EFFECTS OF HUMAN DISTURBANCE ON SHOREBIRD POPULATIONS OF HATTERAS, OCRACOKE, AND NORTH CORE BANKS ISLANDS, NORTH CAROLINA

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ABSTRACT

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. Within each pair, one plot was open to human use and the other was closed to all human traffic. Human beach use peaked in the fall, coinciding with shorebird migration and highest shorebird numbers. Human disturbance levels decreased from time of high tide to low tide. 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. 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. 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. Beach closures were effective in increasing resting times and providing uninterrupted foraging areas for of shorebirds.

ACKNOWLEDGMENTS

First and foremost I wish to thank Dr. James F. Parnell for the chance to participate in this project and for giving me two of the best years of my life. His guidance and support as chairman of my graduate committee helped immensely in getting me through the program. Thanks to Dr. Lawrence Cahoon and Dr. Paul Hosier for their interest as committee members and editors on this project. I appreciate Dr. Martin Posey's patience in the face of incessant statistical questioning. Sincere thanks to Dr. Jefferey Walters, the Department of Zoology of North Carolina State University, the Department of Biological Sciences at the University of North Carolina at Wilmington, and the National Park Service for technical and financial support. Special appreciation is given to the rangers at Cape Hatteras National Seashore for making my field work both possible and enjoyable. I am especially grateful to Suzanne Wrenn for field assistance. Without her this project could not have been completed.

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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 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 many 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. I was unable to place the plots randomly because of legal and political constraints within the national seashore. The National Park Service (NPS) designated certain 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

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.

