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SEASONAL NUMBERS AND DISTRIBUTION OF SHOREBIRDS ON NORTH CAROLINA'S OUTER BANKS

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ABSTRACT.—We documented the seasonal abundance, distribution, and relative importance of outer beach habitats to shorebirds on the Outer Banks of North Carolina. The Outer Banks span 228 km and attract millions of tourists every year, underscoring the need for baseline data for conservation. Twenty-one species were recorded during the study. The most abundant were Sanderling (*Calidris alba*), Red Knot (*Calidris canutus*), and Willet (*Catoptrophorus semipalmatus*). As an assemblage, shorebirds were most abundant in May and August. Peak numbers for each species were recorded between April–May and July–September. The greatest numbers were recorded on North Beach and the lowest on South Beach (1992) and Bodie Island (1993). Shorebird abundance was greater during fall (68 birds/km) than in spring (50 birds/km). Patterns of abundance of the eight most abundant species were examined in detail. Black-bellied Plovers (*Pluvialis squatarola*), Willets, Whimbrels (*Numenius phaeopus*), Ruddy Turnstones (*Arenaria interpres*) and Sanderlings were most abundant on North Beach. North Core Banks harbored the highest numbers of Piping Plovers (*Charadrius melodus*), American Oystercatchers (*Haematopus palliatus*), and Red Knots. American Oystercatchers and Whimbrels were significantly more abundant during spring than fall, whereas Willet and Sanderlings were more abundant during fall. The Outer Banks emerged as an important staging area for the Atlantic populations of Piping Plovers, Whimbrels, and Sanderlings when compared to 7 other areas along the eastern U.S. coast. The importance of the area to Sanderlings was reaffirmed by return rates of 58%, most (69–89%) returning to the beach stretch where they were banded. The area gains special significance because it also supports a nesting population of Piping Plovers. Our findings confirm that the Outer Banks of North Carolina provide a critical link in the migratory path of several shorebird species. Habitat loss or alteration could adversely affect the Atlantic Flyway population of several species (e.g., Sanderlings) as well as the threatened Piping Plover. *Received 1 May 1997, accepted 13 Jan. 1998.*

Many migrant shorebirds rely on a few, key stopover sites to complete their annual migratory cycle (Myers et al. 1987). These sites often provide a unique combination of food resources and habitat necessary to support a large number of birds (Myers 1986, Myers et al. 1987). Examples of important sites in North America are Delaware Bay (Clark et al. 1993), the Bay of Fundy (Hicklin 1987), the Copper River Delta of Alaska (Isleib 1979, Senner 1979), and Grays Harbor in Oregon (Senner and Howe 1984). Because a large proportion of a species' population may be concentrated at one or a few sites during migration, shorebirds are particularly vulnerable to habitat loss and degradation, and thus to population decline (see Gill and Handel 1990). Coastal areas, where the vast majority of these key sites occur, are seriously threatened by habitat alteration and destruction by human development (Senner and Howe 1984, Davidson and Pienkowski 1987). Survey information for additional or alternative sites is lacking, mostly because resources to implement adequate survey programs have not been available (Senner and Howe 1984). Such information is needed in the event of losses of key sites.

The Outer Banks of North Carolina constitute a prime example of a potentially important area for which only limited information on migratory shorebirds is available (Buckley and Buckley 1973, Root 1988, Senner and Howe 1984, Boone 1988). Previous information was gathered as part of short-term surveys and Christmas Bird Counts. From these efforts, it was estimated that 20,000 shorebirds used the Outer Banks annually during autumn. At least 15 species of shorebirds used the Outer Banks during winter. Abundant spe-

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cies included Black-bellied Plover (*Pluvialis squatarola*), Willet (*Catoptrophorus semipalmatus*), Red Knot (*Calidris canutus*), Sanderling (*Calidris alba*), Dunlin (*Calidris alpina*), and Short-billed Dowitcher (*Limnodromus griseus*). These data, while informative, were limited in that they did not rest on geographically extensive, replicated surveys. Because the area is subject to ever increasing development and tourism pressures (Parnell et al. 1992), broader, replicated surveys are needed to better assess the importance of the Outer Banks and potential impacts caused by human use.

Here we present geographically extensive data on the monthly and seasonal numbers and distribution of shorebirds using outer beach habitats in the Outer Banks collected during 1992 and 1993. Information on the shorebird community as a whole, and the eight most abundant species is emphasized. Special attention is given to the following species of concern: Piping Plovers (*Charadrius melodus*), Whimbrels (*Numenius phaeopus*), Red Knots, and Sanderlings. Conservation needs of these species are heightened because of their threatened status (Piping Plover), recent population declines (Whimbrel and Sanderling; Howe et al. 1989), or their localized distribution along the Atlantic Flyway (Red Knot; Morrison and Harrington 1992). We also assessed the relative regional importance of the Outer Banks for these species by comparing peak counts from this study to those obtained through the International Shorebird Survey (ISS, Manomet Observatory for Conservation Science) for seven other sites along the Atlantic Flyway. We estimated Sanderling population size and turnover rates using mark-resight techniques (Dinsmore 1994). On the basis of observations of color-marked individuals we present distribution and site fidelity patterns for this species.

