Wading Bird Response to Recreational Boat Traffic: Does Flushing Translate into Avoidance?

KIMBERLY A. PETERS,[1,2] *South Carolina Cooperative Fish and Wildlife Research Unit, Clemson University, Clemson, SC 29634, USA*

DAVID L. OTIS, *Iowa Cooperative Fish and Wildlife Research Unit, Iowa State University, Ames, IA 50011, USA*

Abstract

It generally is assumed that direct flushing responses to disturbance may affect overwintering bird fitness by altering site use. However, little is actually known about the relationship between the flushing response and resulting patterns of habitat use on a local scale. We examined the association between flushing and local site use among 6 wading bird species in tidal creeks on the Cape Romain National Wildlife Refuge, South Carolina, USA, which is frequently used for recreational activities. Experimental, cumulative boat intrusion caused approximately one-half of individuals of all species except snowy egrets (Egretta thula) to immediately abandon a tidal creek. However, species counts across the refuge tended to be driven primarily by Julian date, tidal stage, and creek width; only 2 species, yellow-crowned night heron (Nyctanassa violacea) and great egret (Ardea herodias), appeared to avoid high-traffic creeks. Overall, patterns of response varied among species, and there was no clear relationship between flushing and site use. Flush rates, thus, may not adequately reflect species sensitivity to human disturbance and should only be used as a management guide in conjunction with other indices such as spatial distribution. (WILDLIFE SOCIETY BULLETIN 34(5):1383–1391; 2006)

Key words

Boats, human disturbance, South Carolina, tidal creeks, wading birds.

Concerns about possible negative impacts of human disturbance on wildlife populations have resulted in more published studies on animal response to activities such as recreation, ecotourism, and hunting (reviews in Hill et al. 1997, Frid and Dill 2002). Studies thus far have tended to focus on the direct, immediate effects of human disturbance on animal behavior (Burger and Gochfeld 1991, Ronconi and St. Clair 2002, Thomas et al. 2003) or on how disturbance correlates with animal numbers and distributions (Skagen et al. 2001, Quan et al. 2002). Several mitigation or conservation tools such as the designation of buffer zones around sensitive species habitat or closing of public areas to certain human activities have been subsequently suggested (Erwin 1989, Rodgers and Smith 1995).

Although evidence exists to suggest that repeated human disturbance can reduce fitness in breeding bird colonies through displacement or increased nest predation (review in Carney and Sydeman 1999), comparatively little is understood about the potential effects of disturbance on nonbreeding birds. Management decisions concerning nonbreeding populations generally have relied on assumptions about the effects of immediate responses, such as flushing (i.e., fleeing response), on individual fitness (Rodgers and Smith 1997). It generally is assumed that direct flushing responses may affect fitness by increasing energetic demands (Ydenberg and Dill 1986, Frid and Dill 2002), reducing feeding time (Stolen 2003, Thomas et al. 2003), or altering habitat use (Burger 1981). The latter of these effects has gained particular attention since several studies have shown that overwintering bird distributions

may be related to patterns of human disturbance (Klein 1995, Lafferty 2001, Quan et al. 2002). However, little is actually known about the relationship between the flushing response and resulting patterns of site use on a local scale. Such a relationship ultimately would depend on return rates after flushing, cumulative disturbance patterns (Riffell et al. 1996), and threshold disturbance levels for eliciting abandonment of a site (Madsen 1985). These factors, in turn, are influenced by conditions relating to the energetic demands placed on individuals and the availability of alternative foraging habitat (Hockin et al. 1992, Hill et al. 1997, Stillman and Goss-Custard 2002). Avian response to disturbance also can be affected by environmental factors such as wind speed (McGowan et al. 2002) and time of day (Bechet et al. 2004).

One way to gain a better understanding of how the flushing response relates to habitat use would be to compare the 2 responses simultaneously among species. Interspecific differences in flush rates and use of heavily disturbed areas have been documented in wading birds (Rodgers and Smith 1997, Skagen et al. 2001, Rodgers and Schwikert 2002, Stolen 2003), shorebirds (Burton et al. 2002, Blumstein et al. 2003), ducks (Quan et al. 2002), and passerines (Riffell et al. 1996, Fernandez-Juricic et al. 2002). If a general pattern also exists wherein species prone to flushing avoid highly disturbed areas, it would appear that the response may, in fact, translate into site avoidance. If individuals are, as a result, required to use alternative habitat that is of lower quality, a strong case for negative impact caused by human disturbance can be made. In this case using flushing measurements (e.g., flush rate, flush distance) as a management tool might offer a relatively simple and fast way to prioritize management actions. If, however, flushing

[1] *E-mail: kim.peters@njaudubon.org*
[2] *Present address: New Jersey Audubon, Cape May Bird Observatory, Cape May Court House, NJ 08210, USA*

does not translate into site avoidance, a more comprehensive approach to determining which species are most vulnerable to disturbance clearly is warranted.

