2
KND[4]/ 2 Sept	M/a	64	3
KND / 2 Sept	F/j	63	4
KND / 2 Sept	M/a	63	4
KND / 2 Sept	F/j	57	2
KND / 2 Sept	F/j	65	3
KND / 2 Sept	M/j	55	2
KND / 2 Sept	F/j	62	3
KND / 2 Sept	F/j	59	3
KND / 2 Sept	F/j	63	3
KND / 2 Sept	F/j	67	4
WVS /23 July	F/a	63	3
WVS /23 July	M/a	59	3
WSM /17 Aug	F/j	49	2
WEL / 9 Sept	M/j	53	2
WEL / 9 Sept	F/j	57	2
Western Sandpiper (*Calidris mauri*)			
KTL /21 July	F/j	21	2
KTL /23 July	F/j	25	2
KSB /28 July	M/j	21	1
KTL / 1 Aug	F/j	23	2
KSI / 1 Aug	M/j	23	2
KMS / 5 Aug	M/j	20	2
KMS / 5 Aug	M/j	21	2
KSS / 9 Aug	M/j	21	2
WVS /21 July	M/a	24	2
WVS /23 July	-/j	26	2
WVS /23 July	-/j	25	3
WBD /31 July	F/j	24	2
WBD / 8 Aug	M/j	22	2
WNM /17 Aug	M/j	23	2
Sanderling (*Calidris alba*)			
WBS /16 July	F/a	76	4
WBD /16 Aug	M/j	68	4
WBD /25 Aug	F/j	61	3
Red Knot (*Calidris canutus*)			
KWB /30 July	F/j	114	2
WBD /26 July	M/a		4
WBD /26 July	M/a		3

Location[1]/Date (1977)	Sex/Age a-adults j -juveniles	Weight (gm)	OCS Fat Code
Long-billed Dowitcher (*Limnodromus scolopaceus*)			
KNF /15 July	F/a	122	4
KND / 2 Sept	-/j	111	4
KND / 2 Sept	F/j	114	4
Northern Phalarope (*Lobipes lobatus*)			
BME / 8 Aug	-/j	39	4
BME / 8 Aug	F/]	39	4
KTL /,1 Aug	F/j	31	1
KSS /10 Aug	-/j	36	4
Red Phalarope (*Phalaropus fulicarius*)			
WBD /31 July	F/j	50	2
WBD / 2 Sept	M/j	46	-
(Barrow Red Phalaropes: stomachs analyzed for asterisked birds; rest for fat only)			
BRW /18 July	M/a	51	
*BME / 8 Aug	F/j	50	3
*BME / 8 Aug	F/j	54	3
BBD / 8 Aug	M/j	47	2
BBD / 8 Aug	F/j	51	2
*BBD / 8 Aug	F/j	54	3
BMW /12 Aug	M/j	--	2
BMW /12 Aug	F/j	45	2
BMW /12 Aug	F/j	49	3
BMW /12 Aug	F/j	54	3
BMW /12 Aug	F/j	53	2
BMW /'12 Aug	-/j	--	4
BMW /12 Aug	F/j	52	2
BMW /12 Aug	F/j	53	3
/16 Aug	-/j	48	3
*BGF /24 Aug	F/j	50	4
*BGF /24 Aug	M/j	46	4
BGF /24 Aug	-/j	42	3

Footnotes:

[1]nearest transect

[2]Tasaychek Lagoon, 2-1/2 km north Of KBI

[3]Sisualik, 15 km NW of Kotzebue

[4]Noatak Delta

Appendix 7 Systematic List of Zooplankton Collected in 1977.

B: Barrow
W: Wales
K: Cape Krusenstern

COELENTERATA
Hydromedusae, several species (B, W, K)

ANNELIDA
Polychaeta
Phyllodocidae (B, W, K)
Spionidae (B, W, K)
unidentified larvae (B, W, K)

MOLLUSCA
Gastropoda: Opisthobranchia: Thecosomata
Spiratella helicina (B)

ARTHROPODA: CRUSTACEA
Cladocera (W, K)
Mysidacea
Boreomysis sp. (B, W, K)
Mysis relicta (B)
Cumacea, sp. undet. (W, K)
Copepoda: Cyclopoida, Harpacticoida, Calanoida, several species of each (B, W, K)
Cirripedia: *Balanus* sp., cyprids (B, K)
Isopoda: *Saduria entomon* (B, W)
Amphipoda: Gammaridea
Apherusa glacialis (B)
Onisimus litoralis (B, W)
Gammarus sp. (W, K)
Gammaracanthus loricatus (W)
Dexaminidae (W)
Calliopiidae, two species (B, W, K)
unidentified juveniles (W, K)
Euphausiacea: *Thysanoessa* sp. (B)
Decapoda: zoea (W)

CHAETOGNATHA
Sagitta sp. (B, W, K)

ECHINODERMATA
Asteroidea: bipinnaria larvae (W, K)
postlarval, undet. sp. (W, K)

APPENDICULARIA
Oikopleura sp. (B)

PISCES
fish, larvae and eggs (B, W)

Non-planktonic organisms taken:

Plants: numerous seeds (B, W, K)

Coelenterata: hydroid colony fragments (W)

Annelida: Oligochaeta (B, W. K)

Mollusca: nepionic bivalves (W, K), nepionic snails (W), operculum (W, K)

Crustacea: cladoceran ephippia (B, W, K), caprellids (W), munnid isopod (W)

Pycnogonida: undet. sp. (W); Arachnida: Hydrocarina (B)

Insects: Diptera (several families) (B, W, K); Collembola [B)

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XIII. Research Personnel, 1977 Season

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