Table 8. Sanderling numbers obtained from beach censuses at five sites on the Outer Banks of North Carolina, 1993.

	Site					
Month	Bodie Island	North Beach	South Beach	Ocracoke I.	N. Core Banks	Mean ± SE
January	224	79	328	106	475	242 ± 73
February	295	80	540	360	438	343 ± 77
March	20	11	178	434	333	195 ± 84
April	395	416	638	978	870	659 ± 117
May	290	1,594	1,198	1,213	1,407	1,140 ± 225
June	2	27	438	26	213	141 ± 83
July	28	9,552	11	325	1,341	2,251 ± 1,841
August	1,135	2,354	2,097	1,114	1,700	1,680 ± 250
September	896	1,500	580	802	1,506	1,057 ± 189
October	172	2,663	982	683	-	1,125 ± 539
November	18	570	774	317	468	429 ± 127
December	15	251	448	474	620	362 ± 105

Table 9. Mean monthly number of Sanderlings on the Outer Banks of North Carolina from mark-resight data ($\hat{N}_i \pm$ 95% C.I.). Counts derived from beach censuses at five sites[1] on the Outer Banks are given for comparison. (the number of estimates used to generate each estimate of $\hat{N}_i$ are given in parentheses).

Month	Mean $\hat{N}_i$	95% C.I. of $\hat{N}_i$	Census count
May	2,352 (6)	1,161-4,764	1,407
June	698 (2)	91-5,347	213
August	8,304 (4)	3,355-20,554	7,743
September	7,078 (4)	2,231-22,454	5,555
October	7,435 (4)	5,364-10,306	5,865
November	5,655 (5)	3,774-8,472	2,140

[1] The five sites are Bodie Island, Pea Island, North Beach, South Beach, and Ocracoke Island.

the number of Sanderlings present on the Outer Banks are obtained by multiplying beach counts by 1.235.

DISCUSSION

Turnover rates as a function of body mass

Residence probabilities were more variable during spring than in fall, indicating that spring birds were departing almost continuously. Spring birds stayed at North Core Banks about a week less, on average, than birds remained at the five sites on Cape Hatteras National Seashore during fall. Significant differences in residence probabilities as a function of body mass were found only during four periods in fall. No significant differences were found during spring. These findings, particularly in spring, suggest that differences in body condition did not always explain patterns of Sanderling departure from the Outer Banks. These results and several confounding factors are discussed below and illustrate the need to carefully design studies of shorebird population dynamics at stopover sites.

Age is known to influence the timing of migration. Adults depart the breeding grounds prior to juveniles for many species (Morrison 1984). In this study, birds captured during the early fall period (late July to early September) were all adults. During that period, residence probabilities of birds in good and poor body condition differed significantly in two of seven periods. Since samples were homogeneous in age composition at this time, the influence of body condition on departure rates was tested in the absence of a known confounding factor. It can be assumed (Gudmundsson et al. 1991) that the mean weight of birds with the highest turnover rates (e.g. ≥80g) met or exceeded the threshold level to trigger departure.

After mid-September, the Sanderling population was comprised of adults from early in the season and new arrivals (of both age classes). Differences in residence probabilities of heavy and light birds from mid-September to late November were detected in two of eleven periods. Lower turnover rates during this period could have been an artifact of mixed age classes or may have reflected the inability of later birds, irrespective of age, to put on the necessary fat reserves as some early birds did. Mean weights after September were below the adhoc threshold of ≥80g, and weights of both body condition classes were more similar (converged) than those earlier in the season. The latter contention may explain the spread between resighting periods before detecting significance (about 6-7 weeks). Periods of significance early in the season were detected soon after the arrival of birds (about 4 weeks) and 2 weeks apart (periods 4 and 6).

This study, though, continued to document departures of Sanderlings post-September, albeit not as fast as early season birds. This undermines the confidence of arbitrarily selecting a threshold level (≥80g) that triggers departure. Birds of both body condition classes continued to depart at similar rates even though mean body mass had dropped by as much as 13g for light birds and 30g for heavy birds. It is hard to tell whether the lower turnover of post-September birds was because they were unable to rapidly build up body fat levels (assuming adequate resources were available) or because their fall migration schedule, coupled with suitable weather and resource levels (Dolan et al. 1993), facilitated a longer stay than predicted by body mass alone. It is also possible that some birds may overwinter if suitable conditions prevail, but are forced to migrate south when food resources declined in late fall (see Chapter 1). Southbound migrations of shorebirds are often considered more leisurely because birds are not as pressured to reach their migratory terminus as they are to reach the breeding grounds in spring (Morrison 1984, Myers et al. 1985, Gudmundsson et al. 1991).

During spring, residence probabilities of Sanderlings of different body condition classes were not significantly different. Birds in poor condition seemed to be departing at slightly faster rates than those in good condition, and mean body masses of heavy spring birds were lower than those of heavy fall birds. This is opposite to the pattern that was used as evidence to support the time-selected hypothesis (Gudmundsson et al. 1991). Several factors may explain these patterns. Fewer Sanderlings used the Outer Banks in spring than fall (Chapter 1). Sanderlings may be bypassing the Outer Banks during spring in favor of more suitable stopover sites. Sanderlings are known to add large amounts of fat reserves at Delaware Bay just prior to departure for the breeding grounds (Myers 1983). At this site, consistently higher spring weights might be expected (Gudmundsson et al. 1991). Alternately, birds may be stopping on the Outer Banks, but only for a short time. In either case, birds present on the Outer Banks may be departing to sites where the expected rate of energy gain is higher (Alerstam and Lindstrom 1990). Under this strategy, turnover rates of birds of both body condition classes would not be expected to differ in a predictable pattern. This explanation hints at the possibility that Sanderlings operated under the time-selected hypothesis. Rigorous testing of this hypothesis would require knowledge of regional movements, body condition information, and assessments of habitat quality along the migration route. Alternatively, the strong selective pressures of spring migrants to reach the breeding grounds may have contributed to the similar turnover rates of the two body mass classes. Time and energy constraints during spring probably interact strongly, making it difficult to partition their individual effects.

The period of time with the fewest confounding factors was probably the early fall migration period. Captured birds were new arrivals comprised entirely of adults, resources were assumed to have not been overexploited, and there was no strong selective pressure to depart quickly. During this period, overall departure rates were higher than later in the season, and significant periods in which heavy birds departed at higher rates occurred soon after arrival and close to each other. This suggests that body condition might influence departure rates during certain, perhaps brief, periods in a given migratory season. Still it is possible that early season birds represented a unique segment of the population. These results raise several unanswered questions that are relevant for future studies investigating the importance of within-season turnover rates. Early fall Sanderlings could be under an inherently different migration schedule than later birds. The higher body masses of early Sanderlings could represent evidence of overloading of fat reserves (see Gudmundsson et al. 1991), not fat reserves indicating a threshold level for departure. The lack of seasonal relationships between body condition and departure rates is not evidence to refute the time- or energy-selected hypothesis. Rather, it simply emphasizes the number of factors influencing migrant birds at stopover sites and the need to partition their effects before explicit tests of some hypotheses dealing with the evolution of migration are possible.

Population estimates

The importance of obtaining accurate estimates of shorebird numbers is critical for their conservation (Myers et al. 1987). The influence of age and sex, an understanding of turnover rates, and the timing and frequency of censuses all affect the accuracy of coastal shorebird counts (Howe and Collazo 1989, Colwell and

Cooper 1993). This study provides information that can be used to improve on current shorebird censusing techniques. Current shorebird censusing techniques, such as the International Shorebird Survey (Howe et al. 1989), do not specifically account for turnover. Counts derived from these surveys may greatly underestimate the number of birds using an area.

A comparison of census counts and population estimates derived from mark-resight information on the Outer Banks revealed that the census counts were consistently lower. Census counts were 55% lower in spring and 26% lower in fall. Estimates derived from mark-resight information incorporated estimates of turnover, and thus may have provided more accurate population estimates. The timing and frequency of counts, and local movements, may have contributed to the discrepancy between estimates. Censuses were conducted monthly in this study, and span the peak migration periods for Sanderlings. In some cases, peak counts were averaged with lower counts within months, and may have biased the estimates low. For example, in July 1993 counts were conducted at three of five sites early in the month when few (<500 per site) Sanderlings were present. Counts at the other two sites were done late in the month when >9,000 Sanderlings were counted at one of the sites. Despite these problems, beach censuses were found to be a useful index of the Sanderling population size. When beach counts were multiplied by a factor of 1.235, they provided reasonable estimates of the actual number of Sanderlings present, based on information from the mark-resight study.

Other studies of Sanderlings (Evans et al. 1980, Myers 1983) have found considerable variability in local movement patterns of individual birds. Myers (1983) noted that at Bodega Bay, California, a census of the local Sanderling population underestimated the true population by up to 50%. Birds not detected on a particular census were temporarily using nearby beaches. On the Outer Banks, some of the discrepancy between population estimates may have resulted from local movements that were not detectable on beach censuses. Individual birds were not always present on the beach, but instead used nearby tidal flats at inlets or temporarily moved outside the study area. A study of the site-faithfulness of Sanderlings (Chapter 1) provides evidence that local movements regularly took place. Sixty-nine percent of the birds remained where they were banded. The remaining birds wandered to nearby beaches, usually no more than 20 km from the banding site. Some birds used up to three or four sites within the fall season. The time scale of such movements was not specifically examined, but may prove useful when designing appropriate survey methods.

Peaks counts have been suggested as an alternative to multiple beach censuses to avoid problems brought about by high variability (Colwell and Cooper 1993). Peak counts could be an useful population estimate to assess the relative importance among areas or for trend analyses. To be useful, counts must be standardized throughout the area or range of interest. Also, its functional relationship with estimates of total population numbers needs to be explored. Qualitative comparisons among sites (Chapter 1) assume that the relationship is positive. Peak counts, on the other hand, are inappropriate as an estimate of total population numbers. The peak fall count, derived by summing monthly mean counts across sites, was 11,257 birds in July. Detailed mark-resight information revealed that nearly all of these birds (>80%) had departed by early September. However, small numbers of Sanderlings continued to arrive through September, with moderate numbers eventually overwintering. The estimated number of Sanderlings using the area during fall (28,744) was more than twice as high as the peak count.

To generate more precise estimates, temporal replication of counts must be conducted on a scale that fits within the length of stay of a given species. For Sanderlings on the Outer Banks, the 10-day sampling interval of the ISS seems adequate, given the length of stay estimates ranging from 15-32 days from this study. This protocol should intercept the peak migration intervals for Sanderlings on the Outer Banks. As turnover dropped in late fall, Sanderlings remained on the Outer Banks for an average of one month. During that period, sampling once per month might suffice. However, as suggested by Colwell and Cooper (1993), the average of several counts replicated over a short period of time will provide reasonable estimates when count variability is low, such as the late fall and winter period on the Outer Banks. If the Outer Banks are representative of other sites along the Atlantic Coast, the trend analyses performed by Howe et al. (1989) for Sanderlings were probably sensitive enough to have detected population declines. If Sanderling declines continue, researchers may have to rely on numeric counts, rather than ISS estimates, to monitor population changes. The results of this study may help in the design of such counts, which incorporate mark-resight studies to estimate population size and turnover rates and the corresponding precision levels.

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APPENDICES

Appendix 1. Seasonal numbers (mean ± SE), total numbers, and month of peak count of shorebirds on the Outer Banks of North Carolina, 1992-93. (Seasonal numbers are means of the monthly counts within each season; peaks are given by month with the number recorded in parentheses)

	Seasonal Numbers		Total Numbers[3]		
Species[1]	Spring[2]	Fall[2]	Spring	Fall	Month of peak count
All species	5,684±2,421	7,760±1,118	17,051	38,798	May (11,540)
Black-bellied Plover	194±113	282±76	582	1,408	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	1,034±452	1,108	5,168	July (2,750)
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	1,363±725	267±27	4,088	1,334	May (2,764)
Sanderling	3,222±1,796	5,692±907	9,667	28,458	August (8,194)
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)

1 Five species were recorded <5 times (killdeer, greater yellowlegs, lesser yellowlegs, spotted sandpiper, and white-rumped sandpiper)

2 Seasons are defined as Spring (April to June) and Fall (July to November)

3 The sum of the monthly means over the season

Appendix 2. Availability of mole crabs (Emerita talpoida) at two sites on the Outer Banks of North Carolina, fall 1993.

In October and November 1993, mole crabs were sampled at two sites (North Beach and Ocracoke) on Cape Hatteras National Seashore. The two sites were selected to contrast areas of high and low sanderling abundance, respectively. Baseline survey data support these claims (Chapter 1). At each site, a transect of 15 stations, each 0.1 mile apart, was established. Each transect was sampled three times, once in October and twice in November. Each time, two scoops of sand were taken from the swash zone at each station, for a total of 30 scoops per transect. The volume of the scoop was 0.5 gallon, and the opening was approximately 15 cm in diameter. Samples were placed in a large shallow pan and all mole crabs were removed and counted.

For analysis, the mean of the two samples at each station was calculated. This resulted in 15 counts per sampling date for each site. The effects of date and site on the variability of mole crab numbers were tested. Station, a repeated measure, was nested within site in the ANOVA model. The whole model test was significant ($F_{33,56}$=2.85, P=0.0003) and fit the data well (model R^2=0.63). The effect of date was significant ($F_{4,56}$=14.26, P<0.0001). Mole crabs were most abundant in October and numbers declined sharply in November. The two sites differed significantly in the number of mole crabs detected ($F_{1,56}$=4.52, P=0.0380). Mole crabs were three times as abundant on North Beach as on Ocracoke.