STUDY AREA AND METHODS

The Outer Banks are located along the east-central coast of North Carolina (34° 34′–35° 50′ N, 75° 27′–76° 39′ W; Fig. 1). The area consists of a series of narrow barrier islands with a length of approximately 228 km stretching from just north of Oregon Inlet in Dare County to Beaufort Inlet in Carteret County. Much of the area is included in Cape Hatteras and Cape Lookout National Seashores. Because of its inaccessibility, this study was restricted to the northern portions of the Outer Banks north of New Drum Inlet.

The topography is typical of barrier islands, with a low elevation and flat relief. Outer beach habitat occupied by shorebirds was sandy and devoid of vegetation. Outer beach is defined as the area from the base of the dune line to the ocean edge, including that portion of the intertidal zone exposed at low tide. Outer beach did not include soundside tidal flats at inlets or other tidal flat habitats. Mean tidal amplitude is approximately 1 m.

Censuses.—From March 1992 to December 1993, five sites ranging from 9–34 km in length were surveyed. These sites were chosen mostly for accessibility, but were representative of outer beach habitat within the study area. Bodie Island (9 km) extended from the south edge of Nags Head south to Oregon Inlet. North Beach (28 km) extended from the Rodanthe pier south to a point 1 km north of the Buxton town limit. South Beach (24 km) extended from just south of the Cape Hatteras lighthouse south to Cape Hatteras point, then west to Hatteras Inlet. Ocracoke Island (28 km) included the entire island from Hatteras Inlet south to Ocracoke Inlet. North Core Banks (34 km) included the entire island from Ocracoke Inlet south to New Drum Inlet. The total amount of outer beach surveyed monthly for shorebirds was 123 km. Additionally, a stretch of Pea Island National Wildlife Refuge (19 km) extending from the Oregon Inlet jetty south to Rodanthe was censused during the fall 1993 season.

Surveys were conducted twice per month by vehicle. All surveys were begun 1.5 h before low tide, except for two counts on North Core Banks in July and August 1992 that were begun 1.5 h before high tide. Numbers and species of all shorebirds present on the outer beach were recorded. Flying birds were not recorded, unless they were clearly disturbed by the investigators. Because large shorebird concentrations (> 500 birds) were rare, data here represent actual counts and not estimates.

Abundance was first calculated as the mean of the two monthly censuses for each site to minimize variance problems associated with repeated measures within a month (Hurlbert 1984). For a few sites, there was only one count in a given month and this was treated as the estimate for that month. We report patterns of abundance in two ways: monthly numbers (mean number of shorebirds per month) and seasonal numbers (sum of the mean monthly counts within a season). We also used a factorial ANOVA to test for seasonal patterns in abundance (JMP 1994). In this model, seasons were defined as spring (April–June) and fall (July–November). All statistical analyses were performed using JMP v. 3.1.5 software on a Macintosh computer (JMP 1994). These seasons span the major migration periods for the species examined (Dinsmore 1994). The effects of site and year on the variability of monthly counts were tested. Month, a repeated measure, was nested within seasons. To meet homogeneity of variance requirements, data were log or square root transformed. The most appropriate transformation was determined