The primary purpose of this study was to determine if flush rates serve as good indicators for species sensitivity to disturbance in the form of site avoidance and to clarify general patterns of species-specific response to boat disturbance. Our objectives were to determine 1) if species differed in their responses to single-pass and repeated, cumulative boat intrusion, 2) what independent factors, including boat traffic, environmental conditions, and creek structure, affected creek use by different species, and 3) whether species that showed strong flushing responses also were those less likely to be observed in highly disturbed creeks.

Study Area

Our study was conducted on the Cape Romain National Wildlife Refuge (CRNWR), located approximately 50 km north of Charleston, South Carolina, USA. The CRNWR contains nearly 26,000 ha of protected saltmarsh, shallow bays, and barrier islands, 11,300 ha of which have been assigned protection under the National Wilderness Preservation System. Approximately 15,000 ha of the refuge are comprised of saltmarsh habitat interspersed with tidal creeks.

The potential impact of recreational boating activity on shorebirds and wading birds has recently become a significant concern at CRNWR (Peters and Otis 2005). The Cape Romain region currently is the third most popular site for recreational shrimp baiting (i.e., baiting and cast-netting) in South Carolina (Low 1998). Small boats with outboard engines comprise the majority of the craft used in this activity. The refuge also has experienced a sharp increase in shrimp-baiting trips. In 1988, 96 shrimp-baiting trips were documented at CRNWR. In 1993 there were 6,896 trips recorded, and by 1997 activity had risen to 20,419 trips (Low 1998). Based on boat-trailer counts, more than 300 boats have been estimated to be present on CRNWR waters during a single day (S. Cofer-Shabica, United States Fish and Wildlife Service, Cape Romain National Wildlife Refuge, personal communication). The shrimp-baiting season is set by law to last 60 days, beginning on the second Friday of September, to coincide with the period when larger white shrimp (*Penaeus setiferus*) are moving seaward.

Methods

We chose 12 tidal creeks to estimate the effects of boat disturbance on wading birds. We conducted our work in tidal creeks because boats tended to concentrate in these areas and potentially could impact wading birds foraging or resting along the creek margins. Upon entering the bay, boats tended to remain relatively stationary and typically were more dispersed. We selected creeks based on accessibility at both high and low tides and to adequately distribute sampling effort across the refuge (Fig. 1). Four of the sample creeks are considered major access routes to preferred shrimp-baiting areas (Casino Creek, Horsehead Creek, Anderson Creek, Venning Creek), whereas the remaining 8 creeks generally receive less use. We could not with confidence identify any creeks on the refuge that received no boat traffic at all, so our study does not include true control sites. Linear length of the creeks ranged from approximately 1,800–2,400 m, and average width ranged from 50–240 m.

Repeated Disturbance Sampling

We conducted repeated-disturbance experiments from early August to mid-September in 2000 and 2001 in order to examine species-specific response patterns to cumulative disturbance. Each sample was comprised of 6 consecutive strip-transect surveys in one tidal creek. Surveys were separated by 5-minute intervals. We performed wading bird counts with binoculars from a 5.2-m boat proceeding at 1,000-rpm motor speed along a creek center. For each transect we counted all wading birds to species within a 100-m perpendicular distance to the creek–marsh interface. This sampling scheme included birds on the creek-facing side of the interface as well as the marsh-facing side, and it is likely that some bias against counts of birds on the marsh-facing side was present due to visibility limitations. We sampled 6 creeks that typically had low boat traffic and completed all repeated-disturbance sampling before the shrimp-baiting season opened to increase the likelihood that ours was the first boat that birds had been exposed to that day (i.e., that we were working with previously undisturbed birds). If another boat passed through the creek during the sample period, we terminated sampling. In such cases, we retained for analysis data from transects conducted before the sampling was interrupted.