Mole crabs are a primary prey item of sanderlings, and their abundance is probably related to the distribution of sanderlings on the Outer Banks (Walters 1984). Census data show that sanderlings were consistently more numerous on North Beach than on Ocracoke.

Appendix 3. Morphometric data for Sanderlings banded during 1992 on North Carolina's Outer Banks.

During 1992, 655 Sanderlings were captured on the Outer Banks of North Carolina. Measurements of weight (to nearest 0.5 g), natural wing chord (bend in wing to tip of longest primary, to nearest mm), and exposed culmen length (bill tip to proximal end of frontal shield, to nearest 0.1 mm) were taken from each bird. Means (± SE) for the three measurements are presented here by cohort for the spring and fall seasons.

Cohort	N	Mean weight ± SE	Mean wing ± SE	Mean bill ± SE
			Spring	
28 Apr-17 May	56	58.94 ± 1.08	118.86 ± 0.40	24.78 ± 0.22
27 May	70	63.49 ± 1.72	121.39 ± 0.43	25.54 ± 0.18
Spring total	126	61.47 ± 1.09	120.26 ± 0.32	25.21 ± 0.14
			Fall	
29 Jul-7 Aug	28	60.80 ± 1.79	121.36 ± 0.71	25.55 ± 0.27
5-7 Sep	146	56.03 ± 0.58	122.68 ± 0.30	26.18 ± 0.12
20 Sep	83	54.08 ± 0.41	122.36 ± 0.52	26.27 ± 0.15
27-28 Sep	69	52.18 ± 0.50	120.80 ± 0.65	26.29 ± 0.18
3 Oct	114	54.29 ± 0.50	121.48 ± 0.45	25.90 ± 0.12
16 Oct	89	61.13 ± 0.71	121.36 ± 0.52	25.82 ± 0.16
Fall total	529	55.96 ± 0.29	121.84 ± 0.20	26.05 ± 0.06

Appendix 4. Morphometric data for Sanderlings banded during 1993 on North Carolina's Outer Banks.

During 1993, 964 Sanderlings were captured on the Outer Banks of North Carolina. Measurements of weight (to nearest 0.5 g), natural wing chord (bend in wing to tip of longest primary, to nearest mm), and exposed culmen length (bill tip to proximal end of frontal shield, to nearest 0.1 mm) were taken from each bird. Means (± SE) for the three measurements are presented here by cohort for the spring and fall seasons.

Cohort	N	Mean weight ± SE	Mean wing ± SE	Mean bill ± SE
			Spring	
22-25 Apr	99	52.81 ± 0.35	122.21 ± 0.28	24.43 ± 0.10
30 Apr	55	56.69 ± 0.74	125.05 ± 0.37	24.93 ± 0.18
18-21 May	34	59.21 ± 1.39	122.03 ± 0.42	24.48 ± 0.19
23 May	16	59.19 ± 1.64	121.50 ± 0.81	24.71 ± 0.27
Spring total	204	55.42 ± 0.42	122.89 ± 0.22	24.59 ± 0.08
			Fall	
26 Jul	53	70.63 ± 1.29	125.45 ± 0.45	25.95 ± 0.19
29 Jul-2 Aug	96	72.59 ± 1.30	125.54 ± 0.34	25.92 ± 0.15
6 Aug	97	78.92 ± 1.33	126.32 ± 0.31	26.48 ± 0.12
9-10 Sep	116	57.24 ± 0.55	124.62 ± 0.43	25.67 ± 0.12
16 Sep	83	57.58 ± 0.43	122.18 ± 0.73	25.95 ± 0.12
29 Sep-1 Oct	211	55.38 ± 0.32	121.80 ± 0.39	25.59 ± 0.10
21 Oct	55	60.19 ± 0.70	124.13 ± 0.43	25.13 ± 0.20
4 Nov	49	64.30 ± 1.07	126.63 ± 0.41	26.20 ± 0.20
Fall total	760	63.41 ± 0.44	124.06 ± 0.18	25.83 ± 0.05

Appendix 5. Parasites found on Sanderlings on the Outer Banks of North Carolina, fall 1992.

On 27-28 September 1992, several captured Sanderlings were examined for external and internal parasites and assessed for general body condition.

Ten Sanderlings were examined externally for parasites. Three species of lice were collected; Carduiceps zonarius, Lunaceps holophaeus, and Actornithophilus umbrinus. Additionally, three mortalities from a rocket net firing were examined internally. Several large tapeworms of the genus Hymenolepis were noted, possibly representing 2-3 species.

The Sanderlings were in very good condition. They were in good flesh with the pectoral muscles even with the keel, there were moderate amounts of subcutaneous and abdominal fat, and there were no gross lesions on any of the major organs. Additionally, the parasite burden of the birds seemed fairly low, a further indication that the birds were in good health.

Effects of human disturbance on shorebird populations on the Outer Banks of North Carolina.

Chapter III

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INTRODUCTION

Little detailed information is available concerning effects of human use of oceanfront beach on shorebirds. Studies in the northeastern United States have observed human disturbance and its effects on shorebird behavior (Burger 1981, 1986). This study was conducted in an effort to determine the impact of human recreational use of barrier-island beaches on shorebirds along North Carolina's Outer Banks. The barrier beaches of the Outer Banks face mostly east to southeast with sandy, gentle slopes. They usually experience moderate wave action in spring and summer with heavy wave action in fall and winter that can move large quantities of sand, drastically altering beach faces. The Outer Banks are not as heavily developed as many Atlantic coast beaches, providing substantial feeding and roosting habitat for large numbers of migratory shorebirds each year (Fussel and Lyons 1990). With human access to these islands greatly increased in recent years through bridge construction and ferry service, recreational use of these beaches has steadily increased (Parnell et al. 1992). Helmers (1992) found human disturbance energetically expensive to colonially nesting waterbirds as they increased attempts to avoid beachcombers, off-road vehicles (ORV's), and pets. Reduced fertility and fecundity, severe changes in social and individual behavior, increased mortality, population declines, and range reductions of colonially nesting waterbirds have been related to human disturbance along North Carolina's Outer Banks (Buckley and Buckley 1976). Because shorebirds are more susceptible to human disturbance than other coastal birds such as gulls, terns, and waterfowl (Burger 1981), there is increasing concern about shorebirds throughout their ranges.

METHODS

Impacts of human activities on shorebird numbers and behavior were measured by comparing shorebird use of paired beach plots. Six paired plots were established: four on Hatteras Island, two on Ocracoke Island, and one on North Core Banks (Fig. 1). Within each pair, 1 plot was closed to all human activities (pedestrians, vehicles, fishing, swimming, etc.) and one plot was left open to human activity. All pairs of plots, except Cape Point (open) and North Core Banks (closed), were adjacent to each other and each measured approximately 0.5 km from end to end. Each included the beach area from dune to ocean edge. We were unable to place the plots randomly because of legal and political constraints within the national seashore. The National Park Service (NPS) designated segments of beach that were already closed to vehicular traffic as available for our study. These areas were subsequently closed to all pedestrian traffic as well and were posted with closure signs from the dune line to the high tide line. One site, at Hatteras Inlet (Fig. 1), did not have a previous closure. Here a closure was posted from the high-tide line to a point 70 m above the high-tide line. Pedestrian and vehicular access was permitted around this plot between the closure and the dune line. There was no prior knowledge or consideration of bird use or disturbance levels among the available sites so we think that site placement was random in relation to those factors. The limits of our site selection and dynamic nature of the barrier beach environment did not allow for physically identical plots.

Three different types of data were collected during each sampling period: 1) Species composition and abundances were gathered through census scans in which all species of birds in the plot were identified and counted. 2) Behavior was determined by focal scans during which a single bird was observed and all behavior changes recorded for 5 minutes or until the bird left the plot. Target species for focal scans were Sanderling (*Calidris alba*), Black-bellied Plover (*Pluvialis squatarola*), Whimbrel (*Numenius americanus*), and Red Knot (*Calidris canutas*), chosen as relatively common species that regularly used the outer beaches during migration. 3) Disturbances were measured by scans during which all disturbance events, human or otherwise, within the plot were recorded along with species responses. Disturbances were classified as stationary vehicles, moving vehicles, stationary humans, moving humans, and other which included disturbance events such as aircraft, boats, swimmers, surfers, and pets.

Each pair of plots was sampled three times each month; once at high tide, once at low tide, and once during an intermediate tide phase. The order of sampling between open and closed plots was determined randomly prior to the sampling period. Samples were begun 1 hour before the appropriate tide phase and concluded 1 hour following the same tide phase. Although many species forage at night, most shorebird species in the northern hemisphere forage during the day (Puttick 1984). Sampling was limited to tide phases occurring during daylight hours.

Census scans were conducted twice during each sampling period, once at the beginning of the hour and once at the end of the hour. After each census scan, a disturbance scan was conducted, followed immediately by a focal scan. Focal scans and disturbance scans were alternated for approximately 50 minutes with a different bird observed during each focal scan. If there were not enough birds present for all 8 scans, some individuals were observed more than once. After a maximum of 8 focal and disturbance scans, the final census scan was conducted and sampling was shifted to the next plot.

Sampling was conducted from April 1992 through July 1993. During that period, 600 census scans, 2600 disturbance scans, and 2600 focal scans were conducted. Data were not collected from October 1992 - December 1992 due to the low numbers of shorebirds in the area during those months.

We expected that disturbance levels in the closed plots would be lower than in the open plots. In response to different disturbance levels, we anticipated that bird numbers, time spent foraging, and time spent resting would be different between open and closed plots. Three-way ANOVA's were used to test for significance of seasonal effects on average per scan values for census data, disturbance values, time spent resting, and time spent foraging. To nullify seasonal effects, which masked other significant trends, deviations from monthly averages were used in subsequent three-way ANOVA's testing for treatment, site, and tide effects. Student-Newman-Keuls tests were used to determine when differences between treatments, seasons, tide phases, and sites were significant.

RESULTS

Disturbance levels in open plots varied by season ($F = 8.92$, $P < 0.002$, $df = 2$) with nearly 10 times more disturbance events in fall than in spring and winter (Table 1, Figs. 2 and 3). Disturbance levels in closed plots were much lower and showed little seasonal variation (Fig. 2). A significant interaction occurred between treatment and season ($F = 8.01$, $P < 0.003$, $df = 2$). Although bird numbers were higher in fall than winter and spring ($F = 3.90$, $P < 0.04$, $df = 2$), the time shorebirds devoted to feeding ($F = 0.55$, $P < 0.58$, $df = 2$) and resting ($F = 2.58$, $P < 0.10$, $df = 2$) did not change with respect to season (Fig. 4).

Disturbance was consistently higher in open plots than in those closed to human activity ($F = 327.77$, $P = 0.0001$, $df = 1$) (Figs. 2 and 3). There were also variations in disturbance levels between sites ($F = 27.69$, $P < 0.0001$, $df = 5$). Disturbance events increased in number from low to high tide but those differences were not statistically significant (Fig. 3).

Shorebird numbers were always significantly higher in closed plots than in open plots ($F = 5.81$, $P < 0.03$, $df = 1$). The number of shorebirds per scan ranged between 15 and 20 in open plots (Fig. 2). Bird numbers were higher in the closed plots, with fall numbers of 35 to 40

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Shorebird numbers were always significantly higher in closed plots than in open plots ($F = 5.81$, $P < 0.03$, $df = 1$). The number of shorebirds per scan ranged between 15 and 20 in open plots (Fig. 2). Bird numbers were higher in the closed plots, with fall numbers of 35 to 40 shorebirds per scan. These were nearly 4 times larger than winter values (Fig. 2). Differences in the number of individuals seen per scan also varied among sites ($F = 9.26$, $P < 0.0001$, df = 5). Tide effects were not significant although more birds were usually present at low tide than at high or intermediate stages (Fig. 3).

Shorebird foraging times were not significantly different ($F = 2.06$, $P = 0.1663$, df = 1) between open plots and plots closed to people, nor were they significantly different with regard to season (Fig 4). Time spent foraging did, however, vary significantly ($F = 13.24$, $P < 0.0002$, df = 2) with tide cycle (Fig. 5). Shorebirds spent more time feeding during intermediate and low tides than at high tide. There were no significant differences in foraging times among sites.

Shorebirds spent nearly twice as much time resting in closed plots than in open plots ($F = 13.42$, $P < 0.002$, df = 1) (Figs. 4 and 5), and significantly more time was spent resting ($F = 7.66$, $P < 0.003$, df = 2) at high tide than during intermediate or low tides. Resting times were similar among all sites ($F = 1.52$, $P < 0.22$, df = 5).

Seven species of shorebirds were regularly recorded within the study plots (Table 2). Sanderlings were the most abundant species during winter, spring and fall. Only Willets (*Catoptrophorus semipalmatus*) and American

DISCUSSION

Closing the beach to human traffic significantly reduced disturbance levels. Even at sites with the most human activity, disturbance levels in the closed plots were always much lower than in the adjacent open plots. Closed plot disturbance values averaged less than 2 events per scan for all sites, and these often represented the research assistants who needed to sit in the center of the plots in order to conduct scans. There was a significant 10:1 difference in average disturbance events per scan between open and closed plots.