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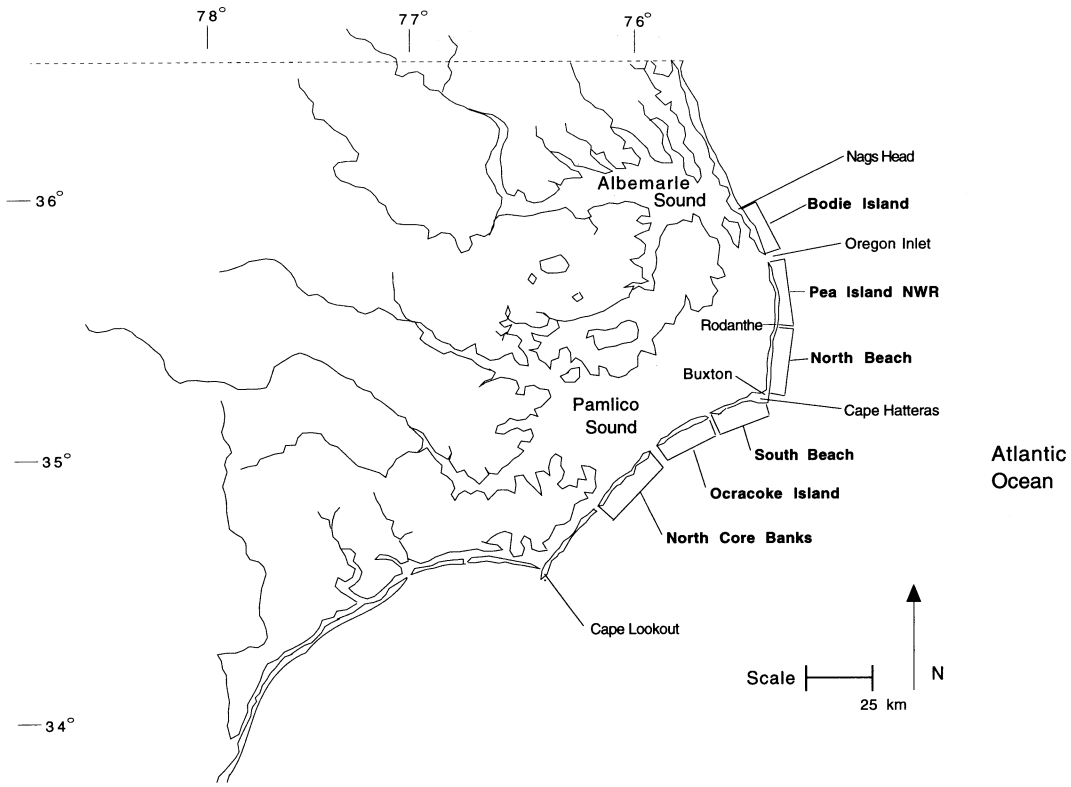

FIG. 1. Map of the Outer Banks of North Carolina showing barrier islands and locations visited between March 1992 and December 1993.

by examining plots of residuals. Abundance, expressed as birds/km, of the eight selected shorebird species was also calculated for each site.

Peak fall counts of Piping Plovers, Whimbrels, Red Knots, and Sanderlings obtained during this study were compared to similar counts obtained at seven other sites, excluding Delaware Bay, along the Atlantic Coast and the Gulf Coast of Florida. Counts were obtained from International Shorebird Survey (ISS) data for the fall migration period (July to November) in 1972–1992. Only marine sites surveyed over at least nine years were used for these comparisons. Censuses at ISS sites were generally conducted at 10-day intervals, but sampling effort was sometimes variable. Thus, the peak count of each species was treated as the estimate for the site (see Colwell and Cooper 1993). Counts obtained during this study were ranked with counts for the other seven sites to assess the importance of the Outer Banks to each of these species.

Distribution and site fidelity of Sanderlings.—To examine the seasonal distribution and site fidelity of Sanderlings, birds were color-marked during 1992–1993. Sanderlings were caught primarily with a rocket net, although some were initially caught in mist nets. Most birds were caught at roost sites where they were herded in front of the rocket net for capture. A few were caught as they concentrated at foraging areas along the outer beach. Because of seasonal changes in distribution, Sanderlings were trapped at North Core Banks in spring and at four sites on Cape Hatteras National Seashore during fall (Dinsmore 1994). Trapping was conducted from 28 April–27 May and 29 July–16 October in 1992 and from 22 April–23 May and 27 July–4 November in 1993. Birds were removed from the net immediately after capture and transferred to cardboard holding boxes. All birds were fitted with an aluminum U. S. Fish and Wildlife Service leg band and a series of either four (1992) or three (1993) color bands arranged in a unique combination. The color bands were U.V. stable PVC bands (A. C. Hughes, London, England). Combinations were derived from six and ten possible colors during 1992 and 1993, respectively. Color band seams were sealed to reduce the possibility of band loss. Birds were released at the capture site within three hours of capture.

Marked birds were surveyed from a four-wheel drive vehicle every 5–7 days. During surveys, complete and partial color band combinations were recorded, as well as the number of unmarked birds examined for color bands. Very large (> 500 birds) concentrations of sanderlings were rare, which increased the ease of examining birds for color bands.

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TABLE 1. Seasonal means (± SE), seasonal totals and month of peak count of shorebirds on the Outer Banks of North Carolina, 1992–1993. Seasonal numbers are means of the monthly counts within each season; peaks are given by month with the number recorded in parentheses.