Bird Surveys

From early September to early December 1999–2000, we conducted standard strip-transect surveys in the 12 creeks at approximately 2-week intervals. We sampled 6 creeks in 1999 and 2000 and an additional 6 in 2000 only. We surveyed each transect in the same manner as our experimental sampling, as described above, with the exceptions that we made only one pass through each creek per sample day and did not terminate sampling if another boat passed through the creek. In 2000 we also recorded whether an individual flushed from the survey area and if it returned to the survey area within 5 minutes, which was the average time we remained in the visible viewing area. We postponed surveys scheduled to take place during foul weather (e.g., rain, excessive wind) until the next available sampling day. To increase survey time, sampling periods were not constrained by tidal cycles or time of day. We noted individual movements to ensure that each bird was counted only one time, and we generally were able to keep track of individuals counted within each transect by noting departure and landing sites within the sampling area. We also recorded all boats observed in a creek during a transect as an index of disturbance. Nearly all boats counted were
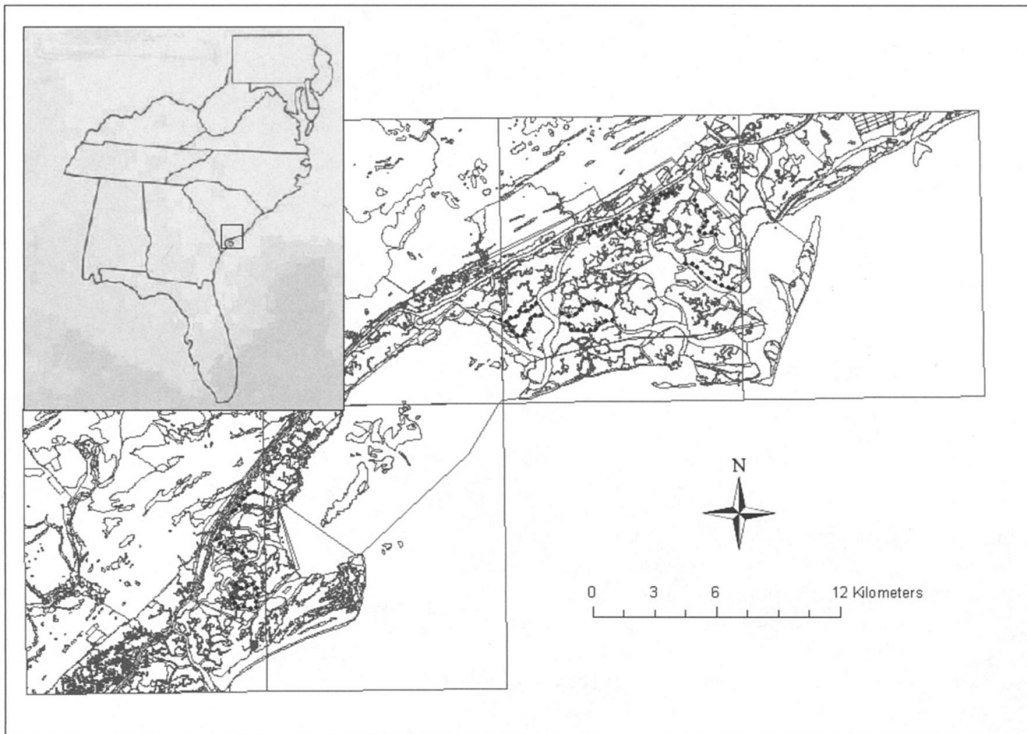
Figure 1. Tidal creeks sampled ($n = 12$, denoted by bold dotted lines) for wading birds on the Cape Romain National Wildlife Refuge, South Carolina, USA, 1999–2001.

entering the bay for the purpose of shrimp-baiting and we easily identified them by the presence of polyvinyl chloride bait-marking poles.

Prior to sampling each creek, we recorded wind speed and direction based on anemometer readings (accuracy to 0.5 miles/hr [0.8 km/hr]). We calculated mean creek width as the average width of the creek taken at each 300-m marker, based on low-tide aerial photographs taken in 1998 (ArcGIS v 8.3; Environmental Systems Research Institute, Redlands, California). Based on the time that the sample was initiated, we estimated tidal stage (centimeters above or below mean low at Moore's Landing and McClellanville, South Carolina; Tides and Currents® V 2.5, Jeppesen Marine, Portland, Oregon), moon phase (percentage of moon illuminated), and minutes past sunrise.

Statistical Analyses

We made inferences about the relationships between environmental conditions, creek structure, disturbance from boats, and wading bird densities based on an information-theoretic approach (Burnham and Anderson 1998). A set of a priori candidate linear models was defined prior to analysis. The response variable in each model was the relative density of a species, defined as the number of individuals recorded in a strip-transect survey, and the independent variables consisted of ≥ 1 environmental (tide level, wind direction, wind speed, minutes after sunrise, percent moon illumination) and creek-based (mean creek

width, creek traffic level) parameters. We classified creeks as 0 ("low traffic") if an average of ≤ 0.5 boats passed through per sample (approx. 1.5 boats/hr) and as 1 ("high traffic") if an average of ≥ 1 boats passed through per sample (approx. 3 boats/hr). The 3 boats/hour level approximated the level of traffic imposed during our repeated-sampling experiment (approx. 3.5 boats/hr). Because wading bird counts were not normally distributed, they were log-transformed [$n = \ln (\text{count} + 1)$] prior to analysis.