Disturbance levels in open plots increased during spring and peaked in fall with disturbance levels nearly 10 times higher than winter values (Fig. 6). Fall data were collected in July, August, and September to coincide with fall shorebird migration (Fussel and Lyons 1990) and to allow for equal sample sizes among seasons. Our findings agreed with Burger (1986) who found disturbance levels in Jamaica Bay, New York, to peak between May and August. During these peak disturbance times along the Outer Banks, it was not unusual to record up to 400 individual sources of human disturbance, including vehicles, pedestrians, fishermen, swimmers, and dogs, during a single disturbance scan in an open plot. The most disturbed plots were at

Frisco and Cape Point, which were grouped together by SNK testing as having significantly higher disturbance levels than all other sites. These beaches were adjacent to campgrounds and had several nearby off-road vehicle (ORV) ramps. They were constantly used by tourists and residents because of their accessibility and proximity to the towns of Buxton and Frisco. The Avon site had the least disturbance. The nearest ORV ramp was about 2 km north of the site and there was limited pedestrian access. These differences in disturbance levels likely accounted for higher bird numbers seen at the Avon site. In Raritan Bay and Delaware Bay in the northeastern United States, Burger (1986) saw fewer birds on beaches with high levels of disturbance than on beaches with low disturbance, indicating that high disturbance levels reduced shorebirds' use of beach habitat. During winter, when disturbance levels in open plots were about the same as in closed plots, more shorebirds were observed in open areas (Fig. 2). They may have been exploiting foraging and roosting habitats that were unavailable to them during spring and fall when human activity kept them out of those areas.

Most species of shorebirds seen along the Cape Hatteras National Seashore were using those beaches as stopovers between breeding and wintering grounds. Our data reflected this with higher numbers of shorebirds observed during spring and fall migrations than in winter (Fig. 2). Shorebird numbers increased significantly during spring migration and peaked in the fall with as many as 526 shorebirds per census scan in the 0.5-km-closed study plots. Higher numbers of shorebirds were observed during fall migration than during spring. This may have been due to some species' use of different migration routes for spring and fall. Shorebirds also tend to migrate slower during fall and may have spent more time in the study area than during spring migration.

Overall, average bird numbers were significantly higher in the closed plots than in the disturbed plots agreeing with Burger (1986); however, sites at Hatteras Inlet and Ocracoke North did not conform to that pattern (Table 1). Although recorded disturbance levels for the Hatteras Inlet site were low in comparison to other sites (Table 1), there were regular trespasses into this closed plot. Tire tracks through the plot and broken sign posts were observed at almost every sampling period. Beach visitors were seemingly less likely to drive or walk through closed plots when researchers were present. There were also notable differences in the physical characteristics of the beach itself. A steep scarp was formed in the closed plot at Hatteras Inlet during a winter storm. This steep beach gradient reduced the amount of usable beach for shorebirds providing little intertidal beach for foraging. The amount of foraging area is related to the number of shorebirds one can expect to see in any given area (Recher 1966, Burger 1977, Puttick 1984). The upper beach area, usually used for roosting, was bordered on 3 sides by open beach with fairly heavy vehicle traffic. The open plot at Hatteras Inlet had a broad gentle slope with more intertidal foraging area and more uninterrupted roosting space. These physical conditions were likely responsible for higher shorebird numbers in the open plot than in the closed plot at the Hatteras Inlet site.

The Ocracoke North site had a wide beach in the open and closed plots and both experienced relatively little disturbance. An area between the open and closed plots had been previously closed to vehicles but not to pedestrians. Large numbers of shorebirds were regularly observed feeding and roosting in the area between the 2 plots. The birds may have utilized that section of beach prior to our study due to its lower disturbance level. A general trend was seen for birds to forage northward toward the open plot then fly back south into the closed area to forage the same section of beach repeatedly. This may have been the result of higher prey densities in that area or could have been to avoid human activities in the open plot.

Analyses of variance showed no significant differences in bird numbers or disturbance levels among tide phases. There was however, a pattern of increasing numbers of birds present from high tide to low tide as seen in other studies (Burger et al. 1977, Meyers 1984, Puttick 1984, Helmers 1992) and decreasing average disturbance levels from high to low tide (Fig. 3). The increase in bird numbers may be attributed to lower disturbance levels (Burger 1986) or to increased feeding opportunity the birds encountered at low tide (Recher 1966, Burger et al. 1977, Meyers 1984, Puttick 1984, Maron and Meyers 1985, Swennen et al. 1989, Helmers 1992) or most likely a combination of the two.

Feeding time did not vary significantly between closed plots and open plots. In open plots, however, feeding areas in the intertidal zone were often divided into small, irregularly spaced sections between groups of humans. This division of the foraging habitat did not allow shorebirds to congregate into large feeding flocks as they normally would, likely resulting in reduced feeding efficiency. In closed plots, we observed that birds were spending up to 70 percent of their time feeding in both large multispecies and single species flocks along the intertidal zone. Advantages of foraging in flocks may include enhanced feeding efficiency and increased safety from predators. In mixed species flocks, individuals may be able to expand their foraging niches and exploit the time and energy of other birds with minimal competition for food items (Recher 1966, Meyers 1984, Barnhard and Thompson 1985).

Most species concentrated feeding efforts in the wet sand at the water's edge. In open plots, this zone of intertidal beach was also heavily used by vehicle and pedestrian traffic. When interrupted by human activities, flocks would often take wing and move to a new location. When disturbed several times in succession, shorebirds were likely to abandon an area completely, as was also found by Burger (1986). It is possible that shorebirds left areas of high prey concentrations to forage less profitable habitat in an effort to avoid human disturbances. Even if shorebirds remained in areas of human activity, foraging behavior may have been adversely affected. Burger (1991) found that human disturbance negatively affected foraging activities of the Piping Plover (*Charadrius melodius*) resulting in a decrease in foraging time and an increase in time devoted to alertness. She suggests that this loss of foraging time caused a decrease in Piping Plover fitness.

Tides influence shorebird feeding habits directly through effects on the amount of time and space available for foraging (Burger 1977, Puttick 1984). Shorebirds along the Outer Banks spent nearly 80 percent of their time during low tide foraging (Fig. 5). That was an increase of 20 to 30 percent when compared to high tide. SNK grouping showed that foraging times during low and intermediate tide phases were significantly higher than foraging times during high tide. Shorebirds were taking advantage of increased foraging habitat resulting from lower water levels. In the northeastern United States, prey items found lower on the beach were found to be more abundant, larger, and may have provided more energy per item than at other tide phases (Puttick 1984). Since prey items exposed at lower tide levels were only available for a short time, shorebirds rarely ceased feeding during low tide phases and were less likely to fly away from disturbance. When disturbed, they usually ran a short distance but were quick to resume foraging with little time spent in alert postures. When foraging under time-stressed conditions, shorebirds tend to maximize foraging time by decreasing search time and handling time per prey item, which increases the overall intake of food (Swennen et al 1989).

Large, multispecies flocks of shorebirds used upper beach areas in undisturbed plots primarily for roosting. Those areas provided broad, flat beaches with little vegetation. Presumably the birds preferred those areas due to the reduced likelihood of predators approaching roosting flocks unobserved (Helmers 1992). In open plots, resting flocks were nonexistent or were split into smaller groups that were more susceptible to disturbance than larger flocks as was also seen by Burger (1986) along beaches of the northeastern United States. Smaller flocks were constantly running and flying to avoid humans and vehicles. With reduced resting times in disturbed plots and no changes noted in foraging times, shorebirds were expending more energy in disturbed areas to avoid pedestrians and vehicles on the beach at the expense of resting time.

Shorebirds had more resting time during high tide than at intermediate or low tide (Fig. 5). With their foraging habitat reduced by incoming tides, feeding efficiency was reduced (Helmers 1992). We observed that almost 60 percent of the shorebirds' time was still devoted to foraging, but it was done in small increments with frequent rest breaks. Often birds would stop foraging and walk to the upper beach, joining roosting flocks for several minutes before resuming foraging. It was probably more profitable for the birds to rest and wait for a falling tide that would expose more abundant prey (Helmers 1992).

Overall, we saw that the main impacts of human beach use on shorebirds in the Cape Hatteras National Seashore were displacement of shorebirds from beach habitat and interference with normal resting and foraging behaviors. The highest impacts seemed to occur during spring and fall seasons when human beach traffic was at its peak. These times coincided with the spring and fall migrations when shorebird numbers were also highest.

Different human activities had different effects on shorebird behavior. Faster, erratic events such as running pets and children, seemed to upset birds more than slower, regular events such as people walking, or slow moving vehicles. This was very similar to Burger's (1986) findings in New York. Along North Carolina's Outer Banks, many shorebirds seemingly ignored stationary humans and stationary vehicles on the beach, often foraging within a few feet of sunbathers and parked vehicles. Beach closures reduced impacts of other human activities by allowing shorebirds to forage and roost in undisturbed habitats.

This project was not designed to compare different parts of the outer banks relative to disturbance and shorebird behavior. The five pairs of plots were used as replicates to provide adequate sample size for statistical tests. It is possible, however, to make some observations about different sites that may be useful for management purposes.

Disturbance levels in the open plot at Avon were comparable to disturbance levels in closed plots at other sites (Table 1). As discussed earlier, the lower levels of human activities observed at the Avon site were likely due to limited access to that section of beach. Most disturbances were fishermen and stationary vehicles. There were observations of people walking and jogging, but pedestrian traffic was not heavy. With beaches adjacent to the Avon site closed to ORVs by the National Park Service, vehicular traffic was minimal. Overall, human activities on this section of beach were very low in comparison to the rest of the study sites within the Cape Hatteras National Seashore.

Cape Point was one of the most heavily disturbed study sites at Cape Hatteras (Table 1, Fig. 8). This site had several access points for pedestrians and vehicles. Cape Point is a popular recreational beach for residents and visitors alike. Most beachgoers were fishing but many were sunbathing, swimming, and walking. Proximity to the town of Buxton and several other points of interest provides for high levels of human activities. At any time during our study we were likely to see between 25 and 30 stationary people and 8 to 10 stationary vehicles within our study plot. On several occassions we counted the total number of vehicles at Cape Point regardless of plot boundaries. During these estimates it was not unusual to see more than 300 vehicles and nearly 1000 people lining the water's edge around the point. As a result, shorebirds were not observed in large numbers at Cape Point, as they were at the Avon site. Shoreirds that were present were constantly running and flying in efforts to avoid moving vehicles, pedestrians, and dogs. As Cape Point is also a valuable nesting area for several species of colonial waterbirds (see the report on colonial waterbirds), the high levels of human activities are of concern.

Disturbance levels in the open plot at Frisco were very similar to those at Cape Point (Figs. 8 and 9). Again the higher levels of human activities were likely due to easy accessibility and the proximity of the Frisco Campground. The Frisco site was used more as a pedestrian beach than Avon and Cape Point. There were still large numbers of stationary vehicles and a steady flow of ORV traffic, but people were using that area more for swimming, surfing, volleyball, and other beach activities rather than sport fishing. As a result, human traffic along the beach, especially near the water line, was generally higher at Frisco than at other sites. As stated earlier, human foot traffic is often more disruptive to shorebird behavior than moving vehicles. On several occassions we observed dogs off-leash running the length of the study plot. This usually resulted in most shorebirds leaving the area. We also regularly saw groups of people on horseback. The horses had the same effect as dogs on shorebirds. Overall, Frisco was one of the most disturbed sites in this study.

The Hatteras Inlet site was mostly used by sport fishermen, as access was difficult except for ORVs. The overall level of disturbance events recorded there were intermediate relative to other sites (Table 1). Vehicular traffic was fairly constant through the Hatteras Inlet site, presumably fishermen heading toward the inlet (Fig. 10). During surf fishing tournaments, the numbers of fishermen in the Hatteras Inlet area increased dramatically. At those times, we observed several hundred people and vehicles along the water stretching out of sight in both directions.

At Hatteras Inlet the closed plot did not extend to the dune line as in the other plots. Space was left to allow for the passage of vehicles above the plot, between the posted area and the dunes. This was done to ascertain whether or not such a closure design would allow birds to utilize the area without blocking all pedestrian and vehicular traffic. Birds did not utilize the closed plot to the extent we observed at other sites (Table 1), but differences between open and closed plots were clearly visible (Table 1, Fig. 10). We also noticed that there was a greater incidence of human intrusion into the closed plot at the Hatteras Inlet site. While results cannot be statistically tested, it appeared that closing the entire beach controls disturbance better than allowing access above the plot.

The site at Ocracoke North had relatively low disturbance levels in comparison to other sites at Cape

Hatteras except Avon (Table 1). Our records averaged less than 10 disturbances for any given time (Fig. 11). The reduced disturbance levels may be attributable to lower accessibility as at the Avon site. There was only one point of access to the Ocracoke North site and no development within several miles. Most sources of disturbance there were stationary vehicles and stationary humans (Fig. 11). It was a popular spot for fishing and sunbathers. There were regular observations of walking and swimming humans within the plot, but almost no joggers or surfers. Shorebirds utilized the open plot there in similar numbers to those seen in the closed plot (Table 1).