Species[a]	Seasonal means[b]		Seasonal totals[c]		Month of peak count
	Spring	Fall	Spring	Fall	
All species	5684 ± 2421	7760 ± 1118	17,051	38,798	May (11,540)
Black-bellied Plover	194 ± 113	282 ± 76	582	1408	October (472)
Wilson's Plover	2 ± 1	1 ± 1	6	7	May, July, August (3)
Semipalmated Plover	28 ± 27	27 ± 10	82	134	May (81)
Piping Plover	13 ± 2	31 ± 9	39	155	September (58)
American Oystercatcher	114 ± 22	79 ± 26	342	397	July (152)
Willet	369 ± 52	1034 ± 452	1108	5168	July (2750)
Whimbrel	175 ± 150	100 ± 60	526	500	May (474)
Marbled Godwit	0	2 ± 1	0	8	October (4)
Ruddy Turnstone	176 ± 125	116 ± 58	527	581	May (419)
Red Knot	1363 ± 725	267 ± 27	4088	1334	May (2764)
Sanderling	3222 ± 1796	5692 ± 907	9667	28,458	August (8194)
Semipalmated Sandpiper	21 ± 18	24 ± 13	63	120	September (70)
Western Sandpiper	1 ± 1	17 ± 8	4	84	September (43)
Least Sandpiper	2 ± 2	5 ± 4	5	26	September (19)
Dunlin	1 ± 1	53 ± 38	4	263	November (196)
Short-billed Dowitcher	1 ± 1	29 ± 22	4	146	July (117)

[a] Five species were recorded < 5 times (Killdeer, Greater Yellowlegs, Lesser Yellowlegs, Spotted Sandpiper, and White-rumped Sandpiper).
[b] Seasons are defined as Spring (April–June) and Fall (July–November).
[c] The sum of the monthly means over the season.

The inter-annual site fidelity (i.e., return rates) of Sanderlings was examined by looking at 1993 resightings of birds banded in 1992 at North Core Banks, Bodie Island, and North Beach. Only birds resighted after April 1, 1993 were used because most overwinter mortality should have occurred by then. Resighting probabilities were assumed to be equal among sites. Birds resighted at more than 1 location in 1993 (n = 117) were excluded from this analysis. A χ^2 test for homogeneity of resightings by location was computed for each of the three locations. The observed values for each of the three sites were calculated by determining the number of birds marked at a given site (e.g., site A) and resighted at sites A, B,and C. The same calculations were made for birds marked at sites B and C. The expected value for each test was then the sum of the marked birds seen at each site divided by the number of sites. In each case, the denominator was 3, and the test had 2 degrees of freedom.

The within-season site-fidelity of Sanderlings was examined during fall 1993. During that season, birds were marked at Bodie Island, Pea Island, North Beach, and South Beach. Resighting efforts were conducted on all sites except North Core Banks. Only birds resighted at least once in each of two different capture periods were used in this analysis. A bird was considered site-faithful if at least two-thirds of the resightings were from the banding site. The percentage of birds that were faithful to their banding site are reported by banding location.

RESULTS

Shorebird assemblage.—Twenty-one species were recorded on surveys (Table 1). Species richness was slightly greater in fall (21 species) than in spring (18 species). Totals of 52,651 shorebirds in 1992 and 58,935 shorebirds in 1993 were recorded. Surveys revealed that Sanderling, Red Knot, and Willet were the most abundant shorebird species and accounted for 89% of the total numbers. Sanderlings were the single most abundant species and accounted for 68% of the total (Table 1).

Shorebirds were present on the Outer Banks throughout the study, although numbers peaked during May and from July to September in fall. The fewest were recorded during June ($F = 4.93$, d.f. = 12, 46; $P < 0.001$; Fig. 2). Shorebird numbers varied between sites and seasons ($F = 2.84$, d.f. = 4, 46; $P = 0.03$). Shorebirds were most abundant on North Beach during both years, and least abundant on South Beach during 1992 and on Bodie Island during 1993. On all sites except Ocracoke Island and North Core Banks, shorebird numbers were highest during the fall season. Abundance of shorebirds was

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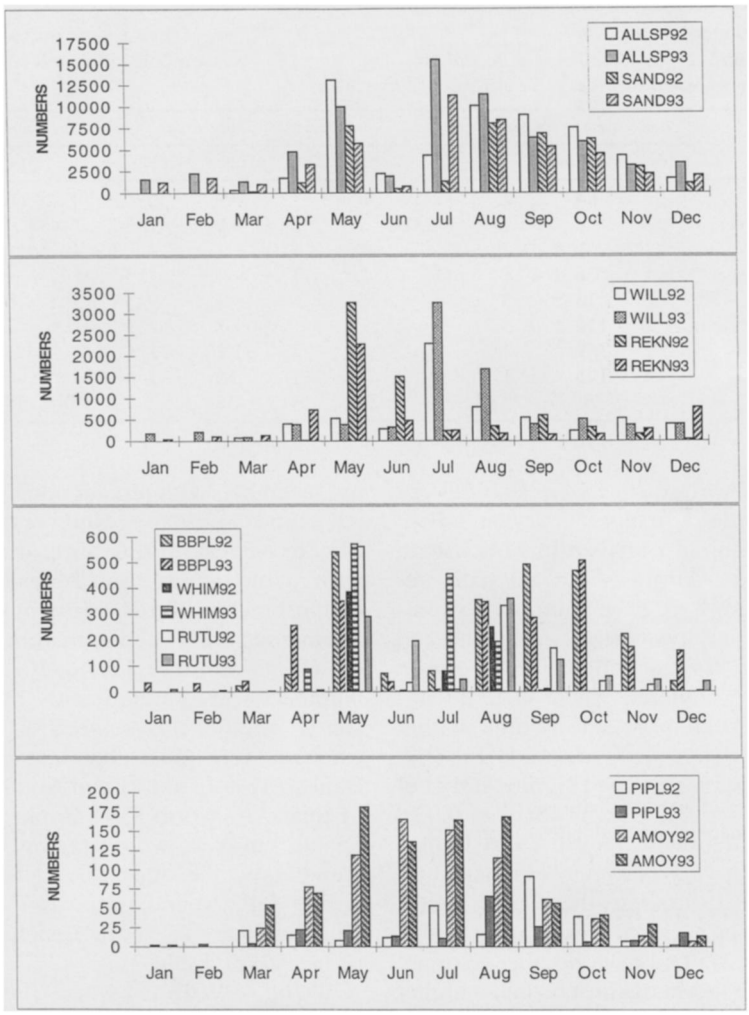