The set of candidate models comprised a global model, which included all available potentially relevant effects on wading bird counts as well as 2 reduced models. We used the global model to examine residuals and obtain an overall measure of goodness-of-fit (Burnham and Anderson 1998). We determined model fit by examining the coefficient of determination, F-score, and its associated P value. We designed the 2 reduced models based on the hypotheses that models containing either environmental or creek-based parameters provided the best approximating model for predicting wading bird densities. Prior to analysis, we performed a correlation analysis on all independent variables to assess multicollinearity (e.g., nonorthogonality) among the data. We did not include highly correlated variables in any one model to avoid inflated standard errors of partial regression coefficients (Zar 1999). The best approximating model had the smallest value of Akaike's Information Criterion with a correction to compensate for sample size (AIC$_c$; Burnham and Anderson 1998). Models with AIC$_c$
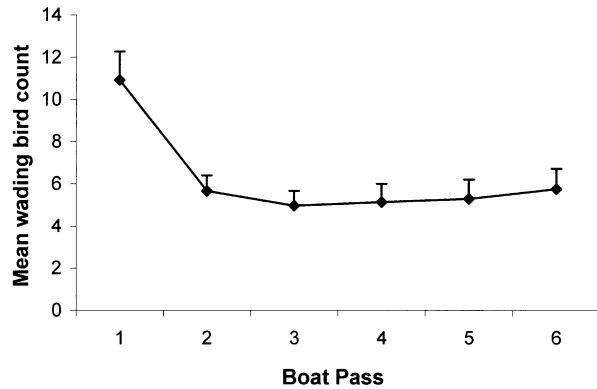
Figure 2. Mean counts (SE) of total wading birds in each boat pass during experimental repeated disturbance sampling on Cape Romain National Wildlife Refuge, South Carolina, USA, 2000–2001.

values within 2 scoring points of the best model were considered to have very strong support (Burnham and Anderson 1998). We compared differences in flush rates, calculated as the proportion of individuals counted that flushed, among species using analysis of variance (ANOVA) and Tukey's Studentized Range (HSD) post hoc tests (Proc ANOVA; Sas Institute 1999). We used a generalized linear model to determine if flush proportions for any species changed during the study period, by testing for a species–Julian day interaction (Proc GENMOD; SAS Institute 1999). We arcsin-transformed flush proportions prior to analysis (p = arcsin proportion flush). We assessed findings from the repeated-disturbance experiments by examining mean wading bird counts and their associated variances for each pass (1–6) through the creeks.

Results

We conducted 44 repeated-disturbance samples. Each transect took an average of 17 minutes to complete (SD = 2), and fully completed samples took an average of 104 minutes to complete (SD = 30). The 6 focal species recorded included great egret (*Ardea alba*, 31% of total recorded wading birds), tri-colored heron (*Egretta tricolor*, 19%), snowy egret (*E. thula*, 22%), great-blue heron (*A. herodias*, 8%), yellow-crowned night heron (*Nyctanassa violacea*, 13%), and green heron (*Butorides virescens*, 7%). The average number of total birds decreased between the first and second transects (X^2 = 4.72, P = 0.03) and did not return to initial levels during the sampling period (Fig. 2). This general pattern was consistent for all species with the exception of snowy egret, which tended to increase in number over each sampling period (Fig. 3). The sharpest decrease was exhibited by yellow-crowned night heron.

Flush rates also differed among species (Fig. 4; F = 4.30$_{743}$, P < 0.001). Yellow-crowned night herons were the most likely species to flush in response to a passing boat (83%), and post hoc tests determined that yellow-crowned night herons and tri-colored herons (76%) were more likely to flush than snowy egrets (67%, P < 0.05), and yellow-crowned night herons also were more likely to flush than
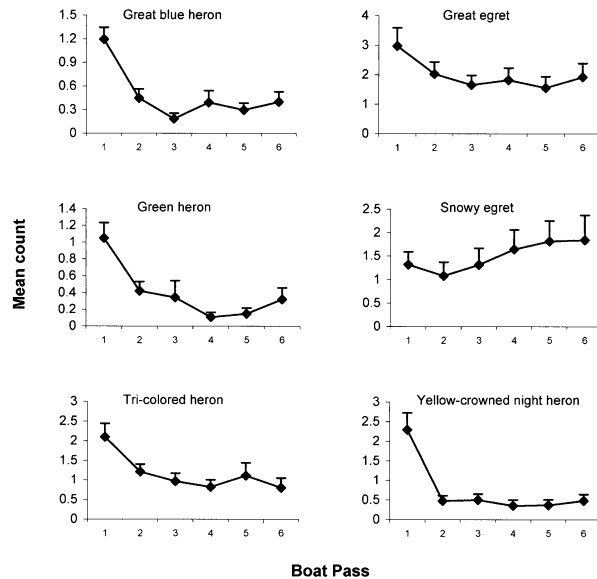