Ocracoke South was busier than the Ocracoke North site in terms of human activities (Table 1, Figs. 11 and 12). It was closer to areas of development and a campground but was still buffered by a large expanse of undeveloped land. The primary disturbances there were stationary humans and stationary vehicles. It was a popular site with sport fishermen and sunbathers. There was regular pedestrian traffic along the water line but vehicular traffic was low. The reduced vehicular flow was due to areas of beach closed to ORVs both north and south of the study plot. With only one point of access and limited development nearby, the heavily disturbed Ocracoke South site would appear to be an exception to the trend of lower disturbance levels seen at other sites with reduced access.

North Core Banks was the least disturbed of all the study sites (Table 1, Fig. 8). As there are no permanent residents of the island and access is only by car ferry or boat, human activity is very limited. Bird numbers and behavior were assumed to be as close to unimpacted as possible at this site.

This site was paired with Cape Point, which represented a very heavily impacted section of beach (Fig. 8), As disturbance levels in this open plot at North Core Banks were very similar to those in the closed plots within the Cape Hatteras National Seashore, North Core Banks may make an acceptable control site for future studies at Cape Hatteras where human use of the beach is much greater.

SUMMARY

1. Impacts of human use of barrier island beaches on shorebirds along North Carolina's Outer Banks were determined during a 16-month period (April 1992 - July 1993) by observing shorebird numbers and behavior relative to human activities in six pairs of beach plots.

2. Within each pair, one plot was open to human use and the other was closed to all human traffic.

3. Human beach use peaked in the fall, coinciding with shorebird migration and highest shorebird numbers.

4. Human disturbance levels decreased from time of high tide to low tide.

5. More shorebirds were observed within plots closed to humans than in open areas. Shorebirds were also more abundant during intermediate and low-tide phases than high tide.

6. Shorebirds spent more time foraging during periods of low and intermediate tide than at high tide. Although time spent foraging did not differ significantly between open and closed plots, high levels of human activity may have reduced shorebirds' feeding efficiency by disrupting flocking behavior along the intertidal beach.

7. More time was spent resting on upper beach areas during high tide than during other tide phases. Resting time was reduced by nearly 50 percent in areas open to human activity.

8. Beach closures were effective in increasing resting times and providing uninterrupted foraging areas for shorebirds.

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APPENDICES

Appendix A: Monthly summaries of disturbance data.

Within each month, disturbance data are broken down to type of disturbance, total number of disturbances recorded, average number of disturbances per scan, and tide phase for open and closed plots.

Appendix B: Monthly summaries of bird census data.

All species recorded in open and closed plots with regard to site and tide phase. Total numbers of individuals, total numbers of species, numbers of shorebirds and percentages shorebirds represent of all recorded species are given.

Appendix C: Monthly summaries of shorebird behavioral data.

All focal scans conducted on shorebirds are given in seconds with regard to tide phase for open and closed plots at all sites. Observations are grouped by species. Species are abbreviated as follows:

American Oystercatcher	Amoy	Semipalmated Plover	Sepl
Piping Plover	Pipl	Black-bellied Plover	Bbpl
Ruddy Turnstone	Rutu	Whimbrel	Whim
Willet	Will	Dunlin	Dunl
Short-biolled Dowitcher	Sbdo	Sanderling	Sand
Marbled Godwit	Mago	Red Knot	Rekn

Table 1. Disturbance events , shorebird numbers, time spent foraging, and time spent resting for open and closed plots at all sites. (Numbers are averages per scan.)

	Tide phase	Disturbance events		Number of shorebirds present		Time spent foraging (%)		Time spent resting (%)	
		Open	Closed	Open	Closed	Open	Closed	Open	Closed
Avon	High	2.58	0.92	16.33	50.34	69.33	58.00	11.11	31.11
	Int	3.86	1.07	34.06	67.89	61.22	81.89	6.11	13.33
	Low	3.33	1.94	23.44	67.22	72.67	70.78	5.22	19.44
Cape Point and	High	17.17	0.78	7.56	15.25	50.67	76.17	5.11	26.20
North Core Banks	Int	15.86	0.98	6.00	17.38	43.89	92.00	22.44	7.60
	Low	11.79	1.09	9.28	20.88	72.22	79.67	6.78	9.60
Frisco	High	16.17	0.97	7.50	12.78	51.44	57.11	0.22	21.44
	Int	16.89	1.10	20.83	20.79	57.33	78.33	7.56	13.22
	Low	20.54	1.10	28.91	56.28	72.67	82.00	4.56	11.67
Hatteras	High	6.31	1.15	4.22	2.44	38.00	35.67	15.11	13.44
Inlet	Int	5.70	0.92	21.89	13.91	68.78	65.11	12.56	3.78
	Low	6.49	1.60	9.22	9.67	76.44	69.78	18.89	8.44

Table 1. Continued

	Tide phase	Disturbance events		Number of shorebirds present		Time spent foraging (%)		Time spent resting (%)	
		Open	Closed	Open	Closed	Open	Closed	Open	Closed
Ocracoke	High	5.15	1.31	34.72	8.44	63.89	52.89	7.33	21.56
North	Int	5.52	1.65	10.39	9.28	79.11	86.89	12.22	17.56
	Low	3.25	1.19	12.50	9.39	86.78	80.22	10.22	6.89
Ocracoke	High	9.43	0.98	19.33	24.50	70.56	64.44	7.56	30.22
South	Int	13.00	1.06	19.72	32.22	77.67	68.78	11.22	15.78
	Low	10.35	1.06	19.56	18.78	77.89	84.11	77.89	7.56

Table 2. Average numbers of shorebirds per scan in open and closed plots with respect to tide.

Species	High Tide		Int Tide		Low Tide	
	Open	Closed	Open	Closed	Open	Closed
Sanderling	10.27	14.69	13.93	19.33	13.07	24.88
Red Knot	0.25	0.18	0.01	0.61	0.13	0.88
Black-bellied Plover	0.55	0.42	0.53	0.47	0.92	0.39
Whimbrel	0.84	1.76	1.51	3.18	0.60	1.46
Willet	0.83	2.99	1.89	6.16	2.89	5.08
Ruddy Turnstone	0.14	0.38	0.24	0.09	0.26	0.44
American Oystercatcher	0.17	0.44	0.33	0.83	0.31	0.60

Table 3. Average numbers of shorebirds per scan in open and closed plots with respect to tide.

Species	High Tide		Int Tide		Low Tide	
	Open	Closed	Open	Closed	Open	Closed
Sanderling	10.27	14.69	13.93	19.33	13.07	24.88
Red Knot	0.25	0.18	0.01	0.61	0.13	0.88
Black-bellied Plover	0.55	0.42	0.53	0.47	0.92	0.39
Whimbrel	0.84	1.76	1.51	3.18	0.60	1.46
Willet	0.83	2.99	1.89	6.16	2.89	5.08
Ruddy Turnstone	0.14	0.38	0.24	0.09	0.26	0.44
American Oystercatcher	0.17	0.44	0.33	0.83	0.31	0.60

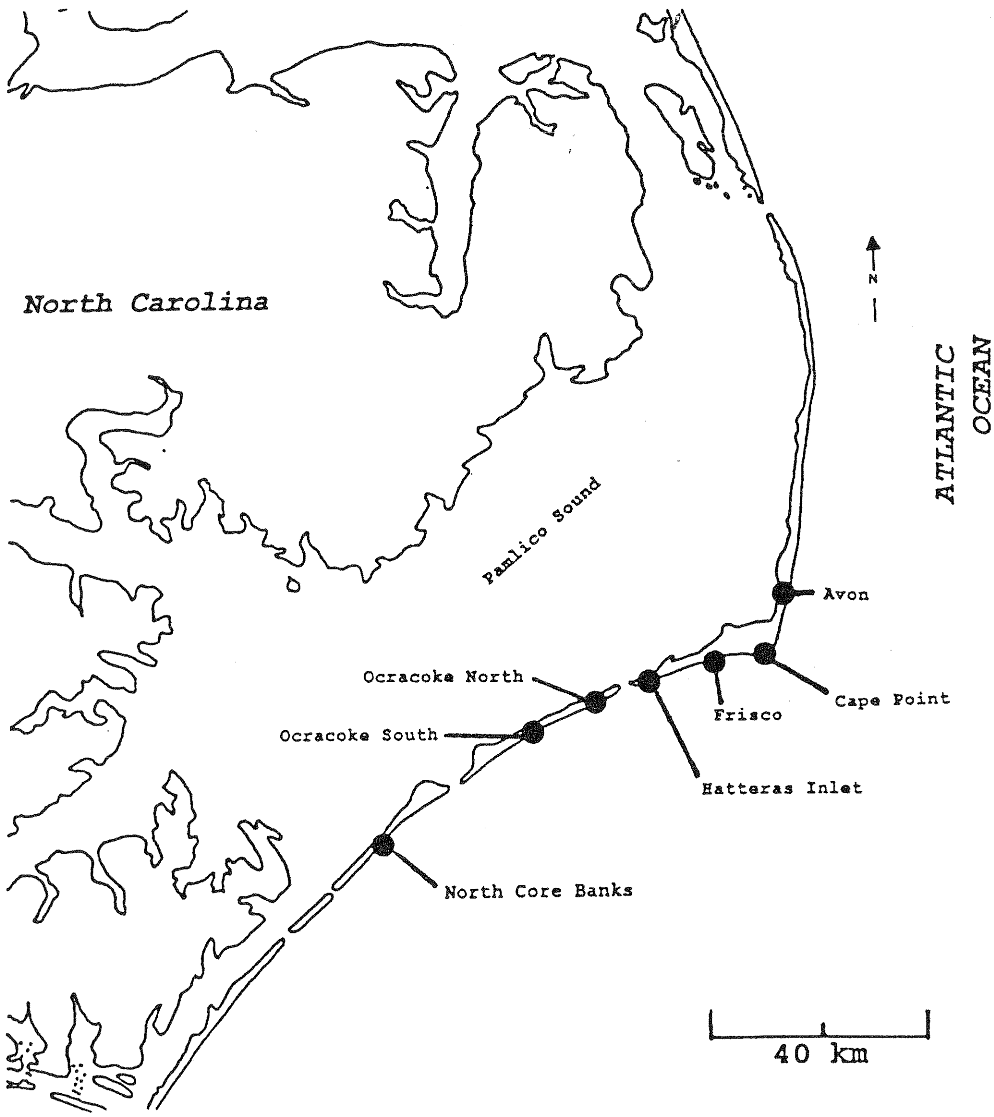

Figure 1. Study sites along North Carolina's Outer Banks. Each site consisted of two paired beach plots, one open to human use and one closed to all human activities. The open plot at Cape Point was paired with the closed plot at North Core Banks.

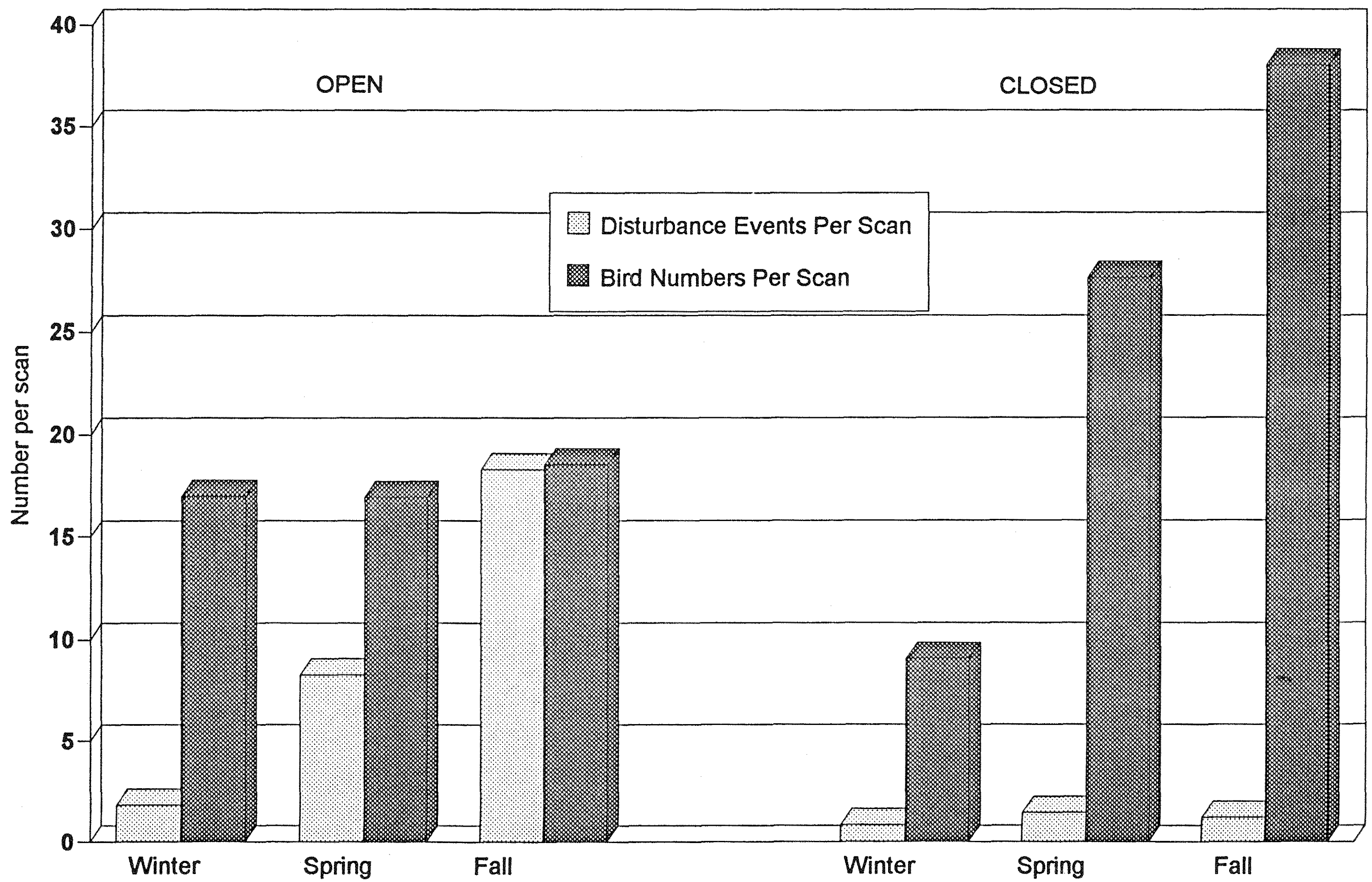

Figure 2. Average disturbance events per scan and average shorebird numbers per scan during winter,spring, and fall.