FIG. 2. Numbers of the shorebird community (ALLSP), Black-bellied Plovers (BBPL), Piping Plovers (PIPL), American Oystercatchers (AMOY), Whimbrels (WHIM), Ruddy Turnstones (RUTU), Red Knots (REKN), and Sanderlings (SAND) and Willets (WILL) detected on beach censuses on the Outer Banks of North Carolina, March 1992–December 1993.

greater in fall (68 birds/km) than in spring (50 birds/km), with a peak at North Beach during fall (117 birds/km; Table 2). Spring passage was rapid, being confined almost entirely to the month of May, whereas in fall, birds began arriving in July and some lingered into November or even December (Fig. 2).

Black-bellied Plover.—Black-bellied Plovers were present every month of the year, although the greatest numbers were recorded in May and August–October. The lowest numbers were recorded from January to March. Spring migrants arrived in April, peaked in May, and were gone by early June. Fall migrants began arriving in August, peaked in October, and most departed by November ($F = 5.74$, d.f.: 12, 46; $P < 0.01$; Fig. 2). Very few birds overwintered. Population sizes did not vary by site or season. Plovers were most abundant on North Core Banks (27% of total) and North Beach (32% of total). Abundance was quite low at all sites, being greatest at North Beach during fall (4 birds/km; Table 2).

Piping Plover.—Piping Plovers were recorded every month of the year, with the greatest numbers recorded July–October.

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TABLE 2. Abundance (birds/km) of eight shorebird species by season at five sites on the Outer Banks of North Carolina, 1992–1993. Mean count/site (all sites considered) by season is listed in the last column. Spring = S, Fall = F. Sites shown in Figure 1.

	Bodie Island		North Beach		South Beach		Ocracoke		N. Core Banks		Mean/site	
	S	F	S	F	S	F	S	F	S	F	S	F
All shorebirds	59	88	31	117	36	41	49	36	74	56	50	68
Black-bellied Plover	3	2	2	4	2	2	2	1	2	3	2	2
Piping Plover	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Am. Oystercatcher	<1	1	<1	<1	2	1	1	<1	1	1	<1	<1
Willet	2	6	3	12	2	6	4	9	5	9	3	8
Whimbrel	7	1	3	2	1	<1	<1	<1	<1	<1	2	<1
Ruddy Turnstone	2	1	1	2	3	2	<1	<1	2	<1	2	1
Red Knot	3	1	<1	<1	1	<1	16	1	34	6	11	2
Sanderling	44	76	23	97	26	28	26	22	29	34	30	51

Numbers from April to June were stable. Very few were recorded during January and February. Spring migrants arrived in March with a slight peak in April. About 40 pairs remained and bred during the summer. Fall migrants arrived in July, peaked in August and September, and most departed by November. A few birds overwintered. There were no significant differences between months within season and year ($F = 1.00$, d.f.: 24, 46; $P > 0.05$; Fig. 2). Numbers varied significantly between sites ($F = 3.01$, d.f.: 4, 46; $P = 0.03$); most (69%) occurred on North Core Banks. Numbers did not vary between seasons. Compared to other ISS sites, the Outer Banks ranked second in regional importance to this species (Table 3). Only Monomoy National Wildlife Refuge in Massachusetts had a higher peak count than the Outer Banks. Bird abundance was very low (<1 bird/km) at all sites (Table 2).

American Oystercatcher.—American Oystercatchers were recorded mostly from March to December, with almost none present in January and February. Numbers peaked from May to August. Spring birds arrived in March, with stable counts from May to August indicating breeding birds. Most birds departed in September, with a few remaining into November ($F = 3.36$, d.f.: 12, 46; $P < 0.01$; Fig. 2). Numbers varied significantly by site and season ($F = 3.36$, d.f.: 4, 46; $P = 0.02$). Oystercatchers were most abundant on North Core Banks (31% of total) and South Beach (33% of total). At North Core Banks and Ocracoke Island, numbers were greatest during spring. Numbers at the other three sites were higher during fall. Abundance was low at all sites, being greatest at South Beach during spring (2 birds/km; Table 2).