Figure 3. Mean counts (SE) of wading bird species in each boat pass during experimental repeated-disturbance sampling on Cape Romain National Wildlife Refuge, South Carolina, USA, 2000–2001. Note that mean count scales differ among species.

great egrets (68%, P < 0.05). Furthermore, green herons were much more likely to return to the sampling area within 5 minutes of flushing than were other species (Fig. 4). Flush rates remained relatively stable throughout this portion of the study (Table 1).

We completed 177 single-pass transects during which we recorded wading birds and boats. We sampled 6 creeks 20 times each, 3 creeks 10 times each, and 3 creeks 9 times each. Transects took an average of 20 minutes to complete (SD = 4). Primary species observed again included great egret (33% of total birds counted), tri-colored heron (20%), snowy egret (15%), great-blue heron (13%), yellow-crowned night heron (8%), and green heron (3%). Boat counts recorded within creeks averaged 0.29 per sample (n = 77, SD = 0.67) for low traffic creeks and 1.83 per sample (n = 100, SD = 2.72) for high traffic creeks. Fits of the global models were fair to good (Table 2). Based on AIC rankings, the global model was the most parsimonious model for predicting relative density for all species, indicating that several environmental, structural, and disturbance factors contributed to their presence during surveys (Table 3). For snowy egret, the model including only environmental variables also provided a strong fit to the data.

The relative influence of individual variables within the best model varied among species (Table 4). All species with the exception of great blue herons decreased significantly over the season. Great blue herons, great egrets, tri-colored herons, and green herons also were more likely to be recorded during higher tides, and snowy egrets and yellow-crowned night herons were seen more often on rising tides. Snowy and great egrets were more prevalent earlier in the day, and yellow-crowned night heron creek use appeared to
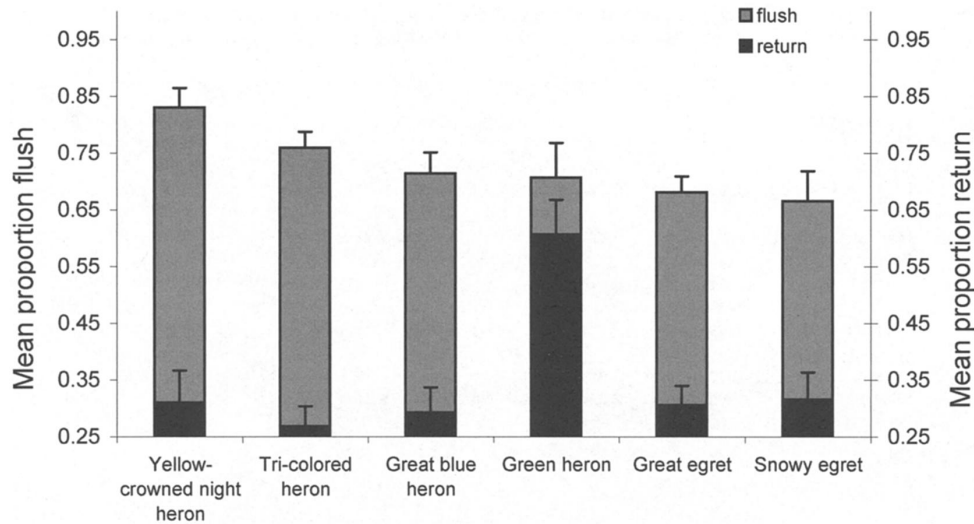
Figure 4. Mean proportion (SE) of individual wading bird species that flushed (gray bars) and returned (black bars) to the sampling area within 5 minutes during single-pass transects on Cape Romain National Wildlife Refuge, South Carolina, USA, 1999–2000.

be negatively influenced by wind speed. Snowy and great egrets also were less likely to be observed during southerly winds, and yellow-crowned night heron was seen most commonly during northerly winds (Fig. 5). Moon phase did not play a role in determining abundance for any species. Several species, including great blue heron, great egret, tri-colored heron, and green heron appeared to prefer wider creeks. Only 2 species, great egret and yellow-crowned night heron, showed an aversion to high-traffic creeks and inclusion of the creek-based variables in the best approximating model generally was driven by the importance of creek width rather than by traffic level.