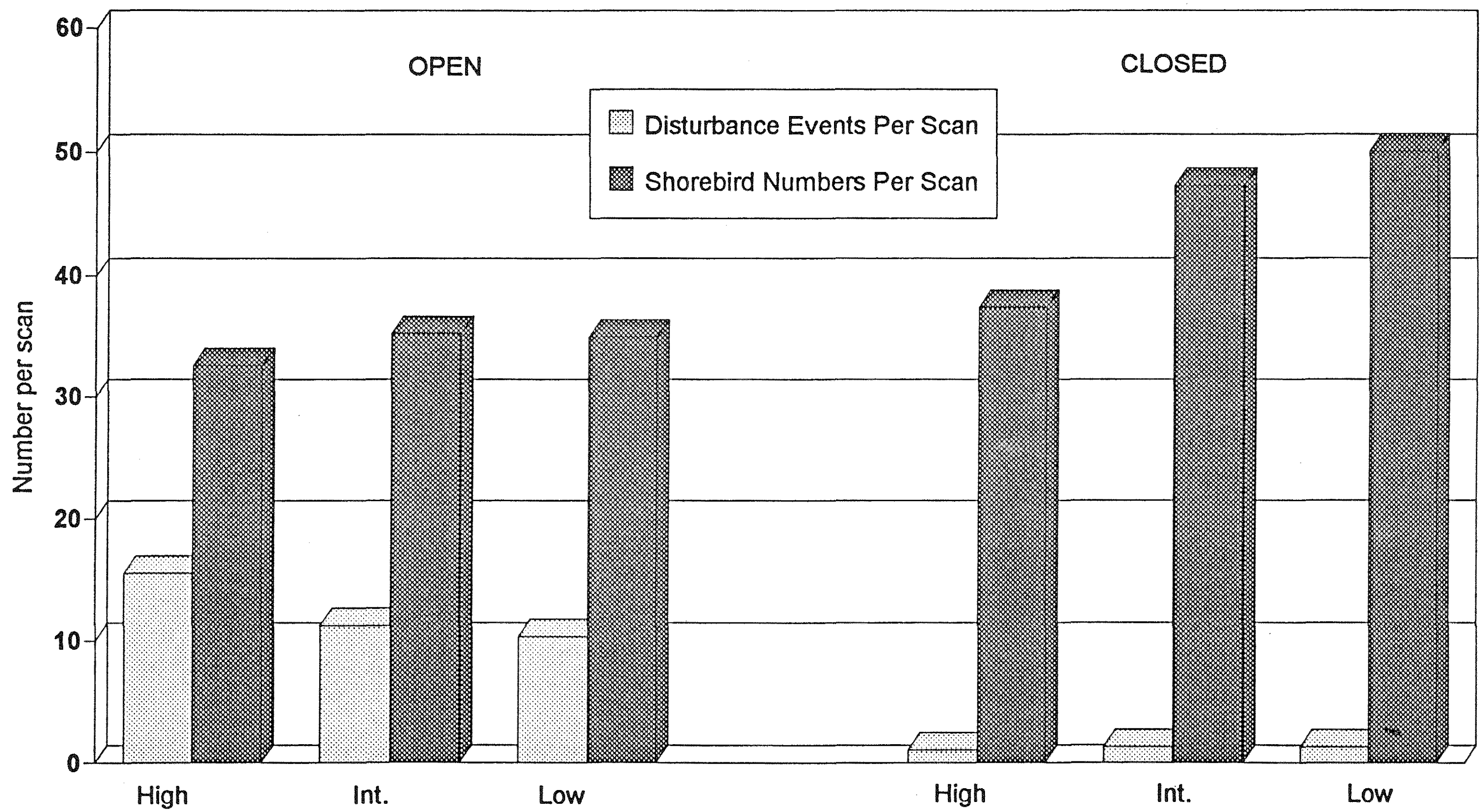

Figure 3. Average disturbance events per scan and average bird numbers per scan at high, intermediate, and low tides.

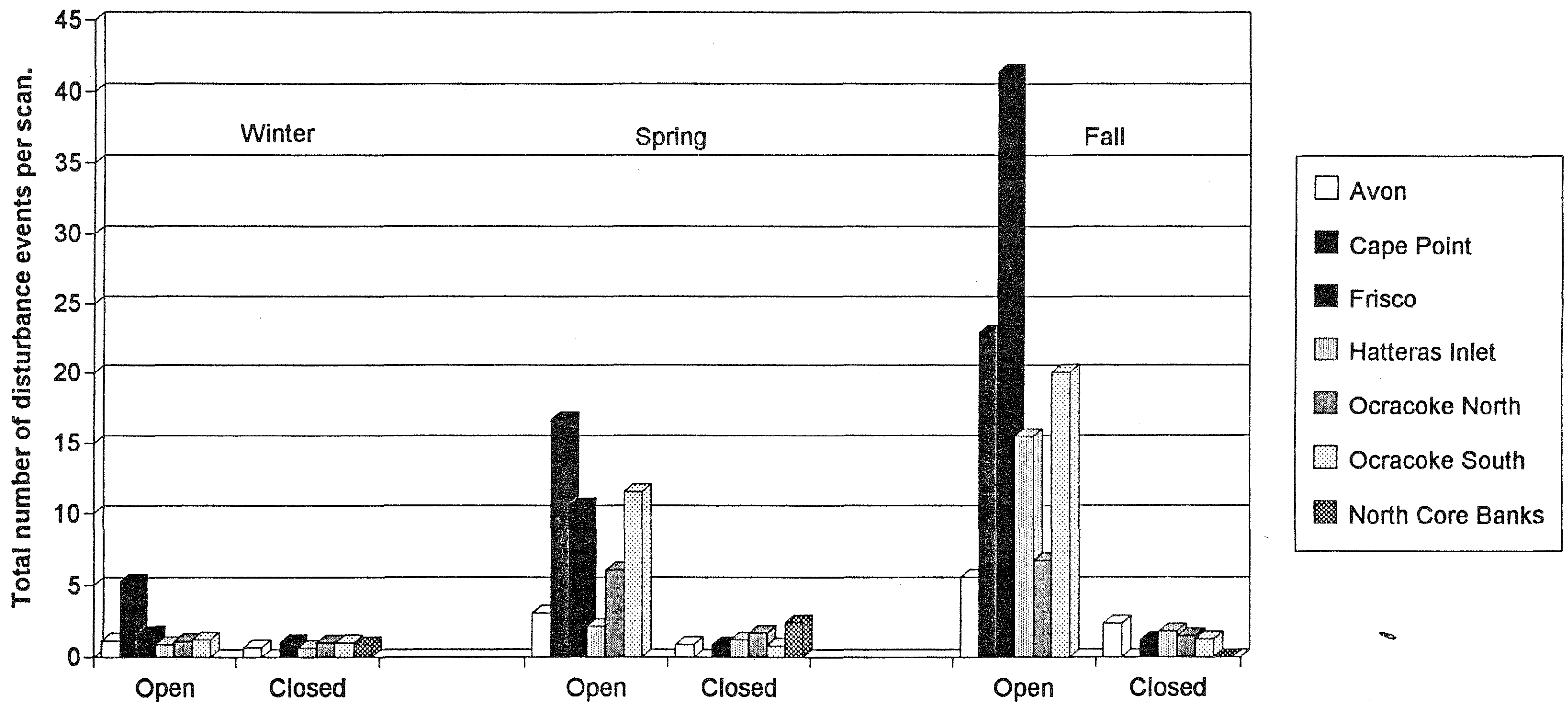

Figure 6. Disturbance events at study sites by season.