Willet.—Willets were recorded every month of the year, although the greatest numbers were recorded in July and August. Otherwise, numbers were quite stable from April to December, with slightly fewer birds present from January to March. Spring migrants ar-

TABLE 3. Peak numbers of four shorebird species at eight sites along the Atlantic Coast and Gulf Coast of Florida from International Shorebird Survey data (Manomet Observatory for Conservation Sciences) and at the North Carolina Outer Banks (1992–1993).

Site	Piping Plover	Whimbrel	Red Knot	Sanderling
Plymouth Beach, MA	57	19	950	2500
Monomoy NWR, MA	100	585	3000	5000
Jamaica Bay NWR, NY	0	10	1685	350
Great Egg Harbor, NJ	23	33	2294	1400
Chincoteague NWR, VA	50	355	2175	11,130
Outer Banks, NC	91	453	600	11,257
Cape Romano, FL	25	7	8115	809
Marco River, FL	24	3	1211	457

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rived in April, peaked in May, with some remaining into June to breed. During fall, the peak was in July, with smaller numbers remaining through December ($F = 7.43$, d.f.: 12, 46; $P < 0.01$; Fig. 2). Numbers varied significantly by site and season ($F = 2.70$, d.f.: 4, 46; $P = 0.04$). Willets were most abundant on North Core Banks (26% of total) and North Beach (29% of total). At all sites, Willets were more numerous during fall. They were three times more abundant in fall than spring at North Beach and Bodie Island. Abundance was much greater in fall (8 birds/km) than spring (3 birds/km) with the greatest abundance recorded at North Beach during fall (12 birds/km; Table 2).

Whimbrel.—Whimbrels were recorded mostly from April to September, with distinct peaks in May and in July and August. None was recorded from December to March. Spring migrants arrived in April, peaked in May, and very few remained in June. Fall migrants arrived in July, peaked in July and August, and nearly all had departed by September with a few lingering to November ($F = 15.63$, d.f.: 12, 46; $P < 0.01$; Fig. 2). Whimbrel were most abundant on North Beach (42% of total) and Bodie Island (24% of total). Numbers increased significantly in 1993 ($F = 5.50$, d.f.: 1, 46; $P = 0.02$) for all sites except North Core Banks. There was also significant variation between seasons ($F = 7.10$, d.f.: 1, 46; $P = 0.01$). Whimbrels were slightly more abundant in spring. Compared to other ISS sites, the Outer Banks ranked second in regional importance to this species (Table 3). Monomoy National Wildlife Refuge in Massachusetts was the only site to have a higher peak count. Abundance was low at all sites except Bodie Island where the peak was recorded during fall (7 birds/km; Table 2).

Ruddy Turnstone.—Ruddy Turnstones were present every month of the year, although the majority were present from May to June and from August to September. Numbers were lowest from January to April. Spring migrants arrived in April, showed a strong peak in May, and most departed by June. Fall migrants arrived in July, peaked in August, and most departed by October ($F = 11.49$, d.f.: 12, 46; $P < 0.01$; Fig. 2). Ruddy Turnstones were most abundant on South Beach (33% of total) and North Beach (30% of total), although site differences were not significant. Abundance was low at all sites with the peak at South Beach during spring (3 birds/km; Table 2).

Red Knot.—Red Knots were present every month of the year, although the greatest numbers were recorded in May and June. Numbers from July to December were fairly stable, with the lowest numbers recorded from January to March. Spring migrants arrived in April, peaked in May, and most departed by June. During fall, birds arrived in July, showed a small peak in September, and moderate numbers were still present in November ($F = 2.87$, d.f.: 12, 46; $P < 0.01$; Fig. 2). Numbers varied significantly between sites ($F = 5.62$, d.f.: 4, 46; $P < 0.01$). Most Red Knots were seen at North Core Banks (65% of total) and Ocracoke Island (28% of total). Compared to other ISS sites, the Outer Banks ranked last in regional importance to this species (Table 3). Abundance was much higher in spring (11 birds/km) than in fall (2 birds/km), with most birds recorded at North Core Banks (34 birds/km) and Ocracoke Island (16 birds/km; Table 2).

Sanderling.—Sanderlings were present every month of the year, although the greatest numbers were present in May and from July to October. The lowest numbers were recorded in March and June. Spring migrants arrived in April, peaked in May, and most departed by June. Fall migrants arrived in July, peaked in August and September, and steadily decreased throughout November ($F = 4.19$, d.f.: 12, 46; $P < 0.01$; Fig. 2). Sanderlings were most abundant on North Beach (41% of total) and North Core Banks (20% of total), although site differences were not significant. Compared to other ISS sites, the Outer Banks ranked first in regional importance to this species (Table 3). Sanderling abundance was much greater in fall (51 birds/km) than in spring (30 birds/km; Table 2). Spring birds peaked on Bodie Island (44 birds/km) while fall birds peaked on North Beach (97 birds/km).