Discussion

Several studies have shown boating disturbance (Batten 1977) or recreational disturbance in general (Pfister et al. 1992) to impact bird distributions on a local scale. However, recent work with shorebird (Lafferty 2001) and passerine (Gutzwiller and Anderson 1999) species indicates that in some cases, although birds may show direct response to human disturbance, this response may not be reflected in patterns of site use. For instance, although 70% of shorebirds flushed when disturbed on a California, USA,

beach, large-scale patterns of beach use primarily were determined by season, tide, and habitat type (Lafferty 2001). A study of subalpine passerines also showed no distributional response to human intrusions for most species, and in fact many of the species that did show avoidance response such as mountain chickadee (*Parus gambeli*) and American robin (*Turdus migratorius*) were those least likely to flush when approached by humans (Gutzwiller and Anderson 1999). There are several possible explanations for why flushing responses may not translate into discernable distributional patterns of disturbance avoidance. These include potential habituation and the fact that other factors related to habitat occupancy may mask disturbance effects.

Several studies have demonstrated habituation to human presence, wherein birds may exhibit a reduction in behavioral (Keller 1989) or physiological (Fowler 1999) response to disturbance. It has even been suggested that some habituation may be beneficial to breeding bird populations (Goehring and Cherry 1971, Keller 1989) and that controlled, deliberate disturbance can be used as a management tool (Nisbet 2000). Comparatively little work has been conducted on potential habituation of nonbreeding birds, although there is evidence that some species (least

Table 1. Results from generalized linear model including a species–Julian day interaction for 6 wading bird species using the Cape Romain National Wildlife Refuge, South Carolina, USA, 1999–2000. Positive parameter estimates indicate that flush proportions increased throughout the study period (Aug–Nov).

	Estimate	X^2	P
Great blue heron	0.001	2.2	0.14
Snowy egret	0.001	0.6	0.44
Great egret	0.002	1.15	0.29
Tri-colored heron	0.002	3.12	0.08
Yellow-crowned night heron	0.002	3.48	0.06
Green heron	0.002	2.13	0.14

Table 2. Coefficient of determination, *F*-score, and associated *P* values for each each of 6 global models relating wading bird counts to environmental and creek-based parameters. Models based on data from Cape Romain National Wildlife Refuge, South Carolina, USA, 1999–2000.

	R^2	F	df	P
Great blue heron	0.181	3.020	12	0.001
Snowy egret	0.337	6.960	12	<0.0001
Great egret	0.395	8.920	12	<0.0001
Tri-colored heron	0.214	3.710	12	<0.0001
Yellow-crowned night heron	0.342	7.090	12	<0.0001
Green heron	0.331	6.760	12	<0.0001

Table 3. Candidate linear regression models for predicting wading bird counts on Cape Romain National Wildlife Refuge, South Carolina, USA (1999–2000). Akaike's Information Criterion (AIC) values reflect the difference in score from the best-performing model. Strong candidate models (i.e., ΔAIC ≤ 2) are bolded.

	Model ID	Model parameters[a]	k[b]	(−)2 log-likelihood	ΔAIC$_c$[c]
Great blue heron	**Global**	days + tide + sunhour + moonlit + RF + WS + dir + boats + width	14	−199.24	**0.00**
	Environmental	days + tide + sunhour + moonlit + RF + WS + dir	12	−190.95	8.29
	Creek	boats + width	4	−171.45	27.79
Snowy egret	**Global**	days + tide + sunhour + moonlit + RF + WS + dir + boats + width	14	−184.39	**0.00**
	Environmental	days + tide + sunhour + moonlit + RF + WS + dir	12	−183.85	**0.54**
	Creek	boats + width	4	−111.62	72.77
Great egret	**Global**	days + tide + sunhour + moonlit + RF + WS + dir + boats + width	14	−114.68	**0.00**
	Environmental	days + tide + sunhour + moonlit + RF + WS + dir	12	−101.81	12.87
	Creek	boats + width	4	−33.62	81.06
Tri-colored heron	**Global**	days + tide + sunhour + moonlit + RF + WS + dir + boats + width	14	−165.23	**0.00**
	Environmental	days + tide + sunhour + moonlit + RF + WS + dir	12	−158.04	7.19
	Creek	boats + width	4	−128.51	36.72
Yellow-crowned night heron	**Global**	days + tide + sunhour + moonlit + RF + WS + dir + boats + width	14	−245.12	**0.00**
	Environmental	days + tide + sunhour + moonlit + RF + WS + dir	12	−234.03	11.09
	Creek	boats + width	4	−182.77	62.35
Green heron	**Global**	days + tide + sunhour + moonlit + RF + WS + dir + boats + width	14	−394.96	**0.00**
	Environmental	days + tide + sunhour + moonlit + RF + WS + dir	12	−388.00	6.96
	Creek	boats + width	4	−329.18	65.78