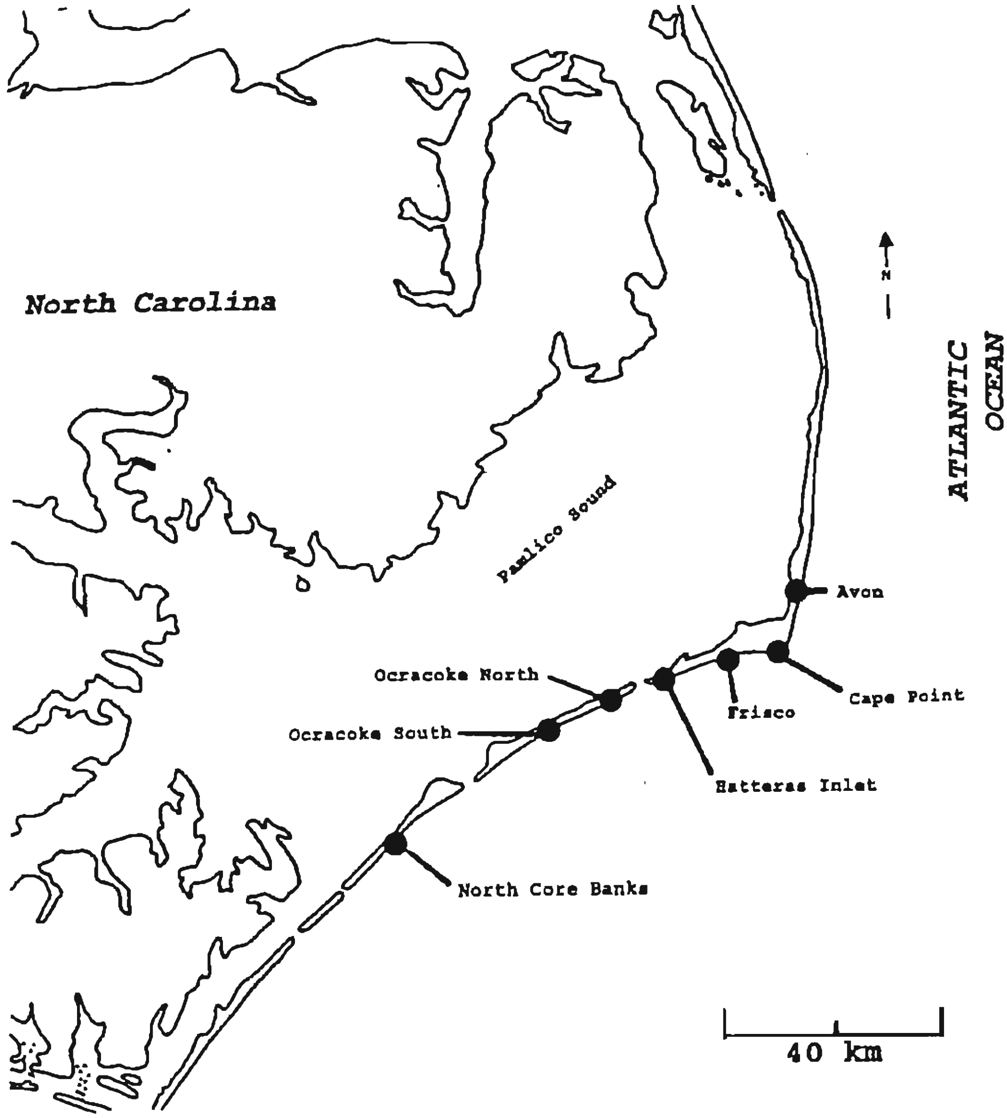


Figure 1. Study sites along North Carolina's Outer Banks. Each site consisted of two paired beach plots, one open to human use and one closed to all human activities. The open plot at Cape Point was paired with the closed plot at North Core Banks.

no prior knowledge or consideration of bird use or disturbance levels among the available sites so I 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). 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 one 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). My 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.