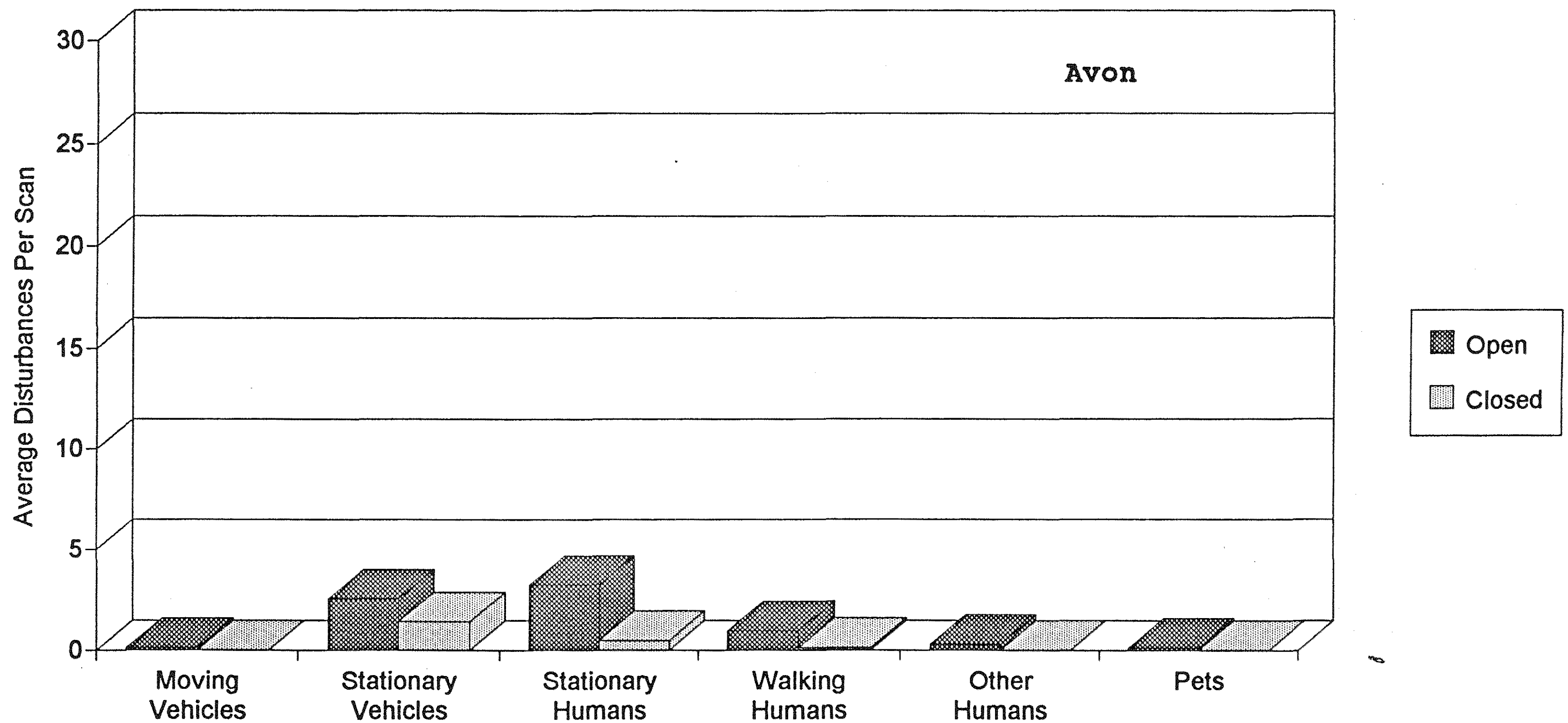

Figure 7. Kinds of disturbance and disturbance levels at the Avon site

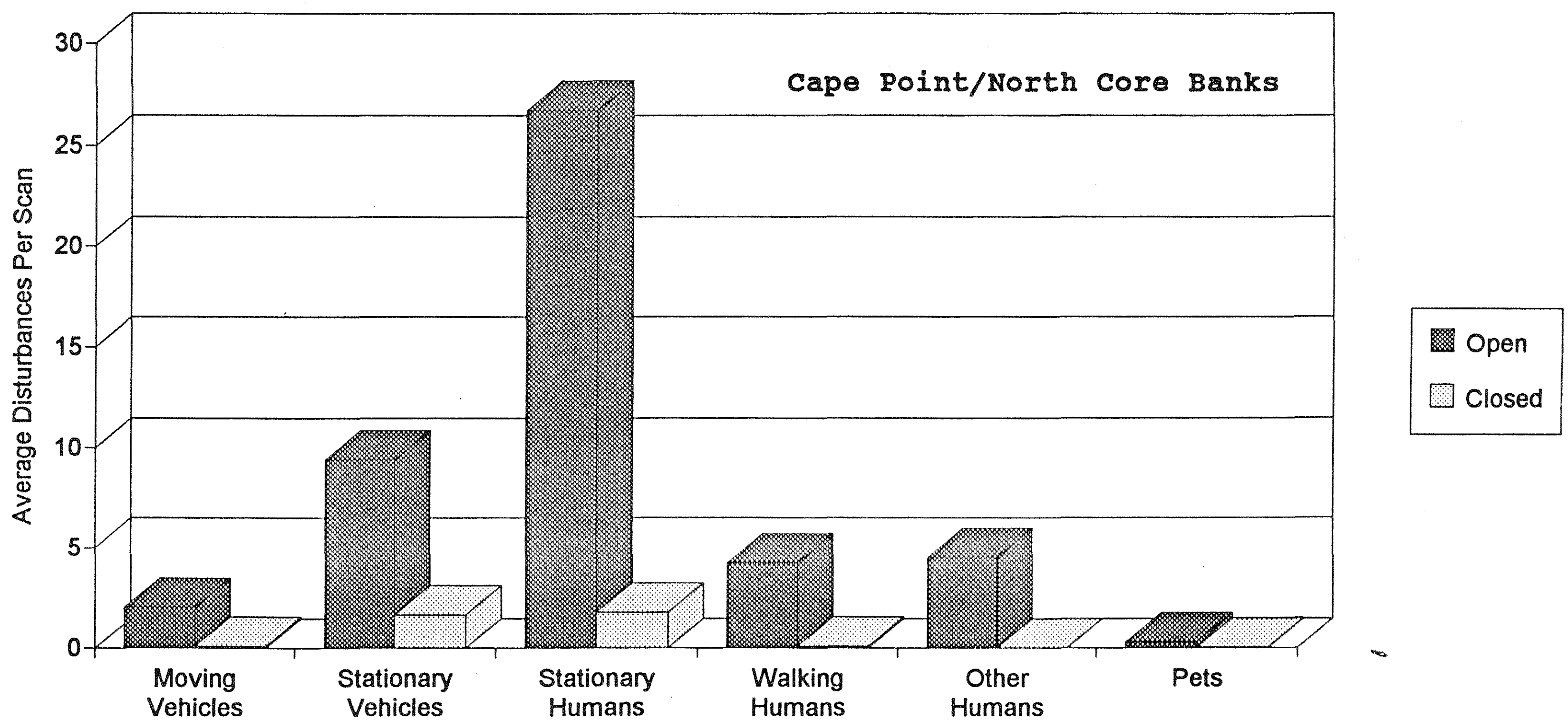

Figure 8. Kinds of disturbance and disturbance levels at the Cape Point/North Core Banks study site

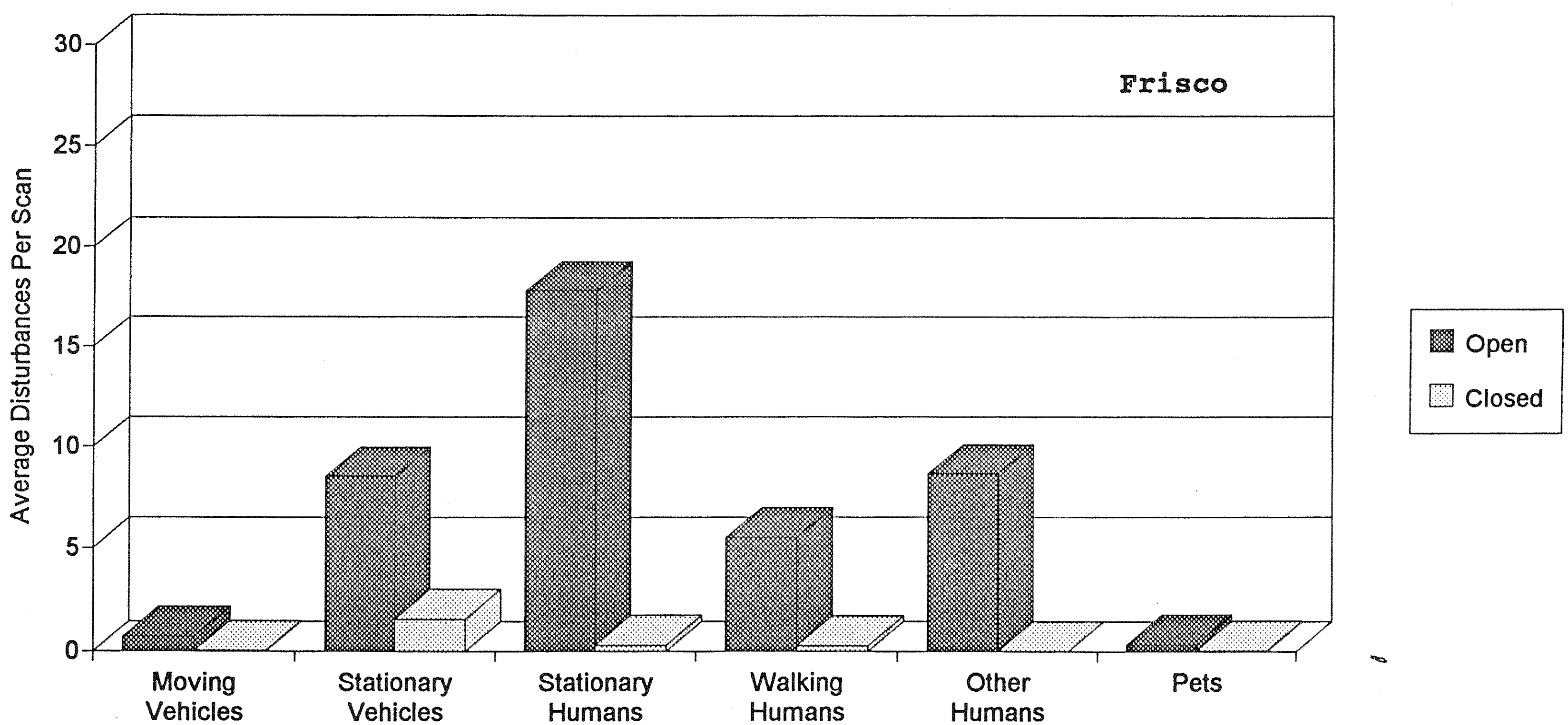

Figure 9. Kinds of disturbance and disturbance levels at the Frisco study site

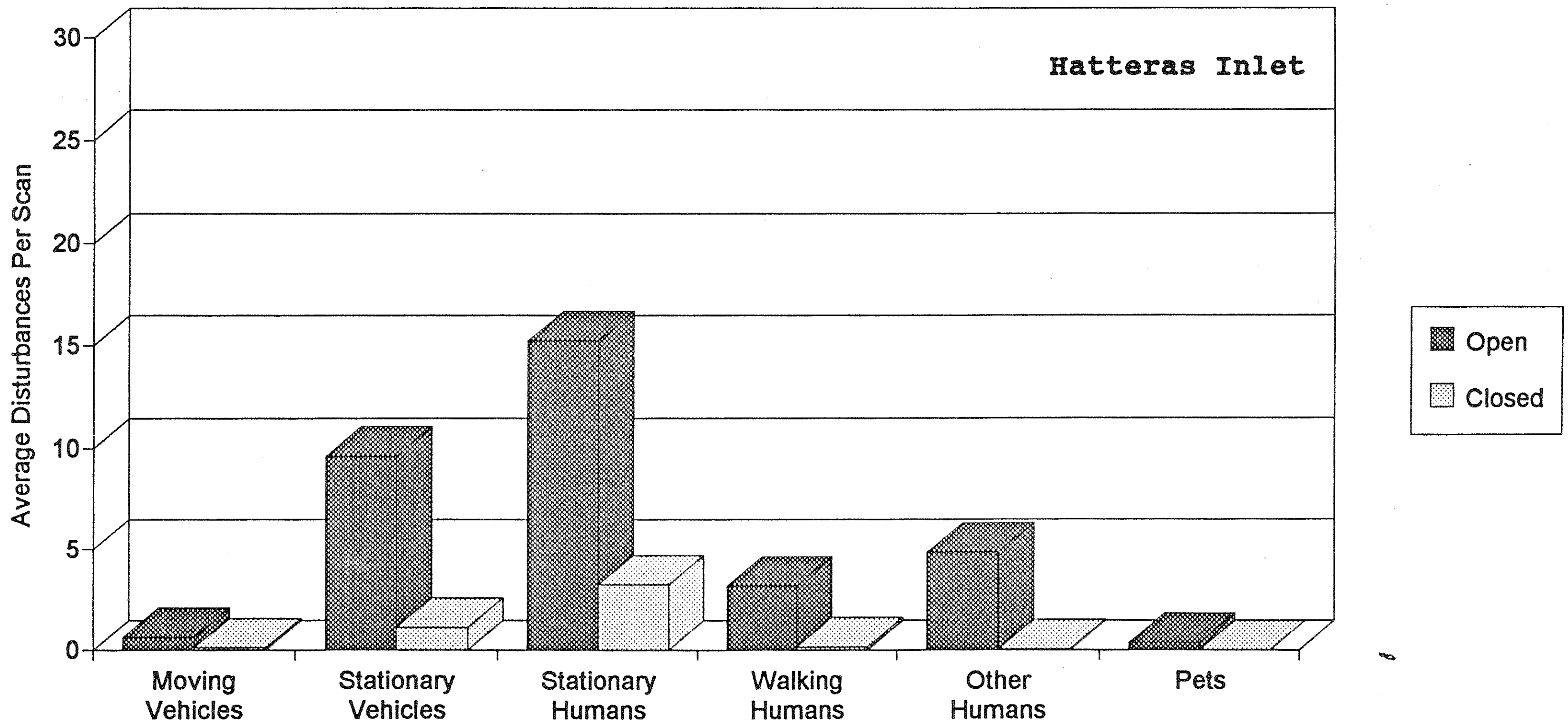

Figure 10. Kinds of disturbance and disturbance levels at the Hatteras Inlet study site

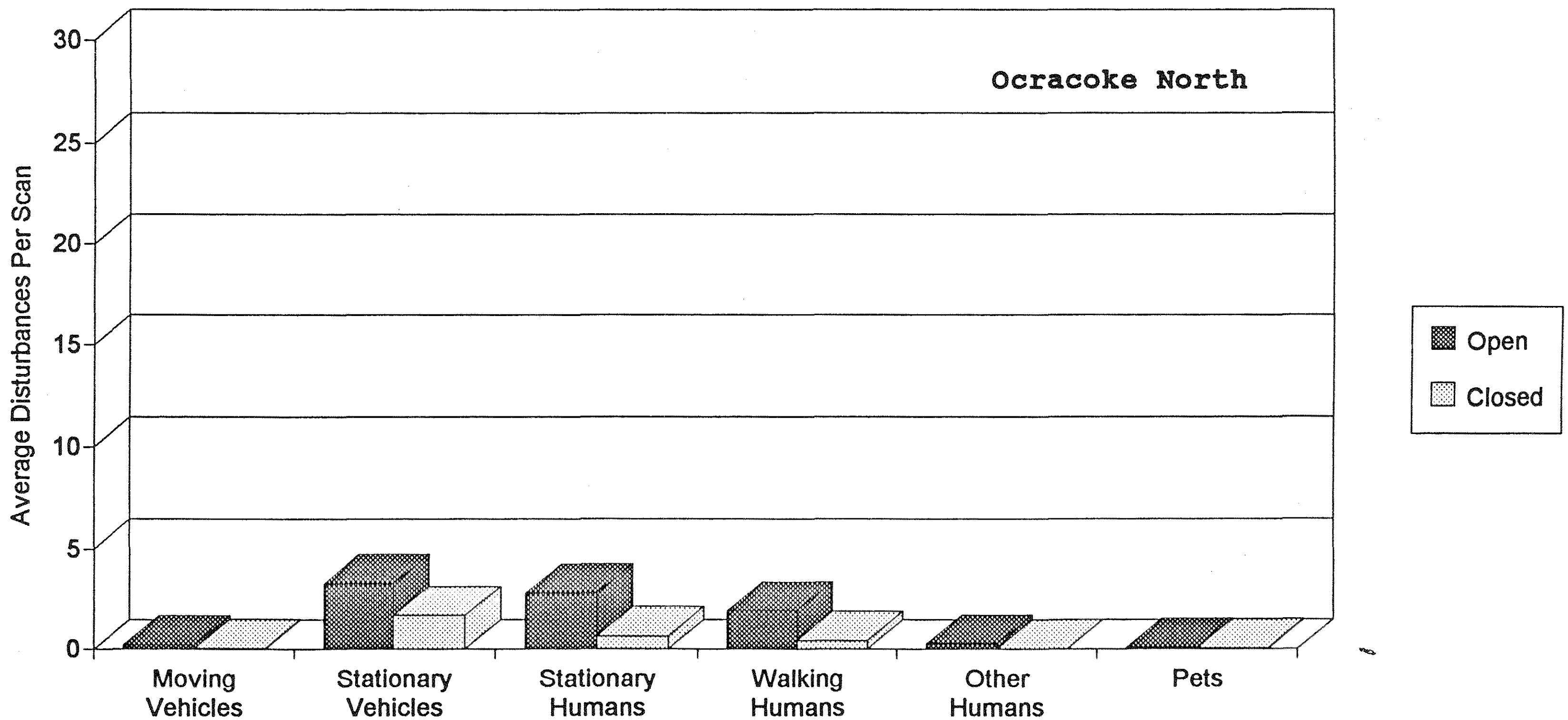

Figure 11. Kinds of disturbance and disturbance levels at the Ocracoke North study site