Sanderlings exhibited moderate within-season site fidelity. Most (i.e., 50–62%) remained faithful to the area in which they were banded during the fall 1993 migration (Table 4). Others usually moved to an adjacent site, less than 10 km away in most cases. Sanderlings showed high inter-annual site fidelity. Fifty-

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TABLE 4. Percentage of resightings of Sanderlings on the Outer Banks of North Carolina by banding site during fall 1993. The percentage of Sanderlings resighted in at least 2 sites are also reported. Banding sites are shown in Figure 1.

	Resighting sites						
Banding site	Bodie Island	Pea Island	North Beach	South Beach	Ocracoke Island	2 sites	>2 sites
Bodie Island	62.6	8.0	1.1	0	0	26.2	2.1
Pea Island	7.5	52.5	7.5	2.5	0	25.0	5.0
North Beach	2.9	2.6	52.2	11.9	1.1	27.0	2.3
South Beach	0	0	6.3	50.0	0	12.5	31.2

eight percent (380/655) of the birds marked during 1992 were resighted in 1993. A significant proportion of the birds returned to their banding site. The proportions returning were 0.89 for North Core Banks ($\chi^2 = 102.9$, $P < 0.01$), 0.82 for Bodie Island ($\chi^2 = 174.7$, $P < 0.01$), and 0.69 for North Beach ($\chi^2 = 74.2$, $P < 0.01$).

DISCUSSION

The 21 species detected in this study were representative of shorebirds commonly found on barrier island beaches along the Atlantic Coast (Senner and Howe 1984). Sanderling was the most abundant species, followed by Red Knot and Willet. The patterns of abundance contrast markedly with those at Delaware Bay, one of the most important stopovers for shorebirds along the Atlantic Coast (Myers 1983). At Delaware Bay, Semipalmated Sandpiper was the most abundant species, followed by Ruddy Turnstones, Red Knots, and Sanderlings (Clark et al. 1993). Differences in abundance between these sites likely are due to the differences in habitats surveyed. In this study we focused on outer beach habitat, while the Delaware Bay study included other habitats such as beaches adjacent to tidal flats and salt marshes (Clark et al. 1993).

The high number of Piping Plovers using the Outer Banks indicates the importance of the area to this federally threatened species. In addition to supporting a breeding population of approximately 40 pairs (Collazo et al. 1995), the area is an important staging site, especially in fall. We recorded a peak of 89 individuals during September 1992, most on North Core Banks. However, single-day counts of 128 on 29 August 1992, 110 on 25 September 1992, and 136 on 20 August 1993 on North Core Banks were made independently of censuses. These counts included large numbers of plovers using tidal flats at Ocracoke and New Drum inlets. North Core Banks is probably one of the most important staging areas for the Atlantic Coast population of Piping Plovers (see Haig and Plissner 1993). The 1991 International Piping Plover Census recorded 1975 adult plovers along the Atlantic Coast of Canada and the United States (Haig and Plissner 1993). Based on these numbers and assuming no turnover, a minimum of 7% of the Atlantic Coast population of Piping Plovers uses North Core Banks during migration.

Moderate numbers of Red Knots use the Outer Banks during migration and in winter. Morrison and Harrington (1992) estimated the North American population of Red Knots at 180,000. The vast majority of these birds stage in Delaware Bay during spring (Clark et al. 1993), with small concentrations noted at other sites along the Atlantic Coast (Hicklin 1987, Marsh and Wilkinson 1991). On the Outer Banks, more than 4700 knots were counted in May and June 1992, most (73%) on North Core Banks. Not accounting for turnover, our peak count of 2764 individuals (Table 1) indicates the Outer Banks host a minimum of 1–2% of the estimated North American Red Knot population during spring. The importance of the Outer Banks as a wintering area is poorly understood. Censuses indicated that over 500 knots wintered each year, the northernmost sizeable wintering aggregation on the Atlantic Coast. The largest known wintering group in North America is on the Gulf Coast of Florida, where a mean of 6300 (± 3400 S.E.) were detected in 1980–82 (Harrington et al. 1988). In South Carolina, no sizeable winter concentrations of knots were noted in the Cape Romain-Santee Delta

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region (Marsh and Wilkinson 1991). The Outer Banks may also be important as a stopover for migrant Whimbrel. Large numbers also use the Cape Romain-Santee Delta region of South Carolina (Marsh and Wilkinson 1991), resulting in single-day counts of over 400 in April and over 200 in August. Information about other critical staging areas for this species is scant.