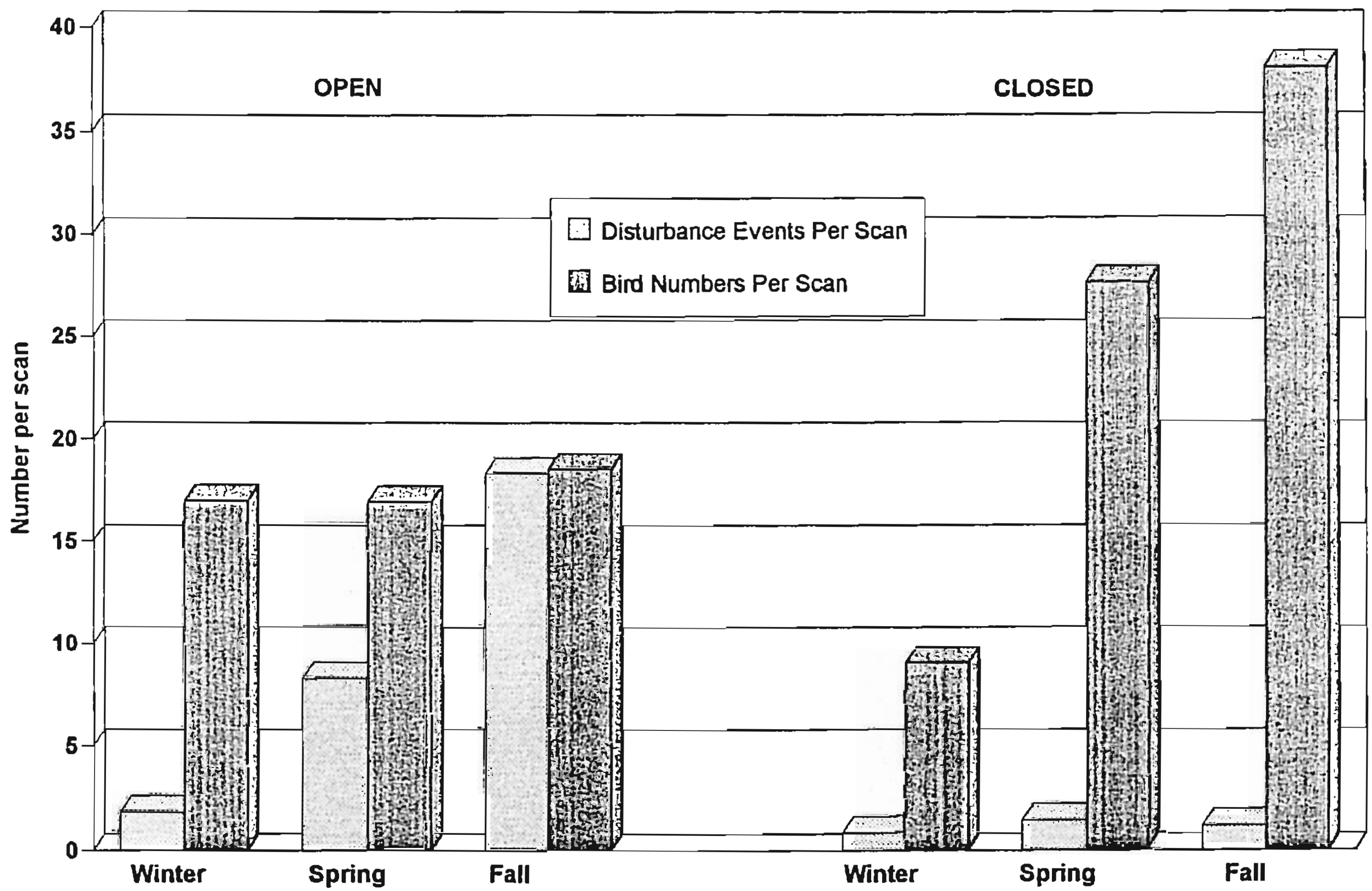
RESULTS

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 (Fig. 2). 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

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



40
35
30
25
20
15
10
5
0
Number per scan
OPEN
CLOSED
Disturbance Events Per Scan
Bird Numbers Per Scan
Winter
Spring
Fall
Winter
Spring
Fall