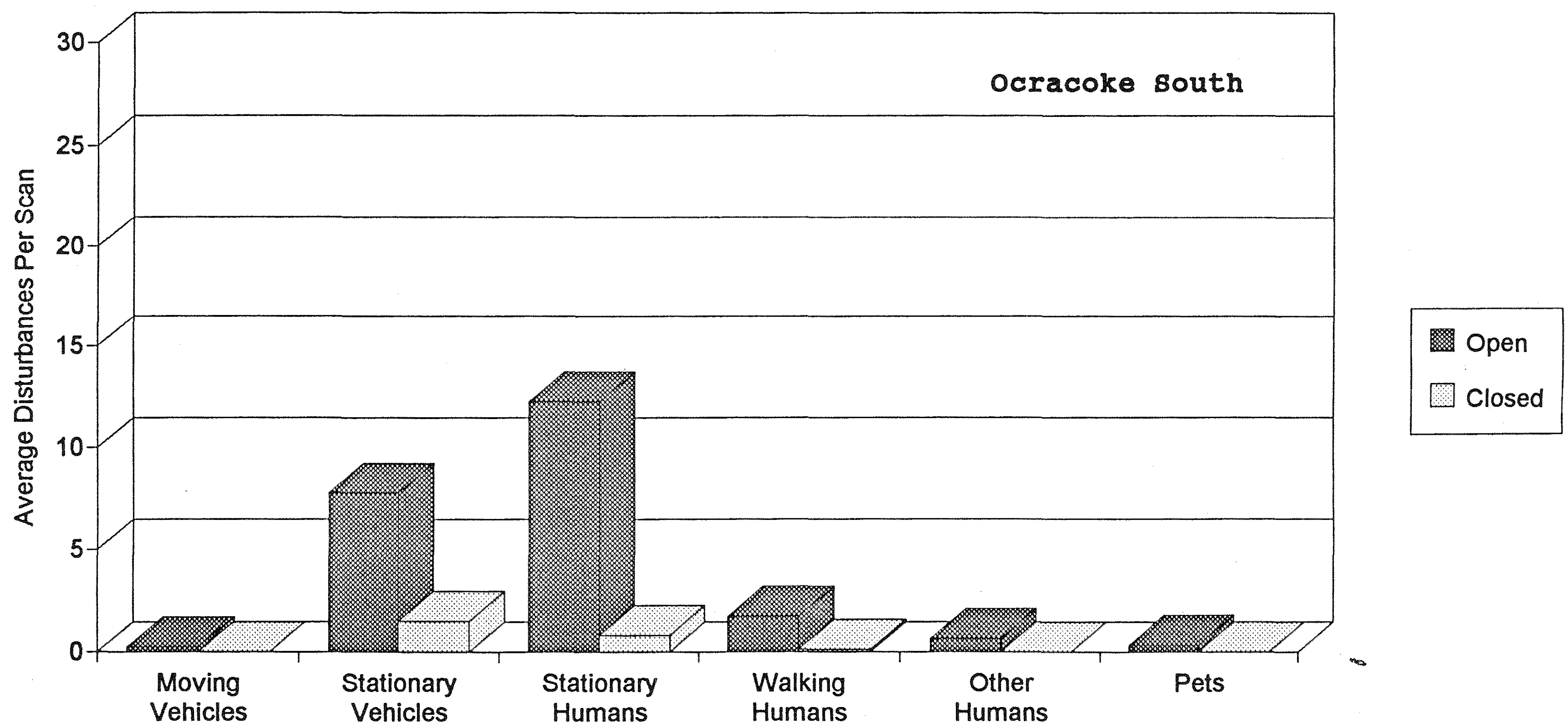

Figure 12. Kinds of disturbance and disturbance levels at the Ocracoke South study site

Breeding colonial waterbird studies on the Outer Banks of North Carolina.

Chapter IV

by

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INTRODUCTION

The primary goal of this phase of the project was to determine nesting populations at all nesting colonies of gulls, terns, skimmers, herons and egrets within the Cape Hatteras and Cape Lookout seashores during 1992 and 1993 and to relate present populations to historical levels and to regional populations outside of the Seashores.

METHODS

All colonies of nesting waterbirds were surveyed during the peak of the breeding seasons of 1992 and 1993. Colonies were located by driving the beaches of the two Seashores and by visiting all offshore islands by boat. When colonies of nesting birds were located, nest counts were made during the period of incubation. Counts usually involved a team of several workers walking slowly through the colony counting all nests within prescribed strips. Personnel from the University of North Carolina at Wilmington, the North Carolina Wildlife Resources Commission, the National Audubon Society and the National Park Service assisted with the colony surveys. These surveys provided total counts of active nests present at the time of the census. This is the same technique that has been used for the past several years by workers censusing colonial waterbird nests along the North Carolina coast (Parnell and Soots 1979, Parnell and McCrimmon 1984, Parnell and Shields 1990).

RESULTS AND DISCUSSION

Spring and early summer of 1992 were unusually cold and wet, and nesting data were not suitable for determining the current status of several species of nesting birds. The 1993 breeding season was more normal, being generally warm and dry, and data gathered was expected to be representative of a reasonably normal season.

Cape Hatteras: There are three sites within the Cape Hatteras National Seashore where beach nesting waterbirds have nested in good numbers during recent years--Ocracoke Flats, Hatteras Flats and Cape Point. Numbers of nesting terns and skimmers have declined at all three sites in recent years. Ocracoke Flats was the earliest site to be heavily utilized, with good numbers of nesting birds from 1977 through 1989 (Fig. 1). It was abandoned soon after stabilization of the interior road from Highway 12 to the inlet. This area had been maintained as an open sand flat by heavy ORV use, and the habitat was appropriate for nesting terns and skimmers. After traffic was limited to a fixed roadway, the flats rapidly grew up to marsh, and appropriate nesting habitat for this group of birds disappeared. It appears that the new natural spit developing at Ocracoke Inlet will again provide nesting habitat for terns and skimmers in that region if it is properly managed. Small numbers of Common Terns (*Sterna hirundo*) and Black Skimmers (*Rhynchops niger*) attempted to nest there in 1992 but were unsuccessful (Table 1). I suggest that this spit be left open to ORV traffic except during the nesting season. Post the colony sites that are utilized by the birds as is now being done at Cape Point and Hatteras Inlet.

Both the Hatteras Flats (Fig. 2) and Cape Point (Fig. 3) colonies grew rapidly after the sites were provided protection from unrestricted vehicular traffic, but nesting at Hatteras Flats has declined recently in spite of continued protection. Heavy use of these sites coincided with the deterioration of habitat on offshore dredged-material islands, specifically those islands just to the east of the ferry channel from Hatteras to Ocracoke. The decline in use of the beach site at Hatteras Inlet appears to be due to vegetation encroachment occurring as a result of the absence of vehicular traffic. Hatteras Flats was not used at all in 1992 but had a small colony in 1993. The Cape Point colony has declined somewhat in recent years but remains a very important nesting site for Least (*Sterna albifrons*) and Common Terns with some Black Skimmers and Gull-billed Terns (*Sterna nilotica*) as well. This colony moves each year into the most open areas available in this vicinity (Table 2).

Least Terns usually nest in small colonies at several sites along Seashore beaches. During 1992, several small colonies were initiated but were always abandoned before chicks hatched. This appeared to be due primarily to the cold rainy weather of spring and early summer. It is likely that most of these birds ended up in the large colony at Cape Point in 1992. In 1993 colonies occurred at Pea Island and near ramp 30 in addition to Cape Point and Hatteras Flats (Table 2).

In 1992, there was a total of 3,327 nests of 13 species counted within the Cape Hatteras National Seashore, if the Ocracoke Village Heronry (located on private property within the Seashore) is included. In 1993, numbers rose to 4,324 nests of 14 species (Table 3). The primary increase was in numbers of White Ibis (*Eudocimus albus*) and Least Terns, although numbers of nests of several other species also were up.

The heronry at Ocracoke Village is developing into the largest heronry in the region. It was first discovered in 1989 when it contained over 600 nests of 10 species. By 1993 it contained nearly 900 nests of 9 species and was the largest nesting assemblage of White Ibis north of Southport. It is likely that this colony developed and has thrived due to the newly developing marsh between Ocracoke Village and Ocracoke Inlet. The conditions that made this site less suitable for nesting terns and skimmers may have provided good feeding habitat for waders, thus stimulating the development of a nearby nesting site.

It is likely that beach sites within the Cape Hatteras National Seashore will continue to be important for the ground nesting terns and skimmers for many years. Dredging practices are not maintaining islands adjacent to ferry channels, primarily due to problems of dumping in estuarine waters containing sea grass beds, and the dredged-material islands that were prime nesting sites in the 1970s are either gone or are growing up into dense grasslands or thickets. This, for example, is happening on the large island between Hatteras and Ocracoke islands.

Oregon Inlet may continue to be an exception, as the heavy boat use and shoaling there appear to continue to dictate that much dredged material be deposited on islands in and to the westward of the inlet. Most colonial waterbirds utilizing the northern portion of the Seashore, for example the herons and egrets using Bodie Island, apparently nest outside of the Seashore on these man-made islands.

Cape Lookout Nesting skimmers and terns on Cape Lookout beaches appear to move more frequently and to be less likely to nest for several years at the same site than at Cape Hatteras. This is probably due to the availability of more open, overwashed beach habitat in this Park. There are, however, several places where good numbers of birds frequently nest--Shackleford Point, Power Squadron Spit and New Drum Inlet (Table 4). The west end of Shackleford Island was occupied by sizeable numbers of nesting birds in 1992 and in 1993 (Table 4). Populations at Power Squadron Spit were lower in 1993 than in 1992 with many birds moving to Lookout Point in 1993. Numbers at New Drum Inlet were low in both 1992 and 1993, apparently due to overwash of this very low site.

Several colonies of Least Terns attempted to initiate nesting along the beaches of Core Banks in 1992 and in 1993. The colony at Swash Inlet was successful in 1992, but most of these birds apparently moved further south along the beach in 1993 (Table 4). Rain and wind apparently resulted in the failure of most other beachfront colonies.

Islands in the estuary behind Core and Shackleford banks are regularly used by nesting colonial birds. Nesting sites and numbers for 1992 and 1993 are found in Tables 5 and 6. Morgan Island, a large dredged-material island adjacent to the channel from Harkers Island to Lookout Bight, has been used for many years. In 1993 a heronry containing 905 nests of 9 species was present. This was more than double the 1992 numbers. This site appears to be attracting birds that are leaving the declining heronry at Phillips Island near Beaufort. Morgan Island also contained over 3,900 Laughing Gull (*Larus atricilla*) nests in 1993. This island appears to be strategically located for the birds and has been used frequently since it was constructed by dredged-material deposition.

Several marsh islands in Core and Back sounds are utilized each year by nesting Forster's (*Sterna forsteri*) and Common terns. Sites used shift from year to year depending on the presence of wrack in the marsh. Numbers of nesting birds appears to be relatively constant (Tables 5 and 6). An apparent trend in this region is the increasing use of these marsh islands by nesting Laughing Gulls. Laughing Gulls traditionally nest in *Spartina patens* meadows on upland sites, as on Morgan Island. In Core and Back sounds in recent years they have begun building elevated nests in *Spartina alterniflora* stands on marsh islands. This may be in response to problems on the nearby upland sites, such as Morgan, or to other unknown factors. In New Jersey, biologists are seeing the same trend and have attributed it to competition with Herring Gulls on the upland sites. Herring Gulls (*Laraus argentatus*) appear too infrequent in summer here to be a factor. Nutria (*Myocaster coypus*) are abundant in the region and are known to disturb nesting Laughing Gulls by grazing near nests at night. It may be that they are less likely to disturb birds nesting in saltmarsh vegetation.

There was a dramatic increase in the overall number of nests present within the Cape Lookout National Seashore from 1992 to 1993 (Table 7). In 1992, a total of 3,912 nests of 16 species were recorded. The most abundant species was the Laughing Gull with 625 nests. In 1993, 8,747 nests of 17 species were counted. Most of the increase was due to the presence of 4,227 Laughing Gull nests, but several other species also showed increases. The new species was the Sooty Tern (*Sterna fuscata*). A single nest was found among the Laughing Gulls on Morgan Island.

Colonial Waterbirds nesting in the Cape Lookout region will likely continue to use the natural beach sites, as bare dredged-material sites are likely to decrease in the region in the future. Use of marsh islands is likely to continue at present levels or to increase.

SUMMARY AND RECOMMENDATIONS

Indications are that colonial waterbirds are doing well at both Cape Hatteras and Cape Lookout. Both parks provide nesting habitat for significant regional populations of nesting colonial waterbirds. Reproductive success appears to be good, and the management strategy of posting colony sites and providing patrol of these sites appears to be effective.

Protection of nesting sites has allowed beach nesters to be successful most years in spite of heavy use of beaches by people. This strategy is now being copied by the State of North Carolina at Ft. Fisher and is allowing nesting to be successful there as well.