[a] RF = rising versus falling tide; WS = wind speed; dir = direction.
[b] The number of estimable parameters in the model including intercept and error term.
[c] Change in values of AIC adjusted for small sample size.

tern [*Sterna antillarum*], black skimmer [*Rhynchops niger*]) may habituate to tangential boat traffic (Rodgers and Smith 1995). Conversely, several shorebird species have been shown to be more reactive to humans when human activity is high (Lafferty 2001), indicating sensitization rather than habituation may occur in some cases. It is possible that habituation may have been a factor for some species on CRNWR and, thus, may have influenced our findings. However, because no relationship was noted with respect to flush rates and Julian date, with flush rates remaining fairly high throughout the season, we feel that habituation probably did not play a role in determining the patterns we observed.

Several environmental factors emerged as significant in determining wading bird distributions on our study site, indicating that these and other factors may have masked any
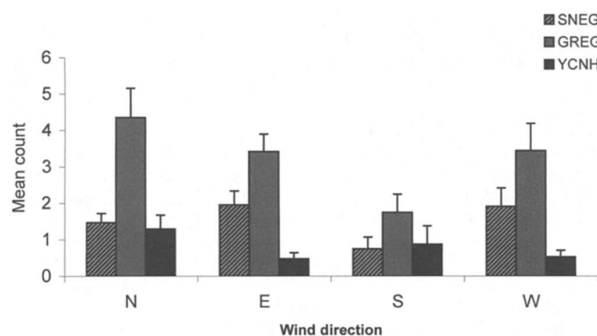

Figure 5. Relationship of mean snowy egret, great egret, and yellow-crowned night heron counts (SE) to wind direction during single-pass transects on Cape Romain National Wildlife Refuge, South Carolina, USA, 1999–2000.

potential disturbance effects. The fact that environmental factors (Kirby 1997) and temporal changes in prey availability (Wolff 1969, Colwell and Landrum 1993) can affect avian habitat use and behavior is well documented. Similarly, avian reaction to disturbance also is likely driven by a complex interplay of factors such as weather, life-history stage, and resource availability (Wingfield et al. 1998, McGowan et al 2002, Stillman and Goss-Custard 2002). For instance, McGowan et al. (2002) found that red knot (*Calidris canutus*) responsiveness to disturbance was affected by temporary small-scale changes in the environment such as changes in windspeed and air temperature, and Stillman and Goss-Custard (2002) reported that Eurasian oystercatchers (*Haematopus ostralegus*) were less likely to respond to disturbance later in the winter, when loss of feeding time was especially costly (Kersten and Piersma 1987). Snow goose (*Anser caerulescens atlanticus*) rates of returning to refugia have been shown to change depending on the time of day (Bechet et al. 2004), and several species of passerines have exhibited low flushing response to pedestrians during high temperatures, purportedly due to an increased cost of reacting in the form of heat stress (Fernandez-Juricic et al. 2002). In our study it is likely that extraneous factors such as tidal stage and wind conditions influenced wading-bird creek use and possibly response to disturbance, thus limiting our ability to detect any distributional changes that may have occurred as a result of human activity. For instance, the apparent higher use of creeks during northerly winds by several species may have been indicative of the sheltering effects of creeks, and the fact that birds were more likely to be seen during higher tides may have reflected foraging preferences. However, it is important to note that our study did not explicitly take into

Table 4. Parameter estimates (Est.) for factors related to increased wading bird counts on Cape Romain National Wildlife Refuge, South Carolina, USA, 1999–2000. Estimates are derived from the lowest values of Akaike's Information Criterion adjusted for small sample size scoring linear regression models displayed in Table 2. Bolded P values are significant at $P \leq 0.05$.