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

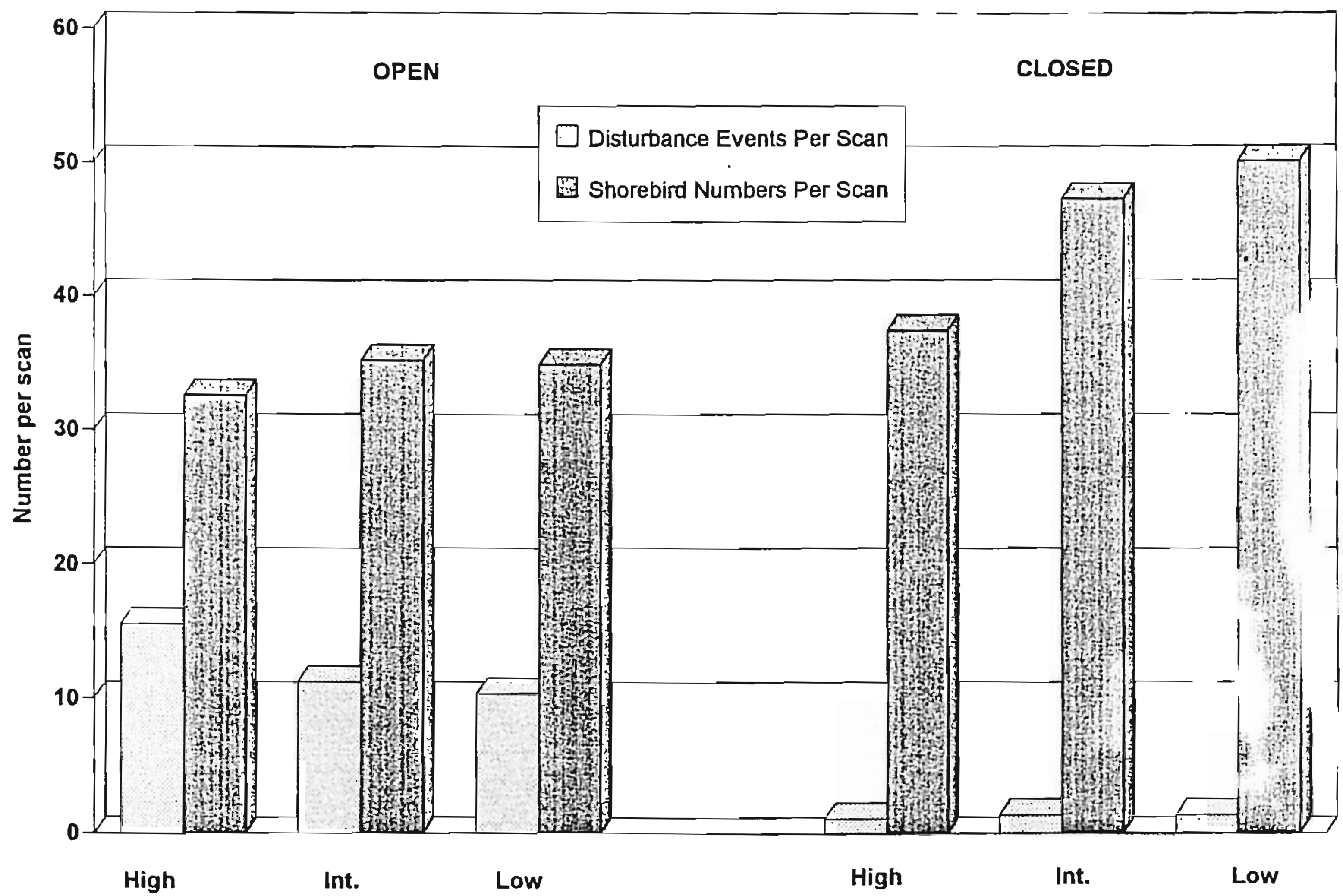
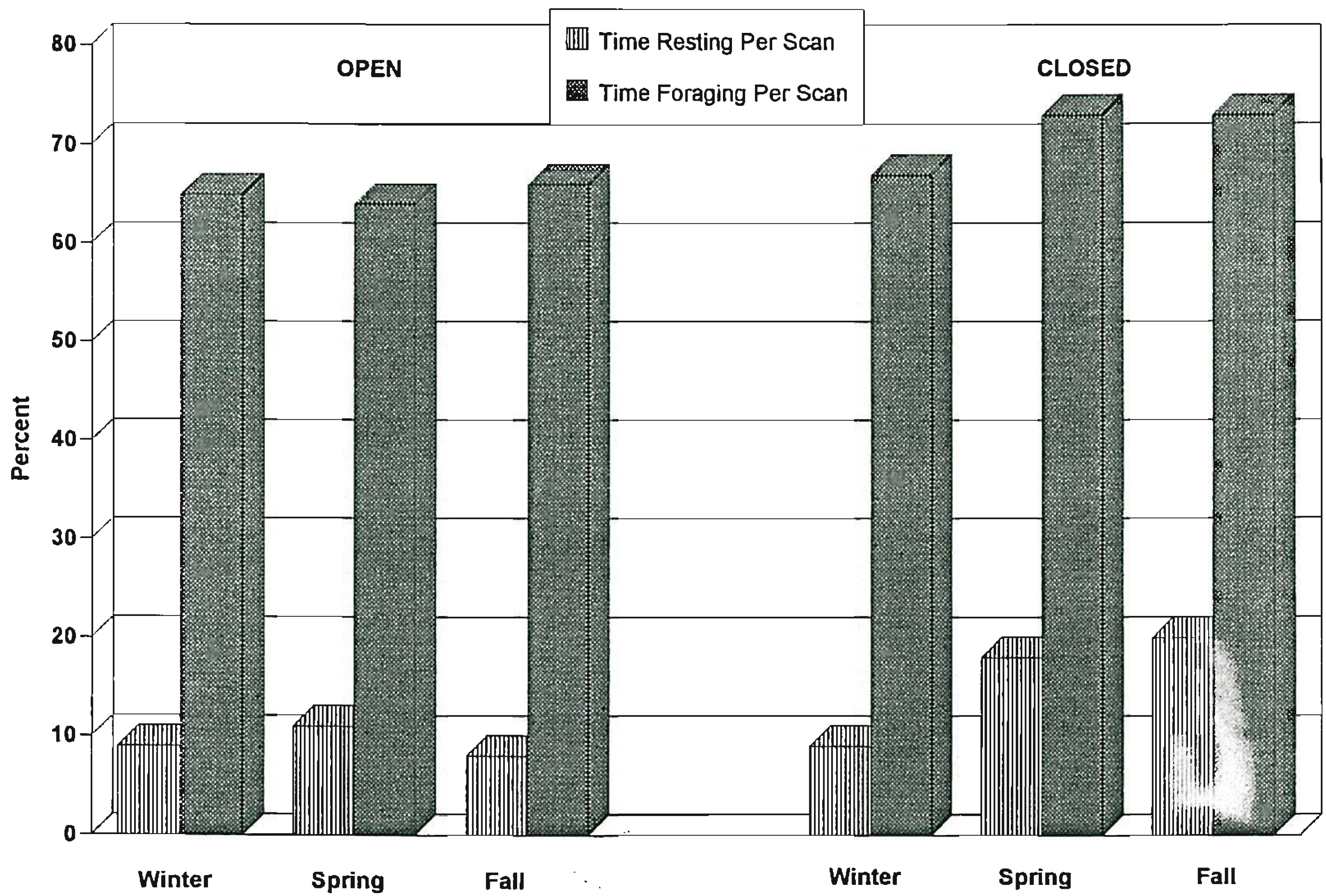