Primary threats to beach nesting within the national seashores appear to be overwash and vegetative encroachment. Predation, especially by mammals such as feral cats (*Felis domesticus*) and raccoons (*Procyon lotor*) may also be important occasionally. Overwash may destroy colonies when it occurs during the nesting season, but will likely be beneficial in the long run, as it helps to maintain the open sandy beach that is used by nesting terns and skimmers. Encroachment of beach nesting sites by plants is a normal part of the succession of overwash communities. Growth is slowed by frequent overwash and now by the action of ORVs. When colony sites are posted throughout the year, vegetation may grow rapidly and the period of use by nesting terns and skimmers will be shortened. Under natural conditions the birds would be expected to move to a new bare area elsewhere up or down the beach or to offshore dredged-material islands. This is much more difficult now that much beachfront is developed and dredging practices no longer result in the regular deposition of new surfaces on islands along dredging channels.

To assure that important sites where nesting birds are successful and where management is possible, we recommend that ORV traffic be allowed in such key colony sites as Cape Point, Hatteras Inlet, Power Squadron Spit, and the west end of Shackleford Island during the fall and winter to assist in maintaining the bare or nearly bare upper beach habitat necessary for nesting terns and skimmers.

Terns and skimmers that nest on bare or nearly bare sites need the most assistance. Laughing Gulls, nesting is dense Spartina patens meadows on islands along the sound are in habitat that is abundant and that will persist for relatively long periods. These are also areas little used by people and so human disturbance is less frequent. We do recommend that such sites be posted and visited occasionally by park personnel.

Herons and egrets usually nest in dense thickets along the back side of the barrier island or on old offshore islands where thickets have developed. There appears to be sufficient habitat, and such sites may be utilized for many years by nesting birds. Human disturbance is most unlikely as such places are decidedly inhospitable. Such sites should, however, be posted. The exception to the natural safety of such sites is when a site is a potential target for development as is the case for the colony near Ocracoke Village.

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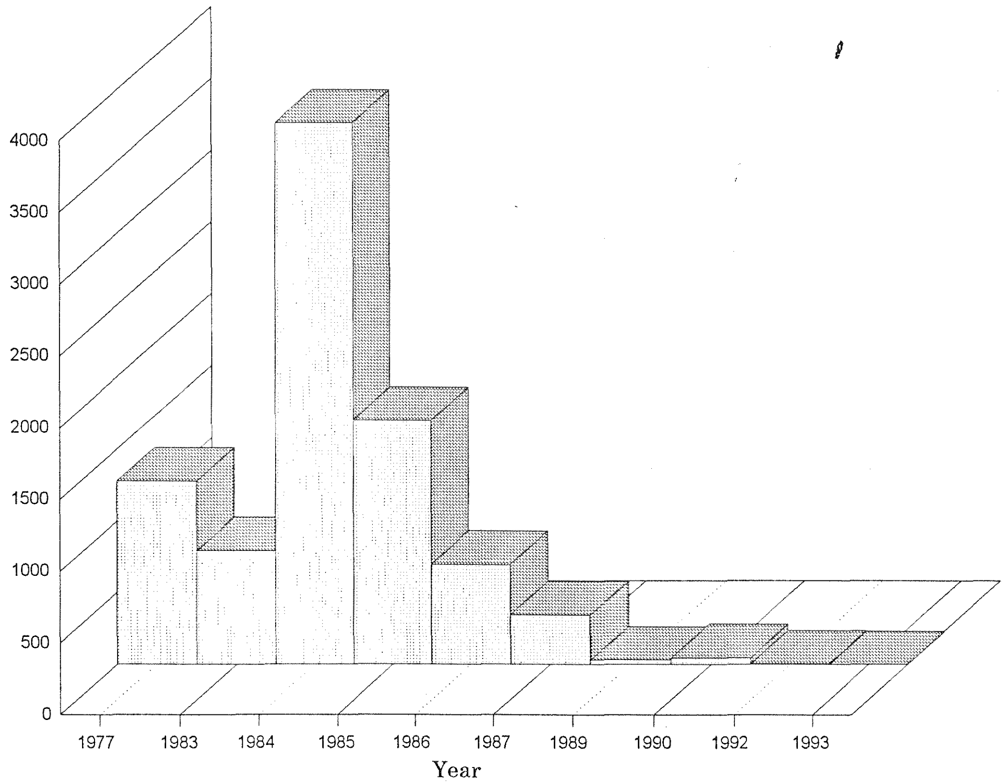

Fig. 1. Total Nests at Ocracoke Flats

Fig. 2. Total Nests at Hatteras Flats

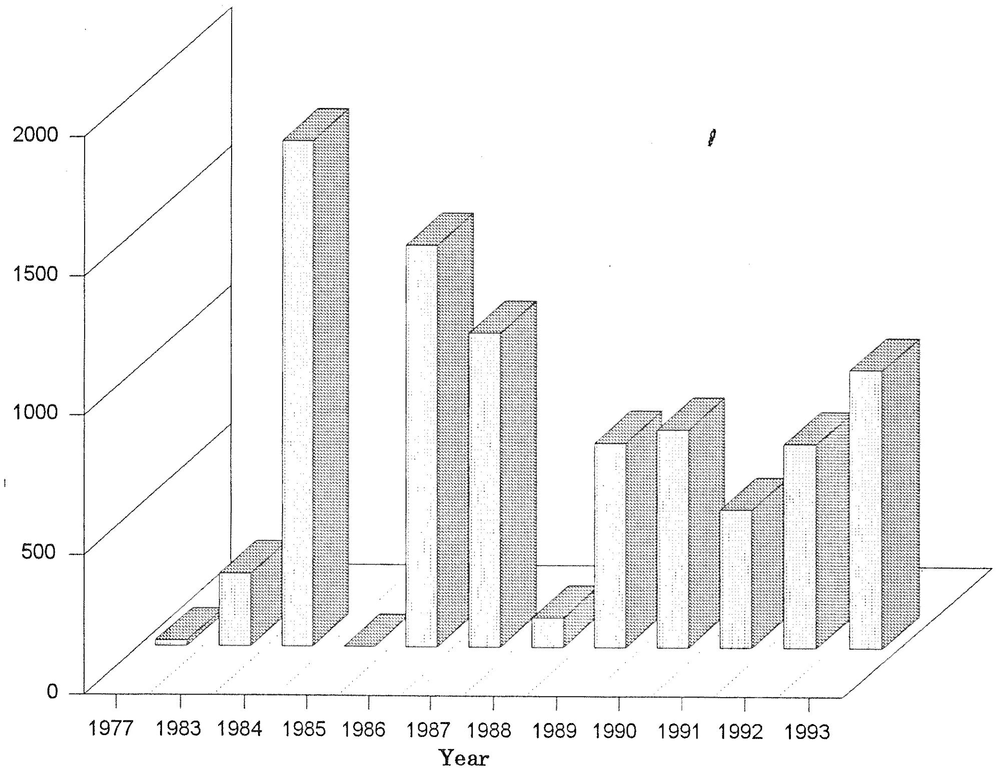

Fig. 3. Total Nests at Cape Point

Table 1. Nesting sites and nest numbers of colonially nesting waterbirds on Ocracoke Island in 1992 and 1993.

	Ocaracoke North		Ocracoke Village		Ocracoke Flats		Pony Pen South	
	1992	1993	1992	1993	1992	1993	1992	1993
Green-backed Heron	0	0	1	0	0	0	0	0
Little Blue Heron	0	0	54	83	0	0	0	0
Cattle Egret	0	0	16	16	0	0	0	0
Great Egret	0	0	17	96	0	0	4	14
Snowy Egret	0	0	77	24	0	0	0	0
Tricolored Heron	0	0	58	39	0	0	0	0
Blk-cr. Night-Heron	0	0	36	13	0	0	0	0
Yl-cr. Night-Heron	0	0	7	17	0	0	0	0
Glossy Ibis	0	0	41	37	0	0	0	0
White Ibis	0	0	262	570	0	0	0	0
Common Tern	0	0	0	0	5	0	0	0
Least Tern	1	0	0	0	0	0	0	0
Total	1	0	569	895	5	0	4	14

Table 2. Nesting sites and numbers of nests of colonially nesting waterbirds on Hatteras Island in 1992 and 1993.

	Pea Island		Ramp 30		Avon		Cape Point		Hat. Inlet	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Gull-billed Tern	0	1	0	0	0	0	0	11	0	0
Common Tern	0	46	0	0	0	0	273	376	0	9
Least Tern	0	151	13	58	0	0	440	502	0	50
Black Skimmer	0	0	0	0	14	0	16	206	0	10
Sooty Tern	0	0	0	0	0	0	0	1	0	0
Total Nests	0	198	13	58	14	0	719	1096	0	69

Table 3. Trends in numbers of nests of colonially nesting waterbirds in the Cape Hatteras National Seashore during the period 1977 to 1993.

	1977[1]	1983[2]	1988	1992	1993
Green-backed heron	0	0	0	1	0
Little Blue Heron	62	58	8	54	83
Cattle Egret	5	1	147	16	16
Great Egret	14	65	17	21	110
Snowy Egret	87	111	8	77	24
Tricolored Heron	50	91	16	58	39
Black-cr. Night-Heron	50	46	5	36	13
Yellow-cr. Night-Heron	2	7	12	7	17
Glossy Ibis	35	20	160	41	37
White Ibis	0	1	12	262	570
Laughing Gull	22	0	0	0	0
Gull-billed Tern	27	7	26	0	12
Forster's Tern	382	63	0	0	0
Common Tern	802	763	678	278	422
Least Tern	121	508	450	454	761
Sooty Tern	0	0	0	0	1
Black Skimmer	286	296	144	30	226
Total	3922	4020	3671	3327	4324

[1] Parnell and Soots 1979

[2] Parnell and McCrimmon 1984

Table 4. Nesting sites and numbers of nests of colonially nesting waterbirds on Cape Lookout National Seashsore beaches in 1992 and 1993.

	Swash Inlet		New Drum Inlet, South		Lookout Beach		Lookout Point		Power Squad. Spit		Shackleford West End	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Gull-billed Tern	0	0	0	0	0	0	0	0	16	0	43	37
Common Tern	0	0	4	2	0	0	4	78	27	0	120	391
Least Tern	200	0	10	3	1	225	10	242	47	61	95	7
Black Skimmer	0	0	0	10	0	68	0	18	42	0	62	157
Total	200	0	14	15	1	293	14	338	142	61	320	592

Table 5. Nesting sites and numbers of nests of colonial waterbirds nesting in the Core Sound area of the Cape Lookout National Seashore 1992 and 1993.

	New Drum Inlet		Big Deep Marsh Isl.		Cockle Marsh Isl.		Whitehurst Island		UNI, Bard. Inlet	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Laughing Gull	0	0	100	81	0	0	125	278	0	40
Gull-billed Tern	0	1	0	0	0	0	0	0	0	0
Forster's Tern	85	23	0	9	23	0	0	0	0	0
Common Tern	85	96	0	0	0	0	0	0	0	0
Sooty Tern	1	0	0	0	0	0	0	0	0	0
Black Skimmer	7	54	0	0	0	0	0	0	0	0
Total	178	174	100	90	23	0	125	278	0	40

Table 6. Nesting sites and nest numbers of colonial waterbirds nesting in the Back Sound area of the Cape Lookout National Seashore in 1992 and 1993.

	Bottle Run Pt. Isl		UNI, Back Sound # 1		UNI, Back Sound # 4		Sheep Island		Unnamed Isl. CR-018-[1]		Morgan Island	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Green-backed heron	0	0	0	0	0	0	0	0	0	0	0	1
Little Blue Heron	0	0	0	0	0	0	0	0	0	0	40	121
Cattle Egret	0	0	0	0	0	0	0	0	0	0	200	462
Great Egret	0	0	0	0	0	0	0	0	0	0	30	138
Snowy Egret	0	0	0	0	0	0	0	0	0	0	15	23
Tricolored Heron	0	0	0	0	0	0	0	0	0	0	40	132
Black-cr. Night-Heron	0	0	0	0	0	0	0	0	0	0	22	18
Glossy Ibis	0	0	0	0	0	0	0	0	0	0	24	9
White Ibis	0	0	0	0	0	0	0	0	0	0	2	0
Laughing Gull	0	0	0	0	0	0	0	0	0	0	500	3909
Herring Gull	0	0	0	0	0	0	0	0	0	0	2	1
Gull-billed Tern	0	19	0	0	0	0	0	0	0	0	0	0
Forster's Tern	0	0	0	6	0	11	18	34	19	0	0	10
Common Tern	7	14	0	0	0	0	0	0	0	0	0	1
Sooty Tern	0	0	0	0	0	0	0	0	0	0	0	1
Total	7	33	0	6	0	11	18	34	19	0	875	4826

[1] Small unnamed and unnumbered marsh island southwest of sheep island.

Table 7. Numbers of nests of colonially nesting waterbirds in the Cape Lookout National Seashore 1992 - 1993.

	1992	1993
Green-backed heron	0	1
Little Blue Heron	40	121
Cattle Egret	200	462
Great Egret	30	138
Snowy Egret	15	23
Tricolored Heron	40	132
Black-cr. Night-Heron	22	18
Glossy Ibis	24	9
White Ibis	2	0
Laughing Gull	625	4227
Herring Gull	2	1
Gull-billed Tern	59	57
Forster's Tern	145	93
Common Tern	242	582
Least Tern	363	583
Sooty Tern	0	1
Black Skimmer	111	307
Total	3912	8748