	Great blue heron			Snowy egret			Great egret			Tri-colored heron			Yellow-crowned night heron			Green heron		
	Est.	SE	P	Est.	SE	P	Est.	SE	P	Est.	SE	P	Est.	SE	P	Est.	SE	P
Julian date	0.001	0.001	0.679	-0.011	0.002	**<0.0001**	-0.014	0.002	**<0.0001**	-0.005	0.002	**0.001**	-0.009	0.001	**<0.0001**	-0.007	0.001	**<0.0001**
Tide relative to mean low (cm)	0.004	0.001	**<0.0001**	0.000	0.001	0.825	0.006	0.001	**<0.0001**	0.005	0.001	**<0.0001**	0.001	0.001	0.053	0.001	0.000	**0.031**
Minutes past sunrise	0.007	0.022	0.741	-0.068	0.023	**0.003**	-0.063	0.028	**0.026**	-0.004	0.024	0.868	0.034	0.019	0.084	-0.010	0.013	0.425
Proportion of moon illuminated	-0.094	0.155	0.546	-0.226	0.161	0.163	0.054	0.197	0.785	0.023	0.171	0.892	-0.122	0.136	0.372	0.009	0.089	0.916
Falling vs. rising tide[a]	-0.017	0.092	0.854	0.307	0.095	**0.002**	-0.069	0.117	0.558	0.019	0.101	0.854	0.092	0.081	0.259	-0.097	0.053	0.069
Wind speed (miles/hr)	-0.004	0.012	0.729	0.013	0.012	0.301	-0.001	0.015	0.923	0.007	0.013	0.607	-0.023	0.010	**0.032**	-0.006	0.007	0.414
Wind direction	N/A	N/A	0.221	N/A	N/A	**0.004**	N/A	N/A	**0.048**	N/A	N/A	0.653	N/A	N/A	**0.035**	N/A	N/A	0.883
Boat level (0 = low, 1 = high)	-0.128	0.098	0.193				-0.348	0.124	**0.006**	-0.077	0.108	0.478	-0.206	0.086	**0.017**	0.077	0.056	0.171
Mean creek width (m)	0.002	0.001	**0.006**				0.003	0.001	**0.004**	0.003	0.001	**0.010**	-0.001	0.001	0.181	-0.001	0.001	**0.014**

[a] Estimates the relative effect of tide; thus, a negative value indicates birds were more likely to be observed during falling tides, whereas a positive value indicates they were more likely to be observed during rising tides.

account factors pertaining to resource availability within the study creeks and surrounding landscape, which can significantly affect habitat quality, animal use of space, and reaction to disturbance (Hockin et al. 1992, Hill et al. 1997). It is likely that such factors influenced the distributional use of space we observed in our study, and they deserve future attention. For instance, birds that did not flush may not have had access to alternative feeding sites or may have been in poor physical condition due to inadequate local resources.

Management Implications

Much evidence exists to show the negative impacts of human disturbance on breeding bird colonies (Vos et al. 1985, Carney and Sydeman 1999) and the use of buffers around colonies appears to alleviate these negative effects (Burger et al. 1995, Carney and Sydeman 1999). Buffers also have been suggested as a conservation tool for nonbreeding wading birds based on studies examining immediate flushing responses to disturbance (Rodgers and Smith 1997). It generally is assumed that birds exhibiting the highest flush rates are most sensitive to disturbance and that conservation measures should focus on these more "vulnerable" species. However, in our study we observed a strong flushing response by wading birds that, for most species, did not appear to affect site occupancy, another index often used to assess species vulnerability. This finding likely was due to the fact that decisions about whether individuals abandon a site are ultimately determined by factors such as the quality of the occupied site, distance to and quality of other suitable sites, and the relative risk of predation and competition at different sites (Hockin et al. 1992, Hill et al. 1997). We suggest that conclusions about negative impacts based on flushing alone may be inadequate, and the issue of impact should be more comprehensively explored on a species-by-species basis.

Acknowledgments

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Kimberly A. (Kim) Peters (photo) received her M.S. in Fisheries and Wildlife Sciences from North Carolina State University in 1999 and her Ph.D. in Zoology from Clemson University in 2006. She has been the Director of Research and Monitoring at New Jersey Audubon since 2005. Her primary research interests include animal habitat use and selection, disturbance ecology, and avian behavioral ecology. **David L. (Dave) Otis** has been Unit Leader of the United States Geological Survey Iowa Cooperative Research Unit at Iowa State University since 2001, after serving in the same position at the South Carolina Unit at Clemson University for 11 years. Prior to these positions, he was a statistician and biologist at the United States Fish and Wildlife Service Denver Wildlife Research Center. His research interests generally involve applied questions in population biology, as well as development and evaluation of statistical methods for use by field biologists.

Associate Editor: Jacobson.