Sanderlings were the most abundant species. Their abundance was similar to those reported by Walters (1984) for fall (50 birds/km) but not for spring (175 birds/km). Comparative data for the Atlantic Coast is limited to Delaware Bay in New Jersey, a site of hemispheric importance to this species (> 200,000 during migration; Myers et al. 1990). Concentrations of up to 30,000 birds/km have been reported at this site. Other comparative data come from the Pacific Coast. From California to Washington, concentrations of 40 birds/km were reported in winter (Myers et al. 1984). Concentrations of 185 birds/km were reported in coastal Oregon and Washington during spring, with a peak of 472 birds/km at Clatsop Beach, Oregon in early May (Myers et al. 1984). Myers and coworkers (1988) reported abundances of 46, 41, and 22 birds/km in California during fall, winter, and spring, respectively. The lower abundance on the Outer Banks compared to western sites might be attributed to poorer habitat quality. Alternatively, the extent of outer beach habitat in North Carolina may be greater than in coastal California (see Connors et al. 1981, Myers et al. 1984), resulting in fewer birds/km.

Sanderlings tended to be sedentary during migration periods. Most (mean = 54%) remained at their banding site during a given season. This figure may actually underestimate site-fidelity, because birds that moved short distances between sites were not counted as site-faithful. For example, North Beach and South Beach were adjacent to each other, and small numbers of Sanderlings fed on North Beach but roosted on the nearest portion of South Beach. Such individuals were not considered site-faithful because they moved between census areas. Our results indicate that individual Sanderlings are somewhat mobile, but most ranged less than 10 kilometers from their banding site.

Distributional patterns may result from differential food availability between sites. Sanderlings were most abundant on North Beach and North Core Banks, which collectively hosted more than 60% of all individuals counted. Observations of food items ($n >$ 1000) captured by Sanderlings and limited work on food availability suggest that Sanderlings prey almost exclusively on mole crabs (*Emerita talpoida*) along the beaches of the Outer Banks (Dinsmore 1994). This is consistent with other sites where Sanderlings and mole crabs co-occur (Myers et al. 1980, Connors et al. 1981, Maron and Myers 1985). Comparisons between North Beach (high Sanderling abundance) and Ocracoke Island (low Sanderling abundance) indicate that the abundance of mole crabs was significantly higher on North Beach (Dinsmore 1994).

Variations in food supply are thought to influence seasonal variation in Sanderling numbers in North Carolina (Walters 1984). At Pea Island National Wildlife Refuge, Dolan and coworkers (1993) reported that mole crab numbers peaked in May–July and in October. Few were detected from December–March. This pattern of mole crab abundance matches the seasonal trends in the numbers of Sanderlings on the Outer Banks (Dinsmore 1994). Sanderlings quickly increase in late July and early August and remain somewhat stable through October. After October, Sanderlings depart from the Outer Banks. The late fall exodus of Sanderlings is a pattern not found in California, where Sanderling numbers remain fairly stable from early October until they begin to decline in February (Myers 1980). It is likely that Sanderlings remain on the Outer Banks as long as possible, departing only when the food supply diminishes. The drastic reduction in mole crab numbers after October may explain the drop in Sanderling (and perhaps other species) numbers in November.

Because the Outer Banks ranked as the site with the highest peak count during fall migration when compared to seven other sites along the Atlantic Coast, it appears to be an important staging area for Sanderlings. Delaware Bay in New Jersey is the only site to record higher peak counts than those on the Outer Banks. The importance of the Outer Banks to migrant Sanderlings becomes clearer when turnover is considered. An estimated 35–

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40,000 Sanderlings use the Outer Banks annually, most during fall migration (Dinsmore 1994). These data suggest that the Outer Banks are an area of regional importance to Sanderlings under the guidelines of the Western Hemisphere Shorebird Reserve Network (i.e., supporting 20–40,000 birds annually during migration, Myers et al. 1987). The dependency of many migrant Sanderlings on the Outer Banks is confirmed by the strong interannual site fidelity reported in this study. The 1993 return rate of Sanderlings banded on the Outer Banks in 1992 was 58%. Philopatry of Sanderlings has been reported in other studies (Evans et al. 1980; Myers 1988; Myers et al. 1988, 1990; Summers et al. 1987). At Bodega Bay, California, the annual return rate of Sanderlings was 72% for adults and 50% for first-winter birds (Myers 1980). Our findings confirm that the Outer Banks of North Carolina provide a critical link in the migratory path of several shorebird species (e.g., Sanderling, Whimbrel). If habitat loss or alteration were to occur, portions of their Atlantic Flyway populations could be negatively affected, perhaps contributing to further population decline (Howe et al. 1989). The threatened Piping Plover, which depends on the Outer Banks for breeding habitat, could also be affected by such habitat changes. Given the regional significance of this area, efforts to ensure the continued availability of habitat for shorebirds amidst demands for development and recreational uses should constitute a conservation priority.

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