Number per scan
60
50
40
30
20
10
0
OPEN
CLOSED
Disturbance Events Per Scan
Shorebird Numbers Per Scan
High
Int.
Low
High
Int.
Low

Figure 4. Average time spent resting and average time spent foraging per scan during winter, spring, and fall.

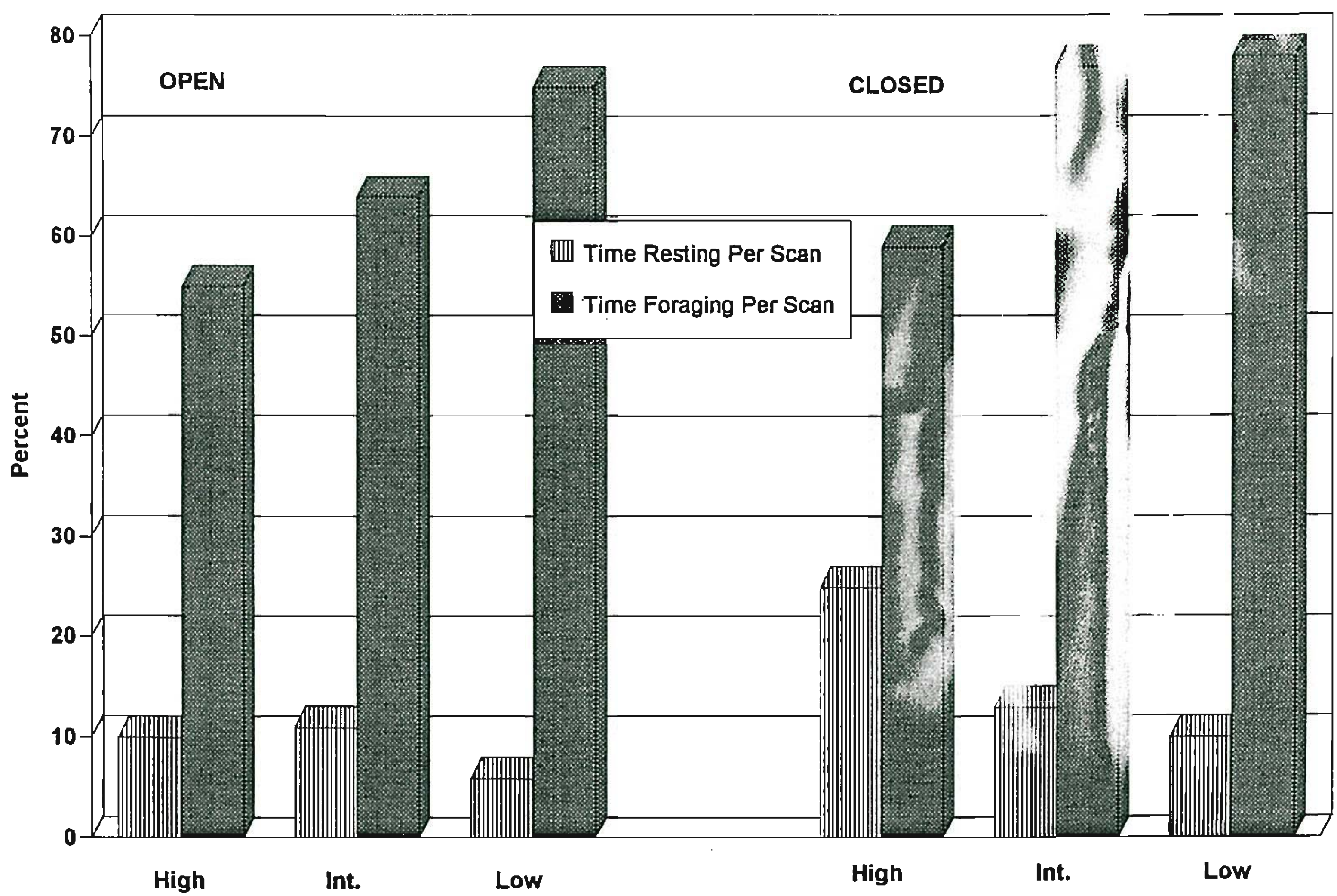

Time Resting Per Scan
Time Foraging Per Scan
OPEN
CLOSED
Percent
0
10
20
30
40
50
60
70
80
Winter
Spring
Fall
Winter
Spring
Fall

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 ($F = 1.52$, $P < 0.22$, $df = 5$).

Figure 5. Average time spent resting and average time spent foraging per scan at high, intrmediate, and low tides.



Percent
80
70
60
50
40
30
20
10
0
OPEN
CLOSED
Time Resting Per Scan
Time Foraging Per Scan
High
Int.
Low
High
Int.
Low

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. 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 are using those beaches as stopovers between breeding and wintering grounds. My 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

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 North Core Banks	High	17.17	0.78	7.56	15.25	50.67	76.17	5.11	26.20
	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 Inlet	High	6.31	1.15	4.22	2.44	38.00	35.67	15.11	13.44
	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

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 of the species we observed concentrated feeding efforts in the wet sand at the water's edge. Unfortunately, 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). I 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, I 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 the 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 shorebirds' 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, 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 human activities by allowing shorebirds to forage and roost in undisturbed habitats.

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BIOGRAPHICAL SKETCH

Eric A. Barbee was born in Charlotte, North Carolina, on 2 April 1969. Shortly thereafter, he decided he wanted to be a marine biologist. In 1987, he graduated from East Mecklenburg High School in Charlotte North Carolina. He received a Bachelor of Science in Marine Biology from the University of North Carolina at Wilmington in 1991. In 1992, he returned to UNCW for graduate school. While studying shorebird populations, he discovered his interest in wetland ecosystems. He received a Master of Science Degree in Biology in December 1994. He plans to remain in the southeastern U.S. to pursue his interests in ecosystem management.